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

BUILDING & FIRE RESEARCH LABORATORY

Activities, Accomplishments & Recognitions

BFRL 2003



CONTENTS

BFRL AT A GLANCE

BFRL MISSION

Meet the measurement and standards needs of the building and fire safety communities.

BFRL VISION

The source of critical tools – metrics, models, and knowledge – used to modernize the building and fire safety communities. Our programs are identified, developed, carried out, the results implemented, and consequences measured in partnership with key customer organizations.

BFRL GOALS

The building and fire communities (builders, suppliers, owners and fire safety professionals) strive to increase productivity, construct better buildings, faster, at lower cost, own buildings that are fire safe, less costly to operate, and have less impact on the environment. To meet the needs of these communities BFRL is focusing on four goals.

- **High Performance Construction Materials and Systems:** to enable scientific and technology-based innovation to modernize and enhance the performance of construction materials and systems.

- **Enhanced Building Performance:** to provide the means to assure buildings work (better) throughout their useful lives. The strategy for meeting this goal is to provide knowledge, measurements and tools to optimize building life cycle performance.

- **Fire Loss Reduction:** to enable engineered fire safety for people, products, and facilities; and enhance fire fighter effectiveness.

- **Homeland Security:** to develop and implement the standards, technology, and practices needed for cost-effective improvements to the safety and security of buildings and building occupants, including evacuation, emergency response procedures, and threat mitigation.

BFRL RESOURCES

- 155 full time staff (126 professional) with expertise in measurement, material and system performance, mathematical modeling, non-destructive testing, and diagnostics

- $44 million annual budget

- Unique facilities including:
  Integrating Sphere UV exposure chamber
  Electron microscope
  Tri-directional test facility
  One million pound testing machine
  Solar tracker
  Large scale fire test facility
  Environmental chambers

BFRL WEB SITE

www.bfrl.nist.gov

This is the biennial report for 2002-2003 for the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST), an agency of the U.S. Department of Commerce. It describes the goals, programs, recent accomplishments, and recognitions for our staff over these two years.

BFRL and its predecessor organizations at NIST (National Bureau of Standards (NBS) before 1988) have a rich history in the building and fire communities dating back 100 years. On February 7, 1904, a fire broke out in the basement of the John E. Hurst and Company in Baltimore, Maryland. Fire services responded from Washington, Philadelphia, and New York; however, each city had its own unique threads for their fire hoses and they could not connect to Baltimore's hydrant system. Those fire services were forced to watch as the fire progressed. Before it was over, the fire had burned for more than 30 hours and destroyed approximately 2,500 buildings in an 80-block area. As a result, NBS began a study of fire hose couplings and over 600 couplings were collected and analyzed from across the country. Based on this research, the National Fire Protection Association (NFPA) adopted a standard hose coupling and an interchangeable coupling device for non-standard hoses as a national model. That document continues today as NFPA 1963, *Standard for Fire Hose Connections*.

The past 100 years are filled with numerous other such cases where NIST rallied to address problems critical to the nation and the building and fire communities. Today the overwhelming issue facing us all is the security of our physical infrastructure, our buildings and structures, to terrorists' attacks.

Following the attacks on the United States on September 11, 2001, the U.S. Congress authorized NIST to conduct a two-year investigation to determine the technical reasons for the collapse of the World Trade Center buildings and look at other technical issues related to fire protection, occupant behavior, evacuation, and emergency response. As a result, BFRL has established a new goal for our Laboratory on Homeland Security. It is described, beginning on page 46, along with the progress of the World Trade Center investigation and an associated research program that have been under way for slightly over a year.

On October 1, 2002, the President signed into law the National Construction Safety Team Act that authorizes NIST to form a team that can investigate building failures where there has been a substantial loss of life or where there is the potential for a substantial loss of life. The Congress envisions investigations and follow-on recommendations similar to what is done by the National Transportation Safety Board following major transportation accidents. This is an awesome responsibility. BFRL staff members are working hard now to develop the procedures, train and equip our staff, and prepare the organization to fulfill this responsibility.

BFRL is involved in an amazing breadth of scientific, engineering, and now investigative work for the building and fire communities. The size of our staff and budget is modest. The time has long passed when any single organization like ours can act alone and expect to make a major impact on the numerous issues facing the building and fire communities and the industries involved. We must build an extensive network and work together to tackle these issues. This will greatly enhance all our chances for success. I encourage you to contact us to discuss collaborations in the many endeavors described in this report.

GOAL 1

HIGH PERFORMANCE CONSTRUCTION MATERIALS AND SYSTEMS

To enable scientific and technology-based innovation to modernize and enhance the performance of construction materials and systems.

The strategy to meet this goal includes the development of world-class science-based tools – measurements, data, models, protocols, and reference standards – to

- *fully integrate and automate the construction process to achieve significant cycle time reductions;*
- *predict and optimize the performance and minimize the environmental impact of concrete in the built environment;*
- *predict the service life of high performance polymeric infrastructure materials; and*
- *enhance the safety and performance of structures under extreme loads.*

The desired outcomes are to enhance global competitiveness of U.S. industry and the safety and sustainability of the Nation's buildings and physical infrastructure.

Service Life Prediction (SLP) of Polymeric Materials

The objective of the SLP program is to develop, validate, and implement an advanced reliability-based methodology and associated metrologies for predicting the service life of polymeric materials exposed in their intended operating environment. This research is being conducted in partnership with industry, other BFRL divisions, NIST laboratories, and Federal agencies along with universities and foreign research institutes.

Intended Outcome and Background

The intended outcome of this research is to develop, implement, and gain worldwide acceptance of a reliability-based methodology for predicting the service life of polymeric materials exposed in their intended service environment. The reliability-based methodology differs from the current methodology mainly in its designation of the standard of performance against which laboratory or field exposure data are compared. The reliability SLP methodology uses laboratory-based exposure results as the standard of performance while the current methodology's uses field exposure results. Since field exposure results are neither repeatable nor reproducible, this seemingly subtle change has transformed the SLP problem from a mathematically and scientifically intractable problem to one that is scientifically tractable.

Introduction and implementation of the reliability-based methodology into industrial practice is being achieved through the activities of a number of on-going and proposed industry/government/university consortia. The three on-going consortia are the Coatings Service Life Prediction Consortium, the Sealants Service Life Prediction Consortium, and the Polymeric Interphase Consortium. Industry is requesting that BFRL consider establishing industry/government consortia to investigate the photocatalytic reactivity of pigments and the optical properties of polymeric materials. Current industrial sponsors include Atlas

Material Testing Technology, LLC, Atofina Chemicals, DAP, DeGussa, Dow Chemical, Dow Corning, Kaneka, MTS, PPG, Sika, Solvay, Sherwin Williams, Tremco, Visteon, and Wacker. Federal Agency sponsors include the HUD-PATH Program, Air Force Research Laboratory Material and Engineering Directorate, Smithsonian Environmental Research Center, USDA Forest Service Forest Products Laboratory, USDA UV-B Program, and the Federal Highway Administration.

Objectives of these consortia include 1) greatly minimizing or eliminating the contributions from experimental errors to the total variation in the degradation response of polymeric materials, 2) linking field and laboratory exposure results, and 3) gaining a fundamental scientific understanding of the degradation failure mechanism and the contribution that each constituent or combination of constituents plays in the service life of the bulk polymer.

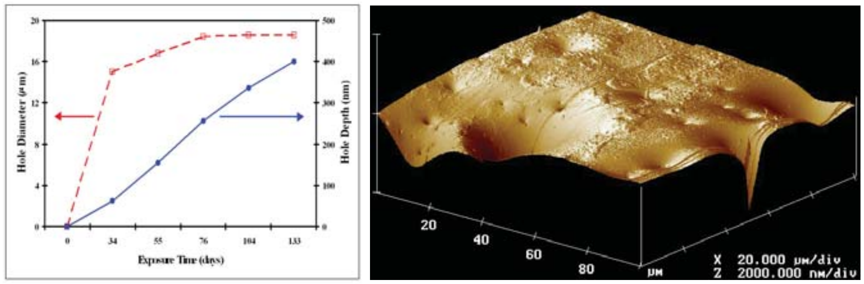
Efforts in FY03 have been aimed at completing the first objective and continuing efforts on objectives 2 and 3. The inability to generate reproducible and repeatable exposure laboratory results, objective 1, has been long recognized by industry as a weakness in current field and laboratory exposure data. A NIST patented weathering device, the SPHERE, has demonstrated capability to minimize or eliminate the variation contribution from all known experimental error sources and, as such, is capable of generating both repeatable and reproducible laboratory exposure results. Extensive efforts have also been made to characterize field weather variables in the same manner that they are characterized in the laboratory. Eight field exposure sites have been instrumented with a solar spectral radiometer and a weather station and the collected data can be mathematically transformed to weathering variables used in characterizing the exposure environment in the laboratory.

Efforts to link field and laboratory exposure data have greatly intensified over the last year. NIST's efforts in making this linkage have gained the interest of industry and have spawned requests from industry to initiate two new consortia—optical properties of polymeric materials and photocatalytic effects of pigments. Linkage between field and laboratory experiments must be and has been achieved at several physical and chemical scales of degradation (e.g., nanoscale damage, macroscale physical damage, chemical changes) in both the field and the laboratory. Parallel to these measurement linkages, an extensive effort has been initiated to derive and verify scientific models for mathematically linking these field and laboratory results. In addition, we are in the process of verifying that total spectral dosage can be used as a common exposure metric for quantifying and comparing the severity of field and laboratory exposure environments. Once a linkage between field and laboratory exposure results has been achieved, then it should be possible to design experiments in which the contribution of individual constituents of a polymeric material can be ascertained relative to the service life performance of the polymeric system.

ACCOMPLISHMENTS

Reliability Approach to Prediction of the Service Life of Polymeric Construction Materials

Starting in the 1980's, the mass and volume consumption of polymeric materials exceeded that of all other materials and this dominance is forecast to continue into the 21st century. The major deterrent to the continued growth, application, and acceptance of these materials is the inability to quantitatively and accurately predict the service lives when they are exposed in their intended service environment. The objective of this multi-agency, NIST-lead industrial consortia research program is to implement a reliability-based methodology to link laboratory and field exposure results and to quantitatively predict the expected weathering service life of an organic coating when it is exposed in its intended operating and service environment. In this methodology, laboratory experiments are experimentally designed to cover the range of exposure conditions that a material will be subjected to in-service.



Nanoscale localized pitting observed in a polymeric coating exposed to ultraviolet radiation at elevated temperature and humidity. Pits grow both in depth and diameter with exposure time (left hand side). On right hand side, a 3-D atomic force nanoscale image of pits is displayed.

Field exposure experiments, on the other hand, are viewed as just another laboratory exposure experiment albeit ones in which individual weathering factors can't be controlled, but they can be monitored and characterized in the same manner as they are in the field (that is, field and laboratory experiments can be compared). A key difference in a reliability-based methodology, relative to the current methodology used for estimating the service life of polymeric materials, is that all measurements are quantitative and of known precision and accuracy and that, as much as possible, the same measurements are applied in both the field and the laboratory. These degradation measurements span the range from nano- to macroscale chemical and nano- to macroscale physical degradation measurements and all measurements are related to an exposure metric delineating the severity of an exposure environment. To date, linkages have been established among chemical and physical, nanoscale to macroscale measurements and total effective dosage, the selected exposure metric. Presently, extensive efforts are being made to mathematically link laboratory and field exposure results. One key requirement for linking field and laboratory results, that the same degradation chemistry be observed in both the field and laboratory, has been met for the study material. Other requirements include our ability to account for changes in spectral ultraviolet intensity and spectral distribution. Model materials have been exposed to either polychromatic or spectral radiation over the range from one to 22 suns of ultraviolet radiation. For all three polymers, the reciprocity law was obeyed. In addition to this fundamental research, extensive efforts have been made to speed up analytical measurements through the implementation of high-throughput analysis techniques and the establishment of an informatics system to analyze, store, share, interpret and reanalyze the collected data.

Dr. Joannie Chin and Dr. Jonathan Martin obtain patent for integrating sphere weathering device—patent number 6,626,052 B1 issued September 30, 2003

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Sealants Service Life Prediction Exposure Consortium

Modern building design increasingly relies on building joint sealants to provide waterproofing and moisture barrier protection. Although building joint sealants represent a small percentage of initial construction costs, the failure of sealants represents a very large fraction of the maintenance and repair costs of constructed facilities. Furthermore, the failure of building joint sealant is often only detected after substantial water damage to a structure has already occurred making repair costs much higher than they need to be. Water intrusion is cited as the number one complaint for homeowners.

Despite the importance of joint sealants in the building envelope, information from the current methods for assessing durability and thus the ability to predict when the failures of sealants might occur do not yield accurate or precise estimates. Without the means to determine the in-service performance, most building joint sealant is selected on the basis of lowest first cost.

The first steps in developing new methods to predict the in-service performance of sealant requires knowledge of the relative importance of each of the primary weathering factors on the durability of the sealant. Currently progressing research studies will determine the relative importance of temperature, humidity, ultraviolet radiation and mechanical loading on a wide range of sealant formulations. In conjunction with two monitored outdoor exposure sites, this data will form the foundation of new methods to assess the service life of building joint sealants. This NIST-lead industrial consortium includes ten major sealant companies plus three other federal agencies and has been operational since October of 2001.

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State of the art field exposure apparatus for naturally stressing sealant samples is positioned on BFRL's roof. Numerous physical and environmental variables are being monitored on a continuous basis. Physical properties include stress and strain within the sealant while environmental variables include sealant temperature and moisture content.

Dr. Christopher White is shown working on custom designed, state-of-the-art, laboratory, sealant testing chambers attached to NIST's SPHERE. Temperature, humidity, ultraviolet and mechanical load can be independently controlled for eight ASTM C719 sealant specimens.

Field Analysis of Lead in Paint and Dust

Analytical methods for extraction and analysis of lead in paint and dust sampled in houses and related buildings are not readily field-portable. A need exists for a field test method for use when important decisions regarding risks associated with the presence of lead in the structure must be made on site. Field-portable ultrasonic extraction-anodic stripping voltammetry (UE/ASV) has been considered an attractive on-site analytical methodology for measuring the amount of lead in a variety of environmental media including paint and dust. At present, UE/ASV is not used in federal programs dealing with lead hazard management in housing. One restriction to adopting UE/ASV is that the effect of the operator (i.e., analyst) on the reliability of the analysis has not been determined. Specifically, laboratory technicians or chemists have conducted the measurements made in previous studies evaluating UE/ASV. Potential users of UE/ASV in practice may be certified lead-based paint inspectors, risk assessors, or others, whose skill in conducting chemical analyses may arguably be less than that of laboratory technicians or chemists. To fill this significant gap in UE/ASV technology, studies have

Dr. Walter J. Rossiter sampling a residential house for lead in paint.

been conducted to evaluate the reliability of UE/ASV for quantitatively determining the amount of lead in laboratory-prepared and field-sampled paint and dust specimens using certified lead inspectors or risk assessors trained to conduct UE/ASV testing. In addition to the operator, other factors examined have included, in the case of paint samples, the paint lead level, lead pigment type, paint-film substrate, particle size of the paint specimen, and sonication temperature and time. In the case of dust samples, the factors investigated have included: the wipe used to sample the dust, the source of the dust, and the lead level in the dust. The results of the paint studies support that UE/ASV is suitable for lead analysis of paint films provided that the particle size of the paint specimens is sufficiently small, or that sonication temperature and time are sufficiently high and long. All three of these factors are controllable in the field. For the dust studies, which are continuing, initial findings are that the wipe, the dust source, and the lead level affect lead recovery.

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Chemical Nanoprobe Microscopy

Chemical measurement at the nanoscale spatial resolution has immense potential as a materials characterization tool for current and developing nanotechnologies. However, techniques used to achieve nanoscale chemical measurement are still in the early stages of development, with vanguard efforts being made in only a few laboratories worldwide. This Advanced Technology Program-Intramural funded project, led by Dr. Tinh Nguyen, is a collaborative effort among BFRL, the Materials Science and Engineering Laboratory, and the Physics Laboratory. The goal of this project is to develop and implement a method for characterizing the chemical properties of materials with nanoscale (or, possibly, sub-nanoscale) spatial resolution. Project objectives include three challenging research areas: 1) fabrication and characterization of chemically functionalized AFM conventional tips and carbon nanotubes for nanoscale chemical measurement, 2) fabrication and characterization of chemically heterogeneous reference samples that can be used for demonstration/calibration of the technique(s), and 3) chemical characterization of materials at a nanoscale spatial resolution. By controlling the relative humidity at the tip-sample interface (Figure 1), results obtained in the past two years have demonstrated that, for a variety of samples, nanoscale spatial resolution of

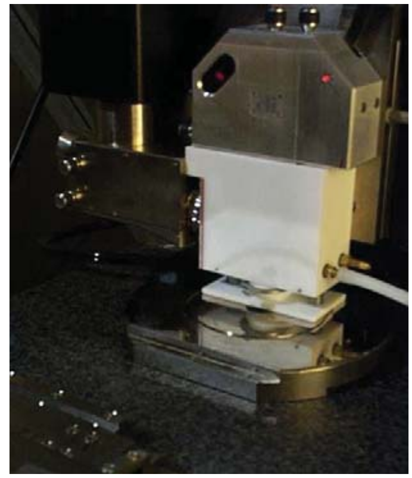

Figure 1: AFM humidity-controlled chamber.

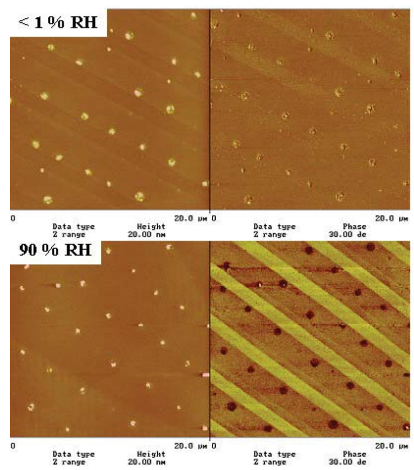

Figure 2: Enhanced chemical contrast of chemically heterogeneous ultrathin film with elevated relative humidity (bright stripes: hydrophilic region; dark areas: hydrophobic matrix).

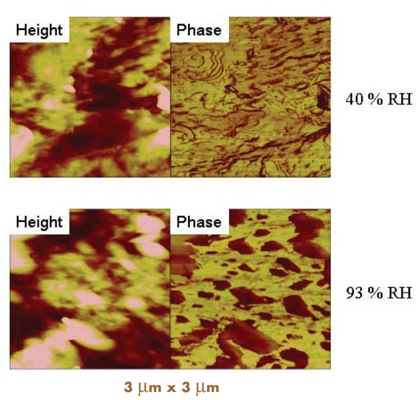

Figure 3: Enhanced chemical contrast of chemically heterogeneous polymer with elevated relative humidity (dark areas: hydrophilic poly(ethylene oxide), bright areas: hydrophobic polystyrene).

hydrophilic/hydrophobic heterogeneity of model self-assembled monolayers (Figure 2) can be imaged and the heterogeneity within a polymer can be mapped (Figure 3).

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Characterization of Polymeric Materials Surfaces

This research falls under the auspices of a government-industry consortium Polymeric Interphase Consortium, which is a joint effort between BFRL and the Chemical Science and Technology Laboratory and led by Dr. Tinh Nguyen. The goal of this project, led by Dr. Peter Votruba-Drzal, is to develop measurement techniques for evaluating dynamic and static surface micro- and nano-mechanical properties of polymeric materials. Nano-indenter parameters studied include loading rate, loading time, and nano-indenter geometry. In collaboration with Dr. Li-Piin Sung and the capabilities of her newly completed optical characterization facility, efforts are being made to assess the impact of surface deformation on surface reflection and optical scattering from polymeric coatings and plastics. Results have shown the feasibility of nano/micro mechanical property measurements on polymeric materials using depth-sensing indentation of a nano-indentor; they have also shown, for the first time, that a clear relationship exists between material microstructure and light scattering from a scratched surface. It is expected that this project will lead to the development of a universal mar/scratch test and the establishment of relationships among mar resistance, appearance, and service life for polymeric materials.

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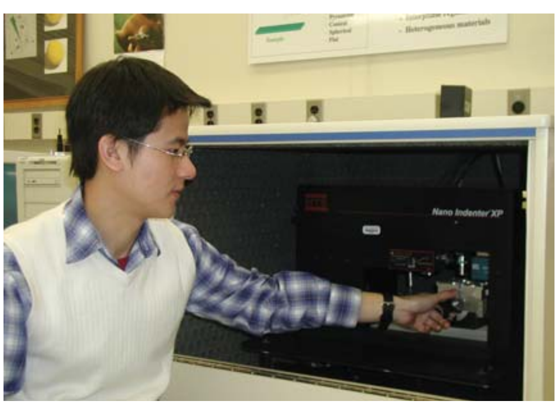
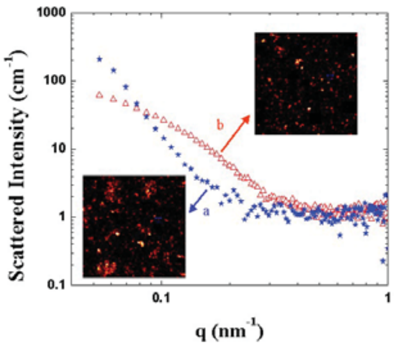


Mr. TsunYen Wu, a student, uses the nanoindenter to characterize the surface mechanical properties of polymeric materials.

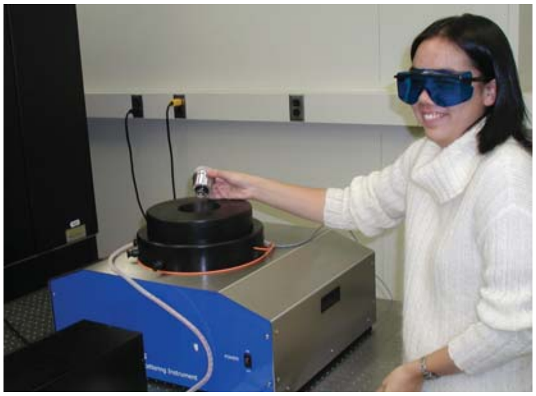
Structure and Dispersion Measurements of Polymeric Building Materials

The objective of this project, led by Dr. Li-Piin Sung, is to develop a non-destructive, efficient method for characterizing pigment dispersion and coating structure distribution on micro- and nano-scales in cured and uncured pigmented polymeric building materials using scattering techniques. We have developed methodologies for quantitative assessment of pigment dispersion using small angle neutron scattering (SANS) beams in the National Center for Neutron Research's cold neutron facility. To develop a more practical and non-destructive method for characterizing the dispersion of pigments in uncured and cured polymeric materials, a state-of-the-art light scattering materials characterization laboratory was established. The laboratory is equipped with two types of light scattering instruments, that are custom designed to accommodate both liquid or solid, pigmented or unpigmented materials, and to allow for a flexible array of experiments aimed at studying the relationship among chemical, physical and optical performance properties (e.g. color, gloss, surface roughness, mechanical and physical properties). These parameters are key in gaining a fundamental understanding of the interaction between light and materials, and for



Small angle neutron scattering (SANS) results of two different dispersion states of nano-TiO2 particles in a polymer coating and the corresponding laser scanning confocal microscopy micrographs demonstrating agglomerates of nanoparticles in each state.

Mr. Joan Jasmin adjusting the two-dimensional detector of the new custom-designed light scattering instrument for measuring the optical properties and microstructure of a polymeric coating.



Ms. Jenny Faucheu using a multiple-angle light scattering instrument to characterize particle size and dispersion of nanoparticles in a polymer suspension.

advancing metrologies for characterizing nanoscale structural and optical properties of polymeric materials and how these properties change over time. Other related research topics and projects using this light scattering materials characterization laboratory include: (1) relating physical and mechanical properties (viscoelastic behavior, scratch damage) to the appearance of a polymeric material, (2) developing a methodology and metrologies for linking nanoscale and microscale physical and chemical changes resulting from photodegradation to materials appearance, and (3) creating metrologies for quantifying the dispersion of particles in a polymeric system.

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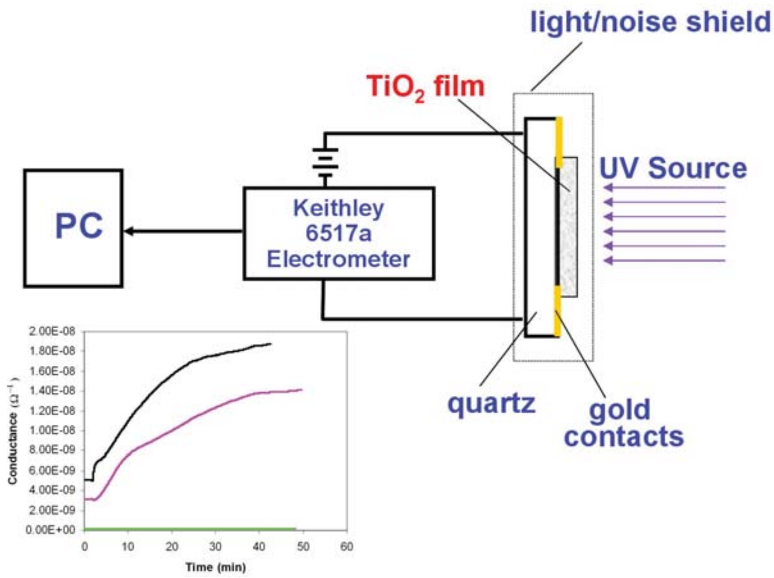
Photoreactivity of Semiconductor Nanoparticles

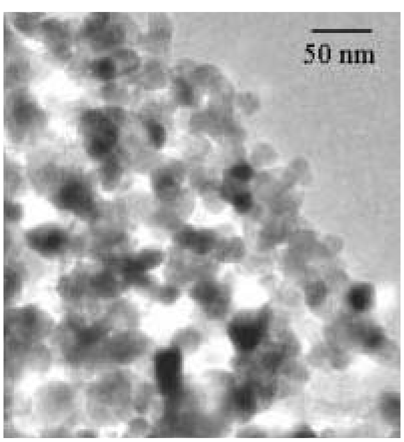
In the service life prediction of polymers, a need exists to understand the role of pigments and fillers in polymer degradation. Pigments are metal oxides exhibiting semiconductor behavior when they are photoactivated. Of the pigments, titanium dioxide nanoparticles in the size range from 30 nm – 300 nm are the most common whitening agent used in coatings and plastics. This pigment readily absorbs and is photoactivated by ultraviolet radiation. Industrial methods currently utilized to measure photoreactivity are semi-quantitative and are often performance-based, providing little fundamental or mechanistic insight. A need exists for a fast, quantitative, reliable, and scientifically based metrology for in-line measurement of the photoreactivity of pigments.

