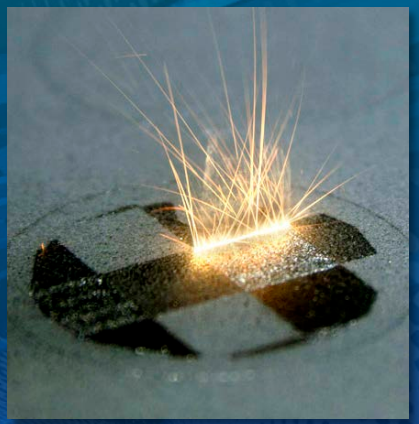
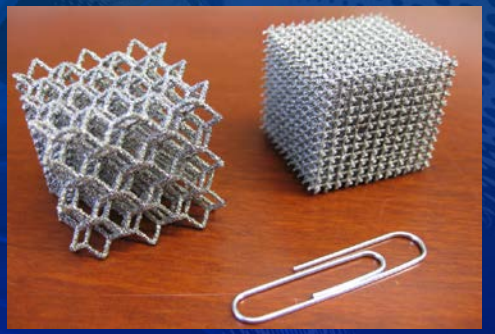
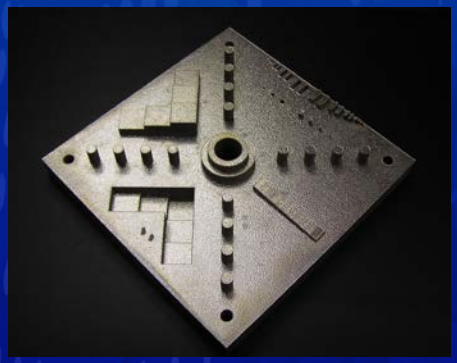
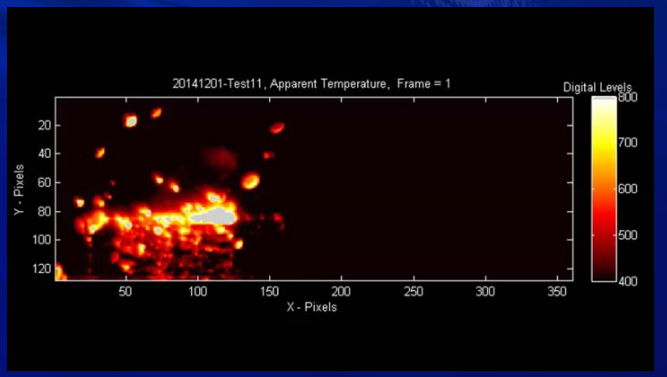
NIST Perspective on Additive Manufacturing Standards









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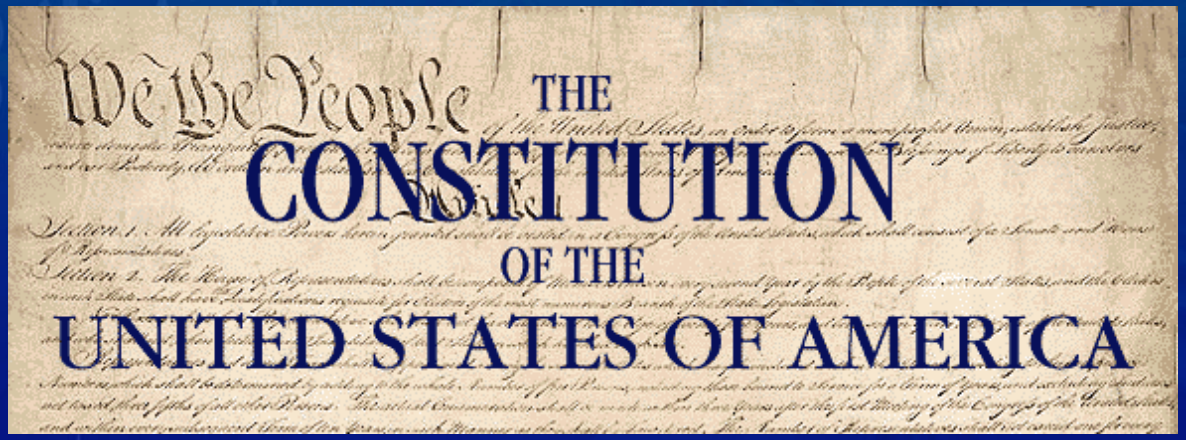
The History of Standards in the U.S.

