



ACTUALIZATION OF THE INTERNET OF THINGS

APRIL 17-19

MONTEREY, CA

PROGRAM

Organizing Committee

Barbara Jones

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Monday, April 17, 2017

Session 1: Industrial Impact of the IoT

Chair: Jeffrey Hunt, Boeing

1-1 9:30-9:40am Welcome and Overview

Jeff Hunt, Boeing, Technical Fellow

1-2 9:40-10:16am Keynote: The Internet of Things for the Cognitive Era

Heike Riel, IBM, Director, Physical Sciences

1-3 10:16-10:52am Fleet Management with Hybrid Physics-Based Models

Mahadevan Balasubramaniam, GE

10:52-11:07am Break

1-4 11:07-11:43am Increasing the Attack Surface through IoT

Nancy Cam-Winget, Cisco, Distinguished Engineer, Security Products

1-5 11:43am-12:19pm Quantum Applications and Microsoft's unique approach to Quantum Computing

Dave Wecker, Microsoft, Partner Architect, Quantum Computing

12:19-1:30pm Lunch San Carlos IV

Session 2: Trillion Sensor Initiative

Chair, Barbara Jones, IBM

2-1 1:30-2:20pm TSensors and Exponential Abundance

Steve Whalley, Strategic World Ventures, CEO

2-2 2:20pm-2:50pm

Energy Storage for the Internet of Things & Trillion Sensor Vision

Bharatwaj Ramakrishnan

Applied Materials, New Business Development

2-3 2:50-3:20pm Enabling Sustainable Solutions for the Global Environment Through Novel Sensing

Leo Kenny, Planet Singular, Technologist

2-4 3:20-3:50pm Medications with Sensors

Mark Zdeblick, Proteus Digital Health, CTO and Co-Founder

3:50-4:10pm Break

4:10-5:00pm Panel Discussion

Tuesday, April 18, 2017

Session 3: Sensor Technology and Physics

Introduction: Jeffrey Hunt, Boeing

3-1 8:30-9:10am Sensor Keynote: Novel Sensor Technologies

David Chow, HRL, Director, Microelectronics Laboratory

Chair: Michael Gaitan, NIST

3-2 9:10-9:46am Photonic MEMS for Calibrated Physical Sensing

Jason Gorman, NIST, Project Leader, MEMS/NEMS

3-3 9:46-10:22am Additive Printing of Flexible Electronics for Sensing

Tina Ng UCSD, Associate Professor

10:22-10:42am Break

3-4 10:42-11:18am "Nose" for the IoT

Kumar Virwani, IBM, Research Staff Member

3-5 11:18-11:54am

Integrated Quantum Plasmonics and Microfluidics for IoT Healthcare Solutions Luke Lee, UC Berkeley, Professor, Bioengineering

11:54am-1:15pm Lunch, San Carlos IV

Session 4: Industrial Applications

Chair: Russel Walters, Johnson & Johnson

4-1 1:15-1:51pm

High Reliability Imperative for Autonomous Networked Vehicles

Allen Adler, Boeing

4-2 1:51-2:27pm Impact of Big Data and Industry 4.0

John Carrier, MIT Sloan School of Management, Senior Lecturer

4-3 2:27-3:03pm Connected Edge - How Things Talk to Each Other

Jean Lau, GE, VP of Software Engineering

4-4 3:03-3:39pm Quantum Technology Landscape in UK and Handheld Quantum Encryption

Iris Choi, National Quantum Technology Hub, University of Oxford

Tuesday, April 18, 2017

Session 5: Poster Session & Reception

3:40-6:00pm San Carlos IV

5-1 Piezoelectricity in single-molecular layer crystal

Hanyu Zhu, Yuan Wang, Jun Xiao, UC Berkeley, Ang-Yu Lu, Lain-Jong Li, King Abdullah University of Science and Technology, Xiang Zhang, UC Berkeley

5-2 Physical Unclonable Functions (PUFs) for Securing the Internet of Things

Calvin Chan, Jason Hamlet, Ryan Helinski, Rachel Dondero, Todd Bauer
Sandia National Laboratories

