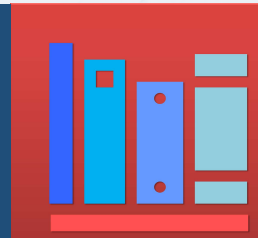
Standards for Advanced Manufacturing Technologies (AMT)



- **Moderator:** Hipolito Gonzalez, Branch Chief, NRR/DNRL/NVIB

- **Panelists/Speakers:**
  - David Gandy (EPRI)
  - Mark Messner (ANL)
  - Kurt Terrani (ORNL)
  - Raj Iyengar (NRC)

AMT Standards and Qualification—Acceleration….

The Potential of Advanced Factory Fabrication Methods

David W. Gandy
Sr. Technical Executive, Nuclear Materials
Davgandy@epri.com

NRC Standards Forum (virtual)
October 13, 2020

Powder Metallurgy-HIP for SMRs/ARs

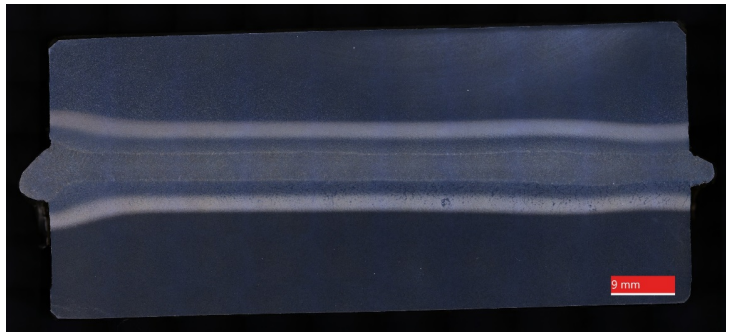
- What if you could manufacture an entire SMR head from A508 RPV steel in <3 months?
  - Near-net shaped (reduced machining) & excellent inspectability
  - Good tensile and toughness properties (>100ft-lbs)
  - Single monolithic structure--with no vessel dissimilar metal welds
- What if it only took 12 months to produce a reactor pressure vessel start-to-finish?
  - Rolled and/or forged shell sections
  - Welded together with EBW
  - USA capabilities re-established!!!

Very Large HIP Vessel:

3.55m (140in) Diameter x 2m (79in) (T)

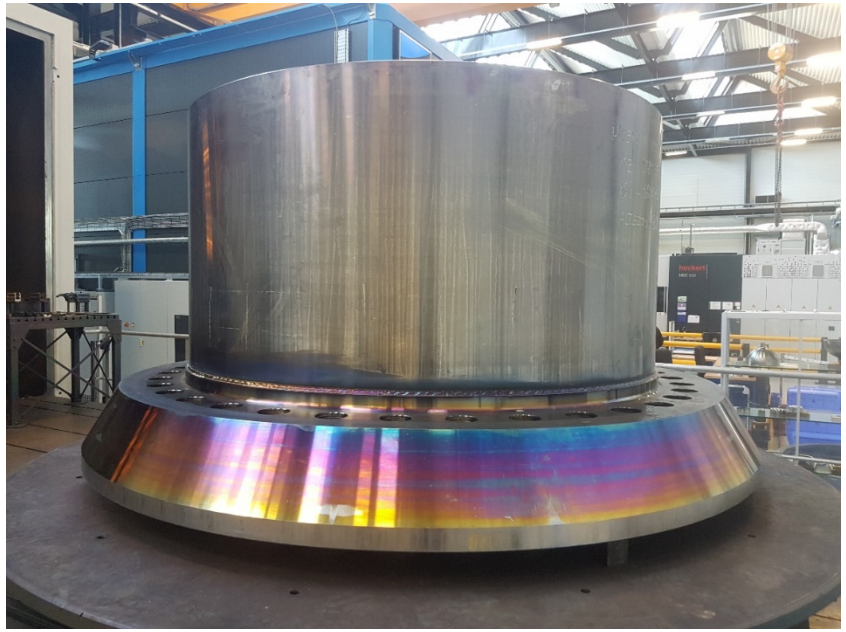
Electron Beam Welding of Thick Section SMR/AR Welds

- What if you could:
  - Perform an entire SMR/AR RPV girth weld in <90 minutes?
  - Eliminate the need for in-service examinations of girth welds?
  - Perform vertical welds to join rolled plate sections without embrittlement concerns?
- Can we eliminate the need for preheat of EB weldments?



