Replacing Long Lead Time Forgings with Directed Energy Built Components

William Evans, Christopher Protz

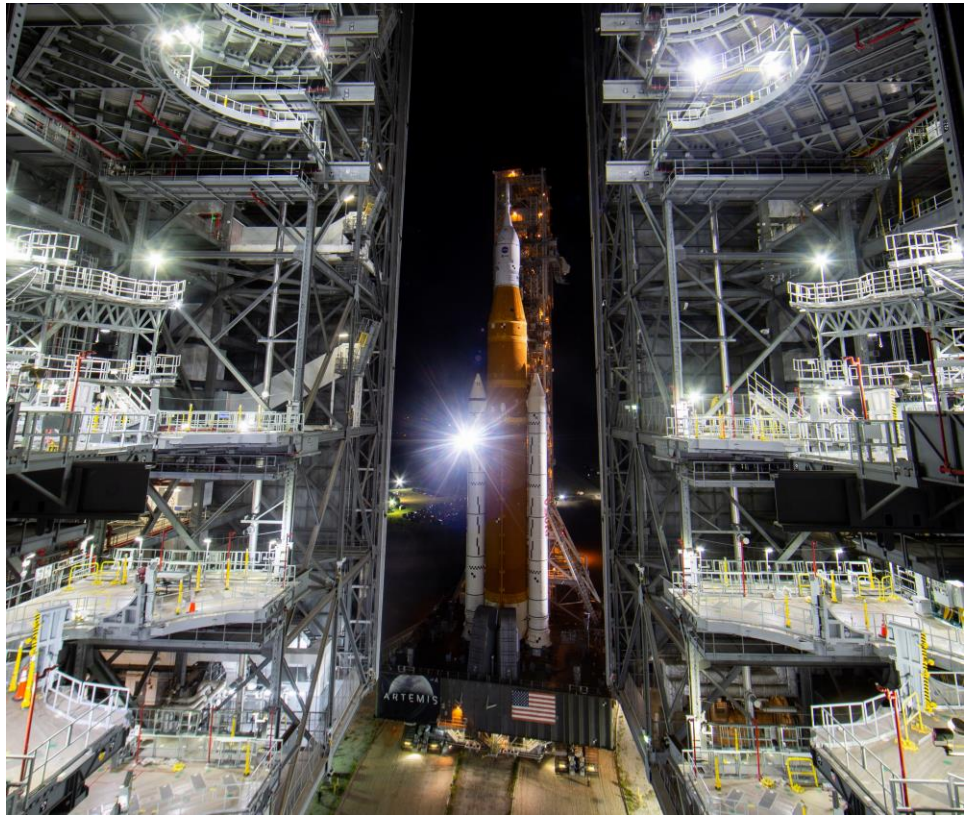
NASA / Marshall Space Flight Center

Welding and Manufacturing – EM32



Agenda

- **Introductions**
- **Background – DED at NASA**
- **Forging Replacement Overview**
- **NASA Partnership Case Studies**
  - Aluminum Ring Forgings – Cryo Fuel Tanks
  - Aluminum Iso-Grid Demo – Vehicle Structures
  - Steel Ring Forgings – Solid Rocket Motors
- **Conclusions**
- **Acknowledgments**



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Introduction – William Evans, Welding Engineer





