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1.0 Overview

The Information Technology Laboratory (ITL) is one of the Measurement and Standards Laboratories at the National Institute of Standards and Technology (NIST). ITL has two primary functions:

1. To provide the U.S. information technology industry and key information technology users with the world's best technical infrastructure and to increase the quality of software in industry, returning the best possible value to the economy and society.

2. To provide the best in information technology services to all of NIST to enable its staff to use IT to improve their service delivery and efficiency and therefore provide the best value to their customers.

Therefore, it is incumbent on ITL to study the current trends and focus its research and service programs on key emerging areas.

ITL's research program emphasizes working with industry to develop information technology measurements and standards that facilitate:

- growth of new information technologies,
- advances in the quality and security of information technologies, and
- application of IT to new market segments.

ITL's service program provides centralized infrastructure support to all of NIST. The services include high-end computing and networking services; advanced mathematical and statistical consulting; site-wide telephone services; hardware maintenance for most personal computers; software dissemination, updates, and support for select widely-installed software products for personal computers and Unix-based workstations; and consulting and training related to the use of central facilities and services at the Gaithersburg and Boulder sites.

To fulfill these two functions, ITL has an operating budget of $70.3M and a highly qualified professional and support staff of 476 (includes part-time), supplemented by 109 guest scientists and faculty members (as of September 25, 1999).

2.0 ITL's Mission, Vision, Values, and Practices

This section shows how the Information Technology Laboratory (ITL) fits into the NIST mission and how NIST's vision, values, and practices apply to ITL and the ITL mission.

Mission

To strengthen the U.S. economy and improve the quality of life by working with industry to develop and apply technology, measurements, and standards.

ITL Roles:

1. To develop measurements and standards to support the IT industry and key users of it, with a special emphasis on supporting federal agencies in computer security and the Federal Chief Information Officer's Council in the area of standards and security.

2. To provide a wide range of information technology to facilitate NIST's work in strengthening the U.S. economy and improving the quality of life.

In June 1999, NIST's senior management completed an in-depth review of NIST's Mission, Vision, Values, and Practices. As a result of this review, the NIST Director approved a revised Mission, Vision, Values, and Practices statement as part of a larger effort to make NIST a more coherent and effective organization for the benefit of our customers and staff.

Vision

To provide U.S. industry with the world's best technical infrastructure and return the best possible value to the economy and society.

ITL Roles:

1. To provide the U.S. information technology industry and key information technology users with the world's best technical infrastructure and to increase the quality of software in industry, returning the best possible value to the economy and society.

2. To provide cost effective information technology services to NIST that enable its staff to use IT to improve their service delivery and efficiency and therefore provide the best value to their customers.

Values

ITL fully supports the values that have been formulated for NIST:

- Technical, managerial, and administrative excellence in our work.
- Integrity, openness, and respect in our interactions.
- Relevance and focus in our programs.
- Leadership, teamwork, and diversity in our staff.
- Innovation in all our endeavors.

Practices

ITL fully supports the practices that have been formulated for NIST:

- We expect performance excellence, respect, teamwork, and ethical behavior among our staff.
- We demand the highest standards of quality and integrity in our work and our workplace.
- We encourage staff diversity, leadership, and professional growth.
- We practice open and frequent communication among NIST's employees, customers, and stakeholders.
- We embrace change and innovation.
- We ensure relevance and focus in our programs.

3.0 ITL Customers

ITL serves three primary customers: industry, government, and NIST. Like the rest of the NIST Measurement and Standards Laboratories, ITL also serves and works with the academic community. Appendix B describes the primary ITL customers.

3.1 Industry Customers

Industry organizations engaged in the development of information technology capabilities are ITL's primary customers. Because of the diverse and dynamic nature of this industry, ITL interacts with a wide variety of entities. For example, we work with industry, consortia (formal and ad-hoc), voluntary standards bodies, industry trade associations, individual companies through formal and informal interactions.

The $703 Billion (estimated)[1] IT industry represents a complex and competitive industrial area that is having enormous impact on our economy and society. In the period covered by this plan, it is anticipated that the impact of this industry will become even more significant. In order to fulfill the promises of IT, industry faces significant challenges. In the recent report of the President's Information Technology Advisory Committee (PITAC)[2] a number of challenges were outlined. ITL has used the PITAC report as a significant input to its programmatic planning and therefore to the development of this strategic plan.

In order to help the IT industry, ITL works with industries to produce measurements and standards that they do not or cannot produce by themselves. These voids in measurements and standards exist for many reasons. In some cases the reason is that no company wants to invest the resources because the benefit will accrue to the whole industry with no significant return to the investor. Sometimes, natural competition prevents companies from working together on common problems: no one company can take the lead without appearing to favor its own products.

> *The Nation needs software that is far more usable, reliable, and powerful than what is being produced today. We have become dangerously dependent on large software systems whose behavior is not well understood and which often fail in unpredicted ways... We are also dependent on the Internet that is growing well beyond the intent of its original designers and our ability to extend its use has created enormous challenges.*
> *Information Technology Research: Investing in Our Future*, PITAC Committee Report to the President, February 1999, p. 4.

[1] Annual Survey of Services and Manufactures, 1998 U.S. Bureau of the Census, published in U.S. Industry and Trade Outlook '99.
[2] *Information Technology Research: Investing in Our Future*, President's Information Technology Advisory Committee Report to the President, February 1999.

ITL partners with industry to ensure that ITL's products meet industry needs in a timely manner. ITL's products include:

- conformance, interoperability, and benchmark tests;
- reference data and implementations;
- standards developed jointly with industry;
- diagnostic tests;
- research to reduce costs or increase efficiency of testing;
- performance metrics; and
- test data, test protocols, scenarios, tasks, testbeds.

ITL also works with non-IT industries who are primary users of IT. Many of the most significant changes in IT occur where IT is applied to real problems, such as education, or healthcare. ITL works with these sectors when:

- there is a clear government role in measurements or standards,
- there will be an impact on the overall economy or on society,
- there is a link to core technologies that will later affect a larger segment of the economy, and
- there is a key link to NIST's general mission.

3.2 Government Customers

Government is clearly an important IT user, and we often work with other government agencies on IT projects sponsored by those agencies. In order to implement the policy of the National Technology Transfer and Advancement Act (NITAA) and Information Technology Management Reform Act (ITMRA), ITL works with the CIO Council to help the government use the voluntary standards systems. Additionally the Computer Security Act (CSA) and the presidential orders task ITL to support the government computer security efforts. A brief description of these key laws and orders follows with working with a specific emphasis on computer security:

- The National Technology Transfer and Advancement Act of 1995 and OMB Circular A -119, *Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities,* impact ITL. The Circular establishes policy to be followed by executive agencies in participating in activities of voluntary standards organizations and in adopting and using voluntary standards. Federal agencies are directed to avoid developing or using government-unique standards unless a voluntary consensus standard does not exist.

- The roots of ITL's mission and scope of responsibilities with respect to standards and computer security are defined in specific legislative mandates found in the Information Technology Management Reform Act

(ITMRA) and its amendments of the National Institute of Standards and Technology Act. The Information Technology Management Reform Act (ITMRA) reaffirmed the essence of the Computer Security Act of 1987 as an integral part of NIST's authorities and responsibilities (at 15 U.S.C. 278g-3[a]). OMB Circular A-130, Appendix III, *Security of Federal Information Systems*, further clarifies NIST's role in assisting federal agencies with computer security. Presidential Decision Directive (PDD) 63, announced in May 1998, calls upon NIST to develop and disseminate standards, measurements, and testing methodologies needed to protect the information technology elements of critical national infrastructures.

3.3 Internal Customers

ITL's third customer group receives services. For NIST, ITL provides IT services ranging from collaborative services in applied mathematics, statistics, and visualization, to core IT services such as the scientific computing facility, Web hosting, e-mail, calendaring, networking, telephone service, Internet access, and PC support to administrative computing. The increasing demands made upon information technology products and services make this a critical ITL responsibility in order for NIST to have maximum impact in its technical programs and best leverage its available resources.

3.4 University Customers

While the academic community its not one of ITL's primary customers, it is an important partner for ITL in accomplishing its mission and is a beneficiary of ITL's research program. ITL collaborates with academia in research areas of mutual interest, thus leveraging leading-edge university research with the potential for significant impact.

3.5 Customer Satisfaction

ITL continually seeks feedback from customers to measure the value and impact of our products and services. Some indications of our value to our customers are adoption of ITL-developed methods and recommendations, direct and indirect requests for products, services, and information, Web usage statistics, NRC Assessment Panel reports, interest at high levels of customer institutions, references to our publications and products, and customer expenditures of time, effort, and resources at NIST. Testimonials, return visits to Web sites, and usage of software and tools are other indicators of customer satisfaction. Sponsorship of projects over several years by government agencies is an additional measure of the usefulness of our work. Metrics used to assess service to the NIST staff include surveys, NIST's Information Technology Services Planning Team feedback, and reviews of new projects.

4.0 Trends that Drive Information Technology

4.1 Information Technology Research

Technology has played a very important role in the economic performance of the United States. The information technology sector alone has been responsible for about one-third of our economic growth.[3] By analyzing current trends and envisioning the future directions of information technology, ITL charts its future R&D directions in order to realize the maximum benefit for our industry and government partners. ITL must identify emerging trends and factor them into program planning efforts. The following key sections describe trends that drive the ITL research program in core IT areas and key application areas.

4.1.1 Core IT Areas

Analysis of the information technology sector points to a continuation of some current trends and the emergence of new paradigms. In view of the rapidly changing nature of IT, some future trends of the industry are not foreseeable today. The following major IT trends define the environment in which ITL currently works and plans its programs:

Convergence. The digital convergence of computers, communications, and consumer electronics continues at a rapid pace. The increase in computing power, increased miniaturization and transistor density, and increased bandwidth are enabling new applications that allow enriched, customized, and "on-demand" information dissemination to the user. This trend impacts the display, transmission, and storage of information as well as generating new applications based on the convergence of previously separate media, such as the merging of the Web and broadcast media. Digital convergence is the major enabler for electronic commerce, entertainment, and banking. New markets will emerge as the underlying technologies that support them merge to provide the user seamless, turnkey solutions.

Infrastructure Protection. Following a study by the President's Commission on Critical Infrastructure Protection (CIP), the President approved Presidential Decision Directive 63 to provide a national blueprint to address CIP. The directive defines a national effort to help assure the security of the increasingly vulnerable and interconnected infrastructures of the U.S. Such infrastructures include

> *"The Nation's security and economy rely on infrastructures for communication, finance, energy distribution and transportation -- all increasingly dependent on networked information systems. When these networked information systems perform badly or do not work at all, they put life, liberty, and property at risk." Trust in Cyberspace,* National Research Council, 1999, p.1.

[3] *Information Technology Research: Investing in Our Future*, President's Information Technology Advisory Committee Report to the President, February 1999, p.1.

telecommunications, banking and finance, water, energy, transportation, and essential government services. Critical infrastructure protection is not the same as computer security. Conventional computer security addresses a wider range of threats including losses by malicious or criminal activity, or disruptions caused by weather or building failures. Critical infrastructure protection, on the other hand, looks at the possibility of failure of an entire infrastructure, especially as a result of an act of war or organized terrorism. Although cyber-focused, it is not limited to the electronic realm. The directive requires immediate federal government action, including risk assessment and planning, to reduce exposure to attack. It stresses the importance of cooperation between the government and the private sector by linking designated agencies with coordinators in the private sector for each CIP sector.

