AWS D20.1 – An Application to Nickel Aluminum Bronze Propellors

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Outline

- Introduction to AWS D20.1
  - A general document for metal additive manufacturing
- Example – Nickel Aluminum Bronze for Propellors
  - The example is actually built on two more specific standards

NAB Deposition Check Block

Introduction to AWS D20.1

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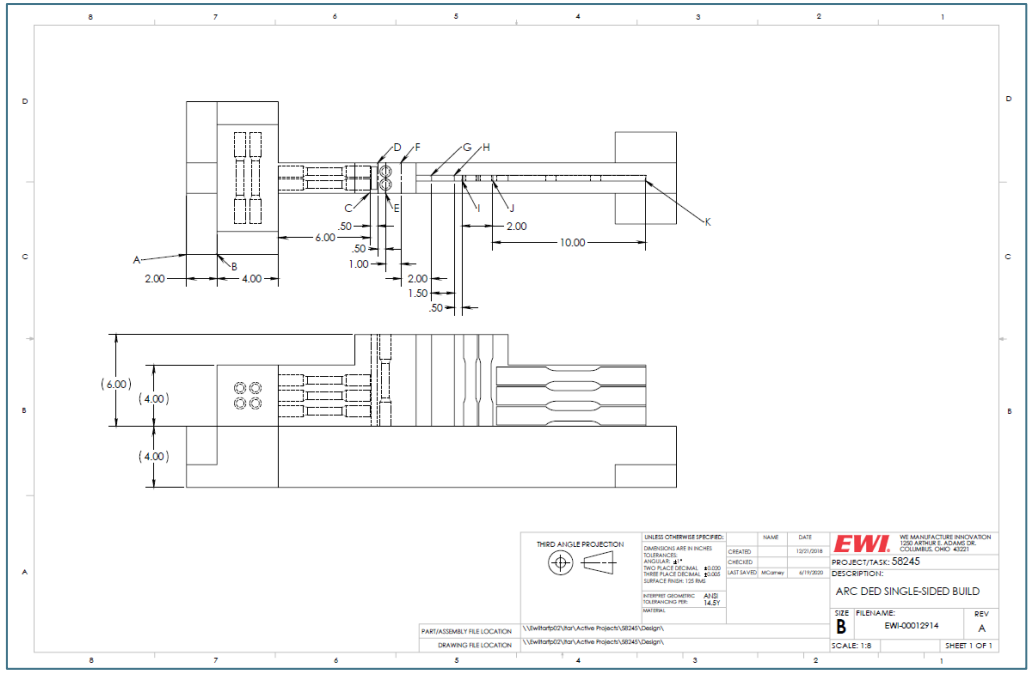
D20.1 Aims

- "This specification provides the general requirements for fabrication of metal components using additive manufacturing. It provides guidance for the interaction between the Engineer and the Contractor. It includes the design, qualification, fabrication, inspection, and acceptance of additively manufactured components. A commentary for the specification is included."

- General requirements – much other input needed
- Fabrication – both entirely from new material and with integrated build plate
- Metal – any metal material could have this document applied
- Additive Manufacturing – both powder bed fusion (PBF) and directed energy deposition (DED)
- Engineer – defined role that defines "acceptable"
- Contractor – defined role that fabricates to requirements

Engineer Role

- Choose Class A, B, or C, based on future use case
  - Inspection and qualification change for more severe use
- Choose material and its acceptable properties
- Choose design and methods of acceptance
- Name possible processes
- Provide a list of requirements



Example Qualification Build Design

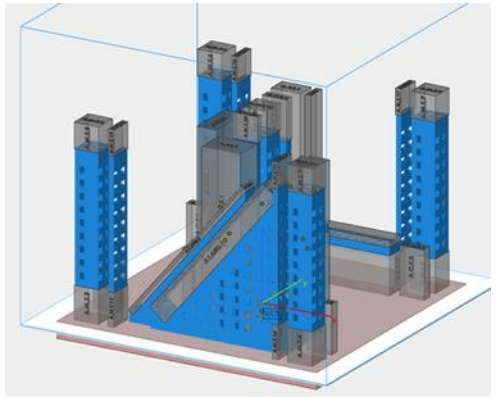
Contractor Role

- Qualify and document process
- Qualify personnel
- Qualify Pre-Production Article(s)
- Perform fabrication
- Arrange Inspection
- Deliver

Standard Qualification Build after machining

PBF vs DED

- Qualifying PBF processes requires more tensile tests
  - Effects of “where” a part of the build is is more important than “what is the heat input and cooling rate”
- Differing Qualification Variables
  - PBF machines may limit access to some parameters
- Differing Pre-Production Specimen qualifications

