Saved Lives and Better Buildings: Technical Contributions That Make a Difference

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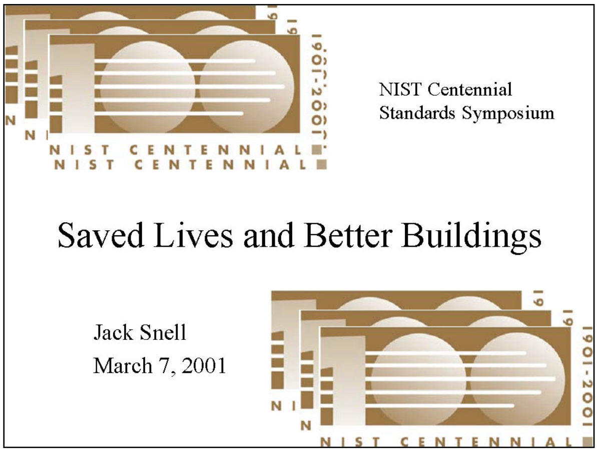
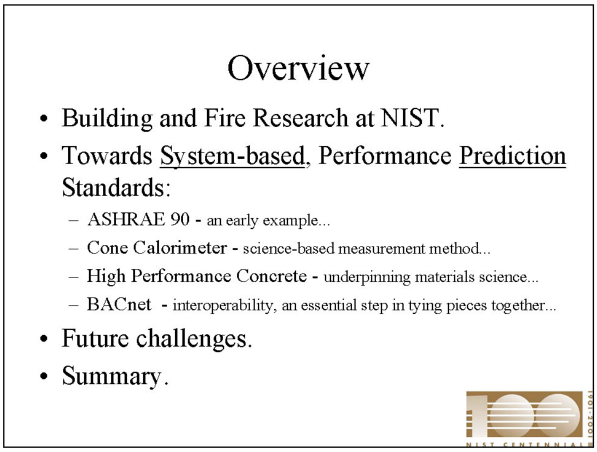
INTRODUCTION



SLIDE 1

It is indeed an honor to have the opportunity to participate in this NIST Centennial Standards Symposium. I, like many of you, was engaged by Larry Eicher's war games model this morning, a Standards War Game. My talk deals mostly with the second and third columns, situations where there are either wasteful or dangerous implications to our interactions. The issues at stake in many of the building and fire safety standards that we deal with are just that: matters of either public health or safety, and often life safety. I also want to focus on the last two of the principles in the national standards strategy in your handout package, and in particular on the bottom of page 4. One deals with the phrase, "Use of current available technology," and the last principle addresses performance-based standards. My point is that I don't think that either of these statements goes anywhere near far enough in describing what, in fact, needs to be done to respond to the mounting pressures for globalization on the one hand, and standards and practices that reduce costly wastes and losses—often involving loss of life and injury—on the other.

As Mathias pointed out earlier this morning, yes, there are political and economic, as well as technical issues at work in standardization. Yet, in a highly competitive global economy, all of the players are challenged to deal responsibly with the best available tools for each of these three elements; technology, economics, and politics. This capability does not come without a price. In my view, he who is willing to pay it is most likely to be the winner in Larry's game. By way of overview, (Slide # 2) I want to say first a few words about building and fire research at NIST, and then use four examples which punctuate the need for systems-based performance prediction standards. I will close with some thoughts about future challenges. (Slide # 3) NIST work in fire began not just with the hose coupling issues in the great Baltimore fire, but also because the same issue arose in a fire on the NIST campus within the same year. I guess that was probably our first war