Research efforts in the Polymeric Materials Group are focused on developing methodologies and metrologies for understanding the fundamental mechanisms that govern photoreactivity and the subsequent service life performance of titanium dioxide and other semiconductor materials used as pigments and fillers in polymeric construction materials. In these applications, zero or low photoreactivity is desired when the appearance of a product is important while high photoreactivity is important in homeland security or healthcare applications in which microbes and other harmful compounds



Schematic of device for photoconductivity measurements; inset shows photoconductance data for a variety of titanium dioxide specimens.

need to be destroyed. BFRL has developed several metrologies for assessing photoreactivity including photoconductivity measurements and electron paramagnetic resonance (EPR) spectroscopy. Collaborative efforts have also been established with the Physics Laboratory (PL) and the Chemical Science and Technology Laboratory (CSTL) at NIST. These laboratories have complimentary metrological capabilities for characterizing the properties and behavior of semiconductor nanoparticles like titanium dioxide. Measurements being made include the chemical nature, number density and mobility of the activated species produced in a photoreactive process. Models will be derived that relate these parameters to material physico-chemical properties, thereby improving our understanding of the semiconductor photoreactivity.



TEM micrograph of nanoparticle titanium dioxide (TiO_2) [image courtesy of Shirley Turner, CSTL]

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HYPERCON: Prediction and Optimization of Concrete Performance

Intended Outcome and Background

The rise of finite element modeling techniques revolutionized structural design, so that today no one would dream of designing a major building without the use of these programs, which are soundly based in continuum mechanics. The objective of the HYPERCON program is to develop and implement similar tools for concrete, computational and experimental materials science-based techniques that will enable the prediction and optimization of the initial cost and service life performance and minimize the environmental impact of concrete in the built infrastructure.

As of 2003, the concrete industry is in a period of rapid change – rapid positive change that needs these kinds of performance prediction tools in order to reach a successful end point. Two examples illustrate the current industrial climate, which in turn demonstrate the need for HYPERCON research on more accurate and reliable ways to predict concrete properties.

The National Ready Mixed Concrete Association (NRMCA), which represents most of the ready mixed concrete producers in the U.S., has announced a sweeping new initiative – P2P. P2P stands for "Prescription to Performance" and indicates the desire of the NRMCA to change all concrete specifications from a prescriptive form, which does not allow innovation and proprietary formulation, to a performance form, which will drive innovation and research for proprietary advantage in the marketplace. This initiative will make an enormous change in the industry. The Strategic Development Council of the American Concrete Institute (ACI), an organization of top executives from all parts of the $100B/year concrete industry, has published *Roadmap 2030*, a 30-year research roadmap that is designed to achieve momentous goals and drastically change the cement and concrete industry. One of these goals is: *The concrete industry will reduce the time required for the acceptance of new technology from fifteen to two years.* The SDC Accelerated Technology Acceptance program has recently begun to make progress toward this goal.

HYPERCON research is designed, working closely with industry, to help the cement and concrete industry transform itself into a performance-based entity using the tools of computational and experimental materials science. This task requires not only cutting-edge research but also high quality knowledge transfer, so that research becomes embedded in practice at an accelerated rate. HYPERCON personnel carry out this dual task by working directly with industry in joint projects like the Virtual Cement and Concrete Testing Laboratory consortium, and by taking leadership roles in various standards committees of importance to the cement and concrete industry. These leadership roles include chair of the American Society of Testing Materials (ASTM) C-9 Concrete committee, task group leader for cement characterization and strategic planning in the ASTM C-1 Cement committee, membership in the ACI Board of Directors, and chair of the ACI 226 Materials Science of Concrete committee.

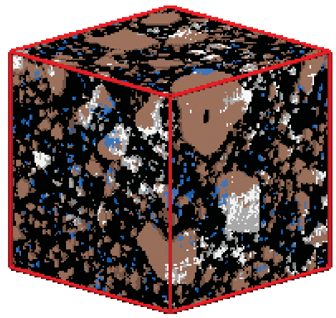
Performing world-leading concrete materials science in collaboration with industry, and transferring that research into practice, is how HYPERCON is delivering value to the cement and concrete industry. The intended outcome of the HYPERCON program is that, by 2010, industry adoption of HYPERCON research will be such that nobody will dream of designing a concrete mixture for a major construction project without using HYPERCON materials science-based tools.

ACCOMPLISHMENTS

The Virtual Cement and Concrete Testing Laboratory (VCCTL)

This project is intended to develop, in close collaboration with industry, a computational materials science software package designed to reduce the reliance of the concrete industry on empirical tests, replacing them with well-validated, scientifically based models that operate on extensive scientific databases. Current industrial partners, who contribute both financial and research resources to the joint project, include: W.R. Grace, Holcim, Cemex, SIKA, Portland Cement Association, International Center for Aggregate Research, Dyckerhoff Cement, VDZ, and ATILH. Research goals for each year are jointly formulated. Successful research is then incorporated into a new version of the VCCTL package at the close of each year. The consortium started in January 2001 with VCCTL 1.0, and ended Phase I in December 2003 with VCCTL 4.0. VCCTL 4.0 is already being used by some of the industrial members to help them in their research and development and quality control work.

Many accomplishments have been made as the third year of Phase I of this project ends. Much greater functionality has been incorporated into the models, including more accurate modeling



Left – the current VCCTL 4.0 interface, offering databases, cement hydration, and concrete property computations. Right – a sample of a cement microstructure, before hydration, from the current version of CEMHYD3D, the cement hydration module in VCCTL 4.0, which uses real cement particle shapes, sizes, and chemical makeup.

of portland cement and alternative materials, mechanical properties of cement paste, mortar, and concrete, mortar and concrete rheology, real shape of cement particles and aggregates for concrete, and sulfate attack. The database of cements and aggregates has been greatly expanded and the user interface has been made far easier to use and much more powerful and flexible. The industrial supporters of this work have grown from the original six companies to nine companies and associations. The next three-year phase, Phase II, was implemented at the end of January, 2004, and started with version 4.0. In calendar year 2004, the National Ready Mixed Concrete Association, which represents most of the ready mixed concrete producers in the U.S., will join the VCCTL consortium. Thus the second phase of VCCTL will include cement, aggregates, chemical admixtures, and concrete producers, uniting all the major materials aspects of the concrete industry in a joint project that will be of major benefit to the entire industry. Judging from Phase I results, we expect even greater research progress and utilization of future versions of the VCCTL software.

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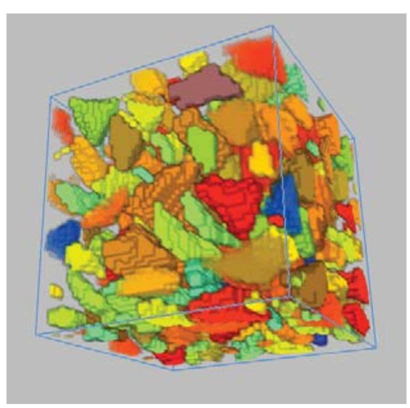
Modeling Concrete Rheology with Real Aggregates

To be properly placed in forms, concrete must flow, either under gravity and added vibration or via pump. In either case, measuring and controlling the rheology of the concrete is crucial for correct placement to occur. In HYPERCON, rheology/processing of concrete is studied experimentally, using quantitative concrete rheometry, and computationally, using dissipative particle dynamics (DPD) methods and parallel processing on a 128-processor computer. There is tight synergy between the two parts, using experimental measurements of cement paste and mortar rheology as the input to dissipative particle dynamics (DPD) computer programs that compute the rheology of concrete by adding virtual coarse aggregate particles to a cement paste matrix. Building on a past accomplishment on mathematically obtaining the shape of real gravel and sand, recently the DPD code has been modified to be able to simulate the flow of concrete containing real shaped aggregates. As expected, even in preliminary results, significant changes in concrete flow properties have been seen with respect to previous models that were only able to utilize simple shape particles like spheres. By using a multi-scale approach, HYPERCON researchers are rapidly becoming able to predict the rheology and hence the flowability of a concrete from its constituent ingredients.



A model concrete mixture, using real-shaped aggregates, being sheared computationally. The aggregate shapes were taken from x-ray computed tomography, reconstructed using spherical harmonic mathematical techniques, and incorporated into the DPD codes.

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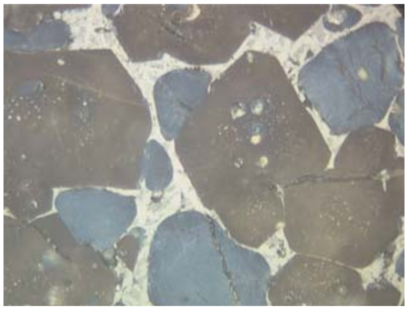
Material Characterization

The ASTM standard C-150, "Standard Specifications for Portland Cement," specifies composition limits for portland cement that are based upon a bulk chemical analysis and theoretical calculation of potential phase composition. These calculations were developed by Bogue at NIST more than 75 years ago. Mr. Paul Stutzman has been leading an effort within the American Standards for the Testing of Materials ASTM C-1 committee to develop the new standard ASTM C-1365, which uses X-ray powder diffraction (XRD) analysis to directly measure the phase abundance of portland cement and clinker. An XRD round robin is currently underway, which will be used to establish the multi-laboratory precision and bias of the test method, facilitating the acceptance of X-ray powder diffraction for phase analysis of cements in ASTM and elsewhere. The Bogue calculations are known to be inaccurate, and the more accurate XRD techniques are also capable of being expanded, unlike the Bogue calculations, to be able to analyze the more complex hydraulic cements of today, which incorporate other materials like fly ash and blast furnace slag. The data analysis procedures necessary to be able to utilize the XRD method are called the Rietveld analysis techniques. These techniques were further developed for cement XRD data and presented to cement plant staff in the 1st Portland Cement Association-sponsored workshop at NIST in June 2003. Using the new standard ASTM C1365 instead of the older bulk chemistry-based approach will open the door for innovation in the American cement manufacturing industry.



Cement clinker, which is manufactured cement that has not yet been ground into cement powder. The material has been lightly etched with hydrofluoric acid to show the different cement chemical phases. The Rietveld procedure allows quantitative XRD analysis of the composition of cement clinker and also cement powder. The field width is 250 micrometers.

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Economics and Environment

Economics and environmental impact are important parameters for selecting materials. HYPERCON deals with both. A new version of BridgeLCC, v2.0, a user-friendly life-cycle costing software package to help bridge engineers assess the cost effectiveness of construction materials in preliminary bridge design and other civil infrastructure applications like pavements and piers, has been developed and is available for downloading at www.bfrl.nist.gov/bridgelcc/. Improvements in version 2.0 include improved Monte Carlo capabilities, context-sensitive help, inclusion of an expanded concrete service life prediction tool, and a probabilistic events wizard that helps add user-tailored events like earthquakes to the analysis.

A new version of BEES (**B**uilding for **E**nvironmental and **E**conomic **S**ustainability), v3.0, a software package based on consensus standards and designed for selecting cost-effective, environmentally-preferable building products, has been developed and released and has already attracted over 9500 users worldwide (http://www.bfrl.nist.gov/oae/software/bees.html). New features in BEES 3.0 include: many more building products analyzed, significant improvements in the state of the art of U.S. life cycle assessment (LCA), more environmental impacts included in the environmental performance score, and, for the first time, the significance of a product's performance with respect to each impact is included in the scoring. While BEES 2.0 included only generic products, BEES 3.0 now includes around 80 brand-specific products thanks to the active participation of a number of manufacturers.

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Logos for the new versions of the BEES and BridgeLCC software, released in 2002-2003. These new versions have greatly increased functionality compared to earlier versions, and are freely available on the Internet.

Modeling Transport in Concrete for Performance Prediction

In partnership with the U.S. Nuclear Regulatory Commission (NRC), BFRL has developed 4SIGHT, a long-term concrete performance prediction tool based on a physicochemical model for transport and reaction. Originally developed for underground low-level waste facilities, the model is currently being extended for application to entombment of concrete nuclear structures. This has raised new technical challenges because in an entombment, the concrete may be required to act as both a physical and a chemical barrier to radionuclides. 4SIGHT is a transport and reaction model that is based on a chemical model for the pore solution and a physical model for the microstructure. The physical model is based on information gained from the NIST CEMHYD3D microstructural development model. The chemical model was quite difficult to formulate, as it had to approximate ionic transport and reaction in concrete pore solution, which is a water-based concentrated electrolyte solution having a pH in excess of 12. An accurate formulation has been achieved by adding thermodynamic properties of the pore solution to 4SIGHT. The model can now accurately predict binary and ternary salt diffusion coefficients, diffusion potentials, solution electrical conductivity, and transference numbers in electrolytes, like concrete pore solution, that have ionic strengths in excess of 1 mol/kg and high pH values. The current transport and reaction model is being developed as both an object code library (CEDAR++) for rapid application development and as a stand alone application for concrete performance assessment (4SIGHT). Under the continuing sponsorship of the NRC, 4SIGHT is being adapted for inclusion into the Framework for Risk Analysis in Multimedia Environments (FRAMES), a software platform developed by Pacific Northwest National Laboratory (PNNL) for selecting and implementing environmental software models for risk assessment and management problems in order to facilitate risk assessment of entombed nuclear structures.

Logos for the 4Sight concrete performance prediction tool and the transport and reaction object code library Cedar++.

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Construction Integration and Automation Technology (CONSIAT)

Intended Outcome and Background

The focus of CONSIAT research at NIST is to achieve breakthrough cycle time and lifecycle cost reductions in the delivery of construction projects by providing, within five years, the critical science-based performance measurement tools that will enable early industry integration and automation of the construction process.

The Construction Industry Institute (CII) – an organization with about 100 members representing the Nation's leading owners, contractors, and suppliers of constructed facilities – has made the development of Fully Integrated and Automated Project Processes, FIAPP, a top priority. However, the construction industry faces special challenges including low R&D investment, the fragmentation of the industry, and the strong project-oriented nature of its processes.

The CONSIAT program is providing the critical science-based performance measurement tools to enable: integration of construction site metrology data and other field information into project information management systems; delivery of just-in-time information to guide field operations; and automation of the construction process.

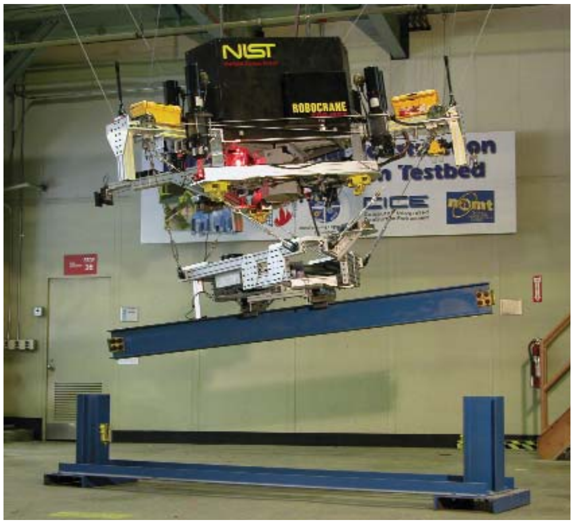
CII, with the support of NIST, has created FIATECH, a collaborative, not-for-profit consortium that will conduct leveraged research and development in partnership with suppliers, with firms in the software/information technology industries, and with the public sector. NIST is working in close partnership with the FIATECH Consortium to maximize the relevancy of the projects and the leveraging of resources on both sides, and to minimize the time to implementation of the program results. NIST is also participating in the FIATECH-led Capital Projects Technology Roadmapping effort. The resulting industry roadmap will help guide the CONSIAT program.

ACCOMPLISHMENTS

Automating Steel Construction

Productivity, reliability, and safety are the three predominant issues facing the steel construction industry today. In both industrial facilities and commercial buildings, hot-rolled steel members are typically joined together either by welding or using high strength bolts. These processes require a significant amount of skilled labor, and in the case of high-rise construction, constitute one of the most dangerous specialties in the already hazardous construction industry. Inspection is difficult and time consuming, and often, the connections are the weakest link in the resulting structure. According to the American Institute of Steel Construction (AISC), a 25% reduction in time required to erect a steel frame structure is needed. In response to this stated need, BFRL and AISC co-sponsored a workshop on Automated Steel Construction at the NIST campus in Gaithersburg, MD on June 6 and 7, 2002. The workshop brought together steel producers, fabricators, designers, erectors, and construction automation experts to discuss factors affecting the steel construction industry and to identify possible courses of action to assist the industry.

As a result of the positive response from the workshop participants regarding the potential introduction of new technologies to the steel construction process, the consensus that automation was needed in the industry, and the expressed support for site visits and pilot studies, the NIST Construction Metrology and Automation Group (CMAG) expanded research in steel erection technologies through the *Performance of Innovative Technologies for Automated Steel Construction* program. This program focuses on developing performance metrics for advanced concepts in crane automation, laser-based site metrology, laser radar (LADAR) imaging, construction component tracking, sensor-based data



Autonomous steel beam docking using the NIST RoboCrane™.

exchange, and web-enabled 3D-visualization. Current efforts are primarily directed towards the development of an Automated Steel Construction Testbed (ASCT) which will be used as a test facility with which to gain working experience, conduct experiments, and establish performance criteria for new steel construction technologies. The ASCT will also provide a mechanism to investigate paths towards an Intelligent Job Site as described in the FIATECH Capital Projects Technology Roadmap.

In FY03 NIST researchers Alan Lytle and Dr. Kamel Saidi of the Construction Metrology and Automation Group successfully equipped a unique cable-suspended six degrees of freedom crane – the NIST RoboCrane™ – with real-time laser tracking to achieve autonomous lift and docking of steel members. The build sequence for the test structure is created and verified graphically in a commercial 4D CAD package. The approved build sequence is then parsed for the robot controller, and used to create a sequence of goals or tasks for the robotic crane. Component identification from the 4D CAD package is used to access object and target locations. Future work will primarily focus on integrating high frame rate LADAR systems for final docking guidance and combining other technologies, such as radio frequency identification (RFID) and high resolution LADAR scanning, for construction object recognition and tracking.

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Bringing Laser Radar to the Construction Site

NIST researchers, Ms. Geraldine Cheok, Dr. Christoph Witzgall, and Dr. David Gilsinn, have been working towards facilitating the use of LADARs in a construction site. The main objective of this effort is the use LADARs (Laser Detection and Ranging) for rapid capture of 3D information at a construction site and to aid in automating some construction processes.

NIST efforts in the past two years have been focused on *i*) object identification using bar codes "read" by a LADAR using the intensity data; *ii*) developing fast post-processing software for LADAR data and the uncertainties associated with this software and the LADAR measurements; *iii*) terrain characterization, in particular, vegetation identification, and *iv*) establishment of a LADAR performance evaluation facility.

The LADAR data processing software use NIST-developed TIN (Triangulated Irregular Network) algorithms for ground truth determination, LADAR scan registration, data cleaning/screening/filtering, and data segmentation. An important aspect of the software development is to reduce or eliminate the need for user interaction and intervention. This software has been successfully used to support efforts for autonomous off-road vehicle navigation.

In June 2003, a workshop on the establishment of a LADAR calibration facility was convened at NIST. This workshop was attended by participants from the private and public sectors and included LADAR manufacturers, researchers, and end users from both the U.S. and Canada. The consensus of the participants was that the use of LADARs would expand rapidly in the next few years and the availability of a neutral performance evaluation facility was essential.

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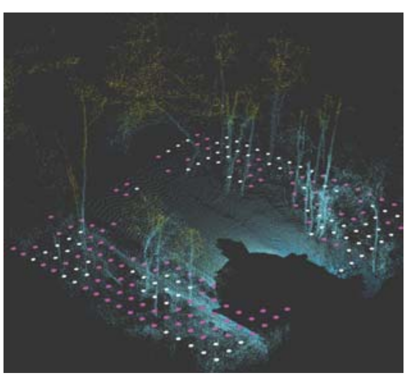
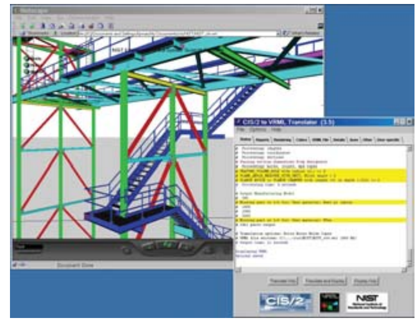


Point cloud of a 20 m x 20 m area showing the identification of trees and bushes.

Electronic Data Interchange for Steel Construction

Mr. Robert Lipman and Dr. Kent Reed have been working to support the American Institute of Steel Construction (AISC) Electronic Data Interchange Initiative. The purpose of the initiative is to create a means for collaboration and data sharing among the various parties involved in steel construction. Dr. Reed participated in the AISC review team whose final recommendation to endorse Version 2.0 of the CIMsteel Integration Standards (CIS/2) was adopted by the AISC Board of Directors. These product data standards were developed in Europe and the U.K. primarily to support steel design, analysis, detailing, and fabrication activities.

Previously a web-based service that translates a CIS/2 file of a steel structure into a 3D interactive model in the form of a VRML (Virtual Reality Modeling Language) file was made available to CIS/2 users. In the past year the Windows version of the CIS/2 to VRML Translator and associated CIS/2 VRML Report Interface was released. The translator has been used by commercial software vendors, who have implemented CIS/2 in their products, as a means to visually verify the contents of their CIS/2 files. Although a CIS/2 file may conform to the standard there is no way to verify that the file represents the intended steel structure. The translator fills this gap. The report interface provides access to non-geometric information contained in a CIS/2 file.



The CIS/2 to VRML Translator translates a CIS/2 file of a steel structure into a 3D interactive model in the form of a VRML file. The steel structure shown is part of the NIST Fire Research Facility Emissions Control System.

Users of CIS/2 files have also been studying how VRML models generated from CIS/2 files can be used to improve their workflow. A large international EPC has used CIS/2 VRML models that can be viewed on the Internet, to have structural engineers, fabricators, and erectors review the detailed design rather than using traditional paper-based shop drawings that are normally mailed between project participants.

Both Mr. Lipman and Dr. Reed are members of the CIS/2 International Technical Committee. In the summer of 2003, the committee released CIS/2 Release 2 that incorporates new features that correct deficiencies of the previous release and adds new ones that have been requested by software vendors and users of CIS/2. Current work by the committee is focused on how data management concepts are implemented in CIS/2 and how the representation of steel in Industry Foundation Classes (IFC) interfaces with CIS/2.

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Interoperability Standards for Capital Facilities – Improving Equipment Design, Specification, Purchase, Fabrication, and Installation

BFRL staff helped establish and lead the Automating Equipment Information Exchange (AEX) Project in collaboration with the FIATECH Consortium, with participation from owners, engineering and construction companies, equipment suppliers and software suppliers. The first step was to document industry information requirements and transaction priorities for the design, procurement and delivery of centrifugal pumps and shell and tube heat exchangers. We then established collaboration agreements with relevant industry organizations, e.g., API (American Petroleum Institute), PIP (Process Industry Practices) and ASHRAE on the delivery of XML schemas for information on engineered equipment. Finally, we developed and tested XML schemas and supporting documentation for automating the engineering and procurement of centrifugal pumps and shell and tube heat exchangers. The draft specifications were distributed for industry review and updated to incorporate improvements from these reviews and trial implementations.

Under this project, we also completed the Draft International Standard (DIS) version of ISO 10303 Application Protocol 227 (Plant and Systems Spatial Design) Edition 2. AP 227, Edition 2, extends Edition 1 to include support for piping fabrication and inspection information, the design and installation of HVAC systems, mechanical systems and cableway systems. Trial implementations of Edition 2 were demonstrated in April 2003. This part of the project was a collaboration with the PlantSTEP Consortium, U.S. Navy, UK Ministry of Defense and Japan ECOM project. The ISO ballot on the AP 227 ed2 DIS resulted in a unanimous "Yes" vote by the member countries (June 27, 2003). ISO TC184/SC4 approved the production of the International Standard (IS). All technical issues from the DIS ballot have been resolved and the ISO version of AP 227 Edition 2 will be published shortly.

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Economic Analysis of CII Benchmarking Data

BFRL is working with the Construction Industry Institute (CII), a leader in the development of best practices for planning and executing capital construction projects, to measure the economic value of CII best practices with respect to reductions in delivery time, construction cost, and construction worker illnesses and injuries. CII's Benchmarking and Metrics Committee (BMC) has established an aggressive data collection effort. Data on more than 1,100 completed construction projects now reside in the database. These data are used to establish industry norms and evaluate how the use of CII best practices helps improve the competitiveness of the construction industry. BFRL provides guidance to the CII BMC on how to provide member companies with performance measures and industry trends which (1) allow member companies to assess their performance against data collected from other member companies, (2) help member companies identify "best practices" and other opportunities to improve their performance, and (3) provide feedback to CII to guide its research program and other related activities.

BFRL has used CII data to help evaluate the economic impacts of its CONSIAT-related research. The CII data were critical elements in estimating the expected CONSIAT-related impacts in the capital facilities industry. The capital facilities industry comprises the industrial sector and the commercial sector of the construction industry. Two CONSIAT-related economic impact studies have been published and widely disseminated. NISTIR 6501 documents the analysis of CONSIAT-related impacts in the industrial sector; NISTIR 6763 analyzes the commercial sector. Current efforts focus on publishing research findings in archival journals. A recently completed article focusing on estimating the expected economic impacts of CONSIAT-related products and services in industrial facilities has been accepted for publication in the *Journal of Construction Engineering and Management*.

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GOAL 2 ENHANCED BUILDING PERFORMANCE

To provide the means to assure buildings work (better) throughout their useful lives. The strategy for meeting this goal is to provide knowledge, measurements and tools to optimize building life cycle performance.

The first strategic focus to achieve the goal of Enhanced Building Performance is to develop measurement methods, fundamental data, simulation models, and life cycle environmental and economic analysis tools to support Healthy and Sustainable Buildings.

The second strategic focus for achieving Enhanced Building Performance is to develop, test, integrate, and demonstrate open cybernetic Building Systems. The word "cybernetics" comes from the Greek work "steersman" and is defined as the science of control and communication of complex systems. A Cybernetic Building System involves energy management, fire detection, security, transport systems, energy providers, one or more utilities, an aggregator, and numerous service providers, and information handling and complex control at many different levels.

Healthy and Sustainable Buildings

Intended Outcome and Background

The intended outcome of the Healthy and Sustainable buildings program is to make available measurement methods, test methods, fundamental data, simulation models, and life cycle environmental and economic analysis tools to support healthy buildings and the wide-spread use of sustainability in design, construction, and operation of buildings and their systems/subsystems.

Global climate change is considered by many as one of the most pressing challenges of the 21st century. Scientific opinion on this matter varies significantly, from the view that contributions to global warming are negligible, to the view that man-made carbon emissions are a disaster in progress, requiring immediate substantial reductions in the emission of the so-called greenhouse gases, principally carbon dioxide.

The purpose of the International Climate Change Conference, held in Kyoto, Japan in 1997, was to accelerate the pace of international action on Climate Change. If adopted by the U.S., the legally binding international protocol would translate for the U.S., into a 7% reduction in 1990 levels of carbon emissions by 2010. The U.S. building sector shares almost equally with the industrial sector and transportation sector in such emissions.

