

# The Machine that Makes the Machine

## The Value of Additive Manufacturing for Rocket Engine Turbopumps – A Supplier’s Perspective



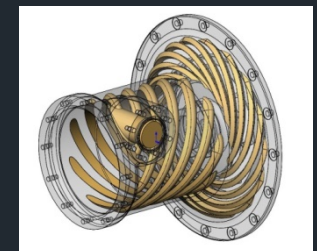
*“...the true problem, the true difficulty, and where the greatest potential is – is building the machine that makes the machine. In other words, its building the factory.” -Elon Musk, 2016*



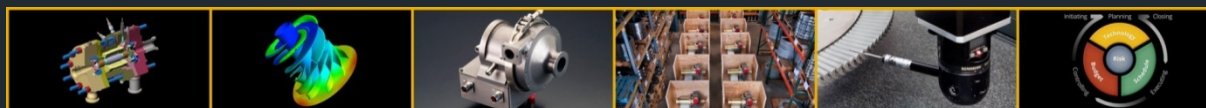
# BNI-Built Turbopumps Have Been Tested on 7 Different Engines



*For 50 years Barber-Nichols has been designing and producing specialty turbomachinery For Space Vehicles to Submarines and everything between. We are currently making production AM hardware for Rocket Engine Turbopumps*

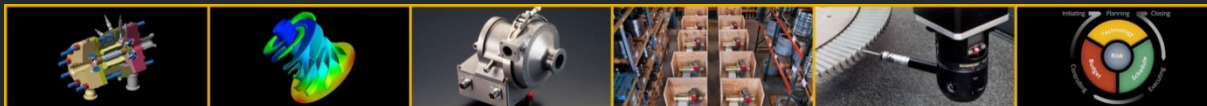


Evolution of an AM designer



## 3 Take-Aways!

- Yes! Additive Manufacturing can be used to reduce cost and schedule of rocket engine turbopump components. By up to 50%!
- It takes 5 years to evolve into an expert.
- The technology still has plenty of opportunities for maturation and growth



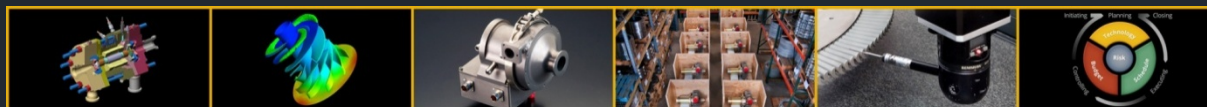
# Low Cost AM Rocket Engine Turbopump Program Goals

1. Develop a 300,000lbf LOX/LNG Turbopump using Additive Manufacturing Design Methodologies.
2. Increase the material properties data set for turbopump operating environments.
3. Compare TPA manufacturing cost and lead time versus conventional manufacturing techniques.



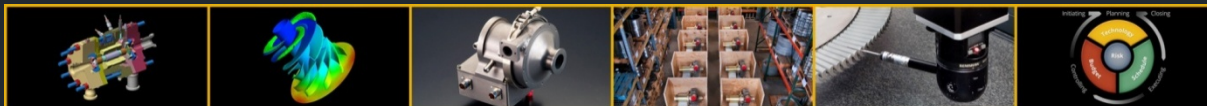
# Lessons Learned

- AM Development is similar to software development programs. Iterative.
- Part size is a factor
- Lack of Materials Properties at Operating Conditions
- Experience is a factor
- Remove as many manufacturing operations as you can. Complexity is free. Labor costs.



# Conclusions

- 1. Current AM build size limiting for 300klbf booster-class rocket engine.**
- 2. Up to a 50% reduction in component lead-time and schedule as compared with traditionally prepared components**
- 3. The whole supply chain is still evolving and will require investment to reach maturity. Process improvement and increasing automation will be the keys to further cost reductions.**



# Acknowledgements

- Air Force Space & Missile Center for funding additive manufacturing work for large-scale rocket engine turbopump applications. Specifically, Sondra Quach-Thomas, Acquisition Program Manager, for the constant review and clear direction for this program.
- Many thanks to the extended Northrop Grumman Aerospace Systems, NASA Marshall Turbomachinery Group, and Concepts NREC team for their dedicated contribution of time, open communication and sacrifice to move the Additive TPA program forward.
- To our AM Vender Partners for their collaborative spirit and perseverance in pushing the boundaries of their experience.
- Our sincerest appreciation for our United Launch Alliance and Virgin Orbit partners who have put there trust in us and for allowing us to discuss some of their amazing work.

