GRX-810 Processing and Component Applications

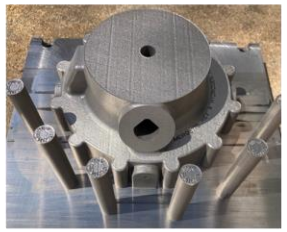
Paul Gradl[1], Timothy M. Smith[2]
[1]NASA Marshall Space Flight Center
[2]NASA Glenn Research Center

26 February 2025

Maturity of Metal AM for Space Applications

Successful Hot-fire Testing of GRX-810

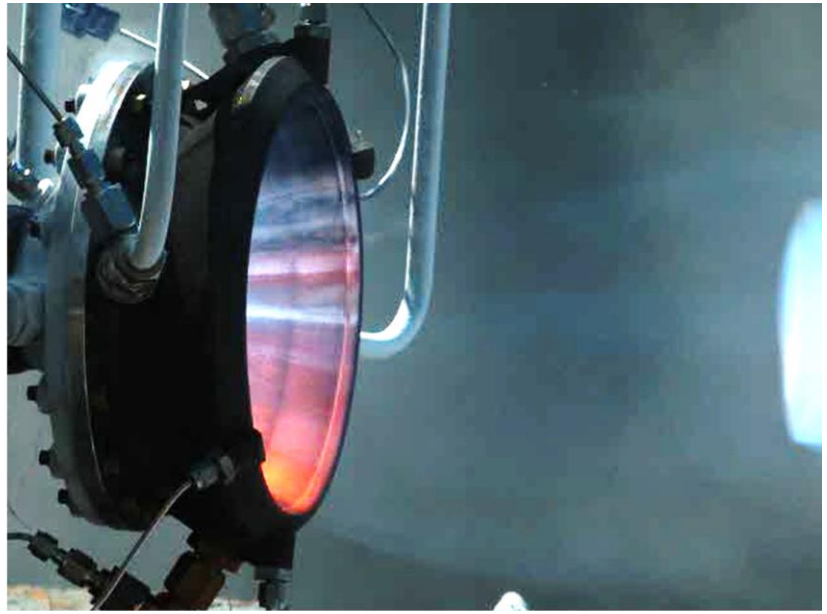
- GRX-810 is actively used for liquid rocket engine various injectors and channel-cooled nozzles L-PBF manufacturing and testing
  - Rotating detonation rocket engines
  - Lander development engines
- Propellants: LOX/LH2 and LOX/LCH4
  - Chamber Pressure ~750 psig (52 bar)
  - LOX/LH2 Mixture Ratio = 5.3 – 7.0
  - LOX/LCH4 Mixture Ratio = 2.7 – 3.6
- Demonstrate successful component fabrication process
- Challenge material at elevated temperatures at MSFC TS115
- Increase TRL from 3 → 5