5-3 IoTs and Automated Psychology for Better Sleep for Babies and Caregivers

Russel Walters, Johnson & Johnson, Thomas Lipoma, Rest Devices

5-4 Plant Disease Detection Using Real-Time Sensors - A Case Study

Alireza Pourreza, University of California

5-5 PVoT for IoT: Photovoltaics on Things for the Internet of Things.¹

Nancy Haegel, Matthew Reese, Joey Luther, Mary Werner, Sarah Kurtz, National Renewable Energy Laboratory

Wednesday, April 19, 2017

Session 6: Practical Challenges

Chair: Iris Choi, University of Oxford

6-1 8:30-9:06am In Pursuit of Brilliant Operations

Paul Boris, GE Digital, VP, Manufacturing Industries

6-2 9:06-9:42am AI for Industrial IoT and Smart Infrastructure

Piyush Modi, Invida, Chief Strategist, Industrial Sector

6-3 9:42-10:18am NIST Focus on IoT

Jim St. Pierre, Deputy Director, NIST Information Technology Lab

10:18-10:38am Break

6-4 10:38-11:14am Finding and Fitting Batteries for Small IoT Devices

Andy Keates, Intel, Principal Engineer

6-5 11:14-11:54am Closing Keynote: Quantum Computing Meets Big Data

Seth Lloyd, MIT, Professor, Quantum Information

6-6 11:54-12:04pm Closing Remarks

Barbara Jones, IBM

All sessions will be held in San Carlos III

Continental buffet breakfast

Served each day in San Carlos III. Included in registration fee

Breakfast food will be available beginning at time shown below through the morning break

Monday: breakfast available beginning at 9AM

Tuesday: breakfast available beginning at 8AM

Wednesday: breakfast available beginning at 8AM

Abstracts

Session 1: Industrial Impact of IoT

1-3 Fleet Management with Hybrid Physics-based Models

Mahadevan Balasubramaniam, GE

Field management of industrial assets and maintenance planning require a forecast of consumed and remaining life. Uncertainties in loads, environment, material properties, physical models and inputs, sensor measurements, maintenance, etc. need to be captured to accurately predict life. Updating models continually with field and inspection data is critical to manage uncertainty and reduce risk. GE's Hybrid Modeling Framework provides a consistent framework in which time-dependent physics, observed usage and field data from sensors and inspection and probabilistic methods come together to build predictive Hybrid Life Models, a.k.a., Cumulative Damage Models (CDMs). The CDMs are stochastic and provide probabilistic forecasts. These are used in a system-of-system simulation for fleet management. Several successful industrial applications in Aviation, Power and Oil & Gas will be highlighted in the talk.

1-4 Increasing the Attack Surface through IoT

Nancy Cam-Winget, Cisco, Distinguished Engineer, Security Products

With the growing use of machine-to-machine devices through the Internet, breaches in IoT are publicized and growing, highlighting the importance of security.

To cite a few examples:

- ATT's 2015 Security report cites an increase of 458% in vulnerability scans against devices
- DHS' annual report continues to cite over 200 reported breaches in the Industrial Control Systems disciplines
- There are many breaches publicized in the media today, but of importance is their impact. The second publically reported breach to have greatly impacted a critical infrastructure came in December 2014 where a steel mill was breached in Germany where physical damage was incurred.

With such an attack surface expanding, how can these networks be secured? What would the security solution look like? This presentation will provide a general framework for how Security can be balanced with safety and availability.

Abstracts

1-5 Quantum Applications and Microsoft's unique approach to Quantum Computing

Dave Wecker, Microsoft, Partner Architect, Quantum Computing

Microsoft's Station Q was founded in 2006. The focus of the team has always been topological quantum computing. By taking a full systems architecture approach, we have reached the point where we now able to start engineering a scalable quantum computer. The goal is to be able to solve major problems in areas of interest (e.g., Chemistry, Materials and Machine Learning). This talk will focus on the types of applications that we will be trying to solve as well as the unique approach to quantum computation that we've developed. For reference, see:

Current Approach: <https://arxiv.org/abs/1610.05289>

Chemistry Application: <https://arxiv.org/abs/1605.03590>

Other papers:

https://arxiv.org/find/all/1/all:+wecker_d/0/1/0/all/0/1

Abstracts

Session 2: Trillion Sensor Initiative

2-1 TSensors and Exponential Abundance

Steve Whalley, Strategic World Ventures, CEO

Sensors are a foundation for the biggest economic tide in the history of humans. The Internet of Things is connecting all things on Earth and through sensors extracting information from all connected devices. The IoT is expected to grow to \$32.5 trillion by 2025 and represent about 25% of global 2025 GDP. Forecasts for sensor demand are as high as 100 trillion by 2030. Sensor derived data moving through the Cloud, Fog and Swarm networks is expected to reach BrontoBytes requiring an unprecedented scaling of data analytics and Artificial Intelligence and Machine Learning algorithms.

This presentation will outline these growth drivers and the subsequent opportunities they may bring to lower cost and accelerate new sensors in key vertical markets in and around the IOT. The role the Trillion Sensors (TSensors) initiative is playing to address these opportunities will also be described.

2-2 Energy Storage for the Internet of Things & Trillion Sensor Vision

Bharatwaj Ramakrishnan, Applied Materials, New Business Development

As the Trillion Sensor vision is taking shape, one of the key issues is powering these sensors. While several battery technologies can power these sensors, some of these sensors are in applications that need to operate for more than 10 or 15 years. Others are in environments that are difficult for maintenance or battery replacement. While primary battery is one solution it is limited to only a few years thus requiring battery replacement and incurring cost. Secondary rechargeable battery with energy harvesting becomes a better solution.

However, conventional rechargeable batteries typically have two performance characteristics that are not favorable. First is cycle life and second is high self-discharge. Cycle Life: The secondary batteries charge & discharge only ~500 to 1000 cycles. Therefore, if there is a daily charge/discharge using energy harvesting, these would not last more than 5 years. Self-discharge: the conventional batteries have high self-discharge. This will negate some energy that is harvested. While Solid State Thin Film Batteries addresses both these issues by having a very high cycle life of more than 10,000 and having a very low self-discharge thus retaining the energy harvested and being able to last for 10 to 15 years, they are expensive. This presentation will cover the various battery technologies and processes, industry battery requirements and the potential solutions.

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2-3 Enabling Sustainable Solutions for the Global Environment Through Novel Sensing Toshikazu Nishida, , Radislav A Potyrailo, Leo T.Kenny

Significant global challenges, such as environmental and climate impacts and adjacent issues (sustainability, natural resource management, infrastructure improvement, materials availability and EHS impacts, product content, etc) are highly complex, touching a broad range of disciplines and activities. The vision and concepts of Tsensors, represents a powerful strategy and critical first step toward understanding the nature of environmental systems and how to address these going forward. Strategies, systems and processes developed in the semiconductor industry over many decades have direct relevance in developing a long term vision and a holistic approach to drive sustainable solutions for environmental issues. Conceptual examples of how such an approach can be applied on a regional scale to drive sustainable solutions, include development of a comprehensive water management system , or real time characterization of air quality (i.e. for the SF Bay Area).

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Session 3: Sensor Technology and Physics

3-1 Sensor Keynote: Novel Sensor Technologies

David Chow and Parney Albright, HRL

Sensors are key enablers for the Internet of Things (IoT) because they transduce physical (analog) quantities presented by the real world into electronic signals that can be digitized and rapidly disseminated to a prescribed network.

Although there are dozens of quantities that need to be transduced, many scenarios are not technologically challenging. For example, webcams are low cost and readily available for most environmental conditions. This presentation will focus on some of the challenging sensor scenarios that impede IoT implementation and novel sensor technologies that can potentially meet these challenges. One of the most challenging classes of problems at present is the requirement for precise (and low cost) transduction of quantities that are rapidly changing, as in some autonomous navigation scenarios. In these scenarios, a suite of optical and RF sensors are currently envisioned, leveraging technologies that were originally developed for defense applications. Another significant challenging class of problems are restrictive environments, such as inside a human body or a jet engine, where conventional sensors would be too invasive or fragile, respectively, motivating the development of sensors based on novel materials.

