OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Overview of the Measurement Science and Systems Engineering Division

Bringing the Science and Engineering of Electronics, Sensors, and Systems to the Nation

Purpose: The MSSE Division was formed to perform research and development in measurement science associated with electronics; sensors; signals; patterns; informatics; communications; and the development of unique, integrated systems.

Sponsors: We provide applied scientific and engineering R&D for DOE, other federal and international agencies, and U.S. industry.

Features: More than 130 research and support staff with degrees in the engineering and physical sciences working in

- Analog and digital electronics.
- Signal and image analysis.
- RF and microwave systems.
- Nanostystems and sensors.
- Robotics and energetic systems.
- Dynamic systems.
- Systems integration and engineering.

Research Facilities: Currently maintain more than 45,000 ft² of laboratory space including 5,658 ft² of clean room facilities.

- MEMS, NEMS, radiation, and other sensor modalities.
- Electronic device development and testing.
- Microscopy development.
- Environmental testing and analysis.

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The Measurement Science and Systems Engineering (MSSE) Division was formed at the Oak Ridge National Laboratory (ORNL) in March of 2008. Although the division is relatively new, our resources, including the talent, expertise, and capabilities of our staff, encompass more than 60 years of electronics, instrumentation, controls, and systems research and development (R&D) at ORNL. Today, we provide a unique blend of applied science and engineering in measurement, sensing, signals, communications, robotics, and integrated systems that helps bridge the gap between basic research and the practical implementation of new technologies. These technologies address our research portfolio in the areas of

- Energy research.
- National security.
- Biomedical engineering.
- U.S. competitiveness.
- Basic science.

Capabilities

The division's 130 research, technical, and administrative staff members are organized into nine technology-focused groups that specialize in R&D related to the creation, testing, integration, and application of science and technology (S&T) that support measurements and the consumption of measurements using appropriate modes of sensing at various spatial and temporal scales in a wide variety of physical environments:

- Analog and Digital Systems.
- Dynamic Systems.
- Image Science and Machine Vision.
- Monolithic Systems Development.
- Nanosystems and Structures.
- Real-Time Systems.
- RF and Microwave Systems.
- Robotics and Energetic Systems.
- Sensor Science and Technology.

Within the ORNL research environment, MSSE provides an important pathway for the translation of basic science into engineering and technology applications. Our core competencies include capabilities in electronics, photonics, sensors, systems, models, and methods that interface science and engineering to produce technology solutions.

Research Facilities

MSSE maintains more than 45,000 ft² of research laboratories, including 5,658 ft² of clean room facilities (e.g., Fig. 1). These laboratories contain semiconductor production systems, measurement and characterization tools, environmental test equipment, robotics systems, and optical and

Fig. 1. Nanoscience, Engineering, and Technology Laboratory and associated SEM facility.

scanning electron microscopes for both S&T development and materials and device testing.

Partnerships

The MSSE Division works closely with a number of ORNL facilities, research organizations, industries, and universities around the world including the following.

- **The National Security Directorate** (NSD) has a mission to provide federal, state, and local government agencies and departments with the technology and expertise required to support national and homeland security needs. NSD achieves its primary missions by leveraging the science and technology capabilities of organizations like MSSE.
- **A wide variety of Department of Energy (DOE) Programs and Program Offices** impacting energy efficiency and electricity, energy materials, fusion energy science, global security and nonproliferation, nuclear technology, and transportation (see Fig. 2).
- **The Center for Nanophase Materials Sciences** is a collaborative nanoscience user research facility for the synthesis, characterization, theory / modeling / simulation, and design of nanoscale materials.
- **The Spallation Neutron Source** is an accelerator-based neutron source and user facility providing neutron scattering and imaging techniques for studying the structure and dynamics of materials.
- **United States Enrichment Corporation** (USEC), Oak Ridge, Tennessee, is working with ORNL to develop USEC's next-generation uranium enrichment process based on U.S. centrifuge technology (see Fig. 3).

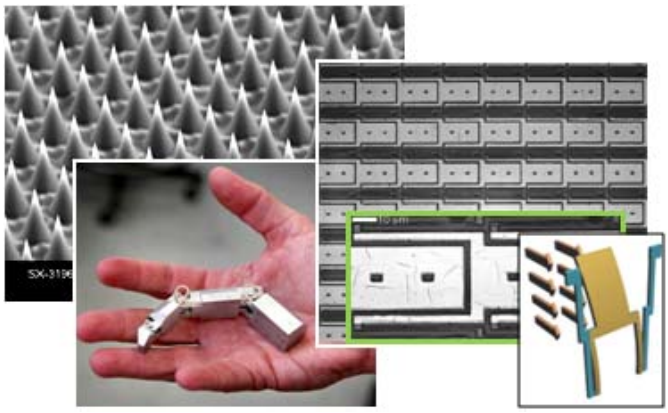

Fig. 2. Examples of functional nanomaterials (left), mesofluidic actuators (middle), and MEMS array (right).

Fig. 3. Centrifuge test stand at the USEC R&D Center in Oak Ridge, Tennessee.

Partnering with MSSE provides collaborative opportunities to pursue programs and projects of various scales that address some of the most challenging science and engineering problems facing the nation today in energy, security, defense, and biomedicine. Through strategic partnerships on a wide range of S&T efforts, MSSE has developed significant experience and abilities that it brings to new partnerships and customers to make the nation and the world energy efficient, safe, and healthy.

Contact Information

For additional information about partnering with the MSSE Division, please contact

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Overview of the Analog and Digital Systems Group

ADS Group: Bridging Technology for World-Class Science

Purpose: The Analog and Digital Systems Group helps give world-class scientists at the Oak Ridge National Laboratory and other government agencies the tools they need to move forward in science and energy research.

Sponsors: Department of Energy and other government agencies.

Group Members:
- Dwight Clayton (Leader)
- Judy Potter (Admin. Support)
- Andy Andrews
- Kim Castleberry
- Mike Hileman
- Don Hurst
- Bruce Jatko
- Roberto Lenarduzzi
- David McMillan
- Carl Sohns
- Brad Stinson
- Christina Ward
- Ken Weaver
- Wes Wysor

Capabilities:
- Analog electronics.
- Digital electronics.
- Programmable logic.
- Low-power systems.
- User interfaces.
- Custom printed circuit boards.