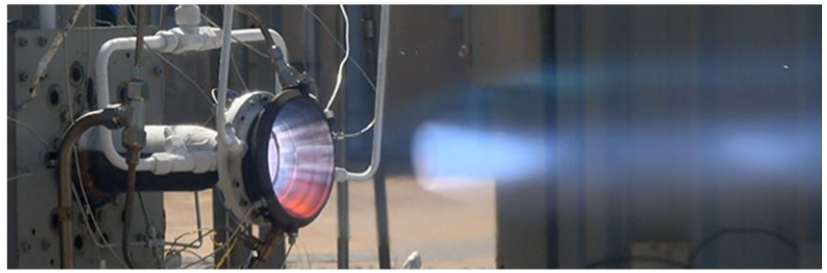


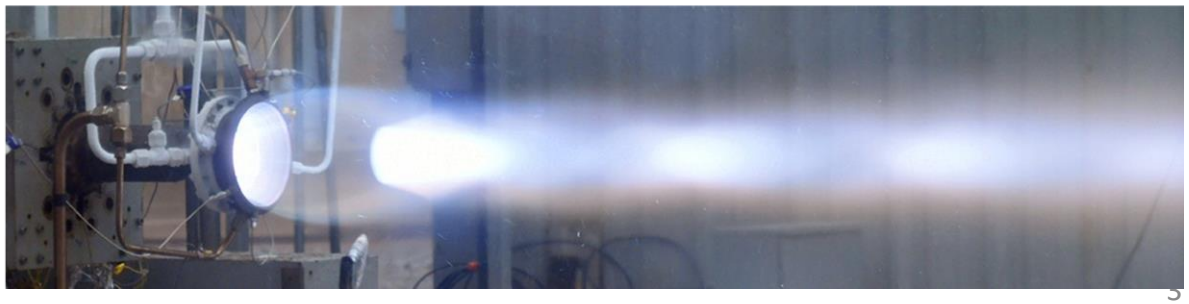
Injector

As-Built Nozzle

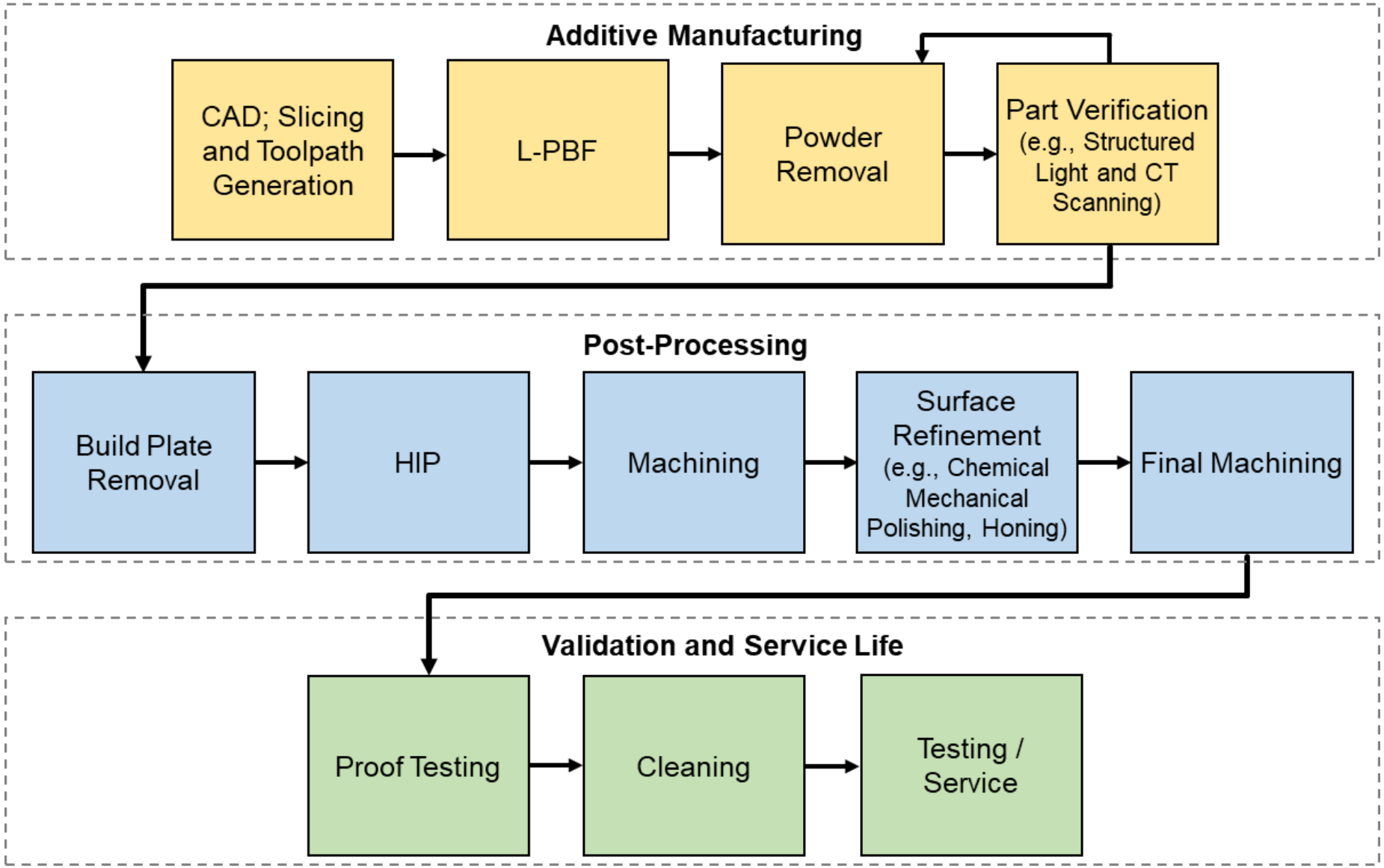
Post-HIP Nozzle



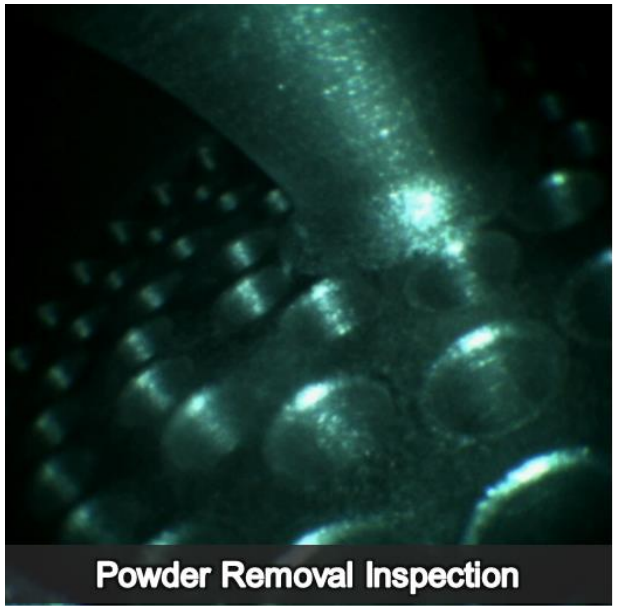




