# Safe Advanced Mobile Power Workshop

Although popular mobile devices use energy storage devices (batteries) as their power source, battery technology for consumer mobile applications has not changed much since mobile phones were introduced to mainstream consumers in the 1990s. Advances in mobile battery technology are much slower than increases in processing power, network speeds, and digital storage technology. This slower technological development in mobile power technology is limiting the application of many new and potentially revolutionary applications. Mobile device power is in need of its own version of something like Moore's law.

We are currently at the dawn of the set of technologies and applications commonly known as the Internet of Things (IoT). Advances in novel battery technologies will enhance the IoT by enabling a plethora of new applications. Features that use "always ON," enabled by higher energy mobile power sources, will revolutionize the IoT's ability to interact with its surroundings and provide a virtual extension of human knowledge and influence in ways we do not yet fully appreciate. Likewise, the availability of more mobile device power would enable the operation of additional hardware such as multiple radios in simultaneous use and widespread use of technologies such as microprojectors in common mobile devices.


SAMP delegates in full session; the workshop provided a unique opportunity to put many minds to work on a shared cross-disciplinary problem.


Philip Catherwood (right) presents the power aspects of medical devices that link with a smartphone.


The SAMP "Gospel according to Tom"; our leader educates students at Limerick Institute of Technology on the need for better power technologies for our handheld devices.

The 2nd Safe Advanced Mobile Power (SAMP) Workshop was held in Galway, Ireland, on 4–5 December 2014. Participants convened on the evening of 3 December for an informal evening briefing session followed by dinner. On 4 December, the first in-person workshop session commenced at 9 a.m. until lunchtime. In the afternoon, a teleconference session with a significant virtual attendance continued the discussion. At 5:30 p.m., most of the group moved to the local university for a public evening session and IEEE outreach with public talks from three to four selected participants. [Three IEEE Distinguished Lecturers (DLs) contributed to these talks.]

The goal of this SAMP workshop was to further develop the initiative started by Tom Coughlin and Lee Stogner in July when the first workshop was held in San Jose, California.

## SAMP WORKSHOP SESSIONS

### OPENING REMARKS

Coughlin opened the meeting with an overview of the purpose of the SAMP initiative. This is the second SAMP workshop, as the first was in July 2014. The main objective of SAMP participants is to facilitate research, development, and eventually market availability of a mobile power supply capable of sustaining a hand-held device for at least one week. Ideally, the SAMP power source will not require external recharging from a fixed power source. In addition to the convenience of such a power source, it would also have life-saving implications and help enable new application fields for mobile devices. The initiative will also serve as a test bed for technology development.

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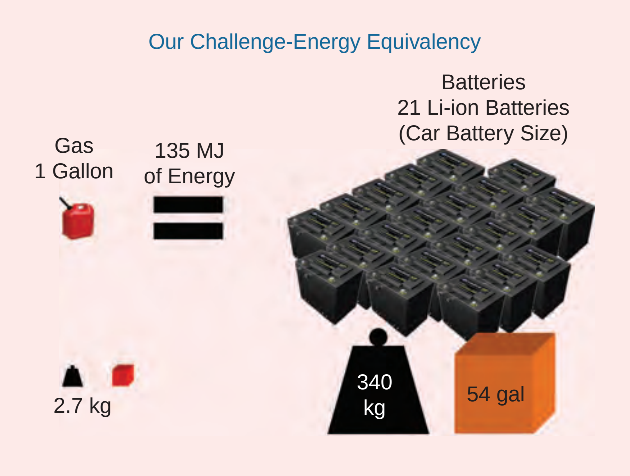


**FIGURE 1.** The challenge of getting batteries to reach the price-performance of gasoline in electric vehicles.

Electrochemical Battery History

- "Baghdad Batteries"
  - ~1000–2000 Years Ago.
  - Terracotta Jars Containing a Copper Cylinder Separated from an Iron Road by a Non-Conductive Stopper and Filled with an Electrolyte
  - Use: Electroplating

**FIGURE 2.** An 1,000-year-old Baghdad battery—believed to be used for electro-plating.

In his introductory remarks, Coughlin considered the Moore's law relationship for improving mobile power. To date, the geometrical rate of improved mobile power has been on a quasi-linear path, with a doubling of the available use time about every ten years. This arises from a combination of improved power sources and improved device efficiencies. However, the pattern is kept in check by the demand of ever-increasing device capabilities, more powerful operating systems, and mobile products. Our goal is to boost mobile performance to a full one-week supply for all potential mobile uses.

## *THE SAMP PROBLEM IN A NUTSHELL*

The "casual" cell phone user gets about 5 h of use without recharging with today's mobile phone batteries, the "power-user" may only get 3 h of use from a conventional mobile phone battery. For the casual user, with a 3.7-V device, the total energy needed for a week's use would be about 36.3 watt hours (Wh) or 130,536 J. For the power-user who really wants 12 h of intense use (e.g., videos), the total energy needed for a week's use may be about 145 Wh or 522,144 J.

Increasing the power available in a mobile phone can enable many additional functions not normally found in today's mobile devices. This could include, as examples, 1) running more radios, 2) powering high-density microprojectors, 3) lifelog recording, 4) providing a local edge connection for the IoT and providing power for external peripheral devices, and 5) providing more powerful processing for applications such as compression and computational imaging.

## *BATTERY POWER AND POWER SOURCES*

Lee Stogner, from the IEEE Future Directions Committee, gave a presentation on battery and power source generation over the last 150 years. Improvement in energy storage density does not follow anything like Moore's law, since the development of energy storage density is only doubling about every ten years. This is much slower than the pace of development of processing capability, network connectivity and speed, and digital storage capacity. Thus, mobile power sources are a significant bottleneck in mobile technology development. We need to nurture ways to boost the energy in mobile devices much more quickly.

The classic example is a gallon of gasoline. This contains more energy than 3 m$^3$ of today's high-power battery technology—one of the key reasons why it is proving challenging to build electric cars that can match the price-performance ratio of conventional gasoline-powered vehicles (Figure 1).