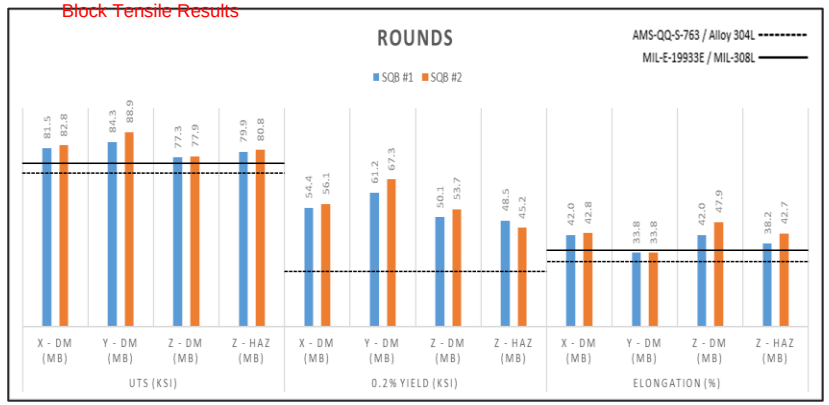


L-PBF Qualification Build configuration (one of five)

DED Standard Qualification Build

Acceptance

- Witness specimen requirements are provided, but may be increased
- Properties are accepted in the final heat-treated condition
- NDE acceptance criteria are provided, but these are not tuned to any particular safety level or any particular service condition.



Specimens and data from a Stainless Steel Qualification

Interaction with Other Standards

- Provides general requirements, so it is easy to integrate with material or industry specific requirements
  - Similar requirements documents come from NASA, ABS, and NAVSEA
  - Multiple requirements documents can be applied
  - Documents can build off D20.1 for use cases (API 20S)
- Engineer can choose inputs, materials and designs from other standards
  - SME materials specifications can be used.
  - ASME corresponding base metal approach can be used.

Example – Nickel Aluminum Bronze for Propellors

Application

- EWI is providing development support for Robotic Arc DED of propellors for eventual application at Wildcat Propellors

- Example here has two industry standards for additive manufacturing one from Navsea and one from ABS that goes beyond AWS D20.1

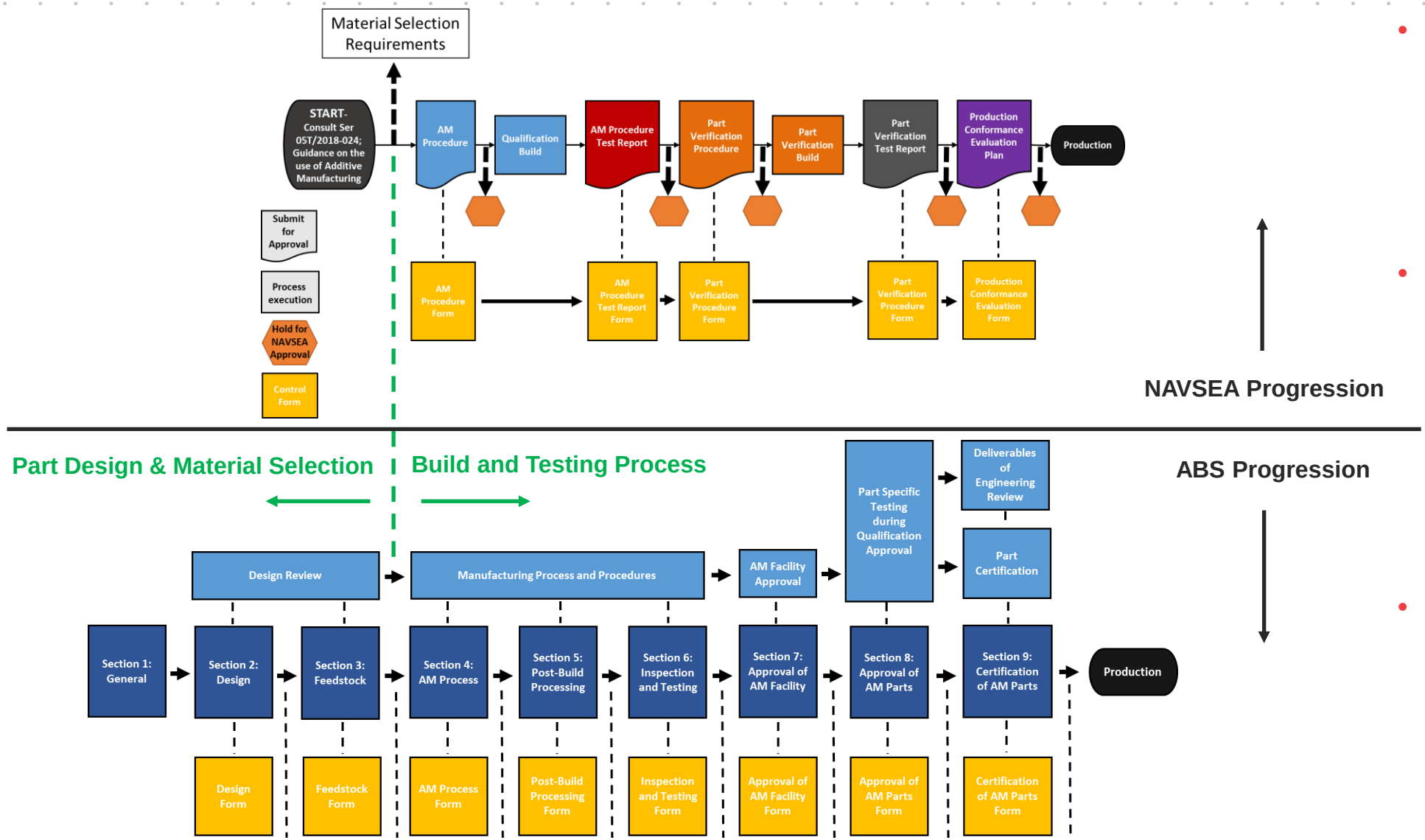
- Funding has been provided for a multi-stage effort by NSRP

- Previous funding allowed development of NAB material properties for the PQR

NAVSEA DED Specification

ABS DED Specification

Dual NAVSEA/ABS Qualification Progression



- Project goal is to get Wildcat dual certified under both NAVSEA and ABS for specific propeller.
- NAVSEA and ABS qualification progressions generally align and share main categories although not structured identically.
- The goal is to create common submission forms can be created that satisfy information required by both specifications.

