Current Westinghouse Efforts

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Meeting at NRC, November 28 & 29, 2017

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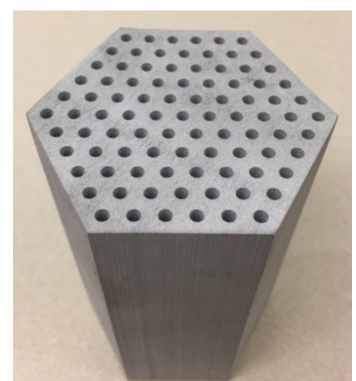
Key Areas of Additive Manufacturing Interest

- **Global Technology Development Efforts**
- **Tooling and Replacement Parts**
- **Nuclear Fuel Components Efforts**
- **Thimble Plugging Device (TPD) Project**



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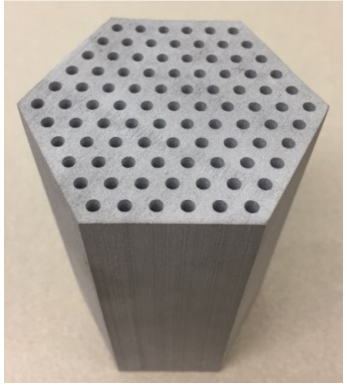
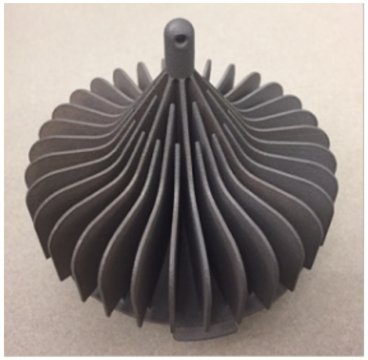
Global Technology Efforts

Global Technology Development Efforts (R&D)



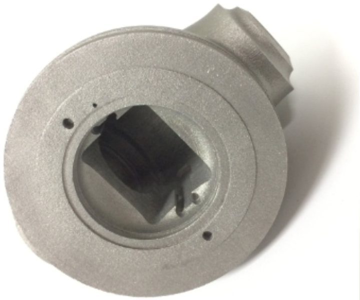
OVERVIEW

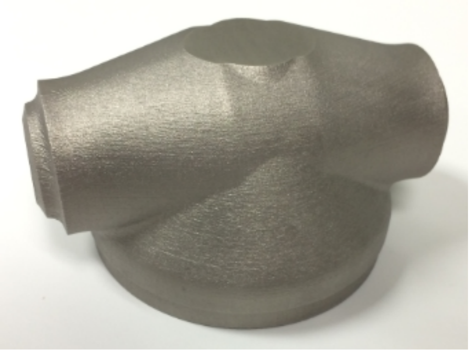
- Prototype components for SMR, advanced reactors and AM manufacturing / design demonstration
- Material development for next generation applications
- Support the development of codes and standards (ASTM & ASME)



BENEFITS

- Design freedom: complex geometries, internal passageways, etc.
- Reduced design time: fast prototyping & mold production
  - Little to no tooling required
  - Design complexity at minimal cost
- Near net shape: reduced material, machining & welding
- Reduced lead-time / reduced supply chain





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Tooling and Replacement Parts

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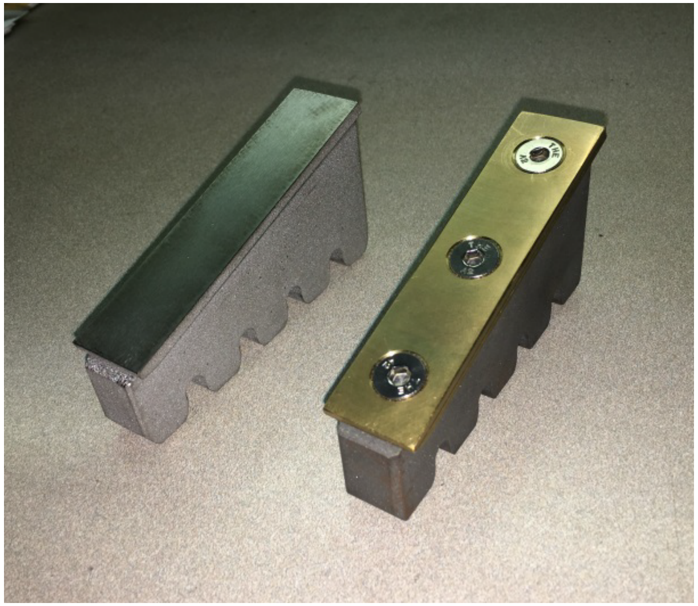
Blairsville Site Tooling Application

