

# HP Labs 2010 Annual Report







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Dear Colleagues,

Welcome to the HP Labs 2010 Annual Research Report. This has been an outstanding year for HP Labs, and I am proud to present our people and achievements to you.

At HP Labs, we believe in Innovation with a Purpose – making important advances to the state of the art and delivering these innovations to HP's customers, improving their businesses and technology experiences. Our researchers pursue a challenging, leading-edge research agenda, and work hard to ensure their discoveries benefit HP's customers by partnering with our businesses on technology transfer and commercialization.

Throughout this report, we will describe our research areas, introduce some of our researchers to you, and share some of the most important contributions from 2010 that have made an impact on HP's products and services. From co-innovation with customers, to collaboration with universities, to real-world demonstrations of our technology in action, HP Labs researchers are turning exciting scientific breakthroughs into solutions for our customers' and society's most important problems.

We welcome you to read about our research here, as well as online at the HP Labs web site: <http://www.hpl.hp.com> .

Best regards,

Prith Banerjee

Senior Vice President, Research, and Director,  
HP Labs



# HP Labs Overview

## About HP Labs

HP Labs, HP's central research organization, is chartered with enabling new opportunities for HP through technical innovation and scientific breakthroughs. Our legacy is to take fresh ideas and turn them into new products and businesses that delight our customers and make the world a better place.

Our goals at HP Labs are to:

- Advance the state of the art, as evidenced through intellectual property (IP) generation in the form of publications and patents.
- Ensure our innovations reach customers through technology transfers to existing HP businesses, new business creation and IP licensing.
- Engage with customers and innovation partners to co-innovate, delivering transformational solutions to real-world problems.

To accelerate the advancement of our common goals, we collaborate with others in the innovation ecosystem through our Open Innovation approach, a core platform of our research strategy.

HP Labs operates in seven locations around the world: Palo Alto, USA; Bangalore, India; Beijing, China; Bristol, UK; Haifa, Israel; Singapore; and St. Petersburg, Russia. This global footprint allows us to reach the best talent, partner with customers and universities around the world, and inform our research perspective through the local environments in which we do our work.

## HP Labs' Impact

HP Labs' researchers tackle difficult technology problems, relevant to HP's customers and businesses. We are doing research in areas such as intelligent infrastructure, cloud services, information analytics, print and content delivery, and sustainability. There's a

common theme across our research areas, consistent with our strategy: we're innovating at every touchpoint of information. Recent innovations include:

- Advancements in intelligent IT infrastructure including the application of our nanotechnology expertise for breakthrough sensing capabilities.
- The creation of immersive experiences including multi-touch and "hover" gesture capabilities, and panoramic 3D visualization.
- Analytics and business intelligence advancements optimizing customer engagement and strategic decision making.

## Our People

The engine of HP Labs' inventiveness is its people. Our researchers are among the most distinguished in their fields. They've received some of the highest honors in science and engineering, including the Turing Award, the Julius Springer Prize for Applied Physics, the Feynman Prize for Nanotechnology, and the Jack S. Kilby Signal Processing Medal.

We have recognized global leaders in areas ranging from nanotechnology and computer algorithms, to data management and data mining, digital signal processing and data compression, thermo-mechanical architectures of chips, systems and data centers, to energy management at these scales. More than 60% of our researchers are Ph.D.s. Collectively, our staff has generated thousands of publications and holds thousands of patents.

HP Labs has 15 IEEE Fellows and six ACM Fellows, as well as fellows of the British Computer Society, the American Association for the Advancement of Science, the Society for Imaging Science and Technology and many other professional societies – along with one technical Emmy® winner and one winner of a technical Oscar®.



Two of our scientists have been elected members of the US National Academy of Engineering and one is a member of the US National Academy of Sciences.

Beyond these external awards and recognition, HP Labs people are recognized technical leaders within HP as well. Our team includes five HP Senior Fellows and seven HP Fellows. Our researchers work closely with HP's businesses and customers to influence, define, and build the strategy of tomorrow, and their expertise is widely sought inside and outside of HP.

While we have some of the best minds in the world at HP Labs, we know that we don't have a monopoly on innovative ideas. So we've taken an Open Innovation approach and are actively partnering with leading companies, academic institutions, and government agencies to amplify our research results.

## Innovation Research Program

The HP Labs Innovation Research Program (IRP) offers the global university research community an opportunity to partner with HP Labs on cutting-edge research topics, while organizing HPL's academic collaborations into a strategic and visible portfolio.

Designed as a global, open, competitive, annual call for proposals, each year HPL publishes a series of research topics, and interested researchers are invited to submit proposals for a collaborative project that

aligns with one of the solicited topics. IRP calls have attracted over 1000 proposals from more than 250 universities in nearly 40 countries in three years, making for a highly selective program.

In 2010, HP selected 65 projects at 52 institutions in 16 countries to receive awards. The results of these varied collaborations speak for themselves: among the initial 45 projects from 2008, 61 papers were accepted for publication, and 13 HP invention disclosures were accepted. In 2009-2010, 111 papers detailing IRP-funded research were either published or accepted for publication, and 16 HP invention disclosures were filed.

IRP awards provide project funding of up to \$100,000 per year to each academic institution and are renewable for a total of three years based on research progress and HP business requirements. Awards are primarily intended to provide financial support for a graduate student to assist the Principal Investigator conducting a collaborative research project with HP Labs. The next class of awardees will be announced in spring 2011.

## HP Labs Singapore

In 2010, HP Labs launched our newest research facility in Singapore. HP Labs Singapore researchers are developing an enterprise cloud software platform, dubbed Cirious, alongside researchers in Palo Alto,





## New Leaders join HP Labs in 2010

### Jamie Erbes

**B.S. Computer Science, East Central University, Oklahoma**

**Director, Services Research Lab, and HP Fellow**

Jamie Erbes joins HPL to lead our Services Research Lab, one of HP Labs' growing research areas. Erbes comes from HP's Office of Strategy and Technology, where she was previously the Chief Technology Officer for Software & Solutions. In this role she helped create a forward-looking vision for cloud services and their impact on Enterprise IT management.

A seasoned leader in networking, datacenters, cloud, services and workflow automation, Erbes brings broad experience to HP Labs, drawing from her roles in both large industry and start-up settings. She earned her computer science degree at East Central University in Oklahoma, and was recognized as one of the Top 100 Women in Computing by Open Computing Magazine.

### Laura Hill

**M.S. Physics, Massachusetts Institute of Technology**  
**Director, Information Analytics Lab**

Laura Hill is Director of the Information Analytics Lab, which develops innovations in the timely delivery of real-time business intelligence to enterprise customers. Her team's research focuses on enabling new business intelligence solutions with robust, scalable data management, data-intensive analytics and the fusion of structured and unstructured information.

Prior to joining HP, she was Senior Director of Shared Services and Cloud Computing at Sun Microsystems. Hill brings a diverse set of leadership skills to HP Labs, having held executive positions in research, engineering, marketing, global operations and planning over her twelve-year career at Sun. Hill began her career as an IT expert in banking systems, and is a Distinguished Member of the Association for Computing Machinery (ACM). She received an M.S. in Physics from MIT and a B.A. in Physics from Reed College.

California and Bristol, England. The opening of this new research lab is the culmination of many years of successful Open Innovation activities in Singapore, including close collaboration with universities, government agencies – such as Singapore's Economic Development Bank (EDB), InfoComm Development Agency (IDA), and the Agency for Science, Technology and Research (A\*STAR) – and industry partners.

Chris Whitney, Director of HP Labs Singapore, notes that the new lab was conceived from the very beginning as both a research and development operation. His strategy with the new lab is to try to start new businesses, as the next natural step from applied research: "Think of it as an innovation center inside HP Labs," explains Whitney. "We plan to actively work with customers and partners, so that we are able to be self-sustaining when our joint funding agreement with Singapore finishes in 5 years. This shows how the face of corporate innovation can change: we want to have a positive impact back to the country, and to leverage an Open Innovation model to partner for success."

To that end, the lab's research center is seeking to work closely with universities in Singapore and Southeast Asia, by developing joint research collaborations, hosting students as interns, and establishing adjunct positions for researchers shared between local universities and HP Labs. Whitney notes, for example, that the lead for the lab's research agenda will be a joint position with Nanyang Technological University (NTU).

## HP Labs Promotes Two Pioneering Researchers to Senior Fellow

Becoming an HP Senior Fellow means reaching the pinnacle of scientific achievement and technical leadership at HP – and it is a rare achievement. Senior Fellows set standards for technical excellence, and push the boundaries of technology in their respective disciplines. They are futurists whose contributions impact HP, and our industry as a whole. In 2010, HP Labs was proud to add two Senior Fellows to the ranks – Norman P. Jouppi and Chandrakant D. Patel – bringing the number of HP Senior Fellows to five. They join HP Senior Fellows Bernardo Huberman, Robert Tarjan, and Stan Williams, among the most esteemed technical leaders in the company.

### Driving the Future of Converged Infrastructure

Norm Jouppi, Director of the Intelligent Infrastructure Lab, oversees HP's research on next-generation servers and datacenters, and is instrumental in the company's

agenda in converged infrastructure. His recent research has included realizing the impact of nanophotonic technology on computer systems, applications of new non-volatile memory technologies, heterogeneous chip multiprocessor architectures and blade system architectures. He leads a cross-disciplinary team of researchers in computer architecture, virtualization, networking and programming languages, who also work closely with HP Labs' Networking and Sustainable Data Center efforts.

A Fellow of the ACM and IEEE, Jouppi is recognized as one of the world's leading computing architects. He has published more than 125 technical papers and holds more than 50 U.S. patents, in addition to his leadership in computing professional organizations and publications. He received his Ph.D. in electrical engineering from Stanford University, and an M.S. in electrical engineering from Northwestern University.

### Setting the Agenda on Sustainable IT

Chandrakant Patel, Director of the Sustainable Ecosystems Research group, has been a driving force behind HP's overall sustainability strategy. Over his 19-year career, he has established HP's leadership in sustainable IT, data center and thermo-mechanical

(cooling) technologies. Most recently, Patel has driven the concept of lifetime "cradle to cradle" consumption of joules of available energy within the IT ecosystem, which is changing the conversation about the role of IT ecosystems in managing global resources. He currently leads a multi-disciplinary research team focused on sustainable IT ecosystems and supply- and demand-side management, and the reduction of carbon emissions throughout the global economy.

A Fellow of the IEEE, Patel was recognized in 2005 with the Joel S. Birnbaum Prize for outstanding contributions to HP Labs. He has published more than 125 technical papers, and has been granted more than 100 U.S. patents. He received his M.S. in mechanical engineering from San Jose State University, B.S. in mechanical engineering from University of California, Berkeley and an A.S. in engineering from City College of San Francisco. He is a registered professional mechanical engineer in California.

### Research Agenda

Our greatest impact comes from working collaboratively on large, multi-disciplinary research activities, with customers and partners, to deliver







## **New Leaders join HP Labs in 2010**

### **David Lee**

**Ph.D. Computer Science, Columbia University  
Director, Networking and Communications Lab**

David Lee leads HP Labs' newest lab in Networking and Communications, boosting HP's efforts in cutting-edge networking and communications research, and addressing the needs of HP's rapidly growing networking product portfolio. His research interests include network system management, reliability and interoperability; information and networking system security; image processing and computer vision; theoretical computer science, numerical methods and approximation theory; and circuit design and analysis.

David Lee started his career at Bell Labs Research, where he created Bell Labs Research China and served as its founding Director. He joins HP Labs from Ohio State University where he is an Ohio Board of Regents Distinguished Professor, and an IEEE Fellow.

### **Min Wang**

**Ph.D. Computer Science, Duke University  
Director, HP Labs China**

Min Wang is the Director of HP Labs China, which focuses on informatics analysis and networking. Her team's research areas include large scale data management, web content extraction and analysis, networking and communications.

Wang joins HP from IBM Research, most recently as a Research Staff Member and the manager of the Unified Data Analytics Department at IBM's Thomas J. Watson Research Center in Hawthorne, New York, where she pursued her research interests in database systems and information management over a 10-year career. She received her Ph.D. degree in Computer Science from Duke University and B.S. and M.S. degrees, both in Computer Science, from Tsinghua University.

innovation to HP's products and solutions and transform the customer experience. Our work falls into eight broad themes. Within these themes, we have 24 "Big Bet" projects. These are ambitious projects that, if successful, could lead to significant business opportunities for HP.

To ensure our large bets pay off, we've established internal review boards to help guide the process of converting discoveries into commercial offerings. Interactions with the board ensure alignment with HP's businesses, while also providing a forum to discuss the next breakthrough advancements.

In addition to our big bets, we encourage our researchers to nurture the seeds of future research efforts by freeing 20% of our resources to work on off-roadmap, and sometimes offbeat, ideas. In this way, we sustain a healthy research pipeline characterized by delivery of tangible results today and creation of new technology advances and opportunities that are yet to come.

Throughout the remainder of this 2010 Annual Report, you will read about our research agenda and people and hear examples of how HP Labs is delivering tangible results, solving interesting problems, and introducing customers to the possibilities of tomorrow.



**CeNSE was named among  
ReadWriteWeb's *Top 10 Internet  
of Things Developments of 2010*  
and its MEMS accelerometer  
received the EE Times' ACE  
Award for *Most Promising New  
Technology of 2010*, the *EDN  
Innovation Award* and the  
Design News 2010 *Golden  
Mousetrap Award***



# Cloud and Security

## Cloud and Security Big Bets

### Cirious: Enterprise Cloud Software Platform

The Cirious vision is to lead HP in becoming the foremost Service Providers' Service Provider, delivering a set of cloud capabilities that enable service providers to take full advantage of the power of the cloud. Our work enables service providers of all types to tap into foundational cloud capabilities – general purpose horizontal capabilities, as well as those tailored for specific industry verticals – that make it easy for them to develop, host and manage their services to deliver value from the cloud, and to integrate with an ecosystem of services from other providers.

### Automating Security

Our security research agenda focuses on developing analytical and architectural computing models to support assured governance of information security management. In the context of a worsening threat environment, increased consumerization of IT, and the highly sought-after cloud computing paradigm, we are creating technology and methodologies that will improve situational awareness and help assure customers that security of their information assets is appropriately managed. Our approach is to introduce innovative analytics in the lifecycle of security management, to help analyze and drive appropriate desired security outcomes at the governance level; and to design the next generation of trusted system architectures that will help ensure that IT operations can achieve those outcomes reliably and with strong assurances.

Today, innovations in information technology are creating a new paradigm for human communication and collaboration on a global scale. The Internet is evolving into the cloud: the means through which everything will be delivered as a service — from computing power to business processes and personal interaction. The cloud is fundamentally changing the way we connect with each other and with information.

