PennState
Applied Research Laboratory

MATERIALS AND MANUFACTURING OFFICE

PRINT PLASTIC TO MAKE METAL (P2M2)

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JTEG Joint Technology Exchange Group

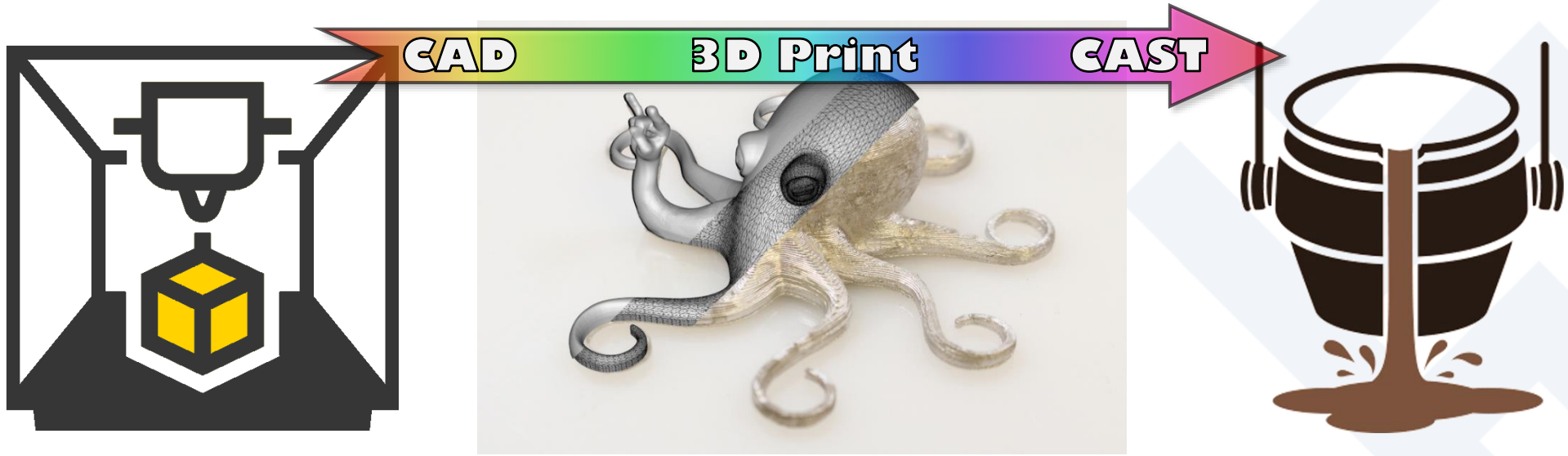
Joint Solutions for Depot Maintenance

JTEG Technology Forum: Casting & Forging Process (including using 3D Mfg to build forms)

Core Principles of P2M2

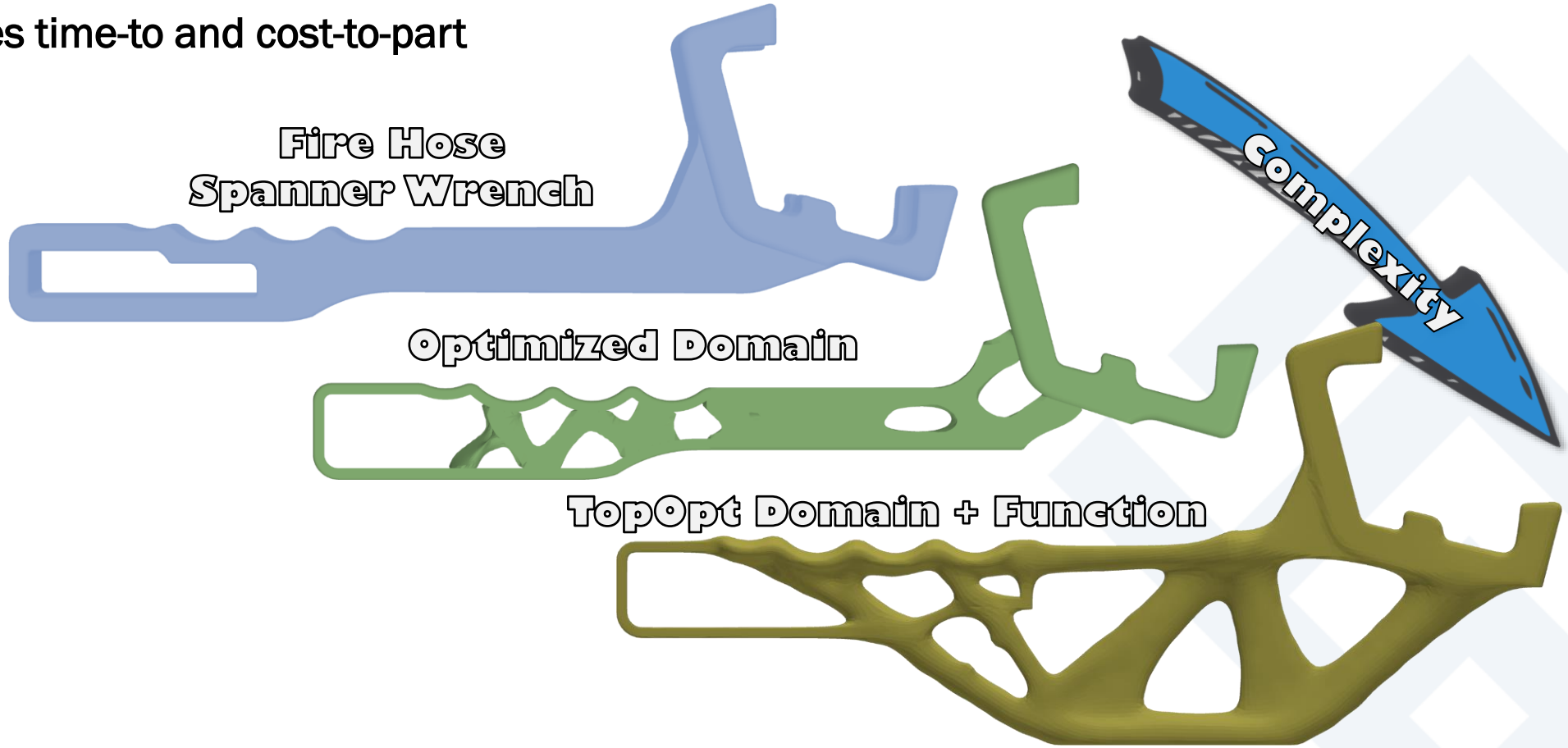
- Reduce lead time and cost to build metal part (temporary, replacement, novel)
- Use easily accessible tools and processes to make “green” metal parts

