1. INTRODUCTION

1.1 OBJECTIVES

Constructed facilities (which include buildings of all types and their service systems, and public works and utilities for transportation, power, communication, water supply, and waste disposal) shelter and support most human activities. They are a principal element of the Nation's wealth, valued at about $20 trillion in year 2000 dollars, with the approximately $1 trillion annually invested in new construction and renovation amounting to about one-eighth of the Gross Domestic Product. Their quality is vital to industrial productivity and everyone's quality of life. Their safety from unwanted fires and other natural, accidental and willful hazards is critical for life safety, avoidance of injuries, protection of property, and national security.

Building and fire research programs seek to provide knowledge bases for decisions supporting functionality, economy and safety at all stages in the life cycle of constructed facilities. The relevant spectrum of knowledge is broad, almost unbounded. Fire phenomena include ignition, growth and suppression of fires, the effects on individuals of fires and combustion products, and the effects on society of fire losses and investments in fire safety. The aspects of performance of constructed facilities include structural stability, durability of materials and equipment, environmental control for building occupants, functionality for the intended purpose of the facility, the costs of construction, operation, maintenance and renovation, and all other social and environmental effects. Therefore, building and fire research involves physical, engineering, life and social sciences. Moreover, this knowledge must be expressed in practices useful to owners, occupants, designers, constructors, maintainers of constructed facilities, and fire services and building regulatory officials responsible for public safety.

Because of the importance of constructed facilities and fire safety to the Nation, the National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards (NBS), has been active in building and fire research almost from its founding in 1901 [1, 2]. Building and fire research at NBS/NIST have been challenged to respond as effectively as possible to these needs with

severely constrained human, laboratory and financial resources. This history describes the challenges, opportunities, accomplishments and impacts of the NBS/NIST programs of building and fire research since 1968 for fire research and since 1974 for building research. It follows from earlier histories covering building and fire research through 1968 [2] and building research from 1968 through 1974 [3]. NBS/NIST-wide histories [1, 4, 5, 6] provide selected information on building and fire research and their place in NBS/NIST's evolving Organic Act (authorizing legislation).

The objectives of this history are:

1. To provide a convenient reference on the principal NBS/NIST programs and activities in building and fire research in the last quarter of the 20th century.
2. To recognize the contributions of building and fire research staff and of collaborators elsewhere.
3. To help current and future staff understand the background of their work and to provide perspectives on successes and failures both technical and managerial.
4. To show the societal importance and technical challenge of building and fire research.
5. To provide perspectives on the needs for and benefits of building and fire research to NIST and higher management, industry and Congress.

The organizational units treated here are the Center for Building Technology (CBT), 1975-1990; the Center for Fire Research (CFR), 1975-1990; and the Building and Fire Research Laboratory, 1991-2000.

1.2 ORGANIZATION

The following chapters are in two groups. First the Management chapters treat in chronological order the policy and planning issues affecting the building and fire research programs: 2. Center for Fire Research in the 70s, 3. Center for Building Technology in the 70s, 4. Center for Fire Research in the 80s, 5. Center for Building Technology in the 80s, and 6. The Building and Fire Research Laboratory. These chapters note accomplishments and awards that were managerially significant.

Second, the Technical chapters describe the most significant work and its effects. These are organized by research areas, ordered alphabetically to avoid any inferences of relative importance, and each, because of the inherent continuity of technical work, covers the entire period of this history. These chapters are: 7. Architecture, Psychology, and Acoustics, 8. Construction Integration and Automation, 9. Economics, 10. Environmental Systems, 11. Fire Safety Engineering, 12. Fire Science, 13. Materials, 14. Standards and Codes, and 15. Structures.

The management chapters describe the environment and context for the technical work. There are real differences between management issues and technical accomplishments. Often, program planning and development efforts were frustrated by inability to obtain resources needed to pursue the planned work. In contrast, some very important accomplishments involved little management attention as researchers well linked to peers and customers produced very valuable results. A researcher with good reputation and ideas could obtain funding from external sources ("soft money") to pursue investigations extensive in size and duration. In these instances, management's role could be limited to assuring that the scope of work was appropriate for NBS/NIST and that the quality of work reflected well on NBS/NIST.

