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# WESTINGHOUSE ADVANCED MANUFACTURING DEVELOPMENT AND IMPLEMENTATION EFFORTS

## U.S. NRC Workshop on Advanced Manufacturing Technologies for Nuclear Applications

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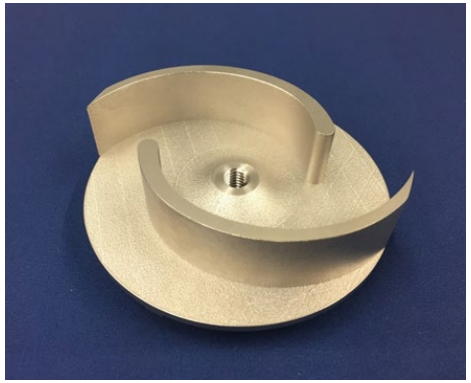
# Westinghouse Advanced Manufacturing Program Objectives

## Improve industry competitiveness, through the development and implementation of advanced manufacturing technologies

- Drive cost reductions in component manufacturing
- Enable new products and services that provide innovative customer solutions
- Leverage collaborative development and external funding sources



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# ADDITIVE MANUFACTURING DEVELOPMENT EFFORTS

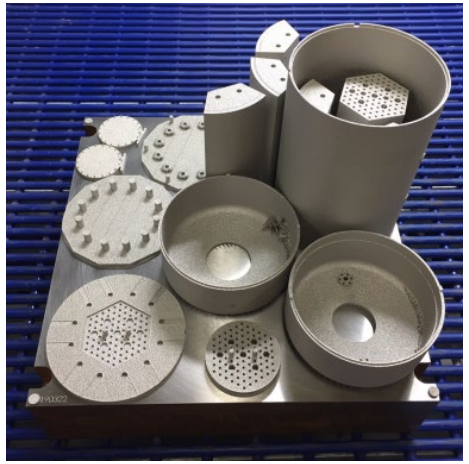
# Additive Manufacturing (AM) Objectives

## Exploiting the Benefits of Additive Manufacturing Technologies

- Producing components with: Powder Bed Fusion (PBF), Binder Jetting (BJ), and Directed Energy Deposition (DED) AM technologies
- Complex components required for performance gains
- Advanced reactor components – eVinci, LFR
- Obsolete and high value / lead-time components
- Tooling / jigs / fixture, prototypes, mockups

## Enabling AM for Nuclear Component Construction

- Leading material development & testing for in reactor use, including irradiation and PIE of 316L, 718 and Zirc-2
- Parameter development and material testing for 304L, 17-4 PH, Haynes 230 & 282, MS1, AFA and FeCrAl ODS alloys
- Supporting the development of ASTM and ASME codes and standards



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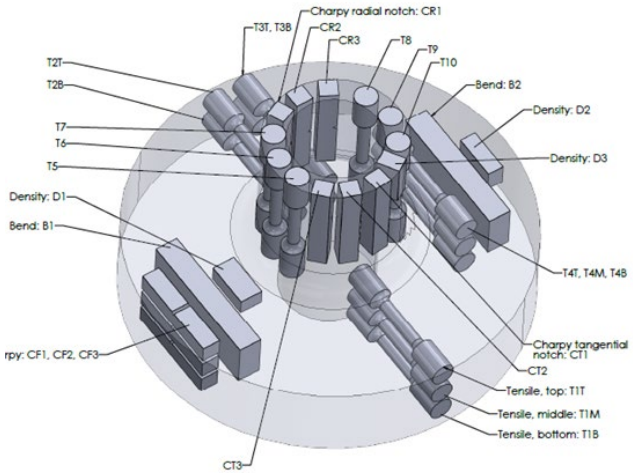
# ASME Engagement – L-PBF AM 316L Code Case

