Opportunities in additive manufacturing for advanced nuclear energy systems

AMM Technical Review Meeting

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December 3, 2020

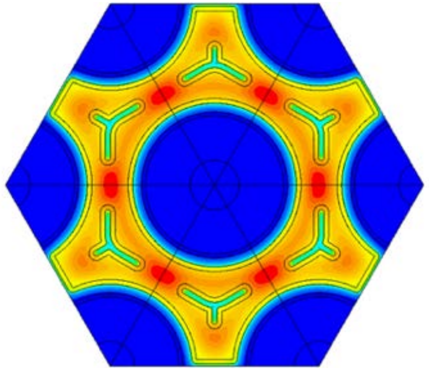
TCR is bringing to bear additive manufacturing (AM) and artificial intelligence (AI) to deliver a new approach

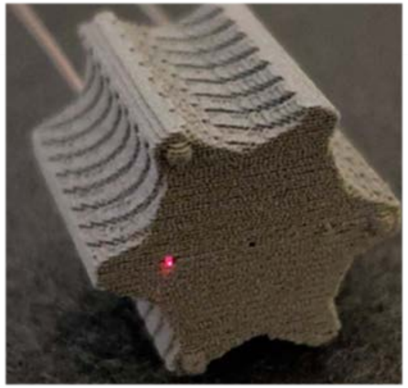
Using AI to navigate an unconstrained design space and realize superior performance

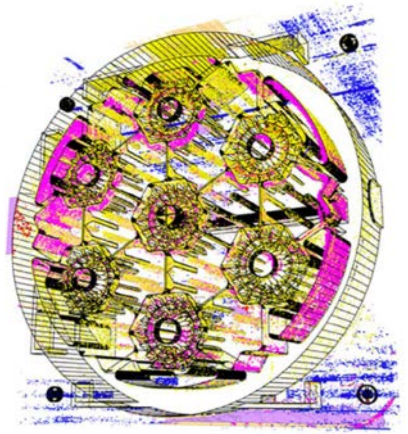
Leveraging AM to arrive at high-performance materials in complex geometries

Exploiting AM to incorporate integrated and distributed sensing in critical locations

Using AI to assess critical component quality using in situ manufacturing signatures







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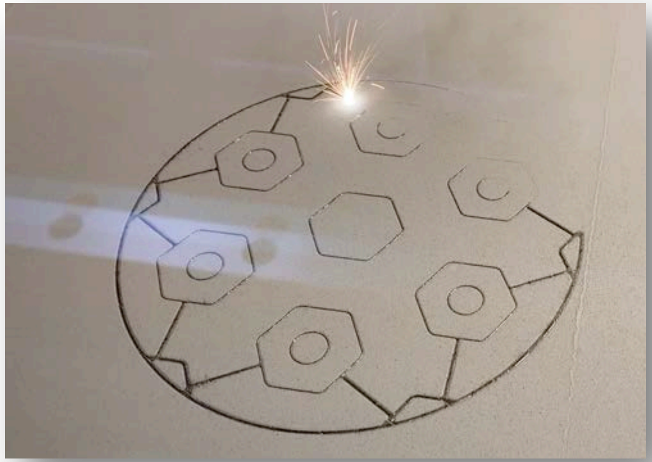
Myriad additive manufacturing methods span a vast dimensional scale across a range of material systems

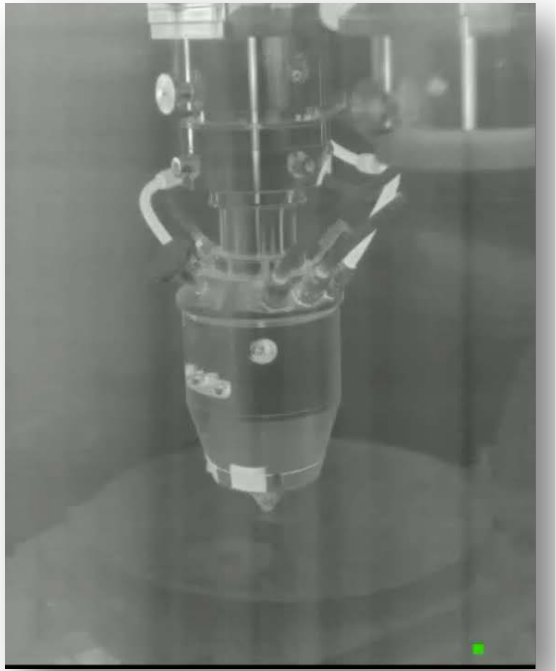
Powder bed techniques

- Metal or ceramic powder or slurry sequentially spread and fused in 2D layers
- Fusion achieved via melting (e.g. laser or e-beam source) or binding (via binder jet or lithography)
- Ability to accommodate most complex geometry with best spatial resolution
- Limited to a single material system
- Build volumes usually < 0.05 m^3 with some extending up to 0.3 m^3