After a brief history of battery technology that stretched back over 1,000 years (Figure 2) Stogner presented detailed discussions on today's battery technology and, in particular, highlighted its limitations. He also presented a range

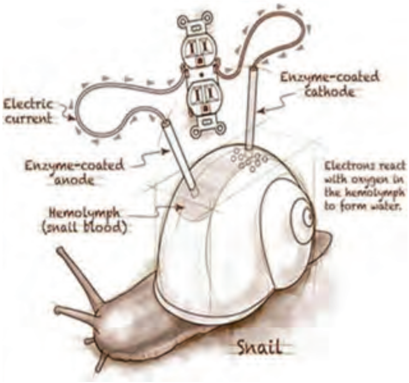


**FIGURE 3.** A biofuel cell concept that makes electricity using the glucose from a snail's blood. In a human where glucose is constantly replenished, it could be used to power implanted medical devices like a pacemaker. However, it probably wouldn't be powerful enough for your smartphone. Maybe this is how they generated electricity from humans in *The Matrix*.

**FIGURE 4.** Researchers at Virginia Polytechnic Institute and State University developed a bio-battery that is charged by sugar. Once this bio-battery is charged, it takes ten days to discharge. Researchers claim that this battery provides more electricity output compared to output provided by a normal lithium-ion battery.

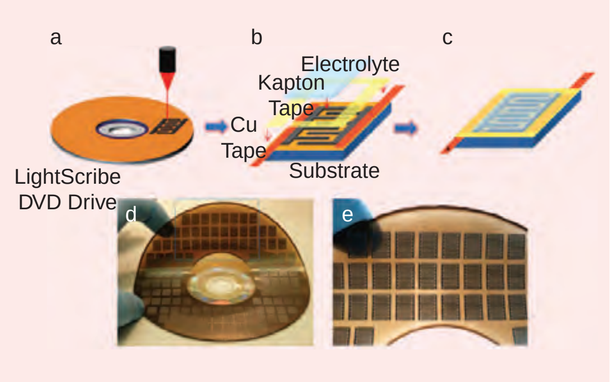


**FIGURE 5.** UCLA researchers have developed a groundbreaking technique that uses a DVD burner to fabricate miniature graphene-based super-capacitors—devices that can charge and discharge a hundred to a thousand times faster than standard batteries.

**FIGURE 6.** Thomas Edison designed a battery to power cars and built an "EV" using it in 1889. Stanford University scientists have recently modified the nickel-iron battery structure using graphene incorporated into the iron anode and carbon nanotubes incorporating nickel as the cathode. As a result, we now have an ultra-fast nickel-iron battery.

of new technological concepts that are the subject of research in laboratories worldwide. These include an eclectic mix of different approaches, and there is a bit of everything in there, including snails (Figure 3), sugar (Figure 4), and digital versatile disk burners (Figure 5). No puppy-dog tails through!

Perhaps one of the more pragmatic approaches is the nickel-iron battery that stretches back to Thomas Edison (Figure 6) and which has been reinvented by researchers at Stanford taking advantage of modern production techniques and utilizing materials such as graphene to significantly improve performance and charging times.

### *FUEL CELLS FOR THE FUTURE*

Another promising technology related to batteries, yet quite different, is the use of fuel cells. These are electrochemical systems, somewhat like batteries, that differ in that the fuel cell obtains energy by chemically converting a "fuel" and releasing electrical energy as a byproduct. The best-known example is the hydrogen fuel cell that transforms hydrogen to water in the presence of oxygen. The energy conversion rates are high, but the challenge is to find energy-efficient ways to manufacture the hydrogen fuel. Fuel-cell technology is well tested from its use in space flight (Figure 7), and so the main challenge is to reduce its size as a power source to meet the needs of handheld consumer devices (Figure 8). We are not quite there yet, but progress is being made.

### *MARKET/PRODUCT DEFINITION FOR SAMP*

Following some discussion, the group arrived at a product definition/goal for SAMP—this would take the form of an energy source for mobile devices that can provide a week's worth of normal use without recharging from proximity to a fixed power source and costing <US$20 in 100 million+ unit production volumes. It must be environmentally friendly and provide at least three years of lifecycle. Normal energy requirements for a week are estimated to be 36 Wh for casual users and 145 Wh for power users. The device must be made in accordance with product safety and regulatory requirements and satisfy environmentally friendly recycling practices.

### *ENERGY HARVESTING AND WIRELESS POWER*

Will Lumpkins led a discussion of energy harvesting and wireless power: Extracting energy from the ambient environment of the mobile device is energy harvesting. This energy may be energy generated by the movement of the phone's user, power recovered by photovoltaic cells and energy recapture from radio frequency identification (RFID)/near-field communication (NFC) systems, power generated by differences in temperature, and other ways to get useful power from the local environment. In Table 1, we list some of the most common energy harvesting sources as they relate to mobile devices.

### *BATTERY TECHNOLOGIES*

Rachel Moore discussed battery technology: For developing innovative advanced and disruptive applications to emerge in mobile devices, a 20× or more improvement in mobile energy is essential. With a doubling every ten years in battery energy density, this would require more than 50 years of technical development at the current development trend. This is far too long to wait for the IoT and the personal mobile technology of the future.

Figure 9 shows a comparison of various approaches for the storage of energy for later use in terms of the total energy storage potential of the technology as well as discharge time. This figure includes physical energy storage methods such as pumped hydraulic energy storage and compressed air as well as a variety of battery technologies now in use or in development. Many of these approaches are not easily implemented in the space available in a cell phone.

### *MOBILE POWER BUDGETS*

Reggie Little was the next presenter, and he discussed mobile power—understanding where the power goes [Figure 10(a)]. This was a very instructive presentation as it helped participants understand the

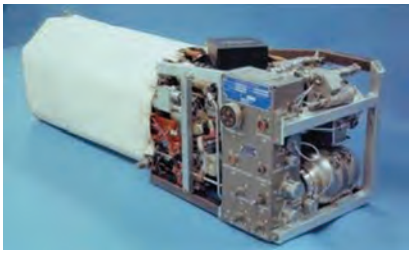


**FIGURE 7.** The Apollo Fuel Cell was designed to provide safe, reliable power to send men to the moon and back. One is on display at the LA Science Museum.

