



# Thermomechanical Fatigue, Sulfidation and High Cycle Fatigue of JT3D Engine Turbine Blade

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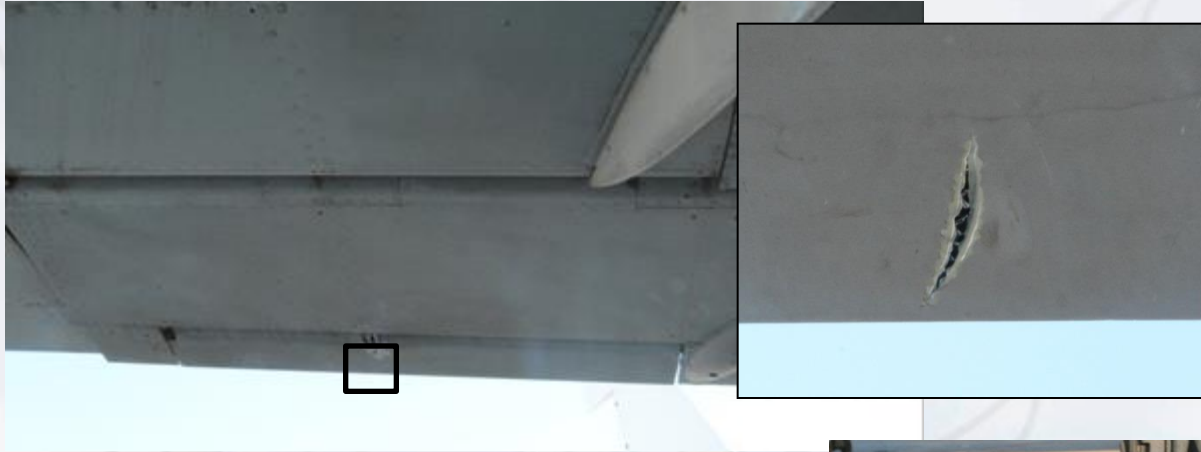
# Background



- Israeli Air Force B707 Tanker aircraft experienced elevated EGT and vibration on one of the engines and was commanded in-flight shut down (IFSD) by the crew.
- The engine, Pratt & Whitney JT3D-3B, was last overhauled 383 flight hours prior to the IFSD



# Background



Failure Analysis Department

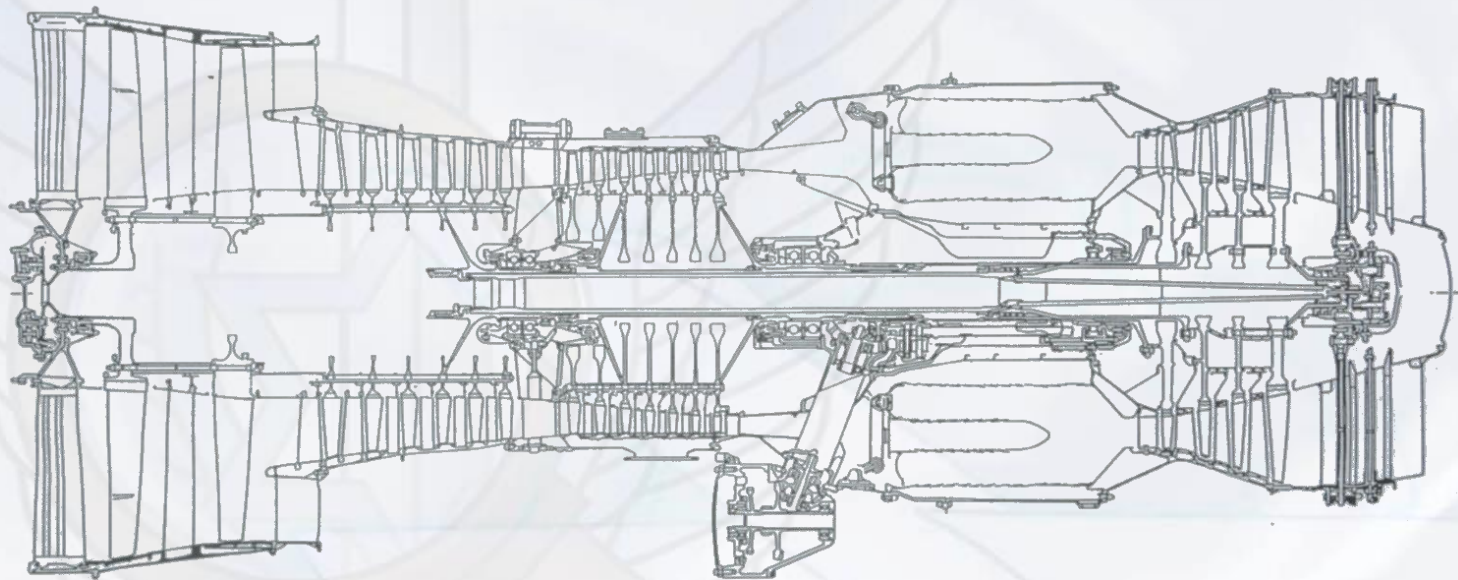
Materials Division

Depot 22 - Air-Craft





# JT3D Engine



Fan

Compressor

Combustion

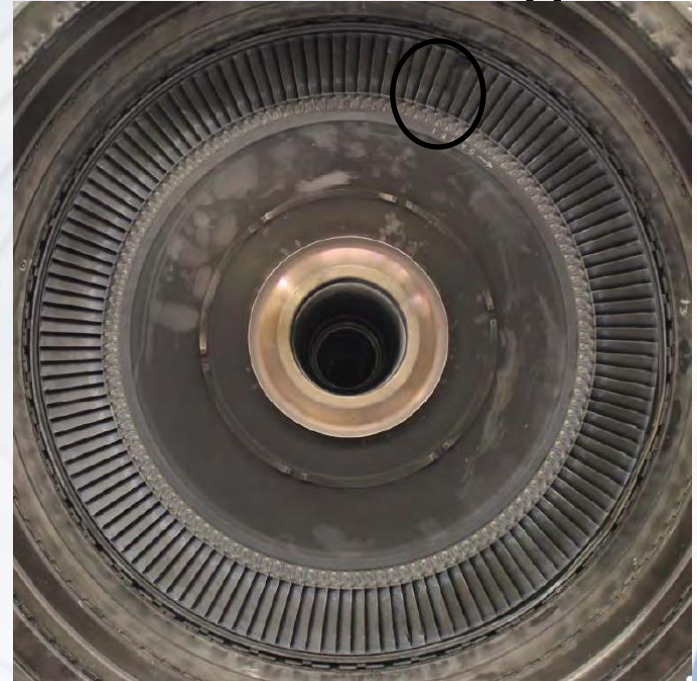
Turbine



# Disassembly Findings



- Single fractured High Pressure Turbine Stage 1 Blade (~1/3 blade height)