3-2 Photonic MEMS for Calibrated Physical Sensing

Jason Gorman, NIST

The internet of things (IoT) will be dependent on billions of sensors to provide real-time information for a large number of measurands, such as temperature, pressure, and acceleration, among many others. Microelectromechanical systems (MEMS) are the obvious technology for implementing such a large network of sensors due to their small size, low power consumption, and direct integration with electronics. One major challenge in creating and maintaining a large MEMS sensor network will be calibration. Sensor calibration is expensive, possibly making it impractical to calibrate so many sensors. Furthermore, calibrations must be repeated over the sensor's lifetime to adjust for aging and environmental factors. This will not be possible in many IoT applications since the sensors will be embedded in complex equipment and may be in remote locations. As a result, the development of sensors that can be calibrated using

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internal references, or self-calibration, is an important goal for the IoT. The merging of micro- and nanophotonics with MEMS provides a strong opportunity for embedded calibration because the wavelength of a laser is an excellent reference standard (i.e., it is can be highly stable) and it can be used to make a large number of different measurements. In particular, micro- and nanophotonic cavities have been shown to be capable of measuring forces, temperature, and mass changes with exceptional precision and can be referenced directly to the laser interrogating the cavity. This presentation will give an overview of photonic MEMS sensors and their application to measurements related to the IoT. It will also describe our research on microscale Fabry-Pérot cavities and their integration into MEMS for calibrated physical sensing. This will include the development and testing of microscale hemispherical cavities and their use in an optomechanical accelerometer that demonstrates the self-calibration concept.

3-3 Additive Printing of Flexible Electronics for Sensing

Tina Ng UCSD, Associate Professor

In this talk, I will present the advantages and limitations of printed devices, and then discuss how to integrate the individual components together. There are two progressive printing approaches: simple systems (<100 transistors) are inkjet printed entirely from solution electronic inks, whereas more complex functions are met by printing interconnects between silicon ICs and printed passive components, to combine the advantages of flexible printed devices with the high performance of silicon chips. I will discuss the design rules we learned in the course of developing a fully printed sensor platform and the approaches to achieve designs that tolerate the variations in printed devices.

Specifically, sensors relying on direct-current (dc) amplitude modulated signals may suffer from drift and noise over long transmission distances across a large matrix. To overcome this limitation, we encoded dc stimuli into digital signals whose alternating current (ac) frequency varies with stimulation intensity.

Printed organic ring oscillator circuits, consisting of odd numbers of repeating inverter stages based on complementary field effect transistors, were used to generate the ac modulation. These circuits were integrated into a power-efficient skin-inspired mechanoreceptor that transduces pressure into digital signals directly. As force is applied on the sensor, the output frequency ranges from between 0 – 130 Hz to mimic slow-adapting skin mechanoreceptors. I will

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discuss the design and show application examples for such pressure sensor. My team is demonstrating application of these pressure sensors for augmenting spasticity diagnosis for pediatric patients, and I will relay the main challenges we encountered in developing this use case.

3-5 Integrated Quantum Plasmonics and Microfluidics for IoT Healthcare

Solutions Luke Lee, UC Berkeley, Professor, Bioengineering

In this talk, I will present quantum plasmonics and its applications in integrated microfluidics for fundamental life sciences and precision medicine. First, I will introduce a quantum plasmonic nanoscope that allows non-invasive optical imaging of quantum biological electron-transfer (QBET) dynamics in live cells. The quantum nanoscope is designed to capture the real-time QBET imaging of enzymes using Plasmon Resonance Energy Transfer (PRET) mechanism and quantized plasmon quenching dips in resonant Rayleigh scattering spectra. Second, I will discuss the important role of nanoplasmonics in integrated molecular diagnostic systems (iMDx) for personalized precision medicine. The iMDx comprises three key elements of precision medicine on chip: (1) ultrafast multiplexed plasmonic PCR for the early detection of DNA and RNA biomarkers in blood, (2) signal amplifications of protein markers, and (3) a self-contained sample preparation from whole blood on chip, which allows a sample-to-answer readout platform. Microphysiological analytics platforms (MAPs) is also created as innovative solutions in pathogenesis life science, personalized drug discovery, and therapeutics. In particular, the real-time imaging of formation and dynamics of pathogenesis in mini-brains MAP and pancreatic islets MAP will be discussed along with the vision of preventive medicine via precision engineering medicine.

