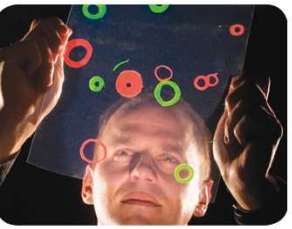
SAND2016-8233C



Additive Manufacturing and Rapid Product Learning for High Consequence Industries

R. Allen Roach, *Sandia National Labs*

Steve Walsh, *Co-Director, Technology Management Center at University of New Mexico*

Sandia National Laboratories

Exceptional service in the national interest

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

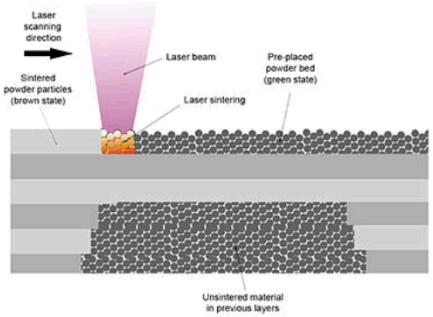
Additive Manufacturing Overview

Sandia National Laboratories

Numerous industries currently using Additive Manufacturing (AM) with common challenge:

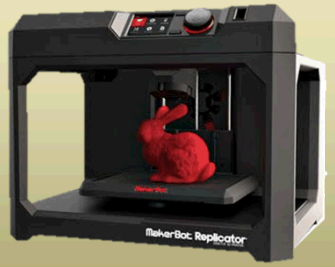
"qualification and validation of materials and processes is an important dimension for integrating 3D printing into production. Removing this barrier is a recurring theme

