SENSORS AND RELATED RESEARCH

In FY 2007, $20.0 million is requested to support leading edge, frontier research across NSF on sensors and other research that is potentially relevant to the detection of explosives and related threats.

Recent advances in sensor research have yielded innovative applications that have been of tremendous value to our national security, healthcare, environmental safety, and energy resource management. Additional frontier research in areas critical to our Nation will yield similar advances. This is particularly true for the detection of explosives and related threats, including improvised explosive devices (IEDs).

ENG will lead this new NSF-wide effort, in collaboration with other agency efforts, which seeks to advance fundamental knowledge in new technologies for sensors and sensor networks, and in the use of sensor data in control and decision-making across a broad range of applications, particularly those that bear on the prediction and detection of explosive materials and related threats. This research is seen as critical to our Nation's ability to deploy effective homeland security measures, and to protect civilians and our military forces throughout the world.

Sensors Research Related to Prediction

New fundamental research into the scientific and engineering principles of prediction through sensors will enable the recognition of explosives and other threats earlier than current technologies allow. The ultimate goal is to identify and isolate a threat at the point of device assembly and placement. Research toward this goal would include the recognition of emplacement patterns, behavioral pattern recognition from video and other sensing systems, human intelligence and social network analysis of terrorist networks, analysis of communications, modeling and simulation of such activity, and knowledge-management systems.

The key to prediction will be the ability to integrate data from diverse sources, which may include psychology and sociology of terrorists, artificial intelligence, explosive characterization, pattern recognition, and information management – areas in which NSF has long been active.

Specific topics of research may include real-time investigation of the detonation process and mechanisms to initiate detonation in solid explosives. This research will enhance our capabilities in efficient detection, sensing, and control of explosive devices.

Sensor Research Related to Detection

The sensitivity and fine resolution of sensors often determine what can be detected, at what location, and how quickly. This is particularly important for the detection of explosive devices, since the earlier a threat can be identified, the easier it is to address.

Once an explosive device is in place, its detection will rely on scientific and engineering concepts that permit rapid, standoff identification and localization of explosives. This research includes the remote surveillance and possible identification of an explosive's unique characteristics. The purpose is to distinguish real threats in an environment, with minimal to no false alarms. Topics in this category include sensor technologies, signal processing, data fusion, and autonomous system technologies.

Specific areas of research may include the development of new detectors based on a fundamental understanding of animal-sensory systems. An example is an "electronic nose" modeled after the olfactory response in mammals such as dogs. Additional research may go toward the development of new detectors that can identify specific chemical signatures. These may be based on principles such as terahertz spectroscopy, laser ionization, chemical ionization, and low-energy electron attachment.

More broadly, the miniaturization of chemical analyzers is needed. Single-walled nanotubes are especially promising in the miniaturization of electronics and photonics; research is needed on the synthesis and characterization of chemical and electronic materials such as these. Also, in order to maintain active sensors in the field, small reliable power sources are required.

Complementing this sensor research would be advances in tagging and tracing explosives to aid in forensic investigations. There are limited chemical approaches available now because of the difficulty of effectively hiding this information while not interfering with the other chemical and physical properties of the material.

Potential Topical Areas

Under the broad categories of prediction and detection, NSF will look at topical areas that cut across all related studies, and will help identify gaps in research and areas of potential exploitation. Examples of possible topics that will build on previous NSF-supported research include:

- **Engineering of Materials, Concepts and Designs for New Sensors and Sensing Systems.** This topical area emphasizes the engineering of materials and devices that are suitable for applications in technology and environmental observation. Proposed research should lead to sensors that are sensitive, selective, and stable with rapid response times.

- **Environmental Sensors and Sensing Systems.** A unifying theme of this topical area is to stimulate fundamental advances *in situ* and remote sensing systems, with a goal toward observing, modeling and analyzing a wide range of complex environmental materials or compounds, life forms, and processes. Proposed research should leverage recent advances in microelectronics, photonics, telemetry, robotics, wireless communication, sensor networks, and other methods for highly resolved spatial and temporal sensing of physical, biological, and chemical threats.

- **Engineering Applications of Networked Sensors; Interpretation of Data; Responsive Action.** This area addresses system-level application areas. Research issues include: decision and control theory for sensed information; sampling, pattern recognition, and false alarms in sensed data. Additional research will address power-aware sensor networks with self-configuring, self-healing, and self-optimizing capabilities. New research also will incorporate uncertainty and risk into decision making for use with imperfectly sensed data.

- **Information Management of Sensing Systems.** In the area of information management, basic research is needed on innovative approaches to tagging data to facilitate subsequent retrieval, and on compression algorithms useful for transmitting large data files, such as high-resolution image files. Innovative new signal processing techniques and algorithms, together with test bed experiments, are needed for feature extraction of anomalies associated with explosives and related threats activity.

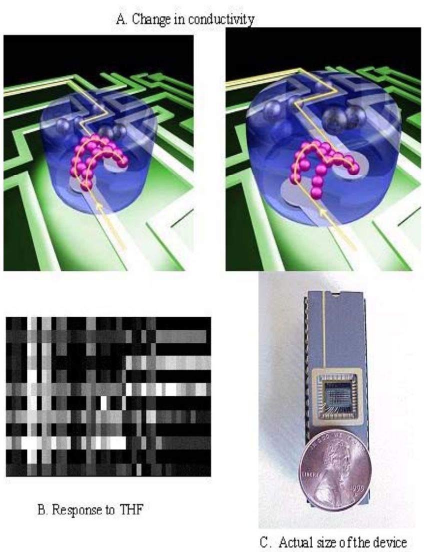
- **Social and Behavioral Science.** The production, distribution, and detonation of explosives involve the coming together of manufactured materials with human beings at particular times and places. Research findings from psychologists, cultural anthropologists, and geographers, can be as critical to successful prevention as understanding physical, chemical, and engineering technical aspects and logistics.

Coordinating Research with the Broader Community

NSF investments will coordinate with and leverage on research currently underway in other areas of the federal government. The U.S. Navy, Department of Energy, and the Department of Defense each have active research into mitigating the dangers from IEDs. Only by integrating all research in the field can effective technologies and systems be deployed.

NSF will be able to use its proven research dissemination and coordination vehicles, such as workshops, focused solicitations, and briefings, to better integrate the research community around this important topic.

Recent Research Highlight



Electronic nose detecting a chemical and a photograph showing the actual size of the device. *Credit: Nathan Lewis, California Institute of Technology*

► **Electronic Nose:** NSF is supporting the development of an artificial "sniffing" device that may rival the extraordinary sensitivity of the canine nose. Such a device would be in great demand for detection of explosives, drugs and other materials. To create the electronic nose, Nathan Lewis and his group at Caltech start by making micro-fabricated devices with surfaces that contain special polymer coatings. When a particular gas is present, it causes the polymer to swell. (Illustration A.) As a result, the electrical conductivity of the device changes, triggering a signal. Arrays of such sensors, depicted at the top of the illustration, can provide the synthetic equivalent of an animal's olfactory system. The pattern of response of the array (B) is different for each type of gas, so identification of the specific substance can be achieved through familiar pattern recognition methods. The devices are small (C) and have already flown on space shuttles to monitor air quality. (MPS)