## FIRST ASME CODE CASE SUBMITTAL FOR ADDITIVE MANUFACTURING

### Laser-PBF AM 316L Code Case

- Submitted the Section III Code Case for L-PBF AM in August
  - ASME Record 20-254
  - Requesting implementation ASTM F3184-16 with addition requirements, for Section III, Division 1, Subsection NB/NC/ND, Class 1, 2 and 3 components construction
  - Presented Code Case and Data Package at the Section III MF&E Sub-Committee and AM Special Committee
- EPRI consolidated the 316L AM Data Package to support the AM Code Case
  - AM test components were supplied by Westinghouse, Rolls-Royce, ORNL, Auburn University and Oerlikon
  - EPRI coordinated material testing and analysis
  - Funded under DOE NEET-1 AMM Program (DE-NE0008521)



# Reactor Ready Component Development Efforts

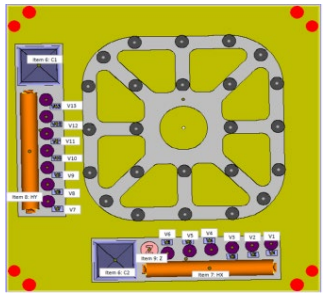
## AM COMPONENT INSTALL IN COMMERCIAL NUCLEAR REACTOR CORE

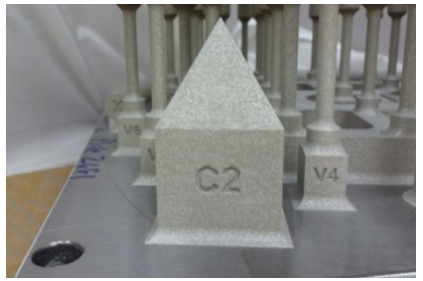
### Advanced Manufacturing Kaizen – Dec. 2014

- Project initiated for development of AM reactor ready component

### Thimble Plugging Device (TPD) selected as first component to test in core

- Low risk component, moderate complexity
- Produced hybrid 304/316L TPD
  - Manufacturing qualification……..2017-2018
  - Production units……2018-2019
  - Delivered Byron 1……..Spring 2020



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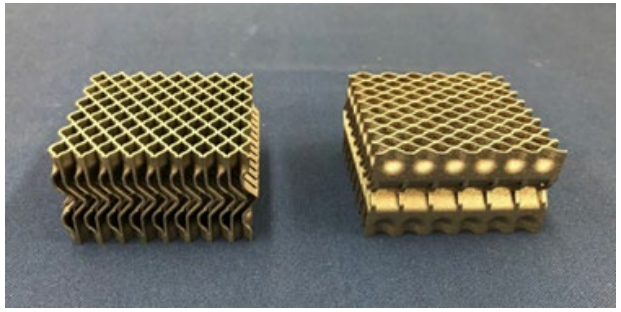
# Fuel Debris Filtering Bottom Nozzle Development

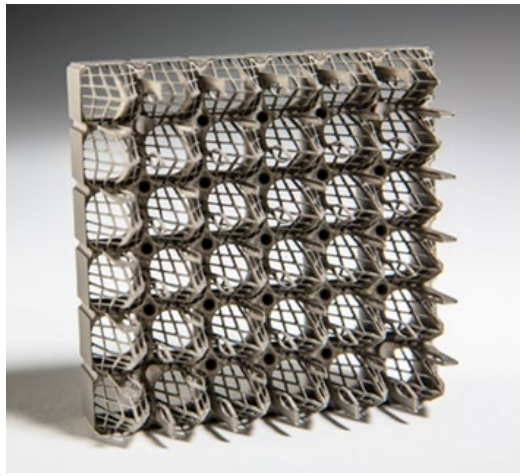
## AM Benefits:

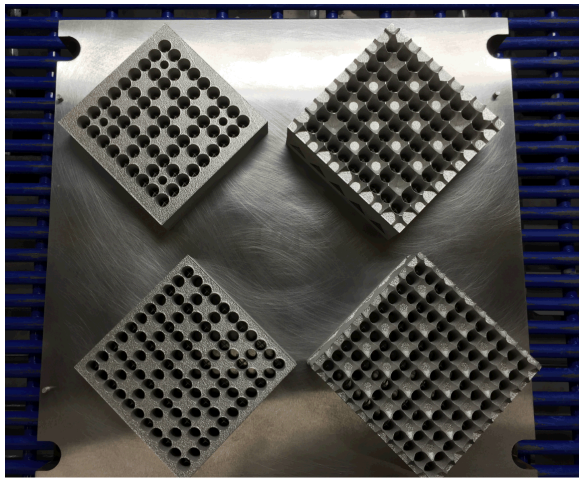
- Improved debris filtration
  - BWR Testing: Up to 100% debris capture in testing
- Reduced pressure drop