- Additive Manufacturing allows geometry to made at point-of-need
- Casting process provides well-known processes, material properties, and workflow

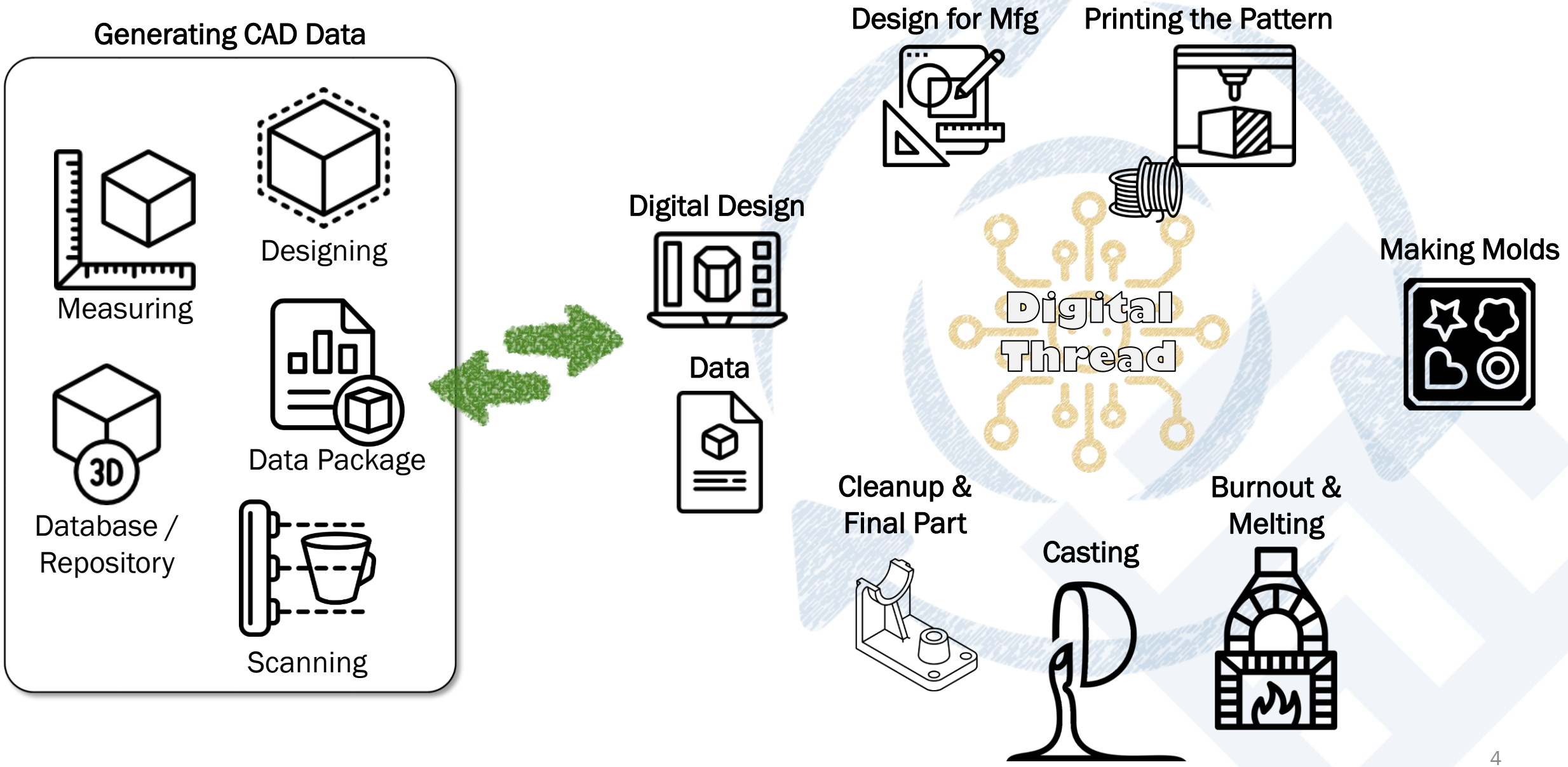


P2M2 enables complex geometries with low-cost metallic solutions

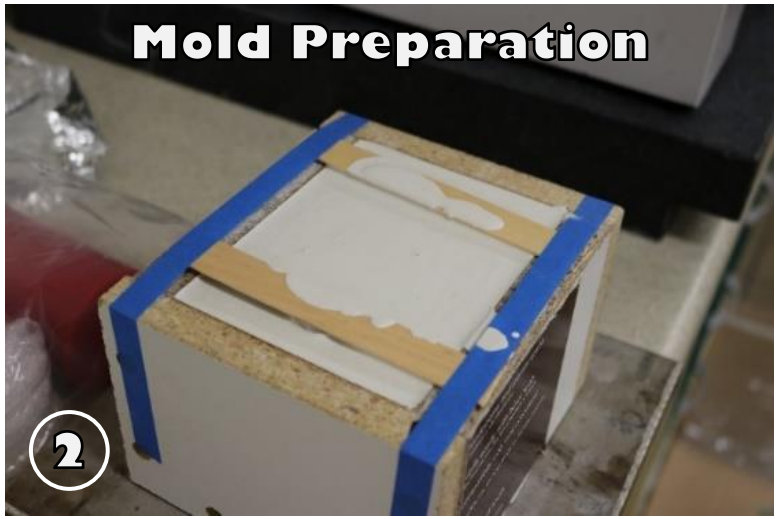
1. AM enables complex geometry
2. Casting provides well-known material and process