Globalization. U.S. competitiveness is reliant upon internationally accepted standards and conformity assessment systems that eliminate non-tariff barriers to global trade and commerce. The Department of Commerce currently estimates that standards are an integral portion of about $150 billion in U.S. exports, and that they serve as barriers to trade for an additional $20-40 billion of exports. Estimates in 1993 suggested that U.S. industries participating in international standards activities (such as information technology and heavy equipment) were responsible for a trade surplus of $26 billion. Those industries for which there were no international standards or no strong U.S. participation contributed to a trade deficit -- perhaps as high as $100 billion. While these figures are not exact, they certainly indicate that effective participation in international standards and conformity assessment activities and policies is crucial to U.S. industry.

Growth of Electronic Commerce. While electronic commerce has already dramatically changed business processes, more changes are coming. Electronic commerce affects transactions between businesses, consumers, and financial institutions and is changing the structure of commerce. Companies are using IT to get closer to their customers and to find the best suppliers. Reduced paperwork and streamlined processes allow companies to be more efficient internally. The growth of electronic commerce affects businesses operating both locally and globally.

Pervasive Computing. Over the last decade, there has been a dramatic increase in the use of computers embedded within and intrinsically part of larger devices. This is leading to a metamorphosis from a world of computers that are used by humans as distinct machines, into a world of sophisticated, computerized, networked machines that are not seen as computers. Computers are embedded in jewelry, human implants, telephones, cars, microwave ovens, credit cards, and a multitude of other devices and systems ranging from fanciful

to mundane. The resulting change in our view of computers and their use by humans is the subject of the field known as pervasive computing. [4]

Shortage of Computer Professionals. The composition of the IT industry will differ drastically in the future. The current shortage of programmers will continue to escalate due to the increasing demands caused by advances in IT. Additionally, and perhaps even more significantly, programmers of the future will not have the formal training that many current programmers receive. According to the National Science Foundation, only 29 percent of all current computer scientists, systems analysts, and programmers actually received a degree in computer science. Already the demand for software exceeds the ability of the U.S. to produce it.

4.1.2 Key Application Areas

Information technology trends such as electronic commerce and the convergence of technologies drive the market for products and services. Users create a constant demand for IT products that are new, better, faster, and more affordable. ITL works directly with users to meet their measurements and standards needs or to link these needs to the IT producer community. There are many IT-intensive industries as described in 3.1 ITL selects users based on impact to the economy or society. We will be working with the following key sectors in the next five years.

> *"... Used creatively, the Internet and information technology can be a powerful tool for tackling some of our toughest social challenges as well as fostering economic growth. Information technology can and is being used to make it easier for working adults to acquire new skills, increase access to healthcare in isolated rural communities, improve the quality of life for people with disabilities, and strengthen our democracy".* President's Memorandum on Use of Information Technology to Improve Our Society, December 17, 1999.

Education. IT is already changing how we teach, learn, and conduct research, but important research challenges in the field of education remain. An entirely new economy in IT-based learning is emerging that will demand high-bandwidth, network-based multimedia content and create challenging new human-to-computer dialog and interaction.

Entertainment. For 1999, the size of the entertainment industry was estimated at $69.2B.[5] The industry is already IT-intensive and is poised to drive and exploit many of the major trends in IT, such as the convergence of different media – voice and data, broadcast and the Internet – or new ways of interacting with IT. For example, one new application is interactive television.

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[4] Taken in part from *Pervasive Computing*, Special Issue, IBM Systems Journal, Vol. 38, No. 4, 1999.

[5] Annual Survey of Services and Manufactures, 1998 U.S. Bureau of the Census, published in U.S. Industry and Trade Outlook '99.

Finance. IT continues to change how financial transactions are conducted including consumer-to-business and business-to-business relationships. Funds totaling many multiples of the U.S. GNP are electronically transferred daily; the velocity is expected to increase, requiring secure, reliable, and flexible IT support. This need is further compounded by the integration of opportunities for financial transactions into new applications.

Government. The federal government represents a key customer of information technology. There is a huge potential to make all government institutions both more efficient and more responsive through information technologies. NIST has played a key role within the federal government since before ITL was created, and ITL has several legislated responsibilities in the area of standards and specifically in computer security.

Healthcare. IT use in healthcare spans a wide variety of applications such as electronic medical records, health-system intranets, telemedicine applications, computer-aided surgery, and bioinformatics. The vast amount of money spent in healthcare and the importance of the services to the individual and the community will drive ITL participation.

Science and Engineering. High-speed computers and networks are enabling new paradigms for scientific and engineering discovery and research. For example, IT is transforming the foundation for industrial development from physical testing, prototypes, and pilot plants to one based on modeling and simulation. The validation, verification, and calibration of models and simulation tools will emerge as a critical issue. At the same time, high-speed networks are providing new methods for the distribution and use of scientific data, information, tools, and other resources, requiring standards for the interoperation of software and interchange of scientific data in heterogeneous, distributed environments are critical enablers here.

Small Business. Small businesses are the backbone of the U.S. business community. This business sector has provided a vital source of innovation for the U.S. economy. Electronic commerce and other information technologies are making enormous impacts on daily life. It is important that small businesses gain the full benefits of electronic commerce.

4.2 Support Services at NIST

The Information Technology Laboratory also has responsibility to provide critical information technology services and support to all of NIST's organizational components. These internal IT activities have grown substantially during the past decade as is reflected in the increase in NIST overhead funds devoted to this activity

NIST funds ITL's support services through three mechanisms: Institute Overhead, Scientific Computing, and Scientific and Technical Research and Services (STRS).

"Raines' Rules" - Under the rules, major IT investments should:

- Support core or priority federal government missions.
- Be impossible for another agency, company or government to efficiently perform.
- Support work already redesigned to cut costs, improve efficiency and use off-the-shelf technology.
- Show a return on investment equal to or better than other uses of available resources.
- Be consistent with agency and governmentwide architectures that integrate work and information flows with strategic plans; comply with year 2000 standards; incorporate standards allowing information exchange and resource sharing; and retain flexibility in the choice of suppliers.
- Reduce risk by avoiding custom design, using pilot projects and prototypes, establishing clear measures of success, securing buy-in from users.
- Be put into effect in phased, successive chunks that are short-term and narrow in scope and independently solve part of an overall mission problem.
- Appropriately allocate risk between government and contractor, tie payments to accomplishments and use commercial technology.

(FY90 OH Budget of $4.2M, $13.5M request for FY00). During this period, the role of IT within NIST, as elsewhere, has evolved into a critical business infrastructure affecting all areas of NIST's activities.

The drivers for the expanding internal IT role include new federal requirements,[6] DoC Departmental IT initiatives,[7] and NIST-identified IT service and support demands.[8] Of these, the initiatives on electronic commerce and electronic government are predicated on secure and interoperable computing environments integrated with a central, integrated administrative environment. Similar external pressures to "do more with less" are compounded by trends (some previously identified in Section 4.1.1) including an expensive and scarce professional IT labor force, an increased need for software interoperability and reliability, streamlined administrative processes, and increasing customer pressure to develop ubiquitous computing environments.

ITL has identified five major trends influencing the approach we take to our IT service responsibilities for NIST that will provide the definition of how NIST evolves IT support enterprise-wide:

Computation in Metrology. The high cost of physical experimentation necessary to carry out the mission of the NIST laboratories is driving an accelerated in-house demand for information technologies. Sophisticated computation is being used increasingly to design physical experiments, as well as to extend and enhance measurement methods. In many areas, as evidenced in the application of combinatorial methods to materials research, IT is playing a central role in the experimentation process, providing methods for managing, mining, analyzing, and visualizing

[6] OMB Circular A-11, OMB Circular A-130, the Government Performance and Results Act, and Presidential Decision Directive PDD-63.
[7] Commerce Administrative Management System (CAMS), Commerce Small Purchasing System (CSTAR), electronic commerce, and others.
[8] NISTNet, Electronic Transactions/Approvals, and stable robust administrative and scientific computing environments.

massive amounts of experimental data. Insights gained through this process provide the basis for developing mathematical models of physical phenomena, which lead to fundamental understanding. Finally, "virtual laboratory" environments based on computational models are emerging as potential replacements for physical experiments, with the prospect of easing data acquisition, increasing the domain of study, and simplifying reproduction of results. Each of these approaches requires increasingly sophisticated mathematical and statistical methods, as well as access to state-of-the-art high-performance computing facilities. Consequently, such trends are leading to greater demands on mathematicians, statisticians, and computer scientists to provide even wider support to NIST scientists.

Consolidation. A widely accepted goal within federal agencies is the need to consolidate operations and standardize computing platforms and configurations where possible. Proper consolidation and standardization allows for more efficient and effective system management while maintaining required system functionality. Thus, to maintain and advance system usability, a comprehensive review and re-engineering of all current IT-related processes must be performed.

IT Planning. There is increasing awareness that explicit linkage to an organization's primary business activities and budget plans is needed to obtain effective allocation and coordination of IT resources. The ITMRA emphasizes the need for central planning and business-oriented decision making for federal IT investments. Thus, NIST's information technology demands and investments need to be included in all of NIST's scientific, financial, and administrative processes and programmatic planning instruments. This linkage will provide IT coordination across the agency and within the Department, which is needed to provide effective and cost-efficient IT support services that allow NIST to meet the needs of its customers.

Performance Metrics. Appropriate service performance and quality metrics must be designed into IT service approaches and implementations. This provides a basis for evaluating and continually improving performance. Careful system design is critical to acquiring quality performance data needed for analysis.

Security. The final critical trend affecting our NIST-specific IT challenges is the increasingly important need for appropriate system security and system interoperability. Both OMB Circular A-130 and the recent Presidential Decision Directive 63 on Critical Infrastructure Protection cite the requirement for overall system security that includes appropriate physical and systems-level safeguards and the requirement that all federal agency infrastructures, including IT, must be protected. For an effective enterprise-wide approach to IT services, additional care must be taken so that system interoperability is maintained, and implementations must maintain adequate security in integrated, easy-to-use, common environments. To meet these security requirements, NIST will need to

increase system administrators and user training, along with designing better security tracking and reporting systems.

5.0 ITL Goals and Strategies

ITL has two distinct sets of goals and strategies supporting our two missions:

1. measurements and standards to support the information technology industries, other industries that are dependent on IT, and government;

2. IT support for NIST including scientific computing and collaborative services, centralized IT core technologies, and administrative computing. Details of these goals and strategies are found in division strategic plan summaries beginning with Appendix D.

5.1 ITL Measurements and Standards Research Program

The Nation needs to continue its advances in information technology to sustain economic growth, address important societal problems such as education, and protect society from catastrophic failures of the underlying complex systems. ITL works with industry to develop information technology measurements and standards that facilitate:

- growth of new information technologies,
- advances in the quality and security of information technologies, and
- application of IT to new market segments.

ITL actively works with industry, government, and academia to identify high-priority areas in which measurements and standards are needed and in which ITL should play an active role. ITL uses many sources of information, including workshops, conferences, journals, one-on-one contacts with key players, and industry roadmaps such as the PITAC report of February 1999.

In response to the rapidly changing needs of the IT industry and users of IT, ITL focuses activities on measurements and standards in four core technologies: networking, software, information access and interaction, and security; in key application areas; and in international standards. ITL works with industry through formal standards bodies, industrial consortia, and other formal and informal collaborations. For each of the four areas, we provide our vision of the future and the goals and strategies that ITL has established for effective contributions.