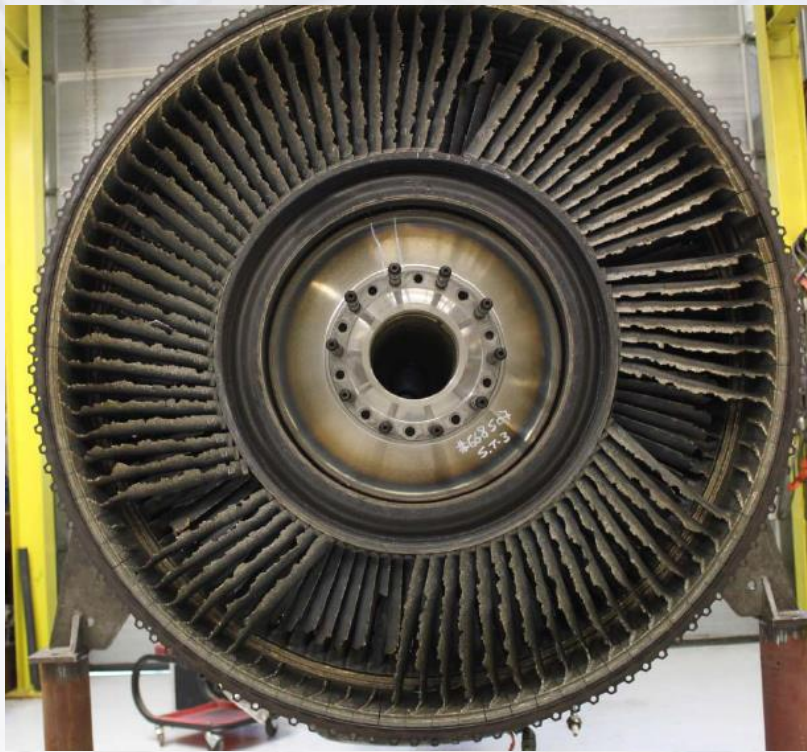




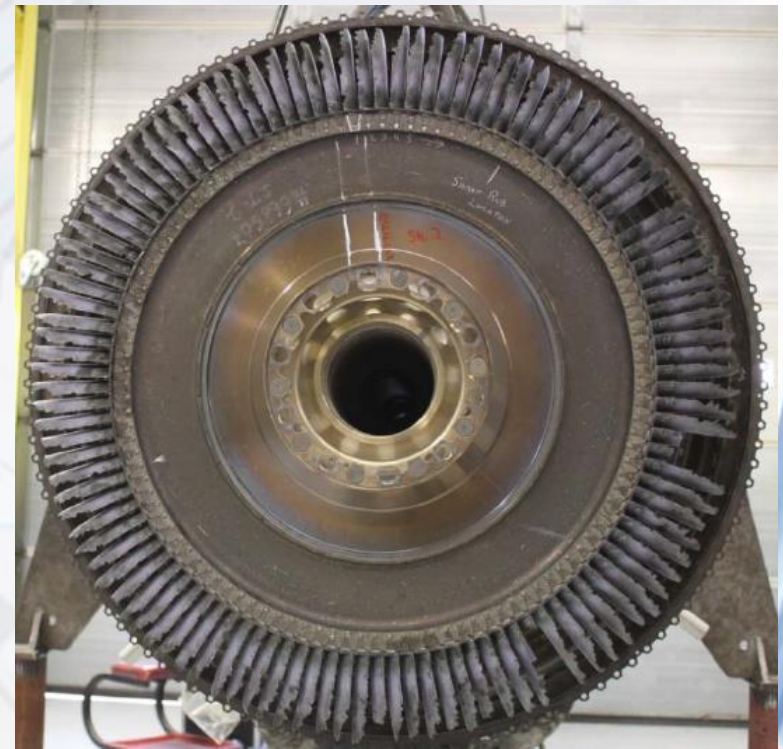
# Disassembly Findings



- Low Pressure Turbine airfoil damage



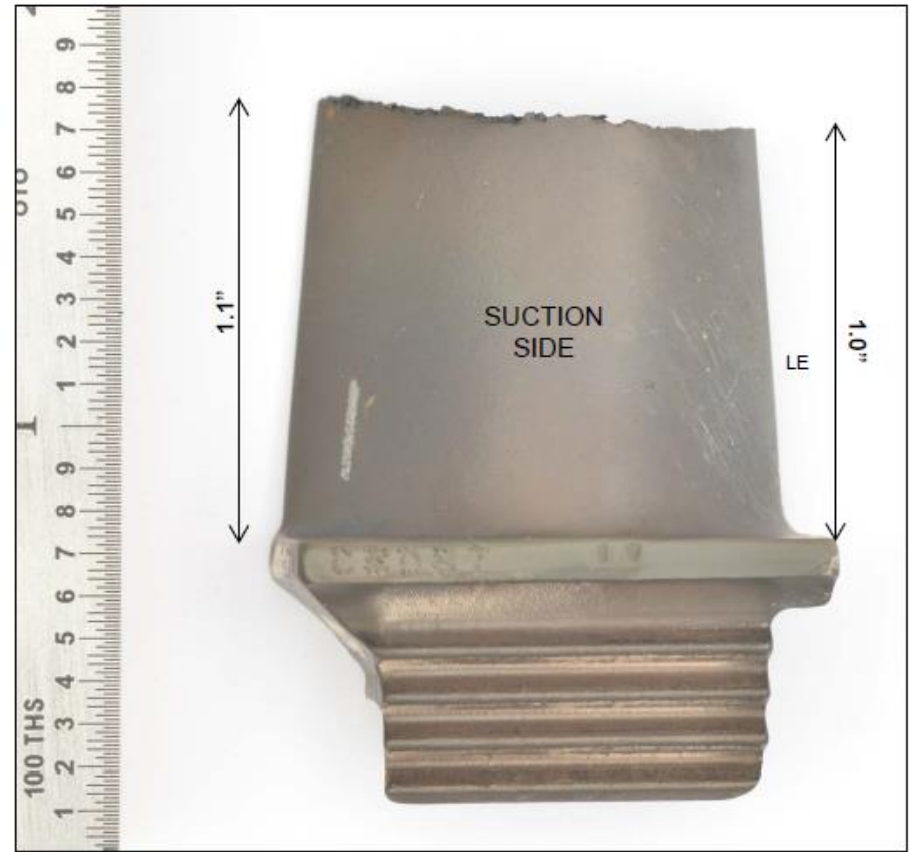
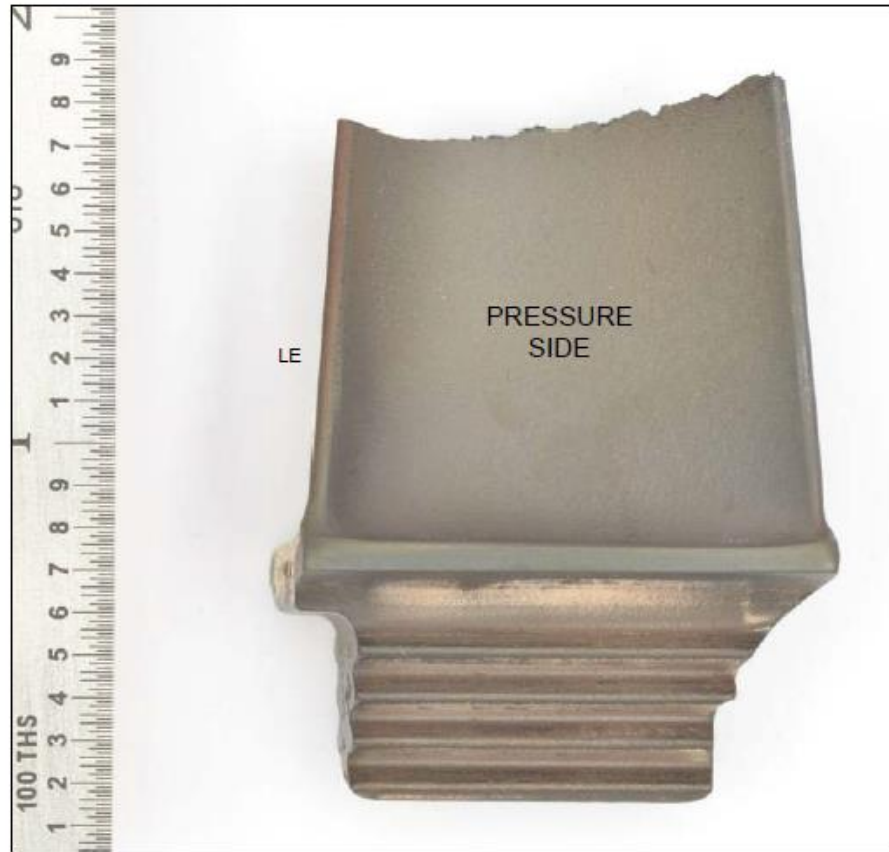
Stage 4



