Measurement Science for Additive Manufacturing

• Additive Manufacturing is a major thrust in NIST’s *Smart Manufacturing Processes and Equipment Program*

• Substantial NIST expertise in manufacturing domains is being applied to AM:
  - equipment and process metrology, process optimization and control, advanced sensor systems, materials characterization, data formats, standards development, design of experiments & statistical analysis, etc.

• Primary focus is **metal-based** AM processes (EOS M270 DMLS) but we also utilize 3D printers and modest polymer-based systems

• Improved measurements and standards will help overcome existing AM limitations and barriers
NIST Work Is Focused...

- On Existing Barriers and Limitations:
  - Materials Properties and Qualification
  - Process Understanding, Improvements, and Qualification
  - A Lack of Standards
  - Part Accuracy
  - Process Speed
  - Surface Finish
  - Limited Materials
  - Data Formats

- Using Input from:
  - AM Roadmapping efforts
  - Stakeholders and Partnerships
  - Standards Development Organizations
NIST Has Substantial Stakeholder Interactions and Partnerships

- Additive Manufacturing Consortium (AMC)
- Interagency Working Group on AM (OSTP, NASA, Army, Navy, Air Force, DOE, NIST)
- Federal agencies: LLNL, ORNL, AFRL, FBI, ARL, NRL
- Industry: Morris Technologies (OH), GE, ExOne, others
- Universities: CMU, Virginia Tech, Louisville, NCSU, UTEP
- Other: ASTM F42, ISO/TC 261, NAMII, JDMTP, Workshops, Conferences, Symposia, National Research Council
NIST Projects in Additive Manufacturing

1. Fundamental Measurement Science for Additive Processes
2. Materials Standards for Additive Manufacturing

Uncertainties in the Input Materials + Uncertainties in Equipment and Process Performance = Uncertainties in the Final Parts
Project #1: Fundamental Measurement Science for Additive Processes

*Develop first-ever standard test methods and validated models that allow industry to evaluate and improve the performance of additive manufacturing (AM) systems to make better parts more quickly and more economically.*

- Physics-based models of metal additive processes to enable process control for improved product quality assurance
- Standard Test Artifact to determine process accuracy and capabilities – submitted to ASTM
- Real-time measurements of additive processes
  - High-speed thermal
  - High-speed vision
  - *In-situ* porosity sensor
Project #2: Materials Standards for Additive Manufacturing

*Develop enhanced measurement techniques that support new, standardized methods for quantifying the material properties of both the powders used for additive manufacturing and the resulting manufactured parts.*

- Foundational Work Already Exists:
  - Background Studies for state of the art in mechanical property testing and powder characterization (NISTIR 7847 and NISTIR 7873)
  - Assessed applicability of existing mechanical property and powder standards for AM parts and powder (Published Shortly)

- Powder Characterization:
  - Size, size distribution, morphology, chemical composition, flow, thermal properties…
  - Study of effects of recycling on powder characteristics and variability in nominally identical powders

- Setting up powder characterization lab to:
  - Develop appropriate measurement techniques and standards
  - Compare those techniques to more advanced measurement methods (SEM, laser diffraction, energy-dispersive X-ray, X-ray computed tomography…)

- Properties of AM Parts:
  - Two round robins to develop test protocols and procedures for industry accepted design allowable property data are underway
  - Residual stress (ORNL and NIST Center for Neutron Research)
Summary

- Two NIST AM projects focus on AM material properties and AM metal processes
- Recent roadmapping workshops highlighted technical needs in metal AM
- NIST AM work contributes to AM standards, and to qualification and certification issues
Questions?

QUESTIONS ANSWERED HERE EVEN THE SILLY ONES