5.1.1. Networking

During the 1980s, large time-sharing computers gave way to ubiquitous desktop computers, leading to a growing prevalence of distributed systems connected through networks. This change, coupled with the emergence during the 1990s of the Web and enterprise management, initiated a radical growth in the centrality and importance of computer networks. These trends can be expected to accelerate into the next decade. Growth in multimedia computing applications will push the networking industry to increase support for the convergence of voice, data, and video on the Internet, and the emergence of electronic commerce will require industry to substantially improve the security among networked computers. Over the next five years, with the emergence of portable, handheld, and embedded computing devices, the existing wired Internet will be augmented with a range of wireless communication technologies, leading industry to place a growing emphasis on the integration of wired and wireless networks.

Goal: Provides testing and measurements support to help the networking industry achieve objectives associated with both media convergence and with Internet security. Developing a strong wireless networking program. Pursue two new strategic directions in networking: agile networking infrastructures and programmable network services.

Strategy 1. Agile Networking Infrastructures: In the coming decade, industry will face the need for agile networking technologies that enable software in end devices to reconfigure dynamically based on the varying characteristics of networking connectivity discovered as users move among wireless cells and as users disconnect wired devices and reconnect them in new locations after some form of movement. Work with the networking industry to define software interfaces that enable run-time applications to obtain salient measurements and parameters reflecting the varying state of network characteristics and that enable applications to adjust various parameters that change the nature of the services provided by the underlying network software and hardware. Work with the distributed systems industry to develop standard mechanisms for dynamic service discovery and automated device configuration. Work with the pico-cellular wireless industry to develop technical solutions to enable co-existence of multiple networking protocols within the unlicensed frequency bands.

Strategy 2. Programmable Network Services: Beyond agile networking infrastructures might also provide some form of internal support to enable service providers, and perhaps even end applications, to dynamically re-program network services to support specific application requirements not foreseen when the networking infrastructure was deployed initially. Work with network router and switch vendors to standardize the nature of programmable network environments and related services, which will be included in future networking equipment. Develop key, missing measurement techniques to enable programmable network services to express their resource requirements in a form that can be interpreted meaningfully among heterogeneous network nodes.

Investigate and evaluate new algorithms for path discovery in programmable networks.

5.1.2. Software

While all of the areas addressed by ITL relate primarily to software (rather than hardware), the software core technology area addresses the process of developing software – creating specifications and testing software products. Industry needs for high-quality, stable, interoperable software are dramatically increasing, as IT becomes even more ubiquitous and interconnected in the enterprise. The current shortage of properly qualified IT professionals has dire consequences in the quality, or lack thereof, of software. In order to accomplish this goal, ITL concentrates on the key areas at the forefront of technology and gets involved early. By partnering with industry, ITL ensures that industry has a stake in the tools and methods developed by ITL, thus guaranteeing industry's use of these products.

Goal: Improve the quality of software in industry by developing critical new software testing tools and methods and joint standards with industry. Develop easier-to-use and more automated testing tools including conformance tests and reference implementations for key emerging software standards, methods for defining standard interfaces to testing systems to ensure interoperability, methods to test autonomous systems components for conformance to standards, and new conformance approaches for open source code. Concentrate on enabling and core technologies and work with vertical markets as needed.

Strategy 1. Develop conformance tests and reference implementations in partnership with industry so that maximum value is achieved through the combination and application of scarce resources in a manner that minimizes the development of redundant or overlapping test capabilities.

Strategy 2. Reduce the high costs of software test development and greatly improve the efficiency of software testing through the development of a generalized approach for the automated production of software tests from specifications defined in a formal (mathematical) manner. Utilizing formal methods as the means to define specifications not only lends itself to automatic test generation but allows for the creation of precise and unambiguous requirements.

5.1.3. Information Access and Interaction

Most of today's human computer interfaces are non-intuitive, requiring difficult-to-remember sequences. Many of these interfaces are slow and error-prone for many people and represent a serious bottleneck in user productivity. To overcome these difficulties, user interactions must become more intuitive. In addition, more and more data are available through the Internet and elsewhere, but the appropriate information can be difficult to find. Pervasive computing, electronic commerce, online learning, and other key trends will continue to drive the demand for more intuitive user interfaces and for efficient access to information.

Goal: Leverage base expertise in voice recognition, text retrieval, visualization, usability, and biometrics to address human-computer interactions that are intuitive for the user and intelligent access to enormous and diverse multimedia information.

Strategy 1. Develop common tasks, evaluation metrics and protocols, reference corpora, and benchmark tests to aid industry and the research community in developing technologies to achieve more intuitive user interaction.

The technology areas to be targeted include natural modes of human-computer communication, such as speech, natural language, gestures, facial expressions, gaze, and touch. These modes of communication are particularly important for embedded devices, which will tend to be invisible to the user. Technologies in multi-modal integration, communicating with multiple, invisible embedded devices, and human-computer dialogue will need to be addressed. Another technology area to be targeted is "intelligent interfaces." These are high-level interfaces in which the user conveys their needs to the computer in an informal, intuitive manner, rather than in a detailed step-by-step manner. This would require that the computer have domain knowledge and internal models of the current situation and environment.

Strategy 2. Develop common tasks, evaluation metrics and protocols, reference corpora, and benchmark tests to aid industry and the research community in developing technologies to efficiently access all of the information and data that will be made available through the Internet.

"The fundamental challenge to greater acceptance and use of information technologies is to make them more usable. The acceptance and popularity of Web browsers demonstrate the importance of user models, human factors, and other areas where research is critically needed. To achieve an information infrastructure in the fullest these efforts must be extended to address intuitive models of use and user interface technologies to enable a class of information appliances that will become a part of everyday life. Intelligent information retrieval systems, systems for understanding speech and pictures, and systems for enabling intelligent dialogues between people and computer systems enhance the usefulness and level of use of the information infrastructure." *PITAC*, p. 32

Technology areas to be targeted include searching, such as metasearching (finding branded or trusted sites for certain classes of information, e.g., medical information), translingual searching, true multimedia searching (where text, voice, video, images, maps, etc., are mixed together and can all be searched simultaneously), and searching large documents. The need for content-based searching implies that technologies in speech transcription, audio/speech understanding, natural language understanding, and image/video understanding will need to be tackled. Other technologies to be targeted include agent technologies and filtering technologies (to intelligently retrieve appropriate information), question-answering technologies (to permit highly focused information to be retrieved), browsing interfaces, information presentation using different devices, visualization to help understand large amounts of information, and assurances that the presentation of the information is accurate and not misleading.

5.1.4. Security

Computer and data network security is at the heart of infrastructure protection but is also a key building block for electronic commerce, advanced networks, and pervasive computing. More robust, reliable, and secure software and networks are critical IT technologies needed to meet IT challenges in the next five years. ITL contributes to efforts to develop standards and test methods for other technology building blocks that integrate security functions including networks, operating systems, database systems, "middle-ware," and application platforms for electronic commerce, protection of intellectual property, and other applications. ITL collaborates with industry to establish standards for cryptographic technologies and provides leadership in the development and establishment of standards for well-defined security evaluation criteria. ITL has an additional responsibility to address the security needs of the federal government regarding protection of sensitive information and related computer systems and to support means to address the security needs of the private sector.

Goal: Work with the IT industry and users to develop necessary security standards, develop and manage supporting testing programs, explore vulnerabilities in new technologies, and develop associated guidance, including guidance on the secure management and use of systems.

Strategy 1. Develop computer security testing methodologies and IT security standards that form the basis for a comprehensive and ubiquitous security environment for use in the government and the private sector. Address needs associated with ITL's pervasive computing initiatives.

Strategy 2. Be a principal catalyst, proponent, and enabler for IT security, advancing awareness of the need for IT security in both the government and private sector.

Strategy 3. Implement NIST's responsibilities under the Computer Security Act, OMB Circular A-130, and PDD 63 to develop and issue appropriate federal

standards and guidance for the security of sensitive information in federal computer systems.

Strategy 4. Develop security methodologies and standards that improve the U.S. commercial IT security products. Establish and manage cost-effective testing programs to help assure interoperability and conformance of security products to security standards.

Strategy 5. Develop evaluation metrics and protocols, reference data, and benchmark tests to aid industry and the research community in developing identification/verification biometric technologies in areas such as face recognition, speaker recognition, and fingerprint identification. These technologies can support improved user literature, increased security, and law enforcement research evaluation techniques for biometrics interoperability and develop interoperability standards to aid industry and users in integrating biometrics technologies with other technologies such as smart cards and digital signatures.

5.1.5. Key Application Areas

Goal: Work with voluntary standards organizations to develop standards and measurements, including reference implementations and testing tools and programs to support work in key markets defined in Section 4.1.2. In addition to the strategies identified above, work in targeted application areas based on social and economic impact, the opportunity of the application area to develop key technologies, and support for the broader NIST mission key IT areas.

> *"... it is clear that the "information infrastructure" ... may have a greater impact on worldwide social and economic structures than all networks that have preceded them. The advances in computing and communications technologies of the last decade have already transformed our society in many ways... .Even so, we have only just begun to grasp the opportunities and experience the transformation that will occur as these technologies mature."* (PITAC p 11)

Strategy 1. Develop measurement tools to support the usability of electronic commerce tools by small businesses. Work with the Manufacturing Extension Partnership on electronic commerce toolkits for small manufacturers.

Strategy 2. Work with industry and government to develop standards for IT-enabled education, entertainment, financial applications, and healthcare.

Strategy 3. Work with the storage and display industries to achieve the interoperability, conformance, and security necessary to support the marketing of new storage and display technologies.

Strategy 4. Work with the scientific computing community to a Web-based infrastructure for

mathematical reference data, standards for efficient core mathematical and statistical operations in mobile code for virtual computing environments, test suites and carefully validated reference codes for selected application domains, such as electromagnetic modeling, and standards for interoperation of compute-intensive applications in distributed computing environments.

5.1.6. International Standards

Goal: Work with the NIST Office of Standards Services (OSS) and Office of International and Academic Affairs (OIAA), IT industry, and key international standards and conformity assessment organizations to establish international acceptance for information technology standards and conformity assessment systems.

Strategy 1. Work with other interested parties, such as the Information Technology Industry Council (ITI), to develop business plans that address the electronic availability of standards and new pricing models for standards so that internationally approved IT standards, such as those developed by ISO/IEC JTC 1, will be readily available in electronic form.

Strategy 2. Work with other interested parties, such as NIST OSS and ITI, to promote "one standard, one test report, accepted everywhere." ITL has been a leader in establishing internationally harmonized standards and associated testing programs for specific IT standards, such as for ISO/IEC 15408- Parts 1-3:1999, Information technology -- Security techniques -- Evaluation criteria for IT security. These precedents in successful international IT standardization and conformity assessment can serve as a basis for developing an overall international infrastructure for acceptance of IT test reports worldwide.

5.2 ITL Support Services Program for NIST

ITL provides centralized infrastructure support services for NIST. These include high-end computing and networking services, advanced mathematical and statistical consulting, site-wide telephone services, hardware maintenance for most personal computers, software dissemination, updates and support for select widely-installed software products for personal computers and Unix-based workstations; and consulting and training related to use of central facilities and services at the Gaithersburg and Boulder sites.

Goal 1: Establish a leadership role in providing information technology services to NIST.

Strategy 1-1. Develop a cost-effective and coordinated approach to designing, procuring, deploying, and managing IT products and services working with the NIST Chief Information Officer and Chief Financial Officer, the Department of

Commerce, and other government agencies to enhance and leverage NIST's IT investment.

Strategy 1-2. Develop a base architecture for an IT infrastructure through careful planning that provides system interoperability, scalability, security, maintainability and extensibility, appropriate performance, and cost-effectiveness that meets requirements of the Department and NIST. Design and implement systems based on criteria in support of OMB A-130, PDD 63, and other federally mandated computer security requirements.