**FIGURE 8.** The fuel cell—mobile packaging.

**Table 1. The most common energy harvesting sources.**

| Energy Source | Technology Example |
|---|---|
| Inductive charging | Power mat, Qi |
| Light (solar) optics | Solar cell, infrared optics, fluorescent optic recovery |
| RF field recovery | Wireless power, NFC, RFID, electromagnetic field recovery |
| Magnetic resonance | Automotive charging stations |
| Kinetic/motion | Currently only used with vehicles, i.e., brake recovery |

many different subsystems used in a mobile device and which of them are significant power consumers. Interestingly, many of the core electronic systems consumer relatively smalls amounts of the total power budget.

An overview of the main subsystems is provided in Figure 10(b). It can be seen that the main variables are the operating frequency of the system clock and the operating voltage [Figure 10(b)].Power scales linearly, according to the operating frequency, so slowing down the central processing unit does improve power consumption but at the expense of fewer computing cycles. In practical terms, this is only useful if the device is not busy, but in the context of a multitasking operating system, it is difficult to manage and reap practical benefits.

For operating voltage, the power consumed increases according to a square law, thus halving voltage levels enables a fourfold saving in power providing a much more tangible benefit. But here the problem becomes physics, as we are limited by the forward bias voltage of a PN junction within the transistors of a logic gate. In practice, this makes scaling operating voltage below 1.2 V extremely challenging for todays semiconductor technologies.

Little next presented some practical results for the various power consumptions within a device [Figure 10(c) and (d)]. One very interesting conclusion was that video processing when you use your smartphone to capture pictures or video is the most significant power sink. In fact, as the latest devices start to feature multiple graphical processing unit (GPU) cores and 4K video technology, you really have to start thinking about video as a key determining factor for battery life, because 4K video will essentially quadruple the processing and thus the power drain in the latest cell phone models. So, saving your precious memories in 4K is

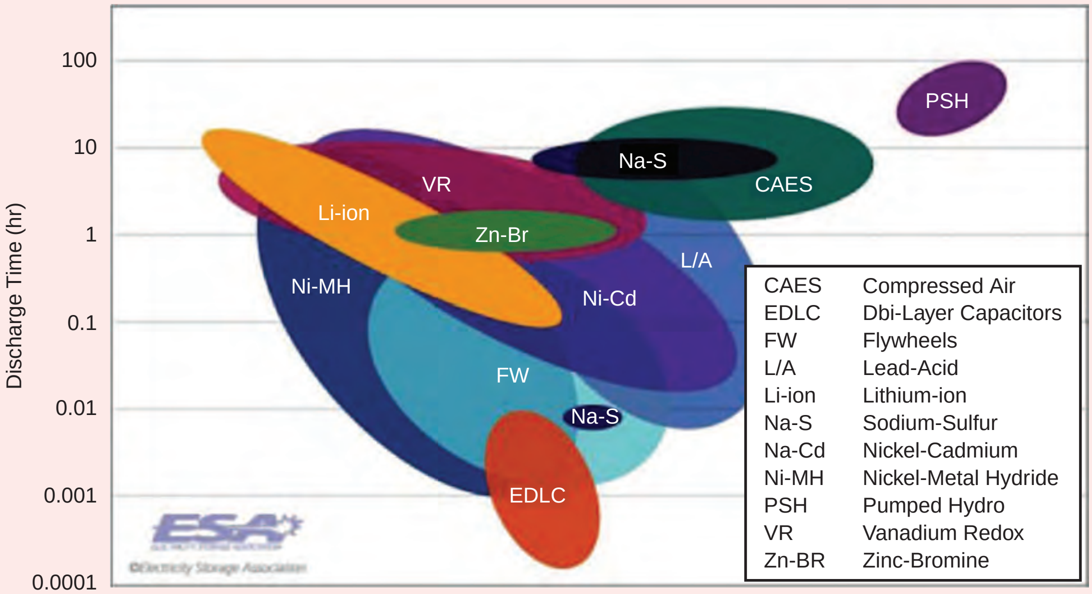
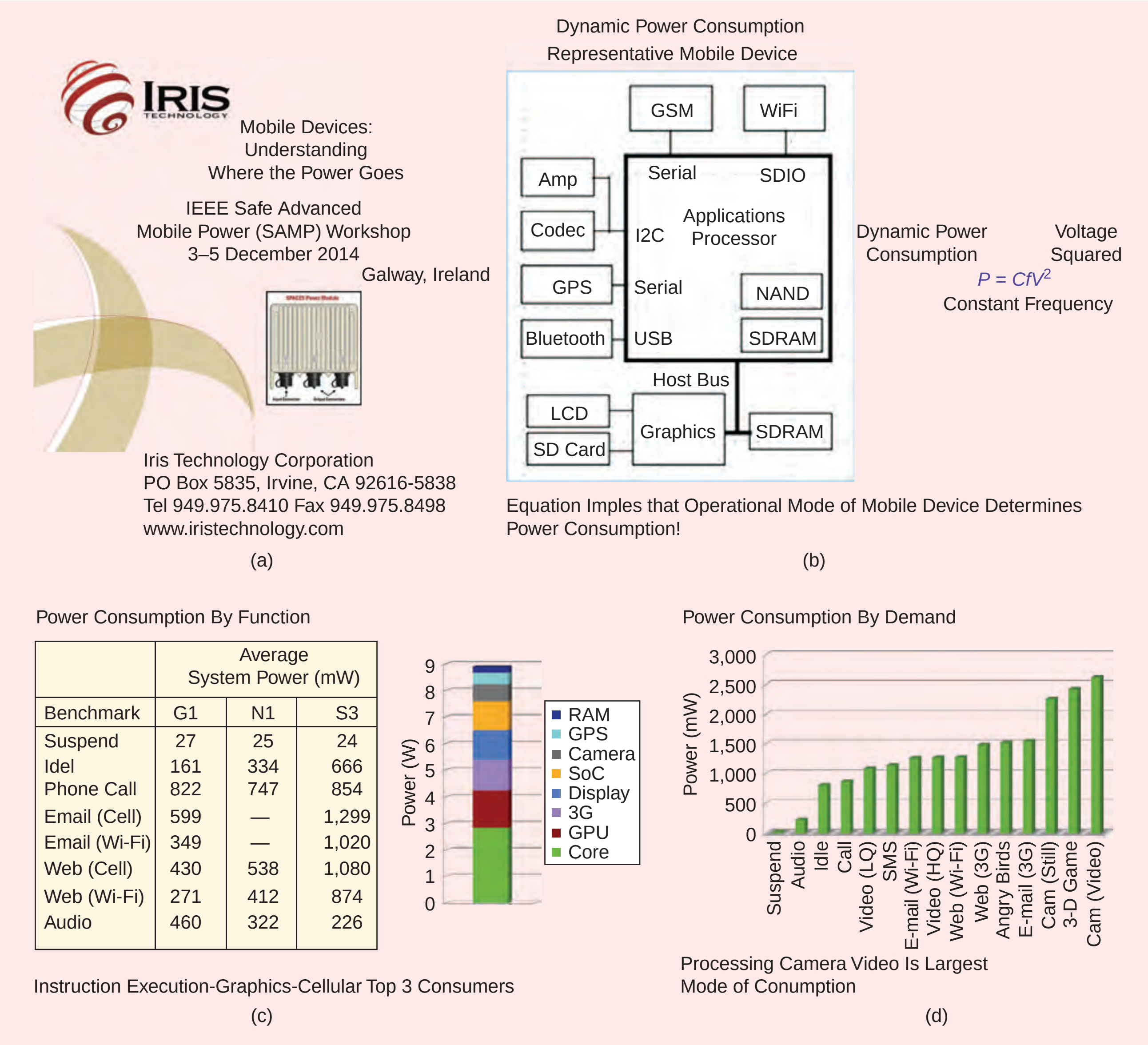