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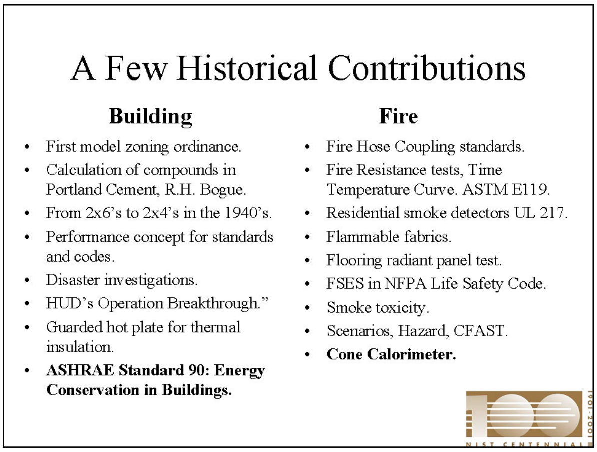
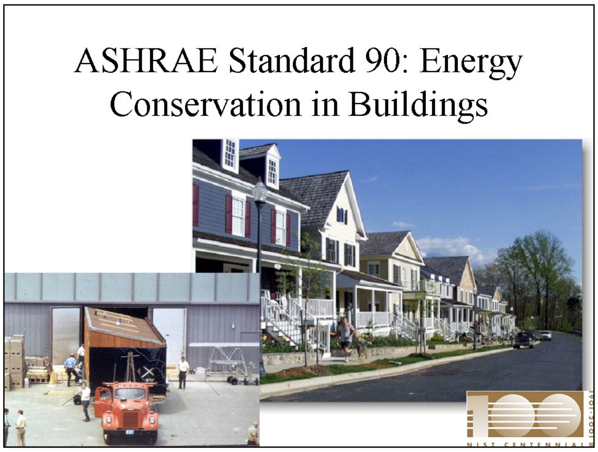


SLIDE 3

game in the standards business. NIST authored the first model zoning ordinance in the early decades of the century, and has gained public attention over the years for a number of our disaster and fire investigations. Two of the more recent examples I wish to highlight are listed on the bottom of this slide: ASHRAE Standard 90 and the cone calorimeter.

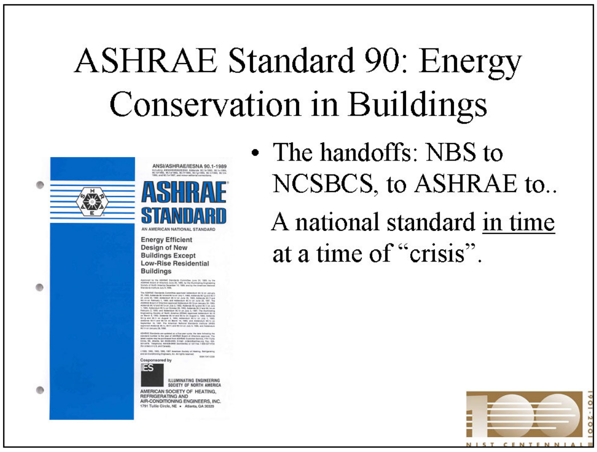
My first example is ASHRAE Standard 90. (Slide # 4) This has to do with the subject of energy conservation in buildings. You may recall that in the early years of the 1970s we faced an energy crisis that was stimulated by activities in other parts of the world, and something had to be done about it, and done in a relatively short period of time. As it turned out, about one-third of energy consumption is used in houses.