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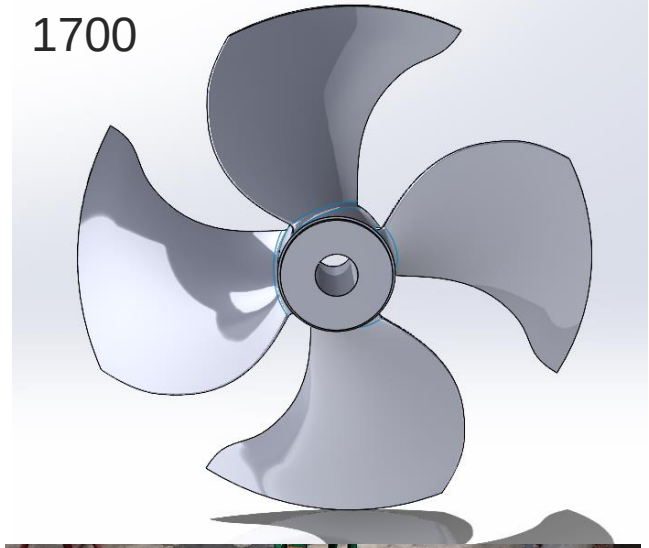
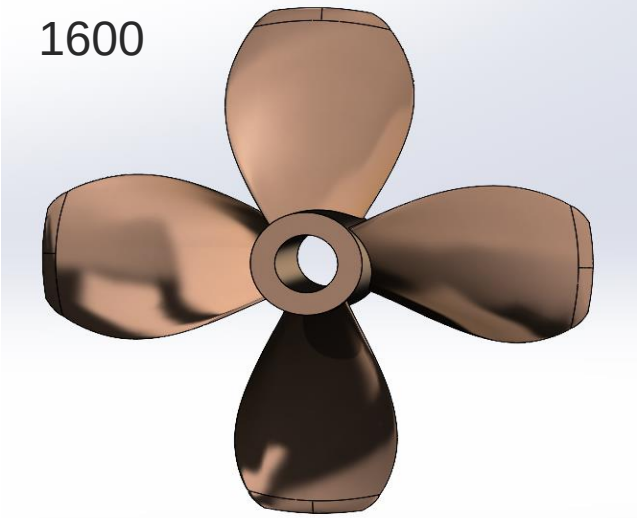
Model Designs Considered for the Gravity Aligned Propeller Blade Build and Demonstration

1700



- 1700 series and 1600 series propeller blades are both candidates
- The 1600 series is currently being used on all of the older LCU and being repaired
- The 1700 series will be the new type that will be used on all the new ships
- Opportunity to replace/repair with the 1600 model
- Opportunity to generate new castings with the 1700 model
- Pictures courtesy of Wildcat Propellers