3. Combination creates opportunity for hybrid design methods
4. Reduces time-to and cost-to-part



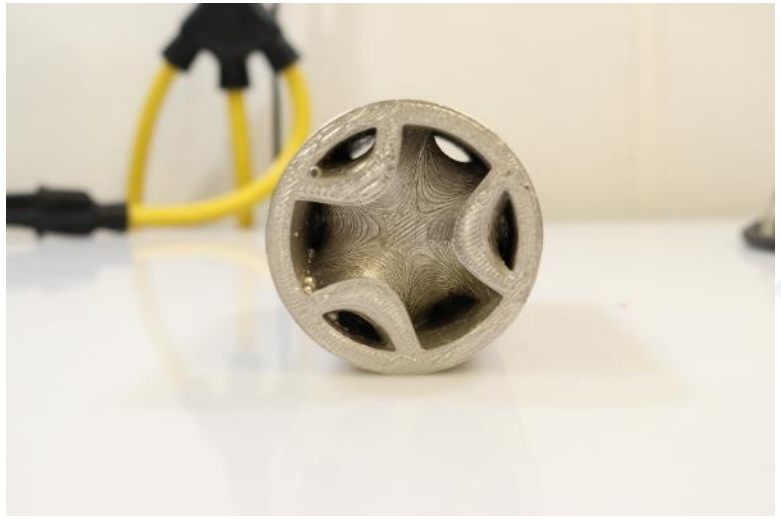
Generating digital design data for P2M2



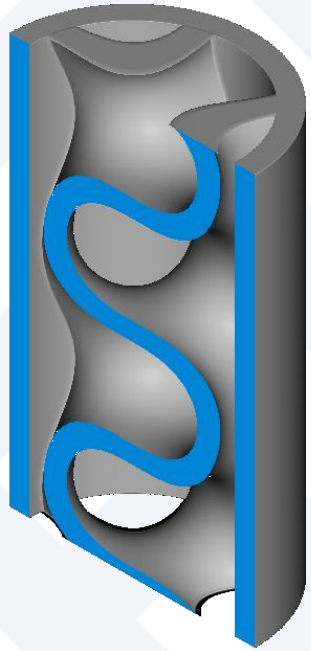
Learning to cast – a simple cylinder



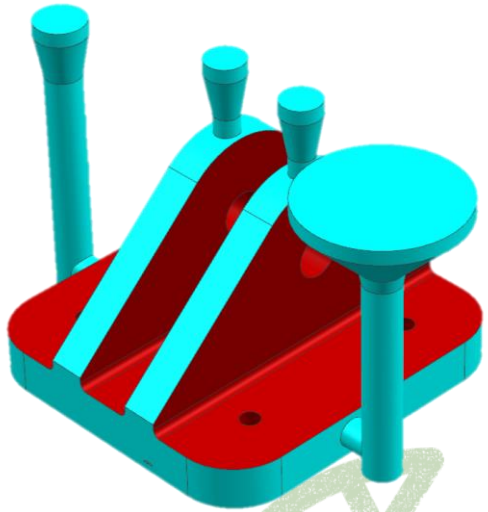
Learning to cast – a complex Gyroid inside a cylinder