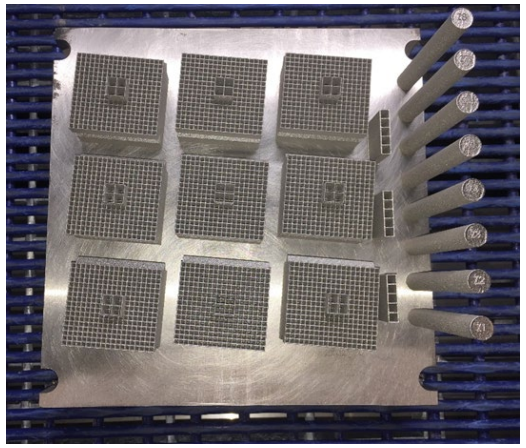
## AM Development:

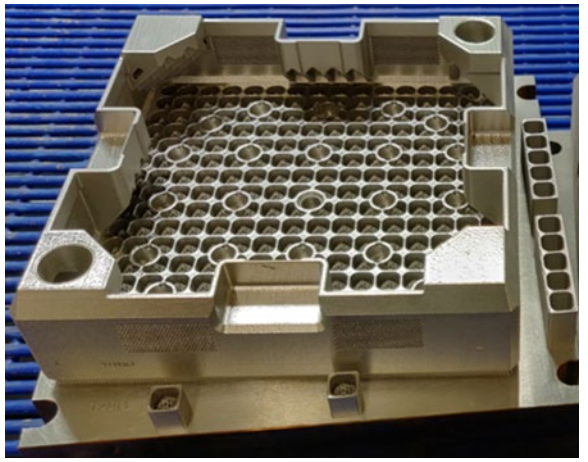
- Multiple complex designs / features enabled by AM
- Significant mechanical and performance testing
- PWR: LUAs in Fall 2021
- BWR: LUAs in Spring 2022











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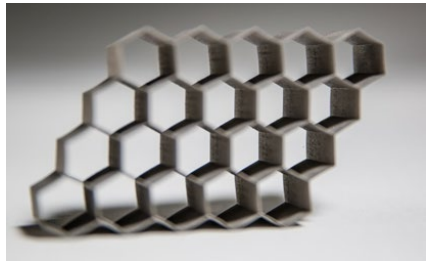
# Fuel Spacer Grid Development Efforts

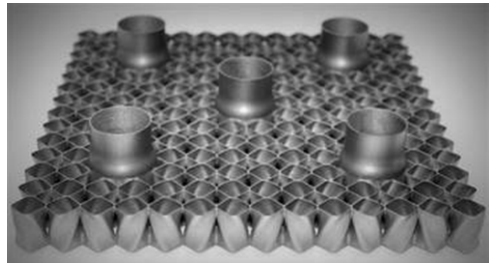
## AM Benefits:

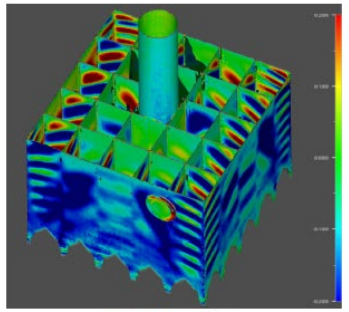
- Stronger support of fuel rods
- Improved mixing characteristics

## Additive Manufacturing of Spacer Grids for Nuclear Reactors

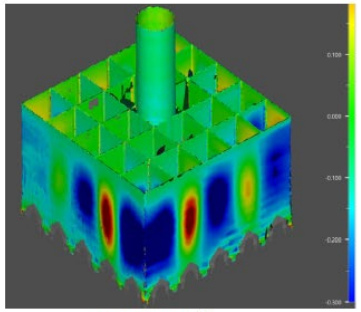
- $1.25M, 3 year, ARPA-E Funded Project
- Collaborative effort with Carnegie Mellon University
- Primary Tasks Include:
  - Establish baseline capability
  - Enable low-cost fabrication
  - Improve the spacer grid quality and performance
  - Improve spacer grid performance
  - Exploring potential opportunities for redesign of spacer grid geometries