1600



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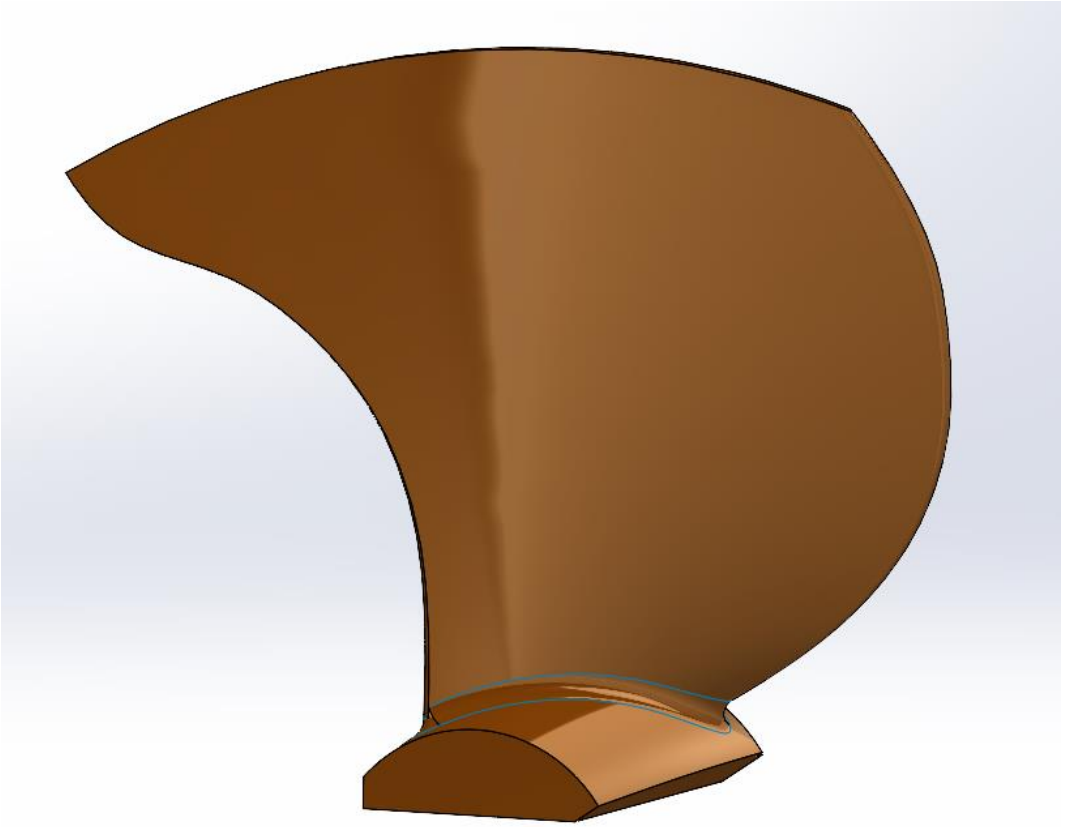
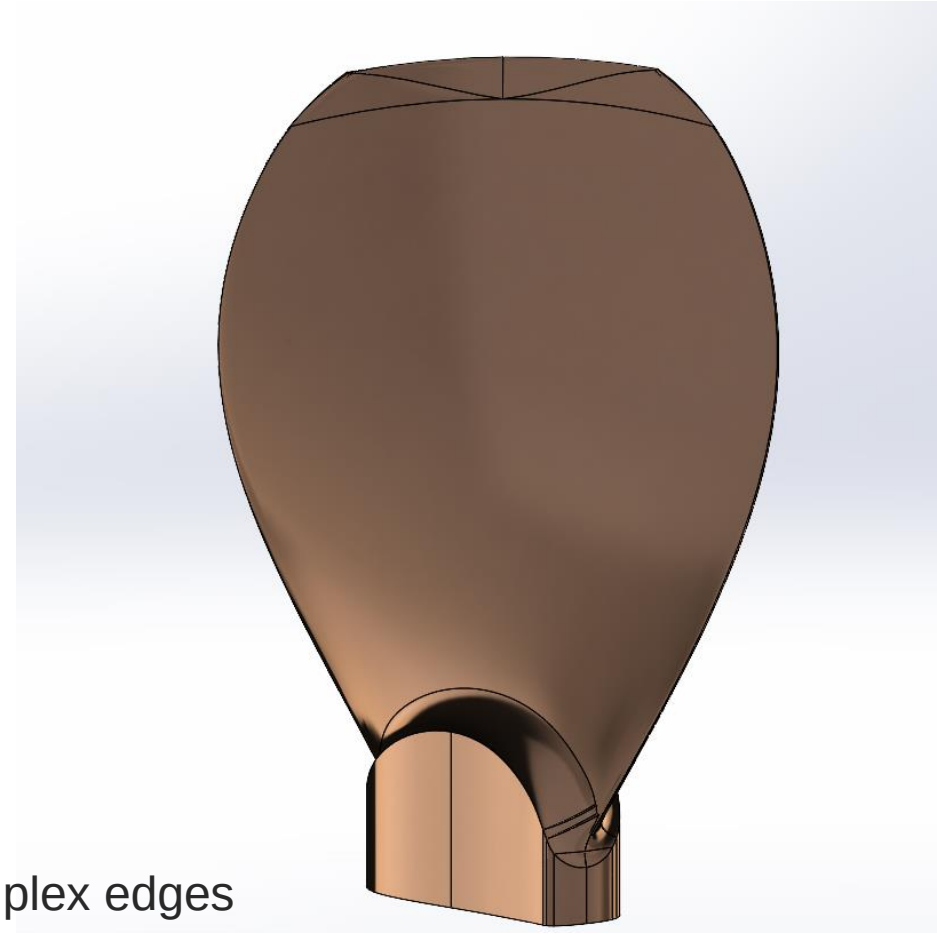
Single Blades Confirming Deposition Strategies