SLIDE 4

NIST WORKING ON FIRST GENERATION MODELS

Now, NIST had been working in the 1960s on first generation models of building energy performance. This was represented in Dr. Tamami Kusuda's "National Bureau of Standards Load Determination," or NBSLD computer model for the thermal energy flows through the envelope of a building. Shown here in the picture on the left is one of three modules of a factory built townhouse that was used for full-scale verification of that computer program, the results of which were published in 1975. Now, during that time in 1973, NBS was approached by the National Conference of States on Building Codes and Standards to develop guidelines home builders could use in helping reduce the impact of this critical sector on the national energy budget. Reece Achenbach, Chief of the Building Environment Division, pulled together a team to develop such a guide, drawing on the division's long-term expertise in prediction and measurement of building thermal performance and lighting. The resulting product was issued in February of 1974, and entitled, "Design and Evaluation Criteria for Energy Conservation in New Buildings." (Slide #5) The National Conference of States delivered the NBS product to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), and they in-turn converted the guidelines into a national standard in the following year! Also, as soon as that was done, ASHRAE set up a national program to train trainers. ASHRAE then set up training in each ASHRAE Chapter throughout the country so that within a number of months practicing heating, ventilation, and air- conditioning engineers all around the country were using this document. Thus, in less than 2 years, (Slide # 6) a national standard was developed, disseminated, and actually put into widespread use, saving energy in a time of public need. Had NBS not been working on the underpinning science and technology in the previous decade, it would have taken years instead of months to deliver such a document. Because we pushed the envelope and embraced best, as well as available, technology, these models are still in use today and much of the science is being enhanced.



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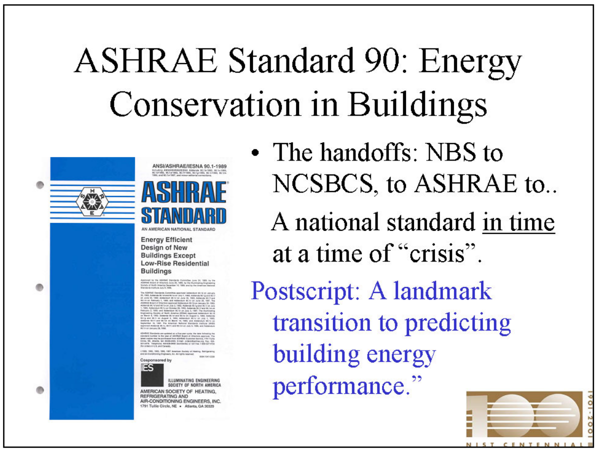
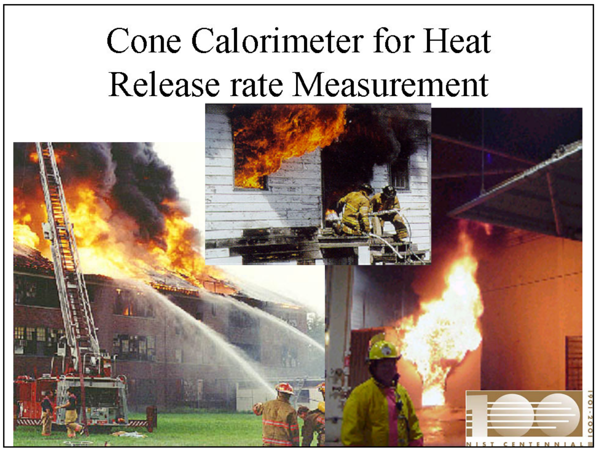


SLIDE 6

The next example that I want to talk about (Slide # 7) deals with the troublesome problem of building fires that Casey Grant talked about earlier. In the early 1980s, U.S. fire deaths were still on the order of 5,000 and the U.S. fire death rate was one of the highest in the world. Now, by that time, a serious program of fundamental fire research was underway at NBS, initiated through the foresight of John Lyons in the 1970s, that began to produce, for the first time, insights into why building fires grow so big so fast. For example, a single couch or set of easy chairs could turn a room into an inferno within 2 or 3 minutes. The reason for this is that much of the energy released in such a fire is in the form of radiation, which when confined, feeds back to the unburned fuel, thus accelerating the process of burning at an exponential rate. Thus, a critical factor in the flammability of a material is its rate of heat release. This is a measure of how rapidly it will decompose into combustible gases and burn when heated by a radiant source. This knowledge—and the scientific insight of chemist, Clayton Huggett—that the amount of oxygen consumed in the combustion of most polymeric materials is a constant—led to the development of a novel approach to measuring rate of energy release. (Slide # 8) Shown on the right-hand side is the original cone calorimeter for rate of energy release measurement as developed by Vytenis Babrauskas. The principle of operation was simple. A conical shaped heater projects a prescribed amount of energy on a sample, and the combustion products rise through a hood and into a tube where oxygen levels are monitored continuously, and a load cell under the sample measures mass loss as the sample is pyrolized or burns. These measurements then provide the oxygen consumption and mass loss needed to determine the rate of heat release as a function of time. This principle of measurement has been codified in ASTM and ISO standards, and embodied in commercially produced apparatus such as the one shown on the left, and are now used world-wide for this critical flammability measurement.