"Uniformity in the currency, weights, and measures of the United States is an object of great importance, and will, I am persuaded, be duly attended to."

George Washington, State of the Union Address, 1790



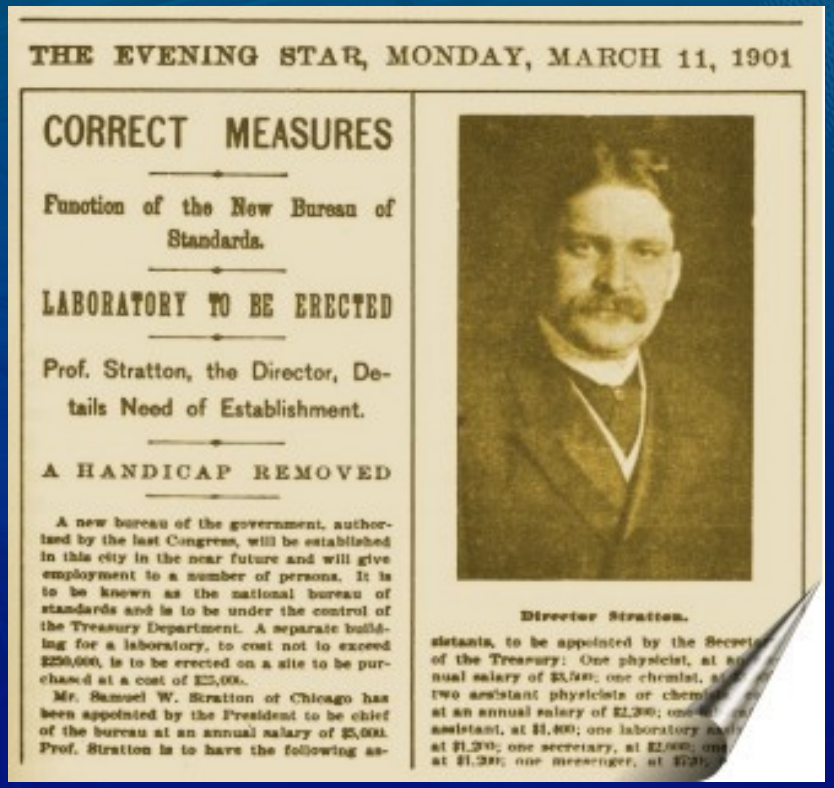
Article I, Section 8: "The Congress shall have the power to…*fix the standard of weights and measures"*

Founding Charge of the National Bureau of Standards (1900)

"It is therefore the unanimous opinion of your committee that no more essential aid could be given to

- manufacturing
- commerce
- the makers of scientific apparatus
- the scientific work of Government
- schools, colleges, and universities

than by the establishment of the institution proposed in this bill."



THE EVENING STAR, MONDAY, MARCH 11, 1901

CORRECT MEASURES

Function of the New Bureau of Standards.

LABORATORY TO BE ERECTED

Prof. Stratton, the Director, Details Need of Establishment.

A HANDICAP REMOVED

A new bureau of the government, authorized by the last Congress, will be established in this city in the near future and will give employment to a number of persons. It is to be known as the national bureau of standards and is to be under the control of the Treasury Department. A separate building for a laboratory, to cost not to exceed $250,000, is to be erected on a site to be purchased at a cost of $75,000.