Goal 2: Incorporate quality metrics in all IT service activities.

Strategy 2-1. Apply quality metrics to IT service activities with emphasis on developing common "information and analysis" databases for acquiring comprehensive performance data on IT systems in order to improve service.

Strategy 2-2. Develop a corresponding quality metrics database for evaluating performance of centrally provided IT services. Agree upon common criteria for selecting, configuring, deploying, and managing secure high-availability IT systems. Strive for best-in-class availability.

Goal 3: Provide an integrated, secure suite of information technology resources and services in a centrally managed environment that:

- efficiently supports current NIST personnel and organizational needs;
- effectively anticipates future IT needs throughout the organization;
- maximizes positive impact to technical and administrative functions while leveraging IT support staff resources; and
- includes effective customer feedback and agreed-upon performance metrics for establishing user service-level satisfaction.

Strategy 3-1. Establish a user-defined computing environment integrating messaging, calendaring, document preparation, and administrative systems.

Strategy 3-2. Establish a common infrastructure needed to support software and hardware maintenance for desktop and server systems including automated software distribution, remote diagnostics, and error-fault reporting. Perform an extensive review of NIST desktop requirements to determine specific needs and commonalties. Identify and make available desktop systems pre-configured to integrate seamlessly into the NIST IT infrastructure. Define and develop appropriate staff resources and skills required to support a centrally managed IT environment.

Goal 4: Enhance our information technology, mathematical, and statistical collaborative and consultative services to all NIST technical and administrative staff through new approaches, tools, and training.

Strategy 4-1. Sustain and enhance broad expertise in information technology, mathematical, and statistical subdomains with direct applicability to the problems addressed by the scientific and engineering staff of NIST.

Strategy 4-2. Remain agile and responsive to the needs of other operating units of NIST and refresh the skills of the ITL professional staff to meet evolving needs of our clients. Leverage long- and medium-term collaborations with NIST staff to build and extend the mathematical, statistical, and information technology foundations/core of problem solving environments for scientific and engineering application domains by developing and disseminating mathematically robust, generic, reusable software tools.

Strategy 4-3. Develop "virtual laboratory" technology integrating sophisticated analytical models as surrogates to traditional laboratory experimentation. Incorporate effective model validation, calibration of simulations, interactive visualization, and mathematical modeling techniques in integrated problem-solving environments.

Strategy 4-4. Promote new approaches to NIST's measurements and testing programs using recent advances in mathematical, statistical, and information technologies to resolve problems and enhance productivity. Assist the application and transfer of mathematical, statistical, and information technology methods to staff in other operating units via consultation, collaborations, and online and formal classroom training.

Strategy 4-5. Identify novel applications of mathematical and statistical mobile code in nascent ubiquitous computing environments. Provide leadership in algorithmic development for distributed virtual machines and intelligent network and sensor systems, leveraging existing expertise in robust and efficient algorithm development and validation.

Strategy 4-6. Develop and disseminate electronic information tools to train and educate NIST customers in scientific and administrative applications and promote development of new education tools and approaches.

Goal 5: Provide an integrated, effective suite of scientific information technology resources and services in an integrated high-performance computing environment.

Strategy 5-1. Leverage scientific IT investments through effective hardware utilization and sharing of software. Perform frequent user job sampling to adjust for proper resource allocation and hardware configurations based on changing mixes of computational models. Incorporate performance metrics for the evaluation of hardware, software, and the management of resources by staff.

Strategy 5-2. Integrate computation, visualization, and interactive modeling into a single seamless resource.

Strategy 5-3. Maintain optimal state-of-the-art hardware and operating system configurations for core IT services through regular hardware and operating system evaluations relative to NIST's customer specific requirements.

Strategy 5-4. Serve as the proactive advocate in the definition and integration of the IT Scientific Program with objectives established by other NIST operating units' strategic directions and their corresponding IT requirements.

Goal 6: Provide an integrated, effective suite of centralized administrative and support applications and services that promote further development of the E-enterprise.

Strategy 6-1. Develop common database infrastructures that allow for sharing of common information and minimize data re-entry in multiple systems.

Strategy 6-2. Develop administrative applications that share information freely, have a common look and feel, and maintain required levels of authentication and security in a robust stable environment. Ensure upward compatibility of systems and data to the division, laboratory, institute, and department levels.

Strategy 6-3. Develop a data warehouse and data mining techniques to readily access and produce administrative reports requested by NIST management, NIST and DoC Budget Offices, and auditors.

Goal 7: Provide state-of-the-art voice telephone and data network services that offers high-availability, cost-effective services with an effective link into federal government-provided services and cost structures.

Strategy 7-1. Migrate current telephone and network infrastructures to a common shared infrastructure technology. Develop necessary staff expertise to investigate and evaluate relevant factors to merging NIST telephone and network services.

Strategy 7-2. Complete the NISTNet network modernization project with the goal to provide a modern, centrally managed, remotely administered, secure and high-availability service.

6.0 Strategic Resource Requirements

ITL's success in achieving the goals identified in Section 5 and in having the desired impact on our customers and partners is dependent on technology, human resources, and adequate budgetary resources. In securing future resources in each of these areas, ITL has the ability to affect, but not control, the final available resource. ITL and NIST will strive to ensure that resources are available to meet our strategic program requirements in a timely fashion. As reference, Appendix C provides detailed information of ITL staffing and budget resources.

Of the three areas, political trends and legislative activities may alter funding levels both for NIST and ITL and cause significant changes to our technical program areas. Our ability to affect the political climate is minimal. We must rely on our many partners in both the Executive and Legislative Branches to keep the Nation focused on the need for IT technology, the future benefits of such an investment, and the accomplishments, effects, and value of our previous IT-related investments.

The availability of the necessary technology to accomplish our research and service activities is also crucial to some of our new strategic directions. In the circumstance that the necessary technology is not currently available, such a void may represent an area of new opportunity for ITL to contribute not only to its mission, but to benefit the IT industry as a whole. Clearly in such a situation, we must carefully examine and re-evaluate our current strategies and goals prior to assuming new responsibilities.

The final resource that ITL must possess is a highly skilled and properly trained staff. The development of human resources is critical to our future likelihood of success. ITL has developed and is committed to a continuous learning program to ensure that ITL staff remains at the forefront of information technology. Staff members are also encouraged to develop with their immediate supervisor an Individual Development Plan (IDP). The goal of the IDP is to integrate ITL's professional skills needs with the employee's plans for professional growth.

Appendix A. Strategic Planning Criteria

Considerations that affect the selection of programs include NIST's scientific and technical mission, budget resources, and Administration policies. ITL formulated this strategic plan based on current resource levels and estimates for the planning period. Through its strategic planning process, ITL reviews customer needs, the problems to be solved, how ITL can address the problems, what can be delivered, and what the potential benefits might be.

ITL considers activities and projects that contribute to

- the ITL mission, goals, or planned core programs;
- the development of needed information technology, standards, metrology, or other information infrastructure;
- the development of specific broad-based solutions with potentially significant impact; and
- the support of the federal government's unique needs for computer security in its mandate to protect sensitive information systems and the privacy of information it needs to conduct government business, and compatible needs in other public and the private sectors.

Activities and projects are selected when they

- support broad industrial development of pivotal, forward-looking technologies;
- are recognized as important by industry, especially when the recognition is through research collaborations and cooperative agreements;
- do not compete with de facto standards that have broad industry support and user acceptance;
- complement, not duplicate or displace, industry or academic efforts;
- take advantage of NIST's unique resources, expertise, and skills; and
- promote new capabilities, or improve effectiveness, efficiency, and responsiveness, or result in cost savings or a beneficial return on investment including benefits to society or the government.

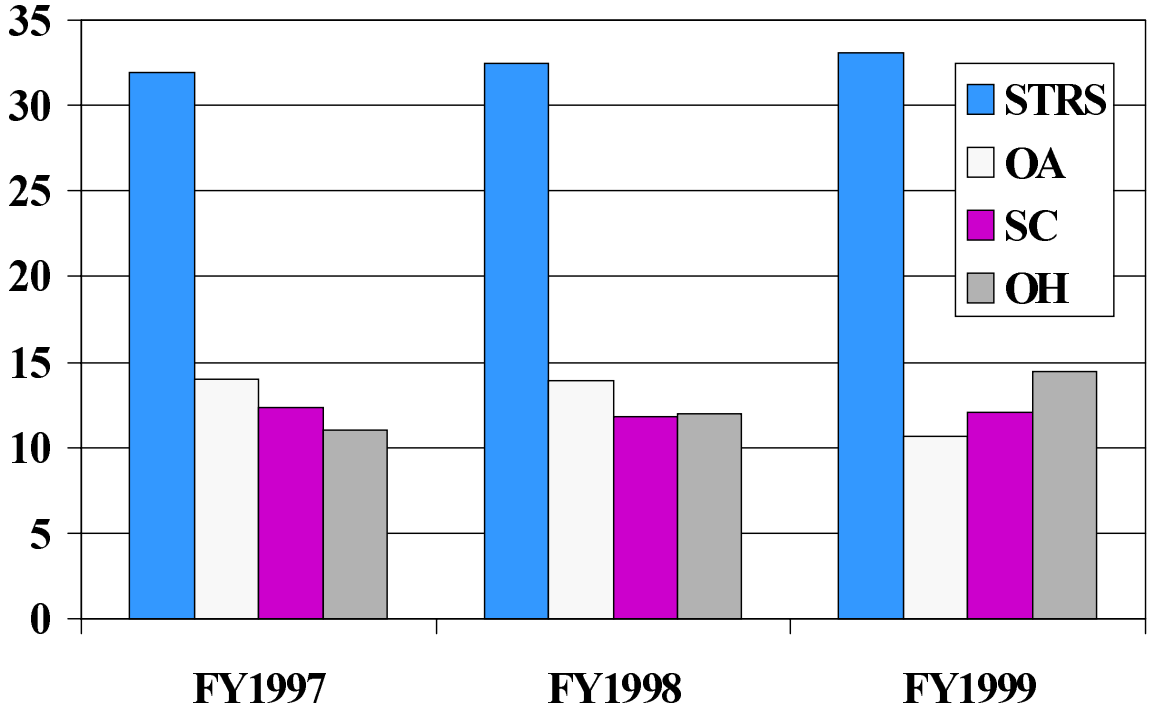
Appendix B. Profile of ITL Customers

ITL's primary customers are sectors of the IT industry, including the software, hardware, and networking segments, other federal agencies, and NIST. Although currently engaged with the major players in the IT industry, we need to strengthen our relationships with them and increase their involvement to include a much broader set of our programs. In particular, we need to increase our involvement with key industry players, the Defense Advanced Research Projects Agency (DARPA), and industry consortia. We want to work with more small- and medium-sized companies to understand their needs better and promote their use of our tests, and testing companies to encourage their use of automated testing products. We also want increased involvement with other federal agencies to provide another source of funding for our projects.

It is particularly important for NIST to establish stronger relationships with consortia and standards organizations building open standards. Standards are our business—helping to create testable standards and building the tests for the standards. All of the industry consortia develop technical specifications based on market requirements, develop test methods for the specifications, and develop products that conform to the specifications and that must interoperate. This is where our customers, the major IT providers, express their measurements and testing requirements. Like consortia and standards organizations, industry and professional associations provide us with a link to our industry stakeholders. We can promote our products within the associations, and if we actively participate in their programs, the organizations are more likely to promote our work to their members.