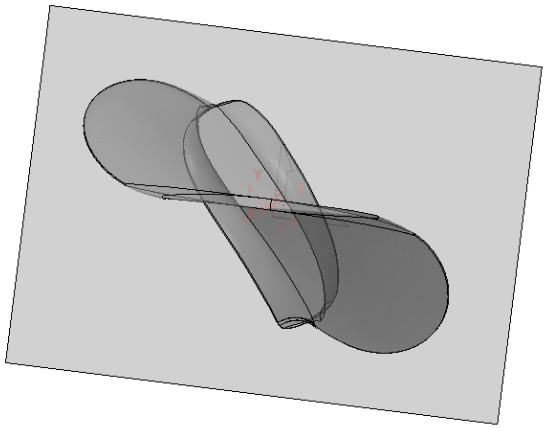


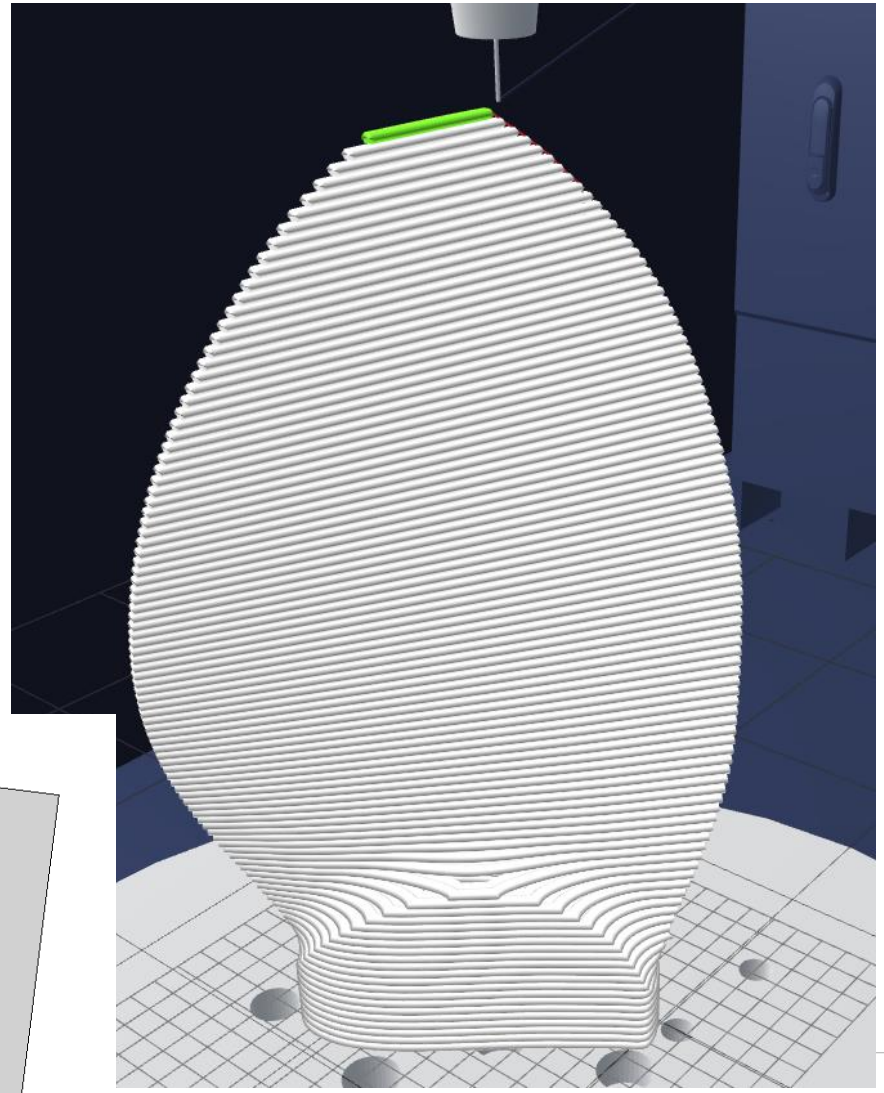


- The 1700 series is more complex with overhangs and complex edges
- EWI has started with the 1600 single blade build

Initial Scaled Half Size Gravity Aligned 1600 Propeller

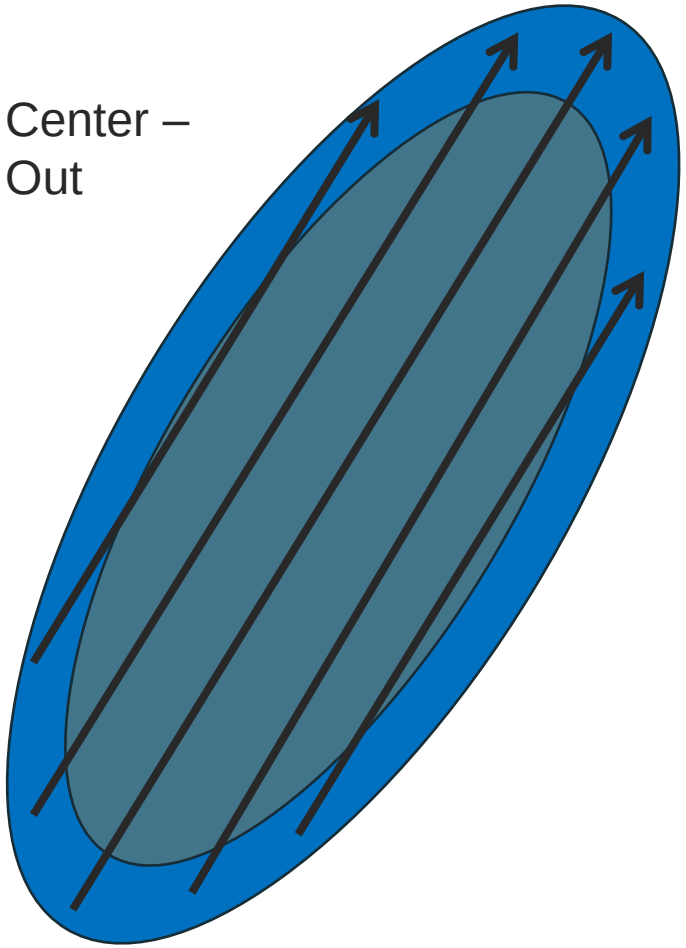
- 1600 propeller blade has been demonstrated on a system without a positioner and complex toolpathing
- The part has been scaled down to half size, and a flat hub added to build from
- The total weight of the final machined part is 4.85lbs with a volume of 46.8 cubic inches
- The as-built model was overbuilt roughly 25% of extra material stock which matches the as-cast material that WildCat Propeller receives
- Notional toolpath shown on the right with the torch aligned with gravity



