which measurements and tests can be developed and designed. Projects under way include:

- Developing a simulation tool, EXiST, for modeling and measuring pervasive computing systems, allowing us to work with industry to understand and assess technical issues before costly implementation;
- Developing Architectural Description Language models of service discovery protocols, including Java™ * technology, Jini™** networking technology, Service Location Protocol (SLP), Universal Plug and Play (UPnP), and Bluetooth™*** wireless technology, to allow errors to be analyzed and corrected;
- Developing an abstract, layered, conceptual model of pervasive computing, enabling industry to better understand the interactions and complex systems issues involved;
- Creating a reference platform of a minimal pervasive computing system to facilitate modeling and simulation as a means to identify problems as more devices work together; and
- Developing measurements of performance of Java on embedded PCs.

***Contact: Mark.Skall@nist.gov***

## Pervasive Networking Technology

In this focus area, we work closely with the networking industry to improve the quality of technical standards and to raise the robustness, scalability, and performance of products implemented to meet those standards.

This area involves protocols and performance measurement, including wireless pico-cellular networking. Our work includes:

- Analysis, evaluation, and modeling of interference in the 2.4 GHz ISM band caused by Bluetooth™*** wireless technology, HomeRF™ Working Group protocol specification, IEEE 802.11, and others as they operate simultaneously;
- Performance analysis and scaling characteristics of service discovery protocols to allow industry to identify problems in very large networks;
- Analysis of multiple service and device discovery protocols, such as Jini™** networking technology, Service Location Protocol (SLP), Universal Plug and Play (UPnP), Bluetooth™*** wireless technology, The Salutation Consortium™**** specification, and Home Audio-Video interoperability specification (HAVi); and
- Research, design, evaluation, and implementation of adaptive algorithms to improve the robustness and scalability of service discovery technologies that will enable the dynamic networking needed for pervasive computing.

***Contact: David.Su@nist.gov***

## Contact us at the Information Technology Laboratory

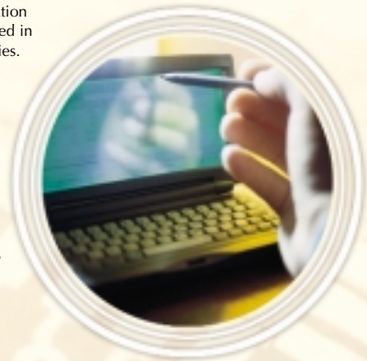
Pervasive computing requires the integration of many hardware and software components, and communications protocols. Information technology companies need coordinated standards and reliable measurements to succeed in creating next-generation pervasive computing environments.

The NIST Information Technology Laboratory staff has expertise in many of the necessary areas and is seeking new industrial partners to cooperatively develop measurements and standards that will improve your productivity and competitiveness in the information technology industry. We are working in computer security, advanced networking, information retrieval, software testing, computer interface technologies, biometrics, and other cutting-edge information technologies. We would like to discuss with you how we could help. More information about ITL and pervasive computing is available at: **www.itl.nist.gov/pervasivecomputing.**

Please feel free to contact us to talk about your interests in pervasive computing:

***William.Mehuron@nist.gov***
***Martin.Herman@nist.gov***





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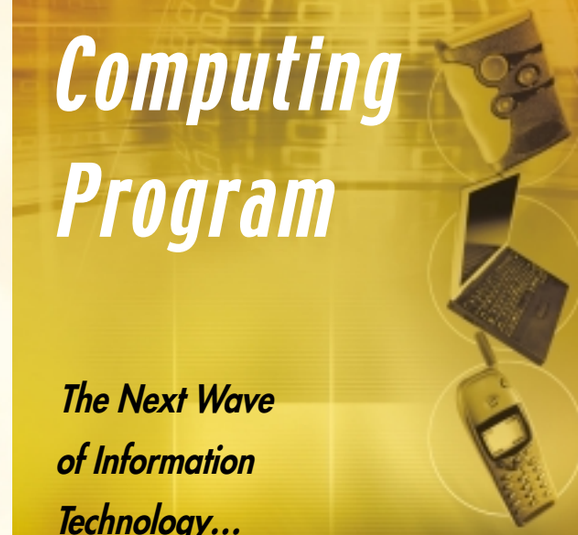
**National Institute of Standards and Technology**
Technology Administration, U.S. Department of Commerce

# Pervasive Computing Program

***The Next Wave of Information Technology...***



NIST INFORMATION TECHNOLOGY LABORATORY

## The Next Wave of Information Technology...

**Pervasive Computing** is a term that signifies several new elements of computing. One element involves pervasive computation – computers and sensors "everywhere" in devices, appliances, equipment, in homes, workplaces and factories, and in clothing. Devices and sensors may be mobile, such as wireless PDAs or smart phones, or may be embedded in the environment, such as sensors and computer chips in walls or furniture. Another element involves pervasive communication – a high degree of communication among devices and sensors through a ubiquitous and secure network infrastructure with a wired core and wireless adjuncts that communicate with the core. Because computation will become so integrated into our lives and activities, natural forms of human-computer interaction, such as spoken dialogue with computers, will become more important.