**FIGURE 9.** Storage capacitive potential.



Mobile Devices:
Understanding
Where the Power Goes

IEEE Safe Advanced
Mobile Power (SAMP) Workshop
3–5 December 2014
Galway, Ireland

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(a)

Dynamic Power Consumption
Representative Mobile Device

Dynamic Power Consumption
Voltage Squared
$P = CfV^2$
Constant Frequency

Equation Imples that Operational Mode of Mobile Device Determines Power Consumption!

(b)

Power Consumption By Function

| | Average System Power (mW) | | |
|---|---|---|---|
| Benchmark | G1 | N1 | S3 |
| Suspend | 27 | 25 | 24 |
| Idel | 161 | 334 | 666 |
| Phone Call | 822 | 747 | 854 |
| Email (Cell) | 599 | — | 1,299 |
| Email (Wi-Fi) | 349 | — | 1,020 |
| Web (Cell) | 430 | 538 | 1,080 |
| Web (Wi-Fi) | 271 | 412 | 874 |
| Audio | 460 | 322 | 226 |

Instruction Execution-Graphics-Cellular Top 3 Consumers

(c)

Power Consumption By Demand

Processing Camera Video Is Largest
Mode of Conumption

(d)

**FIGURE 10.** (a) "Understanding Where the Power Goes," one of the SAMP presentations by IRIS Technology of Irving California. (b) An overview of the different subsystems within a typical mobile device that consume battery power. (c) Different device functions and activities and their relative power consumptions across several models of a mobile device. (d) Comparative estimates for each of the main subsystems; note that video/camera processing is the most power intensive, not any of the wireless or RF subsystems.

going to significantly impact your battery life—I bet the advertising campaigns will conveniently omit this tiny detail when they appear in 2015.

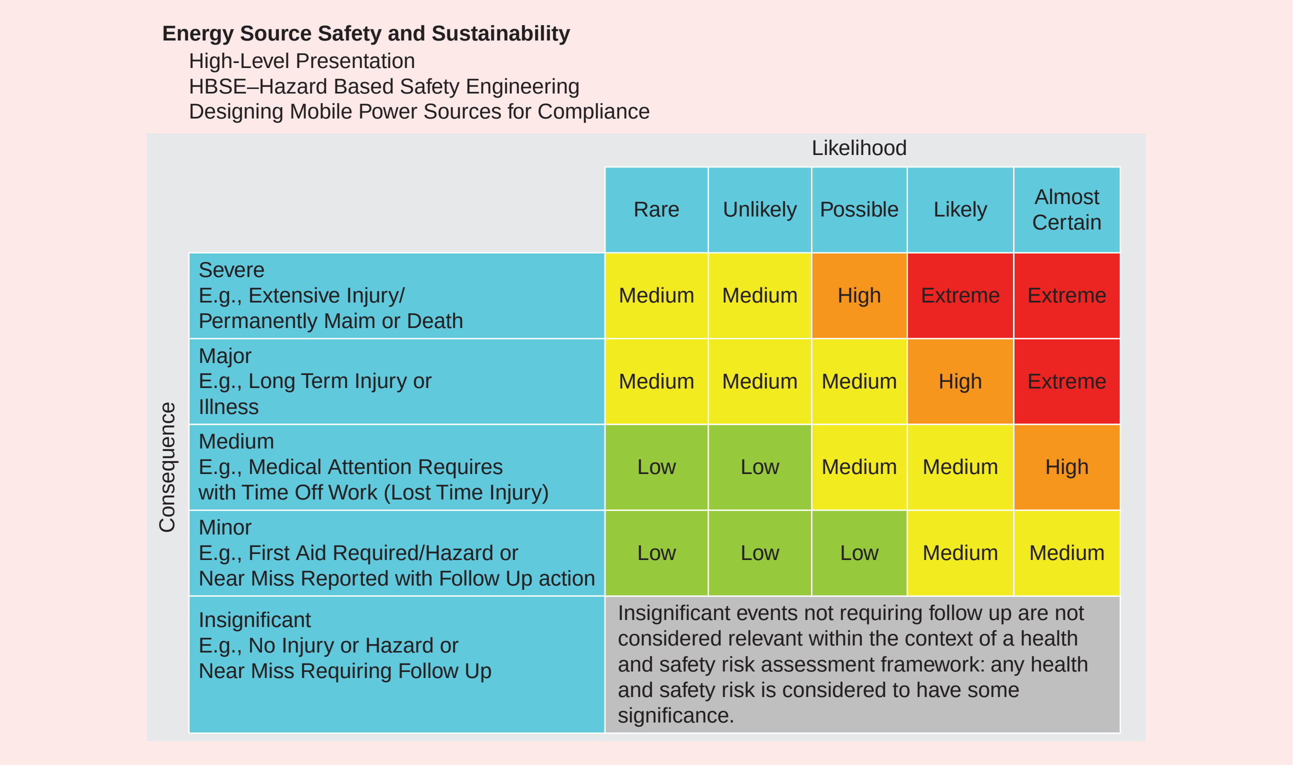
Some discussion followed and Lumpkins noted that if a mobile device possessing a global positioning system (GPS) cannot get a signal, it continually searches, using approx. 47 ma, a significant drain. This is important due to many new smartphone software and services being introduced that employ location-based components. And as many of us are inside buildings during most of the workday, this continual GPS power drain will build up. Knowing where you are has a significant energy cost.