Mick Mahler, DARPA 8/2/2016



Selective Laser Sintering
from Wikipedia

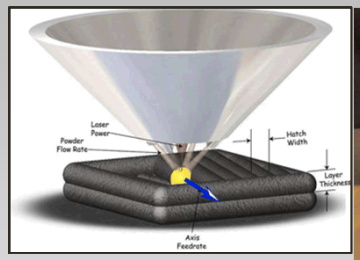
Examples of Polymer AM Tools



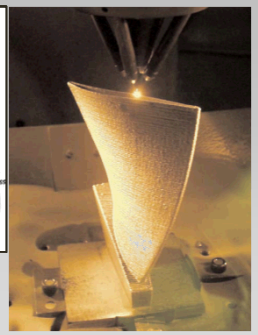
MakerBot

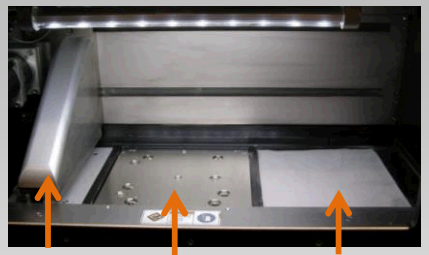
PolyJet

Examples of Metal, Ceramic AM Tools

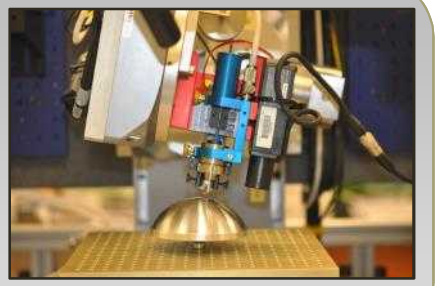


LENS®*





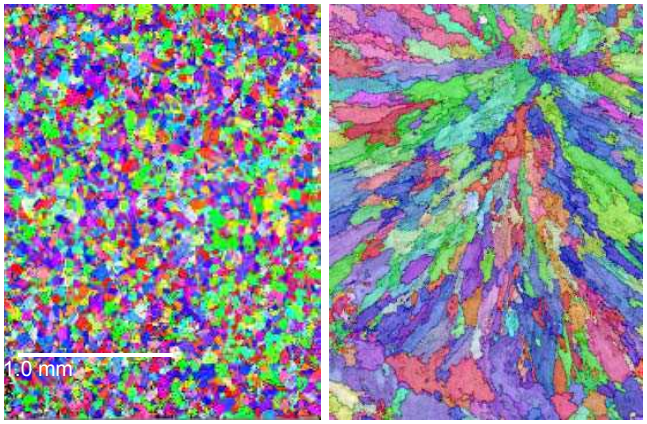
Powder Bed



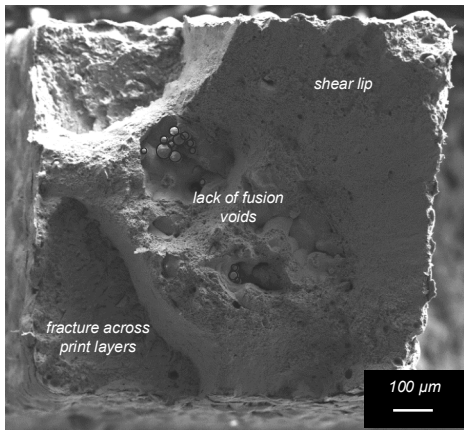
Direct Write

Additive Manufacturing Overview

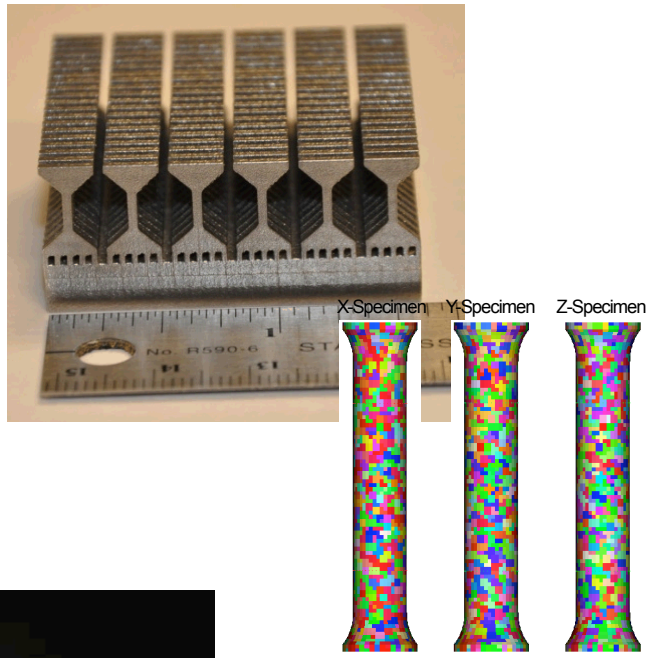
- AM Materials can be different



Wrought 304L SS microstructure (left) & AM (right)



failure at 2% elongation, Vendor 1 H900



- AM parts can be unique

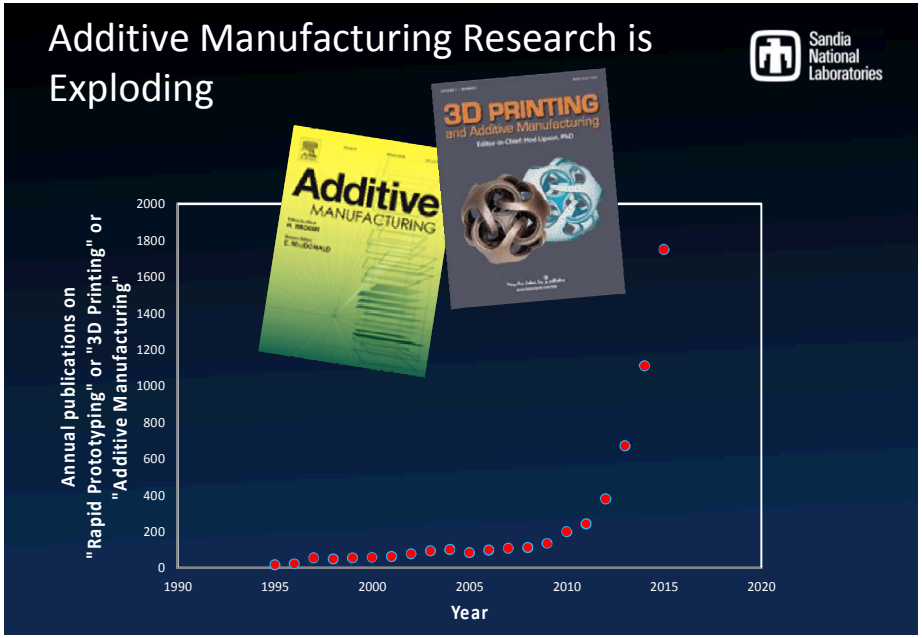
GE Fuel Nozzle

Image credit: CFM International

Why Additive Manufacturing as driver for qualification revolution ?