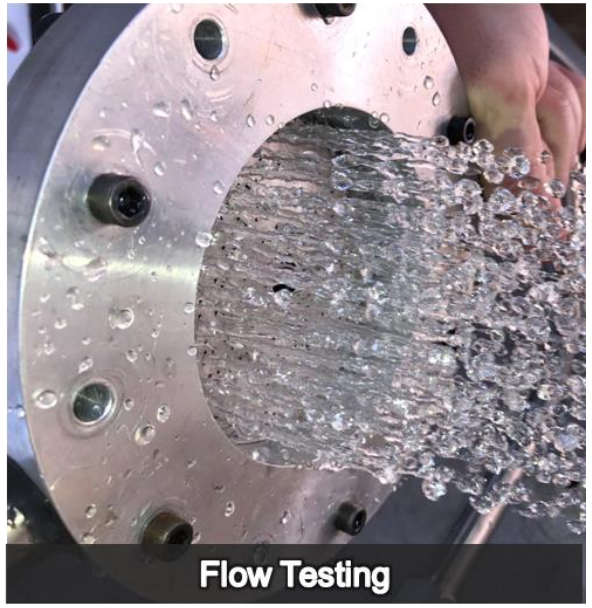
Typical Process Flow of GRX-810 Hardware

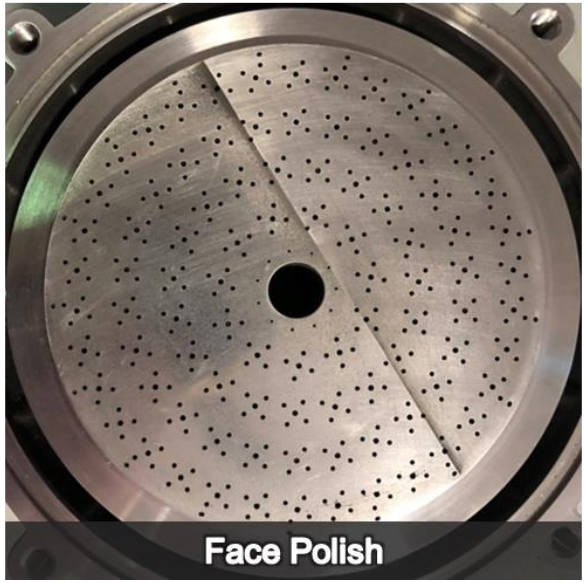


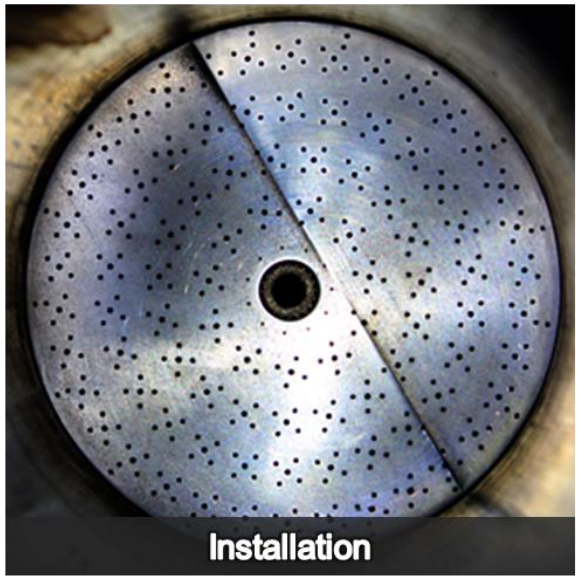
Typical Process Flow of GRX-810 Hardware