There are two important consequences of this work. First, this measurement approach can be used for measurement of rated heat release of fires of any scale where it is possible to capture the combustion products in a collection hood. Secondly, (Slide # 9) the rate of heat release is a property of the response of the material to radiation, so that such calorimeters provide essential data for modeling fire and fire growth in computer-based models and simulations, such as the fire dynamic simulator illustrated on this slide. Here again fundamental fire research, addressing the very mechanisms of burning, was a necessary precursor to the more practical applied tools that came later.



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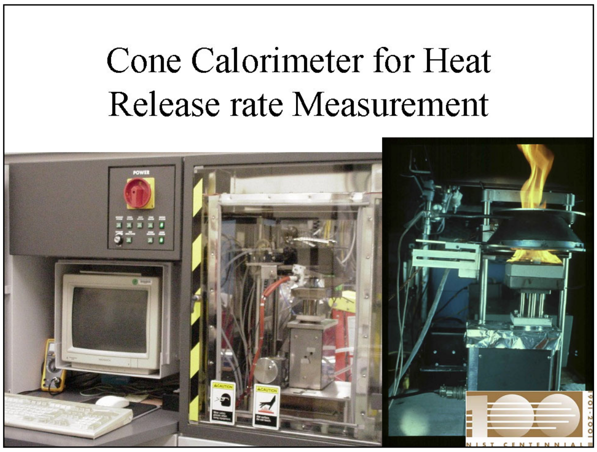

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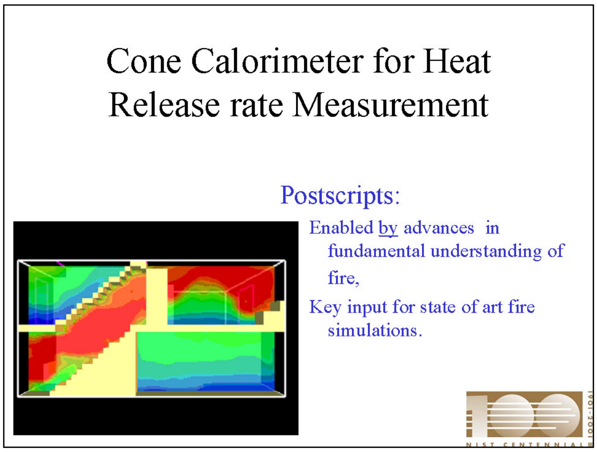

SLIDE 9

My third example deals with concrete, which, along with steel, is a ubiquitous building material of choice for most infrastructure (Slide # 10) and the built environment. In recent years, fundamental research on concrete has produced knowledge to design “high performance concretes,” which will last up to 10 times longer, and have strengths as much as 3 to 5 times greater then those in common use today. However, nagging issues about the performance of these materials remain. (Slide # 11) For example, concrete has been plagued with a number of problems that lead to early failures such as spalling. Spalling is not only an unattractive appearance issue, but also consequent failures can lead to fatalities as well. This is unacceptable. Why is it that in some applications concrete seems to last forever; whereas in others it begins to spall and come apart within a few years of use? How can concrete be used reliably if this is the case? Well, here again fundamental research has been the key. Partnering with industry, we have advanced the state-of-the-art understanding of the mechanisms of strength gain, and failure, such as sulfate attack, as in the case shown here resulting from salt exposures.