Sandia National Laboratories

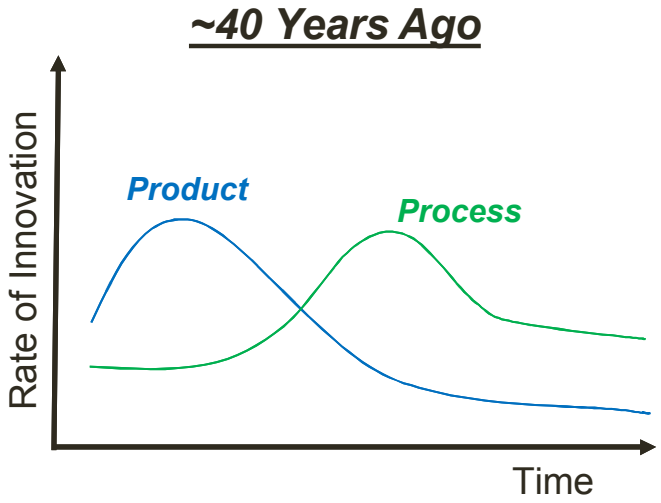
- Disruptive technology that allows simultaneous creation of part and material
- Inherently flexible and agile
- Ability to create near-net shape parts
- Ability to tightly control and monitor manufacturing process at the voxel level
- AM is ideal for low volume, high value, high consequence, complex parts



Innovation and Manufacturing

- History shows that innovations in materials and manufacturing have long been key sources of competitive advantage for industries

- Technology lifecycle

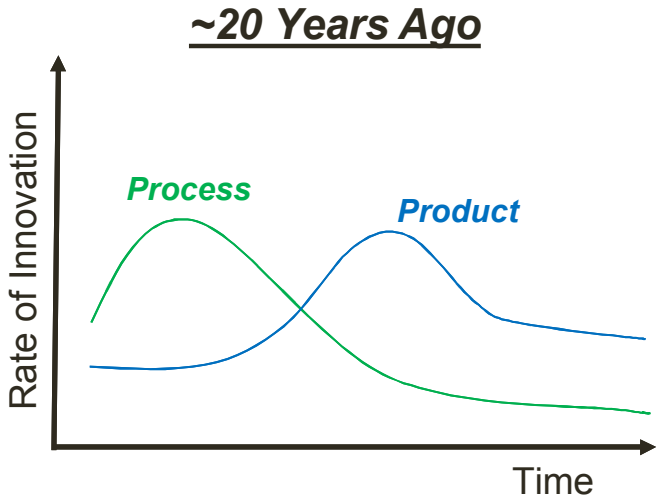


- ~40 Years Ago innovation driven by product design driven by techniques such as continual improvement and six sigma quality management
- Product and Process Innovation are sequential

Innovation and Manufacturing

- History shows that innovations in materials and manufacturing have long been key sources of competitive advantage for industries

- Technology lifecycle

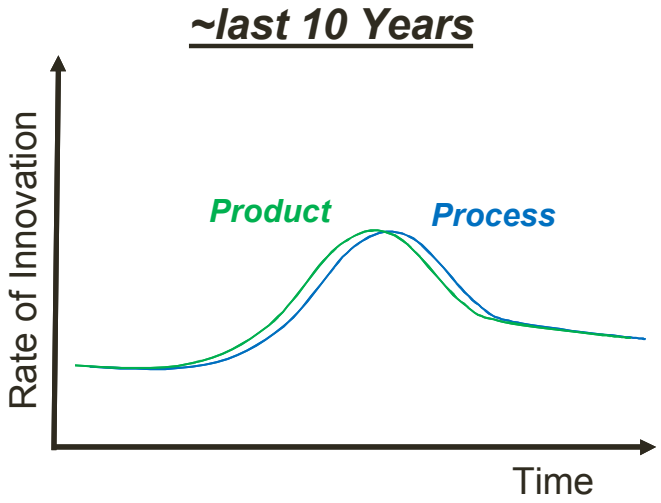


- ~20 Years Ago changes in manufacturing and innovation in the service sector resulted in changes and innovation cycles now 180 degrees out of phase with traditional model
- Service Innovation model Product and Process Innovation are sequential