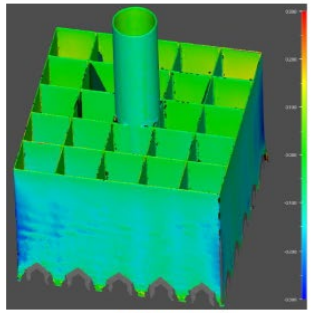




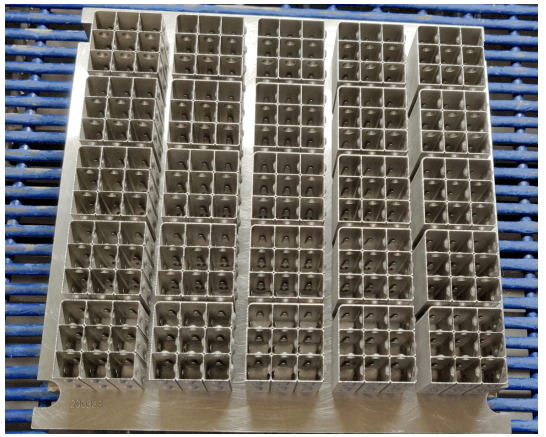
200 $\mu m$ wall



300 $\mu m$ wall



500 $\mu m$ wall



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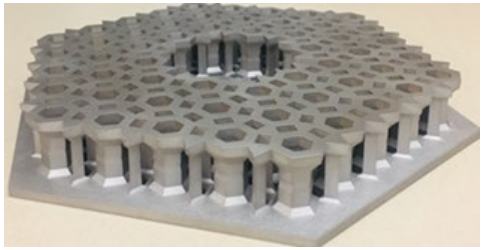
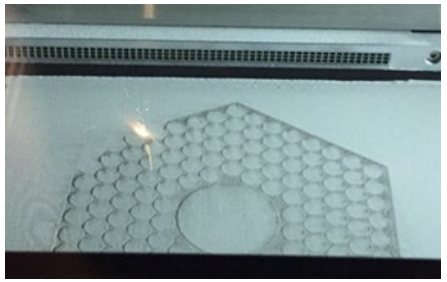
# Innovation Projects

## eVinci™ Microreactor

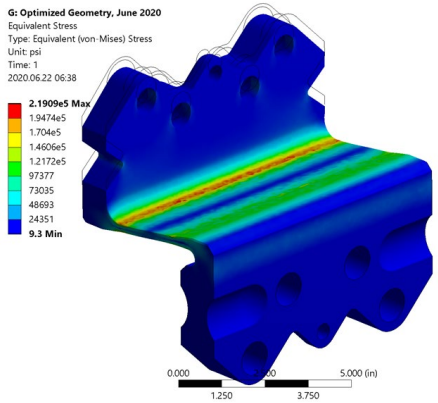
- Utilizing of Design for Manufacturability approach and developing Adv Mfg technologies, where appropriate
- Primary Heat Exchanger (PHX), heat pipe end plugs and fittings, and small parts and structural components are the leading candidates





## Salem Thermal Shield Flexure

- Completed topology and AM optimization efforts
- Successfully complete fatigue testing of topology optimized AM flexure