Abstracts

Session 4: Industrial Applications

4-2 Impact of Big Data and Industry 4.0

John Carrier, MIT Sloan School of Management, Senior Lecturer

While there is overwhelming evidence that the tools, technologies, and leadership techniques developed for operating effective design and production operations, it is challenging to implement these in a sequenced and synchronized way that results in an organization with systemic alignment and integrity. In many cases, the different approaches start to compete against one another (people vs. technology, for example).

Some organizations, such as Toyota, have developed consistent, high performing, and sustainable organizations and have successfully transferred these methods to others, best exemplified by the NUMMI joint venture facility. However, transfer of the approach has been hindered by several factors, including industry-specific language, and the apparent lack of a supporting theoretical framework.

Our approach is to combine the theoretical work done in adaptive control systems with over 100 years of “on-the-floor” production learnings, to create a simple, yet rigorous framework for an operations system that “learns as it earns”, through a correct sequencing of human capital (people), technology (robotics, sensors, computation), and organizational structure (differentiating between corrective and adaptive feedback). We will demonstrate the approach through successful examples, and present a methodology for implementation that avoids short term risks to the customer, to the facility, and to the organization’s financial health (cash flow).

The adaptive control loop, and associated tools are designed to recognize, quantify, and eliminate the “dark matter” that exist in any system and cause 30% of the projects to be late and of poor quality. The elimination of these hidden factories not only produce value (earnings), but also result in learnings (creative problem solving) that raise the overall system’s IQ.

We will also address the role that several giants in the field of Systems Dynamics, including Jay Forrester, Claude Shannon, and John D.C. Little, had in defining the principles that must be considered as part of any successful IoT implementation.

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4-3 Connected Edge - How Things Talk to Each Other

Jean Lau, GE, VP of Software Engineering

The connected edge is transforming the traditional industrial businesses by making industrial machines more intelligent and enabling services using real-time data coming from those machines. The intelligent machines will be able to take actions based on insights generated from real-time data and machine learning analytics on the edge. This requires connectivity and interoperability across sensors, controllers, gateways, cloud system and human operators. When all things are connected and talking to each other and to the cloud, this will change the way how people work in organizations.

In this session, I will discuss GE's vision of the connected Edge and how we make things talk to each other a reality. This presentation will include industrial use cases of the connected Edge.

4-4 Quantum Technology Landscape in UK and Handheld Quantum Encryption

Iris Choi, National Quantum Technology Hub, University of Oxford

In this talk, I will give an overview of the £270M UK National Quantum Technologies Programme, which was launched in 2014. As part of the programme, four Quantum Technology Hubs were established for Imaging, Sensing, Communication and Computing applications. My talk will focus on the Quantum Computing efforts from the Networked Quantum Information Technologies Hub ('NQIT') led by the University of Oxford. NQIT has the objective of building the core components of a universal quantum computer. In the second half of my talk, I will speak about handheld quantum encryption. We have recently built a prototype device to communicate rapidly and securely with a receiver using light-based quantum encryption. This new approach could make payment transactions and wireless communication more secure.

Poster Abstracts

Session 5: Poster Session

5-1 Piezoelectricity in single-molecular layer crystal

Hanyu Zhu, Yuan Wang, Jun Xiao, UC Berkeley, Ang-Yu Lu, Lain-Jong Li, King Abdullah University of Science and Technology, Xiang Zhang, UC Berkeley

Piezoelectricity offers precise and robust conversion between electricity and mechanical force, which originates from the broken inversion symmetry of atomic structure. It is expected that in low dimension the electromechanical coupling becomes stronger as the Coulomb interaction is greatly enhanced. Yet reducing the size of bulk piezoelectric materials to single molecular layer was challenging, since the surface energy can cause piezoelectric structures to be thermodynamically unstable. We experimentally demonstrated piezoelectricity in free-standing single-molecular layer of MoS₂ crystal, with measured piezoelectric coefficient $d_{11} = 2.9$ pm/V. The dependence of piezoelectric response to layer number and the angle of applied electric field agreed with the crystalline symmetry. In complimentary to the natural in-plane piezoelectricity, the single-layer TMDC was also chemically engineered by selectively replacing the sulfur atoms on one side with selenium and created an out-of-plane piezoelectricity of $d_{33} = 0.1$ pm/V in MoSSe. This value can be further increased by varying the substitute atoms. The two-dimensional piezoelectricity potentially enable low-power logic switch for computing and electromechanical sensors at molecular scale----the ultimate material limit.