Mr. Samuel W. Stratton of Chicago has been appointed by the President to be chief of the bureau at an annual salary of $5,000. Prof. Stratton is to have the following as-

Director Stratton.

sistants, to be appointed by the Secretary of the Treasury: One physicist, at a annual salary of $3,500; one chemist, at two assistant physicists or chemists at an annual salary of $1,200; one assistant, at $1,400; one laboratory at $1,200; one secretary, at $1,000; one at $1,200; one messenger, at $720;

House Committee on Coinage, Weights and Measures, May 3, 1900, on the establishment of the National Bureau of Standards (now NIST)

Unique Role of NIST Research Laboratories

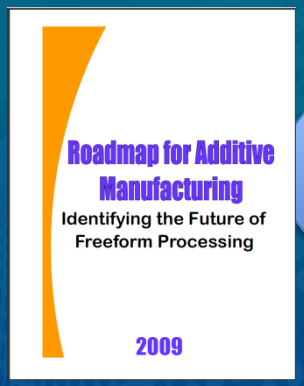
- Emphasis on infrastructural metrology and non-proprietary, standardized metrology methods that address a broad class of measurement challenges
- Emphasis on rigorous and generic procedures to characterize measurement uncertainty that comply with international standards
- Long-term commitment, expertise, and neutrality essential for harmonized and unbiased national and international standards
- Leverage NIST core competences in measurement science, rigorous traceability, and development and use of standards -- as well as specific expertise in measurements and standards for manufacturing systems, processes, and equipment

➢ **Measurements and Standards**

Primary Outputs of NIST Research Laboratories

- Measurement methods
- Performance test methods and metrics
- Technical contributions toward documentary standards
- Standard reference data
- Technology transfer: technical publications, industry workshops, collaborations
- Standard reference materials
- Calibration services

Additive Manufacturing Needs and Priorities



2009 AM Industry Roadmap

America Makes / National Additive Manufacturing Innovation Institute

Public-Private Partnership
National AM Roadmap

Additive Manufacturing Consortium (AMC)

Precompetitive Technology Development

AM Needs and Priorities

AM Standards Committees: ASTM F42, ISO TC261, ASME Y14.46, SAE AMSAM

Standards Development

NIST Workshop: Measurement Science for Metal-Based AM

Needs, Priorities, and Action Plans (Dec. 2012)

Substantial Collaborations and Stakeholder Interactions

Joint research, site visits, events, etc.

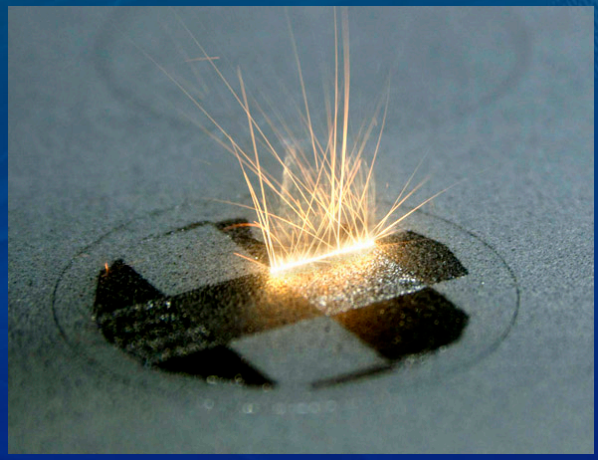
Barriers that Prevent Broad Adoption of Metals-Based Additive Manufacturing

- Limited material types and unknown / non-uniform properties
- Lack of process repeatability and inconsistent system performance
- Consensus protocols and test data for qualification and certification do not exist
- Insufficient part accuracy without significant post-processing
- Insufficient surface finish (e.g., for contoured surfaces)
- Current AM data formats define approximated geometry
- Lack of AM standards (materials, process, machine, quality)
- Need for improved non-destructive evaluation methods for complex defects and part geometry
- Requirements for post-processing (e.g., heat treatment, surface treatment, support removal, finish machining)
- Lack of AM-specific design tools / design guidelines
- Fabrication speed too slow / costs too expensive
- Build volumes / part size too small

NIST-EL Measurement Science for Additive Manufacturing (AM)

Four research thrusts:

- Characterization of Additive Manufacturing Materials
- Real-Time Control of Additive Manufacturing Processes
- Qualification of Additive Manufacturing Materials, Processes, & Parts
- Additive Manufacturing Systems Integration



Program focuses on metals-based AM

One of Four Programs in the NIST Engineering Laboratory Advancing Essential Measurement Science and Standards for Smart Manufacturing