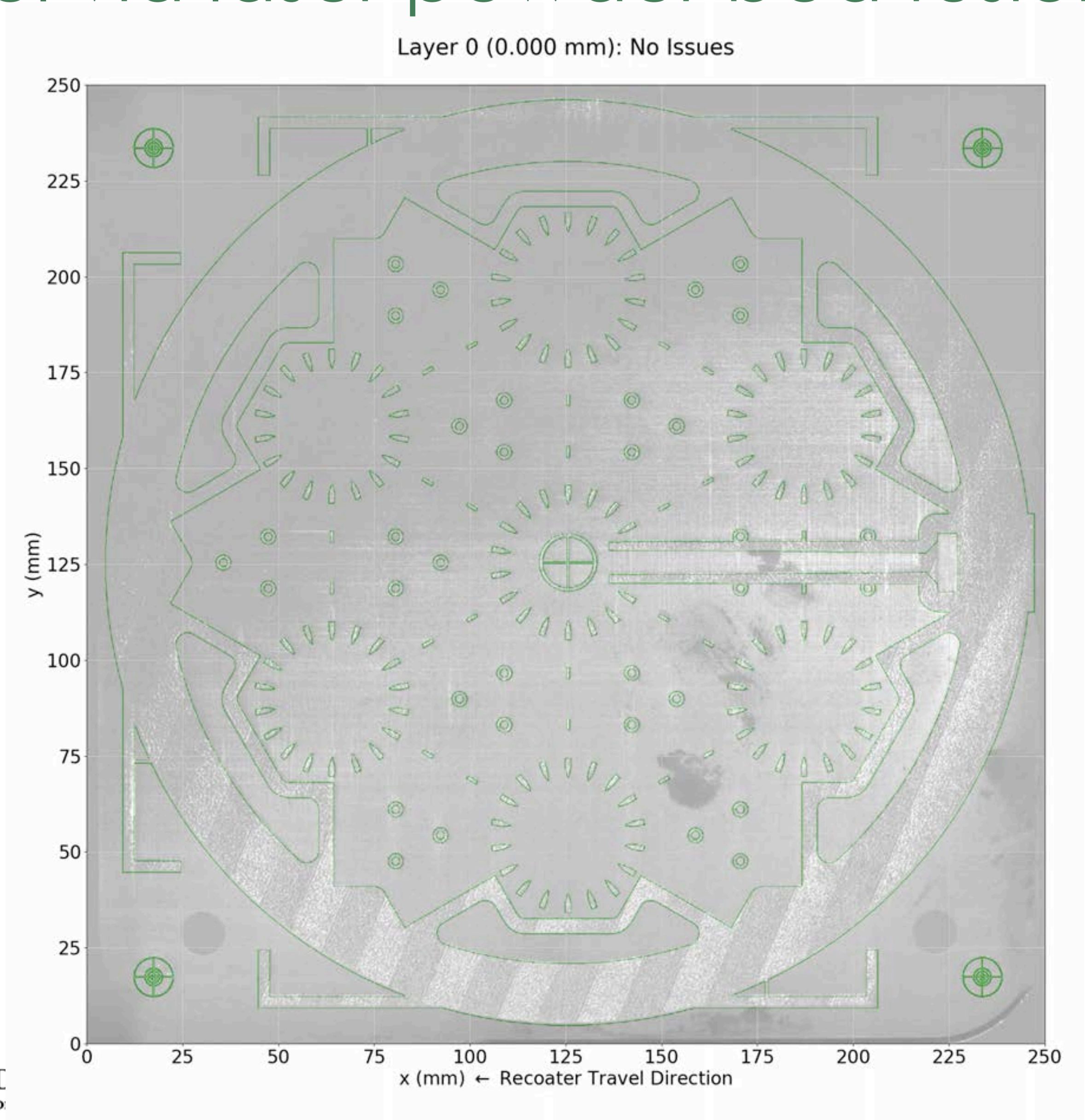


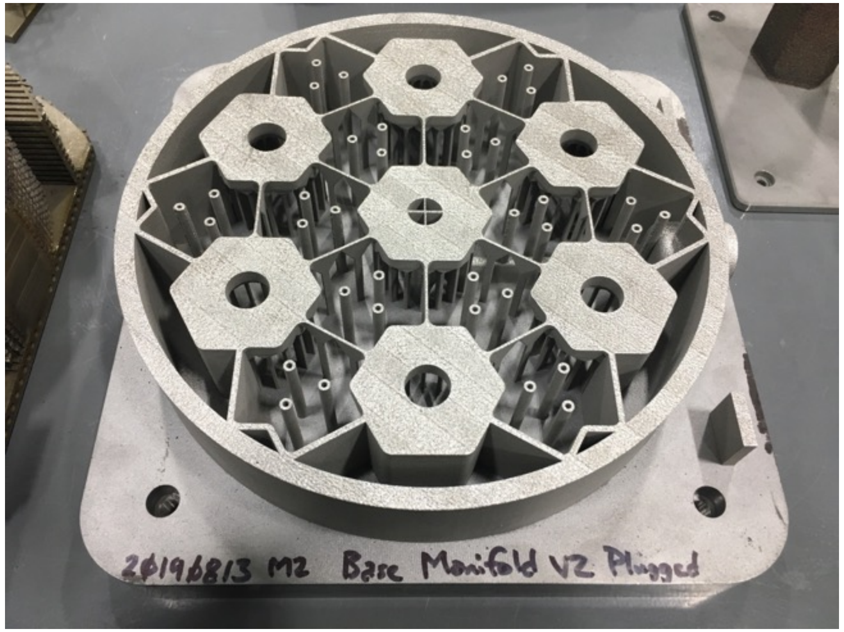
Direct deposition techniques

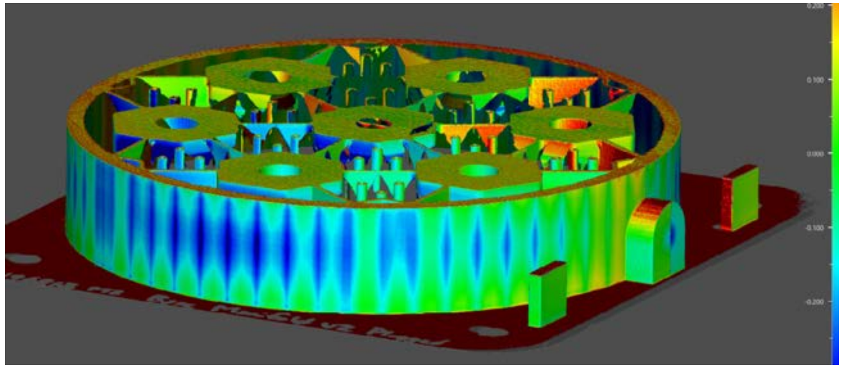
- Metal powder or wire or ceramic slurry directly deposited as continuous point on substrate
- Deposition via melting (e.g. laser or arc welding), drying, or curing
- Complex tool path design is needed, and less geometric complexity is accommodated
- Flexibility to accommodate multiple material systems
- Build volumes usually < 0.5 m^3 with some extending up to 7 m^3



Example of powder bed system: 3D printing of stainless steel via laser powder bed fusion technique