Innovation and Manufacturing

- History shows that innovations in materials and manufacturing have long been key sources of competitive advantage for industries

- Technology lifecycle



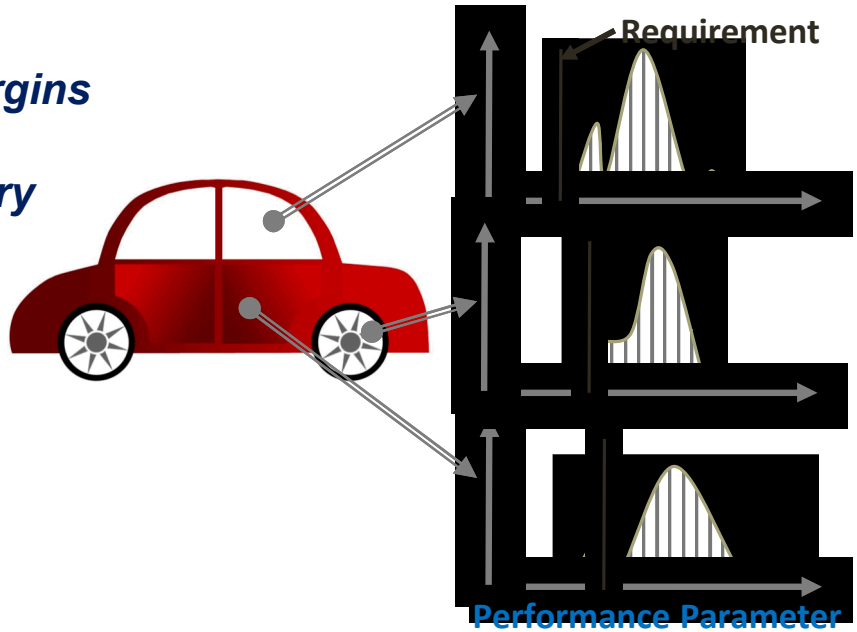
- Last ~10 Years materials based products result in an additional change in innovation cycle driven by ”copy exact” manufacturing processes
- Materials Innovation model Process and Product Innovation are simultaneous
- Impacts are broad and disruptive – metrology, metrics, modeling, infrastructure, …