- **Original was five piece design with brass wear plate - heat treated to 36-44 Rc**
- **AM part printed in one build using tool steel – heat treated to 42 Rc**
- **Reduced need for replacement as the tool steel work hardens increasing useful life**



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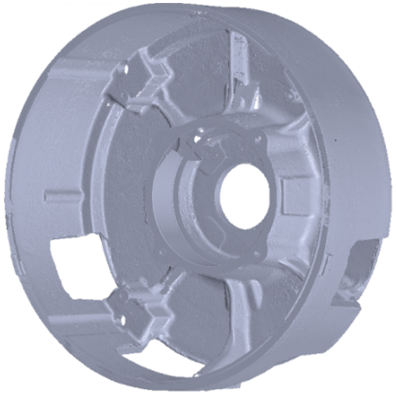
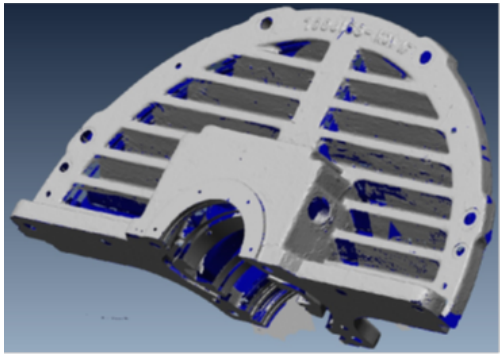
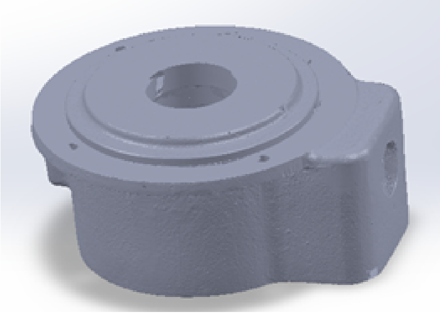
Replacement Parts Development Efforts



- **OVERVIEW**
  - **Demonstrating Reverse Engineering Process:**
    - 3D laser scanning → CAD Models → AM sand molds → traditional casting
  - **Multiple replacement castings have been identified**
    - Difficult to procure replacement castings



- **BENEFITS**
  - **AM complexity with traditional sand casting**
  - **Significantly reduced cost and lead-time**
  - **Conversion to modern, digital design information and manufacturing**



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Replacement Parts Development Efforts

- **Worn out shaft repaired using plasma spray coating**
- **Nickel and molybdenum deposited onto the worn surfaces and part ground back into engineering specifications**
- **Able to return the part to service for about a third of the price of a replacement**

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Nuclear Fuel Efforts

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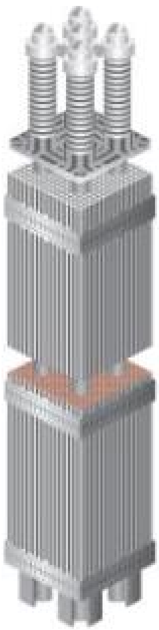
Westinghouse Fuel Manufactured Products

Pressurized Water Reactors (PWRs)

W-PWR

14x14
15x15
16x16
17x17

CE-PWR

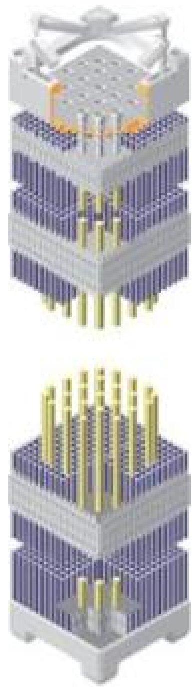


14x14
16x16

KWU/Siemens PWR

14x14
16x16
18x18

NFI PWR



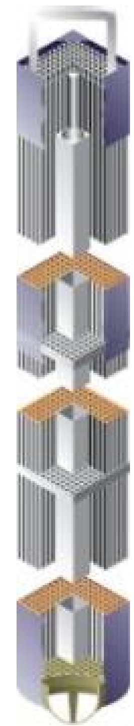
14x14
15x15
17x17
MOX

Boiling Water Reactors (BWRs)

W-BWR

Optima2
Optima3

NFI BWR



9x9
MOX

VVER (PWR)

VVER-1000
VVER-440

Advanced Gas Reactors (AGRs)

AGR Fuel

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Potential Benefits to Nuclear Fuel

