MEETING RECAP

SENSORS: FROM SEA TO SPACE INNOVATIONS AND IMPLICATIONS FOR THE FUTURE

Government-University-Industry Research Roundtable

February 22-23, 2010

This meeting recap was prepared by National Academies' staff as an informal record of issues discussed during public sessions of the February 22-23, 2010 meeting of the Government-University-Industry Research Roundtable (GUIRR). The document is for information purposes only and supplements the meeting agenda available online at www.nas.edu/guirr. It has not been reviewed and should not be cited or quoted, as the views expressed do not necessarily reflect the views of the National Academies or members of GUIRR.

From environmental, industrial, and biomedical applications to advances in aerospace technology, computing power, and biotechnology, sensors impact almost every aspect of our everyday life. With the advent of emerging healthcare technologies, sensors are changing medicine as we know it today, raising questions on affordability and cradle to grave care. In Earth Observation Science, Global Change Monitoring Systems (GCMS) create important, new opportunities for industry, academia, and the scientific community to work together in understanding the complexities of global warming. In other areas, many electrical, optical, biological and biochemical sensors have broader, secondary applications that have potential uses that are not yet fully recognized.

What are the political and economic considerations, challenges, and opportunities in the global sensor market? How can GUIRR members develop innovative concepts for earth-sensing, including new platform opportunities and new instrument architectures and technology? What can GUIRR members do to facilitate competitive R&D programs for rollout of new sensor technology into potentially commercially viable applications that create jobs and future economic prosperity? GUIRR members met in Washington, DC on February 22-23, 2010, to explore these questions and others pertaining to our growing reliance on sensors and sensor networks.

THE NATIONAL ACADEMIES
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Dr. David A. Honey, the new – as of August 31, 2009 – Director for Research, Office of the Director, Defense Research and Engineering (DDR&E), U.S. Department of Defense (DoD), opened the spring 2010 GUIRR meeting with a keynote dinner address titled "DDR&E S&T Strategy." The Research Directorate has policy and oversight responsibility for DoD programs in basic research, applied research, advanced development, and advanced components and prototypes. Dr. Honey provided an overview of the Directorate's organizational structure and budget, noting three broad areas of direction as specified by Secretary Gates: innovation, speed, and agility. Counter-insurgency warfare has changed significantly from conventional warfare, he stated – largely because the timeline has collapsed. The DoD has thus needed to accelerate the delivery of capabilities; indeed, the time from concept to capability is now from 6-12 months. Sensor networks are proving useful in addressing numerous challenges such as environmental pollution of military sites, achieving bandwidth reduction, better understanding dismount intent, sensor system employment concepts, and other uses.

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The meeting opened the next morning, Tuesday, February 23, with a presentation titled "Functionalities and Developments in Sensor Networks" delivered jointly by two representatives from Northrop Grumman Aerospace Systems. **Mr. Leonard Poveromo**, Director, Technology Development, began by providing a broad stroke overview of Northrop Grumman and its business pursuits and priorities. Once merely a combat aircraft company, Northrop Grumman is now a systems integrator with a broad portfolio supporting defense transformation.

Dr. Robert Silberstein, Tech Fellow, Advanced Programs and Technology Division, followed with details of Northrop Grumman's current work with sensors for use in sky, ground, and space systems. He first described sensors for aircraft, reviewing the company's Structural Integrity Prognosis System (SIPS) that involves sensor placement on the wing panel so as to detect earliest incipient material damage. Sensor systems are used for real-time crack monitoring and structural prognosis during full-scale fatigue tests. He further spoke of novel ground sensors, notably infrasound, as well as emerging platforms (i.e., unmanned aerial vehicles – UAVs) that are proving to be versatile, of less risk and cost, collaborative, effective, and efficient. Silberstein continued with a description of new airborne sensors known as LIDAR that are important for mapping and topographic details *("Think of it as a cell tower in the sky, connecting everybody…."),* followed by examples of air and space remote sensing (hyperspectral airborne tactical instrument, HATI), and sensor systems for homeland security (chemical and biological sensor detection systems and technology; WMD sensor detection and prediction, intelligent synthesized sensor and network systems integration). Calibration is a big theme for all these sensors and systems, he noted. He completed his overview by providing a glimpse into future technologies such as wireless power, with applications in both ground and space that could lead to individual space power systems.

Presenters Silberstein and Poveromo closed by summarizing technological advancements over time ("18th and 19th century chemistry gave us the energetic materials of World War I; 19th and 20th century physics gave us nuclear weapons") and pitched a thought-provoking question to the group: *What happens when 21st century computing power, "bio", "nano", and photonics converge*? One can speculate – but only time will tell.