Powder Removal Inspection

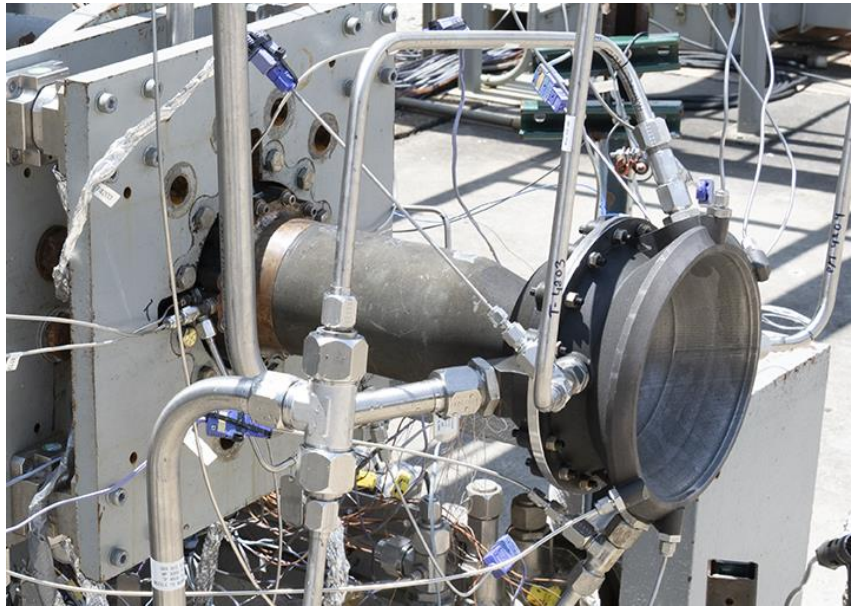

Post-HIP

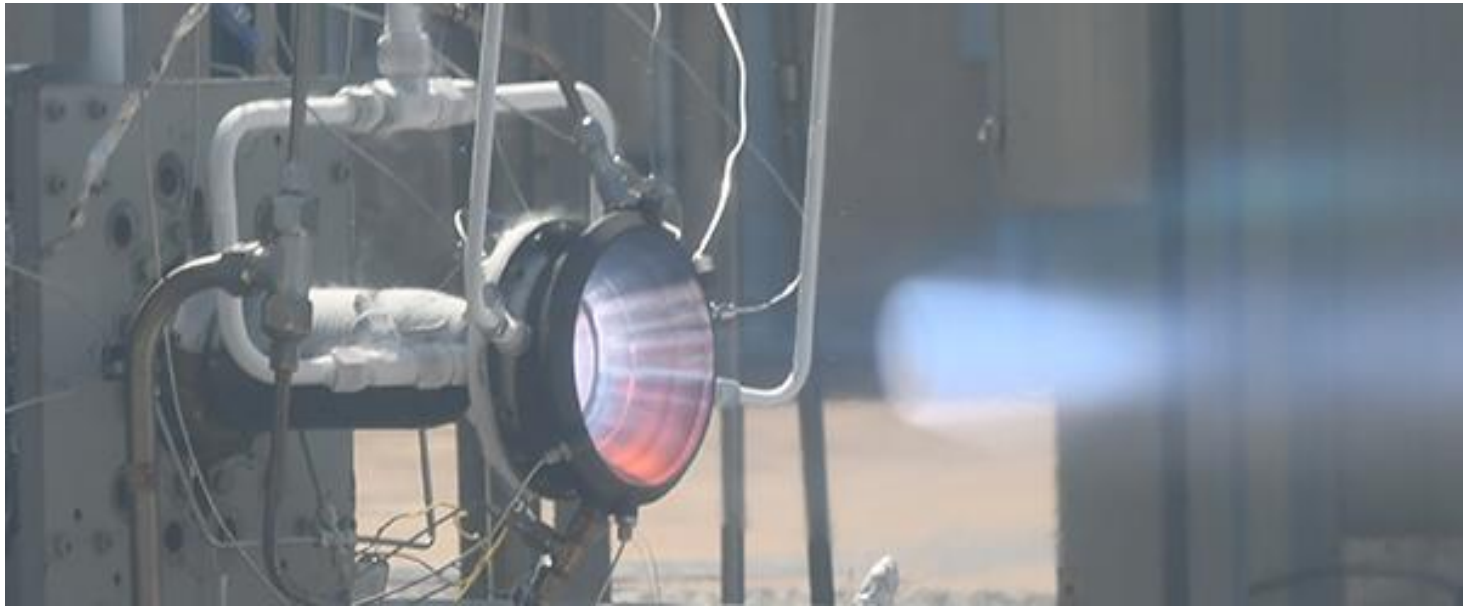

Flow Testing


Face Polish


Installation

Hot-fire Testing of L-PBF GRX-810 Injector and Nozzle

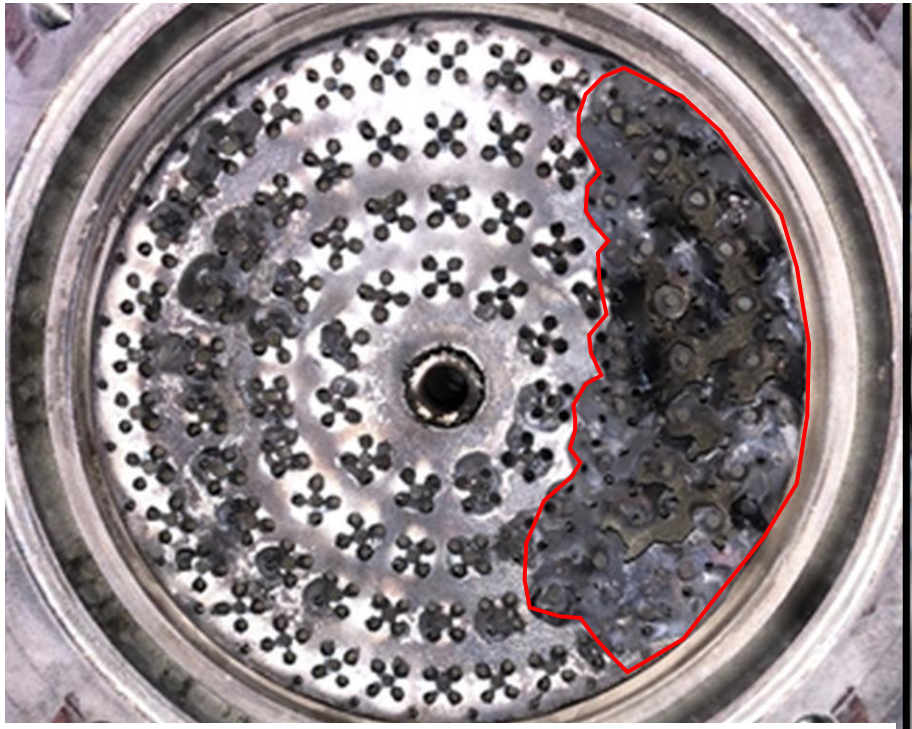




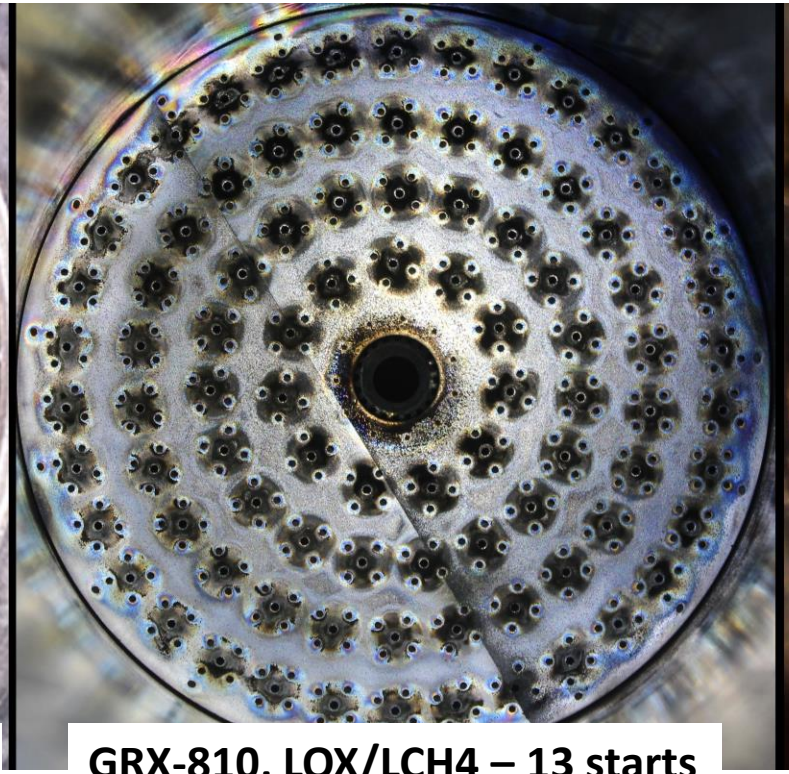
Component (-)		Starts (-)	Duration (s)	Pc (bar)	Pc (psia)	MR (-)
H2 Injector	SN01	9	302.8	49.5 - 57.2	718 - 829	5.33 - 7.02
CH4 Injector	SN02	29	586.5	37.4 - 52.4	542 - 760	3.03 - 3.65