## SAFETY REQUIREMENTS FOR MOBILE POWER

Murlin Marks from the IEEE Product Safety Society next presented on safety issues for smartphones (Figure 11).

For consumers, increased battery life is a priority and high energy density batteries would be desired by most users. Today's mobile phone battery cells are constructed with nonmetallic lithium batteries that use lithium ions. This is much safer than the first cells, which were constructed with inherently unstable lithium metal. By monitoring temperatures during a controlled charging and discharging cycle, the current generation of battery cells is considered safe. Additionally, the cells contain safety circuits that avoid overcharge and undercharge, and short circuit protection in case the terminals are shorted.

With such high energy stored in a small volume, the manufacturers are always looking to improve the safety of the cells.



**Energy Source Safety and Sustainability**
High-Level Presentation
HBSE–Hazard Based Safety Engineering
Designing Mobile Power Sources for Compliance

Likelihood

| Consequence | Rare | Unlikely | Possible | Likely | Almost Certain |
|---|---|---|---|---|---|
| Severe<br>E.g., Extensive Injury/ Permanently Maim or Death | Medium | Medium | High | Extreme | Extreme |
| Major<br>E.g., Long Term Injury or Illness | Medium | Medium | Medium | High | Extreme |
| Medium<br>E.g., Medical Attention Requires with Time Off Work (Lost Time Injury) | Low | Low | Medium | Medium | High |
| Minor<br>E.g., First Aid Required/Hazard or Near Miss Reported with Follow Up action | Low | Low | Low | Medium | Medium |
| Insignificant<br>E.g., No Injury or Hazard or Near Miss Requiring Follow Up | Insignificant events not requiring follow up are not considered relevant within the context of a health and safety risk assessment framework: any health and safety risk is considered to have some significance. | | | | |

**FIGURE 11.** A health safety and risk map.

This largely depends on construction and avoidance of contamination that could potentially cause short circuits. However, even with controlled manufacturing and embedded safety circuits, there have been reported cases of fires or meltdowns such as the case covered by *ABC News*, where a cell phone burned a hole in a girl's bed due to overheating (see Figure 12).

**FIGURE 12.** *ABC News* reported on cell phone fire hazards.

Lithium-ion cells offer twice the energy density of nickel-based cells and four times the energy density than lead cells. Battery manufacturing processes become more critical to make safer products to avoid devastating consequences. In fact, one of the older tests of using a nail to penetrate the cell, causing the cell to short circuit, is no longer applied to cells that have higher energy density than 1,300 mAH, as the test would cause an explosion with a fully charged cell.

To wrap up, Murlin presented a health and safety risk map for smartphone power technology. And the conclusion? With ever-increasing energy densities the potential consequences of a catastrophic failure imply that safety measures and continual risk evaluation of smartphones are an ongoing necessity. The catchphrase "rocket in your pocket" has never been more applicable to a consumer electronics technology—our challenge as safety engineers is to make sure that those rockets are never able to do their "discharge dance" in someone's pocket.

### *A MOBILE POWER XPRIZE?*

Since Chris Frangione was not on the phone, Tom Coughlin led a discussion relating to the XPrize and SAMP's role.

He encouraged everyone to consider what we can do to incentivize an Xprize and find sponsorship that could reach a target of US$10 million. Much of IEEE's role, via SAMP, would be to demonstrate the societal upside and benefits of improved portable power storage. It would be essential to have IEEE involvement in such an initiative and the CE Society should be a participant and champion of this activity.

Further discussion ensued, and there was consensus that SAMP lies closest in interest to the CE Society, rather than other Societies such as the IEEE Power & Energy (P&E) Society. Of course, we did not really have any P&E people to argue their side, but Lee Stogner was on board with this consensus.

## *MORE WIRELESS CHARGING AND ENERGY HARVESTING*

Joe Decuir, recently elevated to IEEE Fellow, discussed wireless charging via harvesting. Decuir took a slightly different approach than Will Lumpkins and put much of his focus on some emerging standards. He began by introducing the problem by sharing his personal experience of a problem that many of us face with today's ever present mobile devices (Figure 13).

He then moved on to discuss the emerging market and standards landscape. The market for wireless power requiring close proximity to the energy source is growing rapidly. The market need is felt from three particular segments:

1) Devices the size of modern smartphones—close proximity inductive power is being deployed now.
2) Smaller devices, e.g., wearables—the demand will grow as this market develops.
3) Larger devices, e.g., kitchen appliances.

There are now three standards setting organizations in the close proximity charging market today:

1) *Wireless Power Consortium*, trade named Qi—deployed now
2) *Rezence aka Alliance for Wireless Power, A4WP*
3) *NFC Forum, Wireless Charging Task Force.*

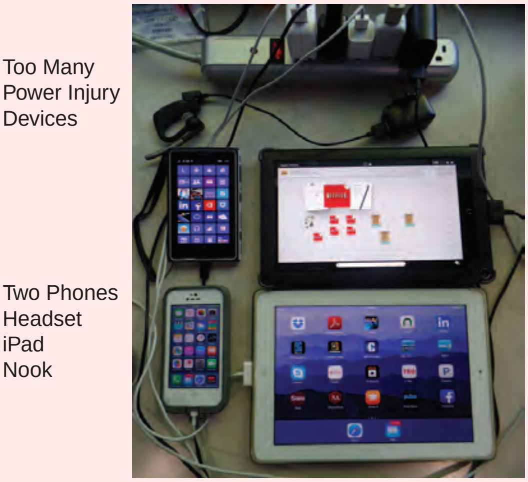


**FIGURE 13.** Many of us carry various power-hungry mobile devices.

Simple Comparison: A4WP and WPC

| Type | Frequency | Power | Contol Signaling |
|---|---|---|---|
| WPC-Qi, Inductive | 100–205 kHz | 5 W | Optional In Band |
| WPC-Qi, Resonant | 100–200 kHz | in Process, Confidential | Required? In Band |
| A4WP – Rezence, Resonant | 6.78 MHz | >5 W; 10 W; 16 W; 22 W; etc | Required Out of Band Bluetooth LE |