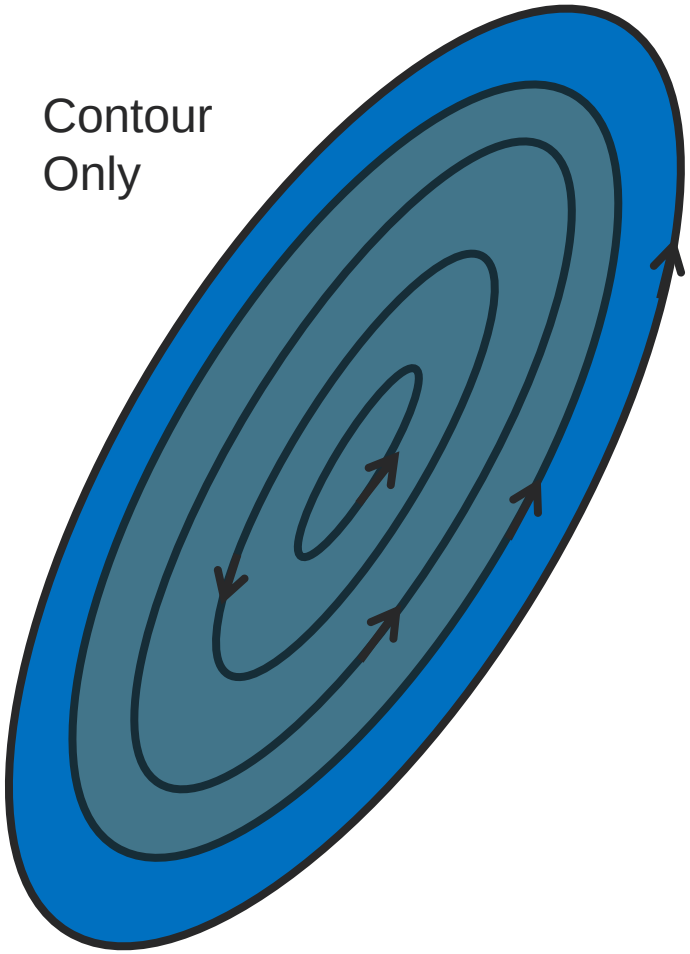


Options for Building the Propeller Blade Cross Section

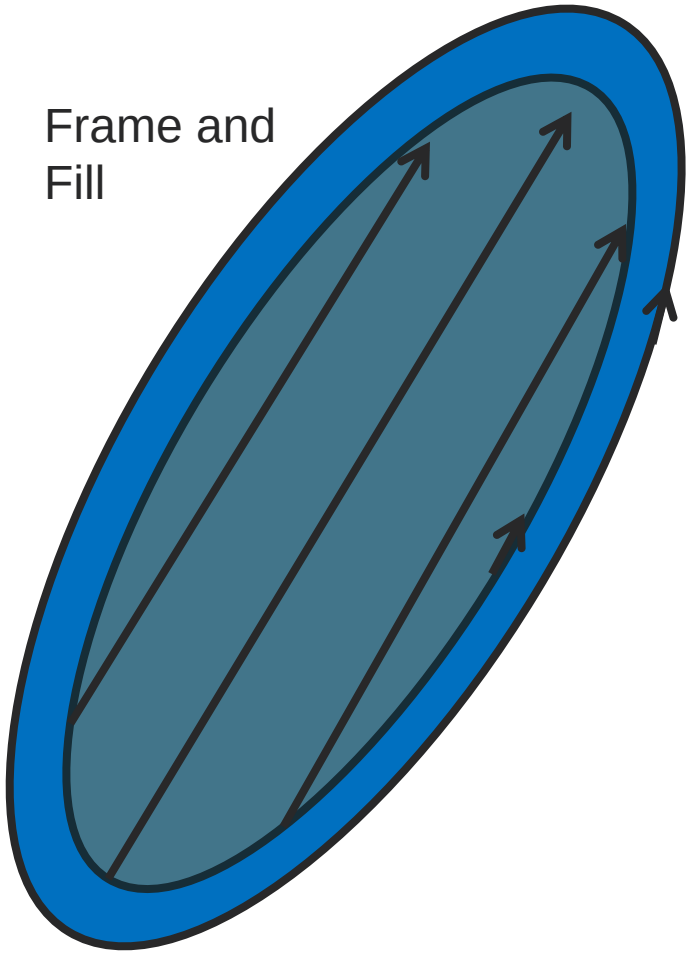
Center – Out



Contour Only



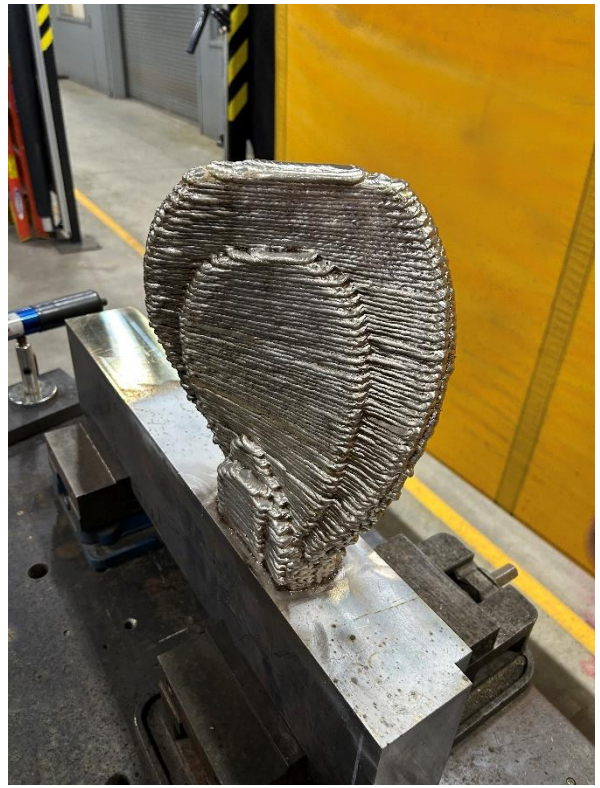
Frame and Fill



First Approach for the 1600 Model Blade

- Consider Center-Out Approach
  - Simplest path plan approach
  - Allows start/stops to be located on the edges to be machined
  - Allows ramping of parameters to promote overhang angle of complex geometry
- Transition start/stop locations along the longest length of the blade
  - Gives longest bead parameters to minimize passes per layer
- Build lower section of the “hub” as demonstration part and transition to thin section
