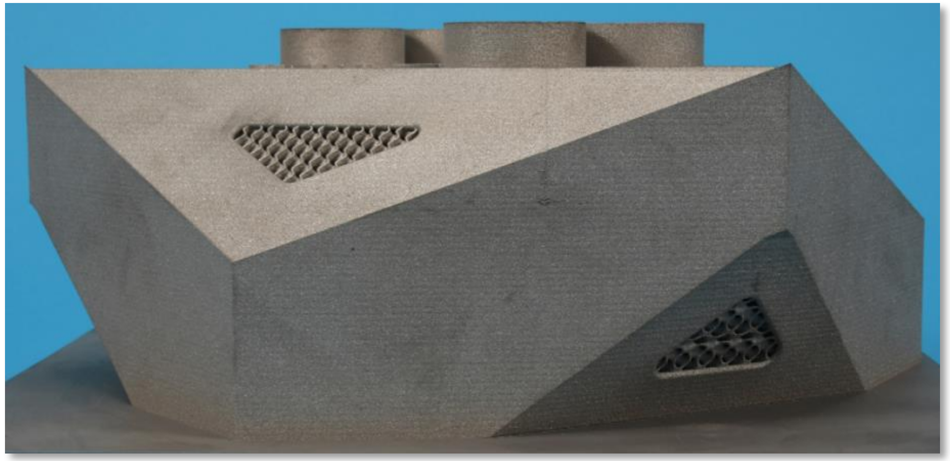
Ultra Performance Heat Exchanger Enabled by Additive Technology (UPHEAT)

Dr. Lana Osusky, GE Research

Leveraging AM-enabled **trifurcating unit cell core** design and GE-made **DMLM superalloy** for enhanced compact heat transfer and manufacturability.



High Intensity Thermal Exchange through Materials and Manufacturing Processes (HITEMMP)
Annual Program Review – March 29-30, 2022

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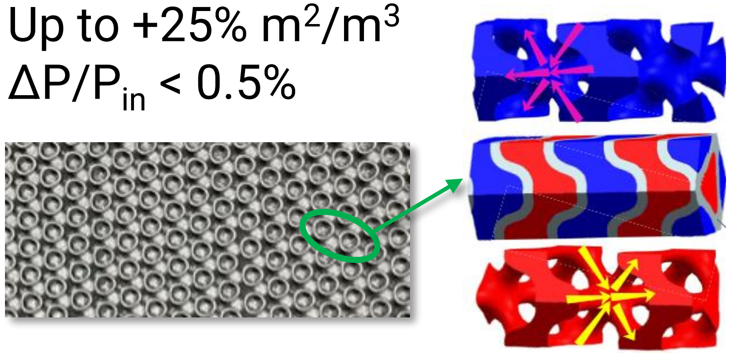
UPHEAT Project Overview

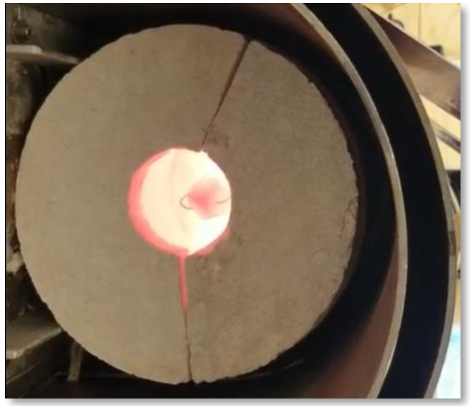
Fed. funding:	$3.1M
Length	35 mo.

Team member	Location	Role in project
GE Research	Niskayuna, NY	Program Lead, Alloy Research, Design & Prototyping lead
University of Maryland	College Park, MD	NGHX design & optimization methods
Oak Ridge National Lab	Oak Ridge, TN	Corrosion Science

Trifurcating unit cell
Up to 2X mass-based power density
Up to +25% m^2/m^3
$\Delta P/P_{in} < 0.5\%$