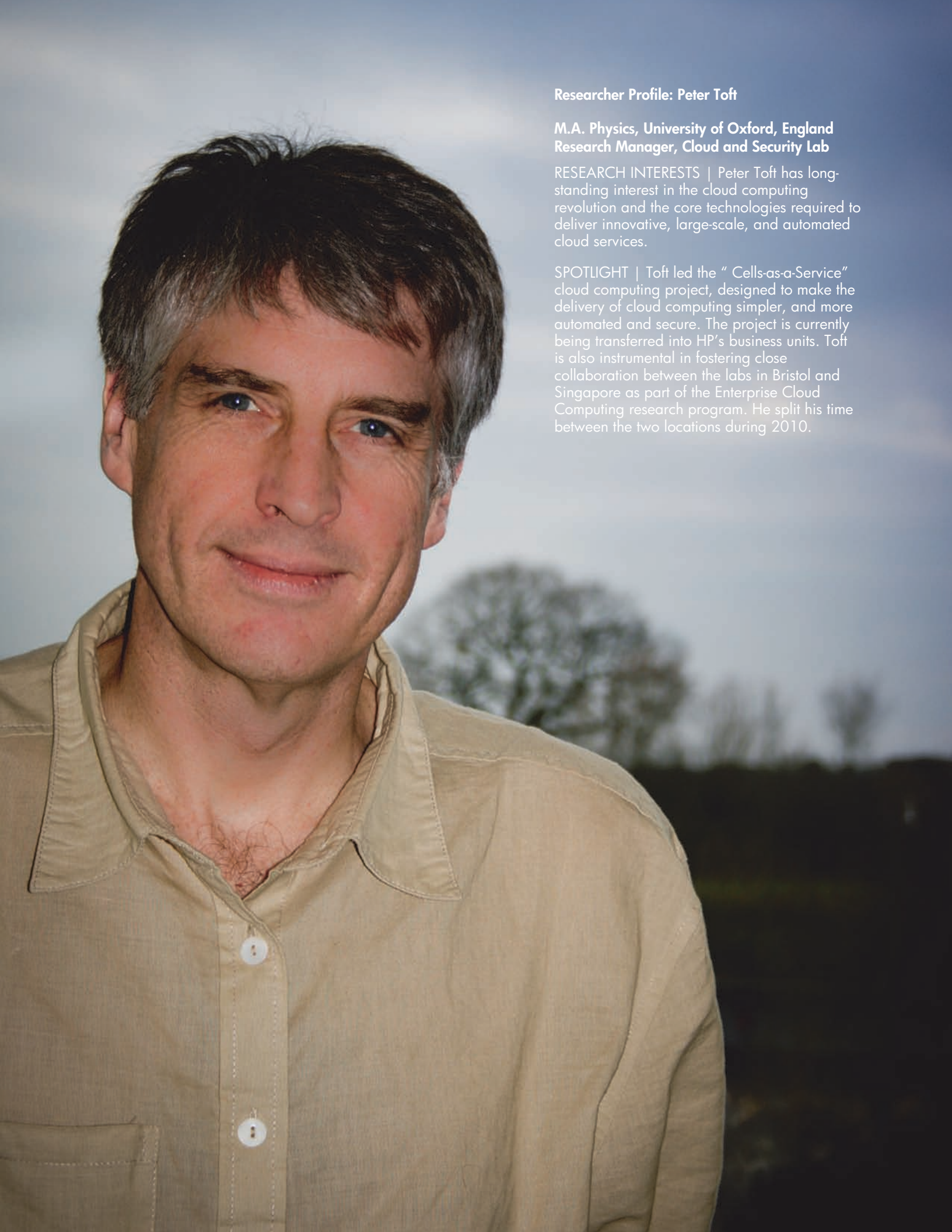
At HP Labs, our research is focused on delivering the secure application and computing end-state of “Everything-as-a-Service.” This research envisions billions of users securely accessing millions of services through thousands of service providers, over millions of servers that process exabytes of data, delivered securely through terabytes of network traffic. We’re creating the foundational technologies to expand the use and relevance of cloud computing in the enterprise. We’re working on an enterprise cloud platform, from computing resources to human skills. And we’re working on the security analytics that will automate enterprise-grade security and address one of the biggest obstacles in the broad adoption of the cloud in the enterprise.

## HP Labs and Global Insurer Lloyds Team Up on Digital Risk Management

Lloyds, the world’s leading specialist insurance market, and HP Labs security researchers teamed up to present an in-depth report, “Managing Digital Risk: Trends, Issues and Implications for Business”, that examines recent trends in cyber crime. The December 2010 report warns that as businesses become more reliant on technology, they also increasingly open themselves to risks on a variety of fronts.

Some of the risks identified by the report’s authors may not be new – extortion or theft, for example – but thanks to technology they can happen faster and leave a larger impact on businesses. Others, such as hacker attacks, have only emerged along with business’





**Researcher Profile: Peter Toft**

**M.A. Physics, University of Oxford, England  
Research Manager, Cloud and Security Lab**

**RESEARCH INTERESTS** | Peter Toft has long-standing interest in the cloud computing revolution and the core technologies required to deliver innovative, large-scale, and automated cloud services.

**SPOTLIGHT** | Toft led the “Cells-as-a-Service” cloud computing project, designed to make the delivery of cloud computing simpler, and more automated and secure. The project is currently being transferred into HP’s business units. Toft is also instrumental in fostering close collaboration between the labs in Bristol and Singapore as part of the Enterprise Cloud Computing research program. He split his time between the two locations during 2010.



**Researcher Profile: Simon Shiu**

**Ph.D. Computer Science, Durham University, England**

**Senior Research Manager, Cloud and Security Lab**

**RESEARCH INTERESTS** | Simon Shiu has a passion for all aspects of information security with particular focus on enterprise security management. As part of his work in the Cloud and Security Lab, ideas that he and the security team are pursuing include security economics, system modeling, situational awareness and trusted infrastructure.

**SPOTLIGHT** | Shiu values engagement with HP customers and believes a key challenge today for chief information security officers is the changing enterprise landscape due to consumerization, cloud, and an increasingly hostile IT environment. The security analytics team has delivered a series of groundbreaking pilots that have helped major customers with many of their toughest IT security challenges. This has resulted in the transfer of a packaged security analytics service to HP's information security business unit. Shiu also strongly supports the Open Innovation model and has been active in numerous collaborative, security-related projects involving the UK government, industry, and researchers at top universities, many of which are in disciplines complementary to HPL's talents, including economics and cognitive science. These partnerships, including the UK government-funded "Trust Economics" and "Cloud Stewardship Economics" projects, have yielded significant research results and press attention. Shiu is a Visiting Professor in the School of Computer Science at Newcastle University and a member of the Institute of Information Security Professionals.





increasing reliance on IT, but are just as capable of causing lasting damage. Beyond just detailing the risks that are out there, "Managing Digital Risk" goes on to make concrete recommendations to companies looking to more effectively manage their risks in the digital space. These include taking steps to ensure cyber crime is seen as much more than just a problem to be tackled at the IT department level; and understanding that risk managers need to develop comprehensive risk management strategies to mitigate against the increasing variety of threats they face.

This successful collaboration is an example of HP Labs' strategy of seeking out the best partners in our innovation ecosystem: "The combination of Lloyds' corporate view of risk with HP Labs' knowledge of future technology trends and information security," notes HPL Director Prith Banerjee, "has enabled us to provide companies with impactful information about the digital threats facing businesses worldwide."

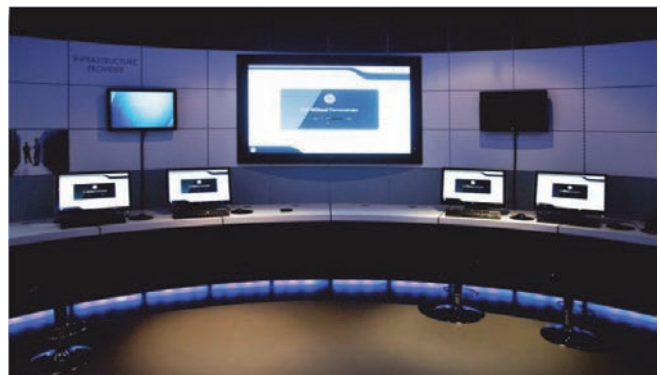


## G-Cloud Demonstrator Brings Cloud Computing Research to Life

Thanks to a collaborative project by researchers in the Cloud and Security Lab, visitors to HP's Bristol, UK Laboratories can now see a tangible demonstration of how cloud computing can help governments around the world deliver thousands of core IT services to their citizens much more efficiently. G-Clouds – or government-specific Clouds – have been attracting increasing interest for their potential to save on IT costs and provide governments with more flexibility and efficiency in providing services.

The G-Cloud demonstrator allows HPL researchers to show how the underlying technologies being developed by HP will make this possible: the platform leverages virtualization to more flexibly provide IT services that respond to changes in demand, while also providing robust and dynamic security for sensitive data. Visitors to the site can view the service in real-time on large monitors, all the way from a top-level view of security, down to the details of how information is moving around inside the cloud. John Manley, Director of Cloud Services at HP Labs, also believes that "the way in which we build cloud computing needs to be common to private clouds and public clouds. We need to understand the requirements on the underlying infrastructure to make that single foundation happen."

For that reason, HPL's researchers are looking at a number of different research areas that will have an impact on the cloud and recognize that the G-Cloud demonstrator is only one avenue. "Everything's still very formative in Cloud Computing," Manley contends, but HPL's research all stems from "a common, centered vision of how we think cloud technology should grow."



# Information Analytics

One of the biggest opportunities in business today is transforming the vast and growing universe of enterprise information into immediate, relevant insight. We all know the amount of digital information is exploding, and at the same time expectations for processing this information are rising. Organizations rely on business analytics to make decisions about everything from internal operations to customers, sales, and supply chains – essentially anywhere that actionable business intelligence can cut costs and improve efficiencies.

Valuable content is distributed across the enterprise, 95% of it in “unstructured” formats – that is, residing not in databases but in a variety of files that include email, documents, presentations, and much more. To have a complete view of their business, companies need analytics that leverage both structured and unstructured information.

At HP Labs, we are working to redefine the twin tasks of taming and exploiting this information to revolutionize enterprise decision making. We’re applying mathematic and scientific methodologies and developing the models, tools, and algorithms that drive informed, highly effective, repeatable, and consistent decision making – to ultimately create better-run businesses. Our research enables near real-time business intelligence with robust, scalable data management; data-intensive analytics of structured and unstructured information; and automatic delivery of information described in the language of business.

## Image-Based Automation and Document Knowledge Management for Increased IT Agility

Customers of HP's Business Technology Optimization (BTO) suite are continually seeking new ways to add agility to their IT departments and reduce the cycle time required for developing and releasing applications.

### Information Analytics Big Bets

#### IT Informatics

HP’s Business Technology Optimization suite offers tools for strategic decision making, test management and operations management; its strength is in its ability to create a unified store of an organization’s resources, provide aggregation of data with reference to resources, and turn this data into useful summaries and visualizations that assist IT managers in making better, more strategic decisions.

Our research dramatically expands these capabilities through the use of more data sources to automatically create knowledge from the organization’s data, sharing IT knowledge throughout the organization, and transforming IT knowledge into IT automation. We focus on semantic automation, data and sequence mining, information association and quality, and program analysis.

#### Live Business Intelligence

Our research mission is to create a unified data and analytics platform, which we call “Live Business Intelligence (BI)” that shifts BI from the traditional back-office, report-generation orientation, to an enabler for delivering data-intensive analytics that transform operational business processes and customer interactions. The LiveBI Platform leverages data management technology and fuses it with new paradigms for analytics development and execution, supports declarative models for computation conducive to massively parallel processing, and integrates analytics over both streaming and historical data.

#### Taming the Information Explosion

Within information lies insight – defined as the contextualized sum of facts, events and relationships obtained through algorithmic analysis of text and data from within and outside the enterprise – used to infer relevant and potentially non-obvious patterns and implications. We are creating a suite of innovative insight-generation services, integrated into platforms for harnessing the entire range of unstructured information types, at the scale of global enterprises and information providers. Research problems include coping with the vast scale of information sources, navigability between related information, and determining the importance of information, i.e. its timeliness and contextual relevance.



A portrait of Ruth Bergman, a woman with dark, wavy hair, wearing a light green ribbed top and a gold necklace. She is smiling slightly and looking towards the camera. The background is a blurred outdoor setting with greenery and a building.

**Researcher Profile: Ruth Bergman**

**Ph.D. Operations Research, Massachusetts Institute of Technology**

**Research Manager, HP Labs Israel**

**RESEARCH INTERESTS** | Ruth Bergman's background is in artificial intelligence and machine learning. She is currently exploring how intelligent algorithms can be used to provide business automation and insight.

**SPOTLIGHT** | Bergman is a Principal Investigator within the IT Informatics research program and has led several successful technology transfers from HP Labs to HP products including Dust & Scratch Removal for scanners and Event Interpretation for the HP Indigo press. She is currently managing the development of an image-based automation technology which represents a new approach to software automation independent of the underlying software application technology.



## Researcher Profile: Umesh Dayal

**Ph.D. Applied Mathematics, Harvard University  
HP Fellow, Information Analytics Lab**

**RESEARCH INTERESTS** | Umesh Dayal is an expert in data management, business intelligence, and analytics. He currently leads research in Live Business Intelligence which combines large-scale data management, analytics, and visualization to enable real-time decision making.

**SPOTLIGHT** | Dayal is a Fellow of the Association for Computing Machinery (ACM). In 2010, he received the Edgar F. Codd Innovations Award from ACM's Special Interest Group on Management of Data (SIGMOD) for his contributions to the field of data management, and a Distinguished Alumnus Award from the Indian Institute of Science. In 2001, Dayal also received the 10-Year Best Paper Award from the International Conference on Very Large Data Bases for the most influential paper published a decade earlier. The paper was focused on a transactional model for long-running activities and is widely-regarded as having launched the field of enterprise-scale, transactional workflow management.

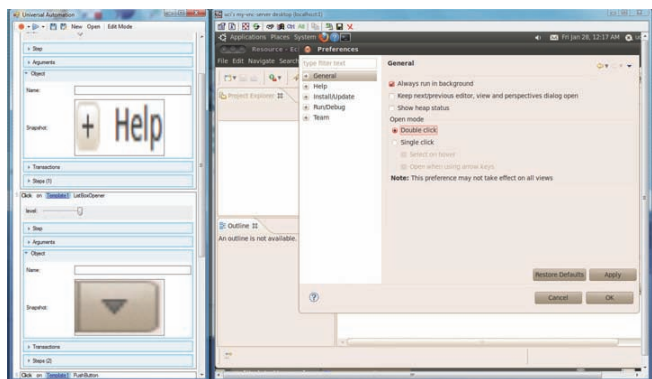




Researchers from HP Labs' IT Informatics project have developed several key advances in 2010, with the potential for impact across a range of HP's BTO products.

HPL's revolutionary research in image-based automation provides a universal automation technology which can monitor users in any operating or application environment, combining universal automation with algorithms for business process recognition and user monitoring analytics. This application interprets user actions and captures the actions in textual automation scripts. This technology has the potential to revolutionize the application management world, providing a simple and flexible approach to IT automation.

BTO applications also handle an overwhelming amount of IT data, arising in multiple contexts from a multitude of IT applications. HPL's research in document knowledge enables these systems to quickly build methodologies and applications to crystallize IT data into an effective source of information that is readily available for automation applications. The IT document knowledge extraction system mines IT forums and technology web pages to retrieve high-quality, relevant information for specific questions or search contexts. This allows IT issues to be resolved faster by making the right information available to IT support practitioners, from a multitude of sources.



## Live Customer Intelligence Helps Brands Make Sense of Their Reputations Online

The proliferation of customer feedback and commentary from online review sites, surveys, blogs, and social networks has created new channels for customers to

share their experiences and voice their opinions. These dynamic, online social channels engage customers, prospects, and influencers – touching virtually every key constituent in an organization's value chain. These channels are reshaping how customers evaluate and choose products, how brands are perceived, and how business processes interact with the customers. Marketing based on traditional customer demographics information is not sufficient and will become increasingly irrelevant. Marketers are increasingly requiring the seamless integration of real-time data analysis into their marketing strategies, including the ability to model, identify, understand, measure and react quickly to sentiment, opinion, intention, and behavioral trends expressed in unstructured content in emerging social channels. These capabilities are transforming the way companies interact and manage relationships with their customers.

Researchers working on HPL's LiveBI analytics platform are developing new techniques to provide these analyses to marketers intuitively and in real-time. Their Live Customer Intelligence platform can turn a massive set of data – for instance, six years' worth of traveler hotel reviews – into a series of easy-to-interpret dashboards that allow a company to quickly identify how customers are viewing their product or brand in real-time, then drill-down into a series of more detailed views on specific attributes or changes in consumer sentiment over time.

Underlying it all is the team's cutting-edge data analytics research that leverages data management technology and fuses it with new paradigms for analytics development and execution; supports declarative models for analytics computation; integrates analytics over both streaming and historical data, and structured and unstructured data; and takes advantage of recent advances in hardware and software architectures.