CH4 Injector	SN03	84	2,227.9	43.2 - 52.1	626 - 756	2.68 - 3.19
Nozzle	SN04	91	2,309.4	37.4 - 52.1	542 - 756	2.68 - 3.11
Nozzle	SN05	8	149.1	49.0 - 50.5	711 - 732	3.00 - 3.19

Injector Test Results

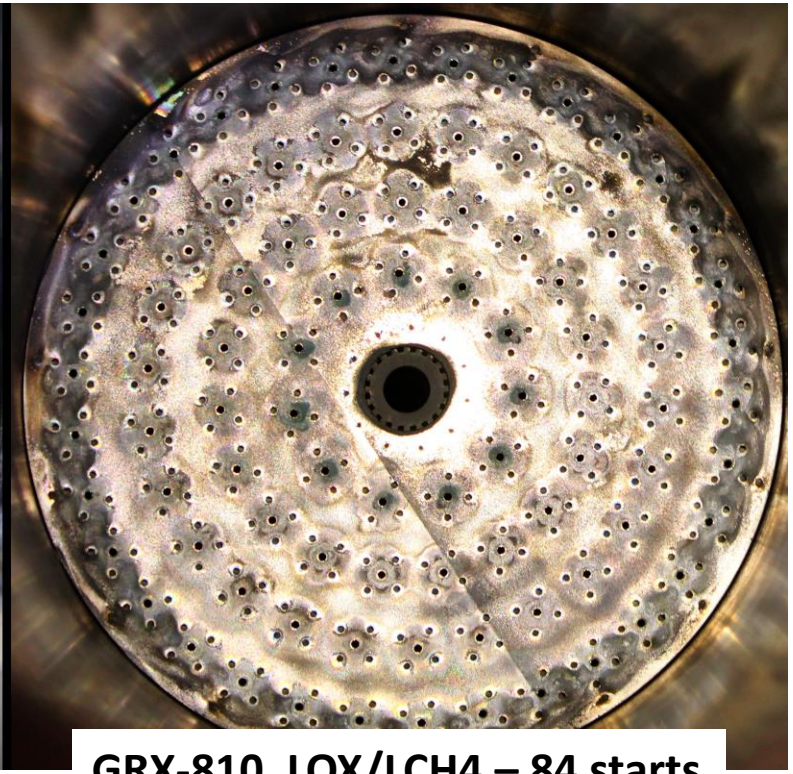
- GRX-810 Injector A achieved 84 starts and 2,228 sec (LOX/LCH4)
  - Demonstrated greater life than Inconel 625/718 equivalent
- GRX-810 Injector B achieved 30 starts and 591 sec (LOX/LCH4)
- GRX-810 Injector C achieved 9 starts and 303 sec (LOX/LH2)