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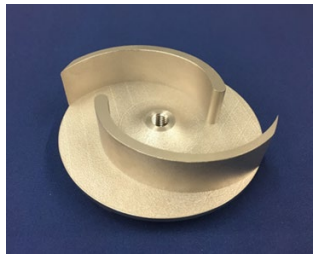
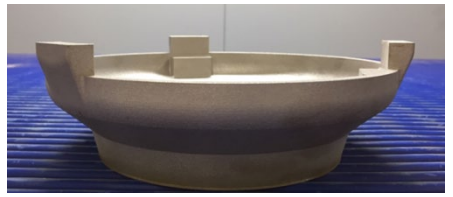
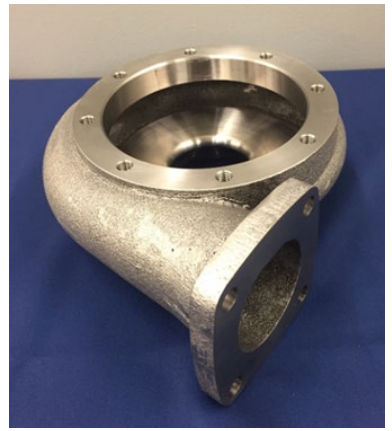
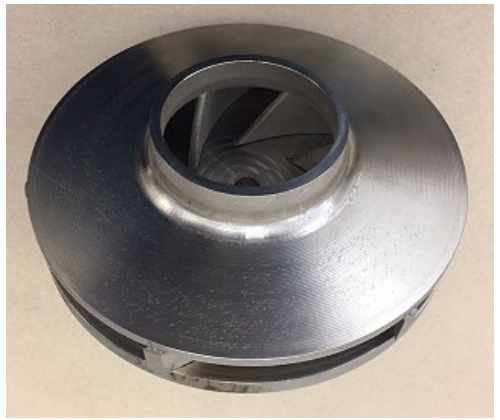
# Replacement Parts

## Replacement Parts Identification Efforts

- Currently working to identify, demonstrate and qualify AM applications
- Data and expert review for application down-selection
- Development of detailed estimates / business cases for top candidates
- Utilizing laser scanning and reverse engineering software to develop editable 3D models for obsolete parts



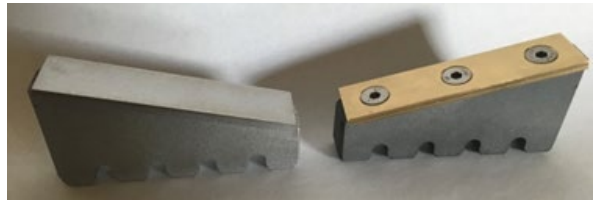

# Tooling

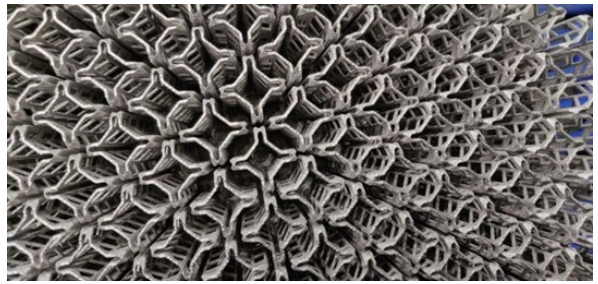
## Immediate benefit from tooling applications

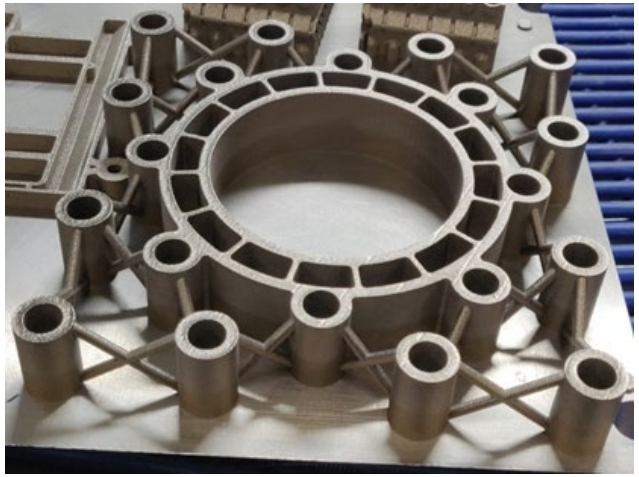
- Lower the costs and improve performance