Concrete really is a very highly complex system, (Slide # 12) whose properties at the meter scale depend on relevant mechanisms at the milli, micro, and nanometer scales, as illustrated on the bottom of this slide. Just above that, on the right, is an image from a computer simulation of water movement in a hydrating cement specimen, and above that, in the right-hand corner, is an image from a model of concrete rheology. Finally, on the left is an image from a molecular dynamics model of reactions near the surface in a hydrating cement. This scientific, state-of-the-art knowledge is now enabling reliable performance and service life prediction for such materials. (Slide # 13) As a consequence of not having to mix concrete by trial and error, as an art, designers are now beginning to be able to design for specific needs of particular applications, and to predict performance reliably. Once again, fundamental research, leading to advances in measurement and prediction technology, is enabling powerful new capabilities for design and application. The consequences will be seen in coming decades in bridges and highways that are not subject to failure from

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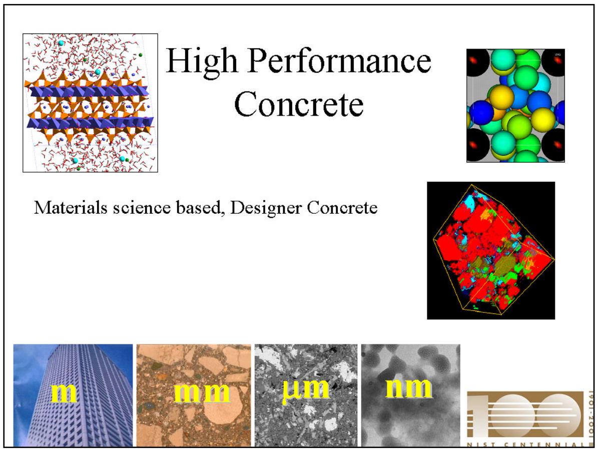
SLIDE 11



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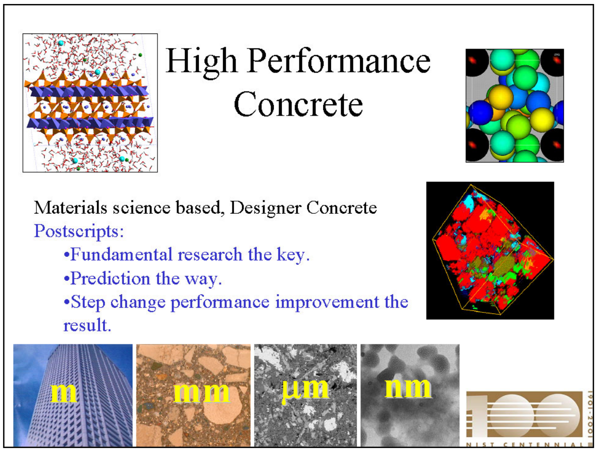
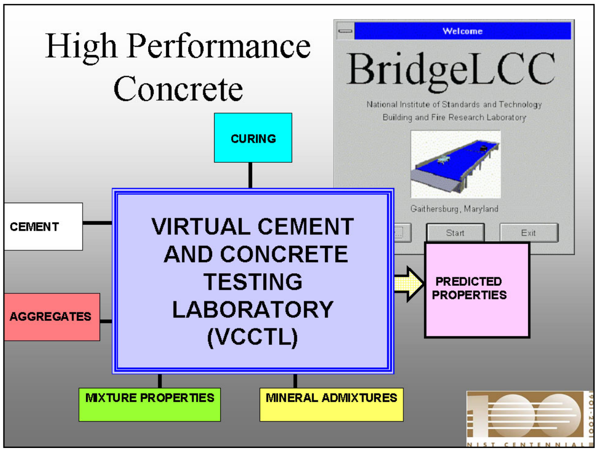


SLIDE 13

salt, to airport roadways, dams, and buildings that can be built better, faster, safer, and at lower cost.

