The "Future of Instrumentation" Workshop Report

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What is the future of instrumentation? It is an absurdly open-ended but interesting question to explore in this age of ubiquitous sensing and wireless devices and the slow but steady realization of the "Internet of Things." At the U.S. Department of Energy's (DOE) Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee, we research and develop sensors and instrumentation for a wide variety of energy-related applications impacting energy exploration, energy delivery, and environmental monitoring (Fig. 1). To support research into these challenging measurement problems, the Measurement Science and Systems Engineering Division at ORNL initiated The Future of Instrumentation Workshop in 2010 in collaboration with the IEEE Instrumentation and Measurement Society (IMS) to reach out to the measurement community and pose this open-ended question.

The first two years of this meeting were in 2010 and 2011 and they were held at ORNL in East Tennessee. They included tours of some of ORNL's national user facilities and unique laboratories, thereby introducing many in the research community to our renewed campus and energy research mission. These workshops brought together industry, academia, U.S. national laboratories, and U.S. federal agencies and provided a unique environment for open and frank discussion on research directions and the merits (e.g., scientific, engineering, or financial) of employing different technologies to achieve practical ends.

While the attendance of around 100 participants for each of the first two years was encouraging, we wanted to create a venue that would reach beyond the impression of this being an "ORNL" event. Consequently, we moved the Future

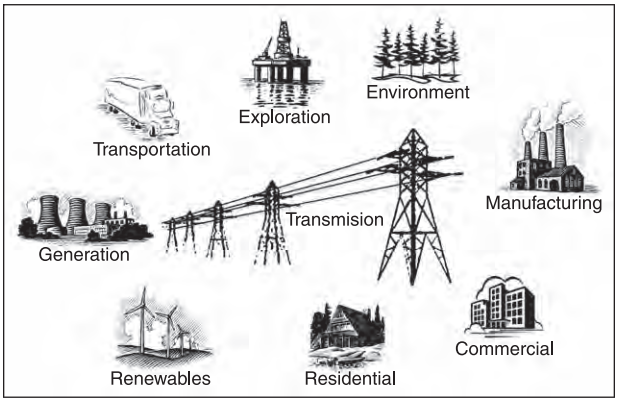

Fig. 1. Sensing, instrumentation, communications, and controls form ubiquitous elements and wide networks of energy management and control. These systems extend from energy exploration, delivery, and utilization to environmental monitoring. Many of these areas require cross-communication and intelligence at the sensing node.

Fig. 2. The Workshop logo from 2012.

of Instrumentation International Workshop (FIIW 2012) to Gatlinburg, Tennessee in October of 2012 (Fig. 2). The Workshop succeeded in attracting a broader range of participants from outside the U.S. DOE national laboratory community.

FIIW 2012 focused specifically on sensing and instrumentation needs in the energy value chain. Experts in technical areas including sensors, communications, and controls gathered to discuss power generation from both fossil fuels and nuclear energy. Separate technical tracks looked at energy transmission and distribution at large scale and in microgrids. Presentations and discussions focused on end-use energy sensing in manufacturing, commercial buildings, and in demand response systems. In addition, we had a cross-cutting area related to advanced instrumentation, including topics such as energy harvesting, wireless sensor networks, and resilient and trustworthy control systems in extreme environments. Over 40 technical papers were delivered during the two day workshop and two panel sessions dedicated to the role of sensors for building-to-grid integration and the deployment of wireless sensor networks for industrial energy efficiency. To drive the topical discussions in these areas, we had sponsors from several program offices within the U.S. DOE's Office of Energy Efficiency and Renewable Energy, Office of Electricity Delivery and Energy Reliability, and Office of Nuclear Energy. The National Energy Technology Laboratory and large industrial and automation companies Invensys Operations Management, Inc., and Mars, Inc. also provided financial, technical, and organizational support.

The workshop format has provided ample time for audience participation and discussion. In each workshop, we have discussed the value of creating a sensors and instrumentation roadmap that will highlight the key research areas that are necessary to achieve impact in energy efficiency through advances in communications and controls. Fig. 3 is a stylized representation of the general observations that have resulted from these annual discussions.