Federal agencies are important to ITL. First, we can more readily establish working relationships with them. Second, in their information management needs, they use almost every kind of system the public uses for managing their businesses. In addition, many agencies must build or regulate some of the most sophisticated and complex systems. Through these relationships, we discover industry needs, and share with the agencies the lessons learned and technologies we develop that they in turn disseminate to their contractors and in-house developers. The explosion of information technology in the medical field makes the National Institutes of Health a key stakeholder in our programs. Establishing stronger relationships with other government agencies is also important for fulfilling our Computer Security Act responsibilities. Finally, we need strong relationships with the National Security Agency to help ensure long-term stable other-agency (OA) funding that supports projects that meet our mission requirements.

Appendix C. ITL Resources ($M)



Appendix D. Division Strategic Plan Summaries

Mathematical and Computational Sciences Division

Mission. The Mathematical and Computational Sciences Division provides technical leadership within NIST in modern analytical and computational methods for solving scientific and engineering problems of interest to American industry.

Customers. In order to accomplish our mission we work to ensure that sound mathematical methods are applied to NIST problems, and improve the environment for the application of computational science at large. Consequently, MCSD customers are both internal and external to NIST. Within NIST, we work with scientists and engineers to satisfy needs for applied mathematics, numerical analysis, and scientific computing. Externally our customers are IT consumers in the technical computing market, both developers of IT products and users of computational science methodologies in industry, government, and academia. We are challenged to achieve both a large impact and balance in our programs with a very small staff.

Strategies. Long- and medium-term collaborations with NIST scientists and engineers are an important means of satisfying our internal customers. ITL mathematicians are best able to contribute to NIST programs if they take the time necessary to learn about the application domain and become partners in a team attacking a given problem. Cooperative efforts to improve the output of NIST research allow ITL to make broad impact in areas where it would not have the necessary credibility to act alone. The expertise we bring to the table in such collaborations lies in areas of applied mathematics, numerical analysis, and computer science. The general techniques employed transcend application domain boundaries, which allows mathematicians to impact multiple areas.

A critical requirement for this work is the establishment of wide expertise in mathematical subdomains that have potential to impact NIST programs. This requires a highly qualified, versatile, and well-connected research staff. In order to track emerging mathematical trends, our staff must be active in professional organizations, attend conferences and workshops, and read widely. We make our capabilities known throughout NIST via seminars, short courses, and active Web services. In order to insure that we are prepared to satisfy future NIST needs, we must also track trends in the NIST Laboratories. We do this by maintaining close contacts with technical staff of other Divisions, and by regular involvement in planning activities involving all NIST OUs. When necessary, we develop new expertise via staff training or developmental assignments. When staff attrition occurs we make new hires with skills in areas identified as high-priority needs.

Another technique for satisfying needs of a large customer base is the development of generic algorithms and reusable software. Many of our long-term collaborations result in the development and distribution of problem-solving environments (PSEs) focused on a particular application area. Such systems typically have a very high-level user interface, a library of problem-solving components, and capabilities for visualization, steering, and data management. These are developed when a critical need exists which cannot be satisfied by any commercial product. The resulting systems can be used by our colleagues in other NIST Labs, as well as by external users, as tools to solve research problems in their domains.

We also make an impact on our internal customers via the development and dissemination of generic mathematical software components that satisfy current and anticipated needs of NIST researchers. In doing this, we are careful not to be in direct competition with commercial entities. Rather, we select areas in which no such software currently exists, and make the resulting software widely available. In this way, we are not only able to satisfy local requirements, we also can catalyze the development of commercial products and standards externally. The focal point for our distribution of software and related information is the NIST Guide to Available Mathematical Software, a popular Web resource available since 1993.

The division's external efforts are focused on the technical computing market. This is primarily science and engineering applications, but also touches other areas such as large-scale financial modeling. We have impact both on the developers of software for technical computing, as well as upon scientists and engineers in industry, academia, and government who use mathematics and computation in their work.

We promote the development of de facto standards for technical computing software. Such standards serve to increase the capability, performance, and portability of technical computing applications. To do this work, we seek leadership positions in relevant community forums, such as the BLAS Technical Forum (for linear algebra software) and the Java Grande Forum (for high performance numerical computing in Java). We develop reference implementations of emerging standards, some of which have found their way into commercial products.

We provide mathematical reference data needed by software developers to test their products. In doing so, we select fundamental mathematical domains which promise the widest possible impact, such as mathematical functions, linear algebra, and differential equations. Such data includes mathematical formulas, graphs, tables, test problems, software, and documentation. This information is also highly valued by the practitioners of computational science at large. Because of this, we develop well-designed Web-based services to disseminate this information to the widest possible audience. Unfortunately, the state of display mechanisms, semantic-based exchange protocols, and distributed

scientific computing systems are still quite primitive. This leads us to be active in community efforts, like the OpenMath Consortium, to develop new standards in this arena.

NIST scientists and engineers are heavy users of technical computing software. Since serving these users is part of the MCSD mission, we are careful to select external projects that also satisfy current or projected needs of our internal customers. This affords us much needed leverage in satisfying a very wide customer base with a relatively small staff. This interaction works both ways, of course, as algorithms and software developed primarily to satisfy an internal need is widely distributed externally. Our work on the NIST Guide to Available Mathematical Software and the ACM Transactions on Mathematical Software provides a focal point for such efforts. Software disseminated using these mechanisms has also found its way into commercial products.

Trends in Applied Mathematics and Computational Science
Advances in information technology will lead to greater demands for applied mathematics, numerical methods, and related software. Modeling and simulation will become a widely deployed technology. Both information resources and computation will become distributed and network-based. NIST scientists will demand more precise models and computation. The problems posed will increase in difficulty due to size, complexity, or inherent pathologies. New application areas and solution methodologies will emerge. The following paragraphs explore these trends further.

Emergence of Virtual Science and Engineering. Information technology is transforming the foundation for industrial design from physical testing, prototypes, and pilot plants to one based on computational modeling and simulation. This has already occurred to a great extent in the aerospace and auto industries. It is beginning to also take hold in chemical engineering, materials processing, and even entertainment, where increasingly realistic representations of the physical world are in demand. Yet, essential ingredients for the successful application of these technologies by industry are missing. The ordinary user of complex modeling packages has few tools available to assess the robustness, reliability, and accuracy of models and simulations. Without these tools and methods to instill confidence in computer generated predictions, the use of advanced computing and information technology by industry will lag behind technology development.

Needs. Developers and users of modeling and simulation need methods and metrics to assess the accuracy, sensitivity, and range of applicability of models, solution algorithms, and software. Examples include problem suites, reference data, reference software, testing protocols, and environments for testing and evaluation. Also of interest is the systematic calibration of models with experimental results.

Evolving Architecture of Tools for Computational Science and Engineering. Modeling problems at institutions like NIST often exceed the capabilities of commercial systems, and hence research groups often must develop special-purpose systems to attain their goals. Such systems typically have a very high-level user interface, a library of problem-solving components, and capabilities for visualization, steering, and data management. These have come to be known as *problem-solving environments* (PSEs). While PSEs are critical, they are complex and expensive to develop, requiring expertise research teams typically do not have.
The widespread availability of low-cost networked workstations will lead to growth in coarse-grained distributed computation. PSEs must be able to operate in such naturally heterogeneous environments. Current mathematical software, a core component of PSEs, is not designed to do this. Reference data and other information resources needed by PSEs will also be physically distributed by nature and integrated with applications on demand. The distinctions between data resources and software components will become fuzzy.

Needs. Careful study of the generic architectural components of PSEs is needed so that toolkits enabling the easy composition of domain-specific PSEs can begin to be developed. The creation of math software components capable of operating in heterogeneous distributed computing environments must be considered. Virtual machines and portable object codes (e.g. Java) are critical to such operation. Standard application programmer interfaces for core functions must be developed. Stable and trusted sources of math reference data and the means to locate it must be available. Exchange of such data demands semantically rich formats for mathematical information.

Future NIST Needs in Applied Mathematics. Emerging application areas within the NIST laboratories with expected needs in applied mathematics include biotechnology, bioinformatics, combinatorial chemistry, computer-aided construction, meso- and micro-scale material models, MEMs, nanotechnology, network modeling, optical technology, and security modeling. Problems in these areas have widely varying characteristics. Some involve the manipulation of very large data sets, requiring operations such as compression, thinning, classification, approximation, search, and pattern recognition. Some data sets are geometrical in nature, such as those from 3D scanning. Other problems involve complex systems exhibiting various kinds of pathological behavior: very large, very nonlinear (e.g. divergence can occur when very close to the solution) ill-posed, non-smooth, noisy. Models from core areas will become more challenging as they seek greater fidelity by increasing in size, becoming three-dimensional, adding more detailed physics, or bridging length scales that have traditionally been attacked by radically different methods.

Needs. Capabilities in the following areas are needed: hybrid and heuristic optimization methods, fast semi-analytic methods (e.g., fast multipole), stochastic methods (e.g. Monte Carlo, importance sampling), discrete methods,

combinatorial methods, computational geometry, methods for inverse and ill-posed problems, adaptive methods.

Strategic Technical Directions for the Division

Measurement and Calibration for the Virtual Sciences. We will focus attention in our modeling and simulation efforts with other NIST laboratories on questions of validation and calibration of mathematical models, as well as in the careful characterization of the properties of solution algorithms. We will develop a collection of core techniques and tools that will lead to increased reliability and robustness of simulation software. Among these tools to will be collections of reference data to aid in the development and evaluation of models, algorithms, and related software.

Problem-Solving Environments. We will seek opportunities to collaborate with other NIST Laboratories on the development of domain-specific problem-solving environments. In doing so we will attempt to characterize architectural elements and components that can be packaged for reuse in the development of other PSEs. In addition, we will work to develop demonstrations and standards for the interchange of mathematical data in support of network-based PSEs. Some of the key technologies are XML, MathML, and OpenMath.

The division will remain involved in community-based efforts to evolve Java for scientific computing. At the same time, it will be necessary to develop core math libraries in Java, both to bootstrap the development of serious applications, and to explore new paradigms for the delivery of numerical components to users.

Modern Methods in Applied Mathematics. We will continue to track the mathematical needs of modeling and simulation efforts within the NIST Laboratories, providing consulting and collaboration in areas where we have existing expertise, and developing expertise in new application areas as significant needs arise. In addition, we will track trends in applied mathematics, developing needed competence as necessary to exploit the most powerful modern tools available in the field. Among the areas in which we will work are the following.

- The Non-Intrusive Scanning Technologies initiative of BFRL will develop technologies for real-time monitoring of construction sites, with demands for complex surface modeling and 3D object recognition.
- Modeling of manufacturing processes at meso- and micro scales (from 10s of mm down to about 0.1 micron), such as that required to develop highly polished surfaces, is a growing concern within MEL.
- New techniques for thinning, compressing, approximating, characterizing, visualizing, navigating and searching massive data sets must be devised. Such data mining will have applications in CSTL, MSEL, and BFRL.
- Combinatorial methods for materials discovery and analysis is a new NIST-wide interest.

- New methods of importance sampling promise to significantly accelerate convergence of Monte Carlo methods, yielding breakthroughs in many previously intractable problems will be further developed and applied.
- Fast semi-analytic methods, like the fast multipoles for evaluating potentials, promise to reduce complexity of continuum problems such as electromagnetic modeling. Further exploitation of this technique is planned.
- Analysis of large-scale systems in a variety of areas, such as networking and security, lead to optimization problems which are very large, highly nonlinear, discontinuous, and noisy. Standard approaches fail in these contexts. We will explore techniques that can be applied to efficiently solve such non-standard problems.