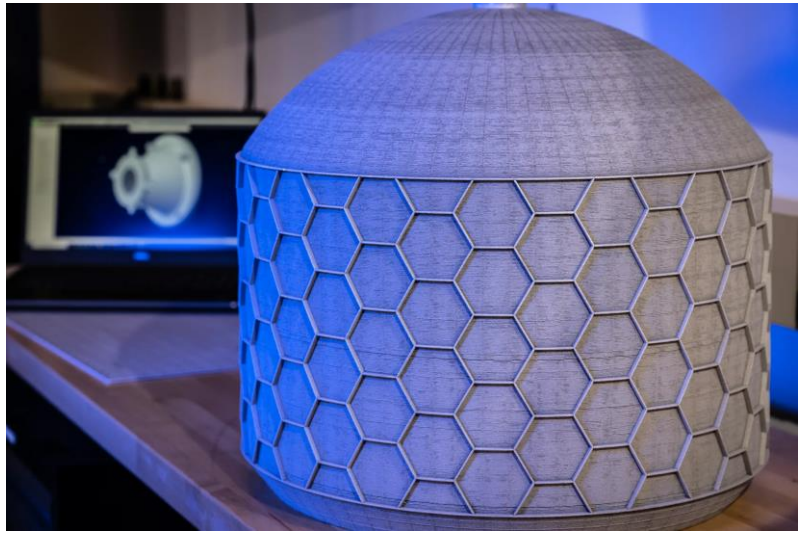


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DED at NASA













Forging Replacement Overview

- **Large forgings are often leading drivers for coast and schedule for launch vehicles**
- **Easy concept, use DED/Freeform AM to produce large components at a reduced cost and schedule**
  - Not an easy task…
- **Many programs may not need reduction in component costs, however AM also allows for rapid fabrication and development/testing**
  - Schedule is often equal to cost for some programs
- **DED material is often an unknown for spaceflight programs**
  - Little to no allowables data
  - Fracture data is uncommon
  - Post build processing is difficult
  - Large DED systems are expensive



Forging Replacement Opportunities









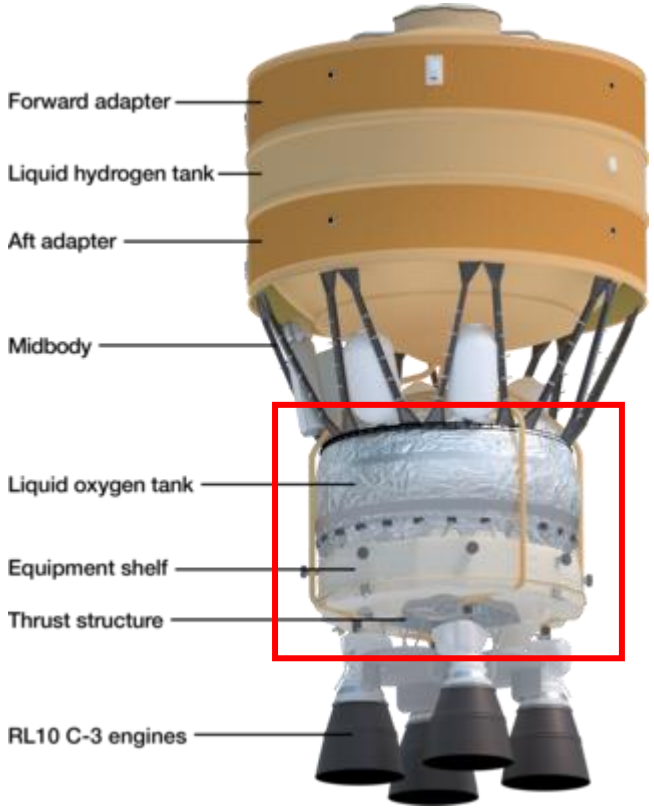


NASA Partnerships Case Studies

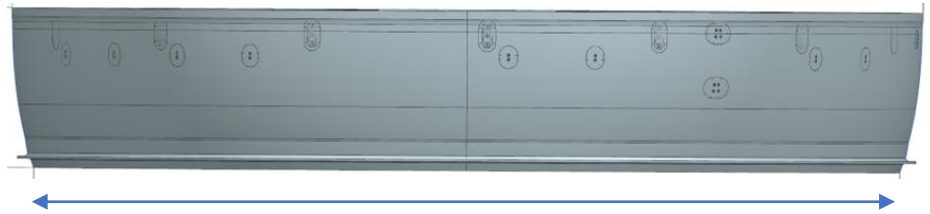
Funded 2022-2023

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Aluminum Ring Forging – Case Study (Overview)