Next to speak was **Dr. William Heetderks**, Associate Director for Science Programs, National Institute for Biomedical Imaging and Bioengineering (NIBIB), National Institutes of Health (NIH), who addressed "Sensors and Systems: Essential Ingredients in Transforming Health Care." The NIBIB is a relatively new Institute, established in 2000 and focused on integrating physical and engineering sciences with the life sciences to advance basic research and medical care.

Sensors and systems will be increasingly important in developing high quality, efficient healthcare as the chronic disease burden increases, stated Heetderks. Sensor systems must be designed for the environment and will be impactful in home health, point of care health, and in traditional hospital settings. Sensors are currently being used for screening and surveillance; disease monitoring, diagnostics, state change, and response to therapy; closed-loop control of therapy; and "theragnostics."

An example of the potential role of sensor technology in home health care is the wearable-sensor system for monitoring motor function, he noted, which can help determine medication state in Parkinson's patients. Additionally, for dietary intake monitoring applications, sensors serve to monitor fluid and electrolyte intake in home dialysis end-stage renal disease patients. Biological sensors are being used for point of care systems (e.g., uropathogen detection using DNA biosensors; microchips to detect influenza infection and type), while customized, fully implantable sensors (closed-loop systems) are being used for various clinical purposes, including spinal cord injuries. Finally, nanosensors that combine sensing and therapy hold significant promise for the merging of diagnostics and therapeutic functions (theragnostics). There has been an increase in research using biomarkers to discover what it is that we need to be sensing.

Dr. Peter Hartwell, Senior Researcher, Hewlett-Packard (HP) Laboratories, followed with a presentation titled

"CeNSE: The Central Nervous System of the Earth." "Sensors," Hartwell began, "will impact human interaction with the earth as profoundly as the Internet has revolutionized communication." He went on to exclaim: "This is the next big thing!"

Sensing can be viewed as "nodes to network to analysis to action", providing us with loads of data that translate into valuable information. We are increasingly reliant upon sensors, Hartwell noted, for safety (e.g., infrastructure, disaster prevention, food safety, automobiles, chemical detection, healthcare monitoring), sustainability (e.g., energy conservation and management of water, traffic, energy, waste, and agriculture), and security (e.g., intrusion detection, location awareness, financial authentication, transportation security, asset tracking, smart intrusion detection). The ubiquity of sensors is certain to have a huge impact on society – and Hewlett-Packard, with its core node technology, node system integration and networking capabilities, and expertise in turning data into information is striving to be the corporate leader in service creation (develop, deploy, collect, analyze) with its CeNSE program. HP's first strategic CeNSE partnership is with Shell Oil, focusing on efficiency of extraction.

Discussion then shifted to sensors and national security, with **Dr. Donald Reago**, U.S. Army Communication and Electronic Research Development Engineering Center (CERDEC), Night Vision and Electronic Sensors Directorate (NVESD) describing some recent initiatives that combine efforts of the National Labs, Federally Funded Research and Development Centers (FFRDCs), universities, and industry to solve problems critical to the Army and Department of Defense. Two examples were highlighted: IED detection sensors and infrared focal plane arrays. Reago suggested several areas where better partnerships might help to foster innovation and preserve U.S. industrial advantage, including encouraging more long-term funded university research that is tied to problems of interest. "Our experience," he said, "is that deliberate relationships between universities, government labs, industry and FFRDCs can enhance the sensor technology developed for DoD."

Dr. Arshad Mansoor, Vice President, Power Delivery, for the Electric Power Research Institute (EPRI), next took the stage with a presentation titled "Next Generation Sensors: Power Industry." Mansoor began by reciting some power sector facts; he then emphasized that, just like with other industries, sensors will play a key role in the energy sector – and the power grid. Next generation grid management systems serve as one example of a future sensor need for the Smart(er) Grid. Whereas operating today's grid involves balancing forecastable demand-side resources with dispatchable power generation, Mansoor noted, tomorrow's grid will require the balancing of unpredictable demand-side resources with variable power generation. Sensors will be a part of operating system innovation. Managing an aging infrastructure will also call for the adoption of sensor technology. Mansoor closed by itemizing the power sector's unique needs with respect to sensor technologies: low cost and low maintenance, more reliability, wide geographic coverage, power harvesting, and capable of functioning in high electrical and magnetic fields and uncontrolled environments. "We will soon be blinded by sensor data," he said.