Inconel 625 Injector after 10 starts (Erosion)



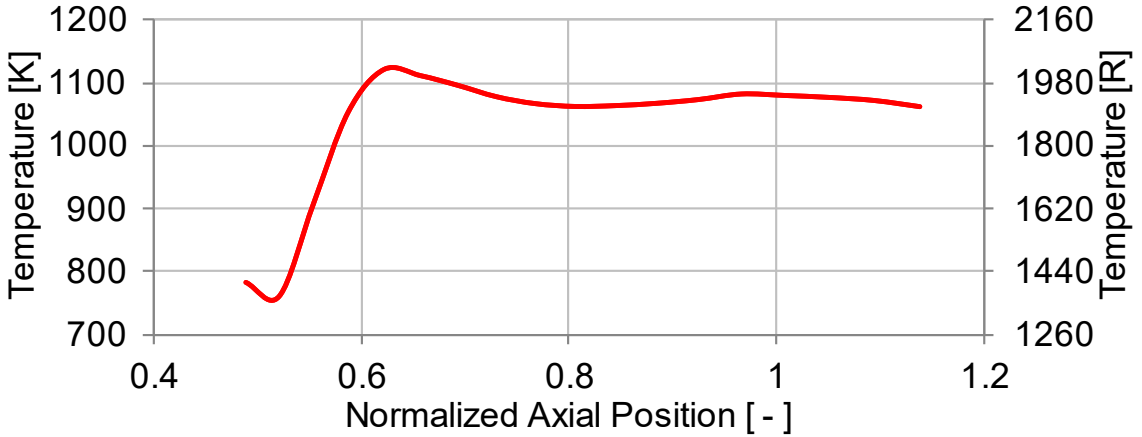
GRX-810, LOX/LCH4 – 13 starts

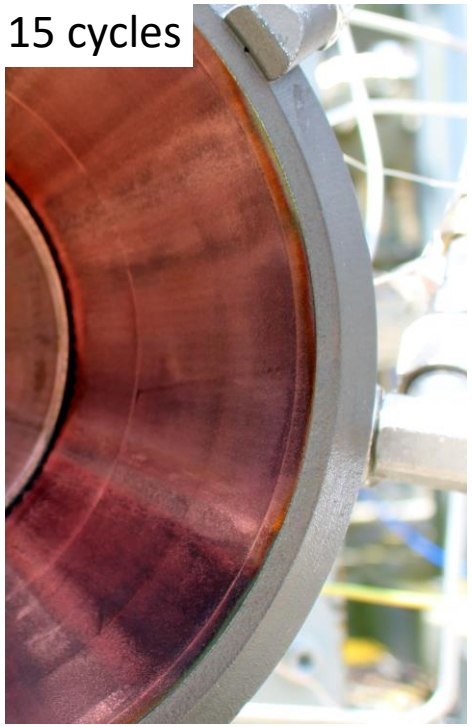


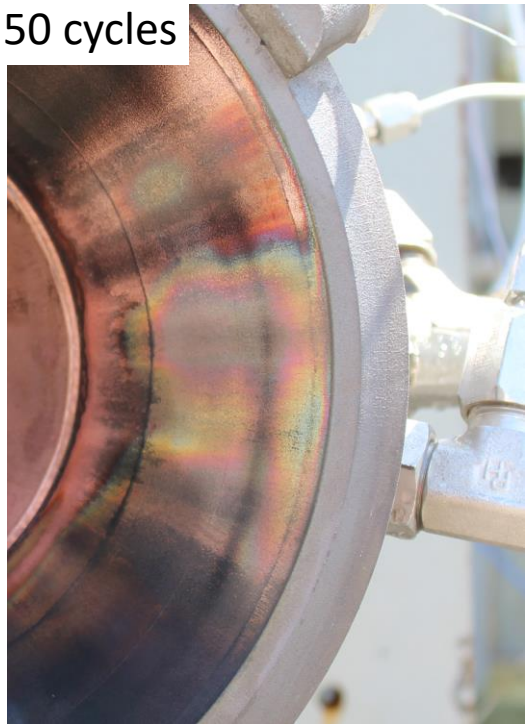
GRX-810, LOX/LCH4 – 84 starts

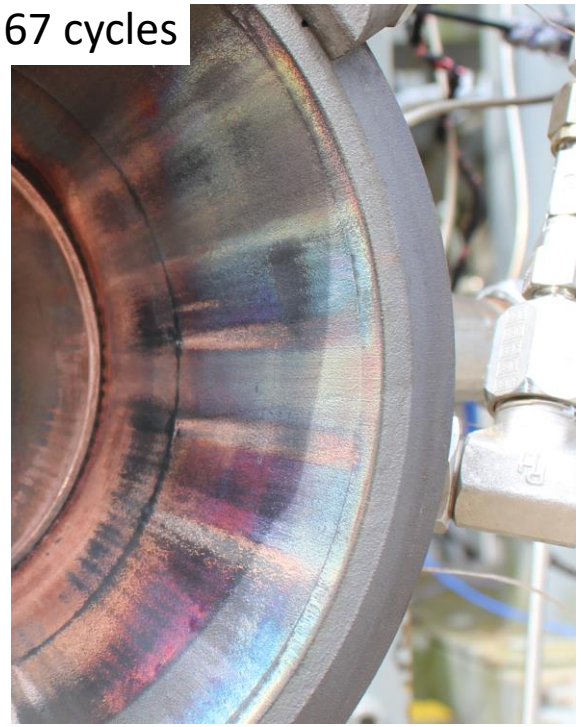
GRX-810 Nozzle Test Results

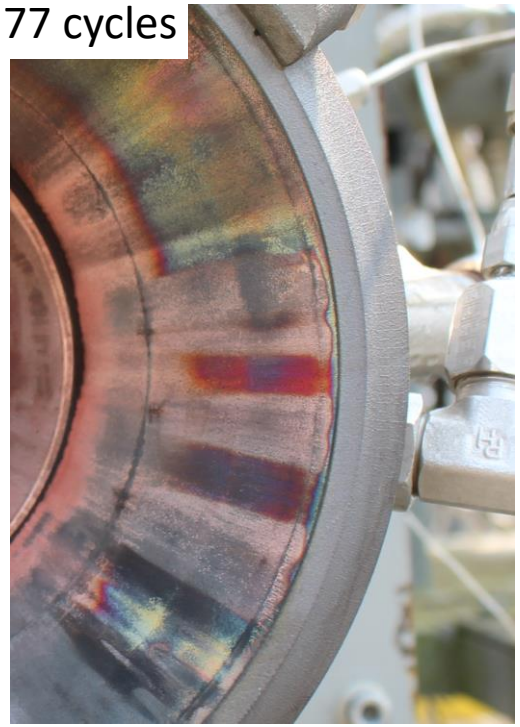
- Regeneratively-cooled (LCH4) nozzle accumulated 90 starts and 2,309 seconds.