Poster Abstracts

5-2 Physical Unclonable Functions (PUFs) for Securing the Internet of Things (IoT)¹

Calvin Chan, Jason Hamlet, Ryan Helinski, Rachel Dondero, Todd Bauer, Sandia National Laboratories

Distributed networks like the IoT requires verifying the authenticity of data and the identity of devices across the network. Authentication and attestation use cryptographic protocols that employ unique, randomly generated, and closely guarded cryptographic keys for each device. However, key generation and storage is problematic in IoT. Manufacturers may pre-program keys into space-intensive memory elements, but these keys are often non-unique and reused. Keys can be computationally generated onboard the device, but there is often insufficient behavioral entropy in an IoT device to guarantee the uniqueness of keys. Semiconductor physical unclonable functions (PUFs) may facilitate IoT security by providing integrated, lightweight cryptographic primitives for authentication and attestation. PUFs leverage the inherent entropy present in materials processing (e.g., dopant distribution), which are observable as statistical variations in device behavior (e.g., threshold voltage). Using this approach, unique signatures and keys can be established for a physical object. Here, we discuss our efforts to: (i) correlate material variations with semiconductor PUF device properties, and (ii) develop methods to correct for the reliability and protocol shortfalls of PUFs.

¹This work was partially funded by SNL's Laboratory Directed RD program. SNL is a multi-mission laboratory managed and operated by Sandia Corp., a wholly owned subsidiary of Lockheed Martin, for the U.S. DOE NNSA (DE-AC04-94AL85000).

Poster Abstracts

5-3 IoTs and automated psychology for better sleep for babies and caregivers

Russel Walters, Johnson & Johnson, Thomas Lipoma, Rest Devices

The physics of social systems has been a co-emerging field along with IoTs, and in the field of pediatric sleep we have combined them along with automated psychology. In the next generation of the IoTs, we moving beyond sensors and data streams to knowledge and actionable advice. Pediatric sleep is a uniquely suited field for an IoTs system combined with automated psychology. Parents are both developing expertise and suffer lack of understanding of the system in questioned (i.e. the baby). After crowd sourcing baby sleep patterns of over 350,000 sleep sessions, we developed Nod- customized sleep program designed to help babies sleep better. Through the Mimo baby wearable sensor or crib sheet baby sleep data is collected. Optionally, caregivers can manually add additional sleep sessions. While the accurate measurement of sleep remains a challenge for IoT devices, the bigger challenger which we address is actionable advice for parents. Previously through a relatively simple online survey question tool, we have shown clinically improved pediatric sleep. With the improved data available from IoT devices, the advice and recommendation that can be provided should lead to even larger clinical improvements in baby sleep.

Poster Abstracts

5-4 Plant Disease Detection Using Real-Time Sensors - A Case Study

Alireza Pourreza, University of California

Sensing is a fundamental component of the Internet of Things (IoT). In agriculture and natural resources, smart sensors have been employed to monitor different factors (e.g. pests and diseases, soil fertility, water stress, fruit development, and yield) that impact plant growth and production. Real-time sensors for accurate and timely detection of plant diseases are specifically important, because a disease can leave a drastic impact on the crop industry if it is not managed well. Citrus Huanglongbing (HLB) is a serious disease with no known cure. HLB-affected tree will not show symptoms for a long time, and after symptoms appear, it will die in a few years. Early detection and eradication of the HLB-affected trees is crucial to protect the rest of the orchard from the infection. Starch accumulation in citrus leaves is an early indication of the disease which remains invisible for months or even years. A vision-based sensing methodology, called polarized imaging, is presented in this study that can highlight the areas on the leaf surface that contains an abnormal level of starch, before the visible symptoms are developed. The results showed that this method not only can identify HLB in 97% of times, but also can differentiate HLB symptom from other analogues symptoms accurately.