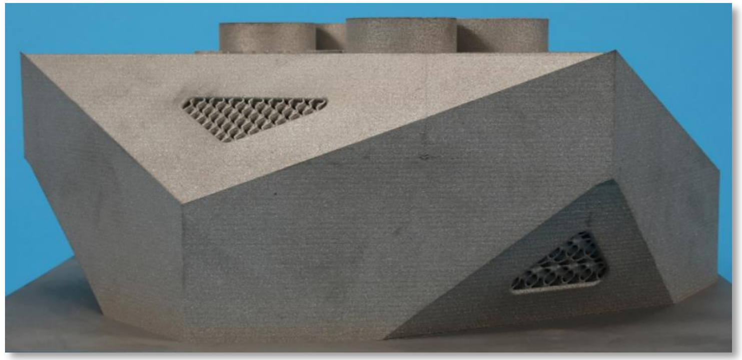


GE's AM303 Ni-based superalloy
Enables 900°C / 250 bar operation
Designed for additive manufacturing



Q3-Q4'21
Successful static pressure tests
Subscale prototypes
>900°C, >200bar

Final deliverable Q2'22
Final prototype 900°C heat transfer test



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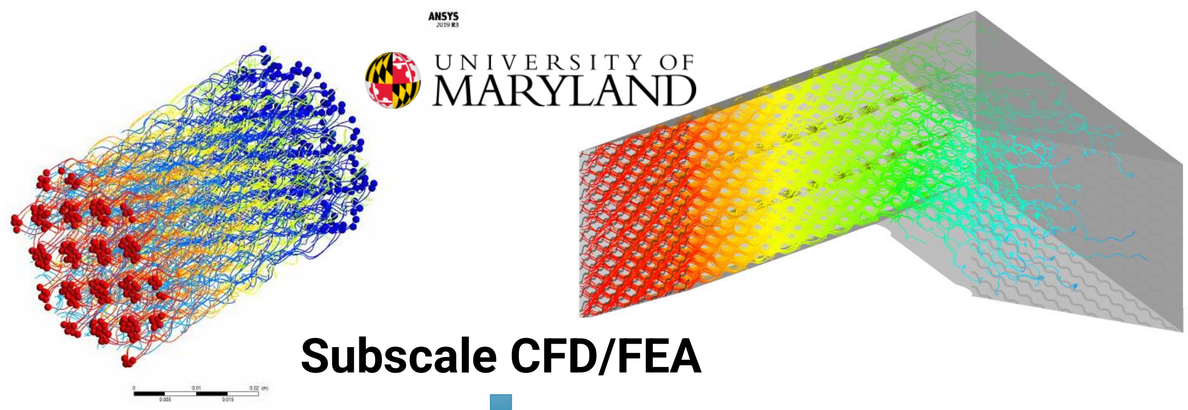
Heat Exchanger Design Details

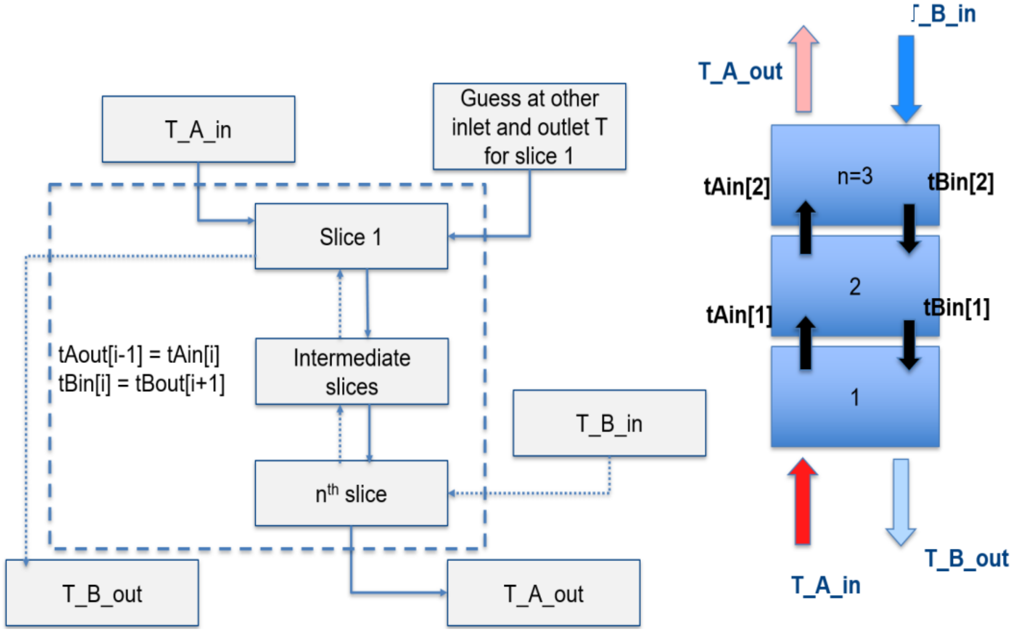
HX Metric	UPHEAT Nominal Design
Hot side	Air @ 900°C, 80 bar
$(\Delta P/P_{in})_{hot}$	<0.5%
Cold side	sCO_2 @ 300°C, 250 bar
$(\Delta P/P_{in})_{cold}$	<0.5%
Effectiveness	>80%
Durability	40,000 hrs