Just as an aside, (Slide # 14) our folks recently established with partners in industry a virtual cement and concrete testing laboratory (VCCTL). This web-based facility, for example, will enable users to replace the old 28-day strength test by predictions made from three-day tests. Three days instead of 28! Just think of the cost savings in delay time on construction sites. Also, such tests cost about $300 each, and a good sized concrete firm will make thousands of such tests a year. Now we are talking about real significant dollar savings.



SLIDE 14

My fourth example (Slide # 15) is a standard for interoperability of the hundreds of elements used in building control systems. This has been an issue in building mechanical systems, as it has been elsewhere, in the worlds of electronics and computing, and it points to the benefits of open systems. NIST, in partnership with a number of foresighted companies and the American Society of Heating, Refrigeration, and Air-Conditioning Engineers, developed the BACnet standard for interoperability for such systems. That standard was introduced in 1996 at the ASHRAE show (as shown in this slide) where the products of 13 companies were interconnected using the BACnet protocol. Today, (Slide # 16) just a few years later, there are some 77 registered BACnet products from some 15 member companies of the BACnet Manufacturers Association. Just six of those firms have installed over 300,000 devices in some 20,000 installations in 82 countries across the world. This is real leverage and impact. (Slide # 17) Now, this has not been an easy trip, and it did involve a standardization war of a sort. At the start, as you might imagine, some of the big guys were reluctant to participate. Now they all want in. As usual in innovation, there was a tension between public knowledge and corporate advantage. Yet when all is said and done, and the new technology is in place, there are great new market opportunities for all.

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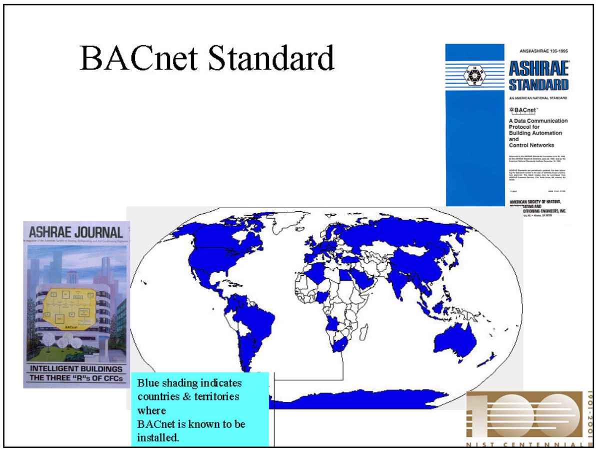

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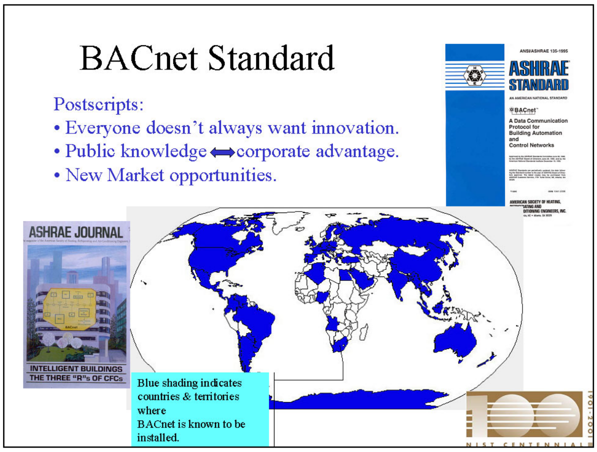
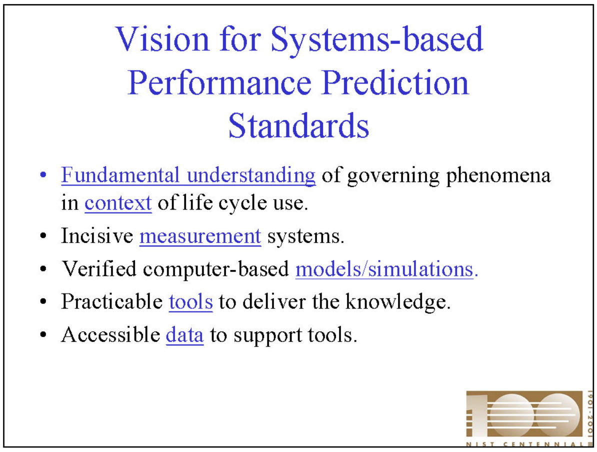