Beyond regulated carbon emissions, the "green movement" is sweeping the building industry. All major building product companies, building designers, and building operators need measurement methods, test methods, fundamental data, and life cycle environmental and economic analysis tools to objectively promote their approaches and products to achieve sustainability.

BFRL will apply its expertise in refrigeration systems, thermal insulation, building integrated photovoltaic systems, indoor air quality, and life cycle economic and environmental analysis methods to promote healthy and sustainable residential and commercial buildings.

BFRL's research on Healthy and Sustainable Buildings will produce a wide range of data, measurement methods, test methods, simulation models, and analysis tools that will assist the U.S. in this "transition towards sustainability." These BFRL "products" include:

- Building for Environmental and Economic Sustainability (BEES);
- performance data on refrigerant/lubricant heat transfer;
- artificial intelligence-aided design procedures for refrigeration heat exchangers;
- new apparatuses/test methods/standard materials for advanced thermal insulation/low temperature insulation/high temperature insulation;
- validated design models for building integrated photovoltaic systems;
- a new seasonal performance testing and rating methodology for residential fuel cells;
- contaminant-based design procedures for predicting indoor air quality;
- methods to evaluate and predict the performance of residential ventilation and indoor air quality control approaches, including the use of different types of air cleaning devices; and
- new/revised test methods and rating procedures for evaluating the energy performance of residential and commercial appliances and products.

ACCOMPLISHMENTS

Residential Fuel Cell Test Facility

Recent large-scale power outages have highlighted the overworked state of the electric utility supply and transmission system. Using residential fuel cells, which are highly efficient, clean, and quiet sources of electricity, to distribute the electrical generation capacity will reduce the loads on central generating facilities and transmission lines.

Although not yet commercially available, widespread use of this technology will require a metric by which consumers can evaluate the financial costs and benefits that fuel cells offer. Using BFRL's experience in creating similar metrics for heat pumps, water heaters, and other household appliances, a Residential Fuel Cell Test Facility was created to determine the factors affecting performance of residential fuel cells.

The facility is capable of measuring the fuel energy consumed by a fuel cell, and the electrical and thermal energy that it produces. Housed within an environmental chamber that can control the temperature and relative humidity level surrounding the fuel cell unit, the facility can adjust the electrical load applied to the fuel cell and the flow rate and inlet temperature of fluid used to extract its thermal energy. The environmental conditions, electrical load level, and thermal load conditions will be varied to determine their individual effects on the performance of residential fuel cells. This information will be incorporated into a test procedure and rating methodology, which will be submitted to a consensus standards organization for further development and eventual publication.

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Residential fuel cell undergoing testing in a NIST laboratory.

Ventilation and Indoor Air Quality Research House

A new research house was constructed on the NIST campus for use in a variety of research efforts related to ventilation and indoor air quality in low-rise residential buildings. This double-wide manufactured home was originally envisioned to support the investigation of a number of technical issues related to the mechanical ventilation requirements issued by the U.S. Department of Housing and Urban Development (HUD). To this end, the house has a number of different systems for meeting these ventilation requirements and is well-instrumented for continuous monitoring of temperature, pressure, relative humidity, system operation and ventilation rate. During 2003, extensive measurements of the house were made to obtain a baseline determination of the building's airtightness and ventilation characteristics. A detailed model of the house was also created in BFRL's airflow and indoor air quality simulation program, CONTAM, for use in subsequent studies under other climatic and operational conditions. Future research plans involving the house include conclusion of a year-long study of emissions of volatile organic compounds from building materials and furnishings, a retrofit study to determine the ventilation impacts of improved envelope and duct tightness and studies of the indoor air quality impacts of combustion appliances and moisture sources.

NIST Indoor Air Quality Research House

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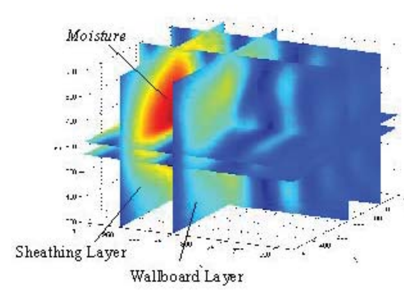
Moisture Detection in Building Envelopes

One of the most significant issues leading to indoor environmental quality and durability problems in buildings is the presence of excessive water in the building envelope. Among the problems that result from excess moisture are mold, mildew, and structural rot. NIST is investigating different methods for measuring the moisture levels of the materials within building envelopes to improve forensic techniques for diagnosing moisture problems.

A promising technology that has been examined is the use of Ultra-Wideband (UWB) Radio signals for detecting moisture. Since water tends to reflect radio waves more significantly than dry building materials, BFRL has been able to determine the moisture contents of different layers within a wall by transmitting radio pulses toward a wall and analyzing the signal that the wall reflects. Because UWB signals contain a large band of frequencies, more information regarding the wall can be gained than with conventional radio waves. For example, some of the frequencies pass through the first layer and reflect from layers hidden beneath the wall, thereby yielding moisture information for layers that are not visible to the naked eye. Algorithms have been developed to combine scans taken



Three-dimensional maps indicate the location of excess moisture within a wall.

at different positions so that three-dimensional maps can indicate where potential moisture problems have developed.

This technique holds the promise of providing a non-intrusive technique for detecting the moisture state in walls. Such a remote detection method will be a significant improvement over current methods that frequently require destruction of the wall to locate water damage.

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EVAP-COND Simulation Model

EVAP-COND, a software package for simulating air-to-refrigerant finned-tube heat exchangers, was released in January 2003 and placed on BFRL's website (http://www.bfrl.nist.gov/info/software.html). The goal of the program is to facilitate the development of optimized heat exchanger designs that will result in improved efficiency air-conditioning and refrigeration equipment.

EVAP-COND employs detailed, first principles-based EVAP and COND simulations models for evaporators and condensers. The models use a "tube-by-tube" modeling scheme, which allows for specification of complex refrigerant circuits, modeling refrigerant distribution between these circuits, and accounts for non-uniform air distribution. A graphical user interface, designed for Windows operating systems, facilitates input of complex heat exchanger design data and provides a convenient platform for reviewing detailed simulation results. The simulation output contains local parameters for each tube which include inlet and outlet quality, temperature, enthalpy, entropy, pressure drop, mass flow rate for the refrigerant, and inlet and outlet temperature for the air. It uses NIST's Standard Reference Database 23 (REFPROP) for representation of thermophysical properties of refrigerant. The current release includes the ten most relevant fluids, including atmospheric ozone-safe HFC refrigerants and "natural refrigerants".

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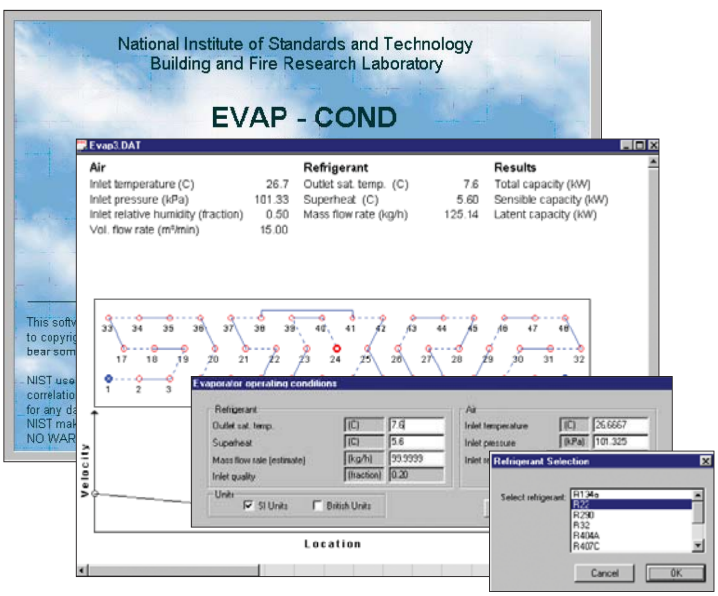

The EVAP-COND Simulation Program

Cybernetic Building Systems

Intended Outcome and Background

The intended outcome of the Cybernetic Buildings Program is to make available tested and demonstrated open Cybernetic Building Systems for improved productivity, life cycle cost savings, energy conservation, improved occupant satisfaction and market leadership. This work will be carried out in close cooperation with the U.S. building industry, industrial partners, building owners/operators and newly developing service companies.

During the next ten years, the building controls industry in the United States will be undergoing a radical change from one with a vertical structure to one with a horizontal structure. Building control companies, equipment and system manufacturers, energy providers, utilities, and design engineers will be under increasing pressure to improve performance and reduce costs. Cost reduction can be achieved by developing cybernetic building systems that integrate more and more building services, including energy management, fire and security, transportation, fault detection and diagnostics, optimal control, the real time purchase of electricity and the aggregation of building stock.

A Cybernetic Building System involves energy management, fire detection, security and transport systems, energy providers, one or more utilities, an aggregator, numerous service providers, and information handling and complex control at many different levels.

The BFRL program, which will include a full-scale demonstration of one or more Cybernetic Building Systems, will involve the following tasks:

- develop standard communication protocols;
- develop enabling technologies, such as fault detection and diagnostic (FDD) methods;
- develop performance evaluation tools;
- develop a standard-based information infrastructure supporting the design, commissioning, operation and maintenance of heating, ventilation, air-conditioning and refrigeration systems;
- construct a Virtual Cybernetic Building System in the laboratory to facilitate the development and evaluation of new products and systems by manufacturers;
- conduct basic research on the dynamic interactions of a fire, HVAC/distribution and the zones of a commercial building through utilization of existing and new simulation models, and validate this new simulation program through both laboratory and field studies;
- develop a consortium of manufacturers and service providers interested in producing, testing, demonstrating and selling Cybernetic Building Systems;
- test and evaluate different security concepts and supervisory security systems for the critical infrastructure protection of integrated building systems; and
- conduct a full-scale demonstration of a Cybernetic Building System in a government owned office building complex.

ACCOMPLISHMENTS

The Virtual Cybernetic Testbed

The Virtual Cybernetic Building Testbed (VCBT) is a real-time emulator consisting of state-of-the-art BACnet speaking control systems interfaced with simulation models running over a network. BFRL researchers, control systems manufacturers, service companies, and software developers can use this unique hybrid software/hardware testbed to develop and evaluate control strategies and products. The VCBT is able to emulate three modes of building operation: normal operations, fault conditions, and emergency conditions such as a fire or hazardous materials release.

The VCBT models a three-story building including a variable air volume (VAV) HVAC mechanical system, the indoor building environment, a building shell model and heat sensors for detecting fires. Each floor is served by

Virtual Cybernetic Building Testbed Control System Hardware

an independent air handling unit (AHU). Controllers for the AHUs and VAV boxes are supplied by several different manufacturers. The VCBT is capable of simulating a fire in the building. The simulation components may each run on different computers, passing data to each other through the use of a central communications and management component. The communications infrastructure is provided by the Common Object Request Broker Architecture (CORBA). A sophisticated user interface was created using Virtual Reality Modeling Language (VRML).

The VCBT has the capability to reliably produce simulated mechanical system faults and outdoor weather conditions and is being used to test prototype tools for detecting common faults in HVAC mechanical systems. It is also being used to develop a sensor-driven fire model for the next generation of smart fire panels that can predict how a fire will grow and spread in the building and to investigate mechanisms for providing information from the building automation system to emergency first responders.

Planned future enhancements include adding central plant and lighting controls, and developing a more flexible and sophisticated VCBT building modeling scheme using product data information represented by Industry Foundation Classes (IFCs).

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HVAC Fault Detection and Diagnostics

Building HVAC equipment routinely fails to satisfy performance expectations envisioned at design. Equipment and control failures often go unnoticed for extended periods of time. Additionally, higher expectations are being placed on a combination of different and often conflicting performance measures, such as energy efficiency, indoor air quality, comfort, reliability, limiting peak demand on utilities, etc. To meet these expectations, the processes, systems, and equipment used in both commercial and residential buildings are becoming increasingly sophisticated. These conditions necessitate the use of automated fault detection and diagnostics (FDD) to ensure fault-free operation.

BFRL researchers focused on developing FDD methods for air handling units (AHU) and variable air volume (VAV) control boxes. The FDD tools for AHUs and VAV boxes were developed with distinct approaches because of the nature of the systems. VAV boxes are simple devices with a limited number of operation modes and possible faults. The VAV boxes typically have little instrumentation and controllers with limited capability. However, VAV boxes are very numerous in a typical HVAC system, resulting in a large amount of

System	Fault	Season	Correct Positive	False	False Negative
AHU-A	Supply Air Temperature Sensor Drift	Heating	X		
	Recirculation Air Damper Leakage	Swing	X		
	Outdoor Air Temperature Sensor Failure	Swing	X		
	Mixed Air Temperature Sensor Drift	Swing	X		
	Supply Air Temperature Sensor Failure	Cooling	X		
	Recirculation Air Damper Stuck Closed	Cooling	X		
AHU-B	Fault Free	Heating	X		
	Fault Free	Swing	X		
	Return Air Temperature Sensor Drift	Swing			X
	Fault Free	Swing	X		
	Economizer Control Logic Fault	Cooling	X		
	Economizer Control Logic Fault	Cooling	X		
AHU-C	Mixed Air Temperature Sensor Failure	Heating	X		
	Return Air Temperature Sensor Drift	Swing			X
	Outdoor Air Damper Stuck at Minimum	Swing			X
	Recirculation Air Damper Leakage	Swing	X		
	Return Air Temperature Sensor Drift	Cooling	X		
	Mixed Air Temperature Sensor Drift	Cooling	X		

Table 1. Summary of results from laboratory testing of Air Handling Unit Fault Detection Tool.

data to be monitored for faults. AHUs are more complex and thus susceptible to more kinds of faults. They also tend to have more instrumentation and more capable controllers. The FDD tools for both systems are designed to be robust so that they can adapt to the variety of applications typical of their use.

AHU Performance Assessment Rules (APAR) is a diagnostic tool that uses a set of expert rules derived from mass and energy balances. Control signals are used to determine the mode of operation for the AHU. A subset of the expert rules corresponding to that mode of operation is then evaluated to determine if there is a mechanical fault or a control problem.

VAV Box Performance Assessment Control Charts (VPACC) implements an algorithm known as a CUSUM chart. The basic concept behind CUSUM charts is to accumulate the error between a process output and the expected value of the output. Large values of the accumulated error indicate an out of control process.

Batch implementations of these tools were developed and refined using data collected from simulation, emulation, laboratory testing, and real buildings. These tools were found to be successful at finding a wide variety of faults including stuck or leaking dampers and control valves, sensor drift, and improper control sequencing. Preliminary investigations have been conducted to study embedding the tools in AHU and VAV box controllers.

Planned future work includes assisting the building controls industry to provide air handling unit (AHU) and variable air volume (VAV) box fault detection and diagnostic (FDD) tools developed by NIST within their own controls products. Future plans also include development of a tool to act as an interface between other FDD tools and the building operator in order to resolve conflicting fault reports from the various FDD tools and to present an integrated view of the HVAC system's fault status to the operator.

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BACnet on Capitol Hill or GEMnet

BFRL is working with the office of the Architect of the Capitol to provide technical assistance in renovating building automation and control systems on Capitol Hill. This is an extensive project that will eventually include the U.S. Capitol building, the new Capitol Visitors Center now under construction, all of the House and Senate office buildings, the Library of Congress buildings, the Supreme Court, and a few other facilities.

The object of the project is to replace the aging system now being used in stages while at the same time adding the capability to improve performance and security by integrating HAVC control, lighting control, access control, fire detection, and emergency response systems in ways that were not previously possible. The key to success is using BACnet building automation and control system products.

BACnet is a standard communication protocol (ANSI/ASHRAE Standard 135-2001) developed by BFRL and industry experts that provides a way to integrate building control products made by different manufacturers. Using BACnet, the Architect of the Capitol can integrate products in innovative ways not previously possible while at the same time procuring products using a competitive process in each phase of the project. The BACnet standard has been adopted worldwide and there are now hundreds of thousands of products installed and operating in facilities around the world.

In addition to working with industry to develop and maintain the BACnet standard, BFRL researchers developed an integration plan for Capitol Hill and are providing technical assistance for design, installation, and operation of the BACnet system.

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BFRL researchers are assisting the architect of the Capitol in the design, installation, and operation of a BACnet System.

Typical fire experiment used to test the SDFM

Sensor-Driven Fire Model

The Sensor-Driven Fire Model (SDFM), currently under development at NIST, is designed to use signals from building sensors to predict the size and growth of fires in buildings. Algorithms have been developed that use the signals from heat, smoke, or gas sensors to determine the Heat Release Rate (HRR) or fire size in each room. Based on the HRR of each fire, the SDFM then predicts the temperature, smoke and gas concentrations, and smoke layer heights in all rooms of the building. With these predictions, an overview of the current fire situation in a building can be transmitted to the fire service. The SDFM is being tested using the Virtual Cybernetic Building Testbed (VCBT). The VCBT provides a simulation of a multi-room building where fires are simulated using the fire model CFAST. Additional testing will be done using fire experiments such as the one shown above.

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To enable engineered fire safety for people, products, and facilities; and enhance fire fighter effectiveness.

U.S. annual losses attributable to fire – 3,600 lives, 22,000 serious injuries, $10 billion in direct property loss, and $128 billion total cost.

Core research to significantly reduce fire loss is organized around three technical programs:

- ***Advanced Measurement and Predictive Methods Program*** *– Leading the world in fire measurement and prediction methods, and accelerating their transfer to practice, to enable engineered fire safety for people, products, facilities, and first responders.*
- ***Reduced Risk of Flashover Program*** *– Reducing residential fire deaths by adapting measurement and predictive methods to better understand conditions leading to flashover; enabling early and certain fire and environment sensing; advancing cost-effective fire suppression technologies; and enabling new/improved materials whose fire resistance does not negatively impact performance, cost, or the environment.*
- ***Advanced Fire Service Technologies Program*** *– Enabling a shift to an information rich environment for safer and more effective fire service operations through new technology, measurement standards, and training tools.*

Advanced Measurement and Predictive Methods

Intended Outcome and Background

The objective of this program is to lead the world in fire measurement and predictive methods, enabling engineered fire safety for people, products, facilities, and first responders. This work underpins the *Advanced Fire Service Technologies and Reduced Risk of Flashover Programs* as well as the *WTC Investigation.* The AM&PM work will be carried out in close coordination with those programs and their partners, towards the BFRL *Goal of Fire Loss Reduction.*

Engineering correlations developed through fire testing over the past 25 years have improved fire codes and technologies in the U.S. and produced a slow decline in the number of deaths and injuries due to unwanted fires (excluding the singular event of the WTC collapse); however, the total economic burden of fire in the U.S. continues to rise. To counteract these losses in an economic manner and to preempt the anticipated increase in fire-related deaths and injuries associated with a larger and more aged population, new fire safety technologies and performance-based codes are needed that only can be achieved by a higher level of understanding of the dynamics of fire, and more certain measurement methods.

During the next ten years, the building industry in the United States and the rest of the world will be undergoing a radical change as prescriptive fire codes for built facilities are replaced by performance based codes. NIST is at the right place and the right time to take a leadership role in this coming "revolution" and assure that the benefit to the general public and the American economy are maximized in this transformation. Designers of fire protection systems in new buildings and retrofit situations will be under increasing pressure to improve performance and reduce costs by implementing new and clever passive and active fire protection. To enable this work to succeed, BFRL must provide leadership in creating the knowledge base that will allow the development of accurate and appropriate predictive tools that are key to the implementation of performance based design of fire protection systems.

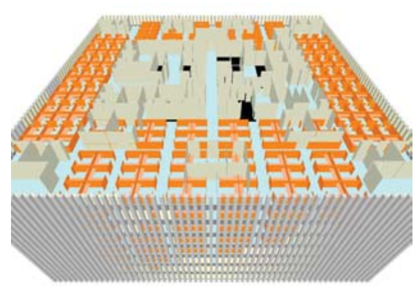
Fundamental experiments and analyses will be coordinated with full-scale measurements and data to increase our ability to numerically simulate and visualize real fire phenomena with increasing certainty. Direct numerical simulation and computational fluid dynamic models of the transport processes will be further expanded to encompass better models of radiation and the behavior of droplets and sprays, and semi-empirical sub-models will be developed for heat and mass transfer at the fuel/flame interface and in the condensed phase itself. New instrumentation and test methods will be developed to support these models, and reference data will be produced against which predictions can be compared at multiple levels: sub-grid scale, single item response to fire, second item burning, and full scale demonstrations. The overall goal of reducing fire loss will guide the research conducted in this program, and a conscious effort will be made to influence other national and international fire laboratories, industrial partners, and standards making bodies consistent with the budget and our vision to lead the world in methods of measurement and prediction of the behavior of fire and its effects.

During the next decade, BFRL will continue to work with industry, fire testing laboratories, national and international organizations that determine fire standards and codes, university researchers, other government agencies, and international fire researchers to reduce fire losses. This program will underpin that work, providing the knowledge and tools to reduce fire loss and become the recognized source of accurate measurement and predictive methods for fire in buildings.

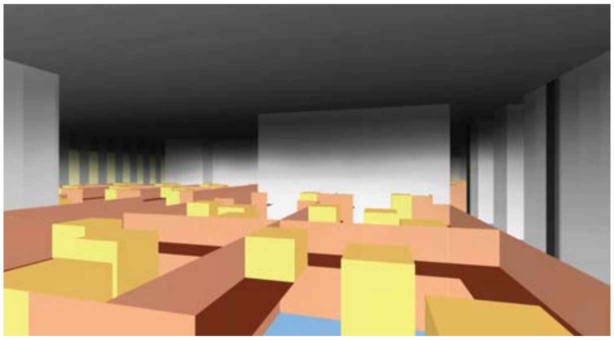
ACCOMPLISHMENTS

Fire Dynamics Simulator and Smokeview

The Fire Dynamics Simulator (FDS) is a computational fluid dynamics model of fire driven flows. It is used widely in the fire protection engineering community for a variety of applications including design, forensic reconstruction and teaching. This year model development has been driven by the World Trade Center investigation. To make it possible to compute the thermal environment in the two towers



Mock up of WTC Tower 1 in FDS/Smokeview.



Smokeview image within Tower 1 of the World Trade Center demonstrating its improved smokeview visualization.

and Building 7, it was necessary to modify FDS to run on a network of computers linked together with a fast network. This improvement will enable engineers to consider larger calculations with more detail than before. In addition, the visualization of smoke has been improved in Smokeview. Now, it is possible to create a scene showing the effect of smoke obscuration on objects within a room.

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Large Fire Laboratory

As the U.S. federal government's principal fire research laboratory, BFRL maintains some of the country's best and most extensive fire testing facilities. More than 300 fire experiments are performed each year in the specially equipped, 27 m (90 ft) x 37 m (120 ft), Large Fire Laboratory.

The facility has several instrumented hoods or calorimeters for measuring heat release rate. Two mobile calorimeters have capacities ranging from 50 kW to 750 kW. The latter calorimeter is sized for burning individual pieces of furniture or other objects of similar size with a hood measuring 3 m (10 ft) on each side. Two large hoods are permanently installed are available for burning multiple items at one time. One hood is approximately 6 m (20 ft) x 6 m (20ft) and has a capacity of 3 MW (3,000 kW). The largest hood is approximately 9 m (30 ft) x 12 m (40ft) and has a capacity of approximately 10 MW (10,000 kW). Burn rooms built to simulate portions of a building or a house can be installed adjacent to or under the large hoods. The smoke from the room fires flows into the large hood for measurement and exhaust from the building.

The Large Fire Research Facility has a variety of instrumentation for measuring temperature, mass, pressure, thermal radiation, real time gas concentrations for oxygen, carbon dioxide, carbon monoxide, nitrogen oxides and

LFL Test Area with 72 ft long experimental enclosure

hydrocarbons, and smoke concentration. The primary Data Acquisition System has 400 channels. The system is used for data recording and experiment control.

The facility has been used for measuring the heat release rate of a wide variety of items including crude oils, office and home furnishings, and transportation vehicle components. Data from many of the large fire experiments are used to develop or evaluate mathematical models and to study the fire performance of furnishings and interior finish materials. The open space in the facility has housed structures built to simulate living rooms, kitchens, offices, corridors, townhouses, buses, portions of a train car, and an electrical room of a nuclear power plant. Measurements on fire suppression systems, such as sprinklers, water mist and gaseous agents have also been conducted in the Large Fire Research Facility.

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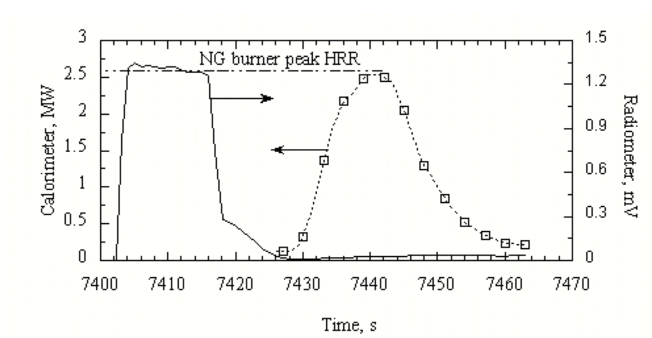
Quantitative Large-Scale Heat Release Rate Measurements

The heat release rate is the single most important quantity in terms of fire safety. It is a key predictor of the hazard of a fire, directly controlling the rate at which heat and toxic gases build up in a compartment or the rate at which they are buoyantly driven into more remote spaces. To study the fire spread within a single object such as a bed or sofa, as well as the spread to adjoining objects leading to the fire flashing out the doorway (typically occurring at 1 MW to 3 MW), it is essential that a facility be able to measure heat release rates as large as 3 MW.

Photo of 3 MW fire from the natural gas burner.

Accuracy is important for heat release rate measurements because fire regulations are frequently based on maximum allowed peak rates of heat release. Testing laboratories must be confident that the tested objects pass the required regulation and manufacturers need accurate information for defining the fire safety characteristics of their products. A second need for accurate heat release rate data is for the development of quantitative models for predicting heat release rate. In comparing a fire experiment and a model prediction, it is essential that the heat release rate measurement have an estimated uncertainty.

The 3 MW heat release-rate facility (3MWHRRF) developed at NIST meets the needs described above for objects that can be placed under the 6 m x 6 m hood, which is approximately 4 m above the floor, or for enclosures whose effluent can all be directed into the hood. It is capable of measuring heat



The heat release rate and the radiometer output as plotted versus time for 15 s pulses for HRR of 2.5 MW.

release rates in the range of 0.10 to 3.0 MW including brief peaks as high as 5 MW. The expanded uncertainty (95% confidence interval) is 11% of the heat release rate for fire sizes larger than 400 kW. This system employs the first quantitative uncertainty analysis for the oxygen difference relative to the background value. The response time of the system is such that it can accurately resolve dynamic heat release rate events of 15 seconds or more.

As an integral step in quantifying the accuracy of the 3MWHRRF, a natural gas calibration burner has recently been developed for validating the operation of the facility, and for characterizing its time response by generating square-wave pulse widths varying from 5 seconds to 60 seconds. The burner is shown below along with a graphical comparison of the 15 seconds burner square-wave pulse with the heat release rate measured by the calorimeter facility.