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The Analog and Digital Systems (ADS) Group uses modern electronic methods to bridge the gap between research scientists and solutions to nationally and internationally significant problems. This group specializes in the design of analog, digital, and mixed-signal electronics including complete supporting software from the device driver level to the user interface. Capabilities include printed circuit board design and layout, programmable logic devices, embedded microprocessors, low-power systems, and complete measurement system design and integration. The ADS Group thrives on providing innovative electronic solutions to challenging real-world problems.

Capabilities

- Analog Electronics: Signal conditioning, low-noise high-gain amplifiers, power modules, high-voltage bias supplies, circumvention circuits, etc.
- Digital Electronics: High-speed logic designs, communication bus interfaces, “interfacing” logic, etc.
- Programmable devices: PALs, PLDs, FPGAs, UARTs and DSP cores for FPGAs, microprocessors, VHDL, etc.
- Low-Power Systems: Battery-operated handheld “smart” instruments (B10 Neutron detector, Hot Spotter, Portable Uranium Enrichment Meter, etc.).

Success Story: Block II Chemical Biological Mass Spectrometer

The Block II Chemical Biological Mass Spectrometer (CBMS) is the first integrated system capable of detecting and identifying both chemical and biological warfare agents. It was developed for the U.S. Army Soldier and Biological Chemical Command for missions such as reconnaissance, point detection, and stand-alone deployment. The development team was led by ORNL and included the coordination of five divisions and several outside agencies. CBMS won an R&D 100 Award in 2000 and is currently in production by Hamilton Sundstrand Sensor Systems. Other potential applications include counter-terrorism, civil defense, and health care.

The ADS Group led the electronics development for the CBMS. This radiation-hardened system was designed to withstand rugged battlefield vehicle conditions such as vibration and shock. Key electronics components include the following:

- Embedded Computer System—ADS modified first Pentium to pass radiation tests.
- Three Custom Compact PCI Circuit Boards—data acquisition and control, arbitrary waveform generation, and RF excitation generation and control.

- Low-Noise Analog Detection Electronics—delivers a new level of system sensitivity.
- Soldier Display Subsystem—compact embedded computer enclosure with removable smart media.
- QNX Operating System—ADS-developed device drivers and real time control and sequencing software.

Success Story: Hotspotter Nuclear Detector

The Hotspotter is an inexpensive portable device for detecting the presence of nuclear materials. ADS developed the required robust electronic circuitry for this compact system. It was designed to detect neutron- and gamma-emitting isotopes concealed in packages, vehicles, or on the human body. In addition, it offers the following features:

- Capability to differentiate medical isotopes.
- Capability to detect the presence of fissile material.
- Onboard multichannel analyzer.
- Library of spectra of selected radioisotopes.

Success Story: B10 Detector

The B10 Detector is a miniaturized neutron detector and counting system based on a Boron 10 diode. With a smaller footprint than a standard calculator, it contains the detector, an analog front end, and a low-power embedded microprocessor. Other features include the following:

- Low power for extended battery life.
- Nonvolatile onboard memory.
- Three operating modes.
- RS232 interface for uploading data to PC.

Success Story: Nuclear Material Identification System

The Nuclear Material Identification System (NMIS) was pioneered by ORNL and the Oak Ridge Y-12 Plant to sense the presence of fissile materials inside closed containers. Applications include nuclear materials control and accountability, process plant monitoring and control, nuclear criticality safety applications, nuclear warhead dismantlement, and nuclear arms control treaty verification. The system uses active and / or passive neutron and gamma interrogation to determine the characteristics of containers or devices containing fissile material. It also has the ability to perform active and passive gamma spectrometry. The ADS Group recently developed data acquisition electronics for the NMIS system.

Some features of this system include the following:

- 5 analog input channels.
- Sustained 1.0 GHz sampling.
- Real-time data compression and formatting.
- Commercial off-the-shelf parts to reduce cost.
- Powered by PCI bus to improve portability.
- Field-upgradeable firmware for flexibility.

Contact Information

The ADS Group looks forward to new challenges in adapting the latest in electronic technology to complex scientific measurements.

For more information about what ADS can do for you, please contact Dwight Clayton (claytonda@ornl.gov) at 865-576-8134.

Overview of the Dynamic Systems Group

The Dynamic Systems (DS) Group is an applied research group that works primarily with mechanical systems. DS has extensive experience with rotating machinery applications, where we have performed modeling, simulation, and rotor balancing and developed diagnostic tools for predictive maintenance. These applications require expertise in the areas of system modeling and simulation, signal processing, and data collection and analysis methods. Additional DS expertise includes thermal modeling, nonlinear time series analysis, wavelet analysis, reliability analysis, and the design and performance of unique thermal measurements. DS also maintains a significant mechanical design capability.

U.S. commercial centrifuge enrichment plant.

Science and Technology Focus Areas

- Rotor dynamics and balancing.
- Electrical Signature Analysis.
- Predictive maintenance and diagnostics.
- Mechanical system modeling.
- Signal processing.
- Mechanical design and fabrication support.

Air Force C-141 Fuel Pump Condition Monitoring System.

Facilities and Capabilities

- Dynamic Systems Diagnostics Laboratory.
- Matlab-based rotor dynamics and supercritical rotor balancing codes.
- B&K Pulse vibration data acquisition and analysis system.
- Proficiency in Labview, Matlab, Mathcad, Visual Basic, Fortran, C, and AutoCad.

A History of Tangible Achievements

DS Group members have developed techniques that have solved challenging industrial problems.

- DS developed the algorithms and codes used to balance the gas centrifuges used in the USEC American Centrifuge Project and

Dynamic Systems Group

Group Facts: Many DS Group members worked on the Department of Energy Gas Centrifuge Program in the 1970s and '80s. This experience forms the basis for DS's rotating machinery expertise.

Sponsors: The USEC American Centrifuge Project is DS's largest sponsor. Support areas include thermal modeling, performance modeling, gas testing, rotor dynamic analysis and balancing, and small-article spin testing.