110mm (thick) EB Weld

Photograph provided courtesy: Nuclear AMRC (UK)



Lower Flange Shell Mockup EB Weld -- ~6 ft (1.82m) diameter (Note, mockup is upside down)

Completed in 47 minutes

BACKUP SLIDE

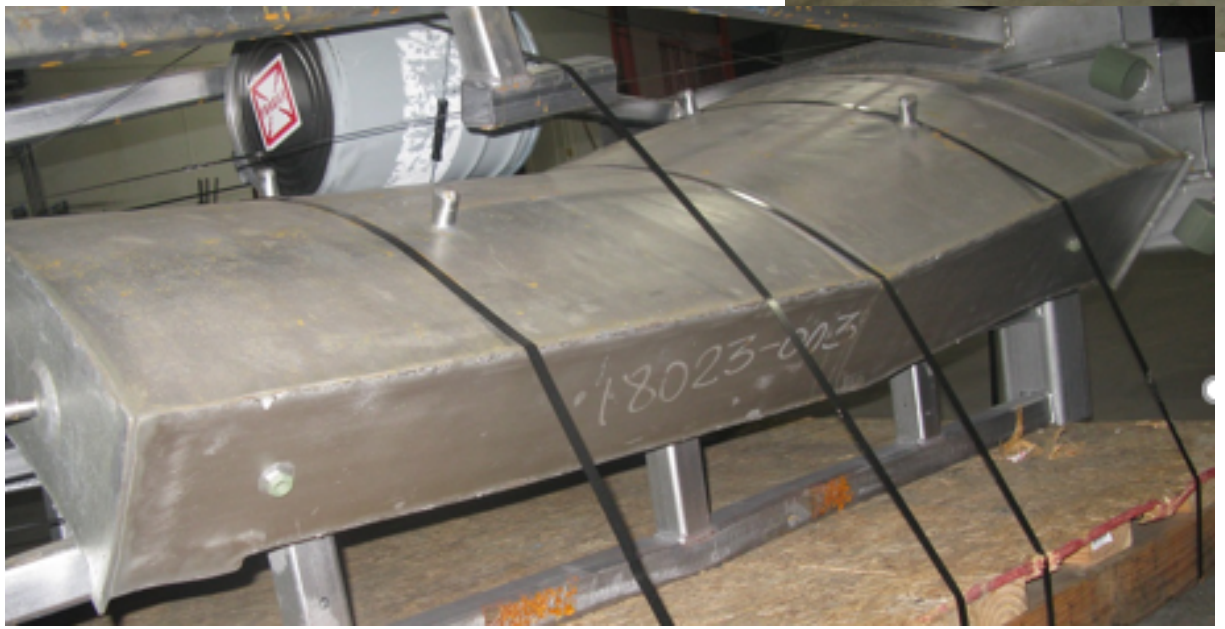
Articles

A508 Class 1, Grade 3

DOE Project: DE-NE0008629

⇦

One-half head; 6910 lbs. x 70 inches diameter



Transition plate section; 4620 lbs. 50 x 55 inches

Single monolithic structure; 27 penetrations 1650kg (3650lbs); 1270mm (50 inches) diameter

WE START WITH YES.