Advanced Network Technologies Division

The Internet faces two technology challenges that industry is addressing currently: improved security and guaranteed quality of service to support the convergence of data, video, and voice traffic. To achieve the needed results, protocols and algorithms must be developed for use in the switches and routers deployed among network trunk lines. The Advanced Network Technologies Division is working with industry to meet these challenges. Over the next few years, industry will likely place a growing emphasis on the integration of the wired and wireless networks. This integration will certainly raise the technical difficulties inherent in converging data, video, and voice onto the same network infrastructure. The division has initiated a wireless communications program in order to help industry resolve the most difficult technical issues. These challenges should keep the networking industry fully occupied over the next five years. But what challenges will the networking industry face five years hence?

A wide range of portable information appliances is beginning to appear on the market. These appliances are meeting with significant consumer acceptance, and so more such appliances are likely to appear over time. Indeed, as miniaturization of digital circuits improves, the capabilities of information appliances will also improve. At the same time, a growing technology in computer-based embedded systems presages a future where our very environment, including homes, appliances, automobiles, and highways, will contain many digital processors that can be networked together for increased effectiveness. The development and deployment of mobile cellular and pico-cellular wireless systems will augment the growth in portable information appliances and in embedded systems. Five years hence, the positive feedback loop created between these complementary trends is likely to be the driving force for economic growth in the networking industry. What new technical challenges will result from this shift?

First, the agility of the networking infrastructure must improve. Increasing mobility among people and devices will mean that network connections become increasingly transient and that the sources of connections and traffic become more difficult to predict. Increases in ad hoc communication among teams that transit administrative boundaries will mean that the restrictive use of firewalls must be overcome on demand for particular communication contexts and that the use of multicast traffic must be enabled, yet be efficiently scoped and managed. An increasing need to integrate portable information devices into local networking environments will mean that service discovery and dynamic automatic configuration protocols, architectures, and standards will grow in importance to the industry.

A second technical challenge facing the networking industry involves the high cost and high risk inherent in deploying new services. As currently deployed,

network infrastructures provide a well-defined set of services to connected end devices. The end devices invoke the available services through specified technical interfaces. In order for the network infrastructure to provide new services two conditions must be satisfied. First, the new services must be designed, implemented, and deployed in switches and routers throughout the network. Second, new technical interfaces must be specified, and then end devices that want to use the new services must implement the appropriate interfaces. This two-step process consumes a large amount of design and development resource both within network equipment suppliers and network service providers. Additionally, the producers of end devices must also devote resources to allow access to the new services. This massive investment involves substantial risk because it is difficult to determine the near-term and long-term demand for the new services, as well as to calculate the price that customers are willing to pay. Further, implementing new services in the network infrastructure can take quite some time. In order to reduce the massive investment, high risk, and long lead-time needed to upgrade the network infrastructure, various companies and researchers have begun to investigate mechanisms to program network services so that the infrastructure can be modified dynamically in real-time. The technology underlying such mechanisms is often called programmable networks, or programmable network services. Inevitably, the networking industry will make some substantive move toward some level of programmable network services. Five years from now, the nature of industry specifications will change to encompass dynamic behavior, and not simply static interfaces. While the ANTD has traditionally worked with the networking industry on conventional specifications for static technical interfaces, five years hence the industry will require technical assistance on specifications and products that are more complex and more difficult to test and measure.

These technical challenges lead the division to recommend that ITL pursue two strategic directions in networking: agile networking infrastructures and programmable network services. Regarding agile networking infrastructures, we envision work along four particular lines: Internetworking, Multimedia Networking, Optical Networks and Wireless Communications. Regarding programmable network services, we foresee work along three lines: adaptive middleware, networking for smart spaces, and active networks.

Agile Networking Infrastructures

Internetworking. The division intends to work with industry to research, develop and standardize new technologies to enable the dynamic creation and management of virtual overlay networks (VONs). Our objectives are to (1) to identify requirements and technology gaps that must be addressed to realize VONs on demand; (2) to establish the need for specific industry technical standards for VON technologies; and, (3) to develop test and measurement technologies that will expedite the commercial development and deployment of VON products.

Multimedia Networking. Streaming multimedia applications levy some of the most challenging requirements on network infrastructures. For this reason, ANTD aims to understand the architecture and requirements of streaming multimedia applications, and to explore relationships between such applications and agile networking infrastructures. Our intent is twofold: (1) to identify the likely sources of Internet multimedia traffic and (2) to develop quality metrics that can be applied to assess how well a network service supports the delivery of multimedia data to users.

Optical Networks. The division foresees a need to use tunable lasers or selectable wavelengths, both at end devices and within opto-electrical or all optical cross-connects and switches. Whether tunable or selectable technologies are used, standards must be established regarding the allocation and stability of the available frequencies. Further, protocols and algorithms must be developed to enable dynamic reconfiguration of light paths within a wave-division-multiplexing network. The division will provide the technical foundation for measurements regarding the physical aspects of wavelength multiplexing, as well as the protocols and algorithms associated with dynamic reconfiguration of light-wave backbones.

Wireless Communications. The wireless communications industry will continue to research and develop coding and signal processing techniques and network protocols aimed to maximize the total information reliably communicated per second per Hertz per Joule. The division foresees a need for a publicly available reference database for the evaluation of wireless communications technology. The division also foresees a need for publicly accessible test beds consisting of a hybrid mix of simulated, emulated, and real wireless communications components that can be used to support research, development and testing of networking systems that include wireless components.

Programmable Network Services

Adaptive Middleware. Significant advances in middleware technologies will be required to enable development of distributed applications that can both dynamically adapt their structure and behavior, and control advanced network services. Such *adaptive middleware* must provide lightweight application frameworks that: (1) enable the design of reconfigurable distributed systems; (2) mask the complexity of accessing and controlling advanced underlying services; and, (3) bridge the gap between logical systems and physical resources. As an initial step in understanding the issues, the division plans to explore the design of middleware frameworks for adaptive, reconfigurable distributed systems.

Networking for Smart Spaces. With the advent of technologies such as Jini and universal plug-and-play, industry is just beginning to address this need for dynamic configuration among network devices and services. The division

foresees the need for commercial standardization regarding a number of techniques for naming, configuration, discovery, and access, and also for service description templates. As a first step toward understanding the issues, the division plans to establish an integrated wireless and wired test bed, and then to explore architectures and protocols for automatic configuration and management of dynamically varying network services and devices.

Active Networking. Currently deployed network infrastructures provide a fixed set of services that evolve slowly over time as the network operator upgrades the software in switches and routers. This model of infrastructure evolution inhibits the rapid deployment of innovative networking services that might reveal new market opportunities. Industry standards groups have taken some tentative steps to devise standards that will enable network operators to inject new services into the network and that will allow clients to discover and access those services. A more radical approach envisions injecting new services into the network infrastructure by using dynamic, mobile code languages, such as Java. Dynamic code fragments might be injected into switches and routers inside the network infrastructure or might be deployed dynamically within network servers. The division foresees that this mobile-code model will provide a flexible approach to programmable network services. For this reason, the division intends to build a base of knowledge and contribute to the development of programmable network services.

Computer Security Division

Mandate: The Computer Security Division's activities support: 1) the broad mandate of the U.S. Department of Commerce to support and enhance the competitiveness of American industry, specifically the IT industry and 2) the specific statutory responsibilities assigned to NIST in the Computer Security Act (and ITMRA96) to develop standards and guidelines for the cost-effective protection of sensitive Federal systems.

Mission: The mission of NIST's Computer Security Division is to improve information systems security by: 1) raising awareness of IT risks, vulnerabilities and protection requirements, particularly for new and emerging technologies; 2) researching, studying, and advising agencies of IT vulnerabilities and devising techniques for the cost-effective security and privacy of sensitive Federal systems; 3) developing standards, metrics, tests and validation programs: (a) to promote, measure, and validate security in systems and services (b) to educate consumers and (c) to establish minimum security requirements for Federal systems; and 4) developing guidance to increase secure IT planning, implementation, management and operation.

Vision: In support of our mission and mandate, we envision our program activities five years hence to be focused in four areas. The first is in the area of cryptography to include not only continuing our current leadership in the area of cryptographic standards and testing, but evolving the program to address mission-pertinent activities related to the seamless integration of cryptography into systems architectures. Secondly, we plan to see a focus on the activities of the National Information Assurance Partnership (NIAP), with a vision of the NIAP as the premier facilitator for the development of security specifications and associated evaluation. Our third area envisioned is in the area of security engineering, which will focus on developing metrology in the area of IT security as well as studying new technologies to advise agencies of secure use and vulnerabilities. Finally, we envision a strong commitment to continuing our statutory responsibilities to support Federal agencies through the development of security standards, guidelines, methods, and techniques for technical, managerial, operational, physical, personnel and administrative controls to protect sensitive Federal systems.

1. Cryptographic Infrastructures Program

Description: Cryptography, a foundation technology for secure distributed computing and electronic commerce, is rapidly becoming a part of the fabric of information processing. The Cryptographic Infrastructure Program will work with industry, leveraging commercial "off the shelf" products and industry standards as much as possible, to develop an overall architecture that includes needed

fundamental algorithm, protocol, and validation standards and tools, as well as the procedures and processes needed for a comprehensive, scalable, interoperable cryptographic infrastructure. That infrastructure will enable security services such as digital signatures, strong authentication, integrity and confidentiality across the government, nation, and world.

The Program will expand the current NIST cryptographic toolkit to encompass a complete suite of carefully chosen, secure cryptographic algorithms for encryption, digital signatures, and key management. Public Key Infrastructure (PKI) is a vital emerging cryptographic infrastructure, with many unresolved issues. The program will support standards, interoperability testing, interoperability profiles, and agency assistance to lead the effort to build a large, diverse, interoperable PKI for the government and nation to broadly support electronic commerce. Under the program, NIST's landmark cryptographic module validation program will be extended to encompass new algorithms and more fully support electronic commerce. The Program will require expanded laboratory facilities to test components of the toolkit and architecture, and gain a better practical understanding of the issues and solutions.

The Cryptographic Infrastructure Program will result in an architecture and toolkit with standardized cryptographic components that users can apply to their applications to construct, manage, and assess a cryptographic infrastructure that meets their needs for secure, interoperable systems for electronic commerce. The program will also develop and promulgate appropriate guidance to agencies.

2. National Information Assurance Partnership

Description: Building secure information technology (IT) systems is of paramount importance to the U.S. Government and the private sector. IT systems depend on well-engineered, security-enhanced IT components, or products. The National Information Assurance Partnership (NIAP) is a NIST and NSA initiative to increase IT security by collaborating with industry in security testing and evaluation, research and information assurance methodologies. The long-term goal of NIAP is to help ensure the security of IT systems and networks through the development and implementation of cost-effective testing, evaluation, and validation programs, supplemented with appropriate guidance.

In pursuit of this goal, the partnership seeks to: promote the development and use of evaluated, security-enhanced IT products; further the growth and development of a commercial IT security testing industry; support a framework for international recognition and acceptance of IT security evaluation results; foster research and development in IT security requirements, specifications, tests, tools, and metrics. The testing, evaluation, and validation programs developed by NIAP are designed to: ensure that evaluations of IT products and protection profiles are performed to high and consistent standards and are seen to contribute significantly to confidence in the security of those products and

profiles; increase the availability of evaluated, security-enhanced IT products and protection profiles for national use; eliminate duplicate evaluations of IT products and protection profiles; and continuously improve the efficiency and cost-effectiveness of security evaluations and the validation process for IT products and protection profiles.