Subscale CFD/FEA

Correlations

Excel-based Slice Solver Tool



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Manufacturing Process Development Updates

Direct Metal Laser Melting (**DMLM**)

Enables thin-wall/mm-scale features & unique geometries

Process de-risking **completed** for **sub-scale prototypes**

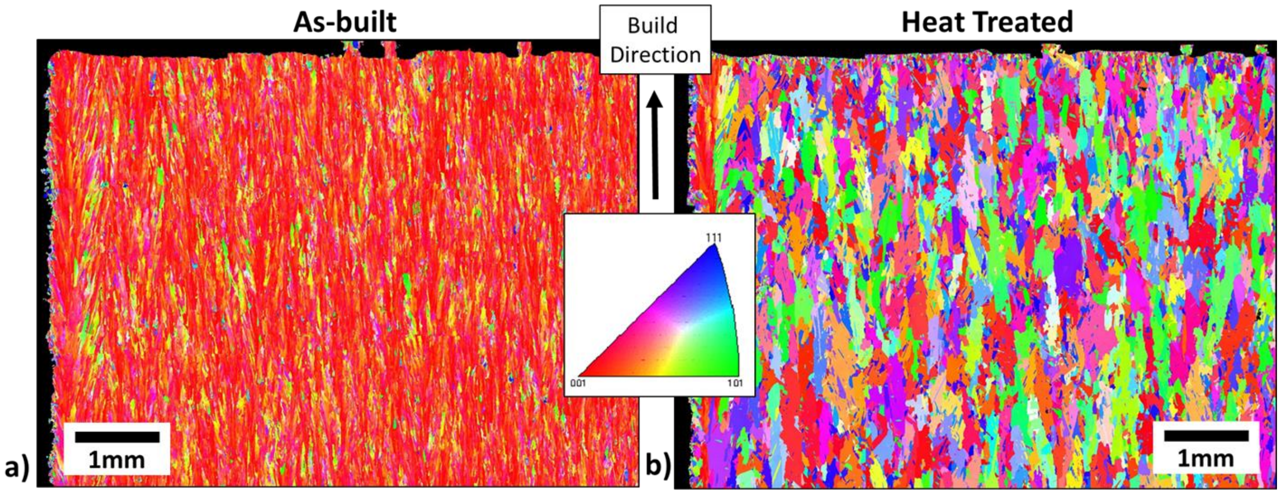
Biggest challenge:

Computational resources required to accommodate design complexity, feature density, part volume

Manufacturing beyond R&D scale will require commercial partners & investment

Manufacturing Process Development Updates

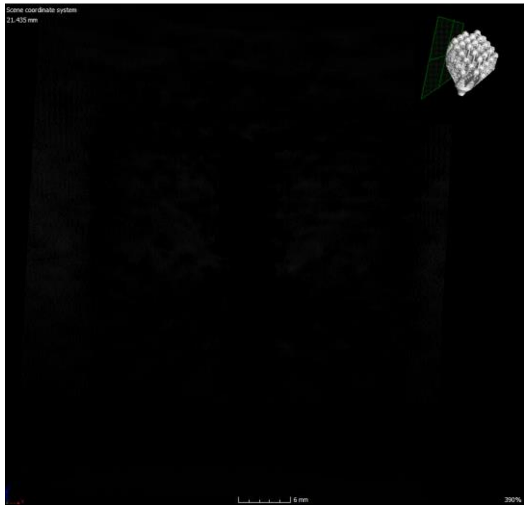
- Post processing heat treatment and Microstructure