# Intelligent Infrastructure

## Intelligent Infrastructure Big Bets

### CeNSE – Central Nervous System for the Earth

A Central Nervous System for the Earth is positioned to provide a new level of environmental awareness through a network of millions of inexpensive sensors, data storage, and analysis tools to improve the safety, sustainability, and security of people and businesses. Our sensor effort is focused on creating a Moore's Law for sensing. We are applying our nanotechnology expertise to push the boundaries of cost, size, power consumption and integration to create more capable sensor nodes, combining technologies such as chemical/biological and inertial sensing. Our networking effort lays the conceptual groundwork for the communication fabric of a CeNSE-scale sensor network, with an emphasis on the wireless component. Areas of focus include the tools of network information theory, allowing for new architectures, protocols, and codes that go well beyond those deployed in state-of-the-art networks today. Finally, our analytics effort applies real-time event visibility to move systems from historical or reactive analysis to proactive, real-time optimization.

### Next Generation Datacenters

The explosion of data that enterprises, consumers and sensors continuously generate, store, search, and mine requires new thinking about the way in which the datacenters processing this information have to be designed, managed and programmed. At the same time, emerging technologies around nonvolatile memories and photonics enable new designs. Our end goal is to build a scalable, power- and cost-efficient, automated and programmable datacenter for the "data-centric" society. To achieve this, we have structured a research plan that ties together novel computing platforms, scalable systems and management software, and programming platforms.

Enterprises are creating and processing information at staggering volumes and accelerating rates. In the next ten years, digital data alone is expected to grow 44 times. By 2020, there will be 4 billion people online creating 50 trillion gigabytes of data. Storage capacity requirements in business are growing 20-40% percent each year. So if an enterprise has 100 terabytes of storage capacity today, then it will require over 370 terabytes within five years.

These mind-boggling quantities of data demand ever-smarter computing architectures, networks, and storage solutions. And that's because today's infrastructure is built on old protocols, strained by enterprise requirements to support bandwidth-hungry applications, mobility, security, and manageability. In a world where IT demands and the resources to meet them don't add up, an intelligent infrastructure can create the backbone of a sustainable society.

An Intelligent Infrastructure is about IT working together in a way that makes sense: a system of smarter, more secure enterprise computing devices, networks, and storage built on scalable architectures. And it's about creating technology that blends into the way we work and live our lives as individuals and in business.

At HP Labs, we're developing radical new approaches to how data is collected, processed, and stored to harness the power of information. HP is embedding technology into the world around us to tap into the power of information and make faster, better decisions.

## Radically Rethinking Datacenter Design

Datacenter energy use continues to be top-of-mind for many in the IT industry: for example, datacenters consume approximately 1.5% of all electricity generated in the United States. Additional energy and resources are used in their manufacture, a figure that can be calculated to understand the total energy, or "exergy," consumed by a typical datacenter over its "cradle-to-cradle" lifespan.





**Researcher Profile: Peter Hartwell**

**Ph.D. Electrical Engineering, Cornell University  
Distinguished Technologist, Intelligent  
Infrastructure Lab**

**RESEARCH INTERESTS** | Peter Hartwell is recognized as a leader in the areas of micro-electro-mechanical systems (MEMS) and quantum science. He specializes in MEMS testing techniques, and has deep experience in commercializing silicon MEMS products and working on advanced sensors and actuators.

**SPOTLIGHT** | Hartwell leads HPL's MEMS team and is currently developing highly-sensitive inertial sensors for measuring motions and vibrations of the smallest scale. He's also been at the center of HP's CeNSE research program, an application of sensor technology which the company calls an "information ecosystem" that will embed trillions of sensors in the earth and connect them with computing systems, software, and services. In 2010, Hartwell and his team received numerous awards recognizing their sensing achievements including the HP CEO Innovation Award, EE Times Annual Creativity in Electronics (ACE) Award for Most Promising New Technology, Electronic Design News (EDN) Magazine Innovation Award for Accelerometers, and Design News Magazine's Golden Mousetrap for Best New Products in Sensors and Vision.



A portrait of Michael R. T. Tan, a man with dark hair and glasses, wearing a blue and white striped shirt and a blue lanyard. He is standing outdoors with a blurred background of greenery and buildings.

**Researcher Profile: Michael R. T. Tan**

**Ph.D. Electrical Engineering, Stanford University  
Distinguished Technologist, Intelligent  
Infrastructure Lab**

**RESEARCH INTERESTS** | Michael Tan is recognized as one of the pioneers of the field of optical interconnects. He and his colleagues performed some of the earliest research in the use of vertical cavity surface emitting lasers (VCSELs) for short reach multi-gigabit optical interconnects.

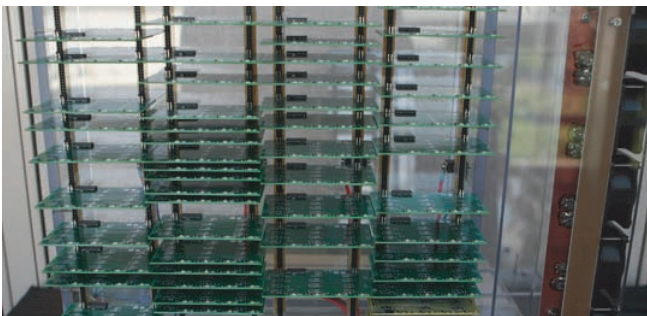
**SPOTLIGHT** | Tan is a member of the Institute of Electrical and Electronics Engineers (IEEE) and has served on numerous technical program committees of international conferences on optical communications. He has co-authored over 80 peer-reviewed journal articles and holds over 70 issued patents. Tan's current research is focused on exploring ways to cost-effectively replace all off-chip copper interconnections within a server rack with light. He seeks innovative optical solutions to remove the electronic bandwidth bottleneck while reducing energy usage.



An HPL team that combines mechanical engineers from the Sustainable Ecosystems Research Group with computer system architects from the Intelligent Infrastructure Lab has been leading radical new thinking on how the datacenter of the future might be designed so that its total exergy consumption is substantially reduced. Their thinking, in a nutshell: “dematerialize” the datacenter for a lower total cost of ownership (TCO).

Thinking about removing materials from the datacenter makes sense, since the energy it takes to make the systems themselves today already comprises 20-30% of total data center exergy consumption, and is only likely to get bigger. Their redesign is radically new. Gone are the conventional “pizza boxes” housing individual servers slotted into columns of server racks. Instead, pairs of vertical backbones, similar to those that anchor the walls of modular bookshelves, hold columns of server blades plugged directly into the supports. After significant testing and some evolutions in the design, the team was able to demonstrate that their proposed design can reduce exergy consumption by about 50%, while keeping the same level of performance.

And while no one is ready to start building these new datacenters yet, the team is using their model to validate their research hypothesis that “designing from cradle-to-cradle with sustainability in mind will get you the most effective cost of ownership,” according to researcher Ampip Shah.



## Photonic Backplane Demonstrated

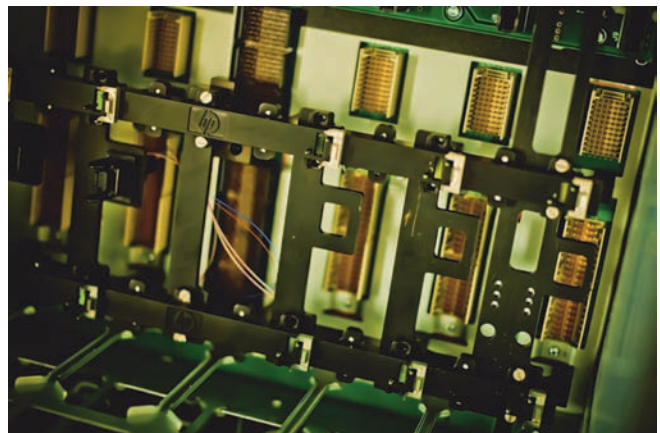
Many of today’s high performance electronic systems face significant future scaling challenges due to the limitations of electronic interconnects both in terms of power and bandwidth density. This is especially a problem in the design of core network switches, which must accommodate both increasing port counts and

data rates. At the same time, the bandwidth requirement for data center switches is increasing dramatically due to the shift to higher bandwidth link standards, such as 100 Gb Ethernet.

Optical interconnects have the potential to improve both the power efficiency and interconnect density of backplane interconnects. However, volume products based on this technology have yet to emerge for reasons of cost and practicality. Researchers in HP Labs are developing innovative optical solutions which can be manufactured using low cost, high volume techniques.

The team has re-architected the data center switch to exploit the unique capabilities of optics, specifically the ability to implement very high data rate broadcast. Their novel architecture achieves greater cost and power savings than by simply replacing the point-to-point electronic interconnects in the existing switch architecture with optical connections. Instead, the solution uses multiple optical broadcast buses to replace the electronic backplane and crossbar fabric switch ASICs in a datacenter network switch. The optical technologies developed are based on existing, commercially-available high volume optoelectronics that have the potential to offer 10× bandwidth scaling and at 10× lower power.

The optical backplane allows the switch function to be distributed equally among the line cards, removing the requirement for costly and power-hungry switch fabric ASICs. The components of the switch interface have also been developed at HP Labs. Researchers in the Intelligent Infrastructure Lab believe that this technology will enable future breakthroughs in storage and networking, leading to greater scalability and power efficiency.



## Intelligent Infrastructure Big Bets

### Next Generation Scalable Storage

The goal of this research is to design the storage platform for cloud computing. Our approach is to exploit a fundamental tradeoff between the consistency, availability, and network-partition-tolerance of distributed systems. Our system offers various consistency models including some that provide high availability by allowing data updates even when there are network failures. Attributes of our system include scalability, low cost, reliability, and self-repair. The system can cheaply and efficiently scale storage capacity and performance, and a single instance can scale across multiple geographies.

### Nonvolatile Memory and Storage

The memristive memory program's goal is to create low-power, high-speed, ultra-high density, low-cost and nonvolatile universal memory and storage solutions that eventually replace Flash, hard disks, DRAM, and SRAM. Our research path is to continuously invent and improve new memristive materials, device structures, hybrid CMOS/memristor circuits, storage and logic architectures, and information theoretic strategies tailored to specific applications. We develop significant intellectual property and work with external manufacturing partners for development and commercialization of essential components.

### Photonics

Photonics research is focused on replacing the copper-based electrical connections used in today's IT systems with optical laser communication links. Using light to transmit information can exponentially increase performance, reduce cost, and improve power efficiency over the conventional copper in use today. This project has ambitious goals to develop and commercialize photonic interconnects: develop photonic interconnects enabled by extremely efficient and inexpensive optical sources, modulators, and detectors; create new classes of optical technologies that rely on advanced physics of new materials; and enable new systems, computer processors, and switch architectures through large-scale integrated photonics.

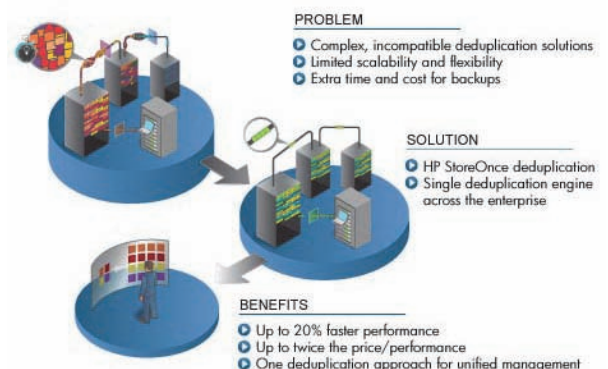
## StoreOnce: Taming the Data Storage Challenge

Data deduplication has emerged as one of the fastest growing datacenter technologies in recent years because of its clear benefits to enterprise customers who are facing a number of complex challenges. Businesses are drowning in data. Regulators are demanding that more documents be saved and available for easy retrieval. IT departments need a way to cost-effectively and quickly back up data, allowing crucial information to be easily found.

In 2010, HP announced StoreOnce software, featuring new data deduplication technology developed with research pioneered by HP Labs researchers Kave Eshghi and Mark Lillibridge. The technology enables customers to stop storing the same data over and over again. Data deduplication looks for blocks of identical data within files. If only one block within a file has changed, then only that block is backed up. All of the other blocks are replaced with pointers to existing blocks. As these pointers take up very little disk space, the more back-ups that are performed, the greater the space gains. If a data loss occurs, the data is simply reconstructed back into its original, undeduplicated state.

Available as part of an HP StorageWorks appliance, the StoreOnce software can improve performance by up to 20%, provide up to twice the price/performance ratio, and offers customers one deduplication approach for unified management. "Customers have been asking us for an amplifier that could boost their storage capabilities," says Graham Perry, HP StorageWorks. "That's what data deduplication does. It allows you to store more data for less money, and it allows you to manage it in a user-friendly way."

### HP StoreOnce Technology







**Researcher Profile: Kimberly Keeton**

**Ph.D. Computer Science, University of California at Berkeley**

**Senior Research Scientist, Intelligent Infrastructure Lab**

**RESEARCH INTERESTS** | Kimberly Keeton works in the area of information management, where she and her colleagues are building a database-like system for data mining, analysis and search applications that simultaneously supports high update throughput and allows queries to trade off result performance for result freshness. In addition, she is recognized as an authority in the areas of automating storage management, computer architecture characterization of databases, and intelligent disk systems.

**SPOTLIGHT** | Keeton has published over 40 papers in peer-reviewed venues, and has been granted 10 U.S. patents, with over a dozen additional applications pending. She is a senior member of both the Institute of Electrical and Electronics Engineers (IEEE) and the Association for Computing Machinery (ACM). Keeton has served on numerous technical program committees, and has co-chaired the program committees for ACM SIGMETRICS 2011, USENIX FAST 2010, and IEEE/IFIP DSN/PDS 2008.

**Researcher Profile: Gilberto Medeiros-Ribeiro**

**Ph.D. Physics, Universidade Federal de Minas Gerais, Brazil**

**Research Manager, Nanoelectronics Research Group**

**RESEARCH INTERESTS** | Gilberto Medeiros-Ribeiro has been focused on electronic properties of nanostructured films for the past 16 years, having co-authored over 125 peer-reviewed papers during his tenures at UC Santa Barbara, HP Labs and the Brazilian Synchrotron Light Source. He has employed novel X-ray scattering and microscopy techniques to unveil chemical and structural properties of nanostructures, and electrical transport, optics and spin-related techniques to determine the electronic properties of materials. Memristors and other nanoelectronic devices are currently his primary focus.

**SPOTLIGHT** | Medeiros-Ribeiro has taken an active role in the fields of nanosciences and semiconductor physics, having served on the IUPAP (International Union of Pure and Applied Physics) committee for semiconductor physics, and participating in several international conference assignments.





StoreOnce is already saving customers significant amounts of storage capacity and money. One major European customer, for example, has a very complex, multinational data network, and with StoreOnce, it is squeezing more back-up data into far less space. The customer is also restoring lost files more quickly and reducing down time.

## HP and Hynix Semiconductor Announce Agreement to Bring Memristor to Market

In 2010, HP Labs turned a 40-year-old computing theory into manufacturing reality. HP and Hynix Semiconductor, a world leader in the manufacture of computer memory, announced a joint development agreement in August that will allow them to bring Resistance Random Access Memory (ReRAM) technology based on memristors (memory resistors) to market. This partnership provides a path to commercialization significantly faster than the 15-20 years it can typically take to commercialize such technology. Memory chips created with memristor technology have the potential to run significantly faster and use much less energy than Flash memory technologies.

The existence of memristors was demonstrated by HP Labs researchers in 2006, 35 years after a professor at

UC Berkeley proposed their existence as the fourth basic circuit element, after the resistor, capacitor and inductor. Subsequent research by the Nanoelectronics Research Group, directed by Stan Williams, led to increases in memory density of four to eight times compared to standard technologies, by stacking layers of memristor crossbars; and demonstrated that the memristors are also capable of performing Boolean logic functions.

This means that memristors have extraordinary potential to transform how computing takes place; for example, computation could be performed where data is stored, rather than by a specialized central processing unit. The potential impact to IT is that computers would run significantly faster than they do today. For now, however, the near-term application for memristor technology is as a replacement for flash memory. According to Williams, Memristor memory has the potential to run at least ten times faster and use ten times less power than an equivalent flash memory chip, and be erased and written over many more times.