NIST-Wide Contributions to AM

- Engineering Laboratory: Measurement Science for Additive Manufacturing program
- Material Measurement Laboratory: AM material property measurement, material testing and modeling, defect detection
- NIST Center for Neutron Research: neutron imaging, AM residual stress measurement
- Information Technology Laboratory: statistical analysis of AM round robin test results; AM cybersecurity and IP protection
- Physical Measurement Laboratory: thermal emissivity of powders and melts; laser power measurement; X-ray CT
- Manufacturing Extension Partnership: industry outreach and assistance provided by innovation centers in every state
- Advanced Manufacturing National Program Office: Measurement Science for Advanced Manufacturing Awards

Role of Additive Manufacturing Standards

- Standards can be used for (among others):
  - specifying requirements
  - communicating guidance
  - documenting best practices
  - defining test methods and protocols
  - documenting technical data
  - accelerating the adoption of new technologies
- Certifying bodies typically reference publicly available standards in their procedures
- Standards development in the U.S. is conducted through voluntary participation and consensus
- Companies and agencies must participate to impact the priorities and content of standards

NIST Measurement Science Contributes to New AM Standards

- Identify needs and priorities through workshops and industry meetings
- Coordination, facilitation, and communication roles
- Develop technical basis for standards through measurement science research
  - Draft content and starting point for standards development
  - Provide unbiased technical expertise
  - Assist in validation testing of proposed standard test methods
- Providing significant technical contributions and leadership in several AM standards committees in various SDOs
  - ASTM F42, ISO TC261, ASME Y14.46

Current Challenges in AM Standards Landscape

- Rapidly growing list of organizations working/planning to develop AM standards
  - Scopes of SDOs have evolved
- High risk of duplication of efforts and overlapping content
- Potential for inconsistencies (or even contradictions)
- Conflicting standards create ambiguity and confusion

Many Examples of Difficult, Time Consuming Standards Harmonization

- ASTM/ISO harmonization of terminology standard
- Roller coaster industry
- Wireless sensor networks, etc.
- International and U.S. machine tool standards
  - Existed in parallel for many years
  - Increased costs for U.S. industry
    - Sellers had limited market penetration due to conformance to multiple standards
    - Higher costs to buyers due to unique requirements (added tests) of multiple standards
  - Complete harmonization took about 20 years

The AM Industry has the opportunity to avoid this challenge

Vision for AM Standards

- **Integrated and cohesive set of AM Standards** – to be used all over the world
  - Consistent, non-contradictory, non-overlapping
- Common roadmap and organizational structure for AM standards
- Use and build upon existing standards, modified for AM when necessary
- Standards committees work together and follow a common standards development plan
- Resulting standards are usable and acceptable for future users of all types (novice and expert)

Structure of AM Standards

General AM Standards

Terminology
- ASTM F2792-12a
- ISO 17296-1
- ISO/ASTM 52921-13

Processes / Materials
- ISO 17296-2
- Qualification and Certification Methods
- Requirements for Purchased AM Parts
- Non-Destructive Evaluation Methods

Test Methods
- ISO 17296-3
- Test Artifacts
- General Test Methods
- Performance Test Methods

Design / Data Formats
- ISO 17296-4
- ISO/ASTM 52915-13
- Data Structures and Metrics for AM Models

General Top-Level AM Standards
- General concepts
- Common requirements
- Generally applicable

Feedstock Materials

Material Category-Specific
- Metal Powders
- Polymer Powders
- Photopolymer Resins
- Ceramics
- etc.

Material-Specific Standards
- Material-Specific Size Specification
- Material-Specific Chemical Composition
- Material-Specific Viscosity Specification
- etc.

Process / Equipment

Process Category-Specific
- Powder Bed Fusion
- Material Extrusion
- Binder Jetting
- Directed Energy Deposition
- etc.

Process-Specific Standards
- Process-Specific Performance Test Methods
- Process-Specific Test Artifacts
- System Component Test Methods
- etc.