- ❑ An incredible amount of geometric complexity from the (cheap) polymer AM part
- ❑ AM feature/toolpath imprinting is visibly evident
  - Fine resolution achievable
- ❑ Tin pour allows for rapid ideation



A356 Aluminum P2M2 for V22 Bracket



Taking CAD and adding DfAM and DfCast features

1st prototype pour for process: Note the shrinkage and poor geometry tolerance

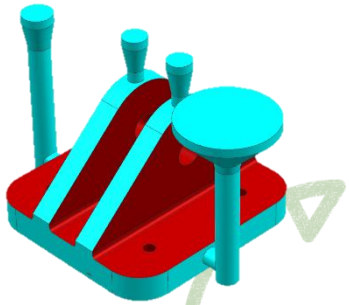
learning

Collect data and method details to refine process

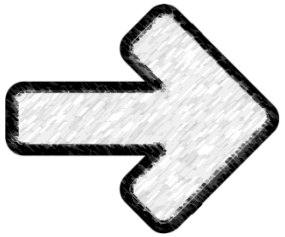
Lessons Learned

- ❑ The first casting won't always come out perfect
- ❑ Learning features, intent, and design considerations improves quality
  - Incorporate Design for X:
    - Casting
    - Additive Manufacturing
    - Manufacturing
  - Any post-inspection requirement?
- ❑ Continue to collect data and build a repository of "curated" technical data packages

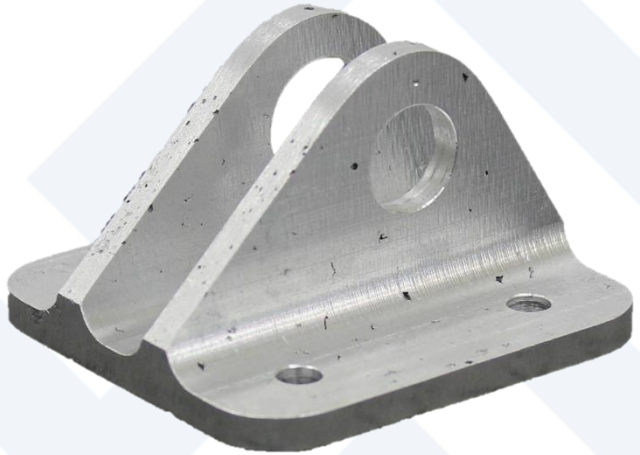
Iterating the lessons learned to the improve P2M2 process