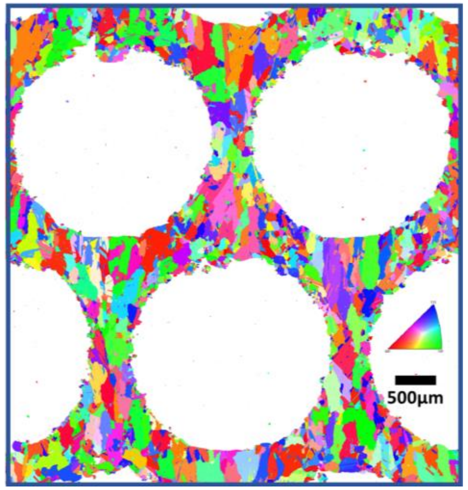
Typical as-built microstructure (a) and bulk heat treated coupon (b).
Grain size average: 120 x 240um (aspect ratio ~2:1)

Anisotropy in grain structure, due to AM processing, will drive direction-dependent performance. Further, loading of thin-wall structures may drive further variability or debits in performance beyond typical bulk creep measurements.

GE's patented "trifurcating unit cell"

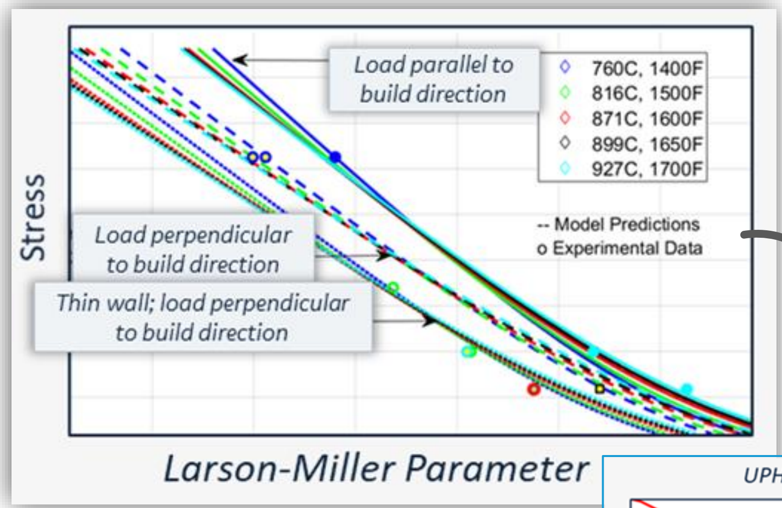


Representative thin-wall section

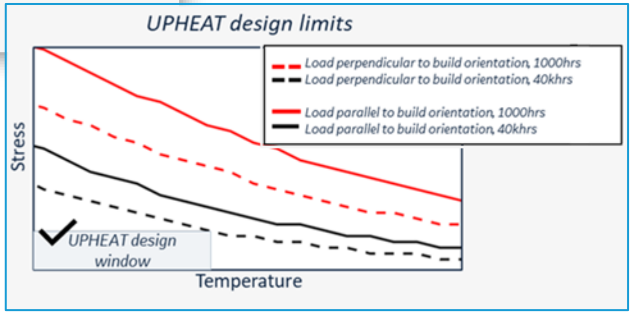


Material Updates: AM303 –Creep and corrosion performance of thin-walls

Creep Capability

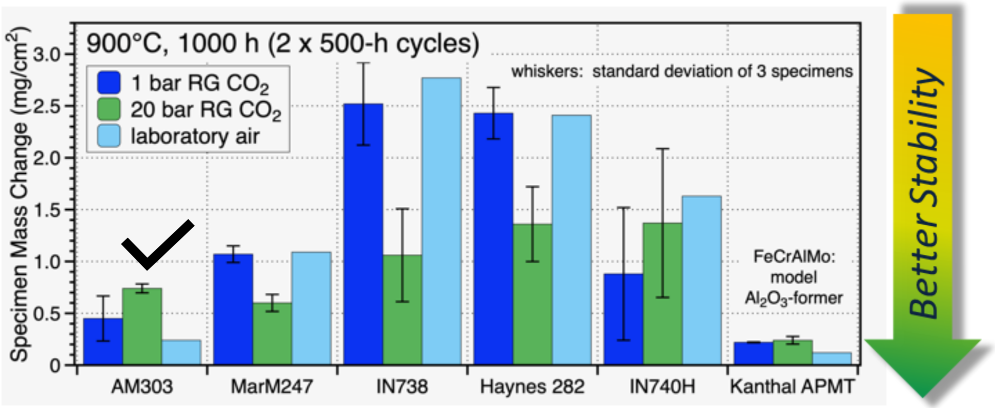


Link to application mechanical and thermal design requirements

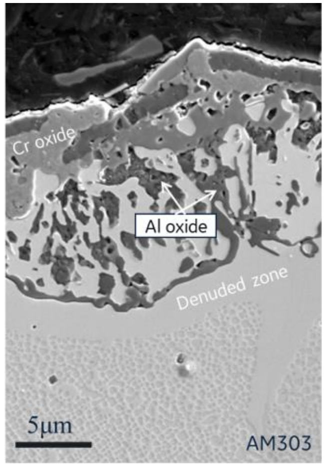