1.3 TOP ACCOMPLISHMENTS

This writer's subjective view of the top accomplishments in this period of building and fire research is provided to highlight the detailed coverage of accomplishments contained in following chapters. All of the top accomplishments arose from outstanding technical work in the programs. Most resulted from world-class scientific and technical leadership of the fire and building researchers and skillful collaborations with industry and other federal agencies to achieve beneficial implementations. The encouragement, even insistence, of NBS/NIST management on world-class scientific and technical leadership, and collaborations with other NBS/NIST laboratories, played a large role in these accomplishments.

1. The wide adoption of residential smoke detectors in U.S. homes, facilitated and driven by CFR research (section 11.5), led to early accomplishment of CFR's challenge goal to halve fire deaths in a generation.
2. Fundamental research on the properties of refrigerants and fire suppressants, and the performance of heat pumps, air-conditioners, and fire suppression systems, facilitated world leadership of U.S. industry in developing and marketing alternatives to environmentally harmful refrigerants and fire suppressants (sections 10.9 and 12.9).
3. Investigations of the performance of structural and fire safety systems in important accidents and disasters provided confidence in the efficacy of up to date structural and fire safety standards and practices, and/or identified needs for their improvement (sections 11.4, 15.1 and 15.2).
4. Improved test methods for the seasonal efficiency of space heating and cooling equipment, major appliances, and insulation have provided the basis for national energy labeling programs that have resulted in roughly doubling the efficiency of equipment, appliances and insulation in the marketplace (sections 10.1 and 10.4).
5. Standard information exchange protocols for building automation allow open systems for controls so that owners can: specify desired performance, not be tied to a single vendor, and update automation systems as demands change or better products come into the marketplace (section 10.8).
6. Reliable and predictable performance (including functionality, safety and durability) of materials and systems based on advanced, probabilistic modeling of environments and resistance (sections 10.7, 10.11, 11.8, 13.2, 13.6, 15.3, 15.6).
7. Economical fire test methods for small specimens that relate rationally to the materials' contributions to the severity of fires and the toxicity of combustion products (sections 12.2 and 12.3).
8. Standard life cycle cost economic methods to guide investments in building and fire safety products and practices (sections 9.3, 9.4 and 9.6).
9. New generation of scientifically-based fire simulations that provide the basis for the world's transition to performance-based fire standards (sections 11.9 and 11.10).
10. Development with industry of the concept of sacrificial, energy-absorbing joint materials to allow pre-cast, pre-stressed, concrete frames to be used safely and economically for tall buildings in high seismic zones (section 15.9).

1.4 TOP DISAPPOINTMENTS

Aspirations have been high for building and fire research, so the top accomplishments can be balanced with top disappointments. Since the writer's role was a manager, the top disappointments focus on managerial issues, which are covered in chapters 2-6, rather than on the conduct of research.

1. Inconsistent alignment of CBT/CFR objectives with those of NBS/NIST often led to a lack of support of NBS/NIST for CBT/CFR initiatives. Principally, this occurred when NBS/NIST primarily valued advances in measurement science and practice, and CBT and CFR were pursuing increasing the usefulness, safety and economy of constructed facilities, and reducing fire losses with whatever technologies would be most effective. By the 90s, BFRL management understood and accommodated the focus of NIST on measurements, standards, and technologies for support of U.S. economic growth, and NIST showed greater respect for potential economic and societal impacts.
2. Partnerships with other federal agencies, which would provide mission, funding and delivery mechanisms for CBT/CFR research, became an Institute for Applied Technology strategy for program growth in the 60s and was relied upon throughout the 70s. Indeed, NBS also relied upon this strategy, and, except for the initial funding of CFR, was unwilling, through the 70s, to request new, directly appropriated funding for CBT or CFR for mandates such as energy conservation and earthquake hazard reduction. This gave other agencies

undue control over CBT/CFR programs and left CBT/CFR vulnerable to other agencies' retrenchments in the 80s.