learning

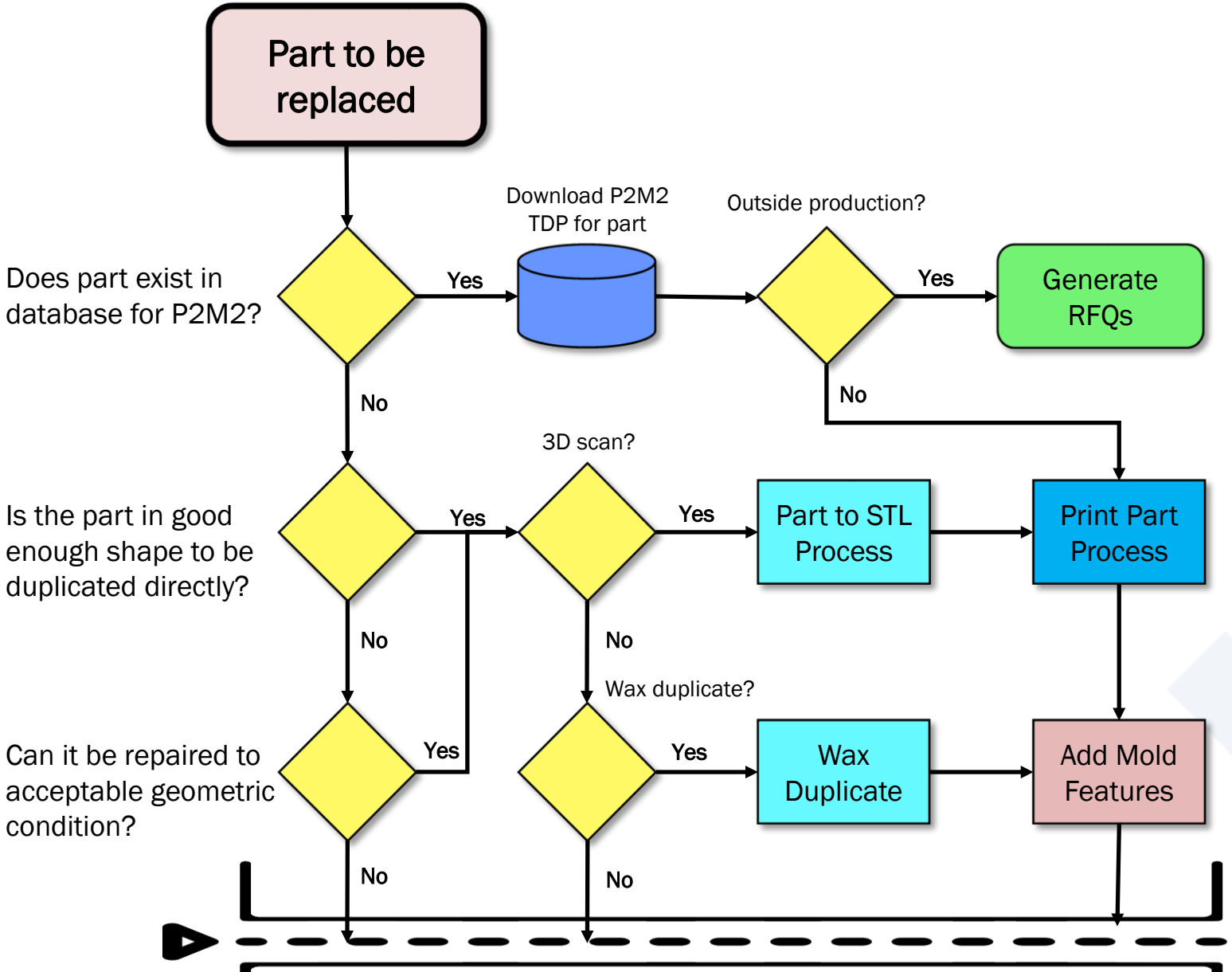


final pour for process: improved geometry and repeatability



post-machined part

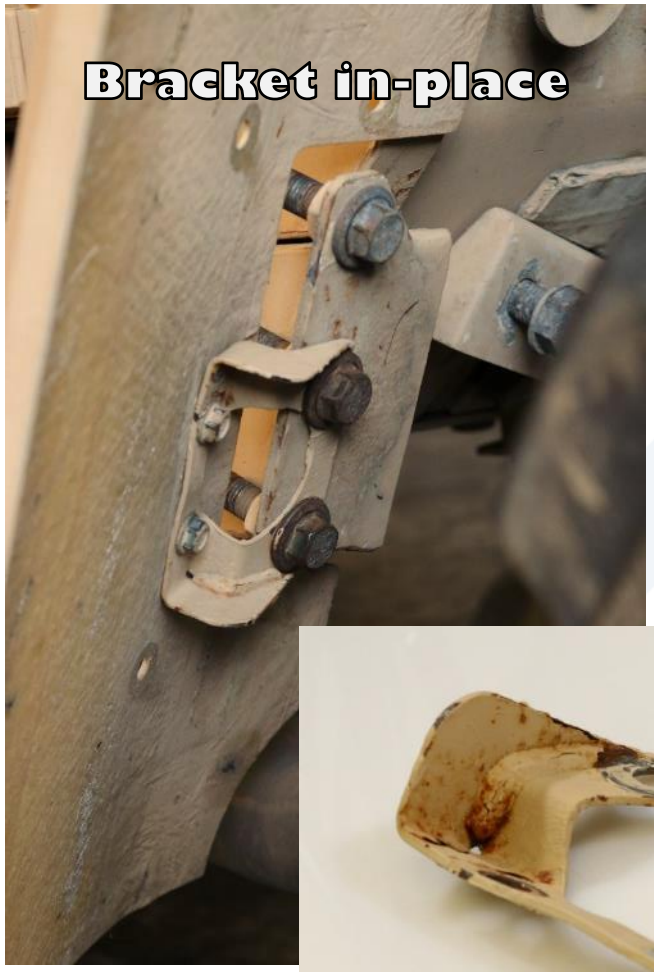
Initial development of decision framework for P2M2-able objects