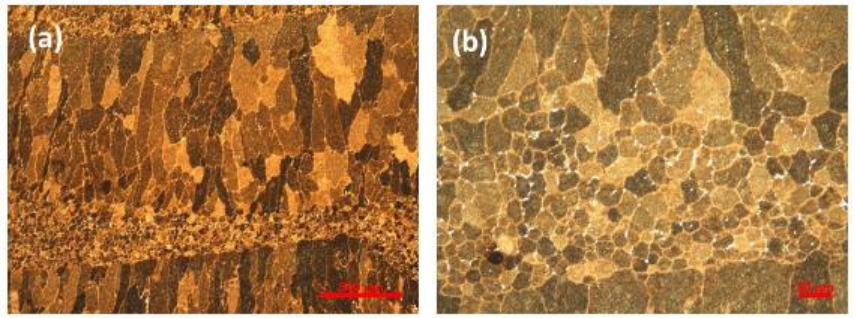


LOX Tank Y-Ring

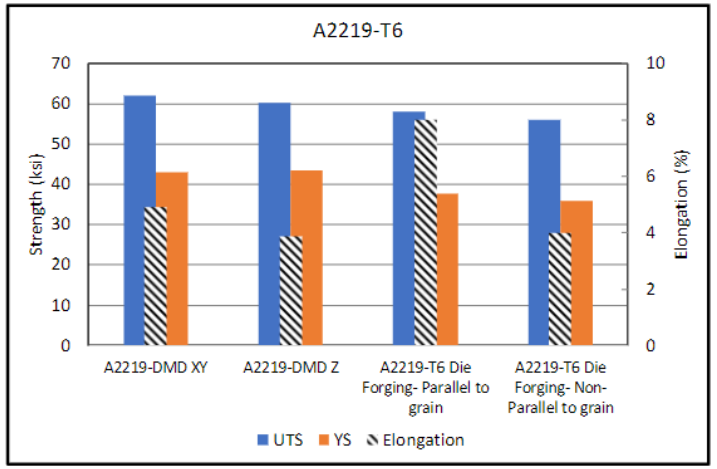
~ 18’ diameter

Aluminum Ring Forging – Case Study (Development)

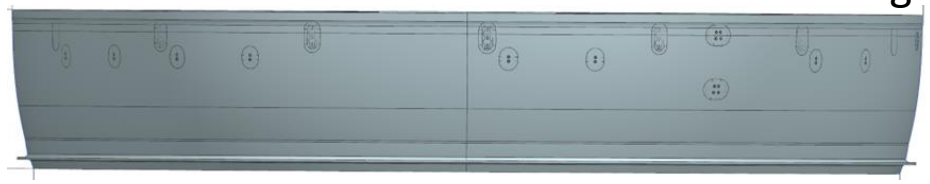
- **Under NASA's Cooperative Agreement Notice (CAN) MSFC Partnered with DM3D to develop aluminum BP-DED for large scale forgings**
  - Funding Split 50:50 for this program
- **Three aluminum alloys were selected for investigation and testing**
  - AA2219
  - AA2195
  - Scalmalloy
- **The final goal was to print a ¼ scale Y-ring demonstration article using BP-DED**
- **AA 2219 exhibited the best response to the BP-DED process**
  - Based on printability, mechanical testing, metallography, heat treat response



Example Microstructure of AA2219 resulting from BP-DED



LOX Tank Y-Ring



~ 18' diameter

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Aluminum Ring Forging – Case Study (End Result)



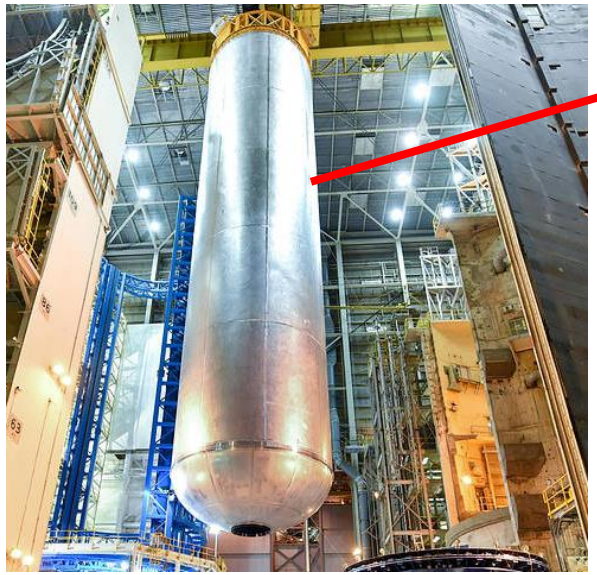




¼ Scale Y-Ring Completed August 2023!