Paradigm Change

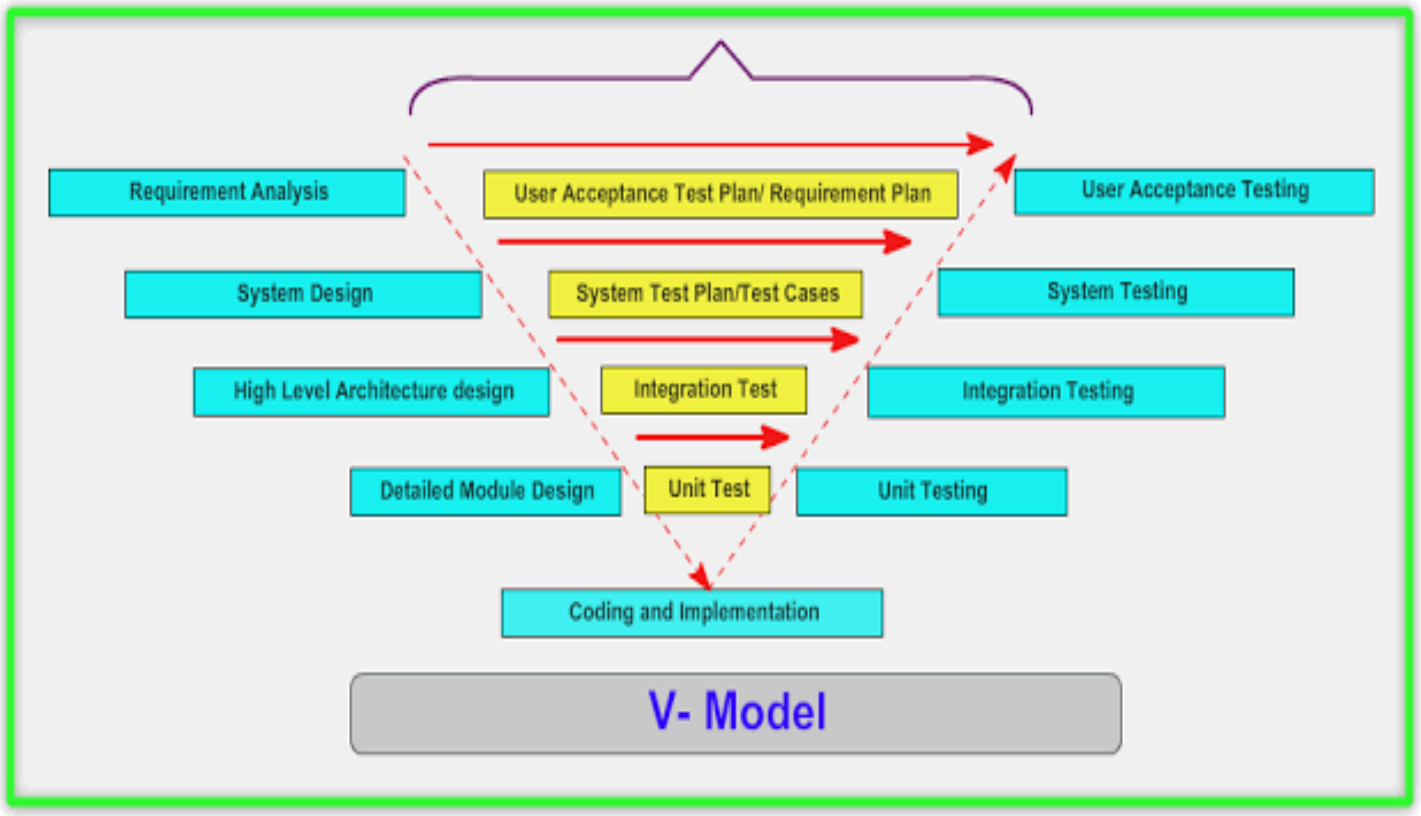
- "Born Qualified" vision for product realization where margins and uncertainties are known at birth

- ***Sandia Goal:*** Combine promise of **additive manufacturing** with **deep materials & process understanding** to revolutionize design, manufacturing, & qualification paradigms
  - Materials, designs, and ultimately components are *Born Qualified/Born Certified*
  - Accelerated Cycles of Learning

Notional example of margins and uncertainty quantification for every part/material