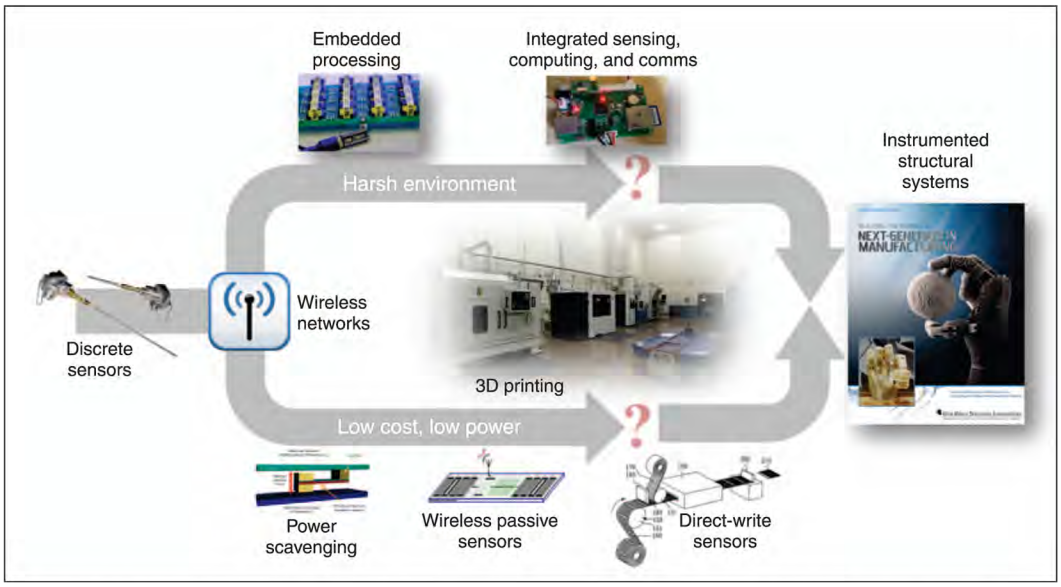

Fig. 3. The roadmap for instrumentation research and development bifurcates between high-performance embedded intelligence (top) and low-cost, low-power applications (bottom). Could 3D printing help bring some of these elements together into smarter structures?

Discrete sensors and instruments have been the mainstay of industry for many years. Their associated communications, albeit automated, were and still are frequently simple observe-and-report methods or sensors wired to control systems. FIIW 2012 discussions amplified the general consensus that with the advent and integration of robust industrial wireless communications standards and devices, it is now technically feasible, cost effective, and financially advantageous to create sensor systems that can be retrofitted into many types of complex measurement environments.

There are two general directions that we are observing today. First, sensors are being employed in harsh environments that require robustness and reliability (e.g., oil exploration, nuclear power industry, environmental monitoring, etc.). These systems are using sensors with onboard computing (e.g., FPGA, DSP, GPU, CPU) coupled with wireless communications capabilities. Power is still an issue with these systems and often difficult to provide or maintain. Meanwhile embedded computing improvements have proceeded to the point where a million instruction cycles may occur within the instrument for the same amount of power consumption as transmitting a single bit via wireless. (For further information on this topic, please visit http://trustworthywireless.ornl.gov.) The net result is that computation takes place on the device resulting in the efficient output of compressed information versus fundamental data.

Second, an alternate path that is emerging includes the development of potentially low-cost, low-power devices that may scavenge power from their environment (e.g., thermal, vibration, wind, solar, etc.). A significant FIIW 2012 discussion topic was the feasibility of using passive wireless sensor tag technologies whereby no batteries are used and the device remains "dormant" until externally interrogated with an RF signal.

FIIW 2012 also broke from the "strictly sensors & instrumentation" mold by examining the extremely important instrumentation integration trends associated with industrial-grade additive manufacturing (i.e., 3D printers). As this technology continues to evolve at a very rapid pace, it is anticipated that significant and rapid advances in both structural and functional printing capabilities will result in the creation of instrumented structural systems that contain hydraulics, pneumatics, electronics, communications, and printable sensing elements to measure temperature, pressure, vibration, stress, and a host of other physical properties. These will be truly intelligent structures that are not producible by any other means known today. These are the topics that make FIIW unique.

In 2013, we will transition the workshop into an international conference, representing a significant shift in the reach, audience, and administration of the annual event. Our goal is to expand the availability and influence of FIIW to an international audience and provide greater involvement from the IEEE IMS community. The focus of the conference will be advanced sensors and instrumentation in extreme environments. We plan to expand the participation of major industrial partners, companies, and U.S. government agencies to include a broader worldwide participation that includes international governmental laboratories, agencies, and research programs. We will also expand the opportunities for paper and poster presentations, panel discussions, speakers and distinguished lecturers, and tutorials. Join us in Orlando, Florida, in November 2013 for an unforgettable and thought-provoking conference!