Aluminum ISO-Grid Panels – Case Study (Overview)

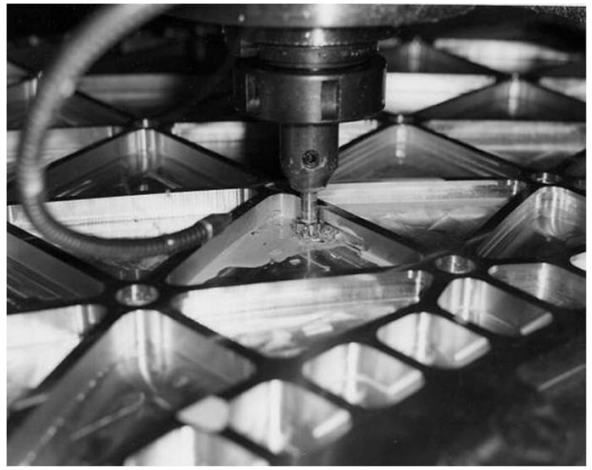








- Gridded panel structure are very time consuming to produce
- These panels have a very high buy to fly ratio
- Can DED be leveraged to conserve materials and time?

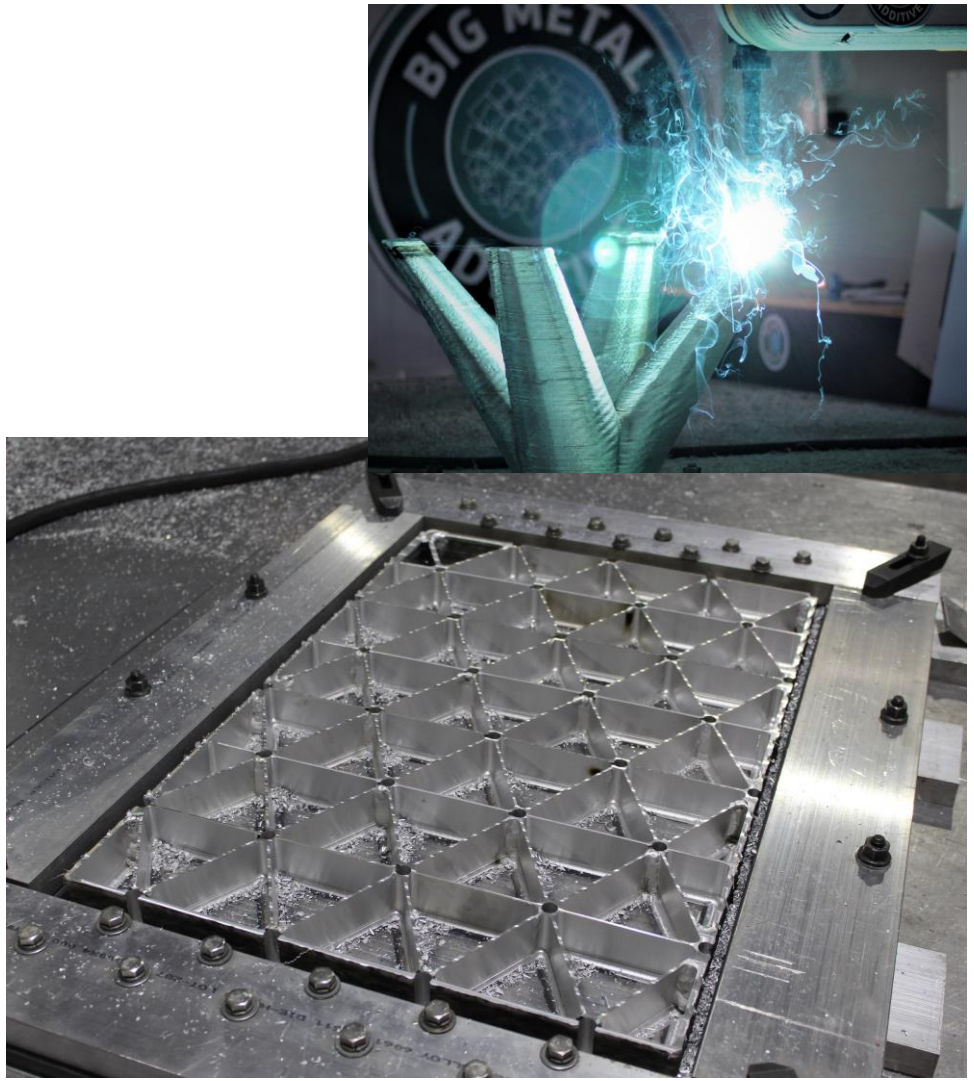


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Aluminum ISO-Grid Panels – Case Study (Development)