Creep model, calibrated through AM303 testing up to 1500hrs, shows margin against UPHEAT targets.

Corrosion Performance



Ex: Detailed characterization of microstructure evolution in CO_2



AM303 mass change similar to commercial alumina-forming alloys. Improvement over chromia-forming alloys.

Next steps: Leverage previously-developed thermodynamic-kinetic simulation methods to predict oxidation induced γ' depletion* and associated reduction of effective wall thickness.

*Pillai, R., et al., A new computational approach for modelling the microstructural evolution and residual lifetime assessment of MCrAlY coatings. Materials at High Temperatures, 2015. 32(1-2): p. 57-67.

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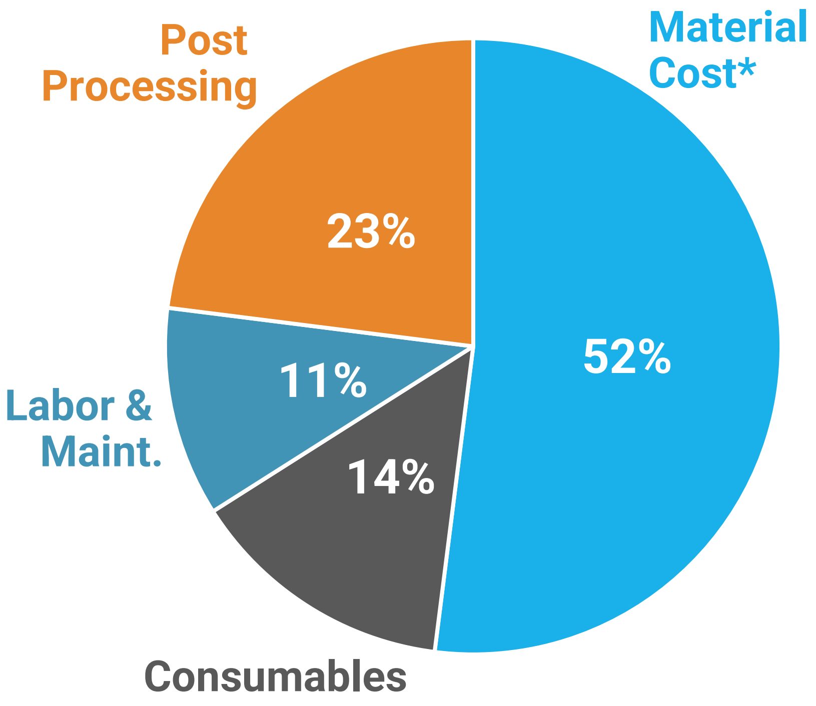
Technology-to-Market & Potential Partnerships