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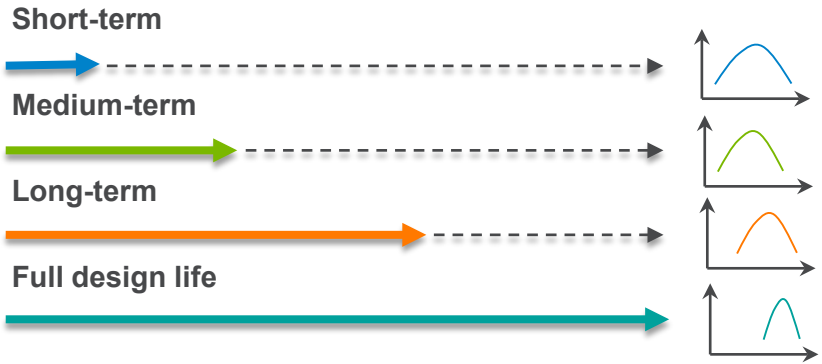
RAPID QUALIFICATION OF HIGH TEMPERATURE REACTOR STRUCTURAL MATERIALS

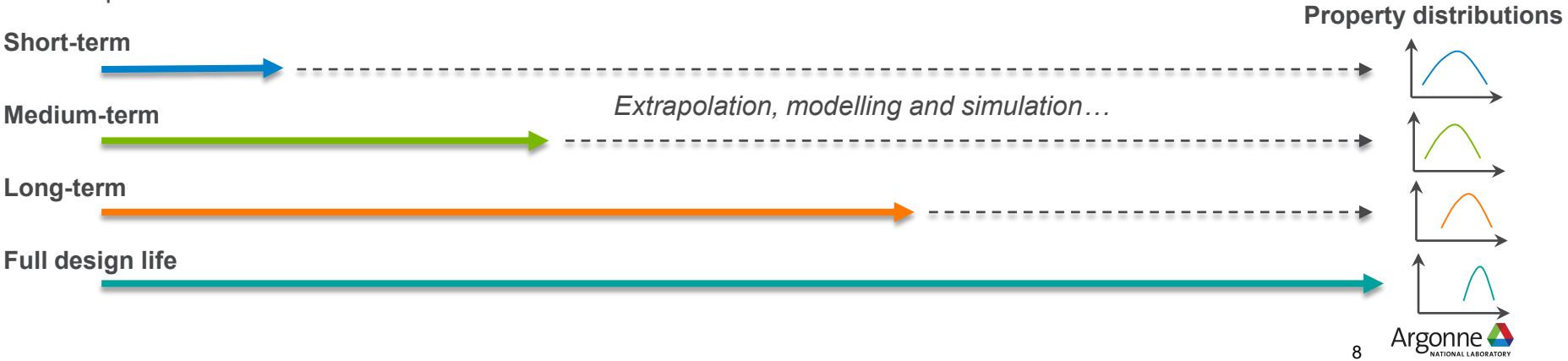


MARK MESSNER, Principal Mechanical Engineer
Argonne National Laboratory

WE CAN QUALIFY HIGH TEMPERATURE MATERIALS FASTER IF REGULATORS AND DESIGNERS CAN ACCEPT UNCERTAIN DESIGN DATA WITH UPDATES AS LONGER TESTS WRAP UP

How would this work?

1. Initiate long-term property tests on many candidate materials (you can terminate the tests for the materials that don't pan out)
2. Use the short-term test results, the best available processing information (in-situ process monitoring, advanced characterization), and material simulations to predict long-term properties *with uncertainty*
3. As tests from #1 conclude, updated models in #2 to provide new best estimates and uncertainties