Group Members:
- Brian Damiano (Leader)
- Regina R. Parks (Admin. Support)
- William J. Allington
- David L. Beshears
- Howard Haynes
- Kathy Hylton
- Philip A. Jallouk
- Rick W. Jones
- Larry D. Phillips
- Raymond Tucker
- John Turner
- Don E. Welch

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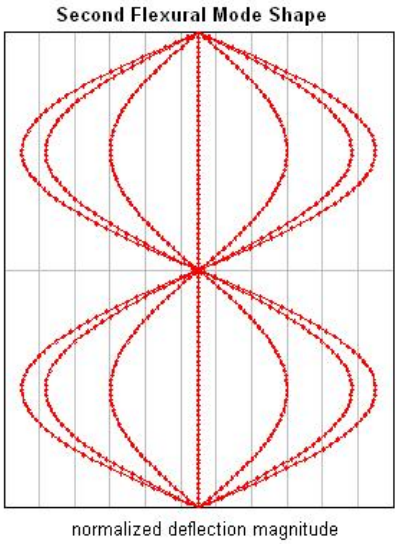
transferred this technology to USEC and its partners. In addition, DS members developed the rotor dynamics codes used to support rotor design and balancing and played a major role in rotor design, suspension design, small article spin testing, performance modeling, thermal modeling, reliability studies, and full machine test design analysis.



Predicted second flexural mode shape.

- DS members pioneered Electrical Signature Analysis (ESA), a method to extract mechanical information from motor or generator electrical measurements without interfering with the actual operation of the equipment.
- Building on its expertise with ESA, the group developed portable briefcase-size units for monitoring fuel pumps and generator bearings in military aircraft, helping to ensure our country's combat readiness and security.
- In the signal processing arena, DS has developed
  - the Enclosed Space Detection System, a wavelet-based system for detecting a person hiding in an enclosed space, such as a vehicle;
  - speaker recognition and voice enhancement techniques; and
  - encryption methods based on nonlinear time series analysis methods.

Contact Information

To learn how you can leverage our group's capabilities to solve your mechanical and systems problems, please contact Brian Damiano (bdz@ornl.gov) at 865-574-5541.

Applied Computer Vision R&D in Biomedical Imaging, Industrial Inspection, and National Security

Image Science and Machine Vision Group

Purpose: The Image Science and Machine Vision Group conducts applied computer vision research and development addressing important issues in industrial and economic competitiveness, biomedical measurement science, and national security.

Sponsors: Government agencies such as the Department of Energy and Bureau of Engraving and Printing, nongovernmental agencies, private companies, universities, and various consortia.

Group Members:
Shaun S. Gleason (Leader)
Janet M. Baucom (Admin. Support)
Deniz Aykac
Phillip R. Bingham
Regina K. Ferrell
Tim F. Gee
Jim S. Goddard
Tom P. Karnowski
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Group Mission and Programs

The Image Science and Machine Vision (ISMV) Group was established in 1987 to develop technologies that provide human-like decision making capabilities for computers and robots. These methods and systems perform image-based metrology, scene analysis and comprehension, and archival image indexing and management. Today we are one of nine research and development (R&D) groups in the Measurement Science and Systems Engineering Division at Oak Ridge National Laboratory.

Base Technology and Experience

The group consists of 15 researchers with electrical engineering, computer science, and nuclear engineering backgrounds. Using strategic partnerships, we conduct applied computer vision R&D that supports U.S. industry, healthcare, and security. Our research encompasses image processing methods that include image modeling, image transforms, dimensional metrology, object and region segmentation, statistical feature analysis, pattern classification, and content-based indexing and retrieval. We apply these methods to three programmatic areas described below.

Biomedical Imaging

- Neuronal morphology and migration research for disease characterization.
- High-resolution tomographic medical imaging (X-ray CT and awake-animal SPECT).
- Content-based image retrieval (CBIR) and data mining for computer-aided medical diagnostics (e.g., ophthalmology, mammography).

Industrial Inspection

- Semiconductor metrology and inspection.
- Manufacturing-based CBIR
- Energy reduction, waste mitigation, and quality control.

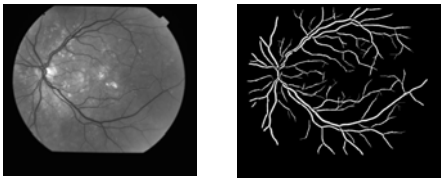
National Security

- Intelligent surveillance.
- Advanced, multimodal biometrics.
- Nuclear materials verification / identification.
- Geographic aerial image analysis.

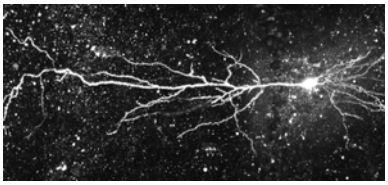
Facilities

Facilities and capabilities include the following:

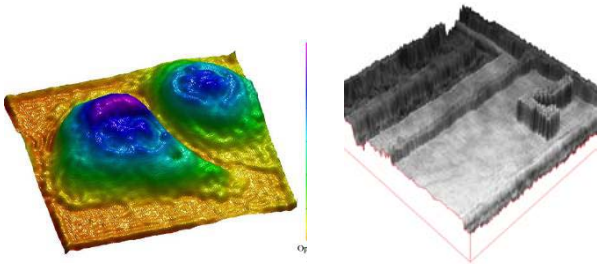
- Digital Holography Microscopy Laboratory.
- Small Animal Imaging Laboratory.
- Oak Ridge Web Test Bed Laboratory.
- Video Analysis Laboratory.



Retinal image analysis for diabetic retinopathy.



Neuronal image analysis.



Digital holography for bio-analysis and semiconductor characterization.

Intelligent surveillance and biometrics: face detection/ID, iris and vein-based ID.

Contact Information

For more information on our research technologies, capabilities, and facilities, please contact Shaun Gleason (gleasonss@ornl.gov) at 865-574-8521.

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Overview of the Monolithic Systems Development Group

Advanced Electronic Devices and Systems

Purpose: The MSD Group bridges the gap between basic and applied research and acts as ORNL's technology and knowledge base in advanced electronic systems, particularly those involved at the interface of biological systems, analog signal processing, and nanostructured materials.

Sponsors: Department of Energy offices, Work for Others agencies, small and large industrial partners.

Complementary ORNL Facilities:
- Nanoscale Science and Technology Laboratory.
- Center for Nanophase Materials Sciences.