The team's experience and deep theoretical knowledge are assets that HP brings to the partnership with Hynix, as well as expertise in architecture, circuit design, and error correction coding – not just the memristor itself. In addition, this is a true collaborative partnership: the HPL and Hynix teams will work closely together to ensure success.

# Mobile and Immersive Experience

## Mobile and Immersive Experience Big Bets

### Continuous View Glasses-Free 3D

The goal of our Continuous 3D research is to build systems that accurately replicate the physical world with respect to our visual and auditory senses. We aim to build technology that will faithfully capture, transmit, and reconstruct the appearance and sound of our 3D world. Multiple viewers, simultaneously looking at the same display, will see different views and see their views change in response to movement, with no need for special glasses. This requires significant innovation in both the capture and display of 3D visual and auditory information. It also requires significant advances in high-quality compression, transport, and processing of 3D video and audio.

### Next Generation Displays

Our mission is to create the display that is the central component of the next generation of “thin” appliances or “Information Surfaces.” The future will bring a display that will be able to show print-quality information as well as video and interactive media, will be lightweight, robust and mobile, and can be manufactured at low cost and with low capital investment. Because of its paper-like and video capabilities, its flexible form factor and ease of customization and integration into products, this display will also enable novel product capabilities such as active surfaces and skins.

More and more people are interacting with technology at work, at home, or when mobile. Over 79% percent of American adults use the Internet, and 59% percent connect to the Internet wirelessly using Wi-Fi or mobile broadband through their laptops or cell phones. And Americans spend 36% percent of their online time communicating and networking across social networks, blogs, personal email, and instant messaging.

People are looking for fast, context-aware methods of interfacing with technology. They expect technology to be easy to use, reliable, and personalized – transparently enabling mobile and immersive experiences. And nothing will drive the continued growth and applicability of technology more than the point of human interface.

At HP Labs, we see a future in which human interaction through and with technology becomes completely intuitive, wherever you are. We’re radically simplifying the user experience by focusing on seamless collaboration, across devices. We’re also harnessing the collective intelligence of connected populations inside and outside enterprises to create novel technologies and services. And by making computer and human interactions intuitive and cognitively simple, the adoption of information technology will be far more pervasive than it is today.

Mobile and Immersive Experience research seeks to create compelling user experiences that fundamentally change how people communicate, collaborate, socialize, and entertain – utilizing multimedia technologies to deliver intuitive, interactive, mobile, and immersive audio-visual experiences.

## HP Labs 3D Research Goes Live in 2010

HP Labs’ 3D team has had an outstanding year, starting with the unveiling of Pluribus 3D technology at the 2010 Sundance Film Festival, and culminating in





### Researcher Profile: Steve Kitson

**Ph.D. Physics, University of Exeter, England  
Research Scientist, Mobile and Immersive  
Experience Lab**

**RESEARCH INTERESTS** | Steve Kitson's focus has spanned the areas of biosensors, quantum optics, and photonic band gap structures. His most recent research targets next-generation display technologies combining high-efficiency optics with nanotechnology, and the development of novel materials and new manufacturing techniques.

**SPOTLIGHT** | Kitson is a technical lead for HPL's displays research group where the objective is to develop novel display technologies rivaling the image quality of paper. His recent contributions include innovative enhancements for a full-color reflective display architecture and a novel display technology where the image persists indefinitely without consuming any power. The latter invention is a key step towards producing displays with many more pixels than is currently possible, enabling print-like resolution. These inventions resulted in Kitson receiving significant press attention, including articles in Science and New Scientist magazines, and formed the core of an HP exhibit at England's prestigious Royal Society Summer Exhibition. Kitson has published over 30 papers and filed over 20 patents.

an exciting 3D show by Earth, Wind and Fire that was broadcast at the 2011 Consumer Electronics Show (CES) in Las Vegas. Viewers at first thought they were watching the venerable funk band warm up pre-concert, but in reality they were watching a near-life size, wide-screen 3D projection of the band.

Behind the screen was HP Labs technology and researchers making it happen: Pluribus software technology controls a rack of off-the-shelf, inexpensive projectors that combine into a scalable “super projector” that rivals any of the best front-projection 3D displays currently available. In addition, the team has demonstrated the ability to capture 3D content using synchronized HD video cameras (in lieu of expensive professional 3D cameras); use sophisticated HP streaming technology to allow live 3D video to be recorded, transmitted across huge distances, and then sent to each projector as needed; and perform real-time processing of the video feed to “stitch” together the images, creating an immersive experience for viewers, all in real time.

The results are exciting – but HP isn’t stopping there. These events – at CES and numerous other customer sites – have showcased that the technology works, and HP Chief Technology Officer Phil McKinney suggested at CES that a whole new category of “3D immersive events” should become possible. The research behind Pluribus might one day impact markets as diverse as gaming, digital cinema, home theater, collaboration and visualization.

## Flexible Displays, One Step Closer to Reality

IT industry experts have long been predicting a rosy future for flexible displays, and manufacturers and consumers alike are expecting future products like tablets, smartphones and personal computers – as well as even newer devices – to feature screens that weigh less and are more durable than today’s glass-based displays. And while HP’s technology is not yet ready for commercial use, HPL researchers working on next-generation flexible display technology are making incredible progress in bringing working prototypes to life.

Working with plastic film that is lighter, and thinner, than glass, the team has developed a roll-to-roll fabrication method that can be far cheaper than current “batch” manufacturing processes for making glass displays. The plastic film runs through a process where it is imprinted and etched to create transistors on the film, that in turn signal electrically-charged particles or diodes in a second layer of plastic that displays text or images. The team has also proven the concept of flexible displays capable of showing color and video, using organic light emitting diodes (OLEDs). The team’s work was recognized with the 2010 FLEXI award at the Flexible Electronics and Displays Conference.

One of the most remarkable aspects of the team’s research accomplishments has been its emphasis on close collaboration with university and external

HP Labs 3D Team



Harlyn Baker, Nelson Chang



Jack Cattolico, Brad Wittke



research partners. For example, a joint program with the Flexible Display Center at Arizona State University is leading to exciting new wearable devices that will be delivered to the U.S. Army; and a multi-year collaboration with researchers at the Renato Archer Center for Information Technology (CTI) in Brazil has helped the HP Labs team speed up the rate at which they can build and demonstrate the concepts they develop in the lab.



## SiteOnMobile: Simplifying Web Access for Millions

While the penetration of the Web in developing countries is still very low, there has been huge growth in the usage of mobile phones. For example, there are approximately 60 million PC users in India, but more than 700 million mobile phone users. It is likely that mobile phones will actually be the primary internet consumption device for consumers in these fast-growing markets. However, over 50% of the handsets sold in emerging markets – like India – are ultra low-end phones featuring only voice and text messaging capabilities.

To address this problem, researchers in HP Labs India launched a new cloud service in 2010 to enable the value of the web to reach this vast market of cell phone users. The service, called SiteOnMobile, makes it possible for hundreds of millions of people using low-end mobile phones to access web content and services.

## Mobile and Immersive Experience Big Bets

### Intuitive and Rich User Experiences

As IT and computing devices become increasingly sophisticated, enhancements in human-device interaction are poised to be key drivers for technology adoption, particularly in emerging markets. In addition, other barriers to adoption that these tech-naïve users may face include lack of a compelling value proposition; unfamiliarity with the interaction metaphors of keyboard and mouse; lack of content in local languages; the predominant use of paper in their daily lives; and unique cultural requirements. HPL's vision is that usage of a personal computing device will become as simple as using a mobile phone or TV, or even as simple as talking to another human being. Our goal is to develop compelling services, a distributed experience software platform, and a hardware/software architectural ecosystem that bridges the gap between mobile and fixed experiences while leveraging the value of the cloud.

### Seamless Collaboration

Our research in Seamless Collaboration aims to extend telepresence from fixed infrastructure solutions to everyday devices. Our work will enable HP personal computing devices to create the sense of effortless connectedness that exists in a face-to-face meeting, and provide a rich range of human interaction and collaboration. We are making fundamental advances in research areas such as audio and video capture, video communication, video rendering, new mobile experiences, and augmented reality.

### Social Computing

Our work aims to harness the collective intelligence of the connected population inside and outside enterprises to create novel technologies and services. Ours is an interdisciplinary approach, combining social and computer science. We focus on the economics of attention, creating models to understand and harness the flow of collective attention, supporting a mobile society with context-aware and anticipative technology. We want to enable a fluid enterprise, where collective intelligence is harnessed via appropriate incentives to predict the future, make decisions, and allocate resources.

## Researcher Profile: April Slayden Mitchell

**M.S. Computer Science, University of Rochester,  
New York**

**Senior Research Engineer, Mobile and  
Immersive Experience Lab**

**RESEARCH INTERESTS** | April Slayden Mitchell's interests span user interaction design, mobile user experiences, technology for education, and innovations in music and video. Since joining HPL in 2002, she has worked on multiple projects including mobile telepresence, secure user interfaces, and personal collaboration.

**SPOTLIGHT** | Mitchell led the design of the original user interface for HP's Visual Collaboration Studios, co-created HP's Gabble video conversation site, and received a best-paper award at ACM CHI in 2007 for her research on mobile video behavior. She has also served as head director and worked for five years on the organizing board for HPL Tech Camp, a week-long technology summer camp for middle school girls. A former ACM HotMobile general chairperson, Mitchell is now a member of the organization's steering committee and has served as a reviewer or program committee member for numerous international conferences and publications including MobiCASE, IEEE ISWC, ACM CHI, IEEE Pervasive, and Mobile Networks and Applications. She is the author of 5 patents and has over 20 patents pending.







**HP Labs' social media  
influence algorithm was  
selected by The New York  
Times Magazine for its *10th  
Annual Year in Ideas* issue:  
*Social Media as Social Index***



## Suryaprakash Kompalli

Ph.D. Computer Science and Engineering, University at Buffalo, State University of New York  
Research Scientist, HP Labs India

## Dinesh Mandalapu

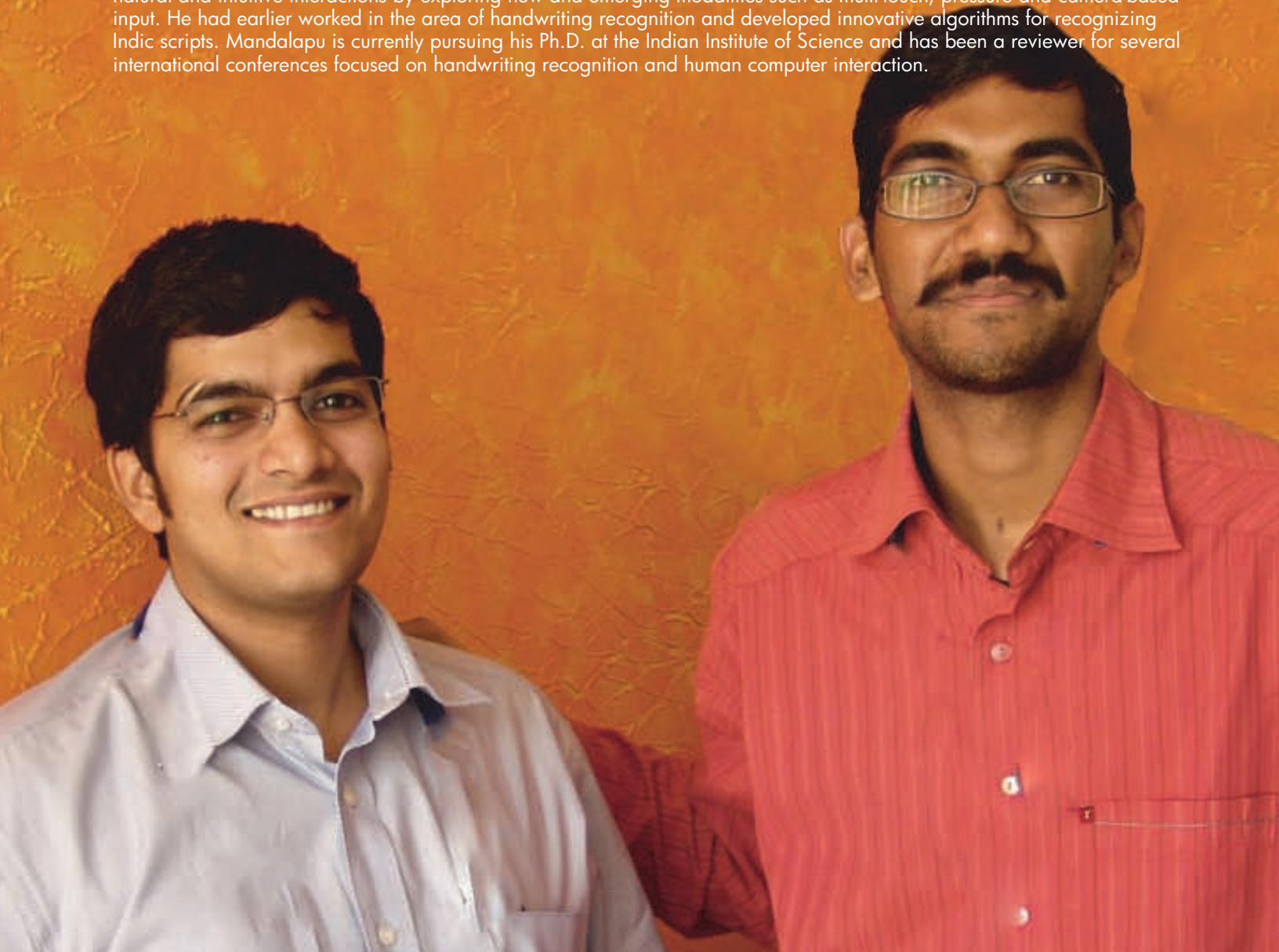
M.E. Electrical Engineering, Indian Institute of Science, Bangalore  
Research Scientist, HP Labs India

RESEARCH INTERESTS | Suryaprakash Kompalli and Dinesh Mandalapu work on the Intuitive and Rich User Experiences project at HPL India which is focused on developing novel interaction paradigms for HP's next billion customers. The project combines multimodal and paper-based interactions, simplified access to the web, security, and novel hardware to create rich user experiences. Kompalli sees this project representing a key value proposition for customers by providing the ability to complete daily tasks in the digital domain using simple interactions on affordable hardware. Mandalapu believes that enabling intuitive and effective multi-modal interactions based on natural input modalities like pen, touch, pressure, hand gestures and speech will redefine human computer interfaces for personal systems.

## SPOTLIGHT

Kompalli's research interests span image processing, GPU architectures for image processing, and techno-social challenges in emerging markets. Prior to his current HPL activities, he also focused on medical image analysis and healthcare IT. Kompalli is a member of IEEE and has been a reviewer for several journals and image processing conferences. He holds four patents and several peer-reviewed publications.

Mandalapu's research interests are in machine learning and human computer interaction. His current focus is on enabling natural and intuitive interactions by exploring new and emerging modalities such as multi-touch, pressure and camera-based input. He had earlier worked in the area of handwriting recognition and developed innovative algorithms for recognizing Indic scripts. Mandalapu is currently pursuing his Ph.D. at the Indian Institute of Science and has been a reviewer for several international conferences focused on handwriting recognition and human computer interaction.