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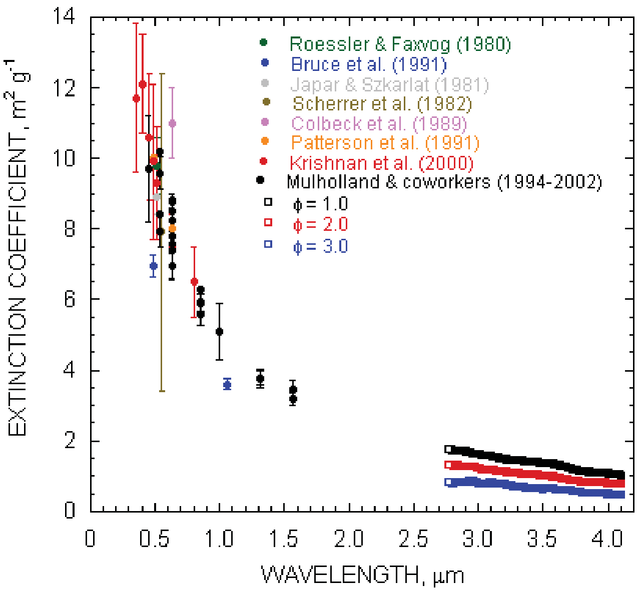
New Measurement of Soot Volume Fraction in Fires

This work is developing the capability to measure local soot volume fraction in and near fires to within 20% of actual values by the end of 2004. Prediction of radiation heat transfer is important in the NIST Fire Dynamics Simulator (FDS) and will continue to be important in future computer codes for predicting fire behavior. A critical component in radiation prediction is knowledge of soot volume fraction in and around the fire. Current extractive techniques are useful away from the fire where conditions are uniform, but they have high uncertainties in hot, near-fire zones. A quantitative in-situ technique is needed for measuring soot volume fraction in and around flames. A multipoint soot volume fraction measurement technique based on laser extinction is currently being developed in order to enhance the measurement capability of BFRL's Large Fire Laboratory (LFL). Since accurate determination of the optical properties of soot is essential to the proper interpretation of soot volume fraction measurements based on laser extinction, we have made the first measurements of soot optical properties in the mid-infrared region, (2 µm to 5 µm) and determined the effect of fuel-air ratio on the optical properties. This spectral region is pertinent to radiative heat transfer in fires. The accompanying figure shows previous ethene results and our new measurements of soot specific extinction coefficient as a



Mass specific extinction coefficient as a function of wavelength for ethene from previous and current works.

function of wavelength. Our work has also resulted in an improved value of the empirical constant in the expression for the Planck mean absorption coefficient for soot particles.

Future effort will focus on the evaluation of the performance of the soot volume fraction measurement device in an ISO 9705 test room in the LFL. Gravimetric measurements at one or two locations will be performed to validate the performance of the device. A high-temperature experimental facility is also currently being developed to study the effect of temperature on soot optical properties.

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Fundamental Properties of Automatic Sprinkler Sprays

Automatic fire sprinkler systems greatly reduce fire deaths and losses. A major impediment to the use of sprinkler systems, especially residential systems, is cost. Optimizing the design of sprinkler systems can reduce the cost, and one approach is to design sprinkler heads which produce droplets of the most effective pattern and spray size.

The present project is aimed at measuring the size, velocity, and spray pattern of droplets produced by sprinklers. Droplet size and velocity data have been gathered by many previous investigators, but existing measurement techniques are incapable of simultaneously measuring droplet size and velocity over a large area, and cannot operate in a fire environment.

The Particle Tracking Velocimetry and Imaging (PTVI) technique was developed by NIST and the University of Michigan under grant. PTVI utilizes two-color fluorescence for large-scale, non-intrusive measurement of particle size and velocity in two phase flows. The method illuminates a 0.5 m by 0.5 m area of the spray field with two pulsed laser sheets, and records images of the fluorescing droplets with a camera situated perpendicular to the laser sheets. Velocity is determined by analysis of the distance between two-color droplet image pairs, and droplet size is determined from the size of the droplet images. Droplet sizes over the range of approximately 200 µm to 3000 µm can be measured, with low levels of uncertainty.

Using the PTVI technique, axis-symmetric sprinklers operating over a wide range of conditions have been recently characterized. The measured droplet sizes and velocities have been used to accurately predict the flux of water at the floor, and entrainment of the droplets has been shown to be unimportant for predicting their trajectory (for droplets of the size typical of sprinklers). The measured properties of the sprays have been used to develop methods to incorporate water droplets into the NIST Fire Dynamics Simulator.

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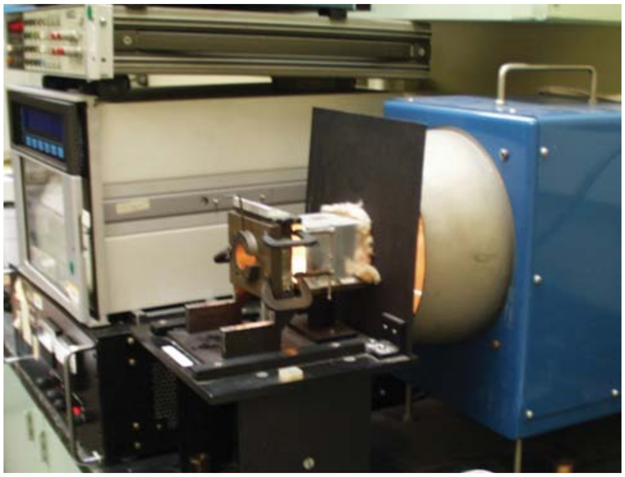
BFRL Participates in Collaborative Heat Flux Gauge Round Robin

Heat flux measurement plays a pivotal role in fire research and testing. Heat transfer is responsible for fire growth and spread as well as playing a dominant role in the harmful effects of unwanted fires. Numerous standard fire tests require the imposition of a known heat flux, e.g., the cone calorimeter, or the measurement of a resulting heat flux.

Two types of total heat flux gauges, Schmidt-Boelter or Gardon, are used most commonly in the fire community. While relatively robust, these gauges require calibration, and it is known that variations in convective heat transfer rates can modify their response.



BFRL facility for heat flux gauge calibration based on a high pressure quartz lamp.

Recognizing the need for consistent heat flux measurements at different laboratories, seven fire laboratories, BFRL (USA), FM Global (USA), Sandia National Laboratories (USA), Fire Research Station/Building Research Establishment (United Kingdom), SINTEF (Norway), SP (Sweden), and Research Institute, State Key Laboratory of Fire Science (China) formed the Heat Flux Measurement Working Group under the auspices of the FORUM for International Cooperation in Fire Research. BFRL serves as the overall coordinator for the group. The working group's mission is to promote mutual confidence in flame heat flux measurements and calibrations of heat flux gauges among Forum laboratories.

The initial task carried out by the working group was a calibration round robin in which five of the laboratories utilized in-house calibration facilities to perform blind calibrations of two Gardon and two Schmidt-Boelter gauges. This was the first time that such a systematic interlaboratory comparison has been performed. The photo above shows the NIST heat flux gauge calibration facility. Results of the round robin demonstrated that calibration variations between laboratories were generally small and comparable to the absolute uncertainties in heat flux measurement reported by national measurement laboratories. This result is viewed as encouraging since a number of different calibration approaches are utilized by the labs. The findings are being made available to an ISO committee (TC-92, WG-1) working on standards for calibration heat flux gauges.

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Reduced Risk of Flashover

Intended Outcome and Background

The intended outcome of this program is to reduce the risk of flashover cost-effectively by enabling: new/improved materials whose fire resistance does not negatively impact performance, cost, or the environment; and early and certain fire and environment sensing and automatic fire suppression technologies compatible with occupants and the environment.

Flashover is the dramatic and sudden transition from a relatively small, slowly developing fire, spreading systematically across adjacent fuel surfaces within a room, to a much larger and dangerous fire in which all flammable surfaces within the enclosure are involved. Estimates based on United States fire statistics indicate that the roughly 20% of reported fires that transition to flashover are responsible for 80% of the fire deaths and property damage in buildings. Annual losses in buildings are typically 3,000 deaths and around $8.5 billion. Clearly, reducing the risk of flashover offers an opportunity to reduce significantly the high human and property costs of fire to the Nation.

Reducing the risk of flashover can be equated with reducing fire spread, fire growth, and the maximum value of the heat release rate. There are two general approaches for accomplishing these

goals. The first is to limit the availability of fuel (e.g., through the use of fire-retarded fuels) and air (e.g., by controlling ventilation) such that a fire cannot become sufficiently intense to induce flashover. The second is to provide physical intervention (e.g., through automatic sprinklers, or by a fire company following early detection) to reduce the fire size before it can grow to a dangerous level. Both approaches are important and are included in this program.

Experimental and theoretical understanding of fire growth and spread within enclosures will be improved, with the goal of developing a modeling capability for real-world room contents that can be reliably used for fire safety engineering, product design, and materials assessment. As part of this effort a workshop designed to assess the current understanding of Fire Growth and Spread on Real Objects was held at NIST in March, 2002 (Peacock and Pitts, NIST Special Publication 998, 2003, http://www.fire.nist.gov/bfrlpubs/flamespread/).

BFRL is working to develop cost-effective approaches that reduce the flammability of polymers while maintaining or even improving their physical characteristics. Success in this approach will provide a strong incentive for polymer producers and product manufacturers to utilize safer materials in commodity applications.

Active measures to limit fire growth require reliable early fire detection and effective suppression approaches. Directed research designed to enhance fire detector response while reducing the number of false alarms and to improve suppression effectiveness is underway.

ACCOMPLISHMENTS

Nanotubes Improve Fire Behavior of Organic Polymers

Flashover (a sudden rapid growth of enclosure fires) is responsible for the majority of fire losses associated in the United States. Preventing or delaying flashover will reduce fire losses significantly. One approach for achieving this goal is to use organic polymers that have been modified to improve their fire behavior. NIST researchers have demonstrated that introducing nanoscale fillers (additives that have at least one dimension on the nanometer scale) into commodity polymers has the potential to be a cost-effective method for enhancing the properties of these materials. In our previous research, we have demonstrated dramatic improvements in the flammability performance of polymers containing small quantities of nano-clays and silicas. BFRL scientists are now investigating the effects of introducing multi-wall carbon nanotubes (MWNT) on the flammability of the commodity polymer poly(propylene) (PP). Nanotubes are a recently discovered form of carbon having unique physical properties.

One measure of the flammability of a polymer is its maximum heat release rate when burned. Experiments have shown that the maximum heat release rate is reduced by up to 58%, as compared to the untreated material, when nanotubes are added to PP (see Figure 1). This improvement in flammability performance is superior to that previously observed for PP/clay nanocomposites.

An important characteristic for determining the effectiveness of nanocomposites in improving polymer fire performance is the uniform dispersion of the material in the polymer. There are

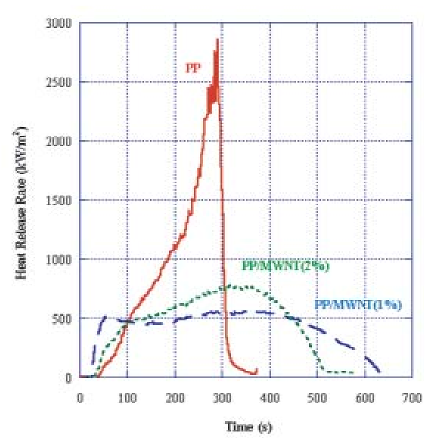

Figure 1. Heat release rate curves of the three samples exposed to an external heat flux of 50 kW/m².

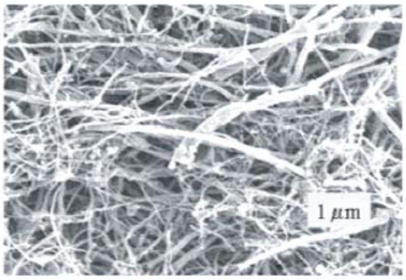

Figure 2. SEM photomicrograph showing the dispersion of MWNT in the poly(propylene) composite after solvent extraction of the polymer.

practical advantages of using carbon nanotube fillers in PP compared with clays or silica. Neither clay nor silica mix well with organic polymers, and it is often necessary to modify their surfaces or the polymer in order to mix the two materials. On the other hand, carbon nanotubes have similar chemical structures to those of many polymers and can be dispersed directly into the polymer without costly pre-processing. The quality of the dispersion of the nanotubes in the polymer matrix can be inferred from the image of the residue obtained from scanning electron microscopy (SEM) after extraction of the polymer with hot solvent. The expanded, as opposed to clumped, morphology of the undisolved nanotubes indicates that they were well-dispersed throughout the polymer matrix prior to its removal.

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NIST Study Provides Basis for New California Mattress Flammability Standard

The State of California has adopted a mattress flammability test protocol that is based on a multi-year study done at NIST. The protocol examines the heat release rate from a mattress (plus foundation) that results from exposure to a pair of gas burners designed to mimic the local heat flux exposure imposed by burning bed clothes. NIST ascertained the nature of this heat flux exposure and designed the appropriate burner system. The California protocol sets a limit on the acceptable peak heat release rate in this test as a means of preventing a bed fire from spreading to other objects in a bedroom. NIST provided the technical basis for relating fire size, second object ignitability and potential life savings. The NIST study also informs the closely related issue of bed clothes flammability which California is currently planning to regulate.

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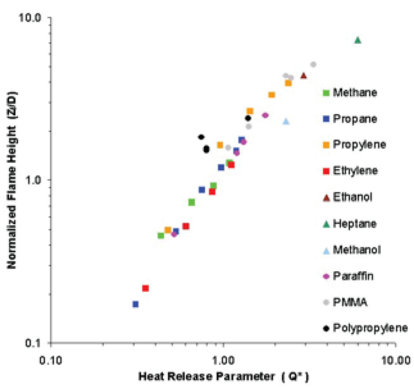
Bed at 1 minute after bed clothes ignition.

Same bed at 5 minutes after bed clothes ignition.

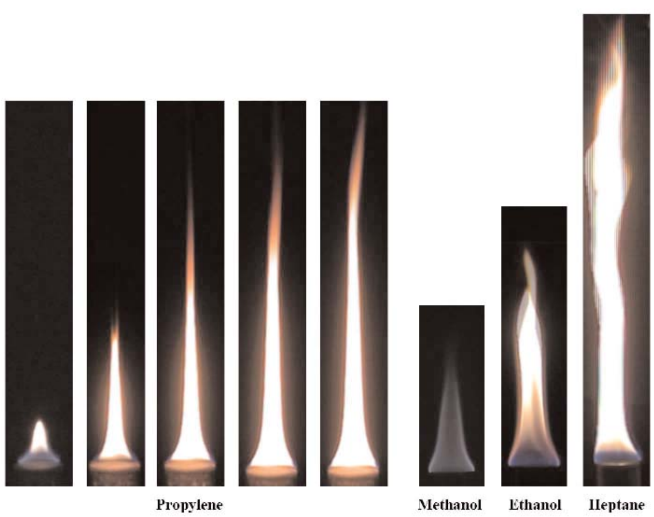
Flame Size Measurements for Determining Heat Release Rate from Burning Polymers

The cone calorimeter is a useful device for both ranking the flammability of flame-retarded materials and extracting fundamental data (such as heat release rate) useful for predicting the full-scale burning behavior of the material. Nonetheless, a cone-calorimeter test requires a relatively large (10 cm x 10 cm) sample, considerable time (0.5 to 2 hours per sample), and the equipment is relatively expensive. If faster and cheaper methods could be developed, heat release rate tests might find wider use in industry, providing better data to approximate full-scale flammability of flame retarded materials. Such simple heat release rate measurement methods might also be used in conjunction with high-throughput polymer development techniques which are of strong interest to industry.

The present project is examining the possibility of using flame size (height, area, or volume) as a surrogate for heat release rate. A laminar flow burner has been developed for controlling the oxygen transport rate to the flame over solid, liquid, and gaseous samples. An image processing system has been developed for determining the flame size from visible images captured from these burning samples, and measured flame size has been shown to be correlated with the heat release rates. Based on these promising results, additional tests of the approach are planned.



Normalized flame height correlated with Q* (the non-dimensional square root of the Froude number expressed in terms of the heat release).



Visual flame images from burning polymers, to be used for heat release estimations.

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Smoke Component Yields from Room-scale Fire Tests

Estimation of the time people will have to escape or find a place of refuge in the event of a fire is a prime need from a fire hazard or risk assessment of an occupancy. Increasingly, the computation in such an assessment involves the impact of the fire effluent (toxic gases, aerosols, and heat) on people in the fire vicinity. The input data for these computations typically come from any of a number of bench-scale toxicity apparatus and are almost all of unknown accuracy. The consequences of a poor safety assessment are severe: not providing the intended degree of safety or alternatively increasing the cost.

Joint with industrial funding from the Fire Protection Research Foundation, BFRL has taken the first step to establishing a technically sound basis for assessing the accuracy of these devices. A series of room-scale fire tests have produced data on the yields of toxic products in both pre-flashover and post-flashover fires. The combustibles examined were upholstered cushions, bookcases, PVC sheet, and household electric cable. For a number of toxicants plus carbonaceous soot, either yields or upper limits were determined, all with associated uncertainties. BFRL also determined the losses of CO, HCN, and HCl as they flowed away from the burn room. It now remains to determine values for the same combustibles measured in representative bench-scale apparatus and to compare the values with the full-scale results. The outcome will determine the confidence with which data from each of the devices can be used in fire safety assessment.

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Nuisance Sources for Residential Smoke Detectors Characterized

Nuisance alarms, or false alarms, from home smoke alarms are a vexing irritant that can have deadly consequences. Frequent nuisance alarms can lead occupants to disable or remove the offending smoke alarm, thereby compromising safety. Surveys have indicated the most common causes of residential nuisance alarms are cooking activities, high humidity conditions from bathing activities, and smoking. The promise of new advanced detection technologies designed to reduce nuisance alarms, while improving detection, was the impetus for NIST to perform a detailed study of several sources that frequently cause smoke detector nuisance alarms. A goal of advanced detection is to improve reliability to a point where it is feasible to connect home smoke alarm systems directly to the local fire station. Earlier detection and suppression would reduce the number of fires that progress to flashover, and hence save lives and property.

Testing was conducted in an instrumented manufactured home. Aerosol number and mass concentrations were recorded along with temperature, humidity, air velocities, ionization and photoelectric smoke alarm sensor response, and carbon monoxide concentration from electrochemical cells. Various cooking activities, candles and cigarette smoking were investigated. Not surprisingly, the frequency of nuisance alarms depended on the alarm type, its sensitivity, placement relative

Thomas Cleary deep frying corn tortillas on a gas hotplate produced alarms in ionization alarms only.

to the nuisance source, and the stimuli produced. The results of these tests are documented in a NIST Technical Note *Performance of Home Smoke Alarms*, and the complete set of test data is available in NIST Report of Test FR 4020, *Home Smoke Alarm Project, Alarm Response to Nuisance Sources*, both of which are available in electronic form at http://smokealarm.nist.gov.

The data gathered during this series of tests is being used to develop a set of nuisance scenarios that are being programmed into the fire emulator/detector evaluator (FE/DE) so that advanced detector designs can be tested in a controlled, repeatable manner. The FE/DE is a single-pass wind tunnel designed to reproduce the environment smoke alarms may experience when in use in residences. High humidity and dust exposure tests in the FE/DE have also been developed. When coupled with emulated fire signatures, the FE/DE will be capable of evaluating the response of advanced smoke alarms to both fires and nuisance sources in a consistent manner, thus tying their response to their expected real-world performance.

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Flammability Measures for Electronic Equipment

Consumer electronics are ubiquitous in today's society. The fact that fires originating from consumer electronic equipment represent less than one percent of all residential fires in the United States is largely credited to the use of flame retardant plastics. Although fires originating within these items are rare, the hazard presented when exposed to a small external ignition source (such as a candle) is not well known. Even when the equipment is not the first item involved in a fire its contribution to the total fire load and impact on flashover of a room can be significant. Both of these issues are important due to an increasing number of candles and electronics in the home. It should also be noted that in recent years the number of electronic fires has increased in many European countries following a reduction in the use of some flame retardant compounds due to environmental concerns. It is anticipated that this trend could follow is the US.

The objective of this work is to relate the full-scale flammability and fire hazard of consumer electronics assemblies having enclosures made from different resin formulations to bench-scale fire performance of these resins. A research consortium was established between NIST, UL, Dow, Polyone, Albemarle and Samsung Cheil to conduct this research. Eighteen commercial resins were evaluated using three different standard bench-scale flammability tests. Based on the bench-scale test results (NISTIR 7031), five of these resins were molded into 19" computer monitor housings and will be examined in full-scale fire tests that measure the overall heat release rate and the heat flux threat to the surroundings. The selection of these materials was based on heat release rate, UL94 performance and physical burning behavior such as melting and charring. The results will be compared and contrasted to the bench-scale results to infer useful guidelines.

There is a current international effort (IEC TC108) to develop a hazard-based standard for electronic equipment. This research will provide part of the technical foundation for developing this standard.

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Computer monitor subjected to an external heat flux of 15 kW/m^2.

Bench-scale UL94 flammability test.

Bench Scale High Throughput Flame Retardancy Measures

Our recent efforts in the development of high throughput (HT) methods for the study of flame retardant nanocomposites have produced several new more efficient methods: 1) direct extrusion of flammability test samples, 2) on-line fiber optic and dielectric characterization of both concentration and nano-dispersion of flame retardant additives, 3) a colorimetric and fluorescent method for measuring nano-dispersion 4) a rapid flame spread test using a flux gradient which correlates well with the standard conventional

Methane-fired panel which creates a flux gradient for flame spread test of extruded flame retardant polymer sample rods.

flammability tests such as UL94, E84 tunnel and cone calorimeter. The rapid flame spread methods were developed in partnership with the High Throughput Flammability Consortium. The impact of this work can already be seen in the following industrial interactions: 1) an industrial partner has recently contracted NIST to use these HT tools to evaluate a new non-halogen based additive that may have unique flame retardant properties, and 2) a member of the consortium has asked NIST to assist in the installation of HT flame spread facilities in their lab to facilitate their development of flame retardant products.

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Advanced Fire Service Technologies

Intended Outcome and Background

The intended outcome of this research program is an information rich environment for emergency response and fire prevention. Enhanced emergency information improves first responder situational awareness and contributes to safer and more effective responses. Providing a means to quantify fire risk aids local authorities in fire prevention and protection efforts.

Today, fire fighting operations, inside and outside of structures, proceed with very limited information about the extent of fire involvement, structure safety, hazards, and even the location of firefighters. For safer and more effective fire fighting, incident commanders and firefighters need access to reliable and timely information regarding fire conditions, developing hazards, and the location and condition of resources. Enhanced training tools based on state-of-the-art computer simulations and measurements of fire can enable better training of firefighters.

The full capabilities and limitations of equipment and systems being introduced into the fire service needs to be understood with respect to the needs of fire fighters. Draft measurement standards for the performance of fire service and other first responder equipment are being developed to aid in the evaluation of new technologies.

As building regulations, materials of construction, and fire service response change, means to quantify the level of fire safety in communities needs to be available as an aid to local fire authorities.

The Advanced Fire Service Technologies research program includes:

- Research to assess the performance among the different available thermal imaging technologies. BFRL has constructed an apparatus to measure performance in controlled exposures that duplicate environments encountered in fire fighting. Laboratory measurements are being compared to field measurements. A second smaller laboratory apparatus will be developed to address some of the needed exposure conditions.
- Research to provide the foundation for the exchange of information from buildings and other sources to first responder decision support systems during emergencies. BFRL has taken a first step with the industry by developing display standards for graphic alarm systems. Similar effort will produce standards for the information set needed by first responders to deal with a range of emergency scenarios.
- Research to advance the heat transfer model for fire fighter protective clothing under wet and dry conditions with associated material property database will be validated by comparisons with data from industrial standard tests. This model will be used as a cornerstone of

a training tool that allows firefighters to visualize the limits of performance of their protective gear in computer-simulated fire environments.

- Research to benefit the fire service is best prioritized, planned and conducted with input from interested and knowledgeable fire fighters. BFRL, in cooperation with FEMA, produces a web-based newsletter, FIRE.GOV directed at the fire service reader to provide contacts for on-going research. The fire service benefits directly from research information that can impact their work published in this easily accessible electronic form.

- Research in fire modeling, understanding of the dynamics of fire fighting, and measurement of equipment performance each an on-going project in BFRL, provides the basis for effective firefighting simulations. BFRL is working with Maryland Fire and Rescue Institute and others to examine effective ways in which fire simulations based on physical modeling can be used to enhance the training for new firefighters.

- Research in community fire modeling conducted at BFRL is producing the first physics-based model of the fire spread process. This community fire spread model can be used to assess the rate of house-to-house fire spread. It is a tool for fire departments and communities to assess the response needs and to quantify the impact of mitigation strategies.

ACCOMPLISHMENTS

Measurement Standards for Evaluation of Infrared Cameras (Thermal Imagers) Performance

A growing number of fire departments are purchasing infrared cameras (thermal imagers). These instruments are expensive, yet there is no way to evaluate the performance from manufacturer literature. Standard test methods and metrics do not exist to compare the performance of thermal imagers for fire fighting applications. The IR Camera Performance Project has developed a measurement facility to evaluate the performance of thermal imagers for fire fighters, advanced fire detection systems, and fire research applications, evaluated the performance of different detector technologies under laboratory and field conditions, and correlated the laboratory-based tests and metrics with imager performance under field conditions. Off-the-shelf infrared cameras that utilize barium-strontium-titanate, vanadium oxide, and amorphous silicon detectors have been examined in lab- and full-scale experiments. Hand-held as well as helmet-mounted thermal imagers have been included in experimental burns. Preliminary results demonstrate: a) large variation in thermal imager cost and performance, b) thermal imagers typically perform satisfactorily when viewing objects through dispersions of cool smoke, but perform poorly through dispersions of *hot* smoke, and c) thermal imagers typically perform satisfactorily through water sprays in the absence of hot combustion products. Work currently underway will include the development of standard tests that can be used to compare

Figure 1. Thermal camera image from full-scale residential test burn with manikins positioned on the tile roof.

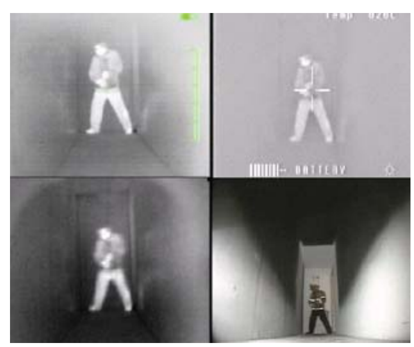

Figure 2. Three different infrared detector technologies, barium-strontium-titanate, vanadium oxide, and amorphous silicon, compared to normal (visible) video camera in lower right. All cameras positioned near floor and looking down hallway with burn room at the end of the hallway on the right.

imagers under various environmental conditions, development of the ability to vary the concentration and temperature of smoke particles independently, determination of the effect of imager temperature on the performance of the imager, development of quantitative metrics for imager performance, and correlation of laboratory-scale tests to full-scale tests.