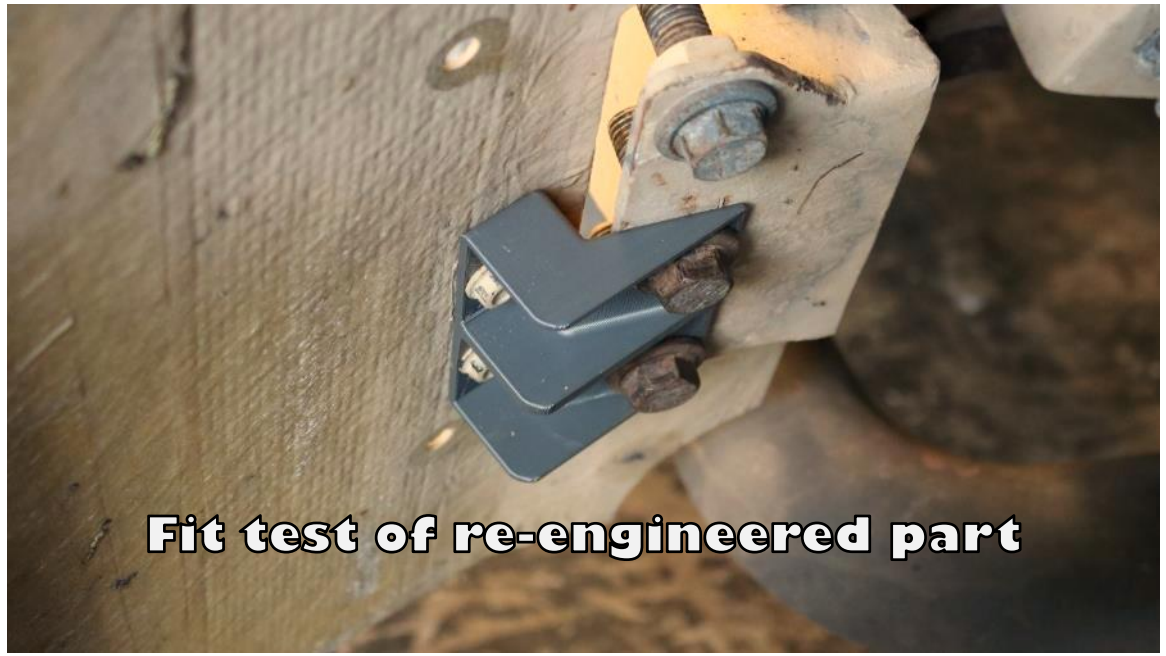
JLTV 45152-4038522 Bracket

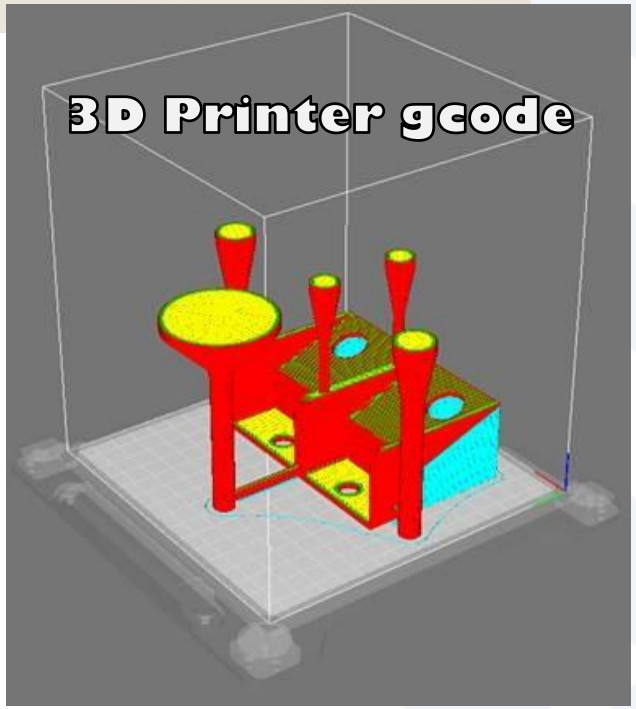
- Bracket on JLTV is a common failure component
- Made of sheet metal, bent and formed, welded
- Difficult to get replacement from OEM

- Use AM to make patterns for castable replacement
  - Used A356 as a demonstrator
  - Used AM to make design mods for
    - manufacturability,
    - Strength, and
    - ease-of-assembly



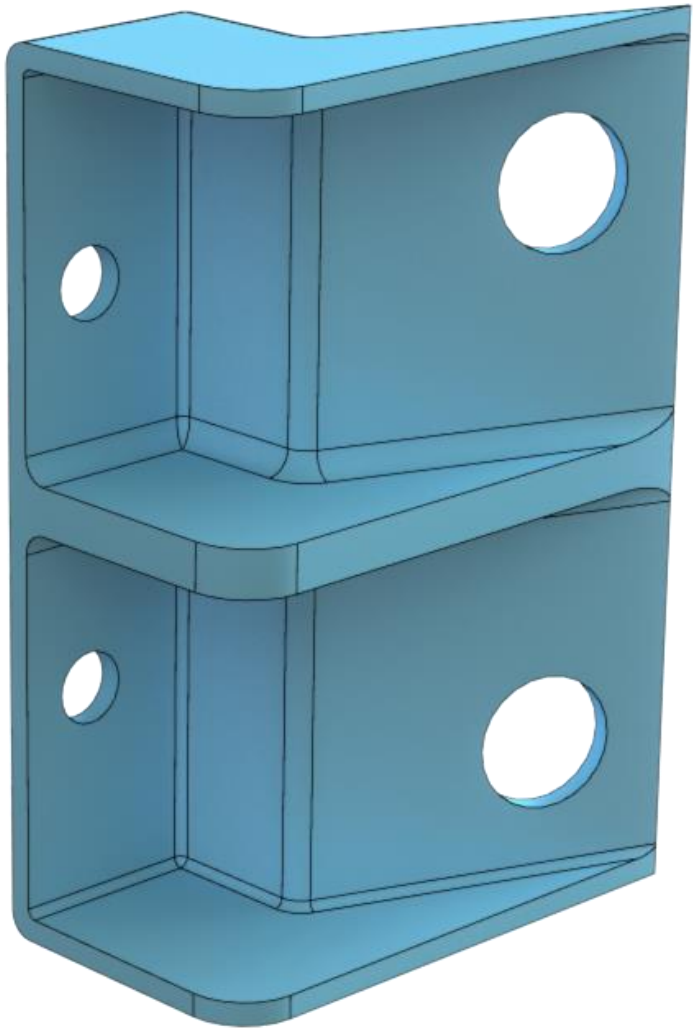
Designing the bracket and the casting with fit-up testing