COST



$4000 part cost

Goal: 50% ↓ for commercialization

- Market screenings complete, with active engagement in **power** and **chemical processing** sectors
- **Next objective**: scale from TRL4 to TRL6 with partner positioned to license HX design and/or material IP
- **Cost modeling complete** using GE Additive proprietary tool
- **Commercial success** will require:
  - Technology **licensing**
  - **Supply chain investment** to manufacture at production scale
  - Product **certification** to ASME standards

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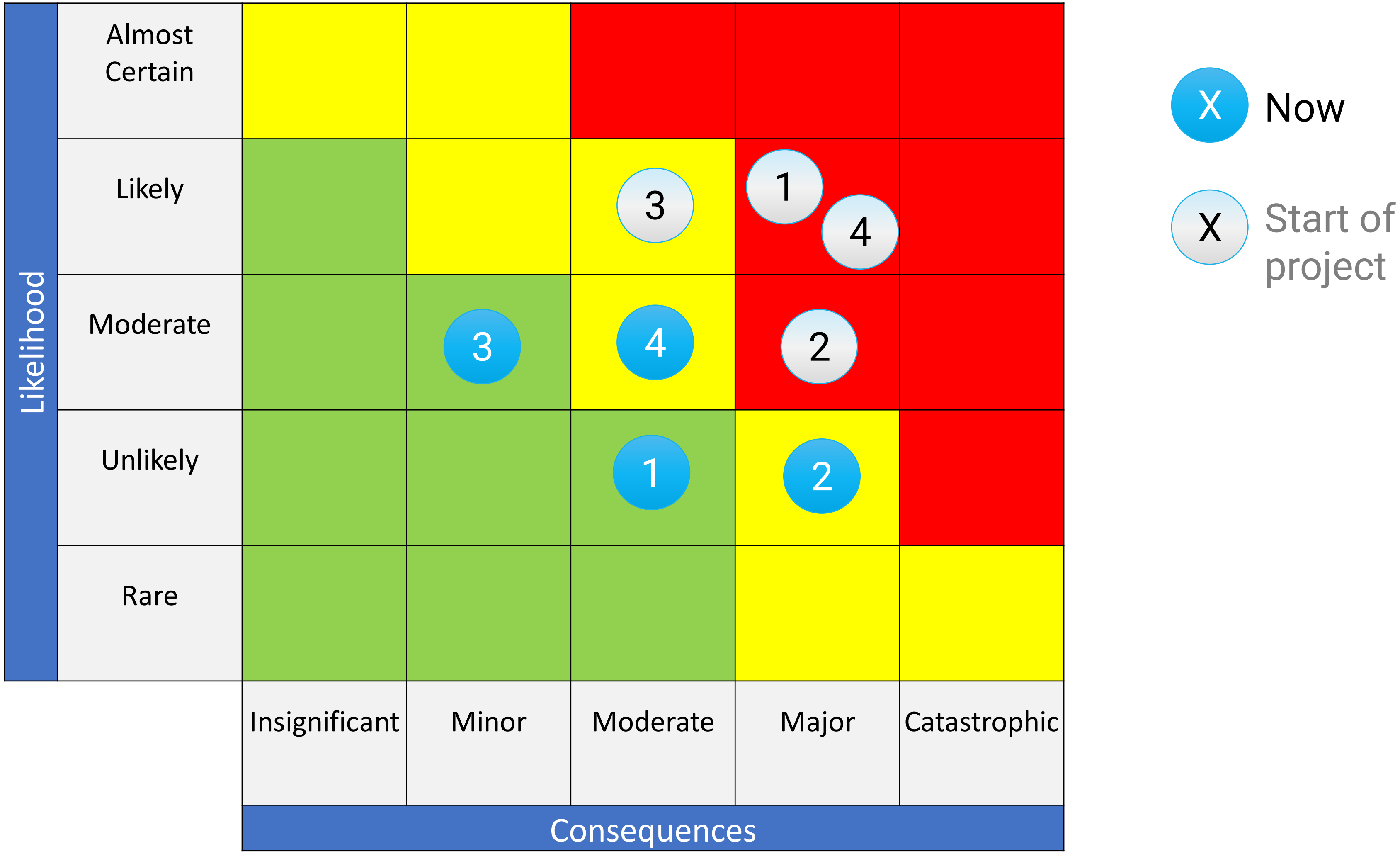
*AM303 not anticipated to be significant additional cost driver compared with other Ni-based alloys