Stage 2

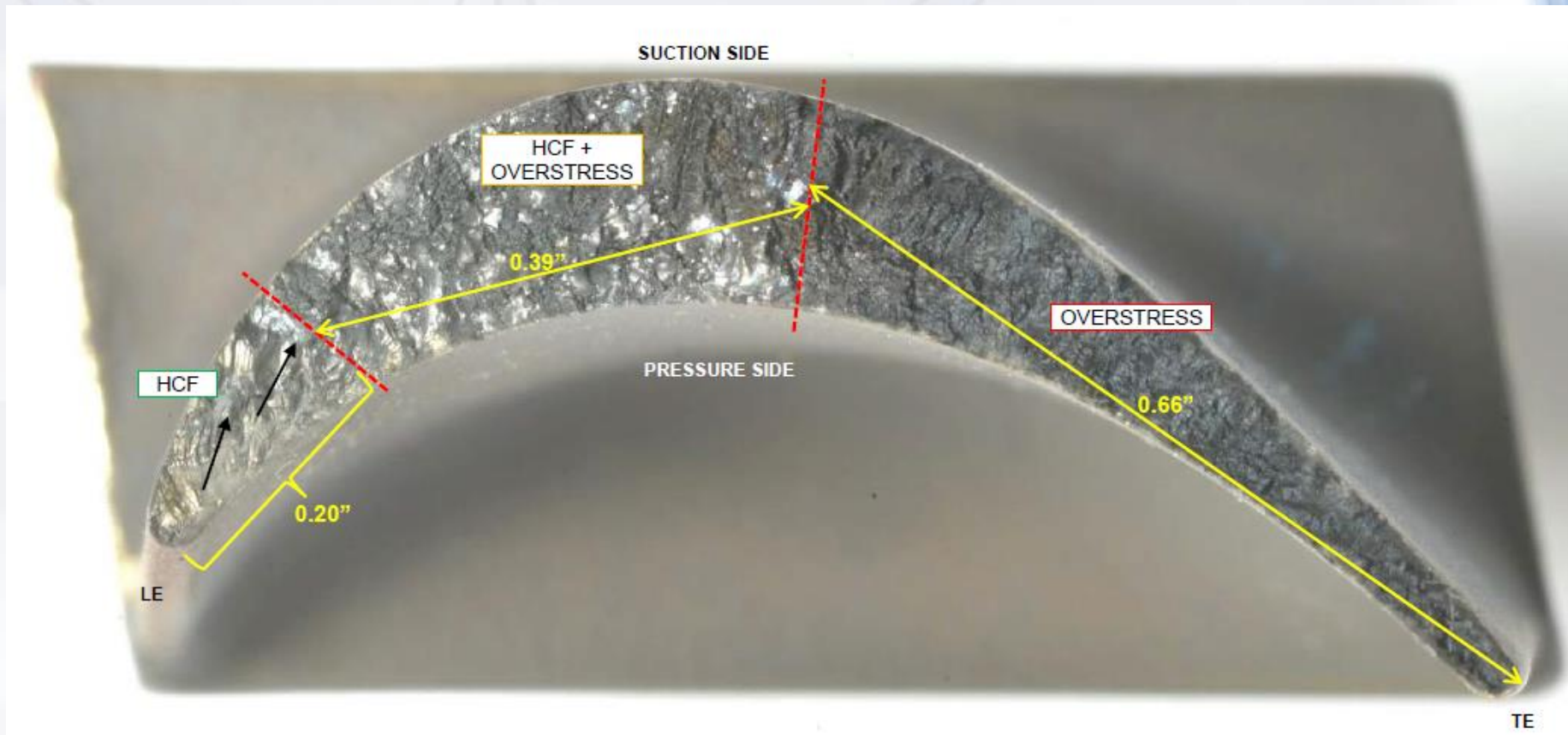


# Fractured Blade





# Fracture Surface

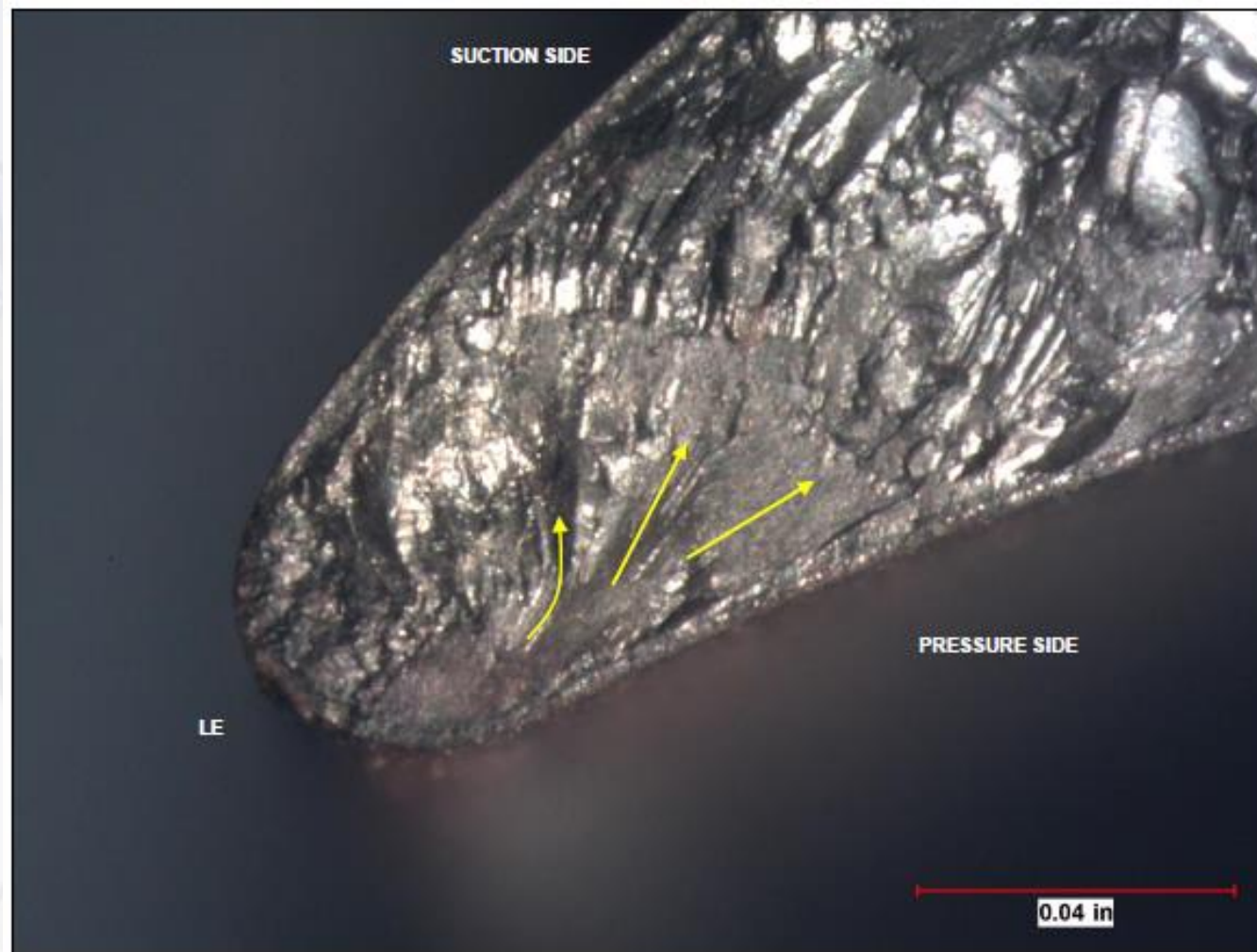


\*Inconel 718

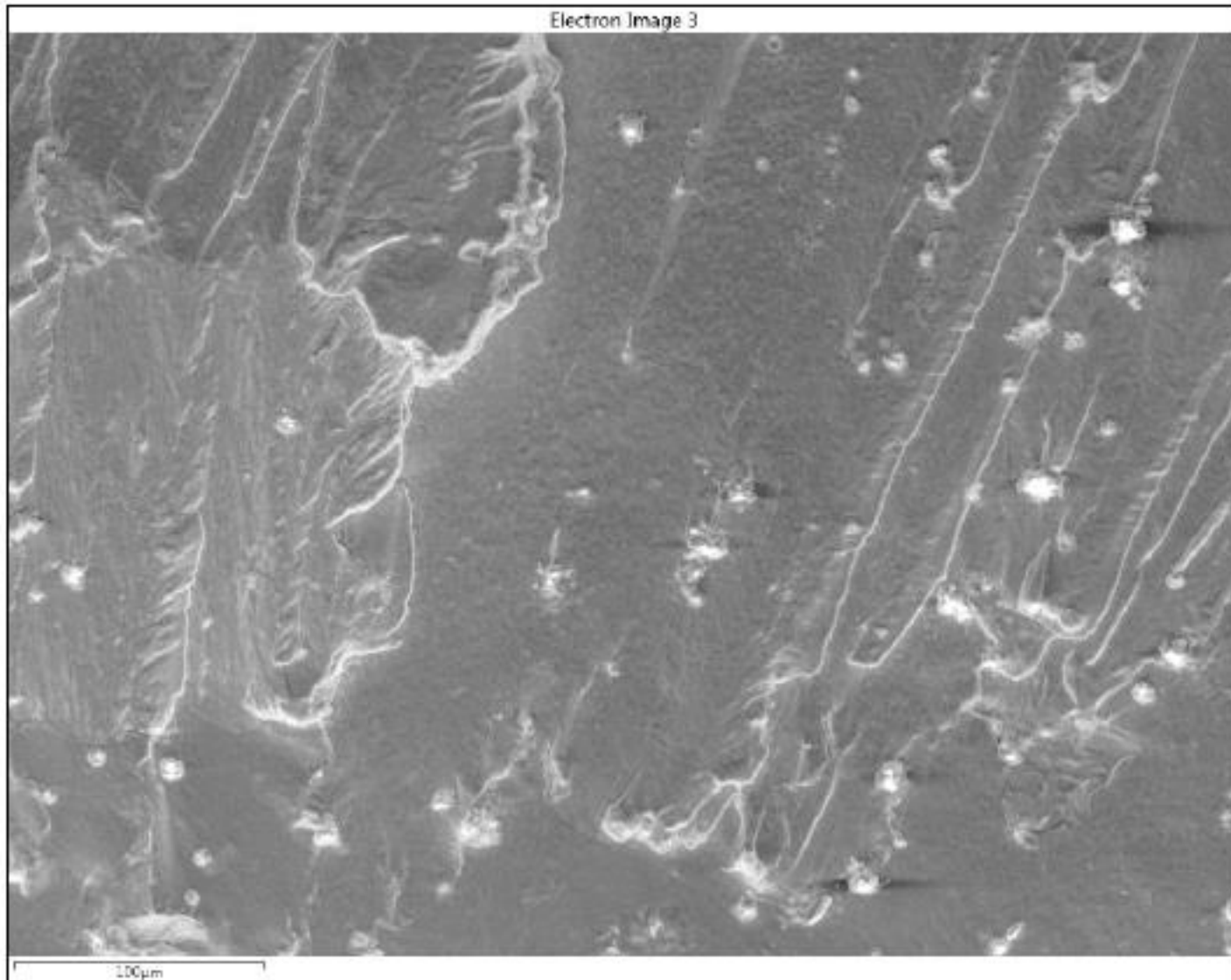