Mechanical design, assessment, and evaluation of alternatives

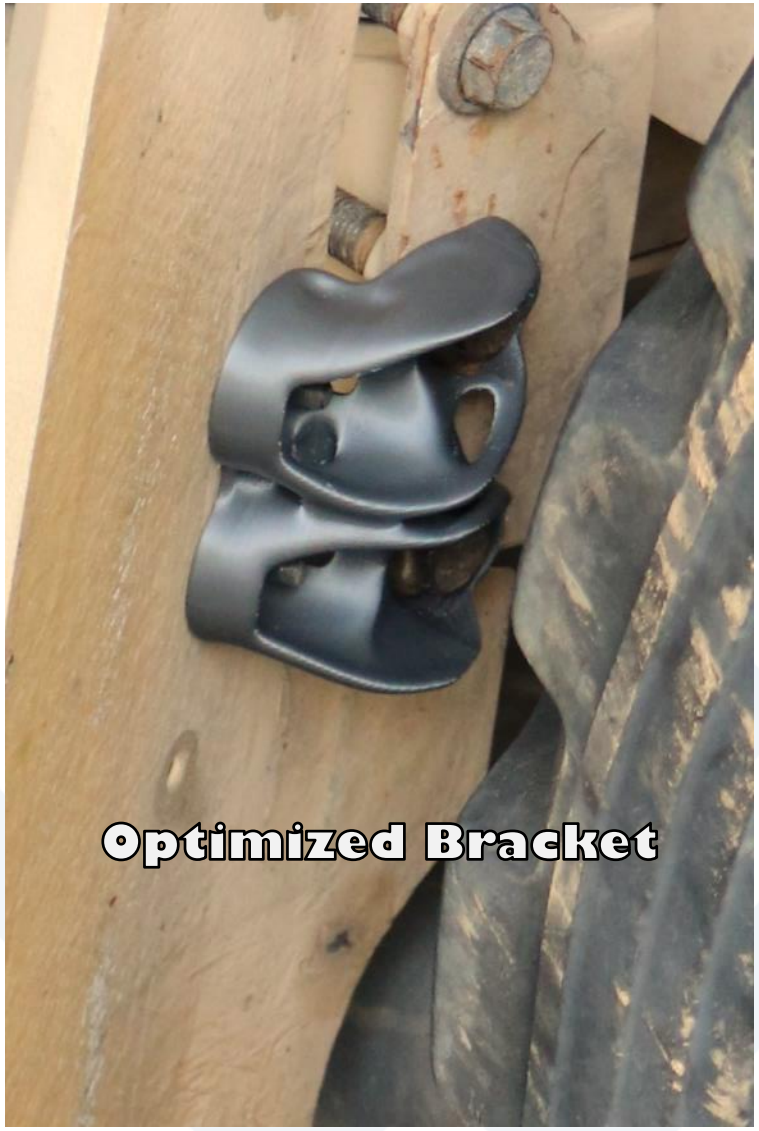
Original Bracket



Redesign for Stiffness

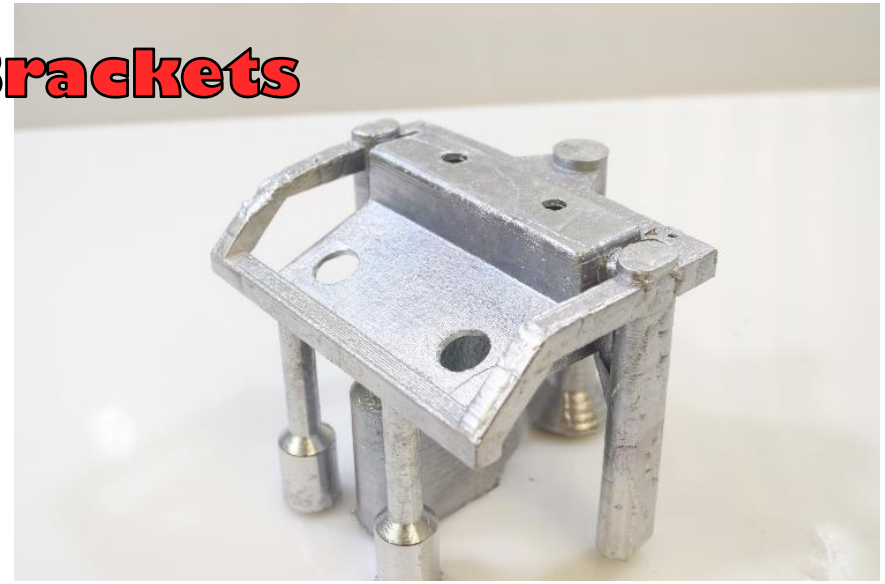
Topology Optimized Bracket

Exploring “optimized” shape and rapid prototyping of modified brackets



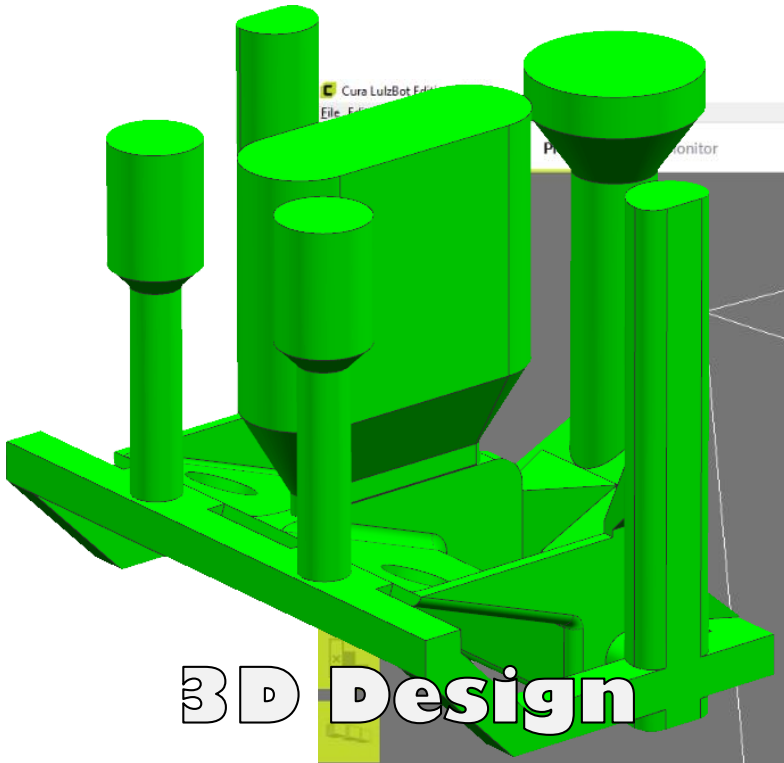
Casting and Machining the Bracket

As-Cast Brackets



Post-Process and Cleanup

From “broken” to fixed!

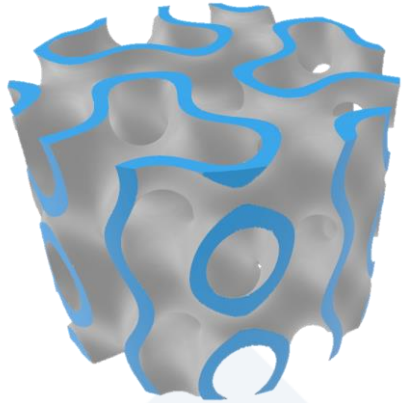


3D Design

3D Printing

P2M2 Final Metal Part

Applying P2M2 to a large 6” complex Gyroid inside a cylinder