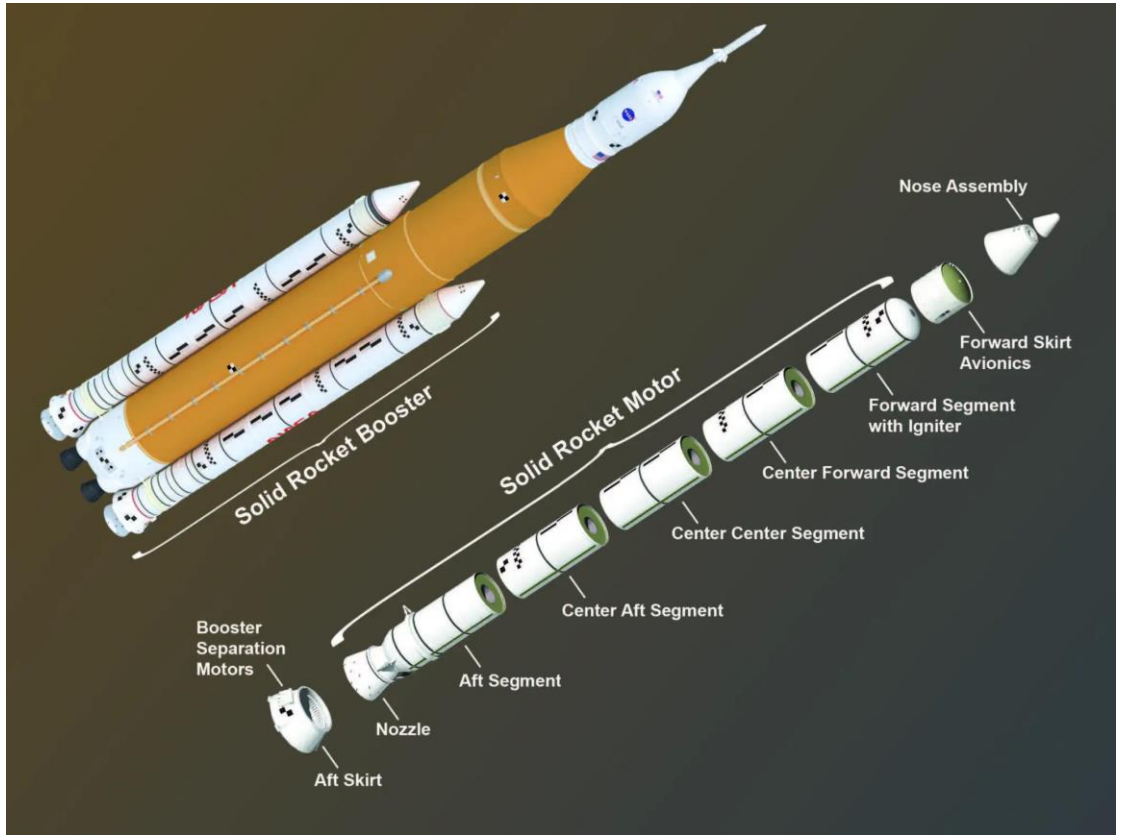
- **Under NASA's CAN Program MSFC Partnered with Big Metal Additive (BMA) to investigate using hybrid DED to produce Gridded Panels**
  - Funding Split 50:50 for this program
- **Material used for investigation was AA 2319**
- **End Goal is to compare mechanical properties of traditionally machined panels to hybrid DED built panels**
- **Three panel conditions are under invetigaiton**
  - Tranditionally machined
  - Hybrid-AM with legacy iso-grid design
  - Hybrid-AM with optimized design

Work is ongoing, testing at MSFC slated for FY24.