Finished Parts

Standard Protocols for Round Robin Testing

Mechanical Test Methods – e.g., Part 1: Tensile Tests, Part 2: Porosity Tests, Part 3: Fracture Toughness, etc.
- Metals
- Polymers
- Others

Part Specifications

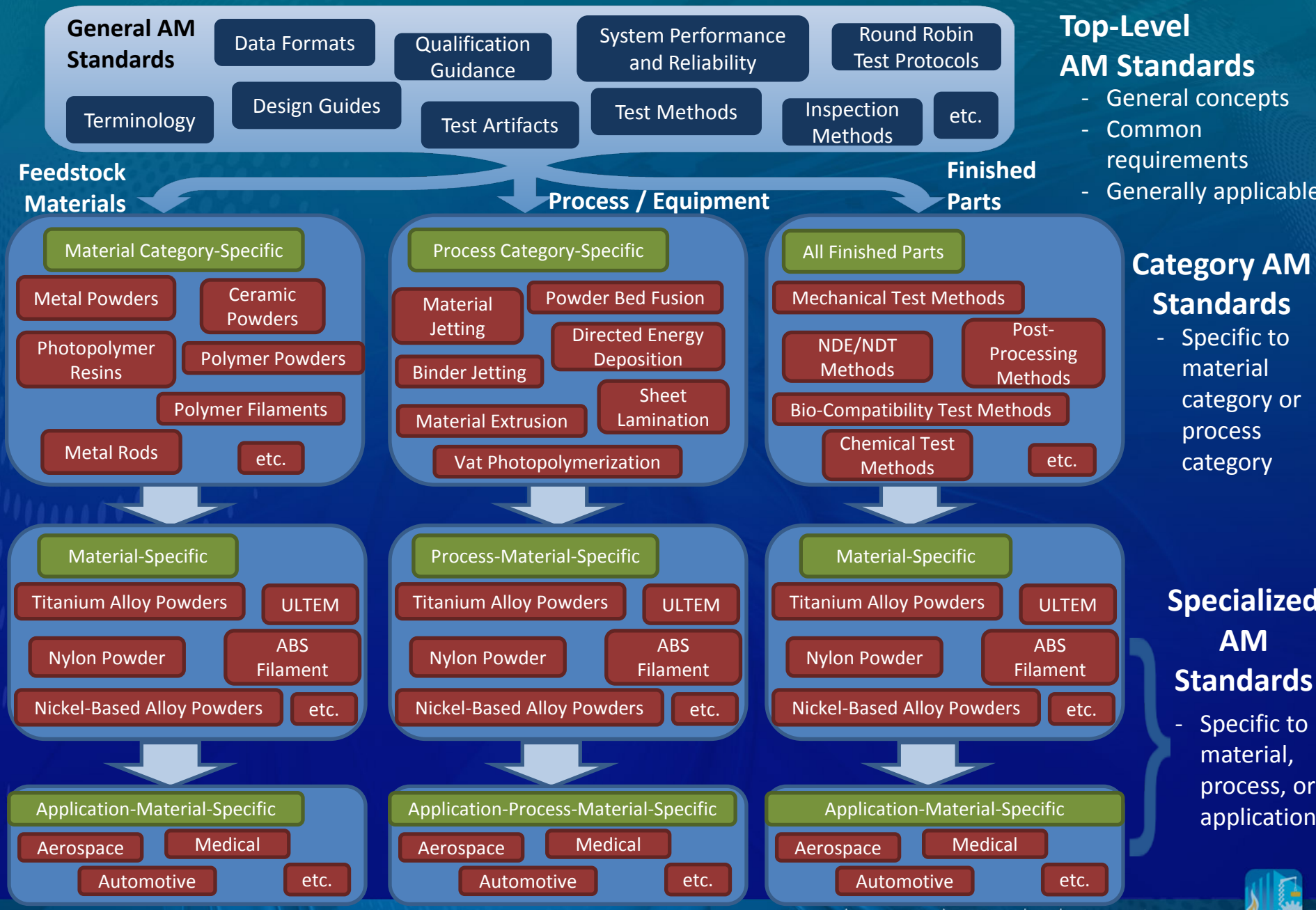
etc.

Application-Specific Standards
- Aerospace
- Medical
- Automotive
- etc.