Rezence/A4WP System Diagram

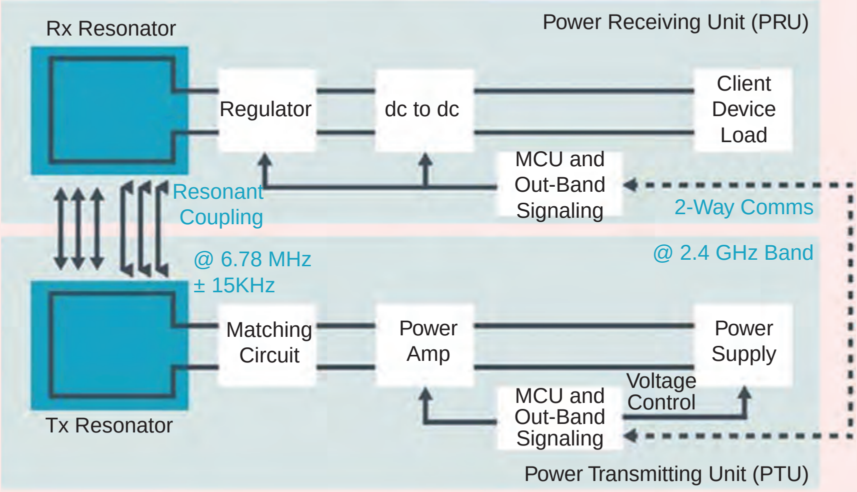


**FIGURE 14.** A comparison of A4WP and WPC wireless power technologies.

The first-generation products used inductive coupling at frequencies of several megahertz, including those harmonically related to NFC. There is the need for modifying these systems so that they can adaptively scale the power delivered. Without this technology, devices can easily get overloaded during a charge cycle and, as a consequence, operational lifetime or even catastrophic failures (and potential safety risks) can occur.

Power regulation is more challenging that a wired solution where you can monitor temperature and limit the load current if required. In the wireless case, because the device under charged (DUC) is not physically connected to the power source, it is not possible for the source device to regulate the power level so the DUC has to communicate back its status/power requirement.

There are two leading technologies in this area—the Alliance for Wireless Power (A4WP) and the Wireless Power Consortium (WPC). It is not clear yet who will win the race for industry adoption but Decuir provided some comparative analysis (Figure 14) and an overview of what these advanced resonant systems would look like at the architectural level. This is certainly going to be a consumer electronics technology to watch out for in the next 12–18 months as it starts to go mainstream.

Additional needs for the proximity-based wireless power technology:

- charge more than one device at a time
- cross compatibility or multiprotocol wireless charging
- more freedom: escaping from the charging mat.

Some resources and sources of information:

1) WPC: http://www.wirelesspowerconsortium.com
2) Rezence: http://www.rezence.com/
3) NFC Forum: http://www.nfcforum.org/.

Besides magnetic induction, magnetic resonance solutions are also being looked at as a way to charge consumer products. Figure 15 shows magnetic resonance as a means for charging electric vehicles.

In addition to the current generation of close-proximity wireless power, there are ongoing efforts to enable longer-range wireless power. Companies such as WiTricity and Artemis are working on technologies that will enable wireless power transmission over significant distances. Figure 16 shows a demonstration of wireless power transmission by WiTricity, and regular readers may recall that we featured a review and analysis of Artemis technology in [1].

## OTHER SAMP INTEREST AREAS

One of the points of hosting a workshop like this is to identify overlapping interests among different industry and research sectors, and SAMP was no exception. Several participants had specific interests in aspects of battery technology for healthcare and medical device technology. We have not detailed these here, as they led to a different set of discussions that will be reported in future articles. Nevertheless, there is an increasing convergence between medical and home health-care applications, and there is a growing realization that many consumer technologies can be repurposed to suit medical and personal care services. I expect that we'll have a special issue on this topic during 2015. If your are interested to champion such a special issue, please get in touch!

Another interesting application area was that of electronic cigarettes, where the latest vaporization technologies have power requirements that are closely aligned with those of mobile devices. And in the United States, the recent legalization of marijuana has led to a parallel and rapidly growing market for handheld vaporization units. One of our delegates, Richard Pruen from the United Kingdom, is a specialist in designing and testing battery systems for these emerging markets. Pruen had some very entertaining, and occasionally cautionary, tales surrounding the power encapsulated in the latest battery technologies. Again, this field represents a topic that deserves separate coverage in a dedicated article. I expect we'll see such a contribution, as these technologies definitely fall within the field of interest of our Society.

## SAMP—CURRENT SCOPE AND FUTURE ACTIVITIES

In our final round-up session, the SAMP delegates decided to expand the workshop discussion to cover activities for the next year. It was clear that there is sufficient broad interest in this topic across different sectors that relate to CE technology, and it is a workshop that appeals to niche interests in Europe, as well as in the United States. It is also a new technology direction that would be suitable to propose through IEEE Future Directions as the basis for a new IEEE initiative.

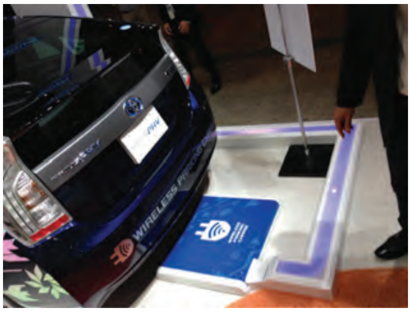


**FIGURE 15.** An example of Toyota's magnetic resonance. (Photo courtesy of Toyota Motors Inc.)

**FIGURE 16.** A WiTricity wireless power demonstration.

One idea that was discussed is to have a student competition at the 2016 ICCE conference on designs targeting the SAMP objectives. These will be available via Tom Coughlin's SAMP proposal to the IEEE in early 2015. Coughlin has introduced a proposal to the IEEE Future Directions Committee to provide up to US$15,000 to fund prizes for this competition. The IEEE CE Society has also provided funding to the CE Society Future Directions Committee and this could be used for planning and promoting this competition.