Poster Abstracts

5-5 PVoT for IoT: Photovoltaics on Things for the Internet of Things.¹

Nancy Haegel, Matthew Reese, Joey Luther, Mary Werner, Sarah Kurtz, National Renewable Energy Laboratory

Most discussion on the intersection of photovoltaics (PV) and the Internet of Things (IoT) centers on the use of sensors, communications and data collection and analysis to optimize performance of PV assets for power generation, as part of intelligent power systems. As the IoT expands, PV also has the potential to provide local power generation for small scale or remote devices. PV could extend the effective lifetime of battery powered systems or support independence and isolation from the grid for IoT sensors and devices. In order to meet size, weight and cost demands, the PV will need to be simultaneously lightweight, high efficiency and low cost. Flexible form factors will also be important. Research at NREL can contribute to these goals. This poster will highlight efforts in the following areas: 1) assessment of the role of packaging in determining PV specific power (W/kg), 2) demonstration of increasingly efficient thin film PV on flexible substrates, and 3) potential for solution-processed perovskite tandem cells that could be ideal for low cost PV with lifetimes matched to the application of interest. PvoT for IoT could be one of many "beyond the panel" applications that will enable new entry markets and lead to more widespread use of solar energy. This presentation will provide the opportunity to interact with the emerging IoT community to understand the role for PV and the associated research challenges.

¹Work at NREL is performed under U.S. Department of Energy Contract No. DE-AC36-08-GO28308.

Abstracts

Reception: special presentation

R-1 The Internet of Things – Present at Its Creation –

Paul M. Grant, W2AGZ Technologies

As the decade of the 1940s came to a close, it had become apparent that the WWII technology of manually recording incoming radar data on wide area transparent panels preparative to subsequent human interpretation to embody retaliation would be insufficient to defeat the looming threat of a massive Soviet nuclear-armed bomber and missile attack. In 1951, two pioneer MIT computer scientists, George Valley and Jay Forrester proposed inserting the immerging digital computer technology to analyze incoming analog radar data, subsequently transforming the digital decisions back to analog for control of the launch and direction of defensive alternatives. Thus was born the actualization of the “internet of things” and the internet itself, designated as SAGE, more than a decade prior to ARPANET and CERN.

In 1954, as an 18-year old IBM system maintenance programmer, I was assigned to Lincoln Laboratory as part of the support team for XD-1, the prototype computer for SAGE (which later morphed into the NORAD North American air defense system). I have many tales to tell, e.g., how the continental linkage of the NORAD sites led to interaction of their respective staffs via flexowriter keystations (aka “social networking”).

Today’s IoT has begun to stress the limits of Turing-von Neumann architecture/technology. Does “quantum computing” offer a path forward? Let’s discuss in Monterey.

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Session 6: Practical Challenges

6-1 In Pursuit of Brilliant Operations

Paul Boris, GE Digital, VP, Manufacturing Industries Finding and Fitting

How the Industrial Internet of Things (IIoT), Big Data and Cloud collide to bring new opportunities to deliver huge outcomes for industrial value chains, and what's holding us back from getting there faster. This is a view from the inside on how GE leverages methodologies like FastWorks to deliver, test and rapidly scale solutions across the supply chain.

6-4 Finding and Fitting Batteries for Small IoT Devices

Andy Keates, Intel, Principal Engineer

The Internet of Things encompasses devices from tiny sensors to cars, each of which has its own challenges in attaining the desired battery performance. This presentation analyses the demands that mobile computing and smaller devices place on the batteries that power them. Batteries that fit into small devices must themselves be small. Packaging efficiency, energy content and power capability all deteriorate with diminishing size. This paper looks at the deficiencies of existing battery choices in terms of static issues (like self-discharge) and also dynamic issues ... the nature of IoT devices to run on very low idle power, but then wake, compute and transmit, demanding orders of magnitude more power for brief periods.