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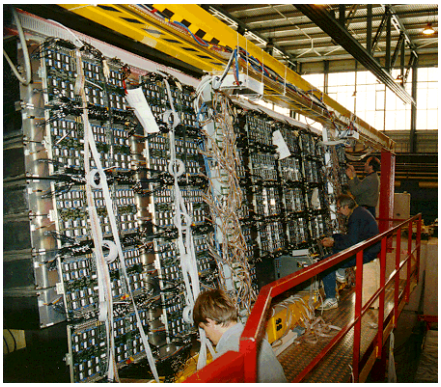
The Monolithic Systems Development (MSD) Group was formed in 1988 to add application-specific integrated circuit design technologies to an already mature analog and digital electronics capability.

The group bridges the gap between basic and applied research and acts as Oak Ridge National Laboratory's (ORNL's) technology and knowledge base in advanced electronic systems, particularly those involved at the interface of biological systems, analog signal processing, and nanostructured materials. This is accomplished by continually assembling and nurturing a research team that is competent, innovative, collaborative, flexible, adaptable, and ready to quickly and effectively respond to multidisciplinary technical issues.

The MSD Group performs research and development of circuits and systems involving custom microelectronics and nanoelectronics, where sensors and circuits are typically integrated into miniature and low-power electronic systems. The group's primary emphasis has been the creation of large-scale, mixed-signal application-specific integrated circuits (ASICs) and the research and development of new techniques, devices, and structures to exploit monolithically constructed circuits and sensors for measurement, control, and communications applications. Current application domains for us include national security, experimental physics, and biomedical systems.

Capabilities

MSD uses a broad range of design, simulation, and testing tools. Fabrication is accomplished by taking advantage of the latest semiconductor processes found in a number of foundries in the United States and abroad. The MSD Group has diverse expertise in analog, digital, radio-frequency, and mixed-signal integrated circuits. Different problems may require more or less speed, power, or size. To optimize a solution to a particular sponsor's requirements, MSD uses a variety of integrated circuit technologies including bulk CMOS, silicon-on-sapphire CMOS, low noise and high-speed silicon bipolar, silicon-germanium, and gallium-arsenide. These technologies are accessed through foundries that supply fabrication services for state-of-the-art semiconductor processes. Sometimes multiple integrated circuit technologies may be combined to achieve a required solution. In these cases, multiple ASIC's have been combined in miniature assemblies using chip-on-board printed circuit board or multi-chip-module techniques.



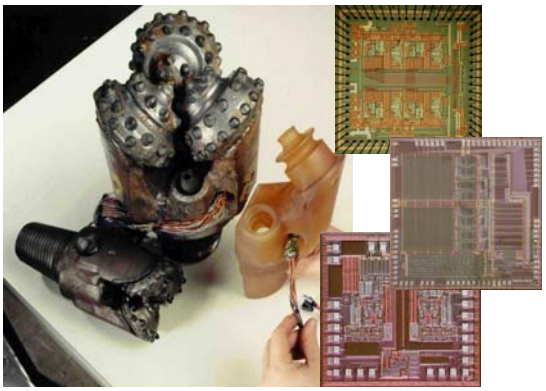
ASICs enable large national and international physics experiments.

Additional Nearby Facilities

- The Nanoscale Science and Technology Laboratory is a user facility incorporating roughly 1,200 square feet of clean room space, a Hitachi S-4700 scanning electron microscope, and a variety of semiconductor processing systems.
- The Center for Nanophase Materials Sciences is a collaborative nanoscience user research facility for the synthesis, characterization, theory / modeling / simulation, and design of nanoscale materials.

Current Application Domains

- Experimental physics detector systems.
- Bioscience instrumentation.
- Distributed sensor systems.
- Harsh environment electronics.
- National security.
- Nanoscale electronics / systems.



High-temperature ASICs for petroleum exploration applications.

Distinguishing Features

Although the group works with technologies that push the envelope and possesses deep as well as broad expertise in electronic device and systems development, these are not necessarily the features that distinguish the group from other institutions and laboratories. Instead, the following characteristics tend to be the distinguishing features of the MSD Group.

A systems perspective and multidiscipline fluency continue to be distinguishing features of MSD staff.

- Ability to rapidly produce working prototypes of proof-of-principle units / systems.
- Ability to work from first principles.
- Staff who are fluent in other disciplines (e.g., biology, physics).
- Ability to conceive and conceptualize from a systems perspective.

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Overview of the Nanosystems & Structures Group

Research at the Forefront of the Micro-/Nano-Scale Revolution

Purpose: The NS&S Group was formed to perform research and development in micromechanical, physical, and chemical sensors; nanostructuring of surfaces; and investigation of novel phenomena at the nanoscale.

Sponsors: Department of Energy and other federal agencies (Department of Defense, National Institutes of Health) and U.S. industry.

Group Members:
- Panos G. Datskos (Leader)
- Regina R. Parks (Admin. Support)
- Joseph Cunningham
- Brian R. D'Urso
- Tom V. Dinsmore
- Troy R. Hendricks
- Scott R. Hunter
- Nickolay V. Lavrik
- Slo Rajic
- Chuck R. Schaich
- John T. Simpson
- Barton Smith

Complementary ORNL Facilities:
- Center for Nanophase Materials Sciences.
- The Nanofabrication Research Laboratory

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The Nanosystems & Structures (NS&S) Group was formed within the Measurement Science and Systems Engineering (MSSE) Division at the Oak Ridge National Laboratory (ORNL) in March of 2008. Today NS&S conducts basic and applied research in the areas of physical and chemical sensing, with a focus on fabrication and measurement techniques in microscale and nanoscale systems and structures; superhydrophobic, electronic, and photonic nanomaterials; and development of MEMS / NEMS devices and sensors.

Capabilities

Within the MSSE Division research environment, NS&S provides expertise in the areas of nano-structured materials and surfaces, and micro- / nano-sensors. Examples of these capabilities include

- Superhydrophobic materials (Fig. 1).
- Uncooled infrared detectors (Fig. 2).
- MEMS chemical sensors.
- Calorimetric spectroscopy.