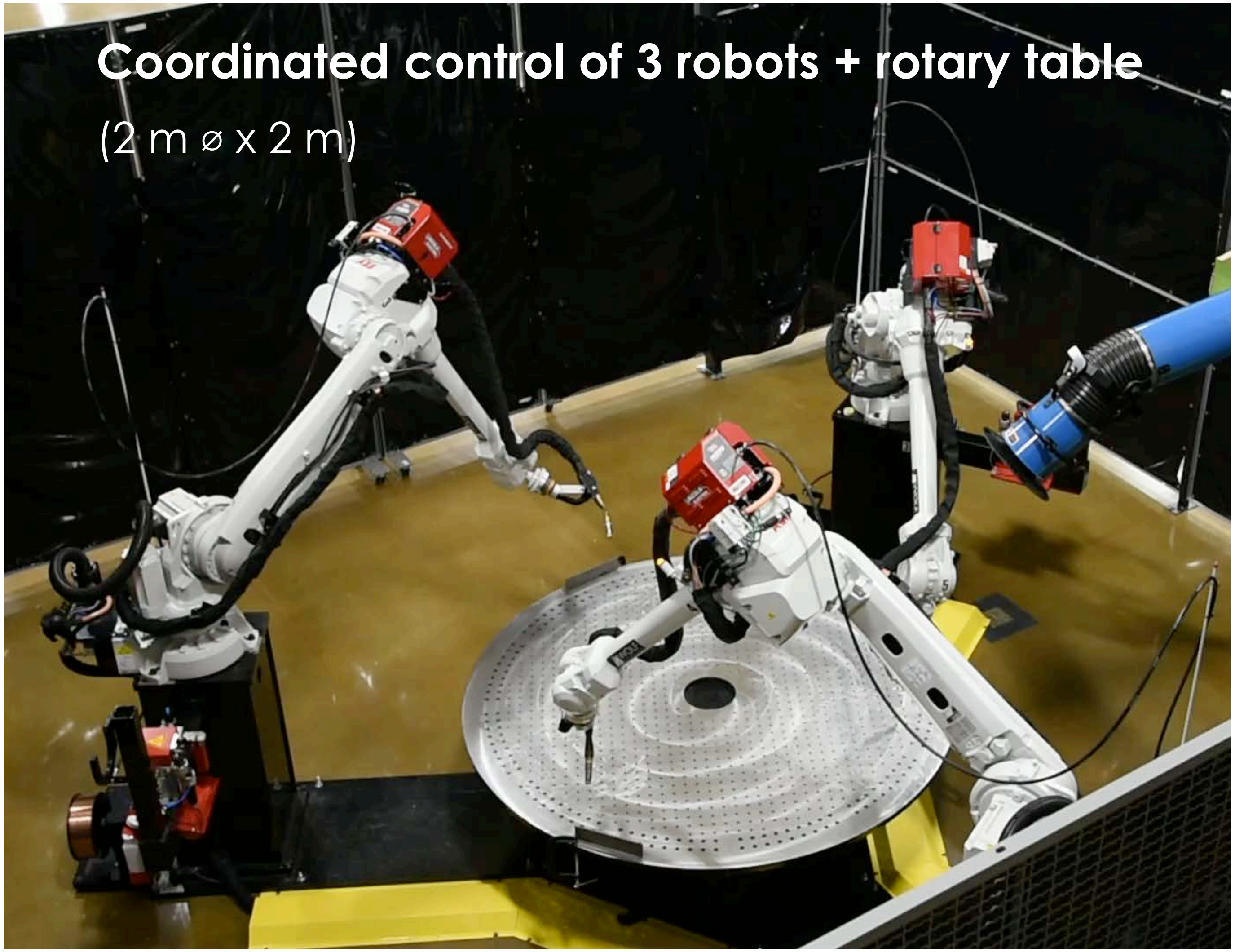


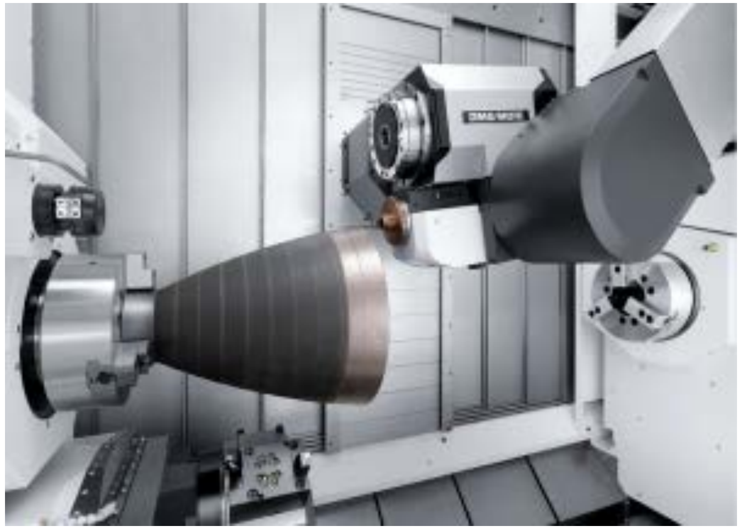


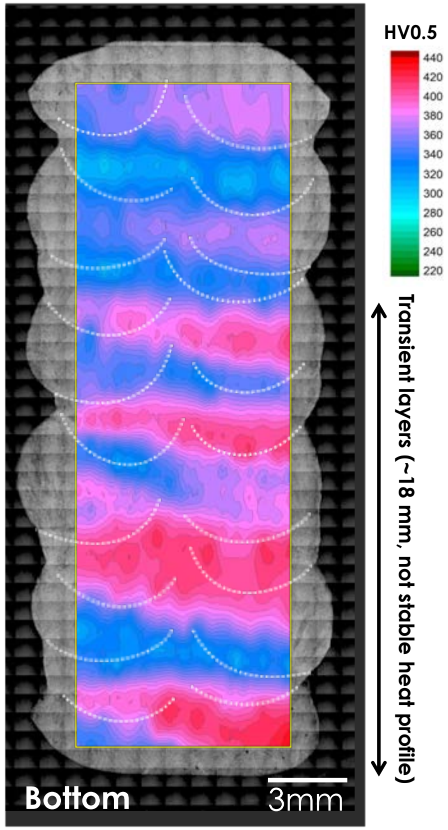


L. Scime, V. Paquit (ORNL)

Example of large direct deposition system: Medusa wire arc additive



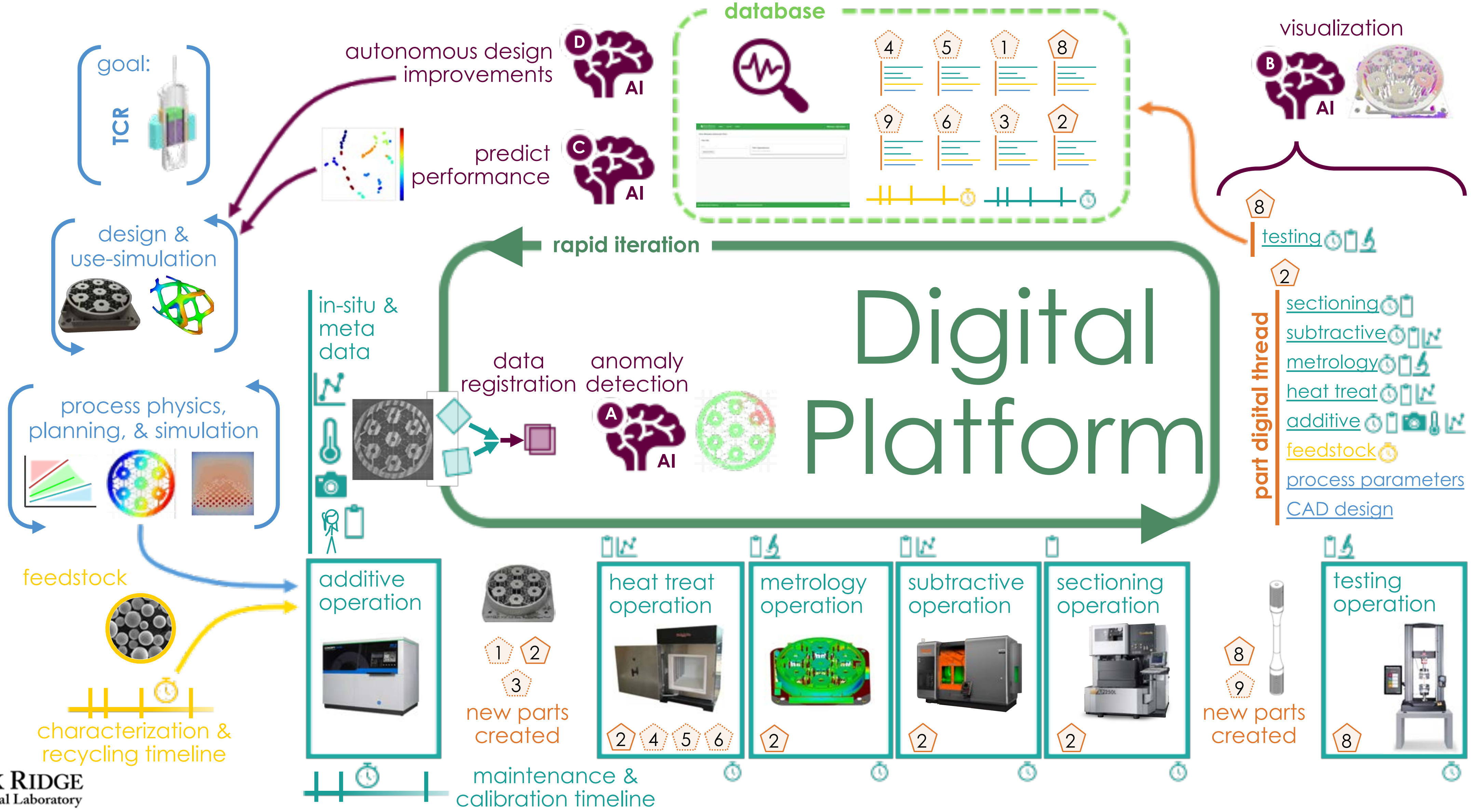