- **Lower fuel assembly pressure drop**
- **Better flow mixing and greater heat transfer ability**
- **Less potential for leakers**
- **Greater accident tolerance**
- **Better fuel margins**
- **Extended fuel cycles**
- **Customizable fuel assemblies**
- **Less supply chain dependence**
- **Fewer overall suppliers**
- **Reduced time from concept to market**
- **Flexibility**

Shatter Paradigms for Fuel Design Constraints Based on Traditional Materials and Manufacturing Limitations

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Additive Manufacturing and Nuclear Fuel

WEC Nuclear Fuel is pursuing the use of Additive Manufacturing (AM) in a variety of manners:

- Design of Advanced Debris Filtering Bottom Nozzle
- Advanced spacer grids optimized utilizing design freedom
- Evaluating available AM metal powders for use in fuel components
- Radiation exposure testing of 316L, A718, and Zr products

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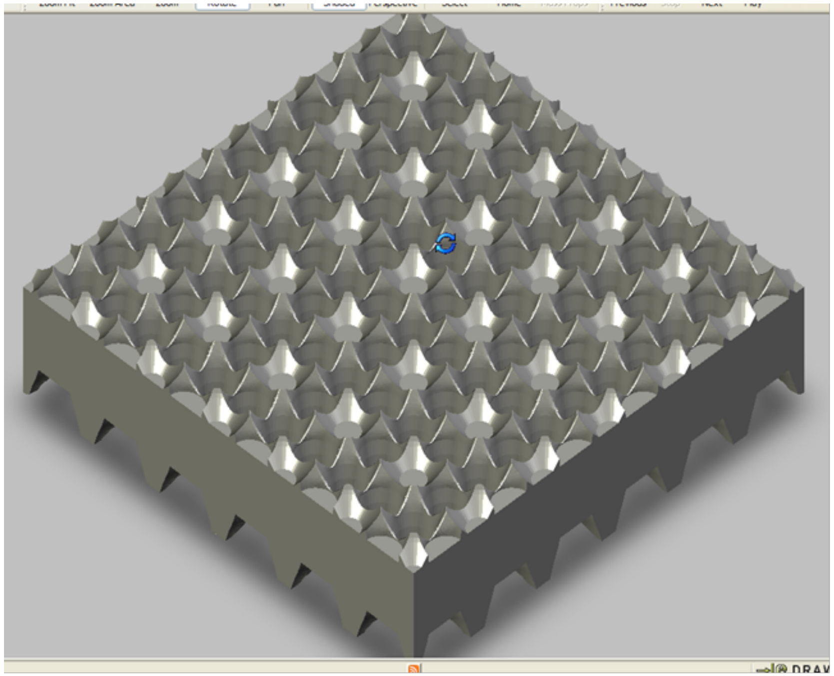
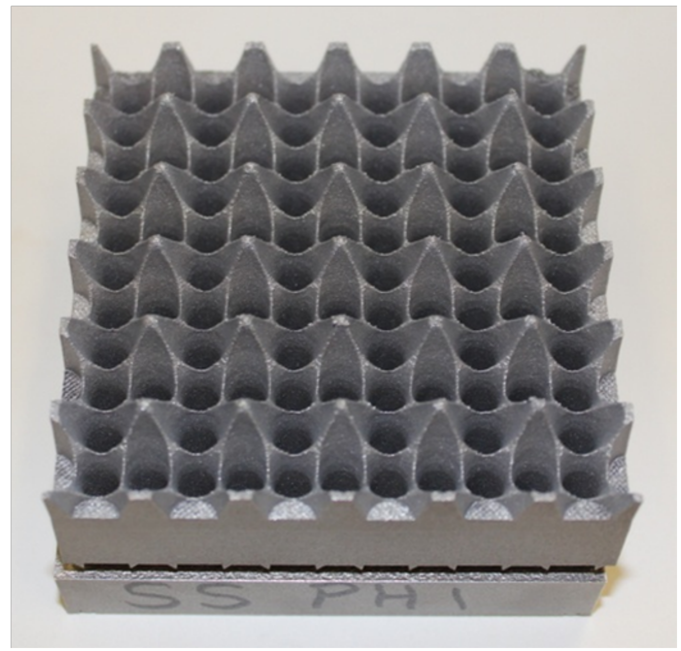
Preliminary efforts to develop AM designs and alloys

Advanced Debris Filtering Bottom Nozzle



Additively manufactured and achieved a substantial pressure drop reduction.