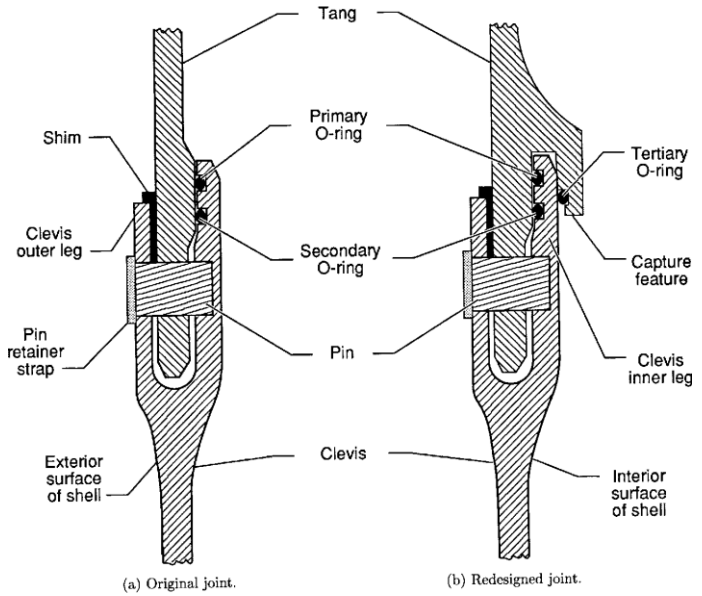


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Solid Rocket Booster Segment Ring – Case Study (Overview)



- **Each booster segment is joined by a steel tang ring, shaped similar to a tuning fork**
- **Rings are one large forging with long machining times and a high buy to fly ratio**



Space Shuttle Booster
Tang Ring Connection

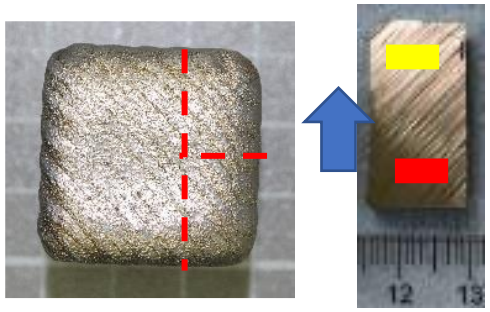
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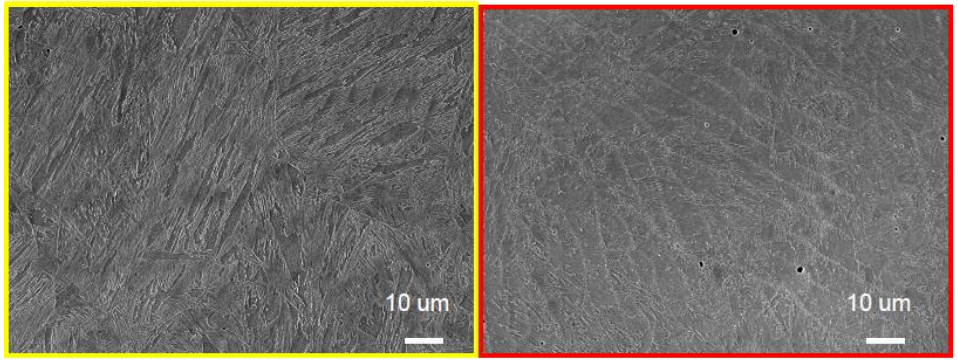
Solid Rocket Booster Segment Ring – Case Study (Development)

- **Under NASA's Small Business Innovation Research (SBIR) program the SLS Booster office funded two projects to investigate using DED to produce Tang Rings**
- **DM3D was awarded a Phase III SBIR to produce a pathfinder article using traditional D6AC steel**
  - D6AC has been known to be hard to process
- **QuesTek Innovations was awarded a Phase II SBIR to investigate developing a steel powder with similar properties to D6AC with improved processing response**
  - Goal being a printable high strength steel for future production of bulk DED component fabrication



Projects are still ongoing, slated to wrap January 2024. Ring fabrication is ongoing as well as alloy validation/testing.





Example microstructure from QT's new alloy

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Conclusions

- **NASA MSFC is leading investigations into large forging replacement utilizing large scale DED for launch vehicle applications**
- **Large scale aluminum using BP-DED shows great promise for forging applications**
  - Many benefits have been observed
- **Aluminum Alloy 2219 exhibits great printability when used in powder form**
  - Wire form is 2319, which also shows great promise
- **Hybrid DED processes can be leveraged for producing iso/ortho-grid structures for structural stiffening, observed in aluminum 2319**
  - In-situ machining can greatly streamline panel production while saving material
- **DED processes have been shown to be good contenders for large buy to fly ratio forgings, in the case of the high strength steel rings a major reduction in machining time has been observed when compared to deposition rate**
- **Additional developments are needed to fully vet out large-scale DED for flight component production**
  - Future work includes, fracture testing, heat treatment analysis, large scale article cut ups

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Acknowledgements

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- Thank you to our industry partners for supplying images and aiding in developing these processes
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Questions?

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