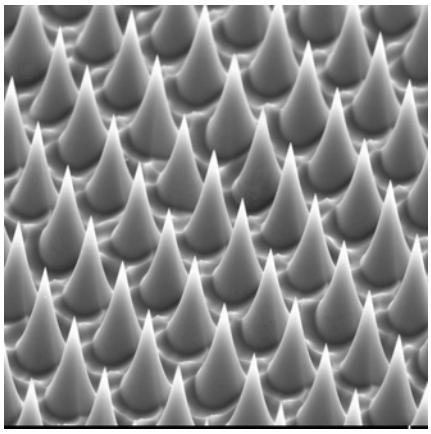

Fig. 1. SEM image of a superhydrophobic glass cone array.

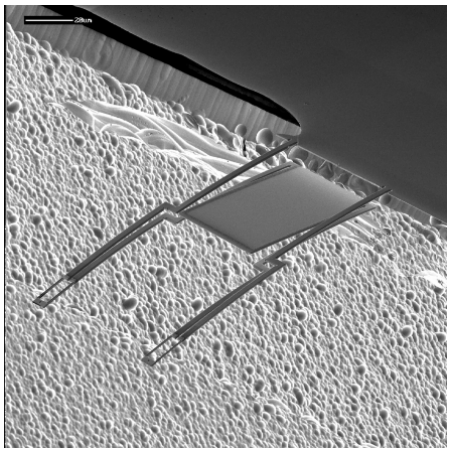

Fig. 2. Example of a microfabricated suspended bimaterial micromechanical element that responds to thermal energy.

- Nanowire arrays.
- Fiber-optic sensors.

Research Facilities

NS&S laboratories include the following equipment and capabilities.

- Microfabrication equipment—Focused ion beam tool with 60 nm beam size, applicable to all materials (Fig. 3); precitech ductile grinding machine.
- Measurement and characterization—Scanning electron microscopy, infrared and photothermal spectroscopy, AFM, optical metrology, finite element modeling and analysis.
- Draw tower—Using a glass drawing process that is based on a modified "Taylor wire drawing" technique, glass coated wire fibers can be fabricated. These fibers can be bundled together and fused into a solid rod, forming large dimension nanowire arrays (Fig. 4), or metal-based polarization preserving optical fibers.

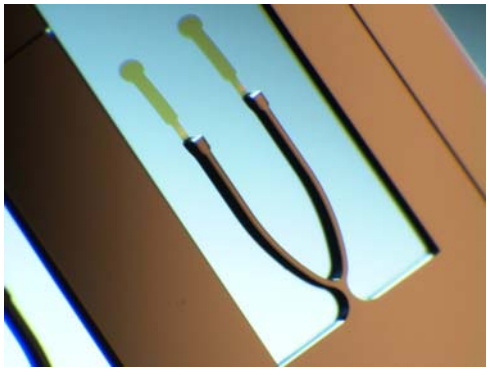

Fig. 3. Microfabricated tuning fork for sensing Coriolis forces.

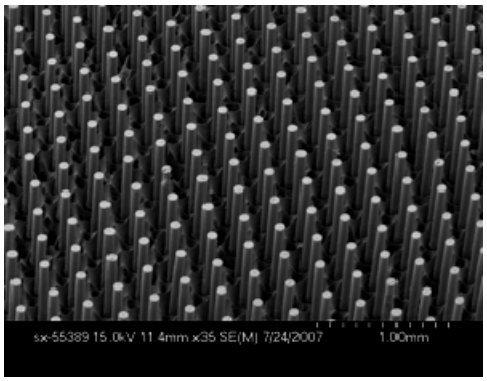

Fig. 4. Tungsten wire array in a glass matrix.

Additional Nearby Facilities

Because of our unique location, in addition to NS&S facilities and laboratories we have access to many other world-class ORNL laboratories and facilities, including the following.

- The Center for Nanophase Materials Sciences, a collaborative nanoscience user research facility for the synthesis, characterization, theory / modeling / simulation, and design of nanoscale materials.
- The Nanomaterials Theory Institute, the theory, modeling and simulation arm of the Center for Nanophase Materials Sciences. Its goal is to span the full range of modeling tools, from electronic structure methods and atomistic simulation through to mesoscale methods and macroscale finite element techniques to perform virtual design and synthesis of new nanostructured materials and nanoscale systems.
- The Nanofabrication Research Laboratory, a 10,000 ft^2 facility for the directed assembly and study of nanomaterials in a clean-room environment.
- The National Center for Computational Sciences, a DOE user facility designated by the Secretary of Energy as the Leadership Computing Facility for the nation.
- The High Temperature Materials Laboratory, a DOE user facility dedicated to solving materials problems that limit the efficiency and reliability of systems for power generation and energy conversion, distribution and use. The HTML includes six user centers available to researchers in industry, universities, and federal laboratories.

Contact Information

To learn more about the exciting NS&S programs and partnering with us, please contact Panos Datskos (datskospg@ornl.gov) at 865-574-62055.

OAK RIDGE NATIONAL LABORATORY
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Designing and Integrating Next Generation Real-Time Information Technologies

Focus: The acquisition and manipulation of data to produce accurate information and knowledge.

Sponsors: Department of Energy, multiple branches within the Department of Defense, the Federal Bureau of Investigation, the International Atomic Energy Agency, and private industry and corporations.

Group Members:
- Randall Wetherington (Acting Leader)
- Mary L. Jernigan (Admin. Support)
- Alan M. Barker
- Barry K. Daniel
- Toby H. Flynn
- Eva B. Freer
- Bill Holmes, Jr.
- Robbi D. Humphrey
- Vernon F. McClain
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MSSE

OAK RIDGE National Laboratory

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Overview of the Real-Time Systems Group

The Real-Time Systems (RTS) Group develops and integrates high-performance systems for the generation, acquisition, analysis, and management of real-time information. The group uses leading edge technological advances to develop high-speed, multichannel systems that can support many concurrent users. These systems are designed to be highly available, secure, and accurate. The systems often use advanced signal processing, control, and database methodologies in uniquely parallel architectures to generate, obtain, analyze, and store highly precise data. With a wealth of advanced systems engineering and project management expertise, RTS has the capabilities to implement systems development from concept to operation. The systems developed by the group are usually production grade designs that clients use at their own facilities.