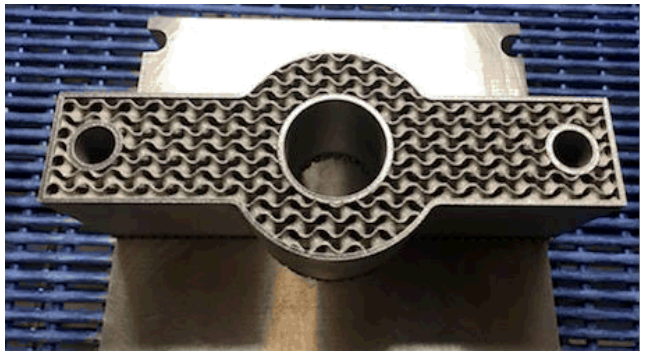
## Improved safety for operators

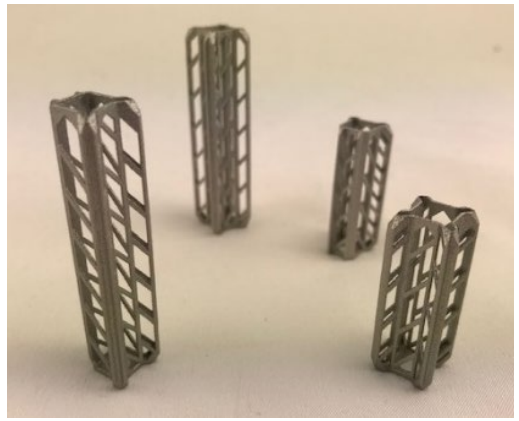
- Reduction of leak points
- Two hands touch control
- Ergonomic designs resulting in less fatigue injuries

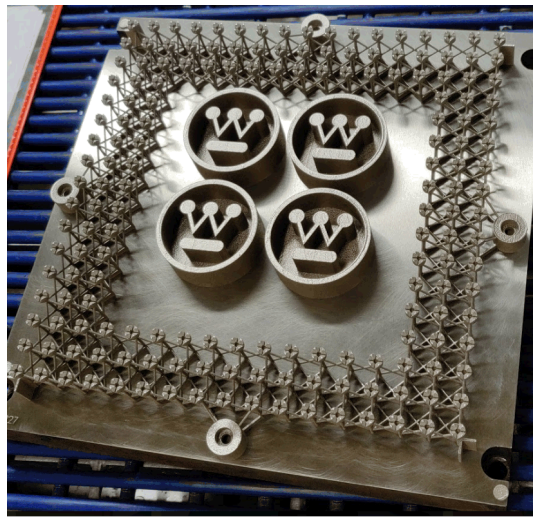












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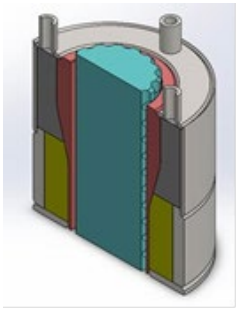
# HOT ISOSTATIC PRESSING (HIP) DEVELOPMENT EFFORTS

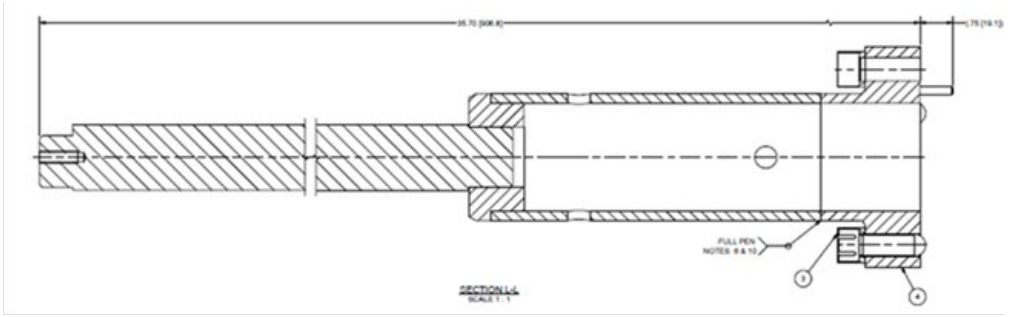
# Hot Isostatic Pressing (HIP) Development Efforts

## NEER Project (Innovate UK-funded): Completed in May 2018

- Focused on reusable tooling, HIP development and demonstration of nuclear components, and UK supply based development
- Produced demonstration components
  - Reactor Vessel Internals (RVIs): Quickloc Upper Support Assembly
  - Control Rod Drive Mechanisms (CRDMs): Guide Funnel Extension
  - Valves: 4” Motor Operated Gate Valve Body



