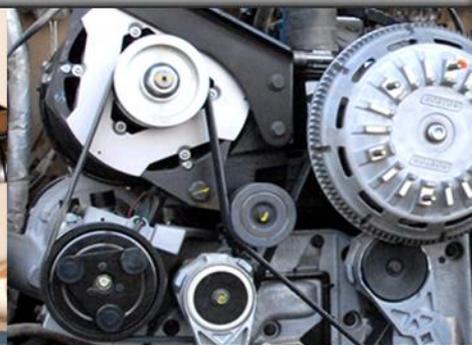
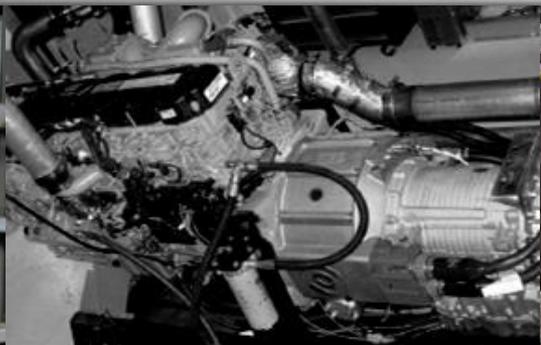


# AGT 1500 Erosion / Corrosion Coating

*Kevin Kauth  
TARDEC - GVPM  
29 July 2014*



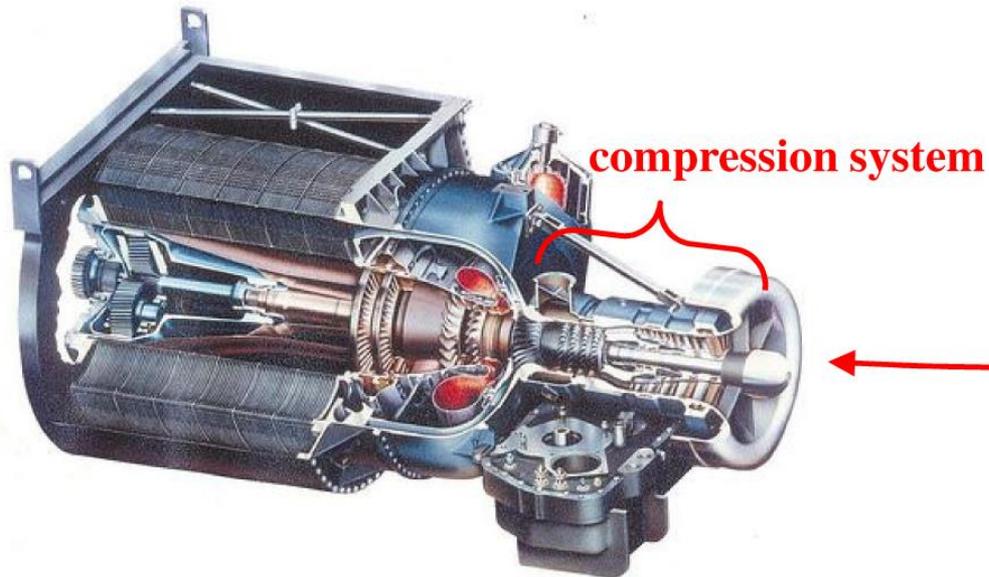


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**RDECOM**

# Coating Products



- Erosion Resistant ER Coating
- ESS Smooth Surface Coating
- Erosion/Corrosion (EC) Resistant Coating



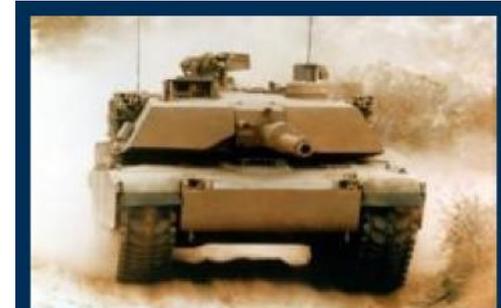


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# Agenda



- Program Objective
- Sand Ingestion Test
  - Overview
  - Measurements/Procedures
  - Results
  - Conclusions
- Vehicle Field Evaluation
- Discussion





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# Sand Ingestion Test



- Purpose: Replicate erosion symptoms seen on engines returned to depot
- Back to back uncoated / coated
- Controlled environment – ANAD test cell, certified erosive media (sand)
- PM Abrams provided AGT 1500 SLE engine
- MCT provided coated hardware
- Performance evaluation
- Hardware inspection