Category AM Standards
- Specific to material or process category

Specialized AM Standards
- Specific to material, process, or application

Draft Revision: AM Standards Structure



General Top-Level AM Standards

- General concepts
- Common requirements
- Generally applicable

Category AM Standards

- Specific to material category or process category

Specialized AM Standards

- Specific to material, process, or application

engineering laboratory

Recommendations for “Way Forward”

- Each committee needs a clearly defined scope statement
- Use of common terminology is essential
- Standards developed by each group should use the structure diagram and indicate where each document is intended to fit in
- Formal agreements between organizations might be necessary

Recommendations for “Way Forward”

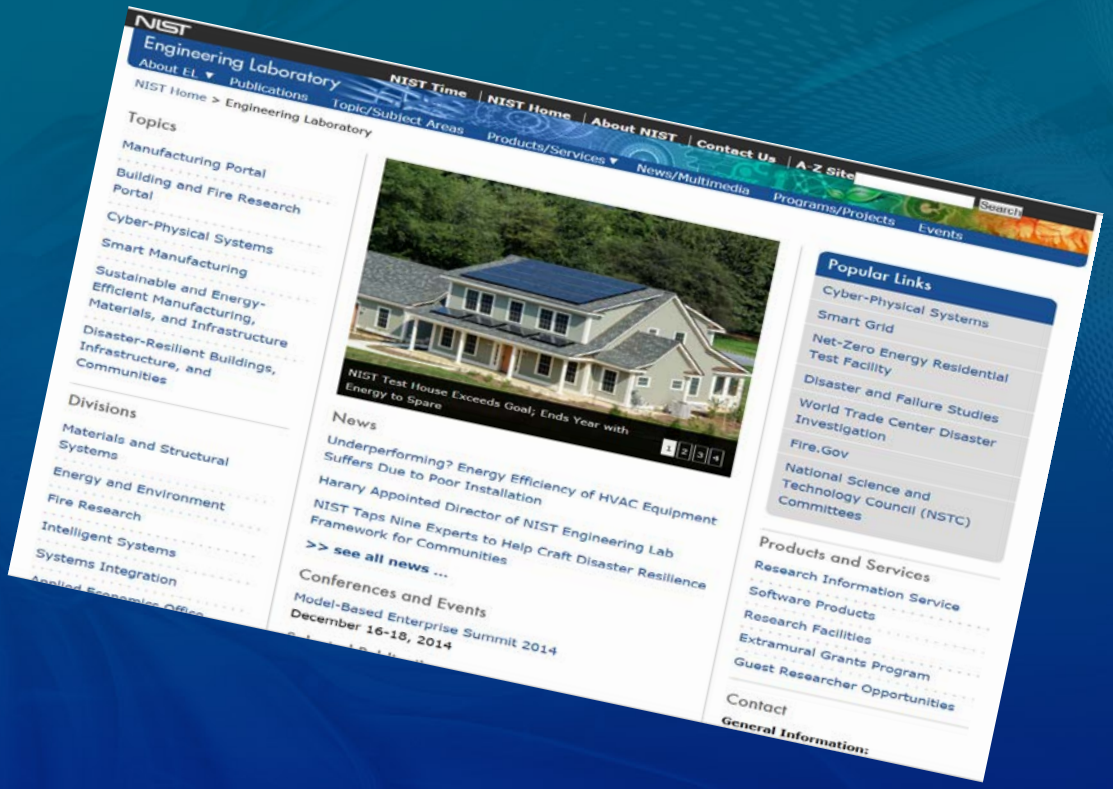
- Liaisons between committees are the key approach for communication, coordination, and collaboration
  - Organizational liaisons: At least at highest levels (committee chairs and administrators) to allow knowledge of procedures, activities, and strategies
  - Technical liaisons: Should have voting rights and ability to make technical and editorial comments on all proposed standards
  - Significant cross pollination of all committees at all levels is preferred
  - It is not enough to merely know what standards have been passed by an organization; must know active and planned work items as well
- Joint planning/working sessions need to be held at regular intervals

Summary

- NIST has been involved in developing AM standards from the start
- NIST will continue to support AM standards development through its measurement science research
- Priorities:
  - High quality, technically accurate standards
  - Usable and high impact standards
  - Integrated and cohesive set of standards: consistent, non-contradictory, non-overlapping
  - No duplication of effort

➢ Several recommendations provided to enhance communication, coordination, and collaboration among AM users, standards bodies, and regulatory agencies

Contact Information



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