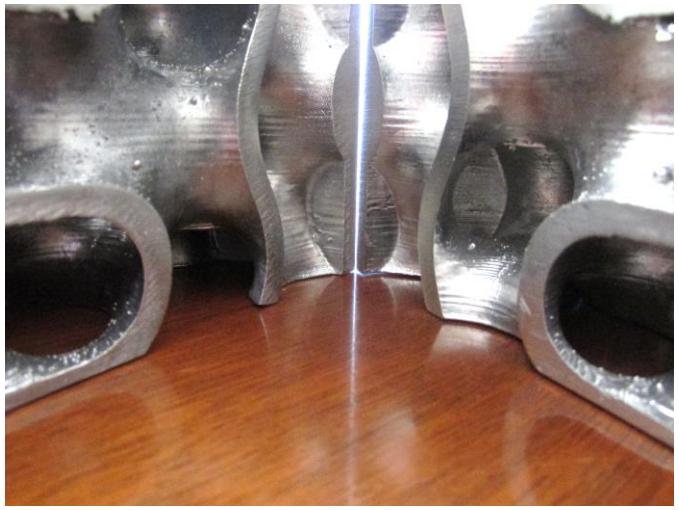
6”OD, ¼” walls

Multiple views of the P2M2 Tin lattice casting

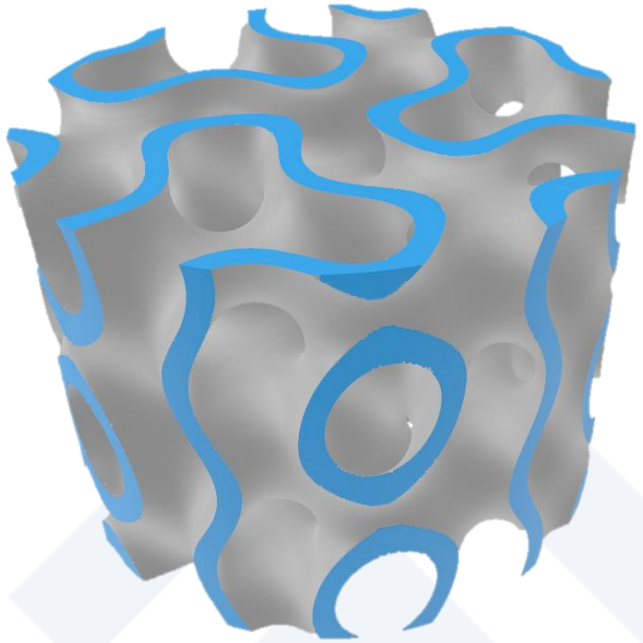
Splitting the seam

Opening up the structure

Zooming into the walls



A casting defect!



6”OD, ¼” walls

Final Thoughts

- AM enables *complex* geometry
- Casting provides well-known *material and process*
- Combination *creates opportunity* for hybrid design methods
- Rapid process turns “broken” to “fixed” in days
- Future work on developing the tech data, process improvements, decision analysis, and repository