3. When NBS was pressured by the Administration in 1981 to offer cuts in its programs, it offered to eliminate CBT and CFR. The rationale seemed to be that losses of CBT and CFR would not greatly weaken the remaining parts of NBS, and that CBT and CFR were very defensible because of high, tangible benefits to industry and the public. Indeed, both centers were defended successfully by industry, and NBS continued to offer them up for seven more years. Why change a successful strategy? However, the freeze on direct appropriations and reductions in support from other federal agencies caused severe attenuation of the programs and the uncertainties led to losses of some of the most productive staff. CBT/CFR productivity remained high through this period, but losses of staff and reductions of program scope had long term detrimental effects.
4. CFR strove to achieve close collaborations with the fire services, and both CFR and CBT sought strong collaborations with consumer organizations. Neither of these collaborations were as fruitful as expected. Fire services seemed more attracted to conflicting collaborations with the tobacco industry, and consumer organizations seemed unappreciative of the values of building and fire measurements and standards.
5. Both CBT and CFR appreciated the need for and value of human factors and architectural research to achieve their objectives. But NBS was reluctant to invest scarce, directly appropriated funding where it lacked a track record for world class results, and patient funding from other agencies became scarce in the 80s. Therefore, CBT and CFR terminated architectural and human factors research, and BFRL did not find the resources for renewing such efforts in the 90s. Architectural and human factors research remains important for achieving BFRL's objectives, and continues to be lacking.
6. CBT and BFRL sought to support industry in all important, economically significant areas of building and construction technology, but the program constriction of the 80s required termination of important areas of research: acoustics, electrical systems, geotechnical engineering, plumbing, and roofing in addition to architecture and human factors as noted above.
7. Fire grants to external experts in universities and industry have contributed greatly to the fire program. The nation's best talent has been focused on program objectives and highly qualified researchers have been attracted to work at CFR/BFRL. However, the fire grants program has been attenuated severely by budget cuts of the 80s and inflation, and BFRL has not obtained additional, directly appropriated funding to maintain the fire grants program and to create similar programs in other areas.

1.5 ACKNOWLEDGEMENTS OF STAFF

The contributions of the managerial and research professional staff of CFR, CBT and BFRL are cited directly in the chapters that follow. It is important to acknowledge here, both generally and with specific citations, the great and essential contributions of support and administrative staff and technicians to the laboratory's accomplishments.

1.5.1 SUPPORT STAFF

The laboratory's work has been conducted in close collaboration with other federal agencies, industry, standards and professional organizations, universities, and other NBS/NIST units. Much of the work has attracted substantial press and public attention. The laboratory's secretaries, administrative assistants and other support staff have performed admirably in providing friendly and helpful interfaces for collaborators and other interested parties, as well as in supporting production of research results.

Many of the laboratory's support staff began work with CFR, CBT or BFRL as young women fresh out of high schools in the small towns and rural areas west and north of Gaithersburg. They have been notable for their helpfulness, intelligence, ability to learn new skills as office automation technologies have advanced, commitment

to their work, and loyalty to the laboratory through good and hard times. The loyalty to and enthusiasm for the laboratory seem to come both from their character and their identification with the goals of the laboratory. Among those meriting specific attention are:

- Linda Beavers joined the Building Research Division as a teenager and grew with it to become secretary to the deputy director of CBT in the 80s. Her team spirit and great personal productivity were extremely valuable in the years that CBT's existence was threatened by the Administration.
- Sheilda Bryner served as secretary of the Building Environment Division during the 1990s and did a wonderful job of supporting the Division and the Division Chief for some major outside responsibilities. The Division was asked to manage a three-year focused program on advanced refrigeration technology for the new NIST Advanced Technology Program for which she took administrative responsibility. In addition, the Division Chief served one year as President of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers and she managed all arrangements effortlessly and error-free for more than 55 of his trips during that year.
- Mary Chandler was the secretary for the founding director of CFR and continued as his secretary as he oversaw CFR, CBT, and then BFRL as director of NEL and NIST. Her helpfulness, understanding, and calm under pressure were a constant resource for CFR, CBT and BFRL.
- Deborah Cramer has been secretary for the chief of the Fire Safety Engineering Division, director of CFR and deputy director of BFRL. She has supported intensive verbal and written information flows and maintained friendly, cooperative relationships with external and internal collaborators, organized numerous meetings and conferences, and maintained contacts with former and retired staff members.
- Gail Crum has provided wonderful support and institutional memory as secretary to the founding director of CBT, the founding director of BFRL and his successor. She is personally productive and develops strong collaborations within the laboratory and with other organizations as the Laboratory conducts leading roles in interagency programs.
- Wanda Eader was a secretary in the NBS director's office before becoming secretary to the chief of the CBT Structures Division in the late 70s and early 80s. Her organizational abilities and skill in dealing with external and press inquiries were extremely valuable to the conduct of high visibility structural failure investigations.
- Nancy Fleegle was a strong producer in CBT's word processing center in the late 70s and early 80s, and then became secretary to the Structures Division for CBT and BFRL. Her compassion, good cheer and steady support have been great resources for fast-paced failure and disaster investigations and in times of financial stringency.
- Carolyn Flood was secretary for the Office of Housing Technology, Building Economics and Regulatory Technology Division, and deputy director of CBT. In these roles she very efficiently handled complex external collaborations, managed office activities and mentored and developed younger staff.
- Barbara Horner joined CBT in 1978 and became Secretary of the Building Materials Division in 1981. She was a highly valued member of the Division management team and was meticulous in monitoring project expenditures and solvency, and producing solvency reports and effectively worked with international materials experts in providing high quality support services in planning and organizing conferences where she received compliments from senior level researchers and managers. In 1985, Horner was awarded a Bronze Medal for "outstanding contributions to the Building Materials Division and international committees and conferences."
- Laurene Linsenmayer was the primary secretarial support for the Office of Applied Economics (OAE) for 18 years prior to her retirement in 1997. She carried out her normal secretarial duties with great efficiency and tact. In addition, she was very skillful in editing and preparing reports for publication, and extremely helpful in making the OAE's Life-Cycle Cost Workshops