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Firefighter protective clothing extreme exposure experiment.

Firefighter Protective Clothing Heat Transfer Model Developed

Significant advances have been made in firefighter protective clothing, however fire fighters are still being fatally burned and significantly injured while wearing protective clothing systems that satisfy all existing performance standards. To understand how these burn injuries can arise and therefore be prevented, BFRL has developed a physics-based computational model, capable of describing heat and moisture transport across multiple layers of protective fabrics. The inclusion of moisture transport is a significant advance in the predictive capabilities of the model as the energy absorption due to evaporation and the energy release associated with condensation play important roles in determining the overall protection offered by a protective garment.

The model and a user interface have been integrated into the Protective Clothing Performance Simulator (PCPS). This simulator has been used to study the role of moisture in burn injuries and the response of protective fabrics to high levels of incident radiant flux. The Thermal Protective Performance ratings, obtained experimentally from standard tests for protective fabrics used by industry, have been successfully predicted for a variety of both single and multi-layered fabrics. Results of this work are published in NISTIR 6967, *Thermal Performance of Fire Fighters' Protective Clothing, Part 3: Simulating a TPP Test for Single Layered Fabrics*, January, 2003, by Scott Kukuck and Kuldeep Prasad.

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Positive Pressure Ventilation Model

Positive pressure ventilation (PPV) is a technique used by the firefighters to remove smoke, heat and other combustion products from the inside of a structure. This allows firefighters to perform their tasks in a safer environment. Typically when using PPV, a ventilation fan is placed in front of the doorway to the building with the smoke being pushed out the opposite side. If used incorrectly, PPV may actually increase the burning rate of the fire or push smoke into an area of refuge. BFRL is using physical measurements coupled with FDS/Smokeview CFD modeling to provide a better understanding of the effective use of ventilation. The flow characteristics of typical PPV fans have been characterized. Experiments have been conducted and the results compared with model predictions. With accurate data for geometry, vent placement, and boundary location, air flow velocities predicted with the FDS fire model are within 10 percent for open atmosphere experiments and 20 percent for simple room geometries. The results from this FEMA funded study are reported in NISTIR 7065, *Characterizing Positive Pressure Ventilation using Computational Fluid Dynamics*, February, 2003 by Stephen Kerber and William Walton. They will be the basis of a training tool for the fire service on when PPV should or should not be used.

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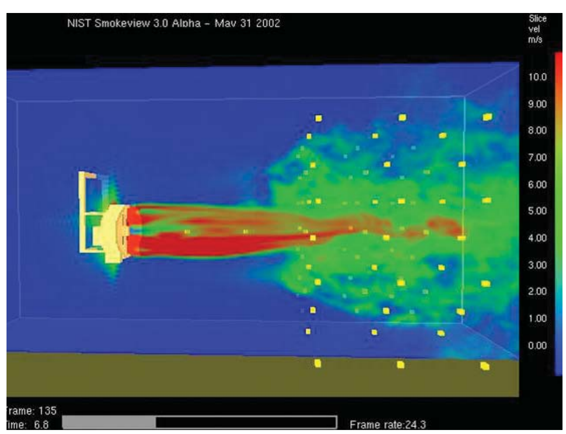
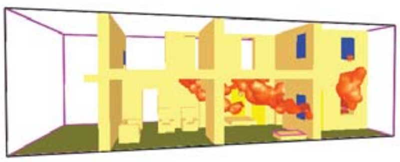


Experiments characterizing PPV fan flow (a) and corresponding model simulations using FDS/Smokeview (b).

Computer Modeling Provides Understanding of Multiple Fire Fatalities

Under the sponsorship of the National Institute of Occupational Safety and Health (NIOSH), NIST has examined the fire dynamics of the 1999 Iowa duplex fire that claimed the lives of three children and three firefighters. In the study, NIST performed computer simulations

Front view of the Iowa duplex home.



Still image from FDS/Smokeview simulation of fire conditions in the duplex home.

of the fire using the NIST Fire Dynamics Simulator (FDS) and Smokeview, a visualization tool, to provide insight on the fire development and thermal conditions that may have existed in the residence during the fire. The NIST FDS computer simulation predicted fire conditions and events that correlate well with information from NIOSH and ATF (Bureau of Alcohol, Tobacco and Firearms) investigations. The critical event in this fire was the onset of conditions consistent with flashover in the kitchen. At this point, the fire started a transition from a single room and contents fire with smoke throughout the structure, to a fire that involved the majority of the structure within approximately 60 seconds. This quick change in thermal conditions and flame spread through the duplex led to the three firefighters being trapped inside and succumbing to the effects of the fire environment.

The report of the NIST study, NISTIR 6854, *Simulation of the Dynamics of a Fire in a Two-Story Duplex—Iowa, December 22, 1999* is available in CD-ROM format. In addition to the report, the CD-ROM contains a video presentation, which provides a summary of the report and includes photos of the fire scene and videos of the computer model results. A copy of the NIOSH Report, F2000-04, dealing with the incident, also is included on the disk. Fire department training officers are using the CD-ROM to demonstrate how rapidly conditions can change in a house fire. More than 12,000 copies of the CD-ROM have been distributed.

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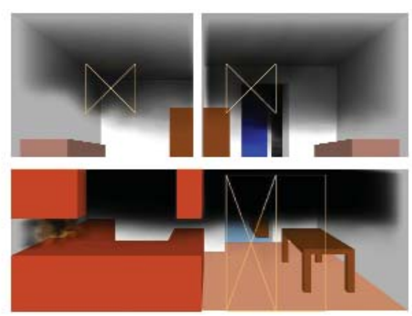
Virtual Reality Firefighter Training

Fighting fires in a burning building has no equal, but is it the only way to train? Is it the only way to demonstrate how different tactics will affect the fire? BFRL is creating a virtual reality training simulation of various fire situations to demonstrate how life-threatening conditions can develop in structures and to test firefighting tactics using computers. In turn, using this technology, firefighter training instructors can provide realistic visualization of fire growth and suppression.

To produce examples of effective firefighter training tools, BFRL have reworked their fire modeling software, Fire Dynamic Simulator (FDS), and the fire imaging program, Smokeview by adding enhanced fire-related simulation technologies, such as "real" visibility through smoke. Other features have



A simulated kitchen fire in a two-story townhouse illustrating the ability of the latest version of Smokeview to demonstrate visibility through smoke layer.

been added to make the visualizations look 3D and to make it easier for the trainee to "move about" the simulation scenario. Continued refinements of FDS will increase the system's ability for simulating smoke and gas flow caused by fire, wind, ventilation and structural conditions.

BFRL is working with firefighter instructors at the Maryland Fire and Rescue Institute and other organizations to develop simulations of all possible outcomes for selected fire scenarios used in training. These simulations will be incorporated into a software package, enabling firefighters in training instantly to learn the consequences of their actions such as opening a window, closing a door or focusing a hose spray in a certain direction.

Recent results are contained in *Understanding Fire and Smoke Flow Through Modeling and Visualization* by G.P. Forney, D. Madrzykowski, K.B. McGrattan and L. Sheppard published in *IEEE Computer Graphics and Applications*, Vol. 23, No. 4, 6-13, July/August 2003.

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Vibrations May Warn of Structural Collapses

BFRL and Harvey Mudd College in Claremont, California are conducting research to learn if measurable changes in building vibrations during fires can be a means to provide reliable early warning for first responders of building collapse. Sensitive accelerometers are attached to the sides of buildings and the vibrations that are excited in the building by the fire are measured continuously. In May 2002, a large-scale fire experiment was conducted in a vacant store of a shopping center in Woodbridge, Virginia scheduled for demolition. NIST, with funding from FEMA and with the cooperation of the Dale City and Prince William County (Virginia) Fire Departments set the fires and allowed the fires to burn until part of the structure collapsed. Analysis of the measurements of the structures vibration showed that significant changes occurred several minutes before the actual collapse. This data is being used to test various methods to analyze the data in real time to determine the basis for a practical warning device. Additional experiments are planned to examine the capabilities and limitations of this technology for advanced sensing of building collapse.

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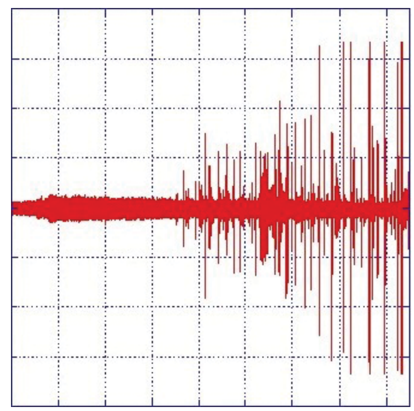
Roof collapses in shopping center store fire.



Measurements of building vibrations during fire up to roof collapse.

To develop the technical basis for the standards, technology, and practices needed for cost-effective improvements to the safety and security of buildings and building occupants, including evacuation, emergency response procedures, and threat mitigation.

The strategy to meet this goal is a three-part NIST-led public-private response program that includes:

- *a federal building and fire safety investigation to study the most probable factors that contributed to post-aircraft impact collapse of the World Trade Center (WTC) Towers and the 47-story WTC 7, and the associated evacuation and emergency response experience;*
- *a research and development (R&D) program to provide a technical foundation that supports improvements to building and fire codes, standards, and practices that reduce the impact of extreme threats to the safety of buildings, their occupants and emergency responders; and*
- *a dissemination and technical assistance program (DTAP) to engage leaders of the construction and building community in implementing proposed changes to practices, standards and codes. Also it will provide practical guidance and tools to better prepare facility owners, contractors, architects, engineers, emergency responders, and regulatory authorities to respond to future disasters.*

The desired outcomes are to make all buildings safer for occupants and first responders and to ensure better evacuation systems and emergency response capabilities for future disasters.

Investigation of the World Trade Center Disaster

Intended Outcome and Background

The focus of this NIST program is to investigate the building construction, the materials used, and the technical conditions that contributed to the outcome of the World Trade Center disaster. The findings of the investigation will serve as a basis for: improvements in the way buildings are designed, constructed, maintained, and used; improved tools and guidance for industry and safety officials; revisions to codes, standards, practices; and improved public safety.

The primary objectives of the NIST-led technical investigation of the WTC disaster are to:

1. Determine why and how WTC 1 and 2 collapsed following the initial impacts of the aircraft and why and how WTC 7 collapsed;
2. Determine why the injuries and fatalities were so high or low depending on location, including all technical aspects of fire protection, occupant behavior, evacuation, and emergency response;
3. Determine what procedures and practices were used in the design, construction, operation, and maintenance of WTC 1,2, and 7; and
4. Identify, as specifically as possible, areas in building and fire codes, standards, and practices that are still in use and warrant revision.

Media attending the Press Conference officially launching the World Trade Center Investigation on Aug. 21, 2002.

Drs. S. Shyam Sunder (left), Jack E. Snell (center), and Arden Bement (right) at the press conference officially launching the World Trade Center Investigation on Aug. 21, 2002.

The investigation includes eight projects that provide focus for the technical work. They are:

- **Analysis of Building and Fire Codes and Practices**
- **Baseline Structural Performance and Aircraft Impact Damage Analysis**
- **Mechanical and Metallurgical Analysis of Structural Steel**
- **Investigation of Active Fire Protection Systems**
- **Reconstruction of Thermal and Tenability Environment**
- **Structural Fire Response and Collapse Analysis**
- **Occupant Behavior, Egress, and Emergency Communications**
- **Fire Service Technologies and Guidelines**

Detailed information on progress is available on the NIST WTC website: http://wtc.nist.gov.

The desired outcomes of the investigation are to make all buildings safer for occupants and first responders and to ensure better evacuation systems and emergency response capabilities for future disasters.

ACCOMPLISHMENTS

Analysis of the Most Probable Structural Collapse Sequence

Structures subjected to extreme loads, such as blasts, high-speed impacts, and uncontrolled fires, experience a sequence of events that require complex analyses to determine the probable cause(s) of failure. Analysis of these types of problems requires a formal approach to integrate multiple disciplines effectively, to discern which parameters significantly influence the analysis methods, and to determine the most probable sequence of events leading to the initiation of structural collapse.

The objectives of the failure analysis are to answer the following questions:

- What is the most probable collapse sequence?
- What confidence levels are associated with the most probable collapse sequence?
- What is the probability of other possible collapse sequences?
- What parameters have the strongest influence on the most probable collapse sequence?

NIST has developed and adopted an integrated approach to identify the most probable of technically possible collapse sequences while accounting for variability in modeling, input parameters, analysis, and observed events. The approach combines mathematical modeling, and statistical and probabilistic methods. While the individual techniques are well understood, their integration and detailed implementation will be refined on the basis of initial and subsequent findings and results.

Simplified, accurate models for impact damage, fire dynamics, thermal-structural response, and collapse initiation analysis are required to enable robust, efficient estimation of uncertainties and collapse sequences. The development of such models is summarized below.

Reference structural, mechanical, and architectural (SMA) models are developed to establish their baseline performance under normal design loading conditions.

Steel column recovered from site of direct aircraft impact on World Trade Center north tower (WTC 1).

These reference models provide a consistent basis for the aircraft impact, fire dynamics, thermal-structural response and collapse initiation models and analyses.

The impact analysis determines the probable damage state(s) of the structure in the impact region, with identification of damaged structural components and collateral damage caused by fragments to the mechanical, architectural, and fire protection systems. Probable damage state(s) provide initial building conditions for subsequent fire dynamics and thermal-structural response analyses.

The fire dynamics analysis determines the probable paths of fire spread from the impact region up until the time of collapse initiation and the time-history of the heat imparted to the structure. The compartment-to-compartment spread of the fires is constrained by the observed timeline of fire and smoke movement through the structure.

The thermal-structural analysis determines the probable time-histories of the impact-damaged structural system response to the identified fire paths, accounting for cumulative heat-induced effects, such as thermal expansion, reduced structural stiffness and strength, and redistribution of loads. This analysis identifies the probable sequences of component damage or failure and provides the initial conditions for analyzing the stability of the structural system.

The collapse initiation analysis determines the most probable collapse sequence from each of the identified thermal-structural response time-histories through a stability analysis of the structural system. This analysis ranks the probable collapse sequences and times to failure, from which the most probable collapse sequence is identified.

Each of these models and analyses are developed through several phases: initial simplified studies for bounding the analyses, detailed component and subsystem analyses to understand the event physics and nonlinear behaviors, and simplified global analyses to capture the essential physics for estimating probable collapse sequences.

Mathematical modeling with mean-centered estimates of parameters provides an indication of a probable collapse sequence. Statistical analysis significantly extends the mathematical modeling by identifying influential parameters and evaluating the sensitivity of the results (collapse sequence and time-to-failure) to ranges of parameter values. Probabilistic analysis uses event tree and Monte Carlo techniques for determining the probability of different collapse sequences, and the parameters that contribute to uncertainty propagation. Parametric variation is estimated using experimental data, event observables, available as-built information and records, and engineering expertise. Systematic model variations are identified and minimized to the extent possible.

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Fireproofing of WTC Floor System

In May 2003, NIST issued an interim report on the Procedures and Practices Used for Passive Fire Protection of the Floor System of the World Trade Center Tower Structures as part of the ongoing federal building and fire safety investigation into the World Trade Center building collapses. The report summarizes factual data contained in documents provided to NIST by the Port Authority of New York and New Jersey and its contractors and consultants; by Laclede Steel Company, the firm that supplied the floor trusses for the WTC towers; and by United States Mineral Products Co. (USM), the manufacturer of the fireproofing material. To the maximum extent possible, the facts are presented without interpretation.

The report discusses applicable building codes and building classification system, which dictates the fire rating required for structural members and assemblies. The structural system for the World Trade Center towers was constructed predominantly of steel, which, in general, requires protection from fire to maintain its strength and stiffness. Attention is paid to the spray-on fireproofing and the procedures and practices used in its selection and application. Additionally, the report discusses the procedures and practices used to determine whether tests were needed to evaluate the fire endurance of the structural elements, and it presents the results from one such test.

This interim report documents the procedures and practices used for passive fire protection of the floor system of the WTC towers. In May 1963, the Port Authority instructed its consulting engineers and architects to comply with the New York City Building Code for the design and construction of the WTC towers. Because the New York City Building Code was being revised, the plans for fire protection of the structural steel underwent continuous modification. While available records that were reviewed suggest that the fireproofing of the columns, beams, and spandrels was not a subject of concern, fireproofing of the floor bar joists was the focus of continuous reassessment and revision.

Key findings are as follows:

- The WTC towers were identified as Occupancy Group E – Business, and classified as Construction Class IB in accordance with the 1968 New York City Building Code. This classification required that the columns and floor systems of the towers have a 3-hour and 2-hour fire endurance, respectively.
- The bar joists that supported the floors of WTC 1 and 2, were fireproofed with 1/2 in. of spray-on fireprotection material. This thickness of fireproofing was expected to meet the Class 1A Fire Rating of the New York City Building Code. The technical bases remain unknown for the selection of fireproofing material and the determination of the thickness of fireproofing for the bar joists.

A computer simulation of the WTC South Tower (2 WTC) fireball seconds after impact of the second aircraft.

- The fire protection of bar joist-supported floor system by directly applying spray-on fireproofing to the joists was relatively innovative at the time the WTC towers were designed and constructed. While the benefits of conducting a full-scale fire endurance test were realized, apparently no tests were conducted on the specific floor system used in the WTC towers.
- NIST is carrying out testing to assess the fire rating and behavior of typical fireproofed floor assemblies under the fire conditions prescribed in ASTM E 119.

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Reconstructing the WTC Fires

The extent, intensity and duration of the fires in each of the three WTC buildings played a pivotal role in its eventual collapse. Because of the dearth of information from inside the WTC buildings on the progression of the fires, the fires must be reconstructed using available information on the buildings' interiors and the photographs of the exteriors. Much of the combustible contents were manifested in numerous workstation cubicles. NIST has completed (1) a series of fire tests of

Photographs of the burning of a typical office workstation.

these workstations, including the effects of rubble and aviation fuel on their burning rate and (2) measurements in the Cone Calorimeter to obtain the combustibility properties of the workstation components. The latter have been used as input to the NIST Fire Dynamics Simulator computational model, which has been used to predict the burning behavior in the former tests. Additional burning phenomena have been identified and will be added to the model.

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Occupant Behavior, Evacuation, and Emergency Response

Thousands of pages of documentary data have been gathered from the Fire Department of the City of New York, the New York City Police Department, the Port Authority of New York and New Jersey, and the Port Authority Police Department. Also, more that one thousand hours of electronic data, in the form of audio recordings of communications during the incident, have been acquired from the above agencies. Project personnel have sorted, categorized the data, and are in the process of analyzing the contents. Types of data gathered includes the design and improvements of the egress system, emergency communications systems, occupant communication records, identification of units dispatched to the World Trade Center, data on their response, information on unit operations at the incident, equipment on hand at the incident, and emergency response technologies used at the incident, etc. A detailed chronology of events related to the emergency response and evacuation is being developed. This chronology contains information on the dispatch of emergency responders, their response and activities at the incident, radio and telephone communications related to responder operations at the incident, public address communications to the occupants, and information concerning the conditions of buildings 1, 2, and 7 as the incident unfolded.

In conjunction with outside experts, NIST has developed a comprehensive protocol for collecting first person accounts from survivors, family members of victims, and first responders. Face-to-face interviews, telephone interviews, and focus groups will assist with documenting the building evacuation, understanding occupant decision making, building safety operations, and the events of the day associated with the emergency response, as well as collecting observations of fire, smoke, and building damage. NIST personnel will conduct some of the interviews, and a company under contract with NIST will conduct the remainder of the interviews.

The history of evacuation of the World Trade Center and the first person accounts will support computer egress modeling. Three computer models will be used to better understand the events of September 11, 2001.

To expedite the process of digesting this large quantity of data additional personnel are being acquired to assist with the review process. NIST has also acquired the assistance of three experts with knowledge of emergency response operations for high-rise buildings in New York City. These consultants are assisting with identification of important emergency response issues and are instrumental in providing clarifications associated with information gathered.

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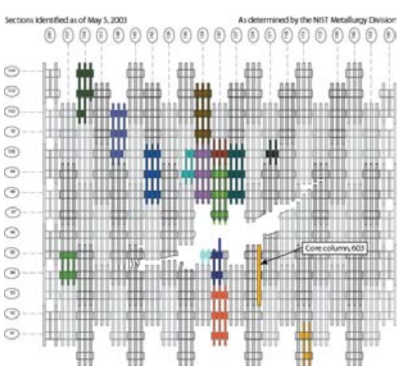
Analysis of Building and Fire Codes and Practices

The primary objectives of this part of the WTC investigation are to document the requirements that governed the design, construction, and maintenance of the structural and fire safety systems of the World Trade Center Towers and Building No. 7. In addition, the requirements applied to the WTC buildings are compared with the requirements applied to other buildings in New York City and Chicago in the same time period. This part of the WTC investigation will also document new technologies and materials, if any, that were incorporated in the design and construction of the buildings, and the criteria and procedure used to accept these innovations. This phase of the WTC investigation will also document major modifications to the structural and fire safety and egress systems following a major fire in 1975 and after the 1993 bombing.

To assist in determining the events that led to collapse of the WTC buildings, it is necessary to know the state of the buildings prior to the 9/11 attacks. Since the WTC Towers and WTC 7 were totally destroyed, the state of the buildings is recreated based on available design, construction, and maintenance documents. Documents provided by the Port Authority of New York and New Jersey, design professionals, contractors, and suppliers related to the design, construction, and maintenance of the buildings are examined for relevant information. The review of documents and synthesis of their content is carried out jointly with industry partners who have many years of experience in evaluating building code provisions, evaluating fire safety systems, and designing high-rise buildings in New York City.



Map of north face of WTC north tower (WTC 1) showing location of column at site of plane impact.

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R&D for the Safety of Threatened Buildings

Intended Outcome and Background

This program will develop and disseminate guidance and tools, assess and reduce building vulnerabilities, and produce the technical basis for cost-effective changes in national practices and standards. Implementation of the results will better protect building occupants and property in the future, will enhance the safety of fire and emergency responders, and will increase confidence in the safety of commercial and public buildings.

Four general areas of research are targeted to support near and long term improvements to reduce the vulnerability of the structure, building occupants and first responders to extreme threats:

Increasing Structural Integrity – Structural integrity will be increased through the development and implementation of performance criteria for codes and standards, tools and practical guidance for prevention of progressive structural collapse. System design concepts, retarded collapse mechanisms, built in redundancy, and hardening structures though retrofit are being considered. Performance criteria for fire safety design and retrofit of structures is being developed through examination of five key factors: the suitability of standard fire resistance test methods; the role of structural connections, diaphragms, and redundancy in

enabling load transfer and maintaining overall structural integrity; the effectiveness of alternative retrofit, design and fire protection strategies to enhance structural fire endurance; the fire behavior of structures built with innovative materials; and models to predict the fire hazard to structures from internal and external fires. Guidance on methods to enhance fire resistance of steel and concrete structures based upon our current state of knowledge are being developed as well.

Enhancing Fire Resistance – Fire resistant steels exist and are in use elsewhere in the world. More efficient and accurate tests for performance of steels under building fire conditions are needed and are being developed to help industry incorporate fire resistant steels into U.S. construction practice. Fundamental mechanical and thermal properties of fire protective materials are being measured. This requires the development of new test methods and instrumentation, and a data base that spans the full range of expected temperatures and mechanical loads. These data will supplement, or may even supplant the need for, the ASTM E119 test in certain situations, and in any case are key to the implementation of meaningful performance codes and design criteria.

Improving Emergency Egress and Access – By working with the primary stakeholders (elevator and construction industries, fire services, professional societies and code making bodies), the role of elevators in providing access by the fire service to a fire in a high rise building is being greatly enhanced over current practice. The development of hardened fire service elevators and new emergency operation procedures/controls will also lead to improved egress capabilities from tall buildings, especially for mobility-impaired or injured occupants. However, the behavior of people in an emergency situation has been altered in unpredictable ways by the events of 9/11. Current egress models may be inappropriate and/or insufficient for the design and placement of doors and stairways and the control of elevator movement. Behavioral and engineering studies are being conducted, drawing on experts in academia and elsewhere, to enable the development of simulation tools that better capture the movement of people within a building under fire and other emergency situations.

Developing Building and Emergency Equipment Standards and Guidelines – Partnering with ASHRAE and other federal agencies, NIST-developed indoor air quality (IAQ) simulation tools are being extended to analyze and guide the assessment and subsequent reductions in the vulnerability of buildings to chemical, biological, radiological aerosols. Standard building information models that facilitate the simulation of building system behavior during adverse events are being developed to allow communication among IAQ controls and other building controls associated with, for example, security, transportation, energy and fire alarm systems. A user-friendly tool is being developed for building owners and managers to aid in the selection of cost-effective strategies for the management of terrorist and environmental risks. Also, facilities are being established for science-based exposures for measurement of firefighter equipment performance attributes essential to support informed fire service procurement decisions.

ACCOMPLISHMENTS

Methodology for Fire Resistance Determination

Compartmentation is the cornerstone of limiting room-to-room and building-to-building fire spread. Standard fire resistance testing of wall/floor/ceiling assemblies provides an indicator of fire resistance and has proven valuable over time. However, these procedures have significant limitations that restrict their value for performance-based design and especially for high-risk occupancies. These limitations include: (a) standard time-temperature curves that may not be sufficient for all threats; (b) uniform heating, while many fires produce hot spots that may make the tests non-conservative; (c) single point thermal measurements; (d) pass/fail criteria, which make

BFRL measured the thermal behavior of gypsum/steel wall assemblies subjected to severe fire conditions.

adaptation to other fire scenarios difficult; (e) documentation of the initial failure mode, but not the relative time to any successive modes, and (f) relative ratings, not absolute values.

Compartmentation is especially important in tall buildings, where the egress of numerous occupants can be a complex process, and barriers to the spread of flame keep the egress paths open, extend the time available for escape, and increase the safe time in places of refuge. For all these functions, it is necessary to know, in terms of real time, how long the interior partitions in a building will contain flames and smoke.

BFRL has embarked on a course to provide such a methodology for inclusion in performance-based design of buildings. The research involves obtaining real-scale experimental data, modeling the behavior of partitions as they are driven to failure by the fire, and developing recommendations for obtaining the input parameters from modifications of standard fire resistance tests such as ASTM E119 and ISO 834. The initial work will focus on non-loadbearing walls of gypsum panels and steel studs, the most common interior construction in tall buildings. A continuing effort will extend the research to glass-panel walls.

The modeling effort will be done in three steps. First is a simple model for failure, beginning with crack initiation and propagation, continuing to the supporting structure, and finally to the fasteners and their failure points. This is now underway. Following this will come a detailed model of the partition materials to ascertain what additional data need to be obtained from the test method. The third component is a detailed model of a partition assembly for use by building design and engineering firms.