  - Can be adjusted and/or machined down to promote starting on radial path planning

Center Out Programs Posted into Robot and Executed



- The boundaries generated are then use to generate center-out spacing at each skew along the blade
- For PowerMill, intensive manual process for each layer to generate the skews in the right direction
- The start/end termination toolpath ends on the outer boundary, ensuring overbuild of geometry

Final Build Pictures

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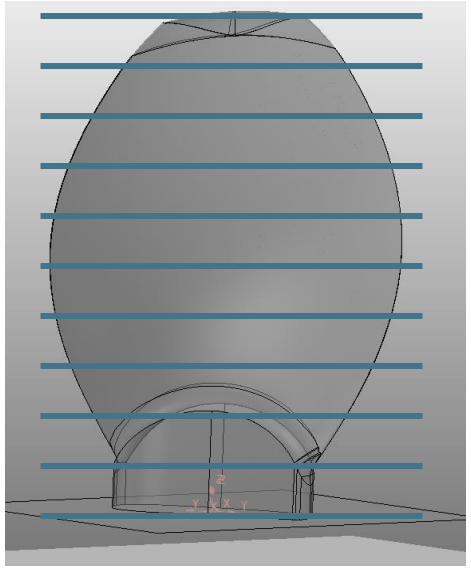
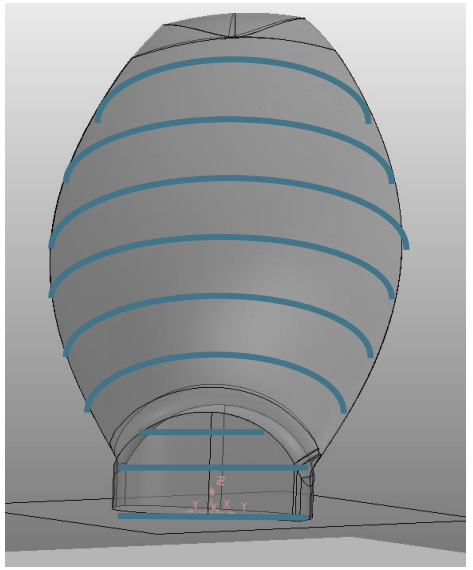
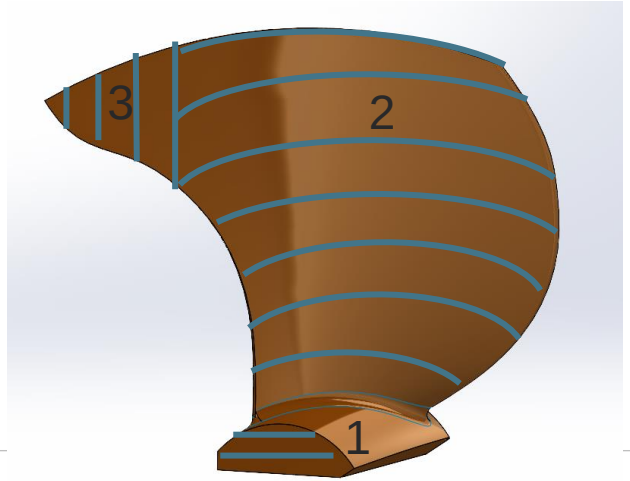
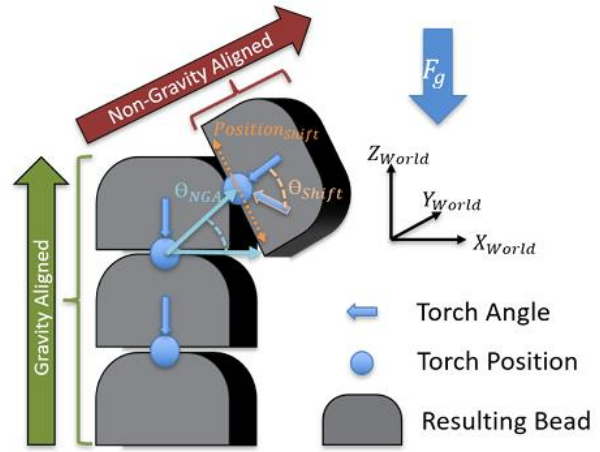
Explore More Complex Toolpath Strategies to Improve Features