- Local wall temperature >1,000°C











Hot-fire Testing

L-PBF GRX-810 Component Examples

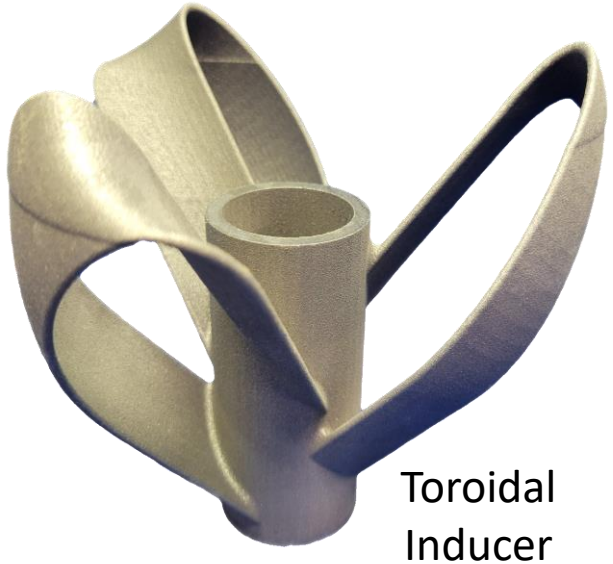
Turbine Blisk Demo

Shrouded Blisk

Inducer with flow passages

Pentad Injector

Toroidal Inducer

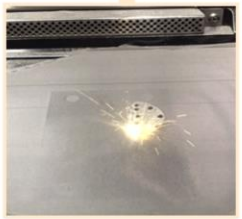


Regen Nozzle

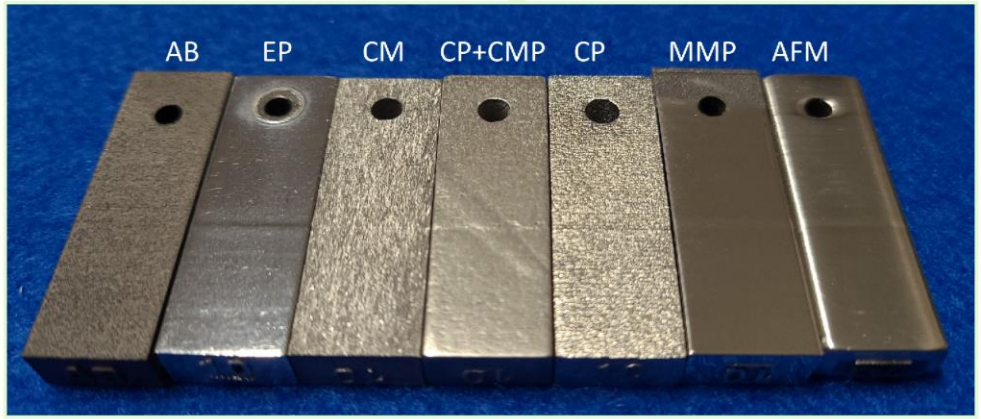
Turbine Blade with integral instrumentation ports