A series of real-scale compartment tests is providing information on the phenomenology of partition response and failure and also quantitative information to guide the model development. Various wall assemblies 2.44 m x 2.44 m were exposed to intense fires from the time of ignition to beyond flashover. Flux meters provided time histories of the energy incident on the walls. Thermocouples and infrared cinema provided data on the transport of heat through the walls and on the progress toward perforation.

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Prevention of Progressive Collapse

Buildings that are designed according to modern building codes are not expected to collapse during their service life period. They are designed typically to resist traditional governing vertical loads and lateral loads such as wind and earthquake. This situation is changing, however, due to an increase in deliberate terrorist attacks. In general, a terrorist attack may lead to failure to a small part of a building. When an initial local failure causes the loss of gravity load capacity in the structural frame, the failure spreads from story to story which may lead to the total collapse of an entire building or a disproportionately large part of the building. This type of collapse is defined as "progressive collapse" (see figure). At present, U.S. building codes do not provide explicitly provisions to enhance the resistance to progressive collapse. In terms of magnitude and probability of occurrence, the traditional vertical and lateral design loads are quantifiable. In contrast, terrorist loads are difficult to quantify as to size, location and the nature of the loads. Terrorist attacks may include thermal, impact and blast loads. Thus, in order to improve resistance to progressive collapse, U.S. building codes have attempted to incorporate structural redundancies by introducing prescriptive requirements for "structural integrity." Changes are needed in the way buildings are designed and constructed so that resistance to progressive collapse is provided explicitly. Following the 2002 National Workshop, NIST is working jointly with the Multihazard Mitigation Council of the National Institute of Building Sciences and industry experts to produce a "Best Practices Guide" for mitigating progressive collapse of buildings for design professionals. This document will be published in FY2004. Subsequent research effort will focus on the development of tools to assist design professionals in the design of new buildings against progressive collapse and methods to enhance the resistance of existing buildings to progressive collapse.

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Collapse of Ronan Point Apartment in England (1968)

Cost-Effectiveness Tool for Managing Terrorists Risks in Constructed Facilities

The September 11th attacks on the World Trade Center buildings and the Pentagon galvanized the nation to strengthen its defenses against future terrorist attacks. The owners and managers of constructed facilities are now faced with the task of responding to the potential for future terrorist attacks in a financially responsible manner. An economic tool is needed to direct limited resources to investments in mitigation strategies that will provide the most cost-effective reduction in personal injuries, financial losses, and damages to buildings, industrial facilities, and infrastructure.

The economic tool, under development by the Office of Applied Economics (OAE), is a decision methodology, embedded in user-friendly, decision-support software, that helps building/facility owners and managers choose the most cost-effective mix of mitigation strategies. Three mitigation strategies are considered: (1) engineering alternatives; (2) management practices; and (3) financial mechanisms. The economic tool will provide decision makers with the basis for generating a risk mitigation plan that responds to the potential for future terrorist attacks in a financially responsible manner.

Early in 2002, OAE economists Dr. Robert E. Chapman and Dr. Harold E. Marshall prepared a white paper outlining the tool development effort. OAE used the white paper to solicit stakeholder inputs, create opportunities for collaborative efforts, and form a Steering Committee of external subject matter experts. This has resulted in collaborative efforts with the Wharton Risk Management and Decision Processes Center, the Construction Industry Institute, ASTM International, and the EPA Safe Buildings Program. Dr. Marshall prepared an expanded version of the white paper entitled "Economic Approaches to Homeland Security for Constructed Facilities" and delivered it at the September 2002 CIB Meeting in Cincinnati as the invited Keynote Address.

Significant OAE products during this reporting period include a prototype version of the software and a NISTIR illustrating the methodology via a case study building. OAE information technology specialist Ms. Amy S. Rushing completed the prototype version of the software and presented it to the Steering Committee in September 2003. The prototype includes the software's graphical user interface and linkage to database files and key reports. The beta version of the software is planned for completion in 2004; it will facilitate a variety of user-specified analyses. All analyses employed in the software will be consistent with ASTM standard practices. A case study report illustrating how to apply the life-cycle cost method (ASTM E 917) to a prototypical commercial building renovation project was produced by Dr. Chapman and published in NISTIR 7025. A subsequent technical report by Dr. Chapman and OAE economist Ms. Chi J. Leng documenting the decision methodology is planned for publication in 2004.

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Fire Safety Design and Retrofit of Structures

Current building design practice does not consider fire as a design condition to predict and evaluate structural performance in the presence of an uncontrolled fire. Instead, fire endurance ratings of building members, derived from standard fire endurance test, are specified in building codes. There is no accepted science-based set of verified tools to evaluate the fire performance of entire structures under realistic fire conditions at present. Thus, there is an urgent and critical need to develop and implement verified and improved standards, technology, and practices that explicitly consider structural fire loads in the design of new structures and the retrofit of existing structures. A workshop was held recently in cooperation with the Society of Fire Protection Engineers to assess current fire safety practice and existing codes and standards, and to identify research gaps for an improved fire safety design and retrofit approach. The workshop was attended by national and international fire safety experts and provided the technical basis for the development of a national R&D roadmap for Fire Safety Design and Retrofit of Structures.

In addition, an evaluation has been performed of state-of-the-art numerical tools, including ANSYS and SAFIR, to assess their suitability for use in analyzing performance of structures under the combined fire and mechanical loadings. The evaluation process of these analytical platforms, which are rarely used in practice for fire safety design, is ongoing and necessary due to the complexity of structural systems, loading conditions, boundary conditions, and the highly nonlinear nature of the material and structural behaviors. Effect of high thermal loading on structural performance of tested concrete column, WTC steel connections, members, and subassemblies was examined. To better inform the modeling effort, a series of large-scale testing was conducted of steel components in a fire environment. The tested components included steel rods, columns, and open-web steel joists that were either left bare or had sprayed-on fire protective insulation material of varying thickness. Test fires were generated using liquid hydrocarbon fuels to produce medium-soot fires and high-soot fires and the tests were continued until the temperature at any steel surface approached approximately 600° C.

Insulated steel trusses, steel rod, and steel column inside the NIST Large-scale Fire Laboratory

View of fire compartment from air exhaust outlet several minutes after the start of a fire test. Note the flame impingement on the steel trusses and bar

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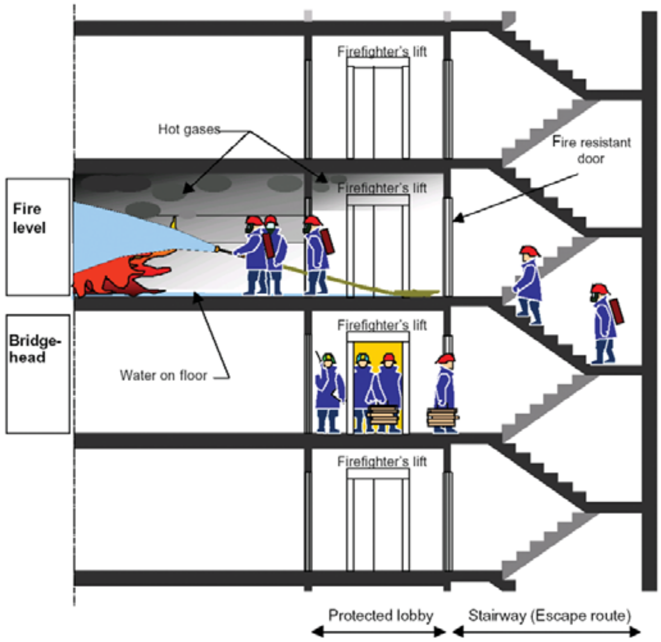

Firefighters elevators provide access to fires on upper floors of tall buildings.

Emergency Use of Elevators

This project is aimed at the development and implementation of protected elevators that can be used for fire department access and occupant egress during emergencies in tall buildings. The general strategy is to first incorporate into U.S. Codes and Standards a protected elevator system for fire department access. These are known in other countries as firefighter lifts and there are existing requirements for these in at least 12 countries (as identified in a report by ISO TC178 on Elevators and Escalators). Once the U.S. fire services are satisfied that elevators are safe and reliable during fires codes, and standards would be changed to recognize protected elevators for occupant egress, secondary to or integrated with stairs.

The key technological advancement offered in the NIST strategy is the (new) concept of remote manual control. Here the elevator system safety is monitored in real time by the fire alarm system and displayed on a standardized fire service interface developed jointly by NIST and the fire alarm industry, through the National Electrical Manufacturers Association (NEMA) and implemented in the 2002 edition of the National Fire Alarm Code (NFPA72). This system addresses residual concerns held by the fire service and elevator industry even where such systems are utilized under existing codes and standards. The system further might be specified for accessible elevators required in U.S. and other building codes for access by people with disabilities but where the safety for use in egress during fires is still considered questionable.

Several technical papers have been written by NIST and presented at a recent international conference on Tall Buildings organized by CIB and CTBUH. NIST organized and chaired the speakers' session on emergency use of elevators, which included papers by two of the largest U.S. elevator companies (Otis and Kone). NIST is also co-sponsoring and presenting papers at a workshop scheduled for the first week in March 2004 organized by ASME and their A17 committee which is responsible for the standard convening the safe use of elevators referenced in all U.S. building codes. NIST is working with the key representatives of the elevator industry and regulators represented on the A17 committee and with the product development engineers at Otis and Kone to implement the required technology and interfaces into their elevator controls, and on a novel approach to work out changes to the elevator control software for emergency operations protocols during fires. This approach would utilize BFRL's Virtual Cybernetic Building Testbed to allow numerous simulations of building fires to test the ability of the control software to adapt to conditions and to maintain safe operations.

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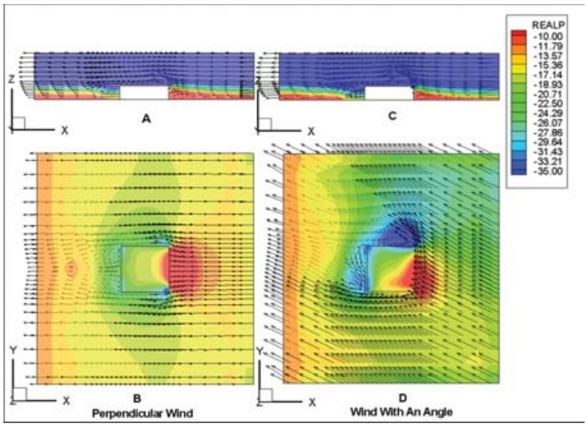
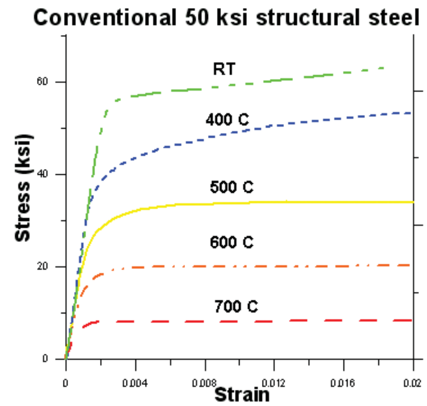
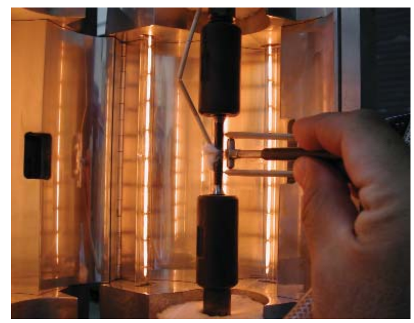


Exterior Flow Field as input to CONTAM model of building



Stress-strain curves of a conventional structural steel, showing degradation of properties at high temperatures.



High temperature tensile tests to measure performance of structural steel at temperatures found in building fires.

Guidelines and Technologies for Mitigation of Chemical, Biological and Radiological Aerosol Attacks

The increased attention to the potential vulnerability of buildings to airborne chemical, biological and radiological (CBR) agents has lead to the need for better simulation tools to evaluate the transport and fate of such agents in buildings. BFRL's longstanding expertise in airflow and contaminant transport modeling in buildings systems has been employed in many such analyses and recently these capabilities have been extended via the release of version 2.1 of the CONTAM software. Among other enhancements, CONTAM is now able to use the output of exterior plume models as an input, such that outdoor contaminant concentrations from an exterior agent release can vary as a function of opening location on the building façade and time. This new capability allows users to link their exterior transport models to CONTAM and allow details analyses of the impact of an exterior release on indoor concentrations. In addition, CONTAM version 2.1 has improved models of particulate contaminants and has added fan and damper transients to the ability to simulate controls. The updated CONTAM model is now being used by an increasing number of researchers and practitioners in their evaluation of specific buildings and of technologies with the potential to increase building protection.

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Fire Resistant Steel

Structural steel loses strength at building fire temperature, leading to the need for costly and potentially unreliable fire-proofing. In contrast, a new class of fire-resistant steels, or "FR steels," is specifically designed to retain more of the design strength at high temperature. These steels are being produced in Japan and Europe, and are now in use, either with or without additional fire protection. The use of FR steels leads to cost savings and schedule benefits during construction when application of fire protection can be avoided, and enhanced performance when protection is applied in the case of damage to the insulation.

Unfortunately, the benefits of FR steel are not adequately tested under the standard U.S. structural fire standards (ASTM E119) and thus are not currently used in the U.S.

A project has been initiated to ascertain which properties of steel are critical for efficient use of FR steels, such as high temperature strength and creep. Conventional steels and FR steels are being characterized to determine these critical properties. Our goals include both provision of accurate data on FR steels and development of quick and accurate tests for measuring relevant high temperature properties.

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AASHTO

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS

AASHTO Materials Reference Laboratory (AMRL)

Established at NIST (then NBS) in 1965, the AASHTO Materials Reference Laboratory (AMRL) is a research associateship with a staff of 48 that provides a highly-valued quality assurance mechanism for laboratories that use AASHTO standards for highway materials; it also provides technical assistance to the AASHTO Accreditation Program (AAP) that currently accredits about 850 laboratories. With Mr. James Pielert as Manager and Mr. Peter Spellerberg as Assistant Manager, the AMRL provides, upon request, as reimbursable services, laboratory inspection and proficiency sample programs. In 2002, over 1500 laboratories participated in AMRL programs. For those laboratories that wish to participate in the AAP, results of the relevant laboratory inspections carried out by the AMRL and the ASTM-sponsored Cement and Concrete Reference Laboratory (CCRL) are the basis for accreditation. AMRL's quality assurance services are complemented by standards-related research carried out in collaboration with BFRL researchers.

ACI

AMERICAN CONCRETE INSTITUTE

Dr. Geoffrey Frohnsdorff, guest worker in the Materials and Construction Research Division, is a member of ACI's Board of Direction and chairs the new Task Group on Implications of Virtual Concrete Technology.

ACI Advisory Group to ISO TC71, Concrete, Reinforced Concrete, and Pre-Stressed Concrete

Dr. Geoffrey Frohnsdorff, guest worker in the Materials and Construction Research Division, is a member of the ACI Advisory Group to ISO TC71, Concrete, Reinforced Concrete, and Pre-Stressed Concrete.

ACI Committee 216, Fire Resistance and Fire Protection of Structures

Dr. Long Phan, Materials and Construction Research Division, chairs the joint ACI/TMS (The Masonry Society) Committee 216 on Fire Resistance and Fire Protection of Structures. During 2002 he lead the effort to revise the committee guide for *Determining the Fire Endurance of Concrete Elements.*

ACI Committee 235, Knowledge-Based Systems and Mathematical Models of Materials

Dr. Chiara Ferraris, Materials and Construction Research Division, chairs Subcommittee ACI 235B, Database Formats for Concrete Material Properties.

Dr. Geoffrey Frohnsdorff, guest worker for the Materials and Construction Research Division, chairs Subcommittee ACI 235C, Virtual Concrete Technology.

ACI Committee 236, Materials Science of Concrete

Dr. Chiara Ferraris, Materials and Construction Research Division, chairs ACI Committee 236 on Materials Science of Concrete and subcommittee ACI 236A on Workability of Fresh Concrete. As the chair of ACI 236A, she leads efforts to coordinate an international study to compare and correlate concrete rheometers. The second trial was held in Cleveland, OH in May 2003. As chair of ACI 236 she is fostering a better understanding on how prediction of concrete properties could be improved by better knowledge of material science.

ACI Committee 318, Structural Concrete Building Code

Dr. H.S. Lew, Materials and Construction Research Division, serves on ACI Committee 318, which is responsible for developing ACI Standard 318—*Building Code Requirements for Structural Concrete.* Dr. Lew introduced new provisions for adoption by ACI 318. Dr. Lew serves on Subcommittee C on safety, serviceability and analysis and the subcommittee for new materials, products and ideas.

Dr. Nicholas J. Carino, Materials and Construction Research Division, serves on to ACI 318 Subcommittee A, which is responsible for the portions of ACI Standard 318 dealing with construction. Dr. Carino has led efforts to update the code as a result of changes to applicable ASTM standards.

ACI Committee 437 on Strength Evaluation of Existing Concrete Structures

Dr. Nicholas J. Carino, Materials and Construction Research Division, was a member of the task group on the revision of the committee report on *Strength Evaluation of Existing Concrete Buildings.* He updated the portions of the document dealing with in-place and nondestructive test methods. The revised report was published by ACI in 2003.

ACI Committee 440, Fiber Reinforced Polymers

Dr. Dat Duthinh, Materials and Construction Research Division, is playing an active role in drafting *Guidelines for Prestressing Concrete Structures with FRP Tendons*, which will be published by ACI as part of its series on emerging technologies, and *Guidelines for Repair and Strengthening of Masonry Structures*, which will be published jointly by ACI and TMS (The Masonry Society).

ACI Electronic Guide on Cements

Dr. Geoffrey Frohnsdorff, a guest worker in the Materials and Construction Research Division, chairs an ad hoc task group of three ACI committees—Hydraulic Cements, Knowledge-Based Systems and Mathematical Modeling of Materials, and Materials Science—to oversee a cooperative pilot activity in the development of an interoperable guide to selection and use of cements.

TAC Specifications Committee

Dr. Nicholas J. Carino, Materials and Construction Research Division, serves as chair of the TAC Specifications Committee, which is responsible to coordinating the standard specifications issued by ACI and maintaining the Specification Manual covering the standard format of ACI specifications. During 2002 he lead the effort to revise the Manual, which was approved by the Technical Activities Committee (TAC). In 2003, he lead the effort to re-organize ACI specifications to eliminate conflicts and facilitate their use in project specifications.

Technical Activities Committee (TAC)

Dr. Nicholas J. Carino, Materials and Construction Research Division, serves on the ACI Technical Activities Committee which is responsible for oversight of all ACI technical activities, including review of all technical committee documents. He initiated numerous revisions of the *Techncial Committee Manual* that governs the operation of ACI technical committees.

ACI Concrete Research and Education Foundation (ConREF)

Dr. H.S. Lew, Materials and Construction Research Division, serves as chair of the ACI/Concrete Research and Education Foundation's Board of Trustees, which is responsible for establishing overall strategic goals for development of concrete technology and administering funds for education, research, and scientific purposes in order to increase the knowledge and understanding of concrete materials and improve concrete design and construction. Dr. Geoffrey Frohnsdorff, guest worker in the Materials and Construction Research Division, is a Trustee of the Concrete Research and Education Foundation.

AHAM HRF-1 Household Refrigerators/ Household Freezers

Mr. David Yashar, Building Environment Division, served on the committee responsible for revising *AHAM HRF-1 Household Refrigerators/Household Freezers*. This standard governs the evaluation of volume measurement, performance measurement and energy consumption of household refrigerators and household freezers. The efforts of the committee have led to the publication of the first revision of the standard in 14 years to be approved by the American National Standards Institute (ANSI), ANSI/AHAM HRF-1-2002.

In 2002-2003, the task force continued to review and revise the text and diagrams. The revised edition will supersede the 2002 edition. This updated version of the standard will contain information specifically relating to compact refrigerators that is based on BFRL research. Mr. Yashar is also serving as a member of the ANSI canvass board reviewing the 2003 version of this standard.

AISC

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

Mr. Robert Lipman, Building Environment Division, and Dr. Kent Reed, in the same division, have been working for the past several years to support the AISC Electronic Data Interchange Initiative. The purpose of the initiative is to create a means for collaboration and data sharing among the various parties involved in steel construction. As members of the CIS/2 (CIMsteel Integration Standards) International Technical Committee, Mr. Robert Lipman and Dr. Kent Reed have provided input to the second edition of the standard which was released in Spring 2003. They are working with vendors of steel analysis, design, detailing, and fabrication software to implement the standard.

AISC Committee on Specifications

Dr. John L. Gross, Materials and Construction Research Division, serves on the American Institute of Steel Construction Committee on Specifications. The Committee is responsible for developing requirements for the design, fabrication and erection of steel buildings and publishes the *Specification for Structural Steel Buildings*. Dr. Gross serves on Technical Subcommittee 3 (TC3) – Loads, Analysis and Systems, and TC 8 – Temperature Effects.

ASCE

AMERICAN SOCIETY OF CIVIL ENGINEERS

SEI/ASCE Executive Committee on Codes and Standards

Dr. H.S. Lew, Materials and Construction Research Division, serves on the SEI/ASCE Executive Committee on Codes and Standards. He worked closely with committees that develop standards for seismic evaluation and rehabilitation of buildings, and for the testing and evaluation of seismic isolation systems and components.

ASCE Committee ASCE-7

Dr. Emil Simiu, Materials and Construction Research Division, is a member of the ASCE Committee on Minimum Design Loads for Buildings and Other Structures (ASCE-7).

ASCE Committee on Structural Condition Assessment of Existing Buildings

Mr. James Pielert, AASHTO Materials Reference Laboratory, is on the control group of the ASCE Standards Committee on Condition Assessment of Existing Buildings.

ASHRAE

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS, INC.

ASHRAE Standards Committee

Mr. Brian Dougherty, Building Environment Division, began serving his third year on the Standard Committee in July 2003. The committee is responsible for overseeing the development and maintenance of all ASHRAE standards, guidelines, and code language documents. Mr. Dougherty is a member of the Technical Committee Liaison Subcommittee and chairs the Inter-Society Liaison Subcommittee. Mr. Dougherty has specific responsibility as the standards committee liaison for twelve technical committees.

ASHRAE 37R Methods of Test for Rating Electrically Driven Unitary Air-Conditioning and Heat Pump Equipment

Mr. Brian Dougherty is the lead editor on this revision of the standard, which was last updated in 1988. The standard is being updated to reflect current laboratory practices and instrumentation and to better address newer equipment features. The laboratory test methods described in the standard are used to obtain the performance data that is ultimately used in calculating federally mandated seasonal rating descriptors. Following its June 2003 Meeting, the committee voted and recommend the revised standard be released for a second public review.

ASHRAE Standard 62.2 Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

Mr. Steven Emmerich, Building Environment Division, serves as secretary of the committee responsible for developing a new ventilation and indoor air quality standard for low-rise residential buildings. The draft document was recently issued for a fourth public review. The committee also started development of a companion guideline under the direction of Mr. Emmerich.

ASHRAE Standard 103 Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers

Dr. Stanley Liu, Building Environment Division, is a voting member of ASHRAE SPC 103 Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers. This standard was last updated in 1993. The standard provides the test and calculation procedures for the determination of an Annual Fuel Utilization Efficiency (AFUE) of central fossil fuel-fired residential heating equipment. The standard is referenced by the Department of Energy in its federal mandated rating of consumer fossil fuel fired central heating equipment. The committee is currently considering changes in this test standard to make the test procedure more precise for certain type of design. A first draft of a revised document is currently being prepared for public comments.

ASHRAE Standard 118.2 Method of Testing and Rating Residential Water Heaters

Dr. William Healy, Building Environment Division, is a voting member of ASHRAE SPC 118.2 Method of Testing and Rating Residential Water Heaters. This standard governs the evaluation of the energy factor which rates the thermal efficiency of residential water heaters and the first-hour rating which provides a metric for the amount of hot water provided by a tank. The committee is currently considering changes in this test procedure to correct errors in calculations and to make the procedure more consistent. Work has been undertaken to determine the differences between the ASHRAE procedure and the Department of Energy's procedure in an effort to align the two methods of test.

ASHRAE Standard 124 Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances

Dr. Stanley Liu, Building Environment Division, is a voting member of ASHRAE SPC 124 Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances. This standard was first published in 1991. The standard provides the test and calculation procedures for the determination of a Combined Annual Efficiency for equipment that provide both space heating and water heating. Combination appliances are either space-heating boilers that also provide domestic hot water, or domestic water heaters that also provide heated water for space heating purposes The committee is currently considering updating of this test standard to correct errors in the standard and to consider proposed revisions from industry. A first draft of a revised document was published by ASHRAE for public review and comment in 2002. Comments were received by ASHRAE and are under review by the committee.

ASHRAE Standing Standards Project Committee 135

Mr. Steven T. Bushby, Building Environment Division, chairs ASHRAE Standing Standards Project Committee 135 (SSPC 135). This committee is responsible for maintaining the BACnet communication protocol standard (ASNI/ASHRAE Standard 135) and a newly published Standard 135.1 Method of Test for Conformance to BACnet. The BACnet Manufacturer's Association and the BACnet Interest Group – Europe have adopted the new testing standard as the basis for testing and listing programs in the United States and Europe.

Addendum *b* to Standard 135, which modifies trending features to fix some problems that were encountered in deployed BACnet systems, was published in 2003. Three other addenda have completed the public review process and are awaiting final approval for publication. Addendum *a* adds a number of new features including more advanced scheduling capabilities, more detailed error reporting, and the ability to dynamically discover the presence of MS/TP slaves. Addendum *c* contains new features that include enhancements to the life safety objects and services and the ability to represent utility meters and other measuring devices that provide pulsed outputs. Addendum *d* contains information on interconnecting BACnet devices with devices that use the European Installation Bus (EIB)/Konnex protocol.

ASHRAE 135.1P Method of Test for Conformance to BACnet

Mr. Steven T. Bushby, Building Environment Division, was the principal author of a draft standard, *ASHRAE 135.1P, Method of Test for Conformance to BACnet*. This proposed standard defines detailed testing procedures for verifying that control products correctly implement the BACnet communication protocol. Although still in the public review process, 135.1P has already been adopted by the newly-created BACnet Manufacturers Association and the BACnet Interest Group – Europe (BIGEU) as the basis for testing and listing programs in the United States and Europe. Mr. Bushby is Chairman of ASHRAE Standing Standard Project Committee 135 (SSPC 135) that maintains the BACnet communication protocol standard for building automation and control systems. In 2001 a revised version of the standard was published that included all addenda approved since 1995. Two new addenda have since been prepared and published for public review and comment. Addendum *a* to 135-2001 adds a number of new features including more advanced scheduling capabilities, more detailed error reporting, and the ability to dynamically discover the presence of MS/TP slaves. Addendum *b* to 135-2001 modifies trending features to fix some problems that have been encountered in deployed BACnet systems. BACnet has been translated into Chinese, Japanese, and Korean. It has been adopted as a Korean national standard, a European Community prestandard, and has recently been adopted as an ISO standard.