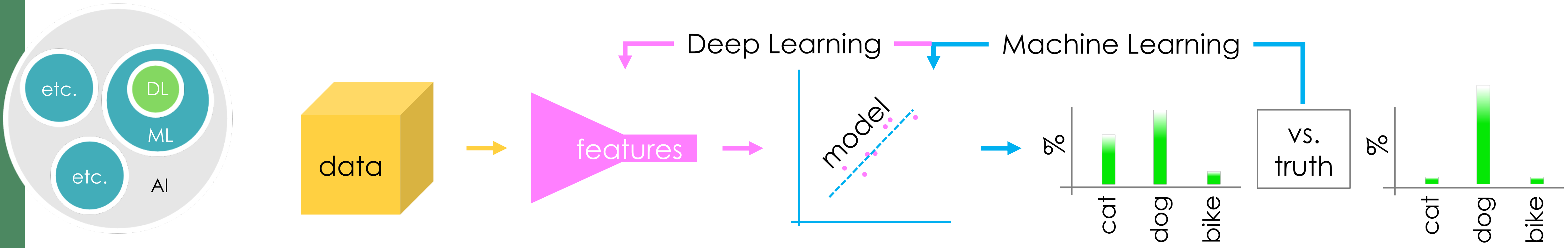
OAK RIDGE National Laboratory

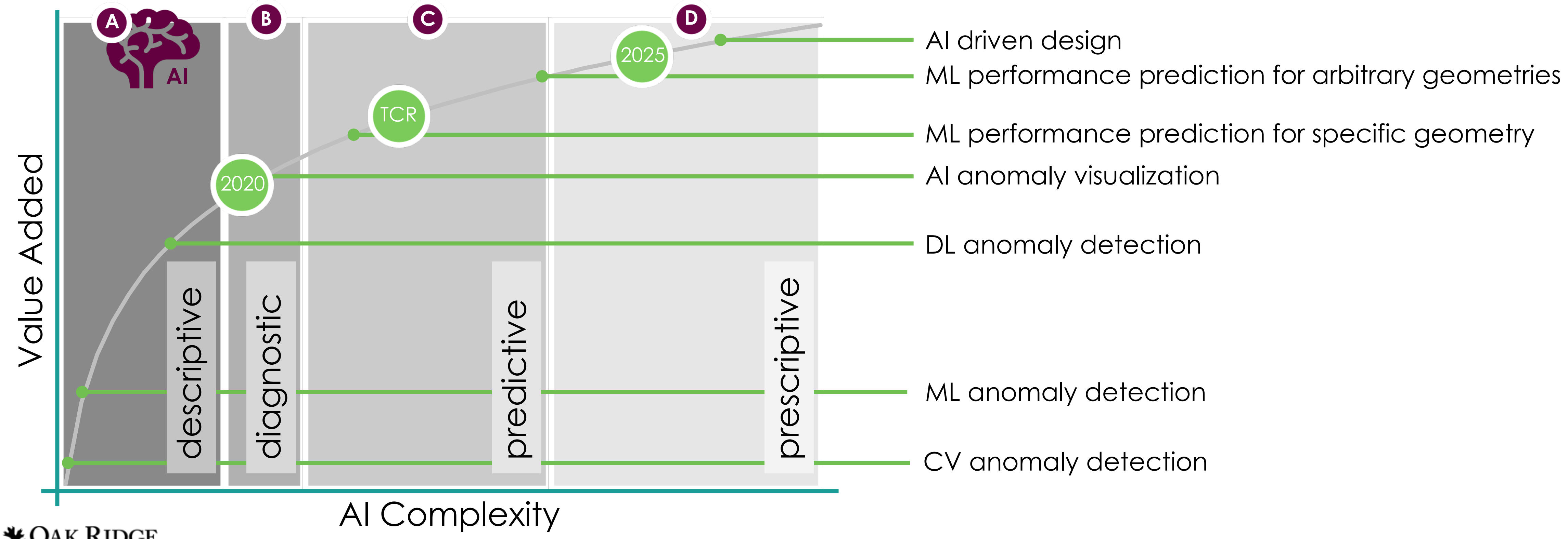
L. Love, M. Noaks, Y. Yamamoto, A. Nycz (ORNL)

Using AI to assess critical component quality using in situ manufacturing signatures: Digital Platform for quality assurance