- Explore other options by utilizing a part positioner to improve dimensional quality without modifying process settings
- Explore slicing/toolpath planning strategies and needs:
  - Radial Slicing and Path Planning
  - Part Segmentation for Overhangs
  - Non-Gravity Aligned Torch Orientation
- Benchmark these options against the initial build plan to maximize feature fidelity & dimensional accuracy









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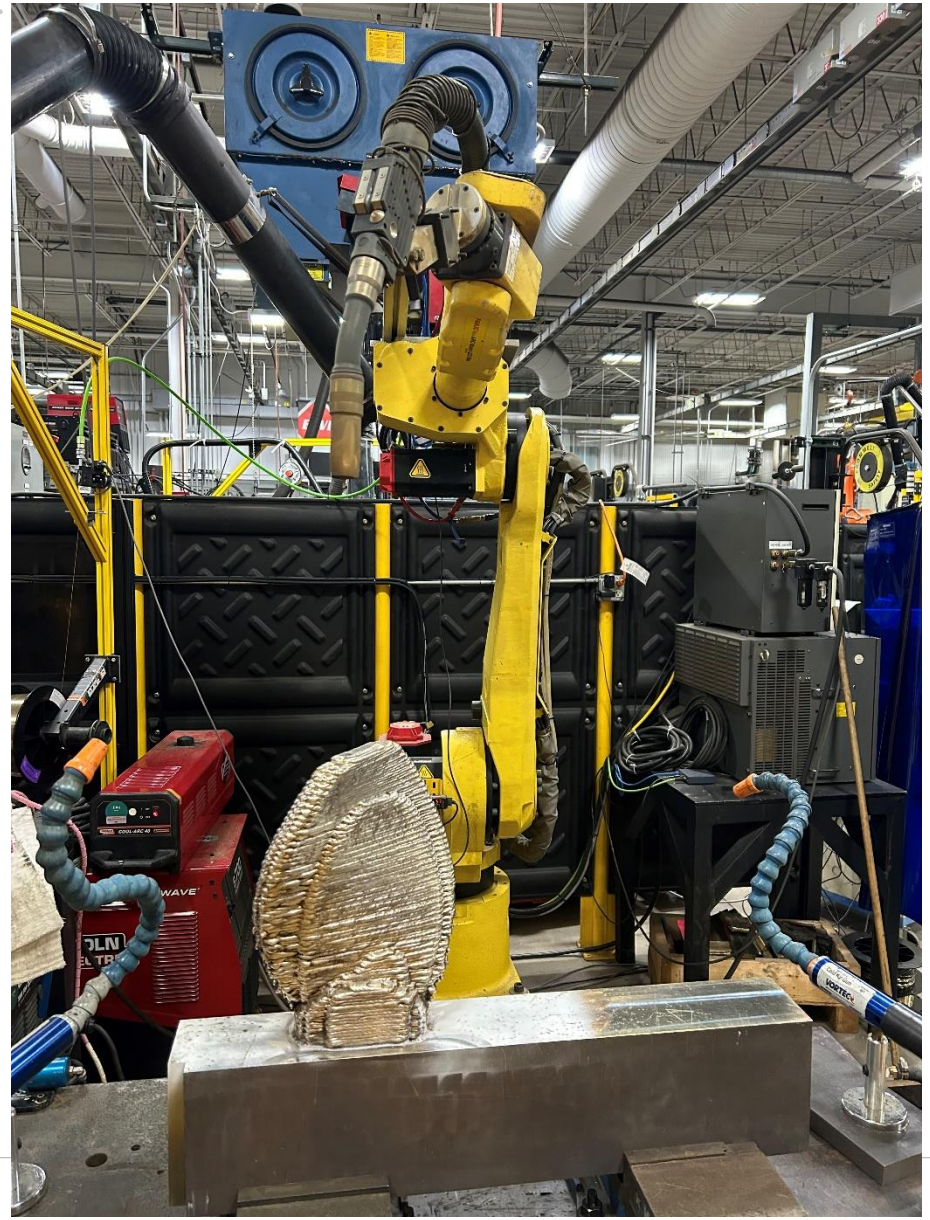
Conclusions

- AWS D20.1 provides a general framework available to all industries and metal materials
- Many specifics need to be defined by the Engineer, possibly from other standards
- A demonstration of a 1600 LCU Propeller blade out of Nickel Aluminum Bronze shows examples of the AM DED development process
- AWS is in the process of updating D20.1 to make two documents, one for powder processes and one for wire processes



Thank you for your time.

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