run smoothly for both our staff and the many international students taking our classes. Her affable, helpful manner won her many friends at all levels of NIST, while her commitment to excellence and timeliness earned her the professional respect of all.

- Katherine Panagos began her career at NIST as the secretary to the Cement and Concrete Reference Laboratory (CCRL). She later became secretary to the Construction Materials Reference Laboratory, which consisted of CCRL and the AASHTO Materials Reference Laboratory. She was very effective in handling the many facets of these NIST Research Associate Programs requiring close coordination with the sponsoring organizations, AASHTO and ASTM.
- Flora Parsons joined NBS and served as secretary to both the Computer Integrated Construction Group and the Solar Equipment Group. As the secretarial demands in both of these Groups increased, she worked exclusively for the Solar Equipment Group. During her eight years of service, Mrs. Parsons performed in an exemplary manner, providing outstanding secretarial and editorial support. Her productivity and team spirit greatly enhanced the efforts of the Building Environment Division.
- Mary Reppert was secretary for the Building Environment Division in the early years of CBT during the height of the energy crisis. She showed inspiring enthusiasm for and loyalty to her division and great editorial support for its work.
- Paula Svincek became the Heat Transfer Group's secretary in 1996 after providing several years of support to NIST's Advanced Technology Program. Mrs. Svincek was largely responsible for packaging, distributing, and making available on the intranet the simulation model MOIST, used to predict moisture movement within homes. Through her own initiative, she acquired the skills and developed the first web site depicting the research related to building integrated photovoltaics. Additionally she has embraced and provided leadership in the implementation of office automation throughout the Building and Fire Research Laboratory.
- Jennifer Wright joined the Building Research Division as a teenager and grew with it to become secretary of the chief of the Building Environment Division before becoming administrative assistant to the chief of the Public and Business Affairs Division of NIST. Her productivity, excellence in collaborations and knowledge of the building community have been a great resource for BFRL.

1.5.2 ADMINISTRATIVE STAFF

The administration of CFR, CBT and BFRL always has been complicated by the need to manage other federal agencies' and industry funds as well as those provided directly by NBS/NIST. Numerous external audits have been conducted, not always with friendly intent, and never were significant problems encountered. Personnel matters also have been challenging with diverse disciplines represented, many reductions in force required, and performance-based adverse actions made when needed. CFR, CBT and BFRL have been renowned in NBS/NIST for excellent and responsive administration. Among the key people responsible for this were:

- Pearl Bowman Kaetzel joined CBT from the NBS Budget Office and became administrative officer for CBT and an administrative officer for BFRL. Her technical skill and knowledge of NBS were great resources for CBT, she was adept at problem solving, and her kindness helped all the staff.
- Lynn Castle was administrative officer for the Division of Building Research and the first years of CBT. She handled complex financial arrangements with sponsoring federal agencies, faultlessly tracked the flows of funds, and educated novice managers in fiscal matters.
- Karen Perry joined CBT when she completed high school and has grown to become BFRL's senior management advisor. Her competence, excellent interpersonal skills and unstinting extra efforts in times of crisis have been great resources for the laboratory.
- Michael Schmitt was administrative officer of CBT in years when it operated mostly on external funding and when it was required to make substantial reductions in staff and

programs. His competence, wisdom and fresh ideas made him an effective member of the Management Council and caused NEL management to transfer him to the Manufacturing Engineering Laboratory that had even greater administrative challenges.