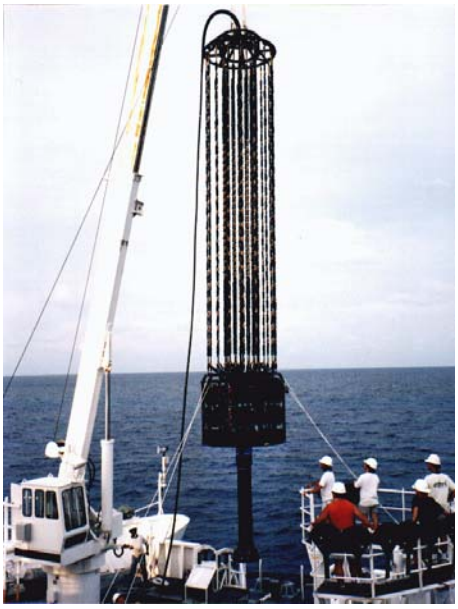
Staff members possess clearances that are sufficient for the most stringent national security needs.

Computer Systems Design

RTS has the capability to design computer systems to meet the most demanding needs of its customers. The group can integrate leading edge and laboratory developed technologies into functioning systems. Approaches used in the designs are independent of specific vendors and include the best technologies for a given customer need.

Digital Signal Processing

RTS specializes in the adaption of digital signal processing techniques in real-time systems. These methods are used to accomplish real-time measurements and simulations that would not otherwise be possible in applications such as sonar measurements and radar simulation.



The group developed a frequency-domain beam former to process the data from this large volumetric sonar array.

Open-Source Technologies

The group has deployment experience in many computer operating systems and technologies. Of particular note are those based on open-source standards and tools such as Octave and SciLab. RTS can take open-source technologies and integrate them with our knowledge base to develop solutions that meet demanding requirements. The use of open-source technologies offers significant flexibility in customization and can lower the final cost of a system.

Multicore Processors

The RTS Group has developed systems that feature advanced multiprocessor architectures. This experience dates back to deployment of array processors, I/O computers,

and vector processors. The focus continues today in the adaption of technologies such as the IBM Cell. These technologies allow the group to deliver unprecedented performance in platforms that occupy relatively small amounts of space.

High Availability and Secure Approaches for National Security

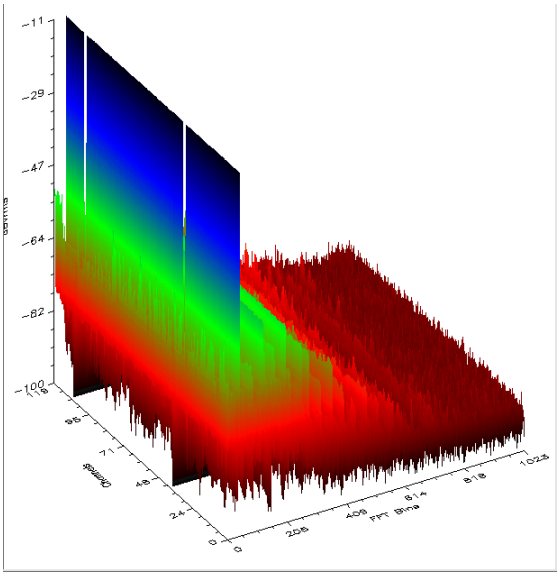
RTS has designed, developed, and deployed system architectures designed for high availability, including systems supporting communities of more than 50,000 users with secure network connection and authentication methods and role-based access.

The Art of Making Measurements

The group has significant experience in analog-to-digital conversion technologies and signal conditioning approaches. These technologies are crucial in the process of gathering accurate data for measurements. We have designed systems that feature more than 2,000 channels of input sensors coupled with real-time signal processing techniques to produce measurements with significantly reduced noise and a reduction in overall data volume. RTS also understands how to design systems where extremely large volumes of data must move and be processed and/or stored in a sustained manner. Advanced hardware and database architectures are used in these designs.

Advanced Data Analysis

Our expertise also extends to advanced data analysis techniques that can be used for mining information that would otherwise not be easily observed. These methods are particularly useful for sponsors who have extremely large data sets and low signal-to-noise ratio. The group has extensive working knowledge of state-of-the-art analysis tools such as MatLab and Simulink.



Graphical analysis of 120 channels of sensor data quickly allows identification of dead sensors.

Contact Information

If you have a problem, we have a solution. To find out more about our capabilities, partnering with RTS scientists and engineers, and/or accessing our user facilities, please contact Randall Wetherington (wetheringtgr@ornl.gov) at 865-574-5717.

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Overview of the RF & Microwave Systems Group

Bringing Innovative Engineering Solutions to Challenging Problems

Mission: RFMS strives to bring innovative solutions to challenging and nationally important engineering problems.

Capabilities:
- Custom electronics.
- Software-defined radio platforms.
- Model-based waveforms.
- System architecture.
- Advanced coding.
- Novel antennas.
- Hardware-in-the-loop simulations.

Sponsors: Sponsors include the Departments of Defense, Energy, and Homeland Security; the U.S. Nuclear Regulatory Commission; the Defense Logistics Agency; the National Geospatial Information Agency; universities; and various industry partners.

Group Members:
- Paul Ewing (Leader)
- Sara Peak (Admin. Support)
- Beverly Kay (Admin. Support)
- Austin Albright
- Miljko Bobrek
- Mark Buckner
- Mark Fioravanti
- Greg Hanson
- Mostofa Howlader
- Ben Huey
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- Brian Kaldenbach
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The RF & Microwave Systems (RFMS) Group strives to provide innovative engineering solutions to demanding and nationally important problems by integrating advanced concepts and new developments into custom radio-frequency (RF) and microwave systems. The focus of the RFMS Group is research and development (R&D) geared toward supplying robust communications for extreme environments; global tagging, tracking, and locating (TTL) systems; and RF- and microwave-based measurement and processing systems. Diverse capabilities and top-notch facilities are two solid attributes of the RFMS Group that make this type of R&D possible. Additional attributes that set the RFMS Group apart from other organizations performing similar R&D are its rapid development and prototyping capability, the depth and breadth of staff experience, and its cache of internally developed intellectual property (IP).