Following Mansoor was **Mr. Frank Pasquale**, Loftus Professor of Law, Seton Hall University School of Law, who spoke about an issue of considerable significance across all sectors, namely: sensor networks and privacy. Pasquale reiterated that which his fellow presenters also stated: "Sensor networks are set to become a truly pervasive technology that will affect our daily lives in important ways." He added: "Cheap, smart devices with multiple onboard sensors, networked through wireless links and the Internet and deployed in large numbers, provide unprecedented opportunities for instrumenting and controlling homes, cities, and the environment."

Applications are readily emerging that draw on sensed information about people, objects and physical spaces. That being the case, Pasquale encouraged GUIRR members to remain fully cognizant of how widely censored (with a "c") data is shared. Among other things, data from a variety of sources and locations are collected and processed to reveal patterns that were previously invisible. Three categories of shared data were identified: personal (e.g., medical monitoring), social (e.g., social networking sites such as Facebook and MySpace), and urban (e.g., mobile phones, cyberspace, shopping). Pasquale also identified data collectors ("sources" – users of the data): public, retail, telecommunications and mobile, financial and insurance, medical, and, of course, the Internet, as well as the myriad "data brokers" (credit bureaus, catalog coops, healthcare analytics, etc.) that get into the mix.

It is clear that sensor networks pose security and privacy challenges that will require new technological solutions. These networks also make clear the need for greater legal protections. Pasquale reported that a patchwork of privacy laws already pertains to various aspects of urban sensing; however, gaps exist. In the U.S. and Europe, fair information practices are one standard for protecting the privacy of personal data, although the principles are no longer enough. Finally, in the international legal arena, the OECD and the EU are grappling with these same issues of privacy and data protection.

Formal presentations were capped with a fascinating luncheon address by **Dr. Michael R. Nelson**, Visiting Professor, Internet Studies, Communication, Culture and Technology, Georgetown University, titled: "The Cloud, the Internet of Things, and the Exaflood."

Nelson asserted that, in Washington (DC), "words matter." "The right words," he added, "can: define an issue, kill a project, stir emotions, and mobilize people." Additionally, for policymaking and otherwise, numbers (hundreds of pages of data, plus two, good, memorable "factoids") and stories (personal anecdotes) matter.

Nelson proceeded to share a few key words and concepts about the Internet of 2020 that underscored the pervasiveness of devices connecting to the Internet and the flood of new data from sensors (predominantly) and other sources. In terms of capability, Nelson called *collaboration*, achieved through Cloud computing (Internet-based computing, whereby shared resources, software and information are provided to computers and other devices on-demand, like a public utility), the third phase of the Internet, preceded by *content* (phase 2: the Web) and *communicating* (phase 1: stand-alone computer). Cloud computing, said Nelson, "is a VERY big deal."

The promise of massive amounts of data and metadata raises a number of critical questions, for example:

- How will you build trust in the Cloud?
- How will you improve security?
- How will you create a market for security and privacy?
- How will you convince people to share more of their personal data?

The questions prompted open dialogue but with no definitive answers. Nelson put forth two predictions: (1) Within 5-10 years, 80% of all computing and storage done worldwide could happen "in the Cloud", and (2) Within 5-10 years, 100 BILLION devices and sensors will be connected to the Net.

Nelson wrapped up by highlighting government's first challenge -- determining how to be an early adopter of new technologies (such as Cloud computing, social media, and sensors) – and he suggested policies in need of updating. The Internet Revolution is less than 15% complete, Nelson concluded, and it will be as disruptive as the printing press, but much faster, totally global, and more unpredictable. "The sky's the limit!"

The February 2010 GUIRR meeting concluded with an open discussion about the ubiquity of sensors and sensor networks across many disciplines, and areas where the three sectors (G-U-I) might collaborate in addressing the issues and challenges around data collection and management, privacy, and computer security. The group also discussed ways to facilitate competitive R&D programs for rollout of new sensor technology into commercially viable applications that create jobs and future economic prosperity.

ABOUT GUIRR

MISSION

GUIRR's formal mission, revised in 1995, is "to convene senior-most representatives from government, universities, and industry to define and explore critical issues related to the national and global science and technology agenda that are of shared interest; to frame the next critical question stemming from current debate and analysis; and to incubate activities of on-going value to the stakeholders. This forum will be designed to facilitate candid dialogue among participants, to foster self-implementing activities, and, where appropriate, to carry awareness of consequences to the wider public."

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