Augmented Intelligence for Advanced Manufacturing

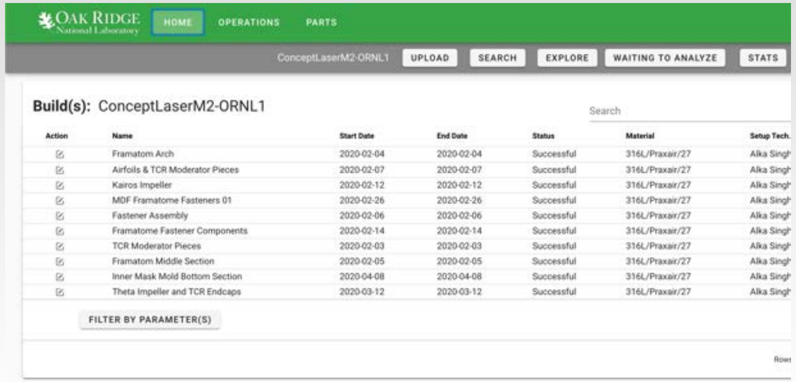




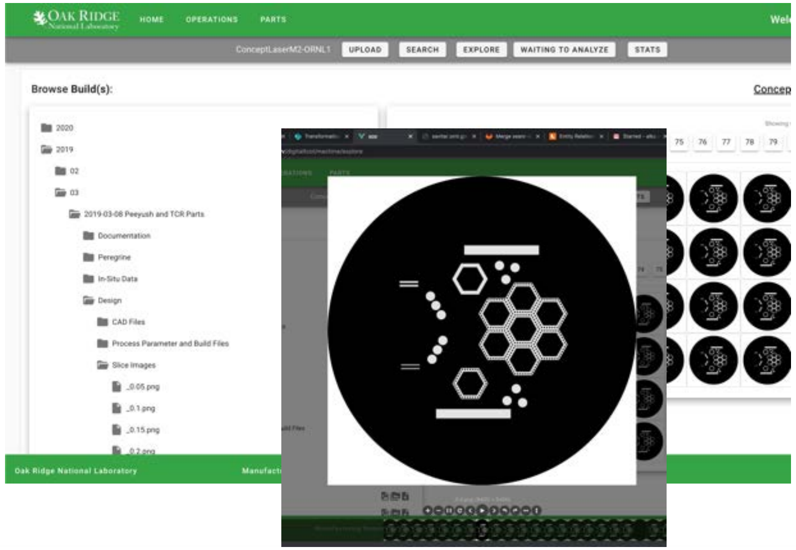
Research Activities

Data management

Metadata search



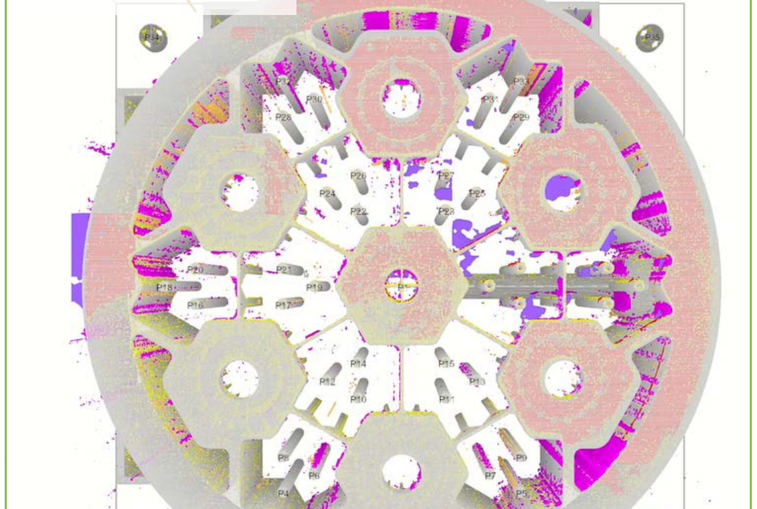
Data viewer



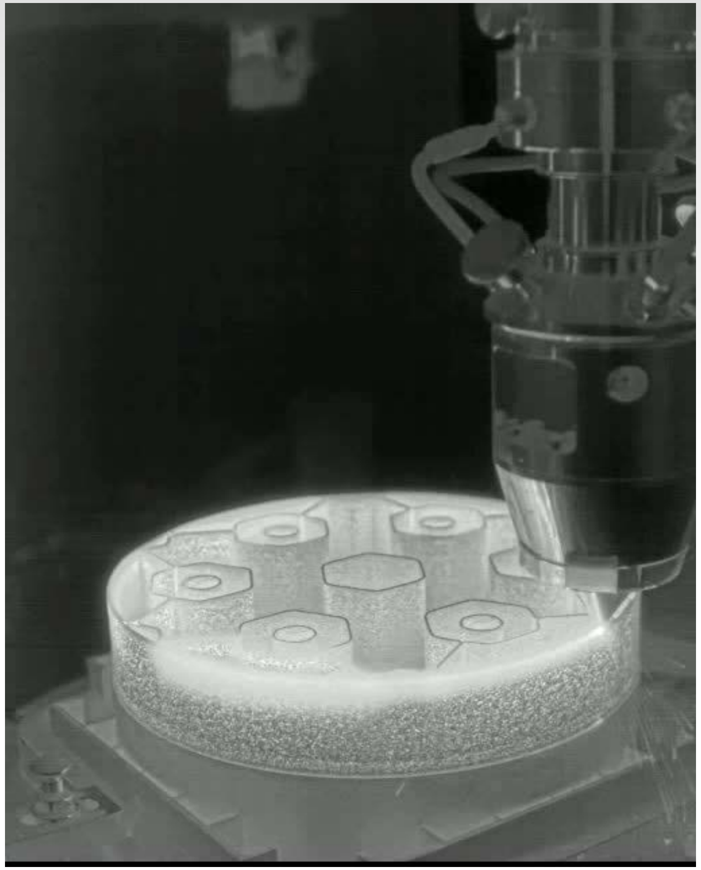
In-situ quality control

printer operator reviewing a *Peregrine* analysis