Risk Update

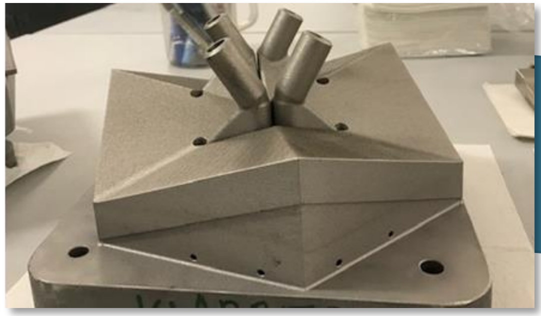
Risk	#
Thin wall print capability	1
HX hermeticity	2
Simulation file sizes/computational time	3
Component life	4

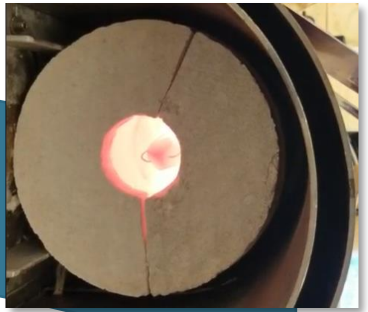


Progress Against Tasks – Timetable

Sub-scale water-water **heat transfer test**

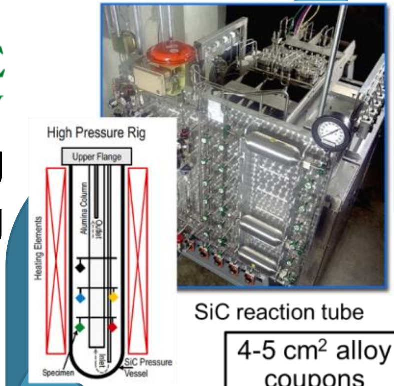
Cost Modeling





Thin-wall manufacturing & sub-scale 900°C / 208 bar **static pressure test**

"Keiser" rig:
500-h cycles, 1+20 bar CO_2

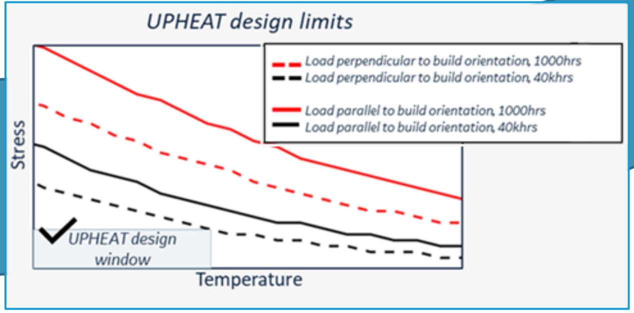


SiC reaction tube

4-5 cm^2 alloy coupons

OAK RIDGE National Laboratory

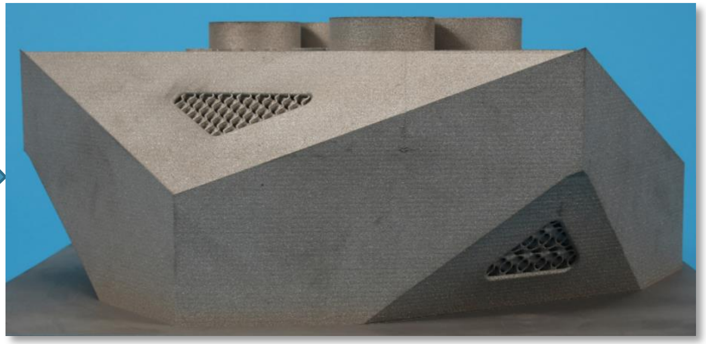
Corrosion testing & modeling



Creep testing & modeling

UNIVERSITY OF MARYLAND

Design system & optimization



Q2'22

Final prototype & 900°C heat transfer test

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Q & A

https://arpa-e.energy.gov

Material Updates

- AM303 Properties