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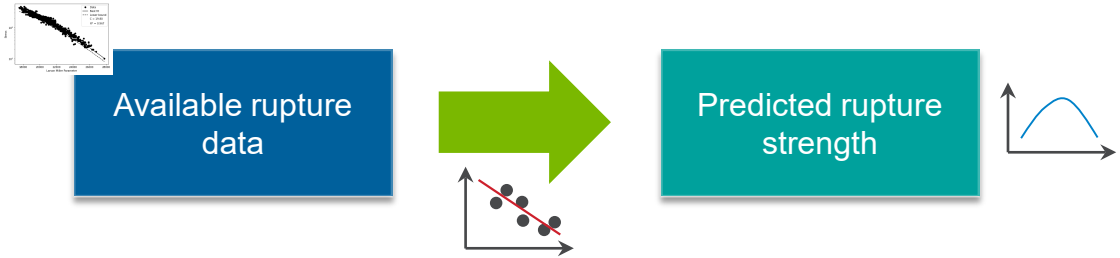
WE CAN IMPROVE THE MODELS USED TO EXTRAPOLATE TO REDUCE UNCERTAINTY AND GENERATE BETTER INITIAL PREDICTIONS FOR DESIGN DATA

Challenges applying staggered, probabilistic approach with conventional modeling:

- Mechanisms not present in short-term data!
- Little opportunity to take advantage of improved processing (data stays in database…)
- Doesn't take advantage of all available data to narrow/improve statistical estimates
  - Processing data
  - Microstructural characterization

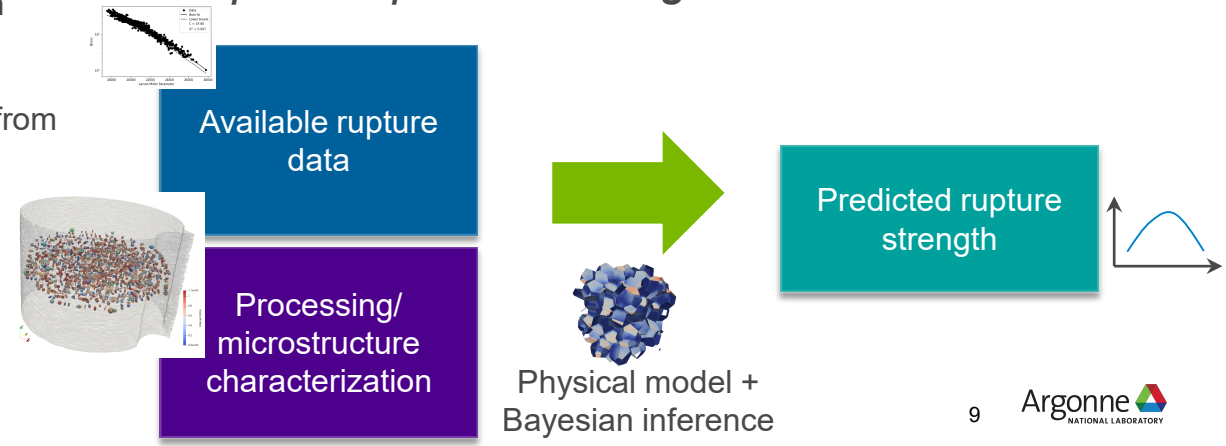
Physical models have a better chance of accurately capturing long-term properties from short term data

Bayesian inference provides a framework feeding in *incomplete* processing and microstructure information to yield better predictions



Empirical model + frequentist statistics

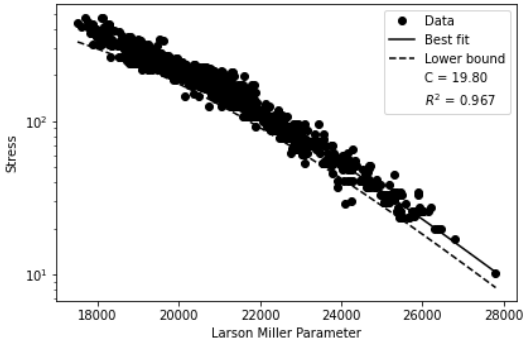
Improved process using microstructure data