nuclear reactor manifold

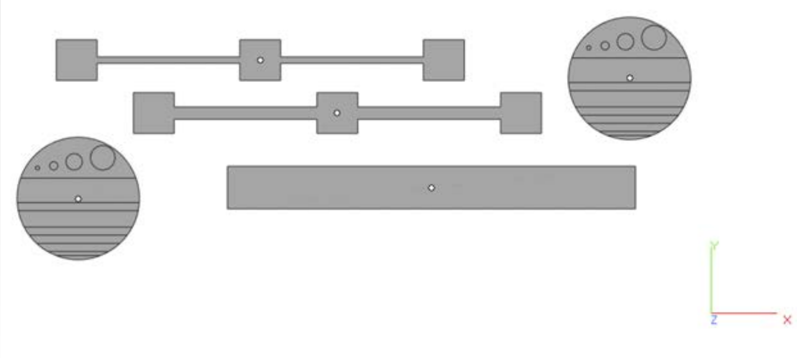


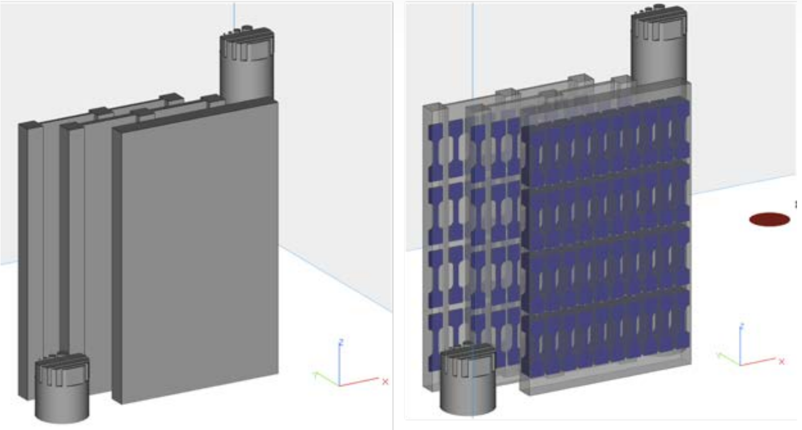
Sensor development



Process Correlation Campaign

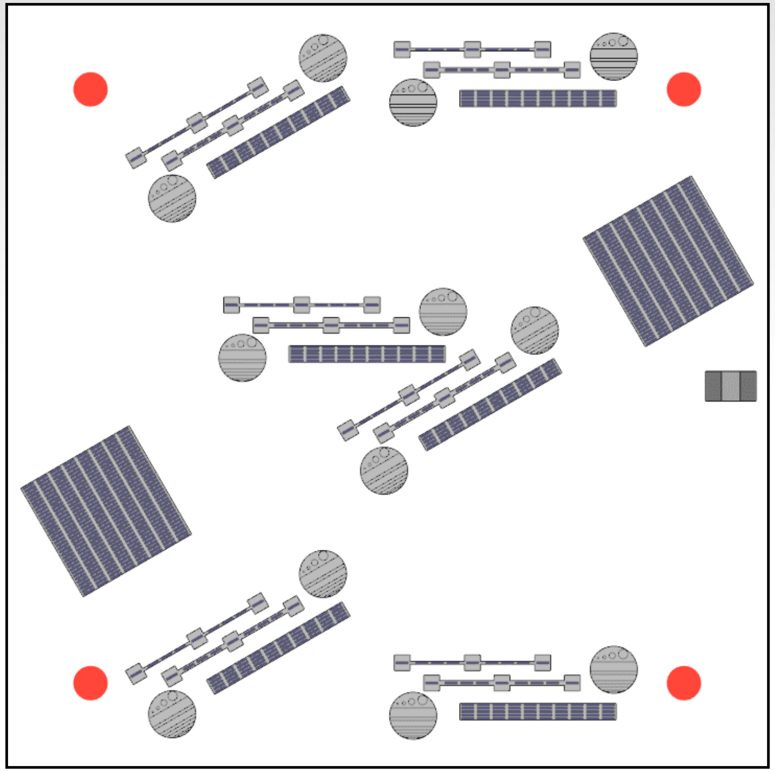
Standard Cluster





Location Specific Sample Extraction

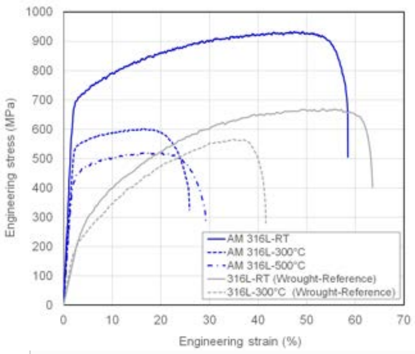
Build 0.1 Layout



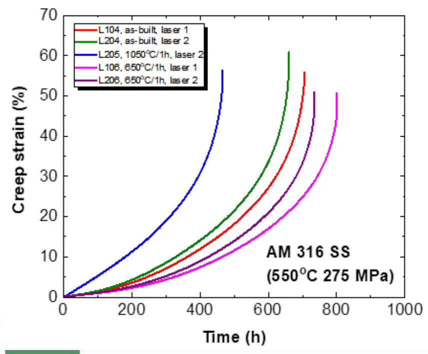
2,784 SS-J3 specimens