# Fracture Surface

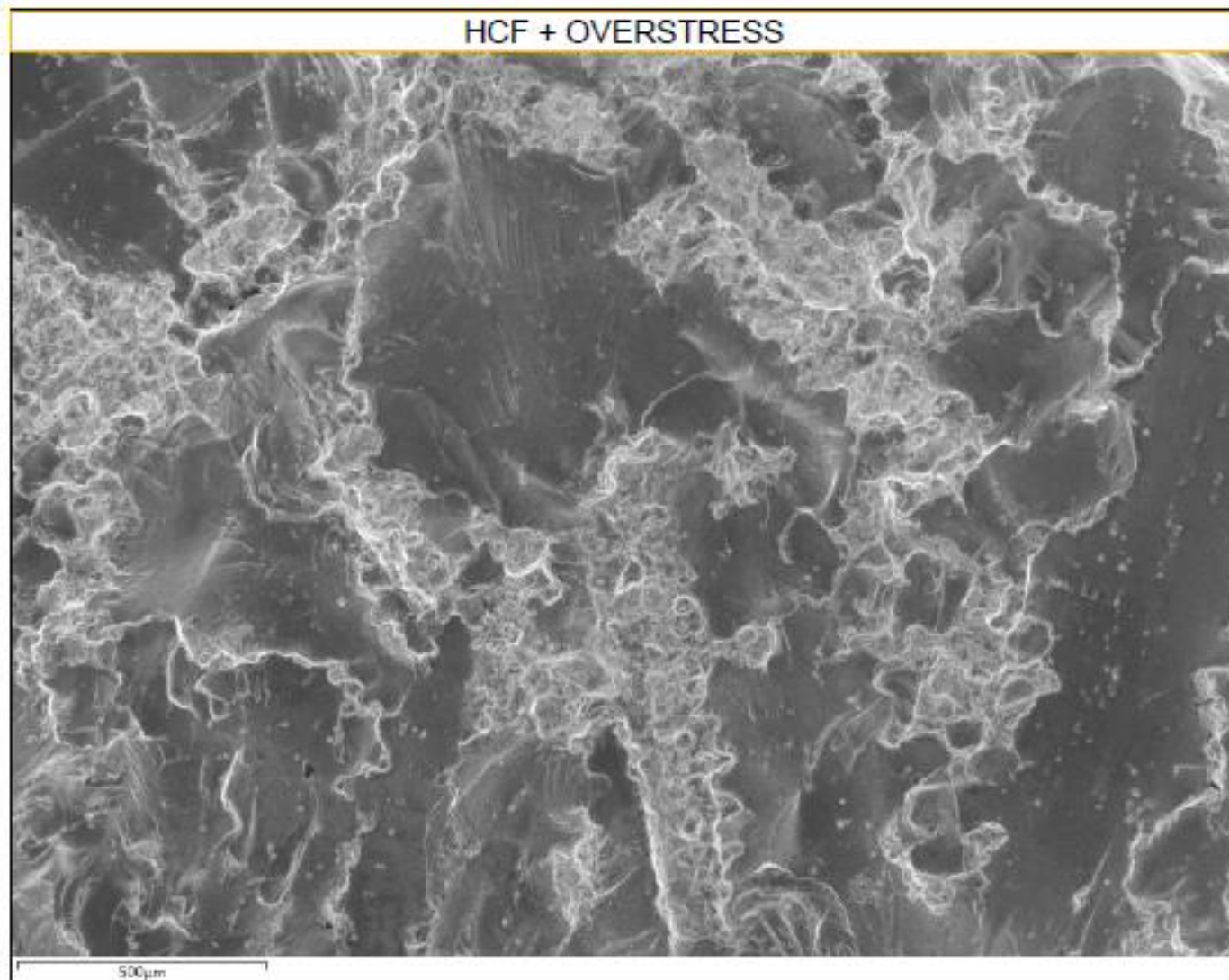


# Fracture Surface - HCF





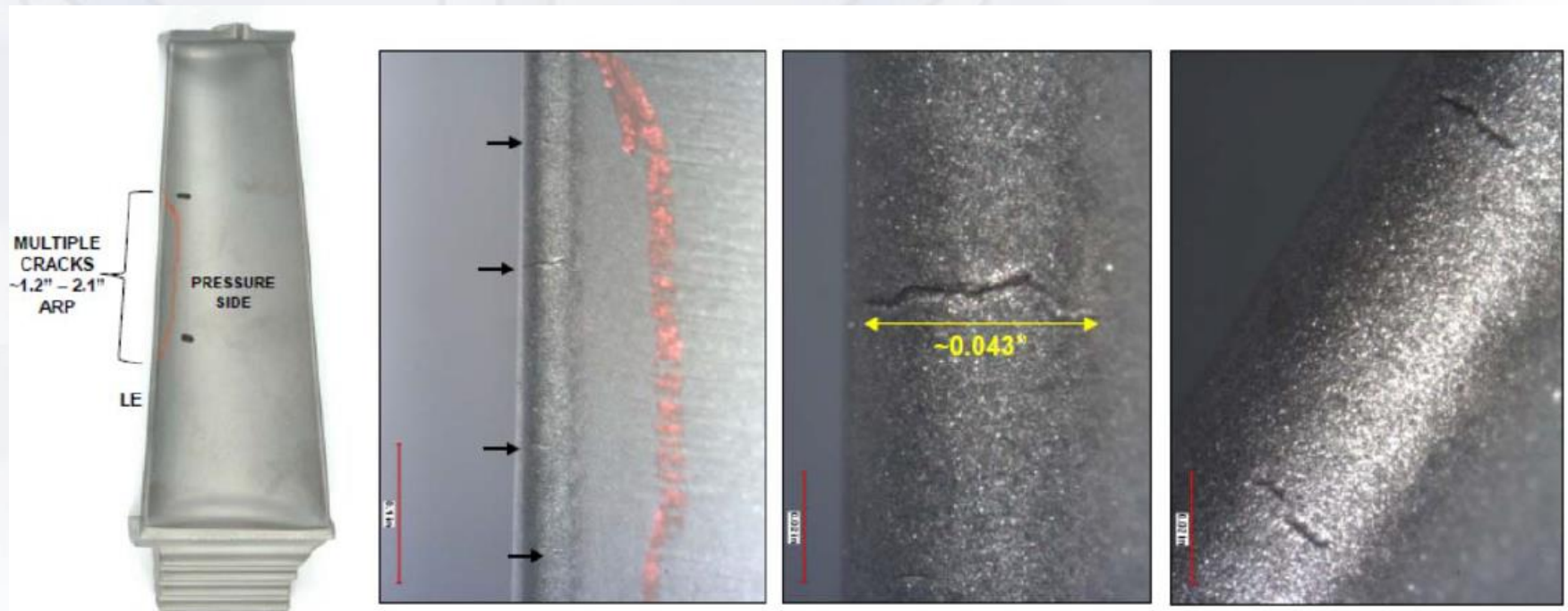
# Fracture Surface - Mixed HCF & Overload



# Additional 1<sup>st</sup> Stage HPT Findings



- 10 additional blades with cracks

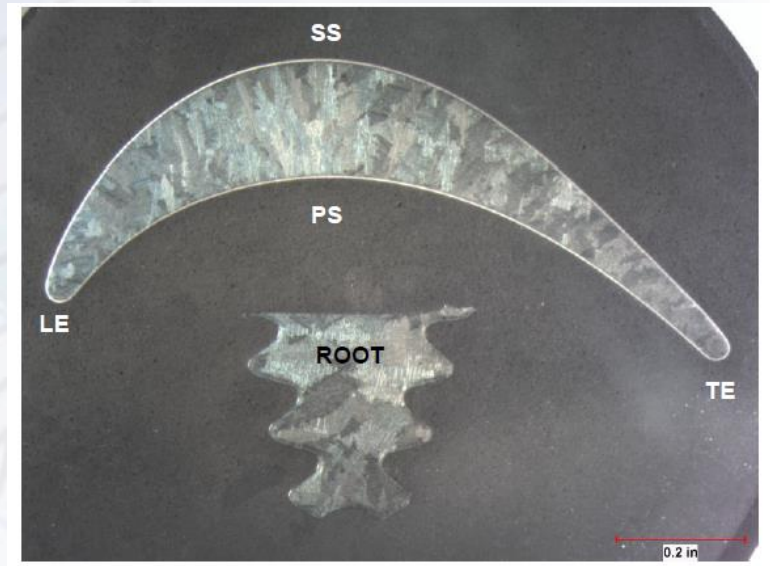
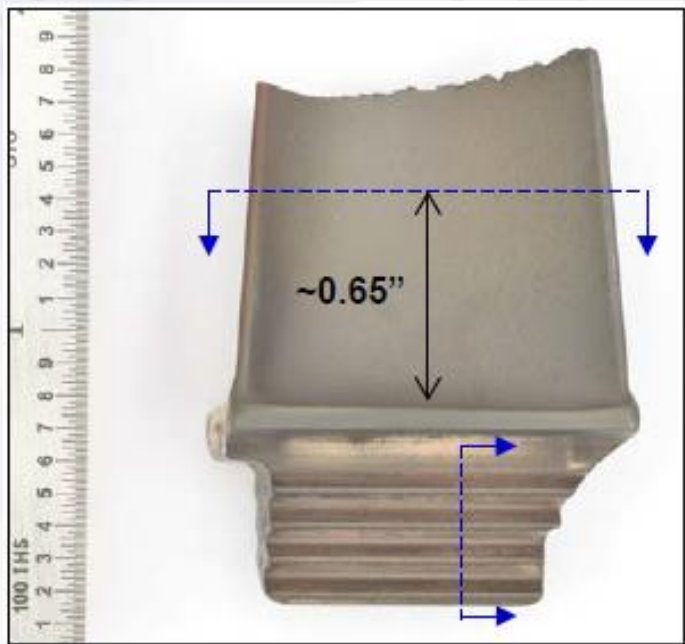