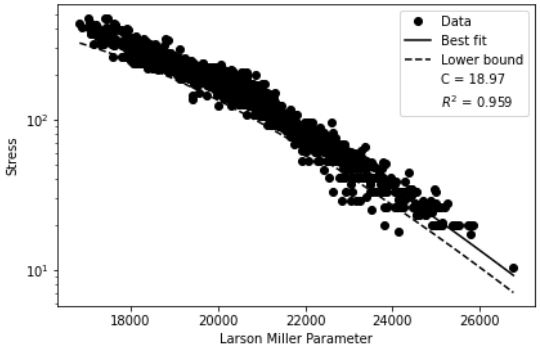


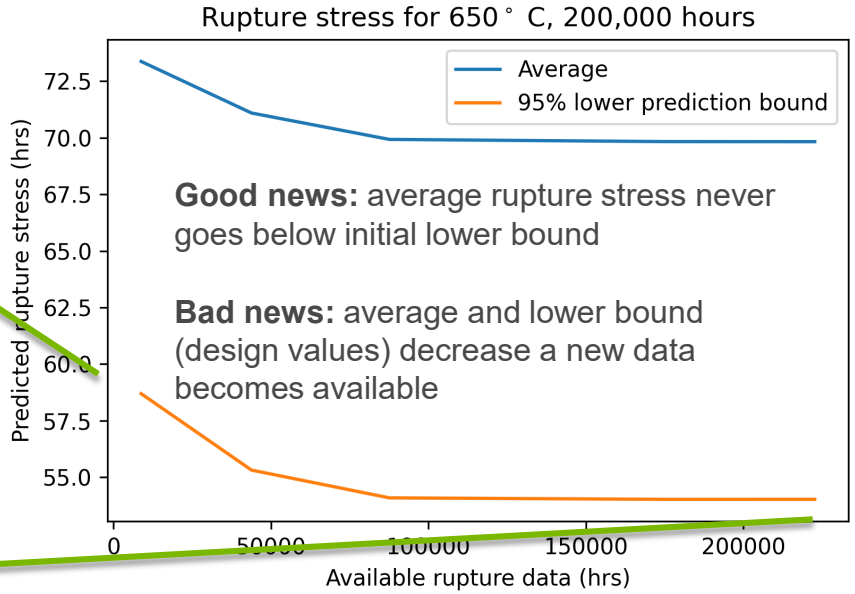
Physical model + Bayesian inference

BACKUP SLIDE

TESTING THE APPROACH WITH 316H RUPTURE DATA AND CONVENTIONAL MODELS ILLUSTRATES THE CHALLENGES DESIGNERS/REGULATORS WOULD FACE







OAK RIDGE National Laboratory

Accelerating Quality Certification of Critical Components with Additive Manufacturing

Oct 13, 2020

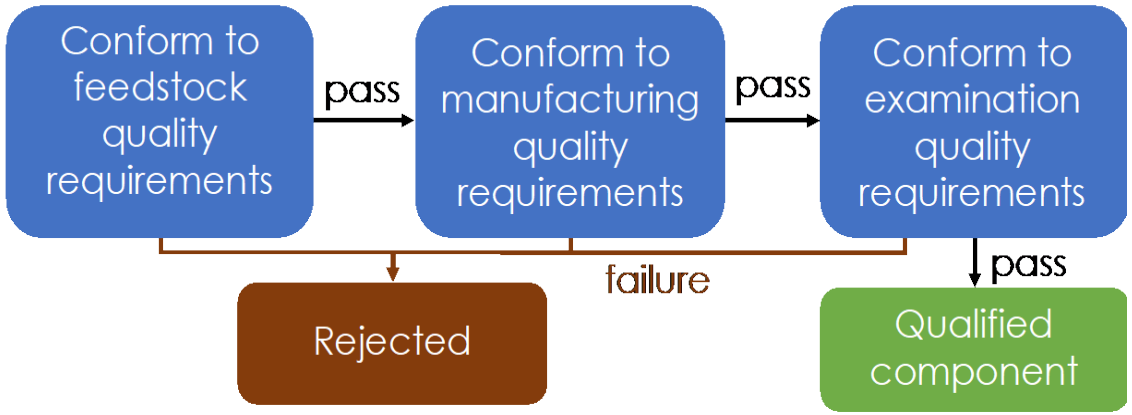
Kurt Terrani
Director – Transformational Challenge Reactor