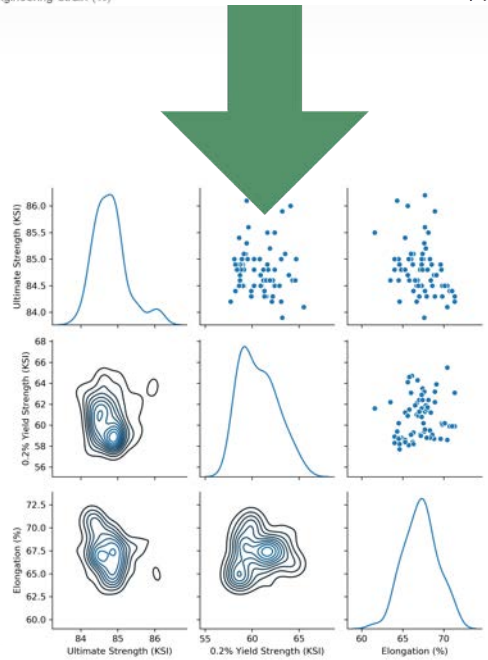
Data Correlation

Mechanical properties



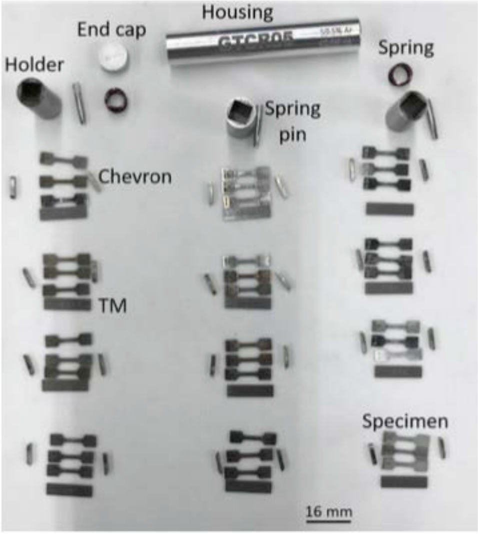
Creep properties



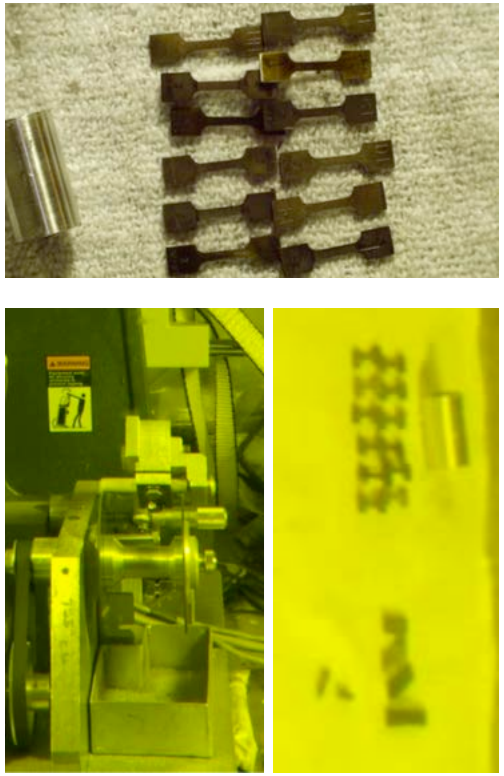


Extensive neutron irradiation testing of additive and advanced manufactured materials was carried out to develop their irradiated properties database, facilitating their adoption