ASHRAE Standard 155P Method of Testing for Rating Commercial Space Heating Boiler Systems

Dr. Stanley Liu, Building Environment Division, is a voting member of ASHRAE SPC 155P Methods of Testing for Rating Commercial Space Heating Boiler Systems. The purpose of the standard is to provide procedures for determining the steady state thermal efficiency, part load efficiency, standby loss rate and application part load value of commercial space heating boiler systems. The standard, when approved and published by ASHRAE, will be referenced by ASHRAE standard 90.1 as the rating procedure for space heating boiler systems used in commercial buildings. A final draft of the document is in preparation, and will be voted upon by committee members for presentation to ASHRAE Standards Committee when completed.

ASME

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ASME Solar Energy Division

Dr. A. Hunter Fanney, Building Environment Division, is a member and past chairman of ASME's Solar Energy Division. This Division is responsible for coordinating all solar energy activities within ASME including the *Journal of Solar Energy Engineering*, annual conferences, student activities, and awards. He has organized and will serve as the moderator at a session entitled *"Building Integrated Photovoltaics"* at the 2003 International Mechanical Engineering Congress in Washington D.C. Dr. Fanney is also serving as an acting Associate Editor for ASME's *Journal of Solar Energy Engineering*.

ASTM

AMERICAN SOCIETY FOR TESTING AND MATERIALS

ASTM Committee C01 Cement

Mr. James Pielert, AASHTO Materials Reference Laboratory, is committee secretary and a member of the Executive Subcommittee of ASTM Committee C01 on Cement; he also chairs the Joint Subcommittee on International Activities of ASTM C01/C09.

Mr. Jan Prowell, Research Associate with CCRL, chairs ASTM Subcommittee C01.97, Manual of Cement Testing.

Dr. Geoffrey Frohnsdorff, guest worker in the Materials and Construction Research Division, is vice chair of Committee C01, serves on the C01 Executive Subcommittee, and is chair of Subcommittee C01.92, Administrative Coordination and Long-Range Planning.

ASTM C01.23 Subcommittee on Computational Analysis

Mr. Paul Stutzman, Materials and Construction Research Division, chairs the task groups on X-Ray Diffraction Analysis and Petrographic Analysis in ASTM Subcommittee C01.23, Compositional Analysis. Under his leadership, standards for improved characterization of portland cements in terms of the phases present using these two techniques have been established. He also serves as the official voting member for NIST on Committee 01.

ASTM C01.25.01 Subcommittee on Particle Size Analysis

Dr. Chiara Ferraris, Materials and Construction Research Division, led the effort to organize and analyze two round-robin tests on particle size analysis of cement. Two reports were published and the SRM 114p certificate was amended to include the particle size distribution measured by laser diffraction using two methods for dispersion. A draft method for measuring PSD of cement by laser diffraction was proposed to the ASTM subcommittee.

ASTM Committee C09 Concrete and Concrete Aggregates

Dr. Nicholas J. Carino, Materials and Construction Research Division, was elected Chair of Committee C09 for a two-year term beginning in 2002. He chaired the task group that prepared a revision of ASTM C 42 (Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete). The revision was approved in 2003 and takes into account new research findings on the effects of moisture conditioning before testing cores for strength. This revision brings the test method in agreement with ACI 318-02 *(Building Code Requirements for Structural Concrete)*. He also prepared revisions to Test Methods C 215, C 597, and C 803 that were approved in 2002. He was instrumental in the preparation of a new specification on corrosion inhibiting admixtures that was approved by Subcommittee C09.23 on Chemical Admixtures. He also contributed to new standards on the pull-off method, cold weather admixtures, and new tests for setting time. He assisted in analyzing round robin test data for a new standard on measuring slump-flow of self-consolidating concrete.

Mr. James Pielert, AASHTO Materials Reference Laboratory, is a member of the Executive Subcommittee of ASTM C09, is secretary of Subcommittee C09.61 on Testing for Strength, and chairs ASTM Subcommittee C09.92 on International Activities.

Mr. Raymond Kolos, Research Associate with CCRL, chairs ASTM Subcommittee C09.97, Manual of Testing for Concrete and Concrete Aggregates.

Dr. Chiara Ferraris, Materials and Construction Research Division, is a member of the Subcommittee C09.66 on Resistance to Fluid Penetration and leads the effort to ballot a "Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes." The document was revised several times and it is now ready for balloting by C09.

Mr. James Pielert, AASHTO Materials Reference Laboratory, is a member of the Executive Subcommittee of ASTM C09, is secretary of Subcommittee C09.61 on Testing for Strength, and chairs Subcommittee C09.92 on International Activities.

Mr. Raymond Kolos, Research associate with CCRL, chairs ASTM Subcommittee C09.97, Manual of Testing (for concrete and concrete aggregates).

ASTM C16 Committee on Thermal Insulation

Mr. Robert R. Zarr, Building Environment Division, chairs a new task group activity covering the development of database formats for thermal transmission data obtained by ASTM C16 Standard Test Methods. Mr. Zarr also chairs the committee's task groups on precision and bias, and the design and operation of guarded-hot-plate apparatus.

ASTM Committee C24 on Building Seals and Sealants

Dr. Chris White, Materials and Construction Research Division, is an active member of ASTM C24 and is also a member of the RILEM Committee on Sealant Durability.

ASTM Committee D04 Road and Paving Materials

Mr. Peter Spellerberg, Research Associate with AMRL, is the Secretary of ASTM Committee D04 on Road and Paving Materials, and chairs subcommittee D04.95.

ASTM Committee D18 Soil and Rock

Mr. Ronald Holsinger, Research Associate with AMRL, is on the Executive Committee of ASTM Committee D18 on Soil and Rock; is the secretary of D18.05; and chairs D18.03.

ASTM Subcommittee D20.96 Biodegradable Plastics Subcommittee

Ms. Barbara Lippiatt, Office of Applied Economics, is writing a standard under the D20.96 Biodegradable Plastics Subcommittee for reporting the life-cycle environmental profiles of products.

ASTM Subcommittee D22.05 Indoor Air Quality

Dr. Andrew Persily, Building Environment Division, is vice-chair of ASTM Subcommittee D22.05. This subcommittee has approved and is currently developing a suite of standards related to indoor contaminant measurement, analysis and interpretation. Several of these standards are based directly on research and methods developed by BFRL.

ASTM E5 Committee on Fire Standards

Mr. James R. Lawson, Fire Research Division, is currently the chairman of ASTM Subcommittee E5.15 on Fire Standards for Furnishings and Contents. and a voting member of the NFPA Fire Test Technical Committee. These committees develop fire standards for building construction, transportation, and furnishings. These fire standards are used by the building codes and other regulating authorities throughout North America. In addition, Mr. Lawson is a voting member of the ASTM F23 Committee on Protective Clothing, and NFPA Committee for the Standard on Protective Ensemble for Structural Fire Fighting while Mr. Robert Vettori serves as alternate. These technical committees develop standards for protective clothing and equipment used by the fire service in North America. Fire Standards and protective clothing and equipment standards are under constant development and revision as new knowledge and technology becomes available.

ASTM Subcommittee E06.23 Lead Hazards Associated with Buildings

Dr. Walter Rossiter, Materials and Construction Research Division, is a member of many ASTM E06.23 task groups. In concert with Dr. Mary McKnight, Dr. Rossiter plays a key role in the development and revision of standards. In 2003, E06.23 issued two new standards and eight revised standards. Two draft standards were also proposed.

ASTM Subcommittee E06.41 Infiltration and Ventilation Performance

Dr. Andrew Persily, Building Environment Division, chairs ASTM Subcommittee E06.41. Under his leadership, more than 15 standards for evaluating building airtightness, ventilation performance and other aspects of air leakage and airflow in buildings are approved or under development.

ASTM Subcommittee E06.66 Performance Standards for Dwellings

Dr. Robert Chapman, Office of AppliedEconomics, completed and obtained approval of the economics attribute standard that ties together the E06.66 family of standards that define total building performance. The standard guide was published by ASTM with the designation E 2156. In addition to describing how to measure economic performance, the guide includes a detailed example of how to apply the methodology to a durability-related investment decision that builds on the companion durability attribute (ASTM Standard Guide E 2136.

Dr. Andrew Persily, Building Environment Division, is writing the indoor air quality attribute standard, which is expected to be published in 2003. He has recently initiated development of the health and hygiene attribute standard in collaboration with HUD.

ASTM Subcommittee E06.81 Building Economics

Dr. Harold E. Marshall, Office of Applied Economics (OAE), has been the sole chairman of ASTM's Building Economics Subcommittee, E06.81, since its inception in 1979. He has played major authorship, educational, and leadership roles in writing and shepherding successfully 21 standards and two software products through the ASTM standardization process. His recent efforts are focused on widespread implementation of a standard elemental building classification called UNIFORMAT II. Based on two NIST reports co-authored by Dr. Marshall, the ASTM standard classification provides the building community a common elemental classification for the description, economic analysis, and management of buildings over their life cycle. R.S. Means has adopted UNIFORMAT II and advertises its cost manuals by saying they are "consistent with ASTM's UNIFORMAT II, the industry standard." UNIFORMAT II is helping owners, project managers, designers, builders, and facility managers construct and manage their buildings more cost effectively. Since March 2001, 75 thousand requests have been made for the pdf file of the UNIFORMAT II NISTIR on the OAE web site. Other building economics standards based on research of Dr. Marshall and his OAE staff include methods for measuring and evaluating life-cycle costs, net benefits or savings, and adjusted internal rates of return.

ASTM Committee E11 on Quality and Statistics

Mr. Ronald Holsinger, Research Associate with AMRL, is on the Executive Committee of ASTM Committee E11 on Quality and Statistics.

ASTM E44.09

Dr. A. Hunter Fanney is a member of subcommittee E44.09 that deals with numerous issues concerning the testing and evaluation of photovoltaics. Current areas of interest include developing rating methodologies for photovoltaics that use short-term data to predict long-term performance, and im-proved indoor and outdoor test procedures.

ASTM Standing Committee on Publications

Dr. Mary McKnight, guest worker in the Materials and Construction Research Division, serves on the ASTM Standing Committee on Publications. The Committee advises the Society's Board of Directors on the formulation of publications policy and administers the Society's publications program, except for the *Annual Book of ASTM Standards.*

CCRL

CEMENT AND CONCRETE REFERENCE LABORATORY

Established at NIST (then NBS) in 1929 as the Cement Reference Laboratory in response to a request from Congress, the ASTM-sponsored Cement and Concrete Reference Laboratory (CCRL) is a research associateship that provides a highly valued quality assurance mechanism for laboratories that use ASTM cement and concrete standards. With Mr. James Pielert of AASHTO as Manager and Mr. Raymond Kolos of ASTM as Assistant Manager, and a staff of 25 ASTM research associates, the CCRL provides, upon request, as reimbursable services, laboratory inspection and proficiency sample programs. In 2002, over 1000 laboratories participated in the CCRL programs. For cement and concrete laboratories that wish to participate in the AASHTO Accreditation Program (AAP), results of laboratory inspections carried out by the CCRL are the basis for accreditation. CCRL's quality assurance services are complemented by standards-related research carried out in collaboration with BFRL researchers.

CIB

INTERNATIONAL COUNCIL FOR RESEARCH AND INNOVATION IN BUILDING AND CONSTRUCTION

CIB W14 Fire

Mr. Richard Bukowski, Fire Research Division, is chair of CIB Working Commission 14 on Fire. The oldest working commission in existence, W14 has a long history of making major contributions to the fire science and engineering fields.

CIB TG37 Performance-Based Buildings

Mr. Richard Bukowski, participates in CIB TG37, a task group that is developing infrastructure and policy in support of performance regulatory systems, internationally. TG37 is closely linked to the Interjurisdictional Regulatory Collaboration Committee (IRCC) that is made up of the chief building code official for each member country and who share common experiences and problems in the operation of performance regulatory systems.

FIATECH AEX Project

FULLY INTEGRATED AND AUTOMATED TECHNOLOGY

Although many of the leading engineering organizations have adopted information integration technologies for the design phase of capital facilities projects, the capabilities and benefits of these technologies are not being exploited broadly for the procurement, fabrication, inspection, materials management and installation of equipment for capital facilities. In collaboration with the FIATECH consortium, Mark Palmer led the formation of the Automating Equipment Information Exchanges (AEX) Phase 1 Project to investigate this problem. The AEX Phase 1 project delivered the promised results at the Spring 2003 FIATECH Member Meeting. This included: 1) the analysis of industry information requirements and transaction priorities for the design, procurement and delivery of centrifugal pumps and shell and tube heat exchangers, 2) XML schemas and supporting documentation for centrifugal pumps and shell and tube heat exchangers, and 3) the demonstration of trial software implementations of these XML schemas. To ensure broad industry input and adoption of the results, Mr. Palmer established collaboration agreements with relevant industry organizations, e.g., API (American Petroleum Institute), PIP (Process Industry Practices) and ASHRAE on the delivery of XML schemas for exchanging information on engineered equipment.

IAAI

INTERNATIONAL ASSOCIATION OF ARSON INVESTIGATORS

IAAI Engineering Committee

Daniel Madrzykowski, Fire Fighting Technology, was reappointed as the Chair of the IAAI Engineering Committee. Under Mr. Madrzykowski's leadership, the committee has been developing and reviewing articles for the IAAI *Fire and Arson Investigator*, assisting with the development of standards and a review process for IAAI technical training programs, and collaborating with IAAI chapters in mutually beneficial large-scale fire experiments to address USFA and DoJ funded research programs at NIST.

IAI

INTERNATIONAL ALLIANCE FOR INTEROPERABILITY

NIST has joined the International Alliance for Interoperability/North America as a government member. Dr. Kent Reed, Building Environment Division, represents NIST in the IAI/NA, is a member of the IAI technical Advisory Group that functions at the international level, and participates in technical projects in the Building Services Domain. The IAI is a global standards-setting organization dedicated to promoting effective means of exchanging information among all software platforms and applications serving the Architecture, Engineering, Construction, and Facility Management (AEC+FM) community.

ICC

INTERNATIONAL CODE COUNCIL

ICC Performance Committee

Mr. Richard Bukowski completed a three-year assignment to the ICC Performance Building Code and ICC Performance Fire Code drafting committees. These two committees eventually merged and produced the ICC Performance Code for Buildings and Facilities, the first combined U.S. building and fire code and the first U.S. performance based code. This document has entered into the ICC code development process where it is open to code change proposals prior to formal adoption. Mr. Bukowski has been named to the ICC Performance Code development committee, which is responsible for accepting or rejecting these proposed changes.

IEC

INTERNATIONAL ENGINEERING CONSORTIUM

IEC/TC 59 A Electric Dishwashers

Ms. Natascha Castro, Building Environment Division, is a member of the U.S. Technical Advisory Group to IEC/TC 59A. This committee determines the U.S. position on issues related to IEC standards related to the performance and energy consumption of dishwashers.

ISO

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO TAG8

Mr. Richard Bukowski is the U.S. representative to ISO TAG8. TAG8 is a technical advisory group to the Technical Management Board (TMB) of the international Organization for Standardization (ISO) which develops ISO standards. A current activity is the development of an ISO policy on performance standards.

ISO TC 59 Building Construction

Dr. Geoffrey Frohnsdorff, guest worker in the Materials and Construction Research Division, is chair of Subcommittee 14, Design Life.

ISO TC 86 Refrigeration and Air-Conditioning

ISO's Technical Committee 86 Refrigeration and Air-Conditioning is composed of eight subcommittees that address topics such as terms and definitions, safety, and testing and rating methods for refrigeration and space-conditioning equipment. Mr. Brian Dougherty participates as a member of the U.S. Technical Advisory Group (TAG) for ISO TC 86. The TAG monitors and formulates the U.S. position on all TC 86-sponsored standards activities. BFRL is also represented on ISO Working Groups 1 and 5 within Subcommittee 6, Factory-Made Air-Conditioning and Heat Pump Units. WG1 is working to revise two testing and rating standards that apply to unitary air-conditioners and heat pumps. WG5 is developing a testing and rating standard for multi-split air conditioners and heat pumps.

ISO TC 71 on Concrete and TC 74 on Cement

Mr. James Pielert, AASHTO Materials Reference Laboratory, chairs the joint ASTM C01/C09 subcommittee that provides the U.S. Technical Advisory Group (TAG) to ISO TC71 Subcommittee 1 on Test Methods and Subcommittee 3 on Production of Concrete and Execution of Concrete Structures. The joint ASTM C01/C09 subcommittee also provides the U.S. TAG to TC 74 on Cement.

ISO TC92 Fire Safety

Dr. Richard Gann of the Fire Research Division chairs SC3, Fire Threat to People and the Environment, and participates in the Technical Program Management Group. He has formulated an agenda for standardization documents for the use of toxic potency information in fire risk and hazard assessment. The Subcommittee has now issued its first document in a decade and has four more entering the later stages of balloting. Dr. Gann also chaired the subcommittee's first Workshop on Fire Threat to the Environment, beginning the development of an agenda in that area.

Dr. Richard Gann led the adoption of ASTM E2187-02, "Standard Test Method for Measuring the Ignition Strength of Cigarettes," and its revision E2187-02b with consensus from regulators, public safety advocates, and the cigarette industry. This method has attracted attention both domestically and internationally. It is to be cited in 2003 regulation in the State of New York, the basis for pending legislation in the U.S. Congress, and the method underlying potential regulation in Canada and New Zealand.

Dr. Walter Jones is the U.S. Expert on SC4, Fire Safety Engineering and a member of the Working Group on model validation and verification.

Dr. William Grosshandler is a member of SC1, the subcommittee on Fire Initiation and Growth, and a member of SC2, Fire Containment.

ISO TC184 Industrial Automation Systems and Integration

Mr. Mark Palmer, Building Environment Division, participates in Subcommittee 4 Independent Data, of ISO TC184 Industry Automation Systems and Integration. In support of the information exchange needs of the process plant industry and the shipbuilding industry, Mr. Palmer led the ISO project which developed ISO 10303 Application Protocol 227 (Plant and Systems Spatial Design) Edition 2. AP 227, Edition 2, extends Edition 1 to include support for piping fabrication and inspection, and the design and installation of HVAC systems, mechanical systems and cableway systems. Trial implementations of Edition 2 were demonstrated in April 2003 at the National Shipbuilding Research Project/ Integrated Shipbuilding Enterprise industry conference. The AP 227 ed.2 project was a collaborative project with the PlantSTEP Consortium, U.S. Navy, UK Ministry of Defense and the Japan ECOM project. ISO approved the AP 227 ed2 Draft International Standard with a unanimous "Yes" vote and approved publication as an International Standard. The International Standard document for AP 227 ed2 will be submitted to ISO in November 2003.

ISO TC 205 WG 3 Building Control System Design

Mr. Steven Bushby, Building Environment Division, is convener of ISO/TC 205 WG 3 Building Control System Design. The working group is developing a multi-part international standard that addresses several issues related to building control systems including control system functionality, communication protocols, system specifications, and project management. ANSI/ASHRAE standard 135-2001 was adopted as the international standard for the communication protocol portion of this standard. ANSI/ ASHRAE 135.1 is expected to be adopted as the international standard for testing conformance to the communication protocol.

NFPA

NATIONAL FIRE PROTECTION ASSOCIATION

NFPA Standards Council

Mr. Richard Bukowski, of the Fire Research Division Division, is a member of the NFPA Standards Council. The Standards Council is the body that administers the NFPA Codes and Standards system including making all committee appointments, initiating and terminating standards projects and issuing all documents. This is an especially important time for the Standards Council in administering the development of the NFPA Building Code and related Codes through strategic partnerships. Appointments to the thirteen-member Council run for two, three-year terms.

NFPA Alternative Approaches to Life Safety Committee

Mr. David Stroup, Fire Research Division, chairs NFPA 101A Committee on Alternative Approaches to Life Safety. The Alternative Approaches to Life Safety standard provides methodologies for measuring equivalency to the prescriptive requirements of *NFPA 101, Life Safety Code*. The document includes several Fire Safety Evaluation Systems (FSES) developed at NIST for various building occupancy types. As chair of the committee responsible for this fire safety standard, Mr. Stroup presented the committee's report for adoption at the NFPA Fall Meeting held in Orlando, FL on November 15, 2000. At this meeting, the NFPA membership approved the latest revision of the standard and, more significantly, accepted the first software package, useful for evaluating equivalency, for inclusion in the standard. The software, which was developed by Hughes Associates through a contract with BFRL, implements an enhanced Fire Safety Evaluation System for business type occupancies.

NFPA Toxicity Advisory Committee

Dr. Richard Gann, Fire Research Division, chairs the NFPA Toxicity Advisory Committee. This committee brings special expertise on combustion toxicity to advise any other NFPA technical committee on toxicity issues that might be part of any proposal under consideration.

NFPA Automatic Sprinkler Committees

Mr. Daniel Madrzykowski, Fire Research Division, is chair of the Technical Committee on Residential Sprinkler Systems. This committee is responsible for developing the standard on the design and installation of sprinklers in one-and two-family dwellings, and in residential occupancies up to 4 stories in height. In addition, Mr. Madrzykowski serves on the Technical Correlating Committee on Automatic Sprinklers, leading the New Technology Task Group and is the NIST alternate on the NFPA Technical Committee on Sprinkler System Discharge. Mr. Madrzykowski revised the residential sprinkler section in the *NFPA Automatic Sprinkler Systems Handbook, 9th ed.* and was principal author on the Residential Sprinkler Chapter in *NFPA Fire Protection Handbook*.

NFPA 921 Guide for Fire and Explosion Investigations

Mr. Anthony Putorti Jr., Fire Research Division, is a member of the NFPA 921 Committee, Guide for Fire and Explosion Investigations. This committee provides guidance to investigation professionals based on scientifically defensible materials and referenced technical data. NIST utilizes its research expertise to provide the latest technical and scientific research information to the committee. At the current time, NIST is studying the formation of fire burn patterns, which is one of the tools used by investigators to determine the origins and causes of fires and explosions. The burn pattern research is supported by the National Institute of Justice via the NIST Office of Law Enforcement Standards and the United States Fire Administration.

NFPA Halon Alternatives Committee

Dr. Jiann Yang, Fire Research Division, is a member of the NFPA 2001 committee developing standards for replacements for halon extinguishing agents. This activity is coordinated with the BFRL research on halon replacements.

NFPA Life Safety Code for Detention and Correctional Facilities

Researchers in the Office of Applied Economics have developed new software to help prison facility managers and fire safety engineers minimize the cost of complying with the NFPA *Life Safety Code for Detention and Correctional Facilities.* The project was funded by the National Institute of Justice through the NIST Office of Law Enforcement Standards. Called ALARM 2.0 (Alternative Life-Safety Analysis for Retrofit Cost Minimization), the software quickly finds the least-cost compliance plan by using construction cost estimating algorithms and a linear programming optimization model. The user first provides minimal information about the facility and then enters data about the initial (or current) safety levels for 13 fire safety parameters. The user also enters data on the dimensions and quantities of the building features that must be modified to improve safety. The cost estimating algorithms quickly estimate the construction costs of every possible safety improvement (which can be overridden by the user). The software then automatically finds the least cost compliance plan for the facility. ALARM includes a User Manual, an extensive help system and tutorial, a sample project file, and a detailed printed report describing the least-cost construction plan to achieve compliance with the *Life Safety Code*. ALARM 2.0 is being distributed by the NFPA and the American Correctional Association.

NFPA National Fire Alarm Code Technical Correlating Committee

Mr. Richard Bukowski, Fire Research Division, serves on the TCC for the National Fire Alarm Code. Like other TCC's this committee addresses technical consistency and correlation among the technical committees responsible for specific parts of the Code.

NFPA and ASTM Rail Transportation Committees

Mr. Richard Peacock, Fire Research Division, represents NIST and DOT on the NFPA 130 committee and the ASTME5.17 committee developing standards for fire safety in passenger rail vehicles.These activities are tied directly to the DOT funded work to develop advanced fire hazard analysis methods to be used in federal regulation.

NFPA Safety to Life Correlating Committee

Mr. Richard Bukowski, Fire Research Division, is a member of the Technical Correlating Committee (TCC) for the Safety to Life Project. The TCC provides oversight to the technical committees developing requirements for individual topics and assures that the requirements are consistent and correlated throughout the document.

NFPA Urban/Wildland Interface Committee

Mr. Daniel Madrzykowski is a member of the NFPA Technical Committees on Forest and Rural Fire Protection and has contributed to the standards and guides on Application of Class A foam in Structural Fire Fighting and Fire-Fighting Chemicals for Class A Fuels. Mr. Madrzykowski also serves as NIST's principal member on the Water Mist Fire Protection Systems Technical Committee.

NFPA Research Section

Mr. Daniel Madrzykowski, Fire Research Division, was elected as the Vice Chair in 2002. The Research Section's principle activity is the facilitation of communication between researchers and research end users. One means the Research Section uses to provide a forum for technology transfer is the development of technical programs for the Annual NFPA World Conference and the NFPA Fall Education Conference. Mr. Madrzykowski has been most active in this area, with 12 NIST researchers being featured in the 2002 NFPA Research Section Technical Programs.

OASIS

ORGANIZATION FOR THE ADVANCEMENT OF STRUCTURED INFORMATION STANDARDS

In technical work funded by the NIST Systems Integration for Manufacturing Applications program, Mr. Edwin Begley of the Building Environment Division completed the specification of the Materials Markup Language (MatML) during 2002 and delivered it to the industry-based MatML Steering Committee. MatML Version 3.0 Schema, available at http://www.matml.org, contains the formal specification for the materials markup language and represents the efforts to date of a cross section of the international materials community with contributions from private industry, government laboratories, universities, standards organizations, and professional societies. The specification has been submitted as the base technical document to the newly formed OASIS Materials Markup Technical Committee.

RILEM

INTERNATIONAL UNION OF RESEARCH AND TESTING LABORATORIES FOR MATERIALS AND STRUCTURES

Dr. Long Phan, Materials and Construction Research Division, is a Senior Member of RILEM Technical Committee HTC, Mechanical Concrete Properties at High Temperatures: Modeling and Applications. The committee is working to develop recommendations to standard methods for determine properties of concrete at high temperatures.

RILEM Technical Committee 166-RMS on Roofing Materials and Systems

Dr. Walter Rossiter, Materials and Construction Research Division, is the past chair of the Joint Committee of CIB W.83/RILEM 166-RMS. In 2002, the Committee published report number 271 entitled *Toward Sustainable Roofing*. This report provides 20 tenets for roofing practitioners to follow in selecting and installing sustainable roofing. These tenets have been published in ten languages. In 2003, the RILEM *Journal of Materials and Structures* (No. 259) published the Committee's report entitled *Condition Assessment of Roofs*. This report provides roofing practitioners with an overview, including flow chart, of the factors that need to be addressed in performing condition assessments of low-sloped roofing systems.