This effort resulted in 24 unique plastic designs each tested in the “Vista” loop for hydraulic performance

Used to quickly “optimize” designs for improved hydraulic performance

Prototyping to evaluate and optimize performance of concepts

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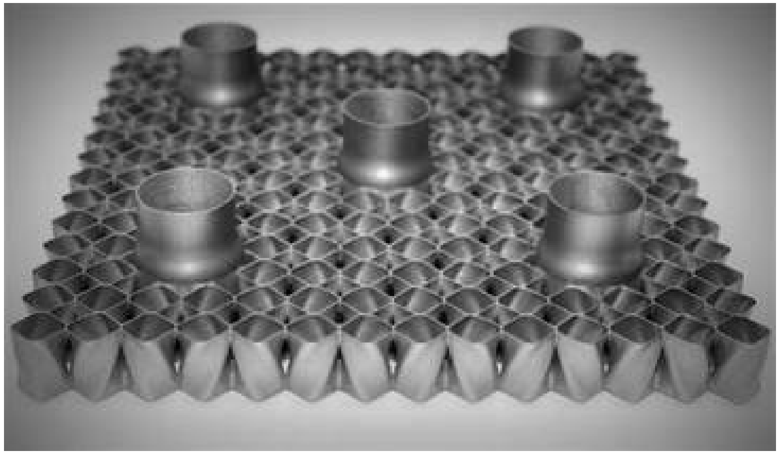
Advanced Spacer Grids

Prototype grid printed using AM

- Grid (not printed) did not perform as expected in DNB testing
- Potential "fixes" could be realized using AM
- Possible opportunity to expand testing capabilities to enable prototype screening greatly reducing costs and improving development cycle times



Prototyping to improve results and shorten development cycle time

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Thimble Plugging Device

Thimble Plugging Device (TPD) Project

- Why the Thimble Plugging Device
  - **Low risk component for which consequences of failure minimal**
  - Fairly complex design promoting enhanced understanding of the AM design and building process
  - Constructed of material that has been previously tested in MIT reactor
  - Located in reactor region with fluence rate comparable to region of ADFBN placement in the core.
- The AM TPD is intended to be produced for technology development and will not be produced in typical production QTYs. AM TPD has not been redesigned to utilize AM benefits.

Improve our understanding of AM materials in radiation environment

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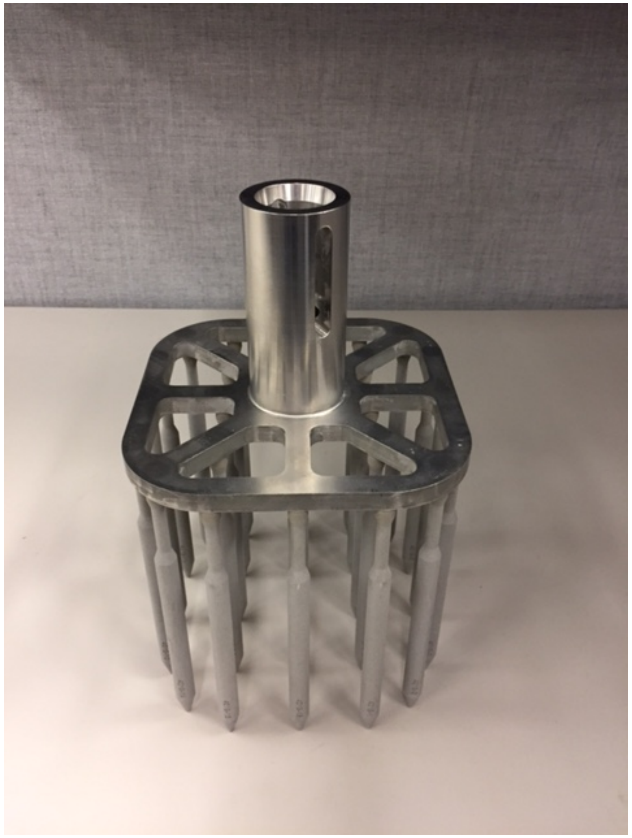
TPD Project

- Current Status:
  - Prototype builds have been completed and proof of concept demonstrated
  - Concepts and Issues meeting completed
  - Design and Manufacturability meeting held
    - Qualification Plans, CDI's, PO's in place for qualification pieces
    - Four qualification pieces have been built
    - Testing of qualification pieces complete



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Summary of Vision

- We see immediate benefit of AM for tooling and replacement parts
- Radiation exposure and mechanical testing of 316L, A718, and Zr products look promising
- Plan to insert first AM part in reactor in 2018 to gain experience
- Next want to focus on building AM parts to obtain benefits in performance, economics and manufacturing relative to current methods