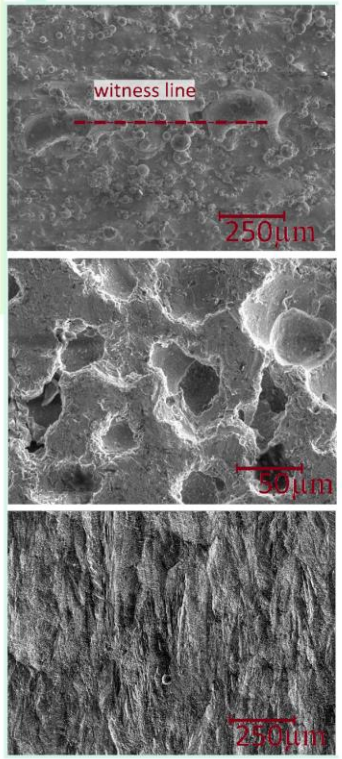
GRX-810 Surface Enhancement Development

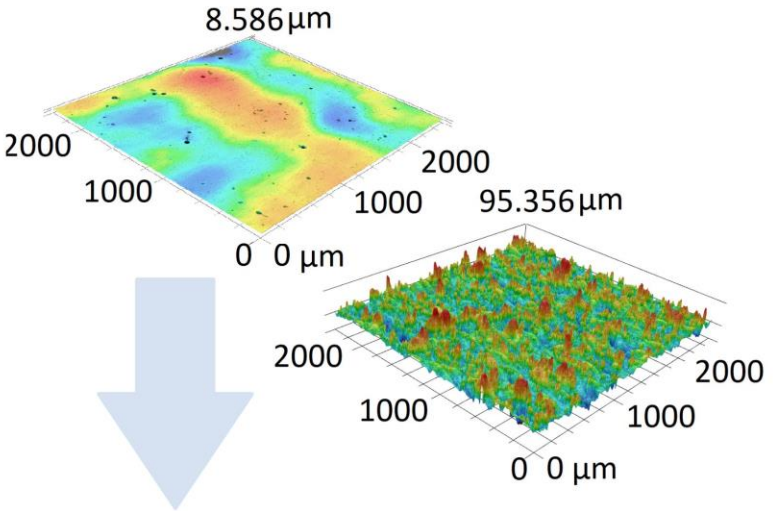
L-PBF GRX-810 → Post-Process → SEM → Surface Texture

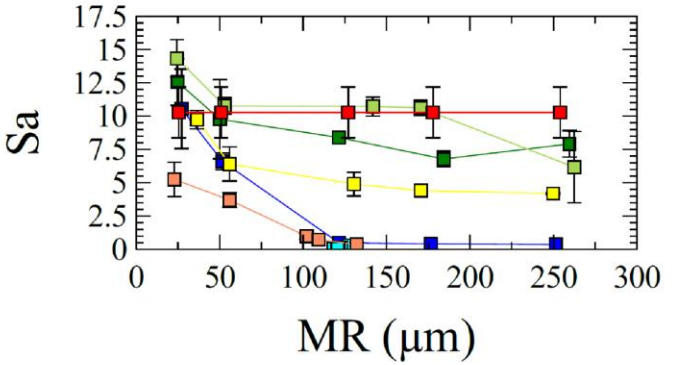


AB: As built
EP: Electropolish
CM: Chem Milling
CMP: Chemical mechanical polish
CP: Chem Polish
MMP: Micro-milling
AFH: Abrasive flow honing









Ongoing NASA and Supply Chain Development

- Material property testing to mature publicly accessible mechanical and thermophysical data
  - Tensile and fatigue
  - Bulk properties and thin-wall studies
  - Elevated temperatures approaching 1300°C
  - Fracture toughness and crack growth
  - Oxidation studies
- Process capability geometric variations
- Process build interruption studies
- Surface enhancements and polishing
- Hot isostatic pressing (HIP) studies
- Weldability trials
- Machinability trials
- Powder recycling studies
- Powder qualification procedures
- Evaluation of laser powder directed energy deposition (LP-DED)

Summary and Future Work

- Demonstrated successful formulation, powder processing and coating, microstructure characterization, mechanical properties, component development and hot-fire testing of GRX-810 alloy.
- Successful scale up to large-scale platform and properties.
- Elevated temperature tensile (1100°C) is 2x Alloy 718.
- 1,000x improved creep rupture compared to Ni-based superalloys.
- Demonstrated successful injectors and nozzle L-PBF builds, processing, and hot-fire testing.
- Accumulated significant time and starts in actual engine conditions, increased TRL = 5