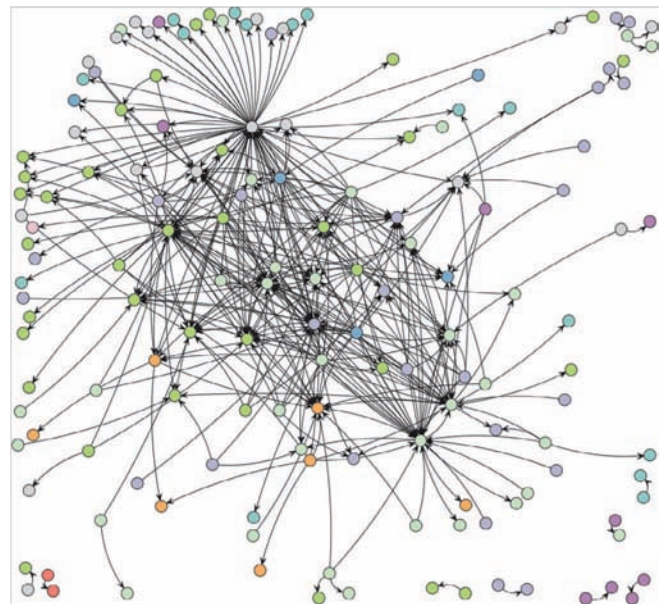
SiteOnMobile is a pilot service that enables SMS and voice access to existing web sites. Rather than delivering a complete web page to a mobile phone, SiteOnMobile delivers only specific content relevant to the user's task—for example, a weather forecast or travel information. The service also supports automatic generation of widgets on Windows mobile, WebOS and Android devices. Businesses of all sizes can easily extend their reach by creating "TaskLets" for business-relevant tasks with zero programming. Users just need to navigate through a series of web pages on their web site to create a new task experience; SiteOnMobile automatically "packages" the task and allows the publisher to release the service for voice, text, or smartphone access.

SiteOnMobile has generated a huge amount of interest since its launch, with coverage in over 50 national and international media outlets and several blogs. The service is being piloted in India with over 250 registered users accessing the service and 100+ potential customers wanting to partner to release their web-enabled services on low-end phones. HP Labs India is currently working with 12 such partners to create and test services for consumers in India. SiteOnMobile was also featured in MIT Technology Review India as one of the 7 winners of "Grand Challenges for Technologists in India."



## Innovative Social Media Services - Watercooler, Rankr and iCatcher - Garner Increased Attention in 2010

A Twitter account may be "popular" – meaning it has lots of followers – but it isn't always "influential," a key finding published by the Social Computing Research Group this year in the paper "Influence and Passivity in Social Media." Analyzing 22 million tweets with a special algorithm, they found that the most influential users somehow persuade their followers to re-tweet; that is, to forward information to others, thereby propagating it across the network. With hundreds of millions of users of online social networks, the incredible explosion of information available on the web, and the millions of internet users that are actively producing, sharing, classifying and rating content, these HPL researchers are working to understand more about what makes content important to users, how to do better crowdsourcing, and how to share information across enterprises.



The team recently demonstrated a service that analyzes the allocation of attention within social media to predict real-world outcomes. In April, after analyzing the positive or negative sentiments expressed in 2.8 million Twitter messages regarding 24 movies, the team predicted the films' box-office revenues. Their results significantly outperformed the Hollywood Stock Exchange, a popular market-based predictor for box-office performance, and proved that social media can

**Researcher Profile: Thomas Sandholm**

**Ph.D. Computer and Systems Sciences, Royal Institute of Technology, Stockholm, Sweden  
Research Scientist, Social Computing Research Group**

**RESEARCH INTERESTS** | Thomas Sandholm studies incentive design in distributed and mobile systems and has contributions related to resource allocation, demand prediction, parallel job scheduling, crowd sourcing, and recommender systems. His latest focus is on context-aware mobile services.

**SPOTLIGHT** | Sandholm invented the Gloc Web geo-tagging service which is now being used by the HP ePrint mobile printing product, as well as in the AfricaMap project, a CERN/UNOSAT collaboration to provide social annotation of satellite images in Africa. He also contributed a new job scheduler to the latest release of Apache Hadoop.



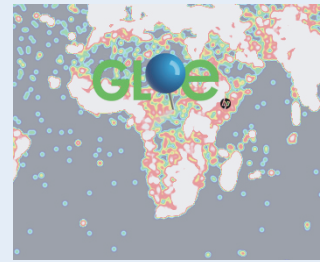


provide more than just information and content to individual users. This research was highlighted by the New York Times Magazine in its 10th annual "Year in Ideas 2010" feature.

Going even further in their search for new methods to swiftly aggregate the collective wisdom of a crowd, the team's "Rankr" web service helps quickly rank order multiple objects, suggestions or web sites that use pairwise comparisons among them. Unlike typical rank voting methods, voters need not compare and manually rank all of the candidate items, particularly useful with a large set of items. Using the votes that others have already cast, "Rankr" automatically determines the most useful pair of candidates a user can evaluate to maximize the information gained while minimizing the number of votes required. This allows the mechanism to scale beyond traditional voting schemes and enables crowd sourcing, helping users more quickly make informed buying decisions, for example.

With so much content being generated on a daily basis, how can marketers boost the chances of their content cutting through the clutter? "i-Catcher" technology increases the attention devoted to content in any web site, by using dynamic measurements of the rate at which novelty and popularity of the content within a web site changes over time. Using YouTube and Digg, two popular content sharing portals, the team showed that initial download and voter ratings information can predict the long-term popularity of submitted content. In the case of Digg, measuring access to given stories during the first two hours allowed for forecasting of their popularity 30 days ahead with remarkable accuracy, while downloads of YouTube videos required 10 days of monitoring to attain the same performance.

Finally, social media and distributed Internet services have been widely adopted by consumers as a means of finding and sharing information, and these users increasingly expect to be able to collaborate the same way at work. The team's enterprise collaboration 2.0 technology, "Watercooler", can be used securely to help transfer expertise across an organization. It gives people better filters than simple "friend" networks, allowing users to explore knowledge throughout the organization. Watercooler is already in use at HP by more than 130,000 users.



### **Open Innovation Spotlight: Social Computing Meets Social Innovation in AfricaMap Project**

Aid workers and volunteers from Non-Governmental Organizations (NGOs) often have first-hand knowledge that can help improve the accuracy of mapping vast, remote regions in Africa, particularly those where there is very limited cartography. However, integrating contributions from a large group of unknown people presents challenges in the accuracy and validity of the information provided. The AfricaMap project engages with a wide community of volunteers with local knowledge to annotate UN satellite maps, improving the coverage and freshness of information available, and sharing their understanding of features that are difficult to interpret from satellite images alone. HP Gloe, a social Web geo-tagging service developed in the Social Computing Research Group at HP Labs, is making this crowdsourcing project possible.

In addition to providing a platform for collaboration, HP Gloe addresses several crucial issues in obtaining quality information, giving users an incentive to participate; and ensuring that individuals provide high-quality, truthful information. AfricaMap will allow volunteers to annotate maps with useful information for humanitarian and development workers from the UN and NGOs. For example, leveraging historical satellite data to build maps that show changes over time, from the progression of deforestation in certain regions of Africa; or how transportation routes have evolved in response to changing social, political and environmental factors; to the positions of and equipment available in rural hospitals.

The project team includes researchers from the University of Geneva, led by Professor Bastien Chopard, and the Kwame Nkrumah University of Science and Technology in Ghana, as well as at HPL, and also involves collaboration with UNOSAT, the Operational Satellite Applications Programme of the United Nations Institute for Training and Research. The team is developing a demonstration of the software that they plan to test with on-site field operatives in real-life settings. Researchers at HP Labs, meanwhile, have an opportunity to test Gloe at a large scale in a challenging and socially-relevant setting.

# Networking and Communications

## Networking and Communications Big Bet

### Flexible Programmable Networks

The Flexible Programmable Networks project aims to deliver a robust, flexible, adaptive, open, scalable, and easily programmable wired and wireless network platform – one that is centrally controlled. This will allow the rapid, easy, and cost-effective introduction of new network features, supporting current and future network requirements. And it will provide real-time, holistic, and automated network management; meet the performance needs of bandwidth-intensive new media-rich applications; enable increasingly demanding mobility, virtualization, and cloud computing requirements; and enable a new level of end-to-end security capabilities. The project's goal is a major disruption of the basic networking platform.

The networks over which enterprises and consumers are creating, accessing, and sharing information are built predominantly on decades-old architectural principles and protocols. These network infrastructures are not designed to support today's bandwidth-hungry applications, nor are they flexible enough to adapt to increased customer appetites for mobility, security, and manageability.

Datacenters are using multiple networks to cater to a wide variety of traffic, including server communications, storage traffic, cluster messaging and management, and more. Because these multiple networks need different types of switches and cabling, the result is excessively high capital and operational expenses; they also waste power and rack space, often require multiple network administrators; and become difficult to scale.

HP Labs networking research seeks to create the next generation of network architectures and communications technologies, which provide predictable, high-quality and power-efficient networking while reducing management complexity. Our research is aimed at delivering network innovations an order of magnitude faster than what is possible today and at a tenth of today's costs. The goal is to provide customers with a fully and rapidly customizable network fabric that can be re-programmed to meet their evolving, and perhaps yet unknown, requirements.

This research area is targeting a rapidly customizable, programmable network framework that revolutionizes the way in which networks are designed, built, and operated today – networks in which behaviors are completely predictable, and new features and applications can be introduced quickly and cost-effectively. As a result, customers will have greater control over their networks and data centers.





## Researcher Profile: Jeff Mogul

**Ph.D. Computer Science, Stanford University  
HP Fellow, Networking and Communications  
Lab**

**RESEARCH INTERESTS** | Jeff Mogul is recognized as a leader in the areas of operating systems, Internet protocols and performance, and network I/O convergence. His recent SPAIN (Smart Path Assignment In Networks) research, initiated by HPL colleagues Jayaram Mudigonda and Praveen Yalagandula, aims to provide low-cost, high-bandwidth multi-path networking for modern data centers. Research on DevoFlow, initiated by Jean Tourrilhes and other HPL colleagues, argues that the popular OpenFlow "Software-Defined Network" model, while a major improvement over traditional device-centric networking, requires some tweaking for efficiency and scalability.

**SPOTLIGHT** | Mogul is a Fellow of the Association for Computing Machinery (ACM) and has made significant contributions to the peer-review process in the field of computer network research. He served as program co-chair of the 2010 ACM/IEEE Symposium on Architectures for Networking and Communications Systems (ANCS), and is serving as program co-chair of the 2011 ACM Special Interest Group on Data Communications (SIGCOMM) conference. He is also on the steering committee of the 2011 Workshop on Hot Topics in Management of Internet, Cloud, and Enterprise Networks and Services (HotICE). In 2010, Mogul co-authored several prominent papers with his HPL colleagues including a Symposium on Networked Systems Design and Implementation (NSDI) paper, "SPAIN: COTS Data-Center Ethernet for Multipathing over Arbitrary Topologies," and a HotNets paper, "DevoFlow: Cost-Effective Flow Management for High Performance Enterprise Networks."



## OpenFlow and HP Labs: Partnering for Success

Enterprise and data center networking poses challenges to the IT industry today, as customers seek to achieve significant increases in scale and throughput at reasonable cost; while creating sufficient flexibility in networking so that it does not become an obstacle to coming evolutions in IT; all while addressing the challenge of management of these networks as a whole, and not just their individual pieces.

HP Labs is playing a key role in advancing networking research, both through the team's research on scaling Ethernet networks in datacenters by using ensemble routing and smart path planning algorithms; as well as HP's participation in advanced research testbeds at universities, including the US National Science Foundation-funded GENI (Global Environment for Network Innovations) testbed.

OpenFlow™, a building block in the GENI testbed, is a protocol proposed by researchers at Stanford and several other universities to improve network programmability. HPL researchers have implemented the OpenFlow protocol in HP network switches with extensions for quality of service (QoS) and easier deployment in production networks. This implementation is now available on HP E3500, E5400 zl and E6600 series switches. In collaboration with HP Networking, the implementation is currently in use in over 40 organizations worldwide.

HP switches with OpenFlow are being used for multiple demonstrations on the GENI testbed by many universities, on a range of topics: virtual machine migration for seamless multi-player gaming experiences; network power management; and dynamic rerouting around failures, to name a few. HP Labs is continuing its research to scale OpenFlow networks and design simpler network management mechanisms using OpenFlow.





# Printing and Content Delivery

The future of commercial printing is digital – flexible, customized, on-demand. Today, only about 10% of commercial print pages are printed digitally. To grow the market we need to match the quality and cost-effectiveness of traditional printing.

At HP Labs, we're meeting this challenge by focusing on printing processes and automation. HP Labs' focus on digital print will evolve the printing industry and our market opportunity within it. At the same time, the digital and physical worlds are converging. So we're building the technologies needed to smooth the flow of information between them. And we're automating the publishing workflow process and making it easier for businesses and consumers to publish professional-quality content by unlocking their media assets, wherever they're located.

## Keeping Patients Safe from Counterfeits in Africa with mPedigree

Imagine taking a pill that has no active ingredient, or one that doesn't have enough of it, so that instead of getting well, you stay sick or build resistance to drugs like antibiotics. Or, imagine consuming a basic medication that has been contaminated (whether intentionally or not) with something harmful. Drug counterfeiting is a serious problem all over the world, with real consequences for consumers and businesses alike: it was an estimated \$75 billion business in 2010, and fake medications are responsible for at least 700,000 deaths every year. Malaria medication is especially at risk: according to the World Trade Organization, fake malaria drugs kill 100,000 Africans a year.

### Printing and Content Delivery Big Bets

#### Document Lifecycle

Documents and the environments in which they are used take on new, richer meaning in the fully-connected, mobile, distributed world. Content exists in electronic and physical form, and must move between these two worlds seamlessly. Our work changes the way printed content is born, lives and dies in the connected world – both as printed and electronic documents, and often both, in the course of a document's lifecycle. To do this, we are inventing powerful algorithms, systems and services for printing and imaging, content transformation and multi-level analytics. Specific technologies include security, next-generation printing, functional image processing, classification and policy-driven workflows.

#### Automated Publishing

Automated Publishing conducts research to create a truly relevant and compelling content experience for mobile and internet users by combining context modeling, preference modeling, user experience design, mobile user interfaces, social relationships, and content semantics.

A professional portrait of Cong-Lei Yao, a man with short dark hair and glasses, wearing a light-colored striped dress shirt and a dark tie. He is looking directly at the camera with a slight smile. The background is a soft, out-of-focus gradient of blue and green.

**Researcher Profile: Cong-Lei Yao**

**Ph.D. Web Mining, Peking University, China**  
**Researcher, HP Labs China**

**RESEARCH INTERESTS** | Cong-Lei Yao is focused on web mining with specific emphasis on semantic-based web content extraction, online computational advertising, and web information filtering and recommendation. His current efforts are around contextual coupon matching and the development of web-based, automated coupon recommendation engines.

**SPOTLIGHT** | Yao leads the Printing and Content Delivery Lab's Automated Publishing team based in China. His team is targeting web content analysis, parallel computing, and image analysis, and has contributed innovative technologies to a number of HP's web printing products including Smart Print and Article Clipper.





each package of participating drugs, revealed by scratching off a coating. The consumer can send this code by text message to a free SMS number, and the consumer receives a text message reply confirming the authenticity of the drug. If the code is counterfeit, the patient receives a text message warning them that the package may be a fake.

Not only is HP providing the cloud infrastructure linking the pharmaceutical companies, telecommunications companies, and mPedigree together to make all of this possible, HP Labs' leading-edge research in anti-counterfeiting technologies in imaging and printing, analytics, and cloud computing are also playing a role in making the solution a reality.

The first drugs to use the system have already debuted in Nigeria and Ghana. HP and mPedigree plan to make the service available for other medications and in more countries in the near future.

Now, through an exciting program led by mPedigree – a social enterprise based in Ghana – HP and other companies are teaming up to actively combat these counterfeits. Thanks in part to HP Labs technology, with mPedigree consumers can authenticate pharmaceuticals free of charge and at the point of purchase, using only a basic mobile phone. The system assigns a code to

## Community Magazines through Interactive Design Reuse

Creating professional-quality brochures and magazines is a demanding task for small businesses and consumers when the budget available precludes professional assistance. Self-help, through customizable templates, is the current commercially-available



## Printing and Content Delivery Big Bets

### Commercial Print Automation

The goal of Commercial Print Automation is to greatly accelerate the ongoing analog-to-digital, and long-to-short-run transformations in the commercial/industrial print industry. By putting new workflow technologies in place to enable efficient, automated, and re-engineered print workflows, we aim to reduce the end-to-end Total Cost of Operation of commercial print publishing systems, driving conventionally-printed pages to digital production and creating new pages that did not previously exist. For example, our Quality Assurance technologies extend the digital workflow across the transformation from bits to atoms, and open the way to monitoring and controlling the downstream part of the digital print workflow. Print quality automation will have a dramatic effect on the total cost of operation for digital print jobs.