Robust Communications in Extreme Environments

Conventional communications are often limited in extreme environments because of their high power consumption, short operating life, and susceptibility to multipath and interference. Extreme environments can include any situation where a clear path for communication signals is absent (e.g., where manmade features such as metal structures and buildings interrupt or interfere with signal propagation). RFMS is developing wireless communications technologies capable of supplying robust wireless communications in these environments. These robust communications technologies are opening a whole new world of wireless applications in extreme environments, including remote measurement and condition monitoring, efficient video and data transfer, and secure asset tagging and tracking.

ORNL Robust Wireless Communications Technologies Team—Winner of 2004 Project of the Year Award from Federal Laboratory Consortium for Technology Transfer.

Tagging, Tracking, and Locating Systems

TTL technologies are on the verge of revolutionizing how the world approaches real-time asset management. Essentially, they offer the opportunity to know the status of assets at all times: where they are, whether they are moving, how fast they are moving, and in which direction they are moving. “Assets” could include military cargo, consumer goods, scientific infrastructure, and people. The RFMS Group is currently applying existing TTL technologies to global applications, while also addressing the technical challenges of new positioning, navigation, and timing techniques. Target applications include all of the major sectors of society (government, commercial, industrial, and military), as well as personal applications. TTL technologies have the ability to reduce manufacturing costs, increase efficiency in supply chains, automate

inventories, track assets from the point of departure to their final destination, and locate lost assets.

ORNL-developed tracking hardware installed on a shipping container in Charleston, South Carolina.

RF- and Microwave-Based Systems

RF- and microwave-based measurement and processing systems have been developed by the RFMS Group for a number of applications, including plasma diagnostics, material moisture and density measurements, material processing and characterization, electromagnetic emissions measurements, and electromagnetic characterizations. RFMS R&D in this area has been primarily focused on magnetic fusion energy research, materials science research, environmental cleanup, and energy efficiency applications. The advantages that can be attributed to these RF and microwave systems include energy savings, labor savings, consistent product quality, reduced waste, and material performance enhancement.

Microwave moisture measurement system for lumber drying.

Capabilities

- Custom RF and microwave electronics/systems.
- Software-defined and cognitive radio platforms.
- Model-based waveform development.
- System architecture design.
- Advanced coding techniques.
- Novel antenna design.
- Hardware-in-the-loop simulations.
- Radiolocation tracking and locating techniques.
- RF- and microwave-based diagnostics and measurements.
- RF- and microwave-based material processing and characterization.
- Electromagnetic characterization.

Millimeter-wave radiometer for measuring plasma electron temperature.

Facilities

The RFMS Group has research facilities that include RF and microwave laboratories, shielded enclosures, an antenna farm, and open area test sites. Equipment in these facilities includes spectrum analyzers, network analyzers, logic analyzers, waveform generators, microcomponent assembly stations, environmental test equipment, and electromagnetic modeling tools (MatLab, Simulink, Sysgen, Rhapsody, etc.). The RFMS Group's IP portfolio includes more than 40 patents and invention disclosures.

Contact Information

To learn more about our capabilities and how you can partner with us, please contact Paul Ewing (ewingpd@ornl.gov) at 865-576-5019.

OAK RIDGE NATIONAL LABORATORY
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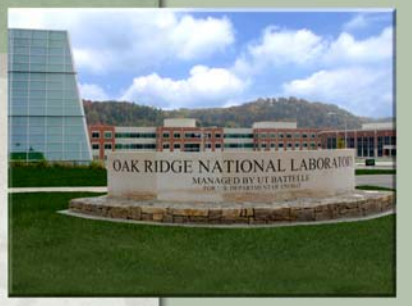
Overview of the Robotics and Energetic Systems Group



Robotics and Energetic Systems Group

Purpose: Since the early days of the Atomic Energy Agency when scientists at Oak Ridge National Laboratory (ORNL) developed servomanipulators to protect radiation workers from radioactive materials, ORNL robotics engineers have been creating unique technologies to meet the needs of workers, the public, and society as a whole, including sensor-based navigation systems, advanced mobility systems, human-machine synergistic systems, and novel power and actuator technologies.

Sponsors: U.S. government agencies such as the Department of Energy and the Department of Defense, university partners, and private companies and organizations.

Group Members:
- Francois Pin (Leader)
- Karen S. Harber (Admin. Support)
- John Jansen
- Randy Lind
- Peter Lloyd
- Lonnie Love
- Mark Noakes
- Brad Richardson
- John Rowe

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The Robotics and Energetic Systems (RES) Group's capabilities and interests range from basic research—with fundamental development in motion planning, reasoning methodology, and advanced controls—to one-of-a-kind integrated system design, development, testing, and evaluation. Major areas of research and development include sensor-based robotics (including mobile robots, advanced manipulators, and combined mobility manipulation systems), human-amplifying machines (including technologies for exoskeletons, human-assist systems, strength-amplifying machines, and prosthetics), power transfer devices (actuation technologies), and energy-transformation systems (mostly for portable energy supplies). Areas in which the group has developed exceptional capabilities include fluidics actuation and controls, both for high-precision and high-payload (multiton) systems and for mesoscale (millimeter to centimeter scale) systems; omnidirectional and holonomic mobility systems (an area in which RES holds a number of patents and an R&D 100 award); biomedical robotics (automated surgical assisting robots, prosthetics, rehabilitation-assist devices); actuation technologies for robotic operations in high-temperature environments; advanced logistics systems (cargo and weapons transport and handling); and microassembly (assembly of microscale / nanoscale components for three-dimensional micromachines).

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Overview of the Sensor Science and Technology Group

The Next Generation of Sensors and Measurement Systems

Purpose: Apply first principles physics, chemistry, biology, electronics, and mechanics in the development of novel sensors and systems of national importance.

Sponsors: Department of Energy, Department of Defense, U.S. Department of Homeland Security, and private industry.

Features:
- Multidisciplinary research staff including physicists, electrical engineers, materials scientists, mechanical engineers, and software engineers.
- World-class R&D laboratories.

Complementary ORNL Facilities:
- Spallation Neutron Source.
- Center for Nanophase Materials Sciences.
- National Center for Computational Sciences.
- High Temperature Materials Laboratory.