The shift toward pervasive computing is already well under way and will impact industry, government, and daily life as much as the personal computing revolution has.

As always, change creates new opportunities and new challenges for U.S. information technology companies, and failure to embrace the future means being left behind.

NIST is developing innovative measurements, standards, and conformance testing methodologies to help industry meet the challenges of integrating these technologies into usable and productive pervasive computing environments of the future.

In developing pervasive computing environments, new hardware and flexible software applications using wired and wireless communications will be needed. Also, effective pervasive computing must present user interfaces distributed across numerous, small, portable, and embedded devices. This requires new techniques in measurement, testing, and radio frequency (RF) management in densely populated wireless environments, as well as in human-computer interactions.

NIST has already begun to address important technical issues in pervasive computing. For example, one critical issue we are addressing arises as wireless palmtop computers begin to crowd the unregulated 2.4 GHz -frequency band for small wireless pico-cellular networks. One hospital reported that many of its vital medical laboratory machines stopped working because of interference when a cell phone tower was installed on the building. Other issues we are addressing include how to interact with computing devices too small to have keyboards and how to present information under small-screen size and color limitations. We are also addressing specialized technical issues in protocols for sensor data exchange and transport to spoken user interfaces, and for biometric security and authentication; pervasive devices that are lost or stolen must keep sensitive information secure from unauthorized users.

**PERVASIVE COMPUTING IS IN ITS INFANCY, REQUIRING HIGH-RISK TECHNOLOGIES FROM NUMEROUS LABORATORIES AND COMPANIES**

At ITL we are prototyping experimental systems using pervasive computing components focused on advanced forms of human-computer interaction, integrating pico-cellular wireless networks, dynamic service discovery, automatic device configuration, and software infrastructure for pervasive computing applications. Our program includes:

- Identifying key areas and partners that would benefit from standardization, such as service discovery, Application Programming Interfaces (APIs), and interoperability studies;
- Developing hands-on experience in applicable measurement technologies, such as conformance/interoperability tests, diagnostic tools, and benchmarks, to define and improve pervasive computing tools;
- Identifying security mechanisms needed to ensure privacy, integrity, and accessibility of implementations;
- Developing metrics, test methods, and standard reference data sets for pervasive computing technologies, such as spoken interfaces;
- Providing reference implementations as models in areas such as data transport and interchange standardization;
- Collaborating with industry standards groups to develop unambiguous, testable specifications;
- Making interconnections to explore key issues associated with distributed smart spaces; and
- Establishing vibrant industry partnerships.

**WE ARE COOPERATING WITH INDUSTRY TO FACILITATE PROGRESS IN:**

- Distributed User Interfaces
- Advanced Information Access
- Pervasive Software
- Computer Security
- Biometric Access Control
- Pervasive Devices – mobile or embedded devices that provide easy access to information and services
- Dynamic Service and Device Discovery – for automatically finding networked resources as needed
- Pico-Cellular Wireless Networking

**THE ITL PERVASIVE COMPUTING PROGRAM FOCUSES ON THREE MAIN AREAS:**

- Smart Space Integration
- Pervasive Software Tools
- Pervasive Networking Technology

### SMART SPACE INTEGRATION

*Smart spaces* are work environments with embedded computers and sensors that provide unprecedented levels of access to information and help from our computers.

In this focus area, we are engaged in a variety of projects that are helping industry bring pervasive computing components together into real and useful systems. This area involves interoperability, usability, multi-modal user interfaces, and information retrieval. Our efforts include:

- Expansion of the capabilities of the NIST Smart Flow system – data flow integration software that allows devices and systems from different companies to work together in a single environment;
- 2.4 GHz wireless test bed to analyze sources of problems and allow us to work with industry to develop more robust communication protocols;
- Spoken language systems measurements and reference data to help industry develop better speech and speaker identification technologies, and to test them against realistic data encountered in specialized smart space applications, such as meeting rooms;
- Advanced data acquisition technologies in support of real time interfaces, including unique microphone array for meeting room data collection; and
- Information retrieval measurements to aid industry as it develops better search and retrieval methods for text as well as spoken documents.

***For more information, visit the web site: www.nist.gov/smartspace.***
***Contact: Martin.Herman@nist.gov***

### PERVASIVE SOFTWARE TOOLS

New design and testing techniques are needed to model and measure pervasive systems – not just isolated components of the systems. Architectural Description Languages and simulation tools can help to identify standardization, measurement, and interoperability issues, provide effective means to explore system-engineering issues prior to costly investments, and serve as the environment in