3. Security Engineering and Emerging Technologies

Description: Building, testing and deploying composable, scalable, and secure networks and systems in a cost-effective fashion is perhaps the single-most demanding technical and management challenge of any modern enterprise. Meeting this daunting challenge requires advances in security metrology and testing technologies and an increased understanding of the available technologies, their vulnerabilities, and cost-effective ways to implement available technology. This program will: 1) research new and emerging technologies in order to develop and promulgate provide guidance on emerging technologies, vulnerabilities and proper use; and 2) work to advance security metrology and testing methods so as to improve the security of commercial products and also to work closely with the NIAP to advance testing and evaluation.

4. Agency Assistance Program

Description: The Agency Assistance program's mission is to assist U.S. Government agencies with a broad range of computer security issues, including guidance on computer security management issues and technical assistance with computer security techniques, technology, and its use in protecting unclassified systems and data. Due to the breadth of this mission, the size of the unclassified U.S. Government, and the small size of the NIST security policy, management and operations program, the program strives to address the most important issues in a way that has the maximum impact and benefit to agencies. Note that the mission of assisting agencies crosses all programmatic areas to varying degrees.

The Agency Assistance program has been concerned primarily with computer security program management guidance and assistance; however the future direction of the program will additionally be expanded to also emphasize technical guidance. The program also requires a strong awareness component. One of the Computer Security Division's strengths has been in creating computer security architectures, with a strong knowledge of computer security technology management. The Agency Assistance program will need to expand to also concentrate on assisting agencies (and industry) in creating and management security infrastructures and interoperability needs, especially in the areas of Public Key Infrastructures (PKI), firewalls, Virtual Private Networks (VPN), and the protocols and interfaces required to combine these technologies into unified,

usable systems. The program will implement these technologies and play a strong technology-transfer role to the agencies. Guidance must continue to retain the computer security program management aspect, but will move towards inclusion of the management of specific computer security technology issues.

Information Access and User Interfaces Division

Expected Technology Landscape in Five Years (2004)

We expect that the Internet will have grown to the extent that perhaps a billion users will have Internet access. The Internet will likely be the preferred source of all information. Electronic commerce will be firmly entrenched and will likely completely change how things are bought. Information access on the Web will have progressed beyond returning a priority list of documents; certain contents of documents, or answers to users' queries based on these contents, will also be returned.

Portable computing devices, with wireless communications and hookups to the Internet, will be commonplace. Networked computers and sensors embedded in appliances, autos, building walls and common objects will start to emerge. Many of these devices and sensors will be very small and largely invisible to the user.

Speech, language, and vision technologies will be used with increasing frequency to interact with computers. PCs will still be very popular, and therefore the keyboard, screen, and mouse interfaces will still be in use. GHz processors with GByte RAM and 30 GByte hard drives will be common place, providing enormous cycles and memory for advanced information access and user interfaces.

Access to computers, bank accounts, files, ATM machines, etc. through biometrics will be commonplace. Although fingerprints will be the main biometric used, applications using other biometrics – including speech, face, retina, iris, handwritten signature, hand geometry, and wrist veins – will also be available. Smart cards for electronic commerce, digital signatures, and access over the Internet will be popular applications for biometrics.

Because of this expected technology landscape, the IAUI Division intends to focus its five-year strategic plan towards providing research, measurements, testing protocols, test and reference data, and standards in the following areas: (1) intuitive user interaction, (2) access to enormous and diverse information, and (3) biometric access control.

Intuitive User Interaction

Most of today's human-computer interfaces are non-intuitive, requiring difficult-to-remember sequences of pointing, clicking, and typing. Many of these interfaces are slow and error-prone for many people. Recall that the basic Windows interface was developed in the 1970s.

To overcome these difficulties, user interactions must become more intuitive. There are several approaches to this. One involves developing natural modes of human-computer communication, such as speech, natural language, gestures,

facial expressions, gaze, and touch. These modes of communication are particularly important for embedded devices, which will tend to be invisible to the user. Issues of multi-modal integration, communicating with multiple, invisible embedded devices, and human-computer dialogue will need to be tackled.

Another approach to intuitive user interaction involves developing “intelligent interfaces.” These are high-level interfaces in which the user conveys their needs to the computer in an informal, intuitive manner, rather than in a detailed step-by-step manner. This would require that the computer have domain knowledge and internal models of the current situation and environment. Technologies by which the high-level interfaces can be automatically learned are important here.

A third approach involves delivery of information in an implicit, rather than explicit, manner. This is modeled after the human focus-of-attention mechanism, where humans pay explicit attention only to a small number of items at a time, while most other environmental events are “implicitly” perceived in a background mode; but once something “interesting” is perceived in the background, attention can be focused on it. If information can be delivered using this model, than the combination of explicit and implicit information delivery can potentially be used to deliver lots of information in an intuitive way. An example of implicit information delivery is generating a soft musical tone whose pitch indicates the amount of network traffic.

Situated information presentation – determining exactly what information to present, which devices to use for presentation (assuming a multi-device environment), and how to present it in an intuitive manner based on the current situation – is an issue that will need to be tackled. Face recognition, speaker recognition, tracking people, and situation awareness are technologies that can be used for providing context for situated human-computer interaction, situated information access and situated information presentation. Another area that needs to be explored is distributed collaboration.

Many current projects within the division are contributing to these objectives, including speech transcription testing, testing for speech understanding, DARPA Communicator testing, speaker recognition testing, face recognition testing, virtual reality and collaboration in manufacturing, webmetrics, and smart space testbed.

Access to Enormous and Diverse Information

As the internet grows, more and more multimedia data will be made available through the internet, including documents and books, images, video, audio, maps, tables, geographic information, and relational databases. Technologies to efficiently access all of this information and data will need to be developed. Searching issues include metasearching (finding branded or trusted sites for certain classes of information, e.g., medical information), translingual and multilingual searching, true multimedia searching (where text, voice, video,

images, maps, etc. are mixed together, and can all be searched simultaneously), and searching large documents. The need for content-based searching implies that speech transcription, audio/speech understanding, natural language understanding, and image/video understanding become important issues. Agent technologies and filtering technologies will be needed to intelligently retrieve appropriate information. Question-answering technologies will permit highly focused information to be retrieved. Browsing interfaces are also important.

Implicit information delivery can provide a way to deliver large amounts of information in a manner that is easy and natural for people to comprehend. Other issues include information presentation using different devices, visualization to help understand large amounts of information, and assurances that the presentation of the information is accurate and not misleading.

Current projects within the division contributing to these objectives include TREC, speech transcription testing, speaker recognition testing, spoken document retrieval, topic detection and tracking, IR framework, face recognition testing, NIRVE, and smart space testbed.

Biometric Access Control

As the number of devices and accounts accessed by users continues to expand in the pervasive computing environment, a reliable method of secure access that is user friendly is essential. Biometrics can provide this secure access technology.

Biometric recognition can be used in an identification mode, where the biometric system identifies a person from the entire enrolled population by searching a database for a match. A system also can be used in a verification mode, where the biometric system authenticates a person's claimed identity from his/her previously enrolled pattern. Face recognition, in both still images and video, can be used for biometric access control, as can speaker recognition and fingerprint identification.

Current projects within the division contributing to these objectives include face recognition testing, speaker recognition testing, and optical information processing.

High Performance Systems and Services Division

Mission

To make a difference for the U.S. information technology (IT) industry by providing technical expertise and leadership in the area of convergent information systems. We will provide an impartial, balanced leadership in IT system areas, which have the potential of making major impacts on the U.S. information industry.

There is today a confluence upon traditional computing of overlapping demands from the internet, e-commerce, multimedia, mobile computing and high-definition, interactive digital TV, to name a few. The division integrates both hardware and software elements of these areas. This may involve data collection, storage, measurement, manipulation, reduction and display. Our focus is at the system level, where interoperability is key and the convergence of technologies gives tremendous leverage.

Elements of our Strategic Planning

Many information system applications have moved to Web-based organization. One of the largest of these is the field of business. Given the explosive growth and enormous potential of electronic-commerce, it is not surprising that much of our research involves e-commerce in one guise or another. Scientific computing continues to shrink in relative computer market share. New scientific systems are often based upon commercial machines designed for distributed business applications such as econometric modeling. Communication and computing are blurred together—telephones use computers and TV is becoming digital and interactive. Small low power PDAs are rapidly gaining increased functionality.

The dynamic nature of e-commerce makes strategic planning unrealistic beyond three years. Our selection criterion is based upon projected economic potential combined with technical assessments we make on feasibility (a rough return versus risk judgment).

Defining and Accomplishing Undertakings

A number of factors contribute to our selection of projects. Careful attention and analysis is paid to recognizing technological and business trends in the IT systems sector. We choose projects that address important barriers to IT and are in areas that we can contribute with good effect. We reappraise the value of each of efforts on a continuing basis. Every project proceeds against measurable goals and milestones, each of which meets expectations of our U.S. IT industry customers. A typical undertaking would be to provide measurements or to develop a reference implementation of a standard. Our contribution is often highly valued because NIST has a reputation for being absolutely fair and even-handed.

Recent project areas have included:

- **Standards and Specifications.** Examples are IMPI (Interoperable Message Passing Interface) and OEB (Open Electronic Book).

- **Reference Implementations.** We have built an IMPI tester and our DASE effort is in progress. (DASE stands for Digital TV Application Software Environment.) Each of these involves significant technical competence and resources.

- **Architectural Evaluations.** Our Biometrics Test Bed has been exploring the issues of interoperability among different devices from distinct vendors. Our interest in micro e-commerce arose from opportunities seen in available commerce architectures.

- **Performance Tools.** In evaluating the characteristics of PC clusters, we have found that there is a lack of simple, easy to use tools. Our code has helped us and has been distributed to others doing similar evaluations.

- **Evaluation Methodologies.** We have introduced automated DVD tests that will make DVD quality assessment less costly. Similarly, our communication stall metric provides a sharp indication of when something is seriously wrong in a distributed program.

Specific instances of industrial sponsorship and endorsement are:

- DASE Committee of the Advanced Television Systems Committee--Lucent Technologies, Gateway 2000, MicroSoft, Motorola, SUN, Scientific Atlanta, ABC, PBS, DirecTV and others (the list is long)

- Open E-book Committee, Electronic Book Exchange Committee--MicroSoft, Adobe, Rocket Book, Softbook, Bertleson, R.R. Donnelly, etc.

- Biometrics Consortium, BioAPI Consortium—Compaq, Intel, MicroSoft, TRW, Miros, IBM, American Express, SUN, CitiBank, among others.

Distributed Computing and Information Services Division

The Distributed Computing and Information Services Division is ideally positioned to generate substantial improvements in the value of information technology at NIST. These improvements will increase the robustness of NIST's IT architecture and yield an environment that will nurture scientific inquiry and streamline administrative processes.

Although technology will continue to change rapidly over the next three to five years, our course of action is clear -- the division must provide value and demonstrate leadership in controlling the cost of distributed computing and providing an IT services infrastructure that will enable NIST to gain maximum benefit from IT. This can best be accomplished through comprehensive desktop support services, integration and modernization of information systems, increased reliance on centrally managed IT infrastructure resources, and diligent implementation of a comprehensive computer security program. Each of these strategic initiatives will provide NIST with greater value from its IT resources through reduced overall cost and risk and improved access to information and resources.

NIST has a core mission to provide leadership to the nation in IT. NIST must also set an example of "Best in the World" implementation of IT principles and practices. Focus within the division on the following strategic initiatives will maintain our vital partnership in support of NIST's mission for the foreseeable future.