- All 10 blades have similar markings:  
no evidence of the coating on the fracture surface at the origin area to indicate that a crack had been present during the last strip and recoat cycle





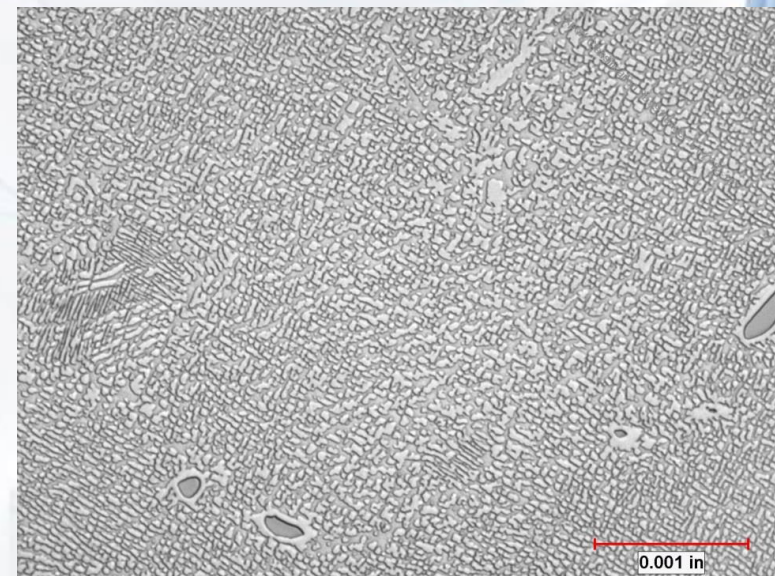
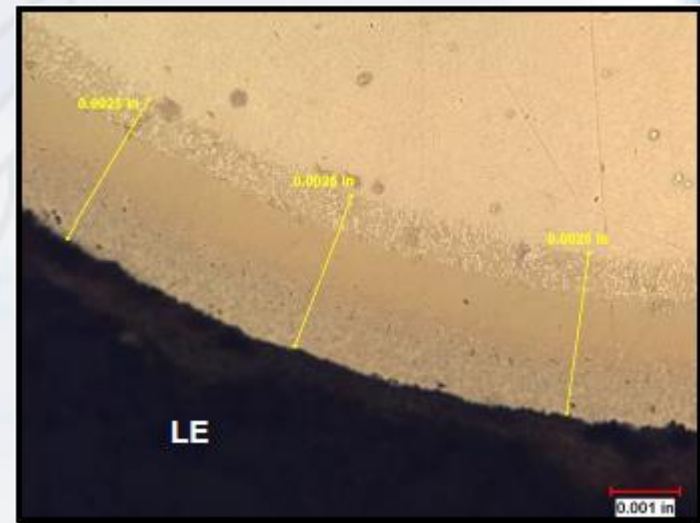
# Metallographic Section - Microstructure



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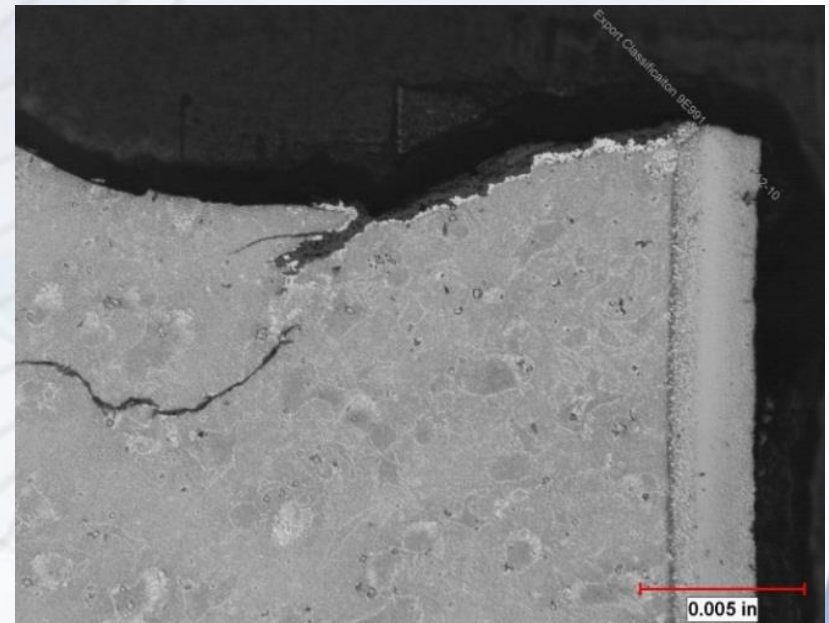
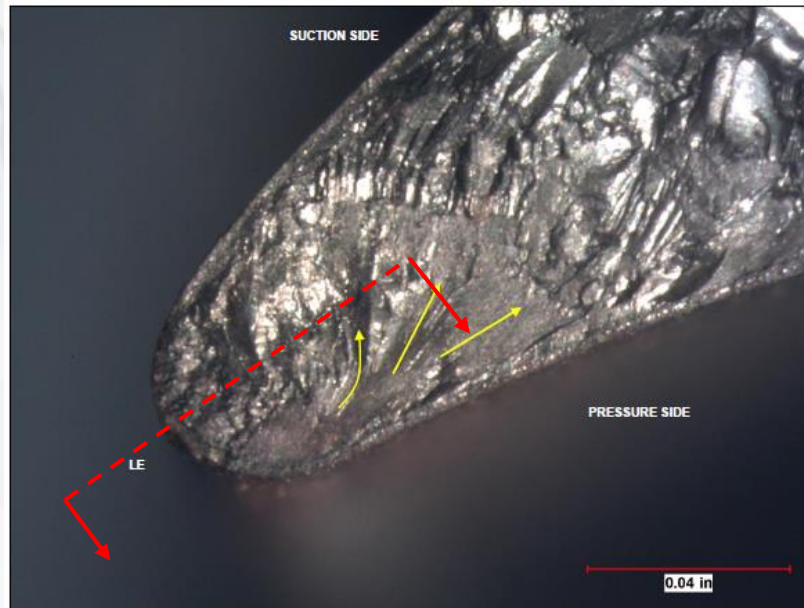


- The coating exhibited a uniform typical three-zone microstructure
- Bulk microstructure appeared typical with no evidence of temperatures 2000°F or above