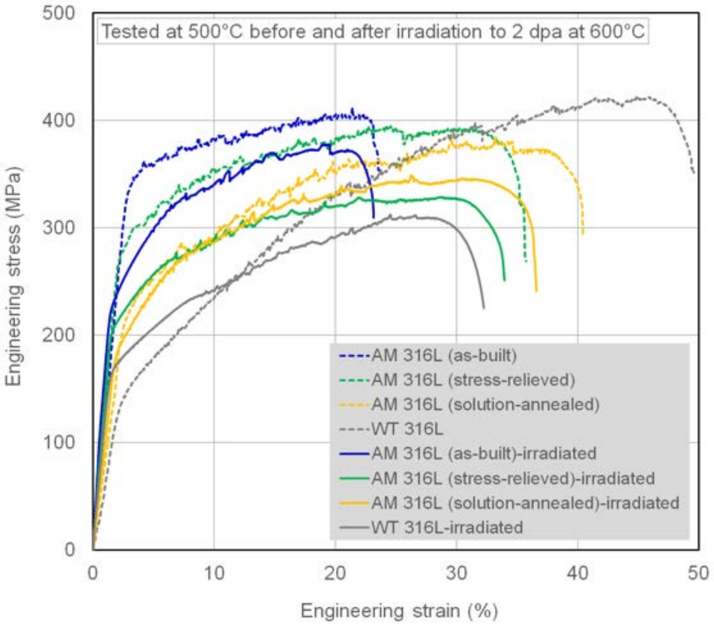
HFIR irradiation capsule



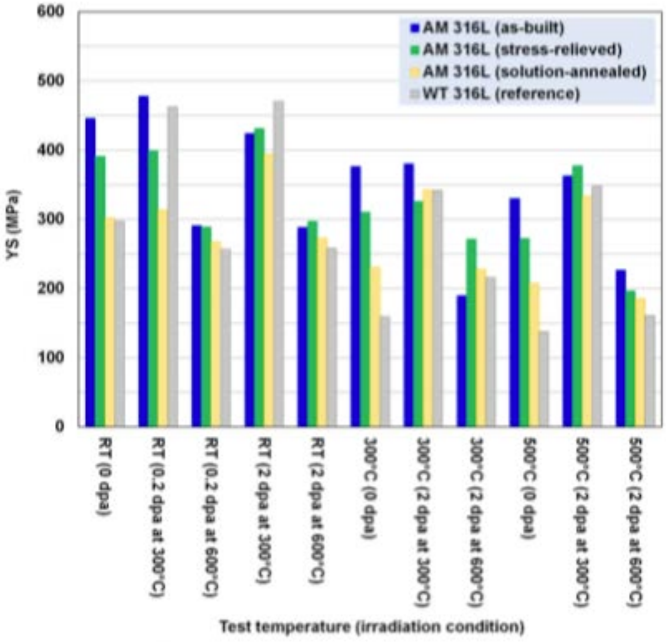
Hot-cell disassembly



In-cell mechanical testing of 3D printed 316L stainless steel



Irradiation hardening of 3D printed 316L stainless steel



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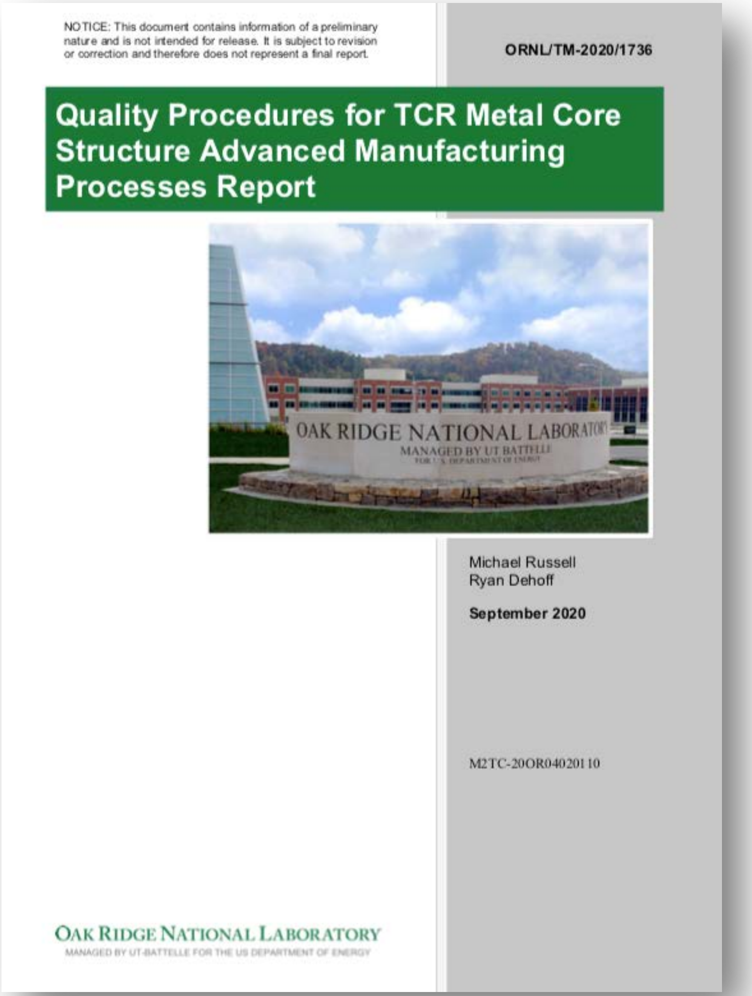
Key outcomes are documented to coordinate and guide industrial application and deployment of additive technologies for nuclear energy



NOTICE: This document contains information of a preliminary nature and is not intended for release. It is subject to revision or correction and therefore does not represent a final report.

ORNL/TM-2020/1736

Quality Procedures for TCR Metal Core Structure Advanced Manufacturing Processes Report

Michael Russell
Ryan Dehoff

September 2020

M2TC-20OR0402011 0

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

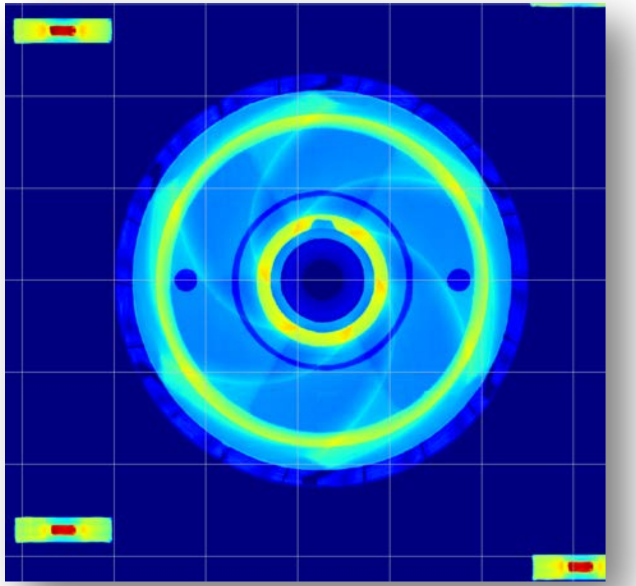
Application of Digital Platform for Certification of Additively Manufactured Components
(in coordination with NRC)

Sep 2021

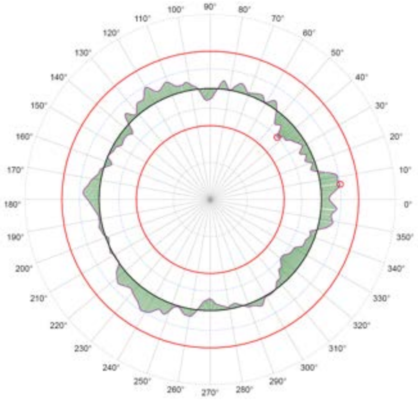
Additive manufacturing of salt pump impeller for Kairos Power


As ORNL builds novel reactor, nuclear industry benefits from technology

At the Department of Energy Manufacturing Demonstration Facility at ORNL, this part for a scaled-down prototype of a reactor was produced for industry partner Kairos Power. Credit: Kairos Power



Kairos Power



Additive manufacturing of framatome fuel assembly components for Tennessee Valley Authority

Reconstruction of in situ manufacturing data