Comprehensive Desktop Support Services

The division provides help desk services and hardware maintenance for NIST PC users. This service is primarily reactionary and does not provide a full complement of proactive support resources and life cycle management. Substantial cost savings could be obtained through greater centralization of software licensing and PC procurement and increased standardization of the desktop-computing environment. Also, technologies now exist to provide greater management of desktop resources thereby reducing the overall cost of desktop support and increasing the opportunity to take advantage of enterprise applications that will increase productivity. The division must increase its advocacy for improved end user computing productivity and continually seek ways to improve service delivery through effective deployment of human and technology resources.

Integration and Modernization of Administrative Information Systems

The division has responsibility for developing and maintaining NIST's administrative databases and information systems. These systems have been developed using various technologies and derive their input from various data

acquisition paths. Initiatives exist at NIST (e.g., Electronic Approval) and the Dept. of Commerce (e.g., CAMS) to integrate and standardize some of these systems. NIST is often looked to for leadership in implementing these new systems. The division must demonstrate leadership in modernizing administrative systems and streamlining related workflow through: (1) planning the migration of DOS-based, stand-alone database applications to modern database architectures; (2) partnering effectively with Department-wide initiatives to ensure their successful deployment at NIST; and (3) seeking to integrate the data from these systems into an integrated data warehouse. Successful accomplishment of this initiative will require alignment of administrative systems with NIST's administrative goals. Success in this area will lead to greater efficiencies in administrative computing and increased availability of management information.

Increased Reliance on Centrally Managed IT Infrastructure Resources

The division has established an impressive array of centralized IT infrastructure resources. These include email, web, news, calendar, directory services, scientific software servers and the NIST NT domain. The division also offers central administration of NT and Unix servers for NIST organizations. This infrastructure is professionally managed and continually upgraded to provide effective services to the NIST community. It is apparent that some of the services are under-utilized and NIST incurs some lost utility and increased risk from the uneven reliance on the central infrastructure. One example is that there are estimated to be over 100 email servers at NIST all requiring separate administration and imposing an additional security risk on NIST. Consolidation of email services to the central email server would free system administration resources across NIST and improve the robustness and interoperability of email. The division must also demonstrate leadership in implementing security components such as PKI to ensure that NIST has a robust IT infrastructure to support electronic approval, e-commerce and other enterprise applications that are currently being planned. The division must continue to promote increased use of central infrastructure resources at NIST and maintain a modern secure infrastructure upon which NIST can base its IT applications to ensure future productivity, efficiency, and security.

Comprehensive Computer Security Program

It is becoming ever more apparent that the need for computer security is increasing. Government agencies (and NIST probably more so than others) are frequent targets of computer attacks from sources around the world. The division has recently been funded to increase its security resources. This is commendable but in and of itself will not be sufficient to combat the various computer security risks facing NIST. NIST is also implementing a firewall. To too is appropriate and necessary but must not lull staff into a false sense of security. A comprehensive program of security policies and practices must be implemented. Awareness of computer security must be heightened throughout

and preventative measures and actions must be taken at all levels. The three strategic initiatives proposed above will position NIST to implement effective security measures. Security is more easily achieved when systems are proactively managed by computer professionals. With increased desktop support services, desktop systems can be configured to protect against the most common vulnerabilities. Modernization of administrative systems will ensure greater protection against data loss and unauthorized access. Increased reliance on central IT infrastructure services will provide professionally managed service to all of NIST in a coordinated manner that reduces security threats.

Software Diagnostic and Conformance Testing Division

The Software Diagnostic and Conformance Testing Division's customer is the U.S. information technology (IT) industry. Thus, the thrust of our strategic plan will focus on: 1) the composition of the IT industry in the future; 2) the products and services that the U.S. IT industry will provide in the future; and 3) the future software development model used in the industry.

Shortage of Computer Scientists

The composition of the IT industry in the future will be drastically different than that of today. The current shortage of programmers will continue to escalate due to the increasing demands caused by advances in IT. Additionally, and perhaps even more significantly, programmers of the future will not have the formal training that many current programmers receive. According to the National Science Foundation, only 29 percent of all current computer scientists, systems analysts and programmers actually received a degree in computer science.

The above scenario has many implications for the division. First, the lack of formally trained IT professionals, combined with severe time-to-market pressures in the IT world, will make it imperative for us to focus on providing easier to use and more automated testing tools than in the past. Second, because of their relative ease of use, scripting languages, like Perl, Tcl/Tk and JavaScript will become much more predominant and, perhaps surpass the use of traditional programming languages

Integration of the Web with Other Media

In the next five years, the blending of the Web, the television industry, and telephony will spur the creation of a myriad of tools and services. The combination of the Web and these other media will lead to the integration of various applications within and between entertainment and electronic commerce, and will be the focal point of people's business and leisure activities.

Electronic commerce (EC) will be greatly enhanced by interactive television which will allow the consumer to buy the clothing, accessories, appliances, etc. that are an integral part of a broadcast show. For example, a "buy me" button displayed during a golfing event will allow the consumer to purchase the golf club or even golfing shirt worn by the golfers.

The infrastructure necessary to support the environment described above will include advances in user interfaces, languages, privacy and architecture. Existing Web standards will evolve to provide base display, data definition, data interchange, and integration technologies. TV standards, such as DASE, which allows interactive television applications to run on all receivers, regardless of hardware or operating system differences, will form the backbone of EC. The

integration of communication devices and the integration of applications into a Web infrastructure imply that there will be a need for new data content, data representation, and interface standards. The division will need to be involved in the development and conformance testing of implementations of these emerging standards.

Autonomous Systems and Assurance

In the next five years, a wide variety of systems having varying degrees of autonomy will proliferate. These systems include: autonomous agents; self-configuring active networks; rule-based automated ordering or scheduling systems; “smart” appliances which will be able to regulate themselves; and expert systems embedded in large systems like spaceships. These autonomous systems will be at the center of electronic commerce (EC). The increasing reliance on these autonomous systems presents problems and provides the following opportunities for research into software testing:

1) Using autonomous systems to improve software testing;

2) Testing and assurance of autonomous systems.

The division's roles in testing and assurance for autonomous systems should focus on two areas: methods for defining standard interfaces to ensure interoperability, and methods to test autonomous system components for conformance to standards

Pervasive Computing Leads to Open Source

In the future, technology will be embedded throughout the environment, found in virtually every device, appliance and piece of equipment, and networked with each other and with the Internet. The pervasiveness of this new technology implies it must have a low, per unit, cost. Artificially high costs will throttle development of new technology necessary for pervasive computing. Since 50 percent or more of software development costs are due to testing, the division will need to accelerate their research into developing new, easy to use integrated tools to enable users to proactively test applications with greater efficiency and near instant results, rather than engaging in a testing process that may take several days or weeks to complete.

As the cost of hardware is decreasing dramatically, the cost of “bread and butter” software, such as operating systems, is increasing proportionally. Since the success of pervasive computing will depend on its acceptance by business and public consumers, it must be cost appealing. This will put pressure on system software developers and suppliers to keep costs and prices as low as possible. One approach that is gaining popularity is “open source” software, such as Linux. Open source is based on the premise that certain common elements (i.e.,

infrastructure building blocks) are necessary prerequisites for software development and should be freely and openly available.

Open source software will enable the division to build software diagnostic tools and measurements that are embedded in the software to determine its conformance, rather than traditional conformance testing tools that are limited to communicating, rather than interacting, with the software.

Statistical Engineering Division

Mission

The Statistical Engineering Division seeks to contribute to research in information technology, to catalyze scientific and industrial experimentation, and to improve communication of research results by working collaboratively with, and developing effective statistical methods for, NIST scientists and our partners in industry.

In carrying out this mission, the division collaborates in NIST measurement science and technology research programs to support U.S. industry through design of experiments, statistical modeling, and data analysis. We participate in ITL's interdisciplinary research and development teams to advance information technology; we contribute to the development of appropriate statistical methodology, building on a foundation of pertinent topics in probability and mathematical statistics; and we provide leadership and computational tools to facilitate the implementation of modern statistical design, analysis and process control procedures.

Challenges and Trends in the Next Five Years

1. The division needs to remain agile and capable in order to contribute effectively to new and evolving research areas into which NIST scientists are moving. Some anticipated areas of expanding opportunity include Information Technology, Biotechnology and Computational Chemistry. Examples can be found in every NIST Operating Unit. We believe that these new research areas will call for increased competence in methodology for dealing with very large and complex data sets, such as arise in image and internet traffic data, for example.

2. There will be opportunity to leverage advances in statistical methodology and information technology for NIST applications. Recent progress in the field of statistics is making available new techniques in areas such as Bayesian methods, nonparametric smoothing, generalized additive models, and tree-based modeling methods. The challenge for the division is to bring these methods to bear on NIST problems where they can be of benefit. Continuing advances in available computing and inter/intranet resources will be available to make this happen.

3. Statistical methods play an ever-increasing role in accomplishing the mission of NIST. The requirements for expressing measurement uncertainty and the need to use statistical tools in conducting research in all fields give rise to increasing demands for use of this technology. As basic statistical methods become more widely used by industry, NIST's leadership in this area will call for continually improving the accuracy, consistency, understandability and

efficiency of our outputs. To keep up, the division must find creative ways to multiply the impact of our limited staff.

4. The division's statistical know-how should be transferred to NIST scientists and industrial collaborators in order to have maximum impact. The need in industry will be pushed by requirements for accreditation and traceability. Successful transfer requires user-friendly means of implementing and understanding statistical techniques that have proven utility in industrial applications. We must bear in mind that most of our customers in industry do not have access to statisticians.

Goals to Meet These Challenges

1. The division's goal is to maintain strong ties to all of NIST, and to be recognized as essential to the mission of NIST. Maintaining this reputation will increase our opportunities to join projects at the earliest stage and to collaborate in new research areas. Moving the division back to suitable space on the main campus would support this effort.

2. We must continually upgrade our technical capabilities. We can work toward this goal by keeping up with current computing technology, bringing outside experts to NIST to interact with staff, participating in professional conferences and workshops, strategically filling vacant staff positions to expand our skill set, and providing professional growth and recognition for our current staff.

3. Automating reusable methods and analyses will allow efficient transfer of proven methods to our NIST and industrial clients, thus extending our reach. These have to be well documented and easily understood for use by non-specialists. As appropriate, this can be implemented as macros for off-the-shelf software and/or Internet facilities.

4. We must take full advantage of the opportunity provided by our competence project to develop and demonstrate Bayesian statistical methods for metrology. This is a chance to discover the benefits and limitations of Bayesian methods for NIST applications. Worthy methodology can be institutionalized through this effort.

5. Statistical education and training provides way to transfer proven statistical technology to NIST colleagues and to industry customers. As our NIST colleagues become more statistically sophisticated, they can take on some statistical tasks for themselves and move the collaborations with division staff to a higher level of sophistication. Training industry customers enables them to benefit from proven statistical approaches that might not otherwise be available. The delivery mechanisms should include appropriate use of a range of options including paper and electronic publications, workshops, short

courses, conference presentations, and carefully chosen standards committee activities.

6. The division should maintain visible staff participation in professional associations and standards organizations. This will support recruiting and retention of excellent staff, and will increase the impact of our activities. A case in point relates to statistical aspects of the Mutual Recognition Arrangement that the BIPM has been promoting among National Measurement Institutes. Establishing and maintaining international respect for the opinions and positions of division staff strengthens NIST's leadership in the international measurement community.