- Kathryn Stewart became the founding executive officer for BFRL after serving CFR as administrative officer. Her administrative skills were complemented by a concern for people that was very helpful to BFRL management.
- Mike Stogsdill began his long career in administration in the fire technology area, became Administrative Officer of the CFR when it was formed, and later of the National Engineering Laboratory. He has continued to serve with distinction in various capacities at NIST to this day.

1.5.3 TECHNICIANS

CFR, CBT and BFRL have been laboratory-based organizations. The quality and efficiency of laboratory work have been made possible by excellent and dedicated technicians. While many are cited for their professional contributions to the research in the chapters that follow, it is appropriate to cite some outstanding technicians here:

- Jim Allen played an instrumental role in the testing of solar energy systems. Allen was largely responsible for setting up the facilities needed at the NIST Annex to evaluate the various components of solar energy systems. His in-depth knowledge of electronics greatly assisted the project engineers in designing numerous data acquisition systems used to measure the performance of solar devices.
- Bill Bailey headed up a team of technician specialists to conduct large-scale fire tests, first at the Connecticut and Van Ness site and later at Gaithersburg. He was responsible for outfitting and commissioning Building 205, a special facility dedicated to large-scale fire work. He and his crew performed this dangerous work flawlessly year in and year out.
- Donn Ebberts assisted in the fabrication, testing, and the data reduction associated with the development of ASHRAE test procedures for liquid and air solar thermal collectors, thermal storage systems, and solar hot water systems. Ebberts assisted in the construction and instrumentation of a passive solar energy home at the NBS Annex used to evaluate various passive solar energy systems.
- Frank Rankin was the lead structural technician throughout the years of CBT and in the early years of BFRL. In field and laboratory studies he developed and mentored young technicians and young engineers with strong attention to safety and efficient conduct of research.
- Willard (Bill) Roberts was a lead technician for the calibration, maintenance, and use of the instruments in the Building Material Division's Analytical Laboratory from the mid-1970s to the mid-90s. Among his contributions he performed testing that provided the foundation for drafting test methods to evaluate the performance of materials used in fabricating solar collector systems for residential use that became the technical basis of standards to support the Nation's solar energy program and the acceptance of solar collector systems.
- Charles Terlizzi provided the technician support needed to develop test procedures for solar thermal hot water systems. Terlizzi conducted numerous experiments to compare the performance of solar hot water systems tested under outdoor conditions, and indoors using a solar and thermal simulator. His diligent efforts resulted in an ASHRAE Standard that is currently used to rate all solar water heating systems sold within the United States.
- Dave Ward provided outstanding technician support in the area of refrigerant mixture measurements and in the development of a test rig for determining refrigerant flammability.

References

1. Rexmond C. Cochrane, *Measures for Progress: A History of the National Bureau of Standards*, National Bureau of Standards, 1966.
2. Paul R. Achenbach, *Building Research at the National Bureau of Standards*, Building Science Series 0, National Bureau of Standards, 1970.
3. Neil Gallagher, *Building Research at the National Bureau of Standards 1968-1974*, Building Science Series 75, National Bureau of Standards, 1979.

4. David R. Lide, *A Century of Excellence in Measurements, Standards and Technology: A Chronicle of Selected NBS/NIST Publications, 1901-2000*, Special Publication 958, National Institute of Standards and Technology, 2001.
5. Elio Passaglia, *A Unique Institution: The National Bureau of Standards, 1950-1969*, Special Publication 925, National Institute of Standards and Technology, 1999.
6. James F. Schooley, *Responding to National Needs: The National Bureau of Standards Becomes the National Institute of Standards and Technology, 1969-1993*, Special Publication 955, National Institute of Standards and Technology, 2000.