SFPE

SOCIETY FOR FIRE PROTECTION ENGINEERING

SFPE Task Group on Fire Model Evaluation

Mr. Daniel Madrzykowski is the Chairman of the Society of Fire Protection Engineers' Task Group on Fire Model Evaluation. This group develops evaluation reports that provide information on the technical features, theoretical basis, assumptions, limitations and sensitivities of selected computer models. The principle means of evaluation is comparing model predictions to full-scale experimental data. The group recently completed the evaluation of one of the most heavily used models in the fire protection industry, DETACT-QS and the group is currently working on the evaluation of another fire model developed at NIST, ASET-B. Mr. Madrzykowski also serves as a member of SFPE's Technical Steering Committee and their Publications Committee.

Gold Medal

The Gold Medal Award is the highest honor award conferred upon an employee by the Department of Commerce. It is bestowed for "distinguished performance characterized by extraordinary, notable, or prestigious contributions that impact the mission of the Department of Commerce and/or one operating unit and which reflect favorably on the Department."

2003

Dr. Jack E. Snell, Director of BFRL (retired), was cited for leadership at NIST in responding to the terrorist attacks of September 11, 2001. He led the NIST/Department of Commerce response to the World Trade Center disaster, the only known case of a total structural collapse in a high-rise building where fires played a significant role. He successfully launched a comprehensive investigation, a research and development program, and dissemination and technical assistance program to permanently change building design practices and building codes and standards. Based on his concept and vision, he recommended the creation of the National Construction Safety Teams to investigate future building failures similar to how the National Transportation Safety Board investigates transportation accidents.

Dr. Richard Gann, of the Fire Research Division, was recognized for distinguished scientific and engineering achievements in the field of fire safety science. The primary source of ignition contributing to residential fire deaths in the United States is a misplaced lit cigarette. He developed methods for quantifying the propensity of cigarettes to ignite soft furnishings that led to a consensus industry rating standard and the development of cigarettes that are significantly less prone to starting and unintentional fire on upholstered furniture. He also established a scientific foundation for selecting environmentally safe fire suppressants for aircraft applications that has been adopted by the U.S. Air Force.

Silver Medal

The Silver Medal is the second highest honor awarded by the Department for "exceptional performance characterized by noteworthy or superlative contributions that have a direct and lasting impact."

2002

Mr. William H. Twilley, was honored for providing outstanding technical design, fabrication, and operational support in the full-scale oil/diesel fuel pool fire experiments. His contributions have caused the national response teams to incorporate in-situ burning at a tool to reduce the negative impact of oil spills on sensitive marine environments. His work assisted industry to develop improved fire resistant oil containment booms and better technology to monitor airborne smoke and particles.

2003

Ms. Barbara Lippiatt, of the Office of Applied Economics, was cited for development of sound environmental and economic performance metrics in the highly charged field of "green" products. The green building decision-making process was based on little structure and even less credible scientific data. She addressed this need by conceiving and developing a systematic methodology for selecting building products that achieve the most appropriate balance between environmental and economic performance based on the decision maker's values. The result was a new program known as Building for Environmental and Economic sustainability (BEES). BEES measures the environmental performance of building products using the internationally standardized and science-based life-cycle assessment approach.

Dr. Thomas J. Ohlemiller, of the Fire Research Division, was cited for achievements which serve as the basis for limiting the consequences of residential bed fires. For the past fire years, he has worked closely with the industry to understand how bed fires proceed from the ignition of bedclothes to the full involvement of the bed. He worked to develop a technically sound method of test and hazard analysis for threat to life safety. Each year, bed fires in homes cost the Nation nearly 500 lives, more than 2,000 serious injuries, and $250 million in property loss. Regulations adopted by the California bureau of Home Furnishings based on Dr. Ohlemiller's research are expected to cut losses from bed fires in half.

Bronze Medal

The Bronze Medal Award is the highest honorary recognition available for Institute presentation. The award, approved by the Director, recognizes work that has resulted in more effective and efficient management systems as well as the demonstration of unusual initiative or creative ability in the development and improvement of methods and procedures. It also is given for significant contributions affecting major programs, scientific accomplishment within the Institute, and superior performance of assigned tasks for at least five consecutive years.

2002

Dr. Joannie Chin, Mr. Edward Embree and **Mr. W. Eric Byrd** were recognized for scientific and engineering achievement in designing, constructing and testing a highly sophisticated, integrating sphere-based ultraviolet exposure device for the ultraviolet (UV) radiation exposure of polymeric materials. This device is novel in both its temporal and spatial control in both the precision and accuracy that can be maintained over all of the weathering variables commonly associated with the photo deterioration of polymeric materials.

2003

Mr. George Walton and **Mr. Stuart Dols**, Building Environment Division, received the DOC Bronze Medal in recognition of their scientific and engineering achievement in the development of the network airflow analysis and contaminant dispersal simulation programs CONTAM and CONTAMW. The CONTAM programs have had significant impacts on several aspects of the built environment including the design and analysis of smoke control systems, the understanding of building airflow dynamics in relation to energy use and indoor air quality, and most recently in the analysis and reduction of building vulnerability to chembio attacks. In the latter case, CONTAM was recently selected to serve as the calculation engine in the Immune Building Toolkit being developed under the DARPA Immune Buildings program.

2003 Department of Commerce Engineer of the Year

Mr. Richard Bukowski, of the Fire Research Division, received the 24th Department of Commerce Engineer of the Year Award. This award, sponsored by the National Society of Professional Engineers, rewards sustained engineering achievements, civic and humanitarian activities, and contributions to the professional and technical societies.

Mr. Bukowski's career in fire protection engineering spans 30 years and has resulted in significant improvements and profound changes to test standards, building codes, and engineering practice. His early study of residential smoke alarms changed NFPA and UL standards and was a major factor in the unprecedented growth of smoke alarm use and the attendant drop in fire deaths in the home. Mr. Bukowski began working in fire modeling, fire hazard, and fire risk assessment during the early years and led the team that developed HAZARD I, the world's first comprehensive fire hazard assessment method implemented in personal computer software. In addition, he is a key player in the development of performance-based codes, chairing CIB W14's TG1, Engineering Evaluation of Building Fire Safety Performance.

2002 Equal Employment Opportunity/Diversity Award

The Equal Employment Opportunity/Diversity Award recognized significant EEO/diversity contributions that have been performed in an exceedingly outstanding manner by an Institute employee.

Dr. Chiara Ferraris was recognized for co-organizing a day of hands-on science experiences, *Science: Get Psyched*, for 200-300 local Girl Scouts. In small groups, the girls visit different rooms and interact with lively science demonstrations provided by NIST scientists. Topics include such things as Polymer networks: the importance of squishy gooey, gummy stuff; and Shake, rattle, and roll: making structures earthquake proof. The Scouts also attend panel discussions where they can ask female scientists why they chose science and what it is like to be a scientist. The volunteer program, now in its ninth year, is designed to increase the pipeline of young scientists on which NIST will depend in the years to come.

2002 BFRL Communication Award

Dr. Fahim Sadek and **Dr. Emil Simiu** were awarded the 2002 BFRL Communication Group Award for the paper "Peak Non-Gaussian Wind Effects for Database-Assisted Low-Rise Building Design," (*Journal of Engineering Mechanics 128, May 2002, 530-539*) and the attendant software. The audience for this paper includes the structural and wind engineering research and design community, as well as probabilistic analysis and structural reliability experts. Following the publication of the paper, the software has been widely distributed to researchers and engineers interested in peak wind effects estimation, structural reliability, and database-assisted design of low-rise building frames.

ASHRAE Fellow

Dr. Andrew Persily, Building Environment Division, was elevated to the grade of Fellow by the American Society of Heating, Refrigerating and Air-Conditioning Engineers. This award was based on his contributions to the arts and sciences of HVAC engineering in the areas of building airtightness and ventilation measurement and the field of indoor air quality analysis.

Society of Fire Protection Engineers Honorary Member

The Grade of SFPE Honorary Member is bestowed upon individuals of acknowledged eminence in fire protection engineering or a related activity.

Dr. Kevin McGrattan, of the Fire Science Division, was responsible for bringing the power of three dimensional computational fluid dynamics modeling of fire environments into the hands of mainstream fire protection practitioners through the development of two CFD-based models and their adaptation to personal computers. While he came from a background that is outside of fire protection engineering (mathematics), Dr. McGrattan has dedicated himself to understanding the concepts behind CFD modeling of fire environments and has also spent countless hours understanding the needs of the fire protection engineering profession and communicating with us to better understand those needs for modeling purposes. Dr. McGrattan received his Ph.D. in Mathematics from New York University in 1991. He is a mathematician at the National Institute of Standards and Technology's Building and Fire Research Laboratory.

Society of Fire Protection Engineers Fellow

Dr. Kathy Notarianni, of the Fire Research Division, was awarded the grade of Fellow for her outstanding contributions to the advancement of fire protection engineering and valuable service to SFPE.

IIR Science and Technology Medal

The International Institute of Refrigeration (IIR) honored Piotr Domanski with the IIR Science and Technology Medal, one of the top three IIR recognitions. The medal was awarded on August 21, 2003 during the Award Banquet of the 21st International Congress of Refrigeration, at the Mariott Wardman Park Hotel, Washington, DC. Based in Paris, the IIR is an intergovernmental organization linking 61 countries that account for 80% of the global population. Its objective is to promote progress and expansion of knowledge on refrigeration technology. The IIR Science and Technology Medal is awarded once in four years, on the occasion of the congress, for outstanding achievements in science and technology over an extended period of time.

The International William J. Conroy Standards Professional Award for 2003

Mr. Mark Palmer was awarded the International William J. Conroy Standards Professional Award for his technical contributions and dedication to the concepts, development, and implementation of the product data standards of ISO TC 184/SC4 (Industrial Automation Systems and Integration/ Industrial Data). The International William J. Conroy Standards Professional Award recognizes an individual who has shown exceptional leadership in the development or implementation of Product Data Exchange standards. This award was established by the US Production Data Association (US PRO) Board of Directors in honor of Bill Conroy, who provided notable leadership to the standards community during his professional career.

The NIST SPHERE (Simulated Photodegradation via High Energy Radiant Exposure).

ACI Wason Medal for Materials Research

Dr. Long Phan and **Dr. Nicholas J. Carino**, Materials and Construction Research Division, were awarded the 2003 Wason Medal for Materials Research by the American Concrete Institute for their paper, "Effects of Test Conditions and Mixture Proportions on Behavior of High-Strength Concrete Exposed to High Temperatures." The paper describes the results of NIST research aimed at understanding the degradation of properties of high-strength concrete when exposed to fires. The Wason Medal was established in 1917 for "original research work on concrete materials and their use, or a discovery that advances the state of knowledge of materials used in the construction industry."

ASCE Robert H. Scanlan Medal

Dr. Emil Simiu, Materials and Construction Research Division, was awarded the inaugural 2003 Robert H. Scanlan Medal for his broad range of research accomplishments in wind engineering and engineering mechanics, including estimation of wind and wave loads on buildings, bridges, and deep-water compliant offshore platforms.

ASTM Award of Merit

Dr. Nicholas J. Carino, Materials and Construction Research Division, was the recipient of the 2002 ASTM Award of Merit. The award was established in 1949 and is the highest award granted by ASTM to an individual member for distinguished service and outstanding participation in ASTM committee activities. He has held a variety of leadership positions on C09 including serving on the Executive Subcommittee, membership secretary, chair of the Subcommittees on Setting Time, Accelerated Strength Testing, Nondestructive and In-Place Testing, and the Task Group on Testing High Strength Concrete.

ASTM Committee C09 Award of Appreciation

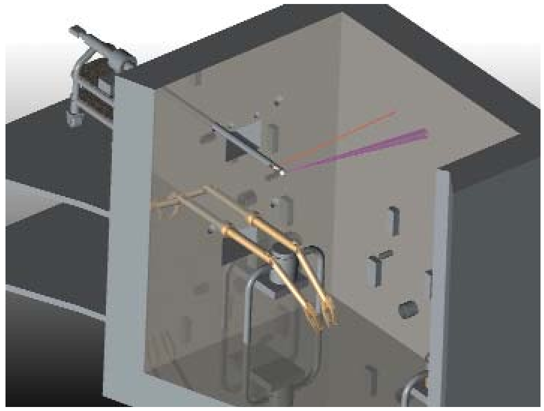
Dr. Nicholas J. Carino, Materials and Construction Research Division, was presented with the C09 Award of Appreciation at the June 2002 meeting in Salt Lake City for his service as chair of Subcommittee C09.64 on Nondestructive and In-Place Testing. During his tenure, he provided leadership in the development of a new standard on the use of the impact-echo method for measuring thickness of concrete members. He led the research program on the impact-echo method, which began at NIST (then NBS) in 1983.

IAARC Tucker-Hasegawa Award

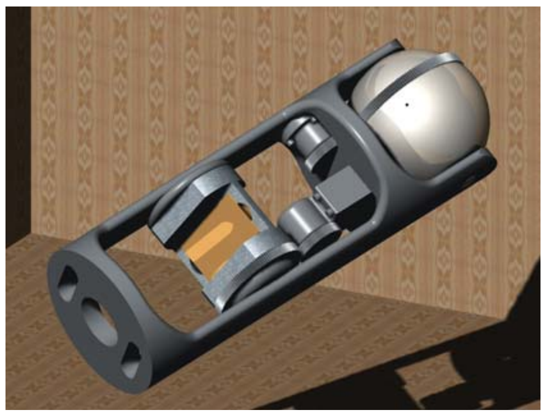
Dr. William Stone, Materials and Construction Research Division, received the 2002 Tucker-Hasegawa Award from the International Association for Automation and Robotics in Construction. The award, which is competitive among some 30 participating nations, is issued annually to the person most influencing world advancement of automated processes and intelligent systems in the construction industry. Dr. Stone leads the Construction Metrology and Automation Group (CMAG) within BFRL. CMAG has conducted ground-breaking work in the use of laser radar, RFID, and other wireless-enabled sensing systems for job site status determination to enable the development of the first generation of fully autonomous construction machinery – including the world's first automated structural steel placement system.

Patent issued on NIST Integrating Sphere-Based Weathering Device

Patent Number 6,626,052, "Method and Apparatus for Artificial Weathering", was assigned to Jonathan Martin and Joannie Chin on September 30, 2003, for the device known as the NIST SPHERE (**S**imulated **P**hotodegradation via **H**igh **E**nergy **R**adiant **E**xposure). In predicting the service lives of polymeric materials, a need exists for accelerated weathering devices that can uniformly irradiate test specimens with a high ultraviolet radiant flux while accurately and precisely controlling this flux in addition to other weathering elements such as temperature and relative humidity. The NIST SPHERE provides a source of high intensity, collimated UV radiation with a spatial uniformity greater than 95%. Ultraviolet radiant fluxes equivalent to approximately 22 "suns" of solar ultraviolet radiation can be achieved at the sphere exit ports. Temperature and relative humidity in the specimen chambers attached to the sphere can also be independently and precisely controlled over wide temperature and relative humidity ranges and over long exposure periods. The ability to temporally and spatially control spectral irradiance, temperature and humidity independently at each of 32 specimen chambers and over wide ranges provides a high degree of flexibility in designing accelerated weathering experiments. The repeatability and reproducibility of accelerated weathering experiments can also be greatly improved through the use of the SPHERE. Additional information on the SPHERE and the NIST Service Life Prediction Program in can be found at http://slp.nist.gov.



Computer simulation of nuclear decontamination and decommissioning of a "hot" work cell in which the NIST 3D scanner produces both a high resolution 3D model of the interior of the chamber but also maps the gamma radiation intensity to the model geometry.

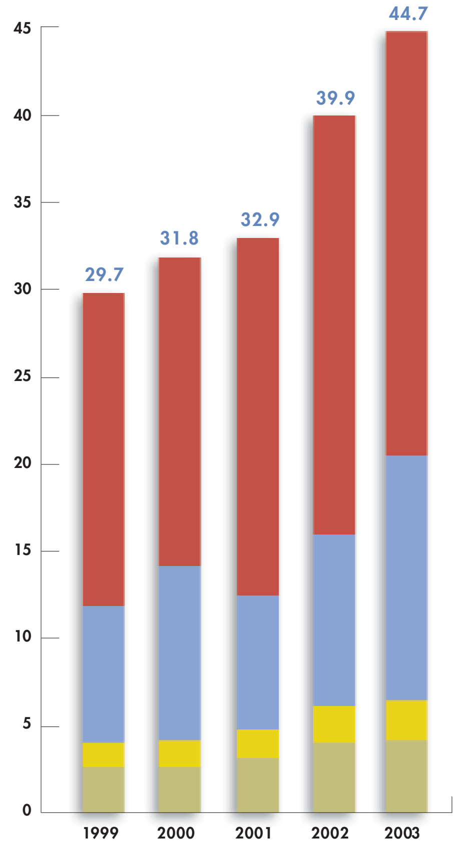


The 3DG (3D Gamma) sensor head used for hot cell characterization. The rotating polygon beam deflector performs the "pitch" scan for the laser radar range measurements while the tungsten sphere at the end contains a highly collimated scintillator for directional gamma radiation intensity mapping.

Patent issued on NIST LADAR System

Patent Number 6,600,553, "Three Degree-of-Freedom Telescoping Geometry Scanner" was assigned to Construction Metrology and Automation Group leader Bill Stone on July 29, 2003. The invention relates to a novel three-dimensional measuring device comprised of a rotating sensor head, a laser scanner, a beam deflection system, and an extendable mast system. The sensor head contains a 360-degree rotating multifaceted beam deflection system along with an optional gimbaled directional radiation sensing element that is responsive to gamma rays. This assembly is mounted at the end of a rotating, extensible nested tube set at the end of which is a laser-based high speed, high accuracy range sensor. Angular orientations of both the extension tube and the beam deflector subsystem are tracked by precision encoders. The measured total path distance, mast system extension, scanner head rotation, beam deflector angles, and mast deflection are all used to calculate the location of a target point in 3D space relative to the scanner. When mounted on an autonomous (robotic) mobility platform the device can produce high accuracy registered three-dimensional maps that have superior terrain and infrastructure definition. Current tripod-mounted LADAR surveying systems are severely limited by line-of-sight restrictions; the new design permits automated variable-elevation scanning which serves to fill in the gaps in scenes produced with traditional LADAR scanning techniques. The device is also particularly suited for use in characterizing high radiation environments, such as those related to decontamination and decommissioning of nuclear plant infrastructure. The sensor head elements are designed to be "rad hard" with the sensitive range measuring laser source and detectors located at the far end of the extensible mast. The device can be used to completely survey the inside of a hot cell allowing only service duct access and produce a 3D model of the cell with gamma radiation intensity mapped to the geometry. This allows for not only safer but vastly more efficient decommissioning since robotic service robots can upload the 3D radiation maps to prioritize work efforts.

BFRL RESOURCES 1999-2003
($ MILLIONS)



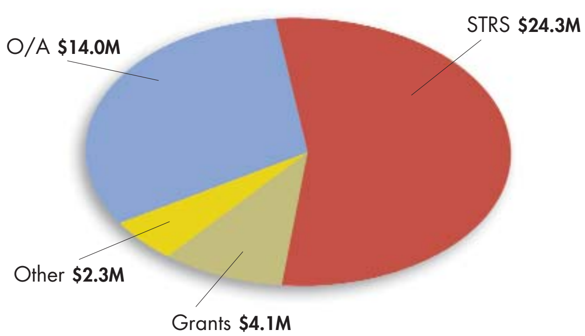
STRS – In-house research, NIST congressionally appropriated funds

O/A – In-house research, other agency funds

Other – Other funds including private sector

Grants – Grants to other organizations including academia

FY 2003



Organizations Funding BFRL's Research

Federal agencies and industry groups, which currently support about one-third of BFRL's overall research, are recognized below:

FEDERAL AGENCIES

Consumer Product Safety Commission
Department of Agriculture
Department of Defense Agencies
Department of Energy
Department of Health and Human Services
Department of Housing and Urban Development
Department of Interior
Department of Justice
Department of Labor
Department of State
Department of Transportation
Department of the Treasury
Environmental Protection Agency
Federal Emergency Management Agency
General Services Administration
National Aeronautics and Space Administration
National Institutes of Health
National Science Foundation
Nuclear Regulatory Commission
Smithsonian Institution

PRIVATE SECTOR

Advanced Fire Alarm System Consortium
Air-conditioning and Refrigerating Technology Institute
American Association of State Highway & Transportation Officials
Association Technique l'Industrie des Liant Hydrauliques (ATILH)
ASTM
Atlas Material Testing Technology, LLC
Atofina Chemicals
Building Joint Sealants Consortium
California Energy Commission (CEC)
Cemex
DAP
DeGussa
Dow Chemical Company
Dow Corning Corporation
Dupont Company
Dyckerhoff
Holcim
International Center for Aggregate Research (ICAR)
Interphase/Interface Consortium
Kaneka
Master Builders Technology
MTS
National Ready-Mixed Concrete Association
Northwestern University
NYACOL Nano Technologies
Portland Cement Association
PPG
Sherwin Williams
Sika Technology AG
Sleep Product Safety Council
Solvay
Tremco
Verein Deutscher Zementwerke (VDZ)
Virtual Cement and Concrete Testing Laboratory Consortium
Visteon
Wacker
W.R. Grace

BFRL Organization

MATERIALS AND CONSTRUCTION RESEARCH DIVISION

The **Materials and Construction Research Division** serves as the world-class resource for developing and promoting the use of science-based tools – measurements, data, models, protocols, and reference standards – to enhance (a) the global competitiveness of U.S. industry through innovations in building materials and construction technology, and (b) the safety, security, and sustainability of the nation's buildings and physical infrastructure. The division: (1) develops and implements computational, theoretical, and experimental methods to predict and optimize the service life performance and cost of advanced materials used in construction, including pigments, cement, concrete, polymers, metals, and composites; (2) provides science-based measurement and predictive tools and protocols for advanced construction technologies – innovative connections, high-performance constructed systems, and process technologies for automated construction – to enhance productivity, safety, security, and life-cycle performance; (3) conducts technical investigations of structural failures, including failures during construction or following natural, terrorist, and technological disasters; (4) provides technical support to national and international standards and codes development and professional practice organizations; (5) conducts cooperative programs with other federal and state agencies, industry, professional societies, testing laboratories, educational institutions, and other research organizations; and (6) supports the scientific and technical information needs of federal agencies in formulating national policies related to building and infrastructure applications.

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BUILDING ENVIRONMENT DIVISION

The **Building Environment Division** reduces the cost of designing and operating buildings and increases the international competitiveness of the U.S. building industry by providing modeling, measurement, and test methods needed to use advanced computation and automation effectively in construction, to improve the quality of the indoor environment, and to improve the performance of building equipment and systems. The Building Environment Division conducts laboratory, field, and analytical research on building mechanical and control systems and develops data, measurement methods and modeling techniques for the performance of the building envelope, its insulation systems, building air leakage, and the release, movement and absorption of indoor air pollutants. The Division also develops standard communication protocols for building management systems and performance criteria, interface standards, and test methods for the Nation's building industry to make effective use of modern computer-aided design hardware and software and database management systems. The Building Environment Division began a Green Building Research and Demonstration Program in 1994. As part of that program, grants were given to Montana State University to evaluate a variety of "green technologies" that could be incorporated into the design and construction of a new classroom/laboratory building for the campus.

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FIRE RESEARCH DIVISION

The **Fire Research Division** develops, verifies, and utilizes measurements and predictive methods to quantify the behavior of fire and the means to reduce the impact of fire on people, property, and the environment. This work involves integration of laboratory measurements, verified methods of prediction, and large-scale fire experiments to demonstrate the use and value of the research products. Focused research activities develop scientific and engineering understanding of fire phenomena and metrology; identify principles and produce metrology, data, and predictive methods for the formation/evolution of smoke components in flames and for the burning of polymeric materials; and develop predictive methods to enable high-performance fire detection and suppression systems. Through the Division's programs in measurement, prediction, systems integration, and the dynamics of fire and its interactions with the built and natural environment, the division provides leadership for advancing the theory and practice of fire safety engineering, fire fighting, fire investigation, fire testing, fire data management, and intentional burning. Extensive publication and technology transfer efforts facilitate the use of fire research results in practice in the fire communities in the United States. Participation in the codes and standards processes helps to reduce barriers to trade and global markets for U.S. goods and services.

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OFFICE OF APPLIED ECONOMICS

The **Office of Applied Economics (OAE)** provides economic products and services through research and consulting to industry and government agencies in support of productivity enhancement, economic growth, and international competitiveness, with a focus on improving the life-cycle quality and economy of constructed facilities. An area of specialty in support of this mission is the OAE's work in interdisciplinary teams with engineers and scientists from BFRL and NIST at large to measure the economic impact of new technologies. The focus of OAE's research and technical assistance is microeconomic analysis. The OAE provides information to decision makers in the public and private sectors who are faced with choices among new technologies and policies relating to manufacturing, industrial processes, the environment, energy conservation, construction, facility maintenance, law enforcement, and safety. It also develops and conducts prototype training programs in applied economics for scientists and engineers.

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Publications

Yearly lists of BFRL's publications with indexes for abstracts, authors, and keywords are available as hard copy and on CD-ROMs. Also, full texts of publications from 1994 to the present are available from BFRL Publications On-line at http://fire.nist.gov/bfrlpubs/.

Ordering Instructions:
To order copies of these free publications or to discuss BFRL's research reports, contact Mr. Paul Reneke, BFRL Information Service, 301-975-6696, paul.reneke@nist.gov

Visit the Laboratory

Potential collaborators are encouraged to visit BFRL when in the Washington area. To schedule a visit, contact Dr. James Hill, Acting Director, Building and Fire Research Laboratory, james.hill@nist.gov, or Dr. S. Shyam Sunder, Acting Deputy Director, BFRL, sunder@nist.gov.

BFRL Inquiries

Questions about specific programs should be directed to BFRL's Management listed in the Chapter, BFRL Finances & Organization. If you have general questions about BFRL programs or are interested in working with BFRL, contact Dr. James Hill, Acting Director, BFRL, james.hill@nist.gov, or Dr. S. Shyam Sunder, Acting Deputy Director, BFRL, sunder@nist.gov.

The mailing address for all BFRL personnel is:

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The National Institute of Standards and Technology

The National Institute of Standards and Technology was established by Congress in 1901 "to assist industry in the development of technology… needed to improve product quality, to modernize manufacturing processes, to ensure product reliability…and to facilitate rapid commercialization… of products based on new scientific discoveries." An agency of the U.S. Department of Commerce's Technology Administration, NIST's primary mission is to develop and promote measurement, standards and technology to enhance productivity, facilitate trade and improve quality of life. It carries out this mission through a portfolio of four major programs:

Measurement and Standards Laboratories that provide technical leadership for vital components of the nation's technology infrastructure needed by U.S. industry to continually improve its products and services; a rigorously competitive **Advanced Technology Program** providing cost-shared awards to industry for development of high-risk, enabling technologies with broad economic potential; a grassroots **Manufacturing Extension Partnership** with a network of local centers offering technical and business assistance to smaller manufacturers; and a highly visible quality outreach program associated with the **Malcolm Baldrige National Quality Award** that recognizes business performance excellence and quality achievement by U.S. manufacturers, service companies, educational organizations, and health care providers.

Editors:

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