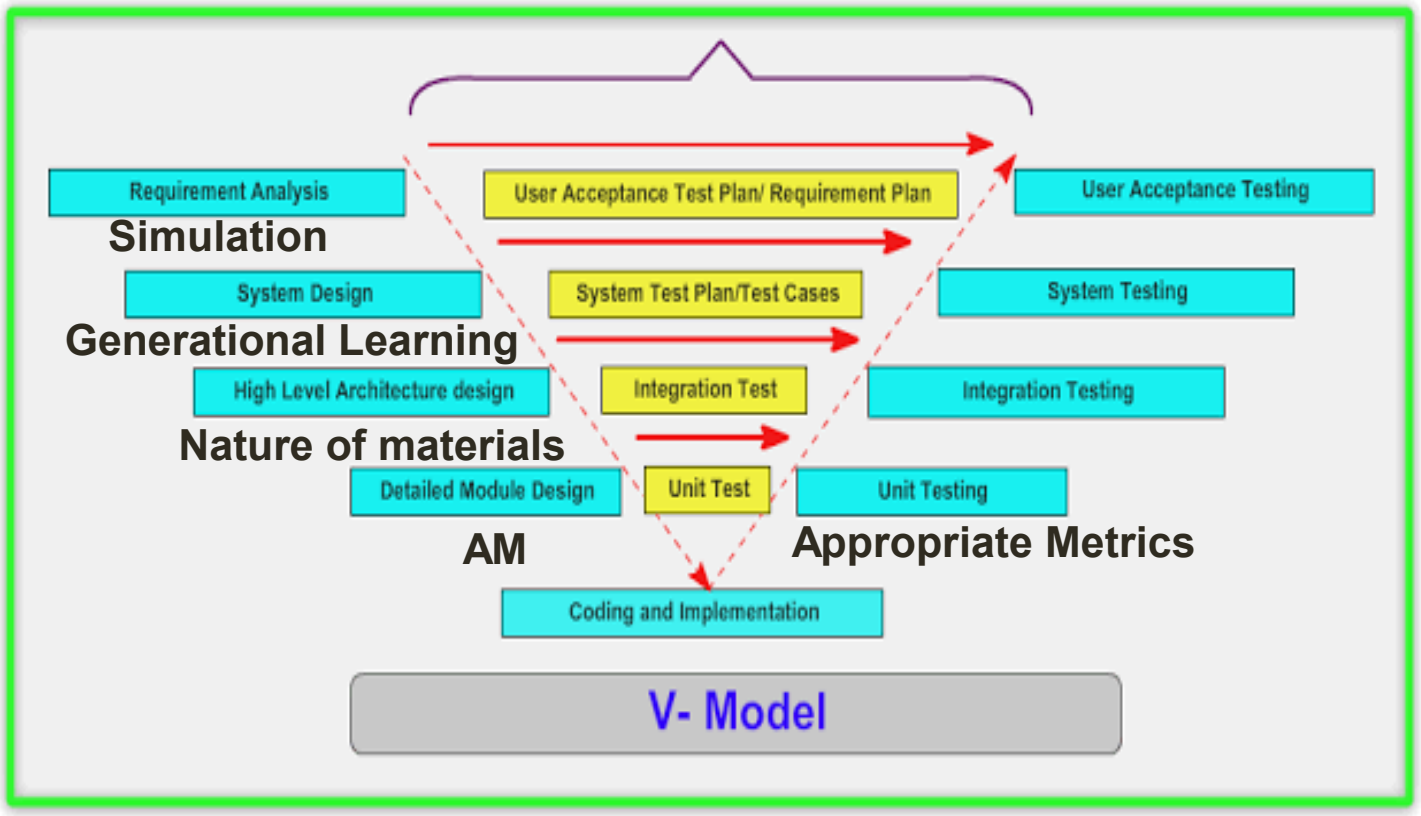


V model for Verification and Validation



High Consequence

V model for Verification and Validation

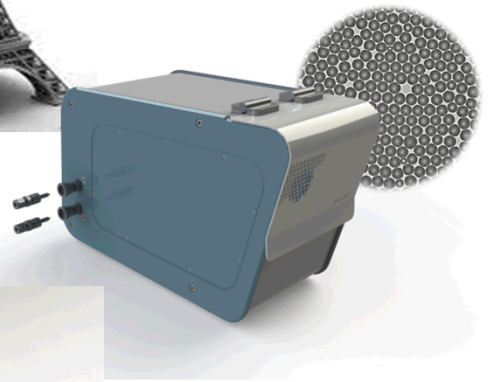


Vision

- Understand how rapid product learning and AM together can improve “time to market” in high consequence industries
- What model is needed to utilize these techniques to not just develop a rapid prototype but to move rapidly to qualification?
- Verification techniques?
  - Dynamic testing
  - Static testing
- Validation techniques?
  - Ordinary Least Squares vs Partial Least Squares
  - Methods and metrics?