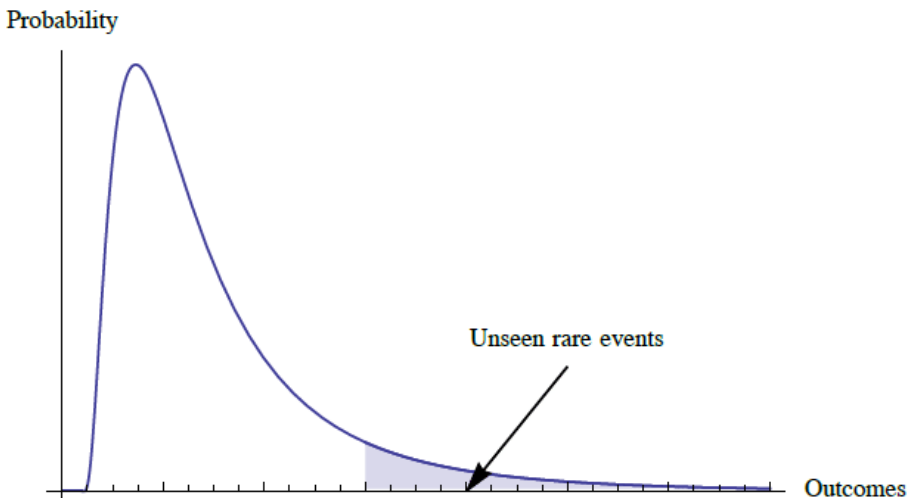
ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Quality certification for critical components: a procrustean approach

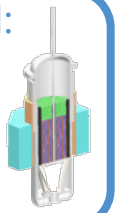
- Try to understand discrete manufacturing and inspection steps and how they match quality
  - Trial and error
  - Apply fundamentals
  - Combination of the two
- Document parameters that I believe control quality
- Introduce controls
- Cross my fingers and hope for the best





goal:

TCR

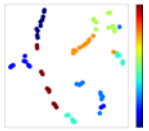


autonomous design improvements

D AI

predict performance

C AI



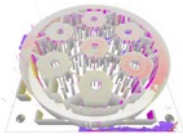
database

4 5 1 8

9 6 3 2

visualization

B AI



8 testing

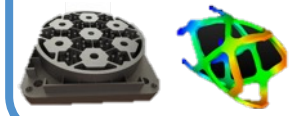
2 part digital thread

- sectioning
- subtractive
- metrology
- heat treat
- additive
- feedstock
- process parameters
- CAD design

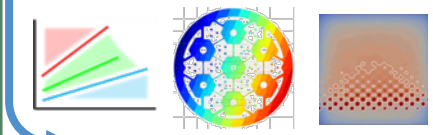
rapid iteration

Digital Thread

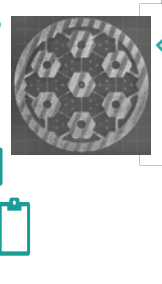
design & use-simulation



process physics, planning, & simulation



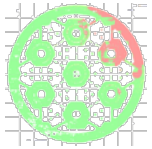
in-situ & meta data



data registration

anomaly detection

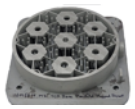
A AI



feedstock

characterization & recycling timeline

additive operation



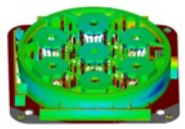
1 2 3

new parts created

heat treat operation

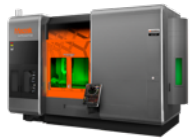
2 4 5 6

metrology operation



2

subtractive operation



2

sectioning operation

2

8 9

new parts created

testing operation

8

maintenance & calibration timeline

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