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The Sensor Science and Technology (SST) Group conceives, designs, develops, tests, and deploys prototypic sensors and systems for applications that advance science, improve energy efficiency, or enhance national security. Specializing in harsh environment sensors (Figure 1), sensor systems integration, and solving multidisciplinary measurement problems, SST has a long history of innovation and commercialization of sensors.

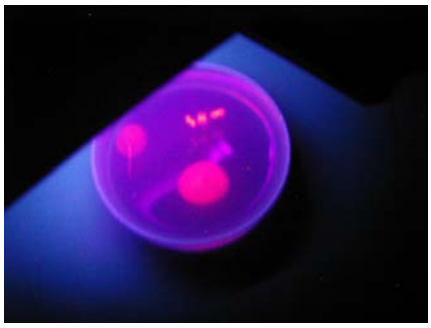

Fig. 1. Thermoluminescent nano-powders for harsh environment temperature sensing.

One area of focus for SST is sensors and systems for energy efficiency applications. Figure 2 shows a microelectromechanical systems (MEMS) sensor array that was part of a building monitoring system capable of measuring temperature, humidity, CO_2 levels, and occupancy (infrared detection) as an integrated system.

Fig. 2. MEMS sensor array building environment monitoring.

Sensor technologies for national security applications is another area of emphasis for SST. Laser-based remote sensing, chemical and biological detection, and advanced radiological and nuclear detection systems are part of our portfolio of technologies. Figure 3 depicts a laser scanning system that was developed and commercialized for safeguards and security monitoring applications.

Fig. 3. Laser-based item monitoring system for high-value storage environments.

We also have extensive experience with electrochemical sensors for power generation diagnostics, carbon sequestration monitoring, and automotive engine controls.

Capabilities

In the last decade SST has been a leader in the development of novel sensor technologies at the Oak Ridge National Laboratory (ORNL). These efforts have led to more than 25 patents, three R&D 100 Awards, and a spin-off company.

SST's areas of technical expertise include

- acoustic sensors and imaging systems;
- flow measurement;
- ultra-precision displacement;
- radiation detectors (Figure 4);

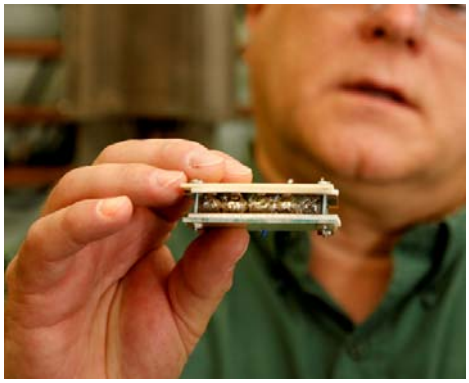

Fig. 4. Advanced neutron detector arrays.

- laser-based sensors and systems (fiber optic, Fabry-Perot, and spectroscopic [Raman, LIBS, PIS]);
- electrochemical sensors (Figure 5);

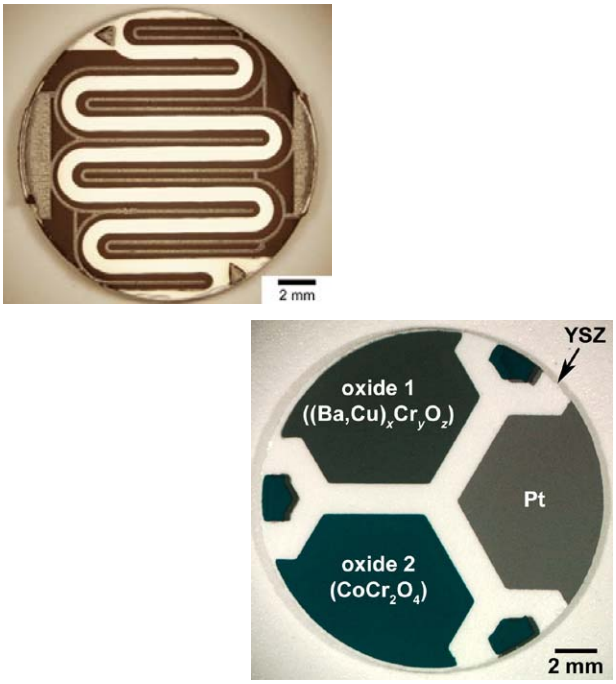

Fig. 5. High-temperature electrochemical sensor designs for CO_2, NH_3, So_x, and NO_x measurements.

- electromagnetic sensors, including electromagnetic acoustic transducer, piezoelectric, magnetostrictive, capacitive, inductive, and Hall effect;
- temperature sensors, including luminescence-based, Johnson noise, infrared, microbolometric, and MEMS-based;
- ultra-precision dimensional measurements, profilometers, and metrology;
- testing and analysis for prototypes; and
- standards development (Figure 6).

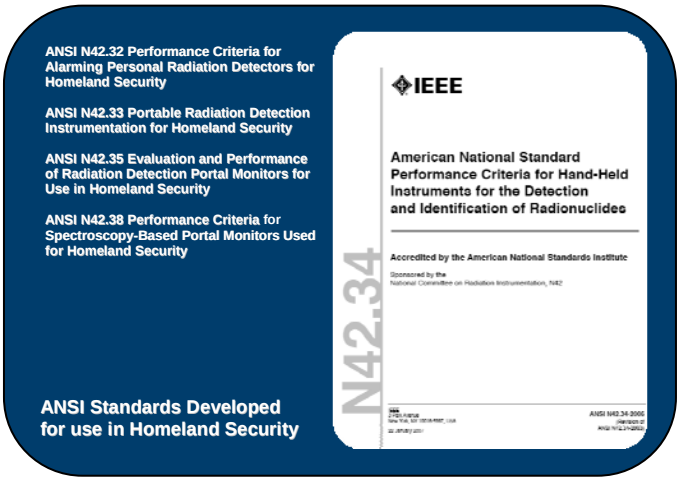

Fig. 6. International standards developed for testing and evaluation of radionuclide detectors by SST staff.

Additional Nearby Facilities

- Center for Nanophase Materials Sciences is a collaborative user research facility for the synthesis, characterization, modeling/simulation, and design of nanoscale materials for sensors.
- Research and development (R&D) laboratories in other research divisions at ORNL, including biology, chemistry, mechanics, materials, condensed mater science, environmental sciences.