There was also interest in staging another one of these Ireland meetings. Peter Corcoran suggested a possible partnership with a larger conference in Dublin. This would make it easier to attract participants, as Dublin is easier to get to than Galway. (Although, as was pointed out by several delegates, the size of the SAMP workshop was ideal to allow good discussion and interaction; too many participants could lead to loss of individual engagement with the workshop.)

We will promote these plans more widely in 2015 after submitting for budgetary support for this work to continue in the 2015–2016 time frame.

## REFERENCE

[1] I. Akbar, "Power from the void?: How Steve Perlmans revolutionary wireless technology works and why it is a bigger deal than anyone realizes," *IEEE Consumer Electron. Mag.*, vol. 3, no. 3, pp. 36–43, 2014.

—Peter Corcoran and
Tom Coughlin

## SAMP PARTICIPANTS LISTING

### IN-PERSON PARTICIPANTS

Reginald Little

**Reginald Little** is the engineering lead at Iris Technology Corporation. He has more than 12 years of experience working as a hardware/software engineer as a civilian in the naval weapons industry and television industry. Before working as a civilian, Reggie spent nine years in the U.S. Navy and earned the rank E-7, Electronics Technician Chief, Surface Warfare. Reggie obtained a bachelor's degree from Chapman University in computer science and an embedded systems engineering certificate at the University of California, Irvine. He has extensive experience in designing high-energy density power system for industrial and military applications.

Prof. Erol Gelenbe

**Prof. Erol Gelenbe**, a Fellow of the IEEE, the Association of Computing Machines, and the Institution of Engineering and Technology (United Kingdom), is a professor of electrical and electronic engineering at Imperial College London. He currently works on the interaction between energy consumption and quality of service in ICT, and on the security of mobile networks. His funded projects include EPSRC ECROPS (2013–2016) on Energy Savings and Harvesting in ICT, a MoD/DSTL Project on Energy Savings in Digital Cities (2012–2016), EU FP7 PANACEA (2013–2016) on Self-Organizing Cloud Computing, and the Smart Networks at the Edge project of the European Institute of Technology. A Distinguished Lecturer (DL) of the IEEE Communication Society, his recent publications can be found at http://san.ee.ic.ac.uk and http://sa.ee.ic.ac.uk.

**Prof. Dónal Leech** received a first-class honors B.Sc. in analytical science from the then National Institute for Higher Education, Dublin (now Dublin City University) in 1988. He joined the National University of Ireland, Galway, in 1997. His research and teaching interests focus on bioanalytical chemistry and electrochemistry, with an emphasis on bioelectrochemical electron transfer reactions an their applications in developing electrochemical devices for sensing and electricity generation. He provides insights into current fuel cell technologies and their potential to act as power sources for mobile devices.

William Lumpkins

**William Lumpkins** is an innovative results-driven technical problem-solving professional with over 20 years of experience designing circuit boards related to telecommunications, defense, and consumer electronic markets, both in the United States and Japan. He is a strategic engineering and business leader in systems, software, program management, silicon, and wireless product development. He is currently a DL with the IEEE RFID Technical Council and an active IEEE volunteer. He provides expertise on the practicalities of energy harvesting technologies and their potential incorporation into mobile device products and smartphone systems.

Dr. Petronel Bigioi

**Dr. Petronel Bigioi** is senior vice president of engineering and general manager of FotoNation, a business unit of Tessera Technologies, Inc. In this role, he leads the engineering team in developing image processing solutions to address various problems in the digital still camera, mobile phone, and other related markets. He is a Senior Member of the IEEE with more than 15 years of experience in the digital still camera and mobile phone industries, working in both image processing and connectivity.

In this workshop he presents energy savings that can be achieved in the imaging subsystems of mobile devices and the relationship to total mobile budget of these devices.

**Dr. Anders S.G. Andrae** received his Ph.D. degree in electronics production from Chalmers University of Technology, Gothenburg, Sweden, in 2005. Between 2009 and 2011, he was the editor of the European Telecommunications Standards Institute's first life-cycle analysis (LCA) standard for information and communication technology. In ITU, he also works on the development of ecorating for mobile devices. He is currently at Huawei Technologies in Sweden as senior expert of energy efficiency, emission reduction, ecodesign and sustainability, and LCA. He will contribute particular expertise on LCA implications of new approaches to mobile power for smartphones.

**Murlin Marks** has worked at Underwriters Laboratories (UL) for over 30 years, both as an active engineer and manager on safety evaluations of a wide range of products. He is a founding board member of the IEEE Product Safety Engineering society and served as its president from 2010 to 2011. He provides extensive


Murlin Marks

safety expertise, knowledge of engineering standardization process, and the benefits of his extensive experience at UL in applying hazard-based safety engineering to cover multiple power sources and operating environments encountered in the mobile industry.


Dr. Ian Matthews

**Dr. Ian Matthews** is a member of technical staff at Bell Labs in the Efficient Energy Transfer Department, Ireland. His current research focuses on energy-efficient telecommunications including thermally integrated photonics solutions, energy harvesting for IoT applications, and high-efficiency solar cells. He completed his Ph.D. (2014) on InP-based solar cells at the Tyndall National Institute, University College Cork, Ireland, where he also received his B.Eng. (Hons) in civil and environmental engineering. He has an M.Sc. (with distinction) in renewable energy systems technology from Loughborough University, United Kingdom. He has published seven journal papers, four conference proceedings, 21 conference presentations, is the author of one book chapter, and has two patents pending. He is a Member of the IEEE.


Peter Corcoran

**Peter Corcoran** has been a faculty member at NUI Galway for 25 years. He is an IEEE Fellow with more than 250 technical publications and a prolific inventor. His research interests include smart grid, cloud computing, and their interactions with CE devices. He is editor-in-chief of *IEEE Consumer Electronics Magazine*. He is the cofounder of several start-up companies. In addition to his academic career he is also an active consultant and expert witness.


Lee Stogner

**Lee Stogner** is the managing principal of the Vincula Group, a consultancy that supports the business development and project management of high-tech companies. He has over 30 years of design, consulting, project management, and business development experience across a range of industries. He has driven growth at companies that include Digital Equipment, Fluor Corporation, and Rockwell International. He is chair of the South Carolina Engineering Cluster and was the 2010–2011 IEEE Region 3 director. He is developing an international program that will organize and promote the engineering industry of South Carolina.