### Printing Processes for Digital Commercial Print

Our vision is a breakthrough print engine technology platform which accelerates the analog-to-digital transformation for high-value commercial pages. We seek to create a unique combination of low-cost, high-quality attributes not found in any single press process today. Specifically, our goal is breakthrough technology that achieves throughput of more than 1,000 pages-per-minute (ppm) with a consumables manufacturing cost per page lower than the current cost – providing the same high ink coverage, image quality, and media gamut as the best current digital presses – while also reducing its carbon footprint.

solution, but the range of templates available limits user choice. Users also often find it difficult to fit their content into these templates. In an ideal world, the style of any media viewable on the web should be reusable with any user content through a drag-and-drop interface.

HP Labs researchers set out to find a solution to the technical, aesthetic and human factor issues involved. The result was Interactive Design Reuse (IDR) technology, which includes developments in automatic layout engines, in-document representation, and user interface design. To focus the early stages of the work, the research team considered the creation and publishing needs of a high school community and produced the Community Magazine research prototype. The prototype leverages HP's MagCloud publishing service for fulfillment and demonstrates the basic feasibility of the approach to HP business groups.

In 2011, the research team plans to deploy the IDR technology in pilots with both HP business partners serving the SMB sector with marketing collateral solutions; and with the high school community that focused its early development.

## GPU-RIP Technology Speeds Up Commercial Printing Pipeline

Commercial print is in transition from being produced on conventional printing presses creating thousands of identical printed products to production on high speed digital printing presses producing customized and personalized products. The amount of data that needs to be processed for "every page is different" digital presses can be staggering – easily equaling and exceeding video rates. HP Labs' GPU-RIP project integrates Graphic Processing Units (or GPUs) into the commercial print pipeline for a more agile, price/performance computational pipeline for commercial print systems. HPL researchers have identified Raster Image Processing (RIP) as a strategic control point for these systems.

Researchers in HP's Printing and Content Delivery Lab have developed and implemented a commercial print RIP system that uses a pipelined CPU-GPU co-design architecture to process data at press speed using a small fraction of the hardware needed for a pure CPU solution. This implementation is an important step in the production of on-demand production of printed products, enabling print to be as responsive and personalized as electronic media, and giving HP an important edge in a very competitive market.





## Researcher Profile: Michal Aharon

**Ph.D. Computer Science, Technion University, Israel**

**Researcher, HP Labs Israel**

**RESEARCH INTERESTS** | Michal Aharon focuses on the field of digital color printing with particular emphasis on efficient solutions for reflectance spectrum estimation. Her Ph.D. thesis targeted the field of sparse signal representation which led to her development of the K-SVD algorithm that designs overcomplete dictionaries allowing for sparse representations of real value signals such as image patches.

**SPOTLIGHT** | While at HP, Aharon's K-SVD algorithm has been leveraged to the field of set theory and formed the basis for the PARIS (Principal Atoms Recognition In Sets) algorithm. PARIS is used to analyze sets of elements such as logs of large systems or documents, and was found to be an efficient tool for automatic understanding of such data. Aharon's work has been published in several prestigious conferences including the Color Imaging Conference (CIC) and IEEE International Conference on Data Mining (ICDM).



**Researcher Profile: Napoleon Leoni**

**Ph.D. Mechanical Engineering, Carnegie Mellon University**  
**Principal Scientist, Printing and Content Delivery Lab**

**RESEARCH INTERESTS** | Napoleon Leoni works in the development of new printing process technologies and in the understanding of printing process physics. His research interests include plasma physics, electrostatics, rheology and precision mechanical design.

**SPOTLIGHT** | Leoni recently led a research effort for a key technology component of one of the future high speed digital press platforms in HP's Graphics Solutions Business. He also spearheaded an effort across several HP departments focused on a novel technology with proven potential to improve production inkjet system reliability. Currently, Leoni is a key contributor on the Printing Processes for Digital Commercial Print project, developing a future print engine platform, and leads one of his lab's Open Innovation collaborations.





Created by real-time compute deadlines and the need for performance at low cost, GPUs are massively-parallel computing devices that are conventionally used in the acceleration of graphic rendering to the screen. HPL researchers believe that the integration of heterogeneous parallel architectures such as GPUs is critical to the efficient transformation of digital content into physical media. The intelligent co-design of cloud infrastructure and these types of distributed parallel devices can create an agile IT infrastructure to drive efficient manufacturing capabilities such as commercial printing.

## Breakthrough Technology from HP Labs Enables 76% Speed Increase in HP Indigo Presses

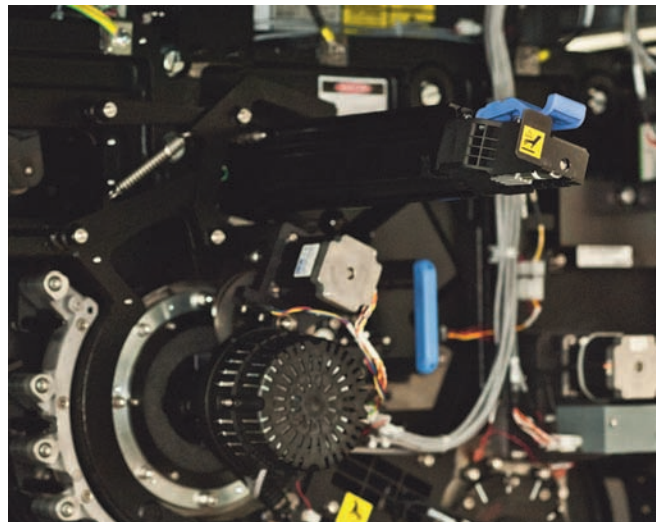
HP Indigo digital printing presses, using Liquid Electrophotography (LEP) technology, dominate the digital commercial printing market with superb print quality and high productivity. To maintain its market leadership, HP Indigo recently introduced its new Series III generation of presses, the latest of which is the HP Indigo 7500, released at the major industry conference IPEX 2010. One key enabling technology is its unique charging system, designed for a marking engine with a speed of 2.15 m/s, placing about three-quarters of a billion dots on the paper per second.

This unique charge roller unit was developed in HP Labs in collaboration with HP's Imaging and Printing research and development team. It is the first such technology used in a production digital press, and

supports by far the highest process speed of any offset-quality electrophotographic press.

This single charge roller replaces three scorotron units used in previous generation Series II presses, providing improved charging uniformity and reduced cost per page. The charge roller is also much easier to maintain and is an environmentally-friendly solution with minimal ozone generation.

Charge Roller technology has been implemented in the HP Indigo 7000 commercial press, HP Indigo WS6000 industrial press and the HP Indigo W7200 high productivity web press, and is already installed in hundreds of customer presses, generating billions of brilliant, high-quality printed pages.



## Services

Too many business decisions are unrepeatable: they're based on hunches and back-of-envelope analyses. The future of services is all about applying scientific and mathematical rigor to how businesses are run. There is a need for models, tools and algorithms to drive informed, highly effective, repeatable, and consistent decision-making processes.

At HP Labs, we're developing these decision-making tools. One of our major research goals is supporting strategic decisions that are, by their very nature, idiosyncratic, unpredictable, and relatively infrequent. These decisions rely on a mix of information – structured, unstructured, and based on judgment. At the other end of the spectrum are decisions made in areas where terabytes of data exist, but analytical solutions don't yield consistent insight and value.

Through projects in operations and personalization, we're bringing new data types and sources into play. We're transforming the effectiveness of complex business processes to create and sell better, more relevant offerings. And we're inventing and developing the next generation of analytical technologies and solutions that take advantage of the information explosion – bringing personalized experiences to individuals and unprecedented operational efficiencies to the enterprise.

### Open Innovation Spotlight: Design and Pricing of Post-Sales Services

Dr. Ming Hu at the University of Toronto has been working with the Analytics for Operations team on designing and pricing innovative post-sales services to appeal to a broader market and improve service attach rates. Together the team has created an analytical framework for modeling the optimal decisions of customers and providers involved in extended warranties and other aftermarket services – explicitly

## Services Big Bets

### Analytics for Operations

We foresee the emergence of the “analytic enterprise”: an enterprise in which clean, real-time data automatically feeds models of key business implications, and in which the decision processes are seamlessly and completely optimized based on predictions and tradeoffs. HP Labs is enabling a radical transformation from backward-looking, information-based enterprises to forward-looking, continuously optimized enterprises. We are creating an integrated system for data-driven advanced analytics services that addresses HP's key strategic and operational challenges while providing the foundation for new offerings in Business Analytics.

### Analytics for Personalization

Personalization enables us to have interesting, novel and convenient experiences in an increasingly connected world, but early technologies in this domain have markedly focused on “sell to” personalization without prioritizing the end-user experience or sufficiently addressing issues of transparency and control. HP Labs is building a secure, transparent, and user-controllable analytics platform, pulling together data from a wide variety of sources to build the most comprehensive and trusted consumer/behavioral personalization technology in the industry. Our technology enables unique experiences and capabilities for consumers, while allowing them to fully control the degree of personalization of those experiences and the information underlying them.

### Service Futures

Our work in Service Futures will focus on three interrelated components: People work via processes to conceive, design, market, sell, transition, and deliver services to customers. Our research will offer people efficiency and improved performance – via significant improvements in the processes and the tools they use. From a technology and analytics perspective, actual service consumption occurs at the “edge” of the IT ecosystem. As technologies improve, more data and work enablement will be distributed to computing devices on the edge, and there is a great opportunity to focus on the policy management, the analytics, and new services that capitalize on the expanding capabilities of the cloud. Finally, services depend on centralized service cores to safely manage data, transactions, and access from the edge. Advancements in infrastructure and data management can therefore be brought together to enable rich application delivery as a platform.





**Researcher Profile: Jaap Suermond**

**Ph.D. Medical Information Sciences, Stanford University**

**Director – Industry Verticals Research, Services Research Lab**

**RESEARCH INTERESTS** | Jaap Suermond's research spans data mining (particularly text mining, automated categorization and quantification), information management, enterprise IT services, uncertainty management, analytics, personalization, operational efficiency, decision support systems, electronic health records, and clinical information systems.

**SPOTLIGHT** | Suermond leads teams within HPL's Services Research Lab focused on analytics research and new services for key vertical markets. In 2009, his team, with their HP business collaborators, received the Institute for Operations Research and Management Science's (INFORMS) Franz Edelman Award for achievement in operations research, honoring the best application of operations research in the world. Suermond is inventor or co-inventor on over 50 filed patent applications, with 32 patents granted so far. He was Program Chair of the Annual Symposium of the American Medical Informatics Association (AMIA) in 2008, and is a Fellow of the American College of Medical Informatics.

accounting for factors like market heterogeneity, information asymmetries, and competition from other service providers.

Now in its third year of collaboration, the team is developing methodology for competitive pricing of HP personal computing products. Professor Hu and researchers in the Services Research Lab are building a methodology for the price optimization problem for an original equipment manufacturer that competes with other manufacturers in selling multiple substitutable products through either direct sales channels, or through competing retailers. Best response and equilibrium analysis are part of the competitive pricing analysis. Hu is also studying grey market issues in aftermarket services.

Their ongoing collaboration has been very productive: Hu and his HPL colleagues have submitted two research papers in 2010, two research papers in 2009, and expect to submit at least one paper in 2011.



## HP Labs' Services Research Portfolio Grows in 2010

For clients with large, complex operating environments, HP Enterprise Services provides end-to-end IT services in applications, business process, and infrastructure technology outsourcing for increased productivity, innovation, and security. This business has experienced some pretty remarkable developments since HP acquired EDS in 2008, and it's clear that HP is aiming to stay at the forefront of global service providers.

Today we are seeing a fundamental shift in IT services, towards an "Everything-as-a-Service" model. An explosion of service providers is emerging, in a variety of areas, to satisfy a growing market of consumers, enterprises and other service providers. While this growth brings substantial opportunities, it also poses enormous challenges to existing service providers who must now rethink their strategies to compete in a market that demands services that are easily customized, and easily consumed.

With that exciting backdrop, HP Labs has launched a new Services Research Lab to expand our investment in services research. Building on our capabilities in operations research, analytics, and cloud service models, the new Service Futures project aims to deliver technology-enablement of the services of tomorrow. Results will be a vast improvement of operations in service delivery, and development of the technologies needed to deliver the next generation of data-intensive services; delivered in the context of business and industry applications.



# Sustainability

A recent EPA report estimates that without significant improvements to both facilities and IT components, datacenters will consume 100 billion kilowatt hours of energy by 2011 – compared to 61 billion kilowatt hours in 2006. Gartner estimates that the manufacturing, use, and disposal of information and communications technology generate about 2% of the world's CO2 emissions. By 2020, this figure is expected to rise to 3%.

The massive-scale, intelligent infrastructure required to power modern business can and should be sustainable. Enter the sustainable datacenter: one that consumes net-zero energy from non-renewable sources like the public electric grid, over its entire lifecycle from initial resource extraction and manufacturing to operation and end-of-life reclamation.

New technologies that can improve worldwide access to IT services make it possible to deconstruct conventional, wasteful business processes and replace them with new models that have a lower impact on the environment. This potential plays out nearly everywhere you look: in supply chain management, energy grids, building operations, transportation, and many other aspects of modern city life.

At HP Labs, researchers in Sustainability are exploring and modeling the way resources can be utilized in datacenters. Many of the principles and efficiencies identified through this research can be used to inform planning and design at city-scale. And when sustainability guides the development of technology and the rethinking of design and processes, incremental steps and advancements can add up to big-picture gains.

## Sustainability Big Bet

### Sustainable Datacenter

The Sustainable Datacenter is a datacenter that consumes net zero energy from non-renewable sources like the public electric grid, over its entire lifecycle from initial resource extraction and manufacturing to operation and end-of-life reclamation. This data center satisfies the Service-Level Agreements (SLAs) of the hosted services, while reducing the Total Cost of Ownership (TCO) and emissions. Research thrusts include IT-facility demand management, supply-side management, integrated design and management, and management information systems.

A portrait of Amip Shah, a man with dark hair and a slight smile, wearing a light-colored checkered button-down shirt. The background is a blurred outdoor setting with trees and foliage.

## Researcher Profile: Amip Shah

**Ph.D. Mechanical Engineering, University of California - Berkeley**

**Senior Scientist, Sustainable Ecosystems Research Group**

**RESEARCH INTERESTS** | Amip Shah is widely recognized as an expert in the application of thermodynamics for environmental management, particularly in the context of electronics and information technology (IT). He is currently involved in the Sustainable Datacenter research project at HP Labs, which seeks to integrate resources that consume available energy in a data center (such as IT, power, and cooling equipment) with the sources that provide available energy to the data center (such as the utility grid, on-site backup generators, and off-grid distributed power sources). Shah's prior research has included diverse topics related to life-cycle assessment, product and process design methodologies, as well as the socio-economic impacts of technology.

**SPOTLIGHT** | Shah has co-authored over 100 technical papers and reports in the areas of environmental sustainability, thermal management, electronics packaging, and energy policy. His honors include the 2006-2007 Best Paper Award from the American Society of Mechanical Engineers (ASME) Journal of Electronic Packaging, 2002 ASME Charles T. Main Gold Medal, 2002 Irene Elizabeth Tracey Award from Rowan University for Excellence in Engineering, and 2001 ASME Arthur L. Williston Medal for his work exploring the relationship between engineering technology and the 1997 Kyoto Protocol of the United Nations Framework Convention on Climate Change. Shah is also Chair of the ASME Santa Clara Valley Section.



## Turning Research into Reality: Demonstrations of Sustainable Datacenters around the World

Research has been turning into reality for the team in the Sustainable Ecosystems Research Group in 2010, with data centers all over the world showcasing their concepts for a Net-zero Energy Datacenter. From the research-driven HP Labs Datacenter located in Palo Alto, to a lab-to-scale datacenter in Fort Collins, Colorado, to a production HP datacenter in Bangalore, India, each of these examples is helping the team advance the state of the art in IT for sustainability.