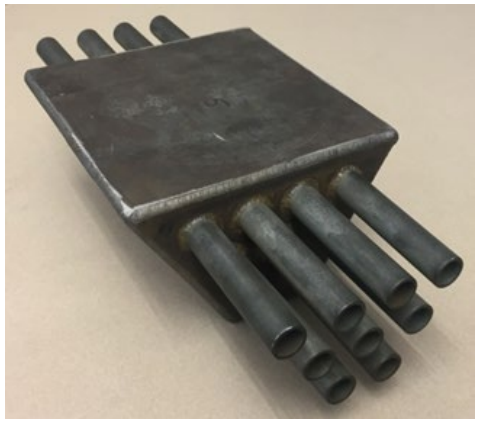
## Producing Prototypes / Mockups for Next Generation Plants



## Completing Cost-Benefit Analysis for Reactor Coolant Loop Components

## Collaborating on Auburn led DOE AMM funded project

- 3 year, $1M effort focused on HIP of dissimilar metal joints, materials, and modeling



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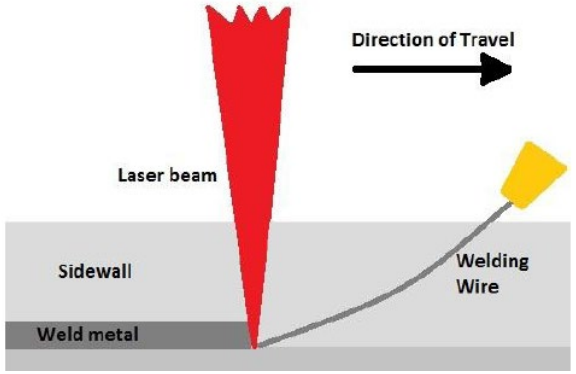
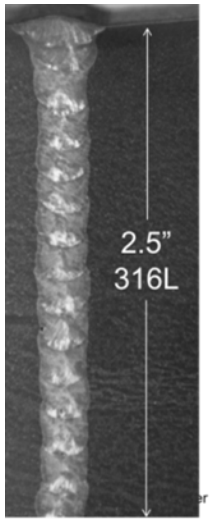
# ADVANCED WELDING AND COATING DEVELOPMENT EFFORTS

# Advanced Welding and Coating Development Efforts

## Collaborating on welding development efforts

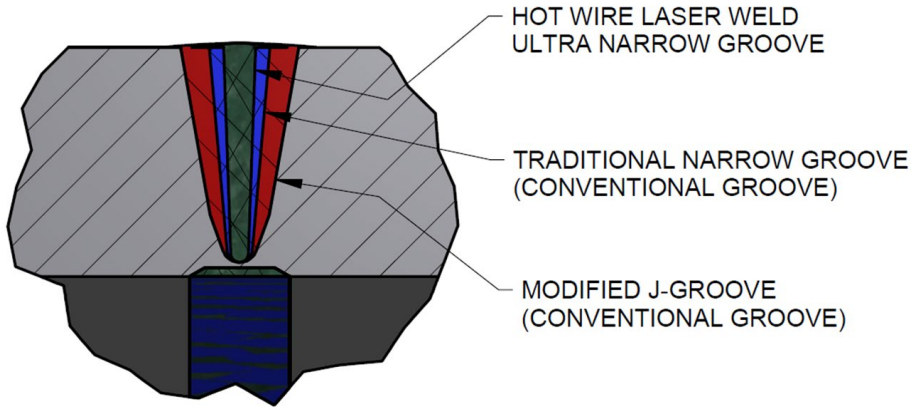
- Hot wire laser welding (HWLW)
- Hybrid laser GMAW
- Laser welding of irradiated materials
- Laser metal deposition for component repair
- Cold Spray & Plasma Arc Spray




## Using emergent technologies to solve fabrication and repair challenges and reduce manufacturing costs

- RCP, RVI and CRDM cost reduction opportunities
- Module fabrication
- Weld distortion reduction and modeling
- In-field component repair

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