Tom Coughlin

**Tom Coughlin** is president of Coughlin Associates and vice president of Future Directions for the IEEE Consumer Electronics Society. He has worked for over 30 years in the digital storage industry before becoming a consultant. He has written several reports on digital storage and applications, organized conferences such as Storage Visions and Creative Storage, and has been the general chair of the Flash Memory Summit. He has six patents, numerous articles and papers, and is the author of *Digital Storage in Consumer Electronics.* He is also director for IEEE Region 6, was VP of operations for the CE Society, and is a senior editor for *IEEE Consumer Electronics Magazine.*


Philip A.
Catherwood

**Philip A. Catherwood** is a lecturer at the School of Engineering at the University of Ulster. He has worked in industry for 11 years developing expertise in bespoke scientific measurement equipment, RF telemetry, and high-speed optical communications devices. He won two prestigious industrial recognition awards from NortelNetworks for delivering excellence in Telecoms Engineering. He was appointed lecturer at the University of Ulster in 2014 with research interests in body-wearable wireless medical devices, indoor radio channel modeling, and connected health systems. He is a member of the Engineering Research Institute at the Nanotech and Integrated Bioengineering Centre.

## REMOTE PARTICIPANTS


Joe Decuir

**Joe Decuir** is a technical leader and contributor in connectivity technologies, especially for devices that are small but plentiful. He works on short range: house scale, but longer ranges (WLAN, WWAN, and TV whitespaces) are interesting, too. He is Internet WG chair at Bluetooth SIG and a standards architect and evalgelist at Camerbridge Silicon Radio for the latest generation of Bluetooth technologies. He is knowledgable about the power and energy profiles of the latest generation of connectivity technologies and provides a link into the Bluetooth SIG.


Christopher
Frangione

**Christopher Frangione** is the vice president of prize development at the XPRIZE Foundation, the world's leader in designing and managing large incentivized prize competitions that motivate and inspire brilliant innovators from all disciplines to leverage their intellectual and financial capital for the benefit of humanity. He has leadership experience across all sectors of the energy industry. At Green Mountain Energy Company, he managed a regional market and defined new business opportunities, policies, and strategies for the retail renewable energy company. Frangione consistently seeks out entrepreneurial opportunities and has founded several organizations and helped others expand into new markets.

**Anna Stukas** is the manager of intellectual property and regulations at BiC. Her responsibilities at BiC include patent portfolio management, technology licensing, standards development, and creation of international regulations for micro fuel cells for


Anna Stukas

portable power applications. She has been instrumental in the creation of international regulations that allow the carriage of fuel-cell-powered portable devices on passenger aircraft and has represented the fuel cell industry to the United Nations and the International Civil Aviation Organization. She received her bachelor's degree in mechanical engineering (co-op, with distinction) from the University of Victoria.

**Avery Lu** is involved in business development for Silicon Valley startups, especially in wearable technology. He has had design, support, and management positions at Xilinx, Viewlogic Systems, Cypress Semiconductor, American Microsystems, Winbond Electronics, and Toshiba American Electronic Components. He is currently a board member of the Chinese American Semiconductor Professional Association.


Joseph Wei

**Joseph Wei** is the CEO of SJW Consulting Inc., which he founded in 2009 after a long career in executive positions for several large global computer companies (Inventec, SGI, NEC, and DEC). He has over 25 years experience in managing product marketing, business development, and engineering functions and was responsible for growing some businesses to over US$500 million in revenue. He is the U.S. partner for Wearable Technologies, Inc., driving strategic partnerships and business development. He is also on the advisory board for several companies.


Dr. Yu Yuan

**Dr. Yu Yuan** is a veteran researcher and practitioner in the areas of transportation, consumer electronics, and the Internet of Things. Currently, he is serving as the president of Cate Global, a multinational think tank focusing on bringing world-class expertise to clients and projects in China, and the CEO of Motiveware Technology Co., Ltd. Previously, he had been working on the Strategy, Ecosystem and Partnership for IBM Research—China and was also a key contributor to the IBM IoT Technology Center. He has filed numerous patents and received many IBM Invention Achievement awards and IBM High Value Patent awards.


Soumya Kanti

**Soumya Kanti** is working on power optimization in smart mobile devices at EURECOM in France. He also works on cross-platform mobile application development. He is involved in various applications with the IoT including e-health services and connecting sensors to a server to make a Manifest Internet of Things. He is active in the IoT Committee of the IEEE CE Society Future Directions Initiative.

**Joe Ziomek** provides consulting to potential new and current automotive suppliers in systems engineering, electrical and electronics, materials, structural composites, marketing, and business development technology forecasting and planning. He is also an expert witness services on vehicular electronics.

# CE Society Steps Boldly to the West (of Ireland)

## *Public Talks Given by IEEE Distinguished Lecturers in the West of Ireland*

Early in December 2014, a group of IEEE experts convened in Galway, Ireland, to discuss the future roadmap for "Safe Advanced Mobile Power" (SAMP) for our handheld devices. As we had such a distinguished group of speakers in the west of Ireland, it made sense to have a number of public talks to promote IEEE Future Directions and the CE Society. Our first series of talks was at the Limerick Institute of Technology (LIT), so I thought it might be interesting to give you a bit of a background on Limerick City and its history and current state following the 2008 implosion of the Irish economy.

### LIMERICK CITY [1]

Limerick is situated in the midwest of Ireland, below County Clare—the site of the world-famous Cliffs of Moher. The city features a well-preserved historic core located on King's Island. This island is actually bounded by the Shannon river—an important aspect of older Irish settlements, as it provided protection from invading armies. The main city is at the head of the Shannon estuary, the largest in Ireland. Limerick is the most populous city in the Midwest, with more than 100,000 people, and has seen significant infrastructural development over the last two decades. It is now directly connected with Dublin and Cork by modern freeways and a freeway link to Galway—about 70 mi to the north is largely completed. Ironically, the train service form Limerick to Galway takes nearly 2.5 h to travel this short distance, which harkens back to the 18th and 19th centuries when narrow-gauge railway was the primary mode of transport in this underdeveloped region of Ireland.

The city charter dates from the 9th century, and there was an established

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