The Palo Alto datacenter today includes a micro-grid that can accommodate multiple sources of power, including a system of solar panels installed at HP Labs, and also features power-switching infrastructure and a system to incorporate outside air for cooling.

In Fort Collins, the research team's latest completed technologies are scaled up to a larger-size implementation, in collaboration with R&D teams from HP's Enterprise Business. The large-scale installation of the HPL-designed adaptive vent tiles, for instance, is providing the team with new data and opportunities for research in power and cooling management.

A third project consisting of a network of over 7,500 sensors installed in HP's Bangalore datacenter is providing a rich set of data, which the team has used to conduct cutting-edge research in data analysis, visualization, and knowledge discovery to detect anomalies, improve reliability and minimize redundancy. The multi-disciplinary team leading this effort received a Best Paper Award at the 2010 Visualization and Data Analytics Conference for their related paper.

The team has even demonstrated that a sustainable IT ecosystem can be created using dairy farm waste, or cow manure: a dairy farm with 10,000 cows could produce 1MW of electricity, enough to power a typical modern data center. This work received significant media attention in 2010, and resulted in more than 135 news articles in top business and technical media across the globe.

Installations like these three datacenters, and the related technologies behind them, allow HPL researchers to prove their concepts, advance the state of the art, and demonstrate business impact, all of which make it easier for HP business teams to showcase the potential impact of sustainability technology to HP's customers.



## Sustainable Cities: Enabled by Supply and Demand Management

HP Labs' research has focused on supply- and demand-side management of energy to devise a sustainable IT ecosystem. The team's vision for the future is to apply this sustainable IT ecosystem in the management of resources in other human-managed ecosystems in much the same way.

The team, led by Senior Fellow Chandrakant Patel, is motivated by the challenges posed by continued population growth and increased per-capita consumption of resources to the quality of life of current and future generations. Exhaustion of limited natural resources, and the subsequent increases in the cost of basic goods, will necessitate new business models and infrastructures that are designed, built, and operated using the least possible amount of appropriate materials and energy. The supply side must be considered together with the societal demand for resources. Therefore, a critical transformation in how we use and administrate key resources and urban services may be enabled through a sustainable IT ecosystem.

Resource management in urban infrastructure relates to holistic management of physical infrastructure at city scale through IT technologies. Unlike previous generations, where cities were built predominantly focusing on cost and functionality desired by inhabitants, sustainable cities will require a comprehensive life-cycle view, where systems are designed not just for operation but for optimality across resource extraction, manufacturing and transport, operation, and end-of-life. IT thus becomes a fundamental tool for efficient management of scarce resources that have an impact on society, such as water, energy, waste management, transportation and even healthcare, to name a few.

The team's supply side perspective calls for using pools of resources of available energy, alongside design and management that minimizes the energy required to extract, manufacture, mitigate waste, transport, operate and reclaim components. This might mean creating numerous "micro-grids" that incorporate various sources of locally-sourced energy, such as solar panels or wind turbines, that complement centrally-sourced electrical energy. The demand side perspective requires

provisioning resources based on the needs of the user by using flexible building blocks, pervasive sensing, communications, knowledge discovery and policy-based control. As an example, given a sustainability policy, upstream and downstream pumps in a water micro-grid can be programmed to operate to maintain an optimal balance of demand and supply.

The multi-disciplinary HP Labs research team, made up of physical scientists, computer scientists, economists, and mechanical and electrical engineers, has applied the fundamentals-driven supply-demand framework to devise sustainable datacenters, and plans to apply the same framework to enable resource management at the scales of cities. It is a proposition that is good for the environment, and good for business.



## Analytics and Sustainability Research for More Energy-Efficient Homes and Neighborhoods

Conserving energy and reducing cost is important to many homeowners these days, but without solid information on how they are using their energy, their efforts can fall short. Indeed, a world made up of "Smart Things" – Smart Meters, Smart Plugs, Appliances, Electric Cars, etc. – offers us immense opportunity to monitor, analyze, and control energy usage.

Looking towards this future, HPL sustainability researchers began a project on home energy monitoring in 2009. They have deployed sensors in



residential homes, collecting energy data for individual appliances and “activity zones” (entertainment, office, kitchen, etc.). An HP gateway in each home receives sensor readings every 3 seconds and sends an aggregated set to the cloud every 2 minutes. Over 20 million sensor readings have been collected over the last 14 months.

The team’s goal is to turn the discovery of a home’s current energy behaviors and usage patterns into a compelling experience that leads to energy savings with an aggressive payback for the investment. The team is combining a simple, intuitive user interface with cutting-edge data mining and analytics to help identify patterns and provide insights on where energy consumption is taking place, and what homeowners can do in response. These insights include shifting usage to optimize costs, determining the efficiency of appliances, reminders not to leave the TV or lights on overnight, and understanding family usage patterns and behaviors.

The service also enables electrical data to be viewed alongside other resources – like gas and water – to enable insights into the bigger-picture tradeoffs. A service provider interface enabling energy oriented analytics, aggregated consumption views, and social comparison is also available.

Ultimately, HPL researchers in sustainability believe that understanding and optimizing residential energy usage will become increasingly important in the future, and that it will be a foundational building block for Sustainable Cities.



**Researcher Profile: Zainab Jamal**

**Ph.D. Marketing Science, University of California, Los Angeles**

**Research Scientist, Services Research Lab**

**RESEARCH INTERESTS** | Zainab Jamal's area of focus is in developing econometric and statistical models to understand and predict customer response behavior. This area feeds into the broader research stream of enabling businesses to optimize their marketing operations through analytical technologies in the backdrop of major paradigm shifts in the landscape such as personalized marketing and EaaS (Everything-as-a-Service). She brings deep industry knowledge to her research expertise in marketing operations, having worked in different roles in brand management and product development after her Masters in Economics (Delhi School of Economics) and M.B.A. (Indian Institute of Management, Ahmedabad).

**SPOTLIGHT** | Jamal strongly supports giving back to the community and has worked for not-for-profits such as CRY (Child-Relief and You) and the Give Foundation. She also co-chaired HPL's Charitable Giving Campaign 2010-11 and helped raise program awareness and donations. Along with HPL colleague Alex Zhang, Jamal won the Don Kuhn Lifetime Value and Customer Equity Competition in 2008, which was organized by the Direct Marketing Association. Competitors had to predict donor behavior using two years' of data from a not-for-profit organization.





# 2010 Results

## Business Impact

What motivates us, above all else, is to see our research ideas made real and put our technologies into the hands of customers. We deliver business impact to HP, through a steady stream of technologies that support our existing businesses, as well as technologies that may open up new markets for HP.

We measure ourselves, and our contribution to the company, on technologies that make an impact both in the current fiscal year and those expected to have impact in the upcoming year, as well as on technologies influencing longer-term business roadmaps.

In 2010, we recorded 121 total technology transfers recognized as having business impact in the current fiscal year. Key transfers have been mentioned throughout this report and in Appendix 1, and include significant advancements in sustainability, storage deduplication, intelligent infrastructure, social networking, printing and imaging, and information management services.

### Demonstrator Program

In 2010, we began a technology demonstrator program, where we selected seven projects to get a jump-start towards commercialization. Demonstrators are proofs of concepts that take HP Labs technologies that are almost market-ready to the next phase of feasibility. Demonstrators show how our technologies can benefit customers directly by applying them to real customer accounts, in partnership with HP's business groups. Projects from 2010 – G-Cloud, Photonic Backplane, Pluribus 3D, Interactive Design Reuse, and Home Energy Monitoring – are featured throughout this report.

For 2011, we have already begun work on a new class of demonstrators. Some of the technologies HPL teams will work to demonstrate in the coming year include:

- Creating an enterprise archive solution, combining HP's scalable storage systems with HPL's scalable metadata management technology, to provide both management and scalability.
- Developing novel, highly-integrated, two dimensional optical engines for applications in processor memory systems.
- Providing secure, centralized management of business IT applications, delivered from the cloud, to tomorrow's consumer client devices.
- Transforming HP printing and scanning devices into enterprise workflow kiosks with key HPL document workflow elements.
- Bringing to life new entertainment experiences for live music, sports, and theater using like-being-there, life-size 3D screens, featuring content captured with panoramic 3D cameras.

### Customer Co-Innovation

Customer Co-Innovation takes commercialization of research ideas beyond what we do with Demonstrators. Working side-by-side with our customers has long been a part of our DNA – and the list of collaborations is growing. Our CeNSE project is actively collaborating with Shell, for instance, leveraging our high-precision sensor network technology to improve seismic monitoring for oil and gas exploration; and our approach to cloud computing and visual collaboration was shaped in part by our multi-year collaboration with DreamWorks. 2010 saw the formation of several successful customer co-innovations and HP Labs is expanding the program for 2011.

By working with our most forward-thinking customers, we are taking advantage of another mechanism to tackle challenging problems, and jointly innovating the



### **CeNSE in Action: Shell and HP Develop Ultrahigh-resolution Seismic Sensing Solution**

In February 2010, HP and Shell announced a collaboration to build a wireless sensing system to acquire high-resolution seismic data on land – the first commercial application of CeNSE technology.

The oil and gas industry requires high-quality seismic data to accurately assess exploration prospects for commercial viability and to effectively monitor producing reservoirs. By vastly improving the quality of seismic imaging, the new system will allow the company to more easily and cost-effectively explore difficult oil and gas reservoirs. The solution provides a better picture of existing and alternative energy resources – allowing Shell to perform more targeted oil exploration and reduce their environmental impact

The new system reflects the breadth of HP's portfolio. It will be delivered by HP Enterprise Services and includes a recent breakthrough in high-performance sensing technology from HP Labs – the company's central research arm – and the company's Imaging and Printing Group. Additionally, the system uses HP ProCurve networking products along with HP storage, computation and software products. The ultrasensitive, low-power MEMS accelerometers being used are up to 1,000 times more sensitive than high-volume, commercial products. There are many other potential uses for these tiny sensors, including detecting pathogens and pesticides in food; warning of structural strains in bridges, buildings, and jets; and monitoring the safety conditions of roads.

next generation of HP products and services. A number of projects are already underway, including product personalization in the financial services sector; improving safety in the health care industry; and using data analysis to gauge customer sentiment in consumer product markets.

Customer Co-innovation is another aspect of our commitment to Open Innovation: where our engagement with universities impacts the early stages of our innovation pipeline, engaging with our customers enables us to solve a particular business problem with the technologies we have developed. It also allows our researchers to have access to real-world data, plus our customers' experience and their knowledge of their industries.

## **Advancing the State of the Art**

As HP's central research organization, discovering meaningful advances to science and technology is at the core of everything we do. We demonstrate our leadership by publishing in journals, external conferences, and our company-internal technical conference; and we also measure our generation of IP through invention disclosures and patents. We are especially proud of our work featured in publications that are influential and well-respected in the industry, and when our researchers are recognized with awards for outstanding publications.

Total appeared publications by HPL authors in 2010 included 215 publications in books, journals and magazines, and 498 conference publications.

### **2010 Technology Awards**

HP Labs' technology has been recognized by numerous media and technical outlets and several prestigious awards in 2010:

- 2010 FLEXI Award granted at the Flexible Electronics and Displays Conference
- CeNSE named among ReadWriteWeb's "Top 10 Internet of Things Developments of 2010"
- CeNSE MEMS accelerometer selected for EE Times' ACE Awards for "Most Promising New Technology of 2010"; the "EDN Innovation Award" (Accelerometer category); and the Design News 2010 "Golden Mousetrap Award" (Sensor category)
- Memristor featured in the nanotechnology exhibit of Deutsches Museum, Munich
- New York Times Magazine "10th Annual Year in Ideas: Social Media as Social Index" highlights social media influence algorithm





**Researcher Profile: Lueny Morell**

**M.S. Chemical Engineering, Stanford University  
Program Manager, Strategic Innovation and  
Research Services**

**RESEARCH INTERESTS** | Lueny Morell has a passion for engineering education research and curriculum innovation and has grown and applied these interests both during her 8 years in HP Labs and prior to this for 24 years as a University of Puerto-Rico-Mayagüez Chemical Engineering faculty member and administrator. While at HP, she has actively developed global engineering education and student initiatives to support HPL's research themes.

**SPOTLIGHT** | Morell has held numerous leadership roles with national and global organizations focused on engineering curriculum innovation, including the International Federation of Engineering Education Societies (past president), Engineer of the Americas Initiative (co-founder), and several U.S. National Academy of Engineering (NAE) and National Science Foundation Committees. In 2006 she received the NAE's prestigious Bernard M. Gordon Prize for innovation in engineering and technology education, and in 2009 she received the Latin American and Caribbean Consortium of Engineering Institutions' (LACCEI) Academic Merit Medal for her leadership and global impact on engineering curriculum innovation and support for economic development in Latin America. Morell helped architect the Engineering Innovation Fellowship Program (EIFP), a first-of-its-kind collaboration between ASEE, NSF, and industry sponsors, which provides U.S. engineering post-docs with industry research opportunities. HPL hosted five post-docs in 2010.



### **HP ePrint: Securely Print Anytime, Anywhere**

When researchers in the Social Computing Group at HP Labs set out to transform printing from mobile devices, they created a technology called CloudPrint. Today, their technology is widely available as the HP ePrint platform, a service from HP that allows users to print directly to HP printers by sending an email to the ePrint-enabled printer's email address.

The HP ePrint platform harnesses the cloud to break down the barriers of distance and connectivity and allows people to send the files they want to print from their mobile devices. Mobile devices and smartphones – including BlackBerry, Palm Pre and iPad, among many others – now have an easy way to print without installing any special drivers or software, whether printing on a home printer, or securely sending a document for pick-up at a FedEx Office store. And it's easy to use: if you can use email, you can use ePrint.

- India's NASSCOM selects SiteOnMobile as one of "Top 50 Innovations in India"
- MIT Technology Review India selects HPL India's SiteonMobile and FutureSchool Vision among 7 winners of "Grand Challenges for Technologists in India"

## Thought Leadership

We are passionate about technology, and we are passionate about HP. That means representing HP among customers, the media, analysts, partners, and our academic and industrial peers. We serve as chairs and organizers of industry conferences, provide our expertise as members of industry standards boards and government steering committees, and lead many of HP's externally-funded research efforts. We also share our work with universities and customers – in 2010, HPL hosted hundreds of customer visits across the world, including over 300 in Palo Alto alone, from customers in a wide range of industries, including banking, entertainment, telecommunications, transportation, and utilities, among many others, as well as from academia and the public sector.

### **HP Labs Partners on EU Research Projects**

HP Labs is actively involved in the European Union's Framework Seven (FP7) research programme which funds collaborative research between industry and academia in Europe. Across Europe, researchers compete for funding for their research consortia in response to calls for proposals from the European Commission (EC). HP Labs is currently involved in four FP7 consortia: BonFIRE, in which HP Labs will provide cloud capacity into a pan-European cloud testbed; SAIL, in which HP Labs is working with Ericsson Research and other partners to create a wide-area distributed cloud; and PICOS, which is exploring privacy management in on-line communities. Finally, in the EFFECTSPLUS project, HP Labs supports the EC in developing an agenda for future research in Trust, Security, and Privacy in the future internet. HP Labs benefits tremendously from the knowledge and insight shared among the many leading industrial and academic partners in each of these projects.

## People

Our people have made incredible advances in 2010, and we are proud to introduce you to just a few of them throughout this report. Our success is founded on these teams of brilliant individuals who exhibit their





## Researcher Profile: Nick Wainwright

**B.S. Electronic Engineering, University of Bristol, England**

**Director, HPL European Projects , Cloud and Security Lab**

**RESEARCH INTERESTS** | Nick Wainwright currently leads HP's involvement in a number of European research projects in the area of internet cloud technologies and internet security research. His other interests include internet communications technologies, computer architectures, and digital media technologies.

