Additive Manufacturing Challenges for the Gas Turbine Industry

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Take-Aways

• **AM Can Impact Product Development without Being Used for Production**
  - Impact on Prototyping and Simulation

• **Full Mastery of AM Part Production Requires Broad Expertise**
  - Five (at least) Design Spaces to Navigate!
  - Process Design is Moving Quickly
AM Prototyping Impact on Product Development

- Model from the Last 25 Years

- Lots of simulation, then prototyping (expensive, minimized), then production
- Cost barriers to prototyping and production due to tooling

- New Model

- Concurrent simulation and prototyping (first cost barrier gone)
- Shortened product development times

Note: AM for production tooling begins to eliminate the 2nd cost barrier as well
AM Impact on **Product Manufacturing**: Thread of Five AM Design Spaces

- It is not just designing components for AM – at least 5 design spaces
- Each design space category depends on the others

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Unifying: Need to balance *Five Design Space Categories* Using 6) **Cost** 7) **Time to Market** and 8) **Performance Enhancement** as Objectives

- **All are supported (or will be) by simulation**
Process Design for Microstructure

- Average Expected Grain Size in Bulk Region = 109 µm
- Average Expected Grain Size at Stress Concentrators = 212 µm
Porosity in Processing Space
(Internal rasters, Ti64, EOS)

Increasing in beam power

Increasing beam travel speed

Keyhole Boundary

Lack of Fusion Boundary

Research by:
Jack Beuth
Tony Rollett
Chris Pistorius
Students

#1 Nominal+2 Other Hatch Spacings

#5 Hatch adjusted to give some overlap

#6 No Overlap at all!
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Industry Steps in Adopting Metals AM
(with Insights from Kirk Rogers, GE)

1) Preliminary evaluation through information gathering and planning

2) Identification of potential components for transitioning to AM

3) Component fabrication by service providers

4) Acquisition of a metals machine

5) AM Machine use for in-house prototyping and tooling fabrication

6) First AM-manufactured parts

7) First AM-manufactured part assemblies

8) First subsystems by AM

AM for Component Production

AM not Used for Production
Looking Ahead 5-10 Years (or sooner!)

- **AM processing will change significantly.** Within 5 years AM Machine Users Will be Able to
  - Design the process as they design a part (integrate with cost models and part design)
  - Exploit sophisticated process monitoring and controls
  - Vary microstructure and properties within parts
  - Choose from a wide variety of powders
  - Eliminate porosity
  - Exploit merging of computer science with additive
  - Use new alloys for AM

- **The CMU NextManufacturing Center is performing research enabling each of these advances**
AM Production Impact on Product Manufacturing

• New Model

- Cost barrier to component production goes away
- Door is open to small production lots and components intensely designed for AM

Note: 2nd cost barrier (tooling) is now gone