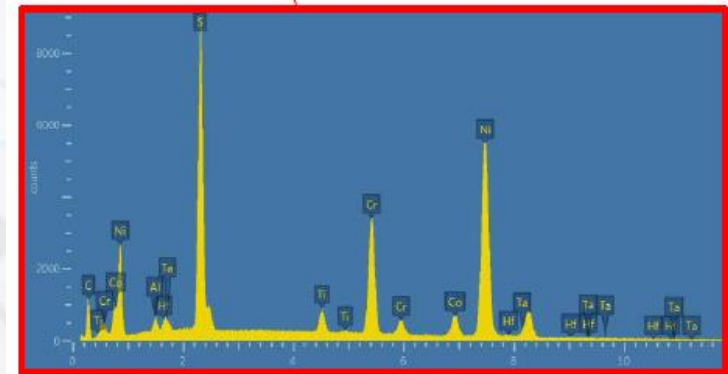
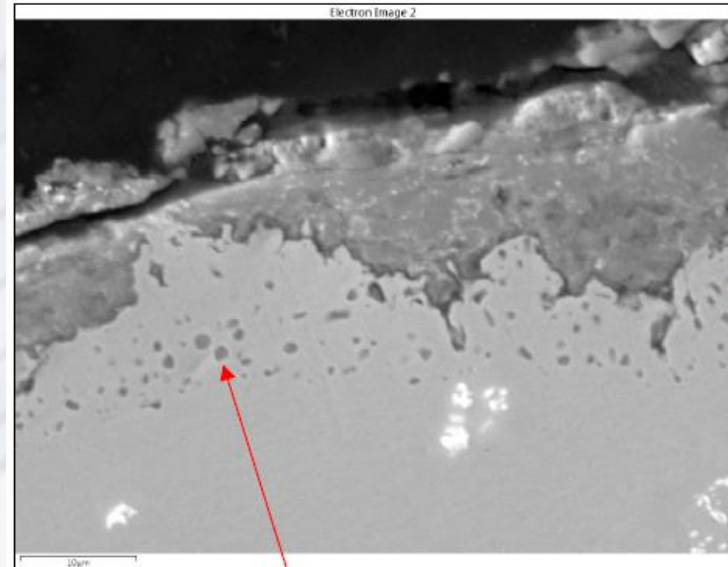
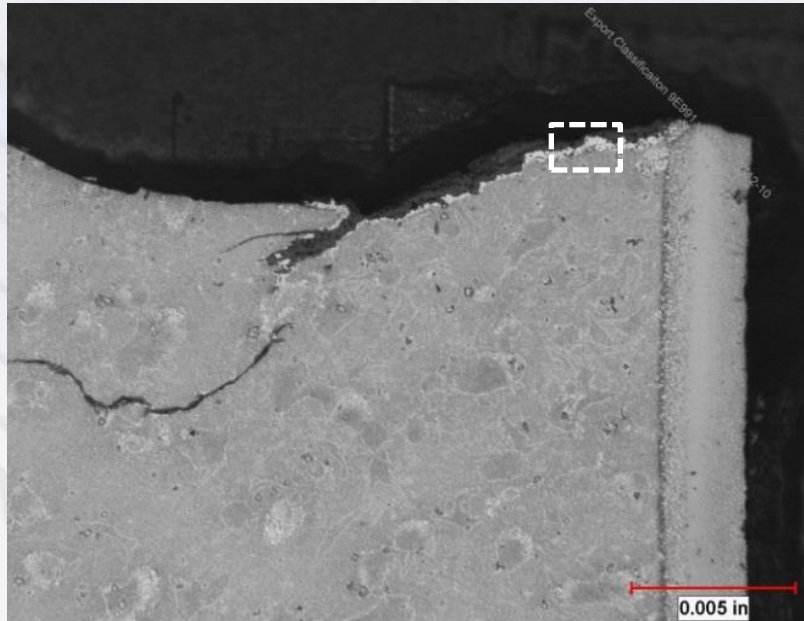




# Metallographic Section



# Metallographic Section



- EDS spectrum:  
(Energy dispersive spectroscopy)

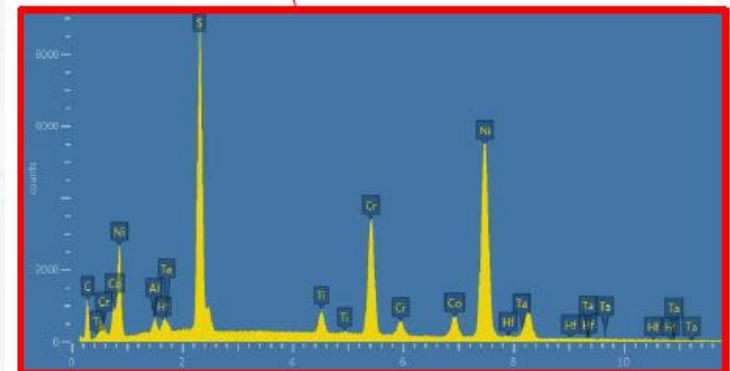
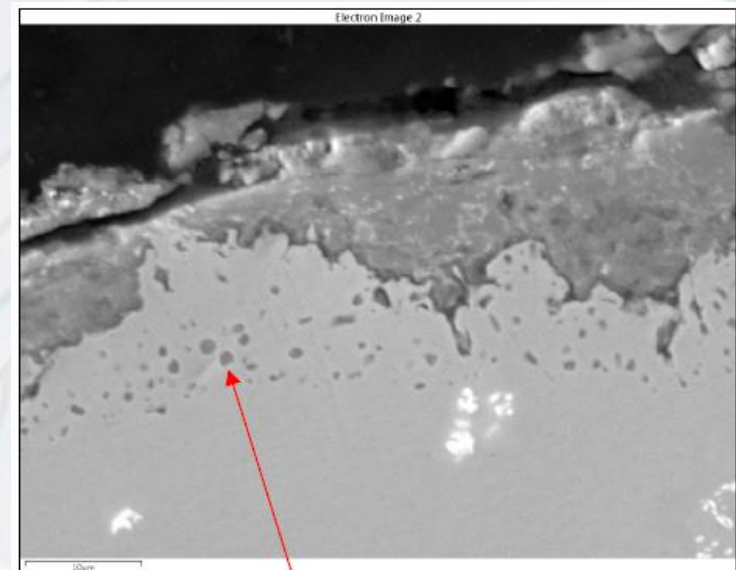
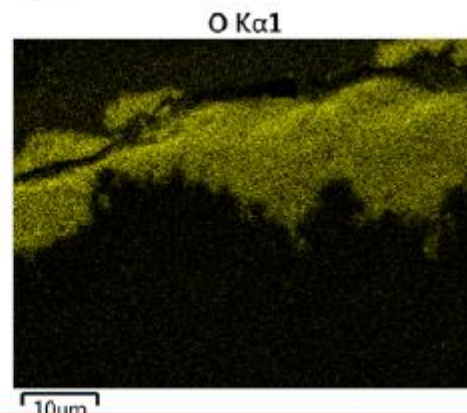
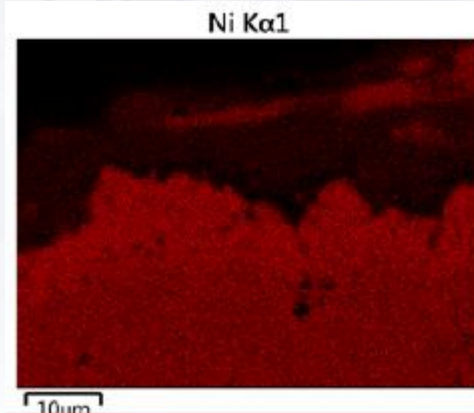
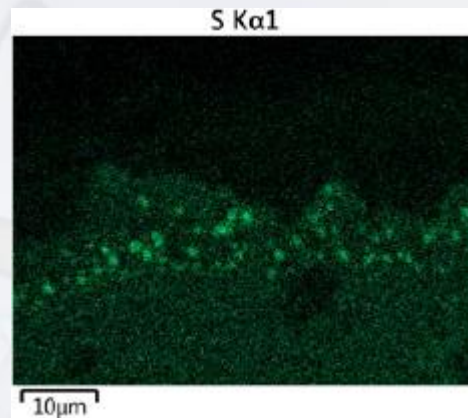