**SPOTLIGHT** | Wainwright is actively involved with a number of high-profile European technology strategy-setting organizations. He is a member of the EU's Future Internet Assembly steering committee where he works to facilitate interaction across the European research community in cross-cutting issues of technology, applications, and usage of the internet of the future. Wainwright also chairs the UK's Future Internet Strategy Group which provides a forward-looking view on internet technologies including cloud to UK national stakeholders including the UK's Technology Strategy Board and the Department of Business, Innovation and Skills. Finally, he is a board member of the Networked European Software and Services Initiative (NESSI) European Technology Platform.

passion for our customers every day. We are constantly seeking to recruit, challenge, and develop the best talent in the industry, and look for employees with fresh perspectives, an appreciation for multi-disciplinary work, and a healthy dose of motivation. Bringing these amazing people together helps us turn research into reality, every day.

### Awards and Honors

Some of the awards and honors received by HPL researchers in 2010 include:

- Umesh Dayal – 2010 SIGMOD Edgar F. Codd Innovation Award
- Giordano Beretta – IS&T Raymond C. Bowman Award
- Dejan Milojicic – Fellow, Institute of Electrical and Electronics Engineers (IEEE)
- Lueny Morell – Fellow, American Society for Engineering Education (ASEE), and LACCEI Academic Merit Medal
- Erik Ordentlich – Fellow, Institute of Electrical and Electronics Engineers (IEEE)
- Cipriano Santos – Named among “2010 Most Important Hispanics in Technology” by Hispanic Engineer & IT Magazine
- Robert Schreiber – Fellow, Society for Industry and Applied Mathematics (SIAM)
- Ronald Schafer – 2010 IEEE Jack S. Kilby Signal

Processing Medal

- Steven Simske – Fellow, Society for Imaging Science and Technology (IS&T), and Invited Member, World Economic Forum Global Agenda Council on Illicit Trade
- Jaap Suermondt – Fellow, American College of Medical Informatics (AMIA)
- Mitchell Trott – Fellow, Institute of Electrical and Electronics Engineers (IEEE)

### Looking Forward

As we look forward to 2011, our focus remains on delivering our research ideas into the hands of customers and HP businesses, and launching the next big ideas. We are expanding efforts to commercialize our ideas by investing in a larger number of even more ambitious demonstrators, and launching a new program in Customer Co-Innovation. We are growing our investment in services, networking and software research, as well as adding new talent to our global research labs in Singapore and China. We are bringing together multi-disciplinary research to demonstrate a seamless end-to-end customer experience from cloud to mobility. Finally, building on our success over the past several years, we are actively starting up the next generation of “big bets” – leading the way on future innovations for our customers and HP.



**HP Labs' flexible displays  
technology received the *2010 FLEXI  
Award* at the Flexible Electronics  
and Displays Conference**



# Appendix 1: Selected 2010 Technology Transfers

## Cloud and Security

### **Analytics for Defense Verticals/Cybersecurity**

Countries around the world are facing ever-increasing challenges in their ability to detect sophisticated attacks. In 2010, HPL developed the rules engine for a demonstrator to detect anomalous behavior from multiple information sources that would be indicative of an attack.

### **Analytics for Security Services**

Security analytics provides a methodology and tools for stochastic what-if examination of a range of future risks together with comparative analysis of alternative policy and operational responses. In 2010, HPL transferred the technology to HP Information Security (formerly Vistorm, an HP subsidiary) which launched it as a service.

### **AP4SaaS “Generic Plug-in” for Service Integration**

As more services become available in “Everything as a Service” model over the cloud, it becomes increasingly important for service providers to integrate third-party offerings into their own cloud offerings. The HP Aggregation Platform for Software as a Service (AP4SaaS) is an HP product that enables service providers to create bundled services. In 2010, HPL transferred a service integration toolkit that allows service providers to rapidly integrate and provision cloud services into the platform without detailed knowledge of the platform design and operation.

### **Privacy Advisory Tool/Expert Systems Tool**

Understanding appropriate actions when different nation states have varying data and privacy protection laws is becoming an increasing challenge for businesses. In 2010, HPL leveraged the Privacy Advisor Tool it built in 2009 to develop a new service targeting large enterprise customers. The service helps these companies better understand and manage accountability of privacy protection concerns through all aspects of developing, marketing and operating a product or service to their customers.

### **Trusted Virtualized Clients**

Confidence is needed that devices can and will enforce appropriate separation of concerns. In 2010, HPL completed work on architecting modular trusted virtualized clients, user management frameworks, and software to facilitate central security management of multi-vendor PC environments.

### **Credit-Cards for Ultra-low Latency Transit Applications**

Today’s transit system customers are faced with door-to-door journeys involving different ticketing models with incompatible payment mechanisms, including paper tickets, smart cards, near-field communication chips, and cell phone micro-payment schemes. HPL’s research addresses an opportunity to leverage hardware, software and services to offer an end-to-end ticket procurement solution to transit providers. In 2010, HPL developed technology to enable ultra-low latency local credit or debit card payment processing at the gate while managing fraud risk.



## Information Analytics

### **Application Lifecycle Automation**

Managing IT application lifecycles from planning and inception, through development and testing, to operation and change, is a growing problem in the IT management and IT services worlds. Variability in authoring tools, technologies and practices constitutes a growing challenge to automation. HPL is introducing a revolutionary approach to this problem and developed image-based automation and web automation technologies in 2010.

### **Information Management for Business Technology Optimization**

Business Technology Optimization applications handle an overwhelming amount of data. The data arises in multiple contexts from a myriad of loosely-confederated IT applications. HPL's research builds methodologies and applications to crystallize IT data into an effective source of information that is readily available for automation applications. Key work completed in 2010 includes algorithms for event correlation rule discovery, log analysis, acronym extraction and disambiguation.

### **MapReduce Paradigm in Enterprise Analytics Platform**

The MapReduce paradigm is a powerful framework for parallel analytics processing in the enterprise analytics market, and HPL's research supports this paradigm in a parallel data management system. Key 2010 contributions include development of relation-valued functions and the mechanism for preparing and composing user-defined functions.

### **Puma: Information-Aware Storage and Classification**

With the information explosion of unstructured data, there are opportunities to apply innovation in IT management, business governance, compliance, and risk management. In 2010, HPL delivered to HP's product groups information-aware storage technology, run-time optimization algorithms, and backup provisioning and capacity planning tools.

### **Rule Discovery for Event Correlation**

Operations Management (OM) is a research area which focuses on the process of keeping complex systems in multiple domains – such as Smart Transportation, Sustainable Datacenters, and Emergency Response – running smoothly. Key OM challenges include the need to correlate events being reported from different system components, the requirement for human experts to input rules for correlating events in current systems, and writing and maintaining rules given underlying system complexities. HPL's research addresses these issues and, in 2010, we contributed a machine learning algorithm and process for automatically finding events that are correlated and for creating rules based on these correlations.

### **Sentiment Analysis**

Today's businesses are faced with the challenge of harnessing the explosion of unstructured and external content. HPL's Sentiment Analysis effort applies specialized text analytics technology to these types of data sources and distills actionable insights for enterprise functions ranging from marketing to product engineering. In 2010, we actively engaged with a number of customers to apply and deliver the technology as a service.

### **Taxonom2**

HPL is focused on the challenge of developing precise, efficient and powerful techniques for information extraction from unstructured data. Taxonom2 is a system for parsing, indexing, and querying the content and the context of entity enumerations in unstructured or semi-structured text. Technologies developed in 2010 include a query language and optimizer, parser-indexer, and render engine.

## Intelligent Infrastructure

### **CeNSE**

Sensing capabilities developed by HPL are providing novel capabilities to create differentiated value for HP's sensing practice. HP CeNSE will utilize HPL technologies to generate unique, data-driven opportunities leveraging HP products,

services and relationships to create high-value outcomes for HP's customers. An example is an innovative program with Shell that is creating an industry-changing, ultra-high resolution seismic data solution for land-based oil and gas exploration. 2010 technology contributions include a next-generation accelerometer, new electronics package, system networking topology, and network system architecture analysis.

### **Data Deduplication**

HPL Data Deduplication technologies significantly enhance HP's storage business with the potential to have major impact on customers' overall data integrity and disaster recovery experiences. Key 2010 contributions have facilitated product line scalability and incorporation of the technology into HP StorageWorks and future Data Protector products.

### **Dynamical NanoElectronics**

HPL is focused on the invention and improvement of new memristive materials, device structures, hybrid CMOS/memristor circuits, and storage and logic architectures, which will enable HP to build a superior technology alternative to next-generation DRAM, Flash and disk storage. 2010 technology contributions include lab-to-fab memristor technology to Hynix Semiconductor for flash memory replacement.

### **Optical Interconnect**

HPL's advances in Optical Interconnects will allow HP to utilize low-cost optical components to create leadership datacenter switching systems. 2010 technology contributions include a high-performance, low-power optical data center switch demonstrator and enclosure-level optical interconnects and interconnect topologies.

## **Mobile and Immersive Experiences**

### **Attach**

The attach rate of a product represents how many complementary products are sold with the primary product. HPL's research focuses on increasing product attach rates by harnessing the collective intelligence manifested in the web. The Attach algorithm was deployed in 2010.

### **BRAIN Forecasting Tool**

The ability to predict the outcome of future events quickly and accurately is critical in today's business environment; however, month-to-month forecasting is difficult in business and data environments. HPL's BRAIN is an information aggregation tool which addresses this issue and takes much of the bias, manipulation, and hierarchy out of prediction. Key 2010 technologies developed include a calibration process and user interface and system for capturing individual estimates.

### **CloudPrint (ePrint)**

CloudPrint is a free, cloud-based mobile printing service enabling smart phone users to find and securely print a variety of content to printers in their vicinity. The technology was deployed on BlackBerry smart phones in 2010 and many printers in the HP Officejet, LaserJet, Photosmart and Envy printer families have been enabled to take advantage of this innovative capability.

### **Halo**

Jointly designed and developed with DreamWorks, Halo telepresence and video conferencing technology provides seamless collaboration and HP-managed services across the enterprise. In 2010, HPL provided support and consulting for continuing development efforts, and established and led a pan-HP steering committee focused on core Halo and SkyRoom software technology.

### **TouchSmart**

TouchSmart is a novel technology providing intuitive multi-touch capability on computers and other consumer devices with unique "hover" gesture support. Key HPL technologies developed for TouchSmart PC in 2010 include the Canvas 2 Photo Sharing Application, Personalized Video Application, Multimodal Interaction Toolkit components, and TouchSmart tasklets.



## Networking and Communications

### **Flexible Programmable Networks**

HPL's research targets network platform programmability and management which builds on HP's leadership in enterprise and data center networking. Key contributions in 2010 are tied to: scaling Ethernet networks in datacenters; implementation of the OpenFlow™ protocol (from Stanford University) on HP network switches, with HPL extensions for quality of service (QoS) and easier deployability in production networks; and network energy monitoring.

## Printing and Content Delivery

### **Automatic Color Calibration**

Color experts are rare and expensive in the printing market, and manual color calibration routines are complex and extremely time-consuming. Automatic color calibration is a key focus area for HPL and, in 2010, we developed a proof of concept for a novel spot color calibration procedure and a fully-automated color calibration system yielding dramatic time savings over manual procedures.

### **Charge Roller for Indigo 7500**

HPL is focused on innovations which enable high-speed charging units with low cost per page (CPP). In 2010, the Charge Roller (CR) system was successfully implemented in the new Indigo 7500 Digital Press LEP engine which was presented and sold at the IPEX conference in May 2010.

### **GPU-RIP**

HPL repurposes video gaming Graphic Processing Units (GPUs) for the commercial print rendering pipeline resulting in optimal price/performance ratios. In 2010, HPL completed GPU-RIP technology integration with commercially-available RIP interpreters, and are currently working toward enabling more efficient, flexible late-binding workflow for signage files.

### **Global Traceability Exchange Registry Architecture and Roadmaps**

Current supply chains suffer from a lack of consistent standards and protocols resulting in an ad hoc approach to important supply chain workflows, including product recall and supply chain analytics. HPL created an early version of the Global Traceability Exchange Registry (GTER) to address this problem and extended the architecture to the "Cloud Platform for Shared Supply Chain Services" to accommodate next-generation supply chain and authentication services. In 2010, HPL provided technical consulting for several HP contract wins as well as technology and the architectural roadmap for the GTER/Manufacturing Cloud Computing Platform.

### **Deinking Chemistries**

HPL is working on creating industrially-scalable deinking chemistry and protocols to solve recycling challenges for HP's digital commercial LEP (Liquid Electrophotography) and inkjet prints while also efficiently de-inking prints from DEP (Dry Electrophotography) and conventional analog printing presses. During FY10, our neutral deinking chemistry was optimized on a number of fronts and a new alkaline deinking chemistry was developed for paper mills.

### **Image-Based Forensic Service 2.0**

HP provides a wide variety of supply chain and investigative services to its enterprise customers, many of which have significant, persistent counterfeiting problems in their distribution network. As part of its consulting services strategy, HPL has developed the Image-Based Forensic Service (IBFS), a suite of technologies facilitating the assessment of counterfeiting in a supply chain, even when no security deterrents are currently deployed. IBFS provides batch inspection-based forensic imaging which enables HP to "reverse engineer" counterfeit supply chains and to target specific counterfeiters. IBFS 2.0 was developed in 2010.

## Services

### **Chameleon: Personalization Analytics**

HPL is focused on creating new types of services in the emerging personalization space. 2010 work included development of behavioral analytics, persona assessment tools, contextual reminders, and program recommendation frameworks. We also started multiple proof-of-concept engagements with HP's Personal Systems Group and HP Enterprise Services' Communications and Media Solutions businesses and several of their co-innovation partners.

### **External Analytics Go-To-Market**

Tapping innovative and deep analytics, HPL is focused on developing services for some of our customers' toughest business problems including forecasting, scheduling and workload distribution. Initial models were successfully demonstrated to several key customers in 2010.

### **Gossamer: Next Generation Supply Chain**

Gossamer is focused on developing the next-generation, increasingly-sophisticated and optimized supply chain. Key 2010 results include the development of algorithms for optimization modeling and analysis, and alternative forecast data analysis.

### **HP Download Store**

HPL developed HP's Download Store to help customers enhance their PC experience. Launched in April 2010, the web-based platform enables customers to purchase and download software, games, and services throughout the lifecycle of their computer. Notable HPL contributions include a product selection tool and customer segmentation analysis to support web site design, and the development of advertising, couponing and discounting strategies.

### **Marketing Analytics**

Many of HP's customers face challenges in pricing optimization and discrimination. In 2010, HPL developed business models for coupon programs which address these challenges.

### **Labor Strategy**

With tens of thousands of projects, many thousands of enterprise customers in every geography, and hundreds of thousands of employees with unique skills and training opportunities, planning "who works on what and when" is an extreme exponential optimization problem. HPL has developed a conceptual prototype of a scientific decision-support system that helps forecast, plan and manage its global workforce. In 2010, HPL completed first-phase development of the prototype, including integrated revenue forecasting with labor planning optimization capabilities.

## Sustainability

### **Sustainable Datacenter**

HPL's work in Sustainable Datacenters addresses cradle-to-cradle design and management of data centers. It also focuses on enabling the Net Zero Energy Data Center to achieve total cost of ownership targets, creating new opportunities in growth economies and resource management in other ecosystems. Key 2010 transfers include a data aggregation and modeling architecture, data center cooling infrastructure recommendation tool, and IT performance modeling and service energy estimator which will be incorporated into HP's sustainability products and services .





## Credits

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**Automated Publishing contributors:** Niranjan Damera-Venkata, Eamonn O'Brien-Strain, Ke-Yan Liu, and Lei Wang

**Cover Photograph:** Chris Willis

**Portrait Photography:** Chris Willis, Serge Vejvoda, Andy Hunter, Alan Parry

**Photographs and Images:** Chris Willis, Eric Montgomery

**Content Development:** Martina Trucco (Editor-in-Chief), Connie Chao, Laurel Krieger, Lueny Morell, Simon Firth

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