SLIDE 17

These four examples lead me to the main point of my remarks, and that is that the national standards strategy is great, as far as it goes. (Slide # 18) And yet we must not be content with currently available technology or simplistic notions of, typically component, performance-based standards. Each of the examples I described dealt with applications of fundamental knowledge to measurement and prediction of system performance in the context of life cycle use. What the end-user desperately needs is knowledge of real performance through the life cycle of the product or design in the context of actual use. Our vision in the Building and Fire Research Laboratory is to provide the scientific and technological capability to do just this. Inescapably, real performance-based standards require all of the things listed on this slide. Yet, despite all of the advances that I have described, in most aspects of building performance, current knowledge remains woefully insufficient to be able to do these things. The sad fact is that in many countries and laboratories traditional and empirical tests are passed off as performance tests and most existing performance standards fail to match the vision I just outlined. That is, they are not taken in the context of actual life cycle use for the product or design, nor do they actually predict end-use performance. (Slide # 19) Even worse, few building research laboratories still do real research aimed at fulfilling this vision. Most of our counterparts around the world have been privatized and are mostly consultancies or doing commercial product testing to the limit of their capabilities. Make no mistake about it. There will be no meaningful performance standards that do not meet the criteria of quantifying the real benefits of better quality or of value added. In a highly competitive global economy, who wants to settle for a standard that simply benchmarks against the legal minimums? What incentive does that offer for innovation or for new products? If no one is doing the research, who will verify the new tools and models? (Slide # 20) If most facilities are used for commercial product testing, who will do the real scale tests or come up with the funds for such costly tests? Only state-of-the-art scientific measurement systems, with known accuracy and measured uncertainty can be used for such an undertaking. As a footnote, none of the fire labs in the world today are even capable of uncertainty measurement in fire tests.

Models need maintenance and vast quantities of data. (Slide # 21) Who is going to provide this data? Who will affirm its quality, and who will maintain objectivityin the use of it? (Slide # 22) Clearly, each of



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SLIDE 19

SLIDE 20

Implications for Future Global Performance Standards

- Where is the use-inspired fundamental research being done?
- How will the resulting performance prediction tools be verified?
- Who will provide the underpinning infrastructure?

SLIDE 21

these questions needs to be addressed to reach the goal of practicable systems- based performance prediction standards that are based on best available technology. Once they are in existence, the payoff is tremendous to the consumer and to innovative product producers. The result is better, faster, safer, and less costly buildings and facilities. (Slide # 23) The bottom line, as we all know, is that there is no free lunch. Yes, science, economics, and politics are different, and one is no substitute for the other, especially in an open and highly competitive marketplace. It has been said that if you build a better mouse trap the world will beat a path to your door, and this may well be true, especially if you have a way to demonstrate in quantitative terms meaningful to the buyer that what you have is indeed better. If not, others will, and in the end they will get the business. Let's not lose it.

Implications for Future Global Performance Standards

- Where is the use-inspired fundamental research being done?
- How will the resulting performance prediction tools be verified?
- Who will provide the underpinning infrastructure?
- From <u>minimum standards</u> to <u>standards for optimums: "better, faster, safer, less costly."</u>

SLIDE 22

Summary

- History is a powerful teacher.
  - The laws of science are just that.
  - Change is the name of the game.
  - The standards strategy is a good start.
  - Old ways will give way to better ones.
- Are you ready?

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