# Metallographic Section



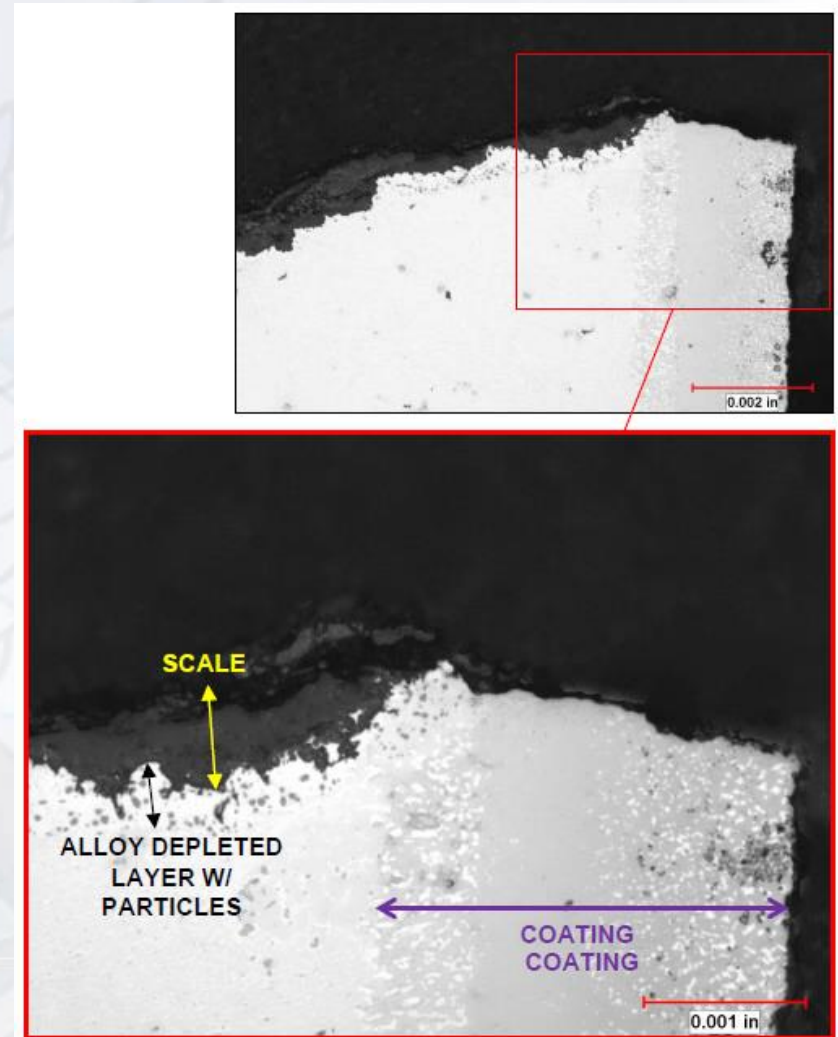
- EDS maps:



# Metallographic Section

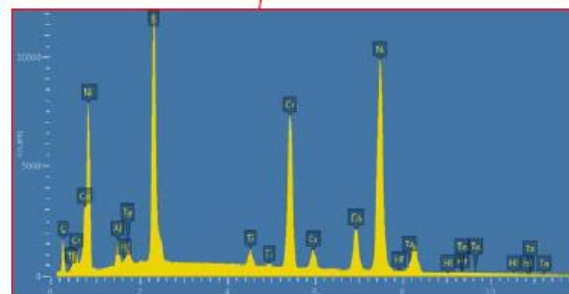
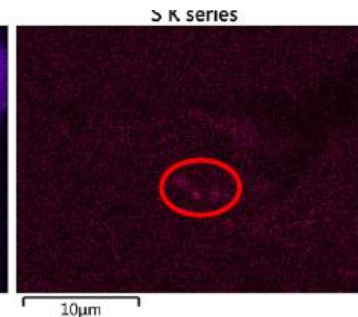
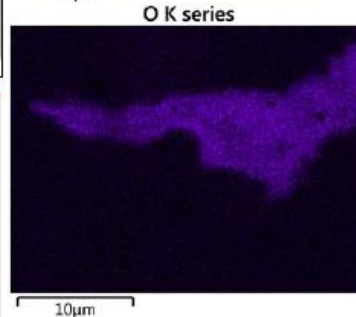
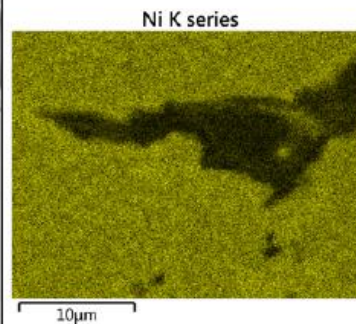
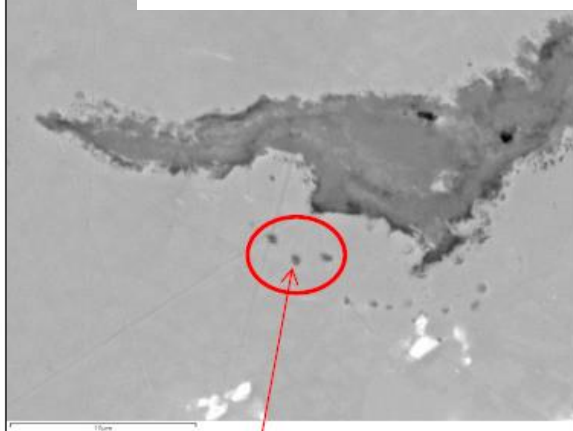


- Oxidation on fracture surface
- Alloy depleted layer along the fracture surface indicative of Sulfidation





# 1<sup>st</sup> Stage HPT Blade #16



Division



# Conclusions



- The cause for the engine failure was the fracture of a single High Pressure Turbine Stage 1 blade.
- The blade fracture was due to High Cycle Fatigue propagating from an initial crack
- The initial crack is a Thermal Mechanical Fatigue crack originating at the lead edge at approximately 30% span
  - The TMF was accompanied by Oxidation and Sulfidation process





# Conclusions



- TMF cracking was found at similar locations on 10 other blades with similar markings suggests a shared service
- There were no material, manufacturing, service or overhaul factors that were identified as probable contributors to the blade fracture
- The most probable cause for the TMF crack is the blade material having exceeded its useful TMF life



# Recommendations



- limit blade service life to three service intervals (first run and two strip and recoats)







# Questions?