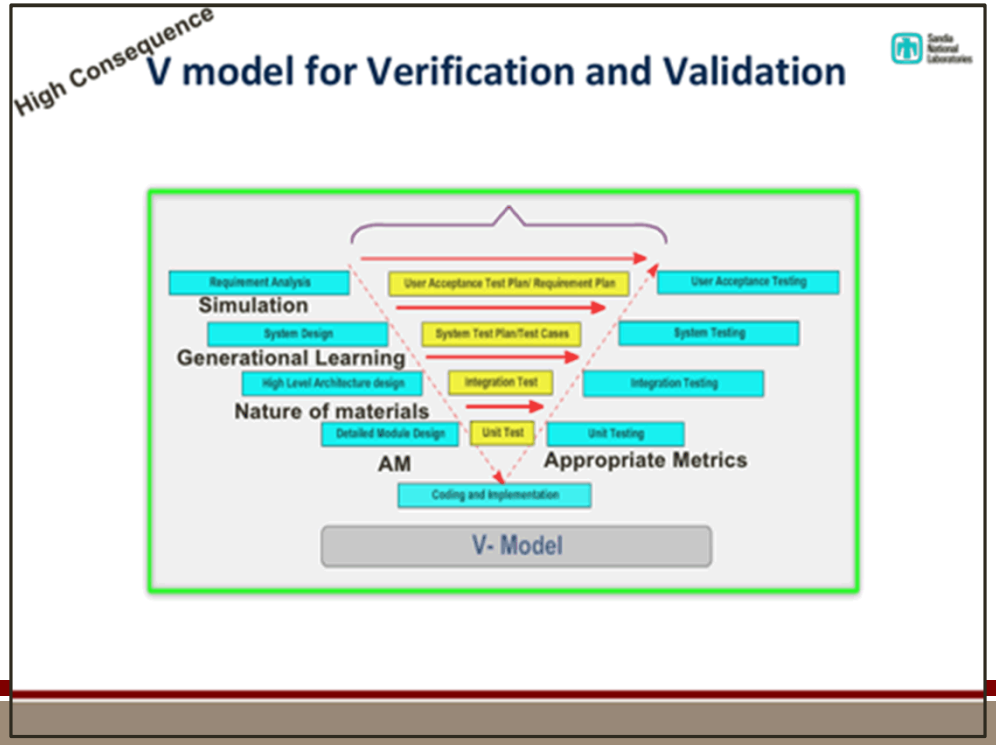
Model Development

- Select 5 Firms to Develop Model
  - Aprecia Pharmaceuticals
  - Karlsruhe Institute of Technology
  - Tide Microfluidics
  - Cagent Vascular
  - Sandia National Labs



Model Development – To Date

- Case studies showed all used Accelerated Cycles of Learning & AM based on Materials Innovation
- Focus can be either on
  - Verification portion of V if focus is product built to specifications
  - Validation portion of V if focus is user requirements
- Acceleration in time to market fastest in aircraft sector, then biological devices, pharmaceuticals, and energy-related
- Entrepreneurial firms utilized techniques faster than larger organizations



More work needed…

Many collaborators to team

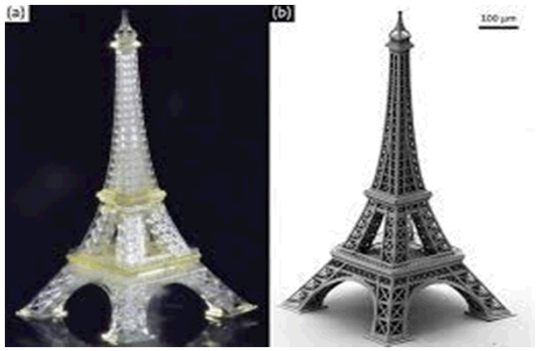
Backups

Sandia National Laboratories

ApreciA Pharmaceuticals Spiritam

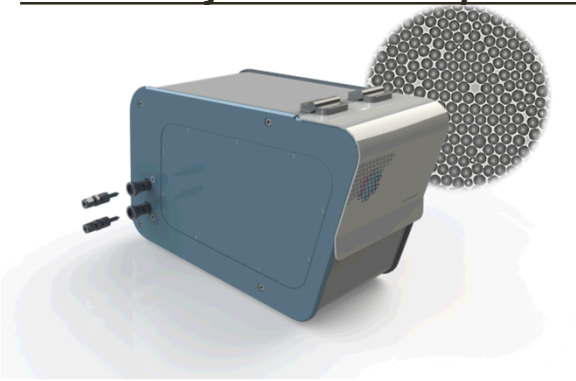
Using AM as a tool to meet US FDA CGMP and moving both down the Verification curve and up the validation curve for a high consequence industry products

KIT - NanoScribe



KIT is using Nanoscribe's AM as a tool to move quickly through the TRL cycle of product qualification in both the verification and validation portions of V curve

Tide Microfluidics Microsphere Creator



Tide Microfluidics is using the consortia model to expedite their high consequence medical carrier potential

Clear flight solutions Robird in flight

- Clearflight solutions is using AM and rapid cycles of learning, as well as regulatory body embrace to accelerate time to market by rapidly moving through the validation phase of the V curve. They are focused on the FAA compliance and its European counterpart.