# Sand Ingestion Lab Test



## AGT1500 Sand Ingestion Test:

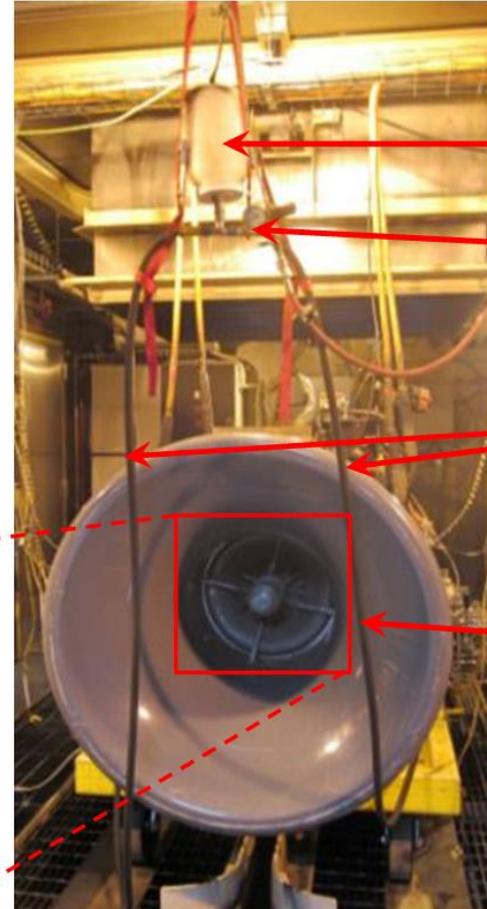
- Location: Anniston Army Depot (ANAD)
- Dates: May to September 2012

## Test Articles:

- Uncoated AGT1500 Engine – LE82956
- Coated AGT1500 Engine – ANAD 388

## Media:

- Mixture: 95% ARD A4 and 5% C-Spec
- Average Ingestion Rate:
  - $\approx 0.93$  lbm/hour (Uncoated Engine)
  - $\approx 1.41$  lbm/hour (Coated Engine)\*



Sand Hopper

Flow Control

Sand Feed Lines

Engine Inlet



Sand Ingestion Nozzles

Four sand ingestion nozzles oriented 90° to flowstream

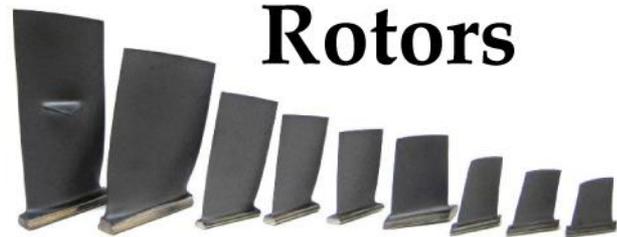
\* Lessons learned during uncoated testing allowed increased ingestion rate



## Uncoated Engine

4 parts per stage – **BlackGold**<sup>®</sup> v4 LEAP

Remaining parts - **Uncoated**



**Rotors**

**Uncoated**



**Stators**

**Uncoated**



**Impeller**

## Coated Engine

4 parts per stage – **BlackGold**<sup>®</sup> v4 LEAP

2 parts per stage<sup>1</sup> – **Uncoated**

Remaining parts – **BlackGold**<sup>®</sup> v4 Anti-LEPER

LP02 & LP05: **BlackGold**<sup>®</sup> v4 Anti-LEPER

**BlackGold**<sup>®</sup> v4

Remaining: **Uncoated**

<sup>1</sup>High pressure first stage rotor did not include uncoated parts



# Measurement - Chord Length



## Purpose

- Chord length determines if a part is acceptable
- to remain in service

## Procedure

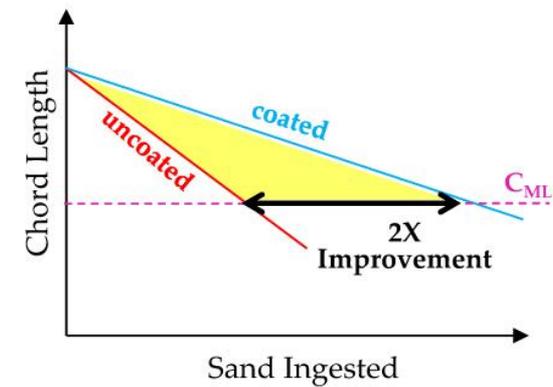
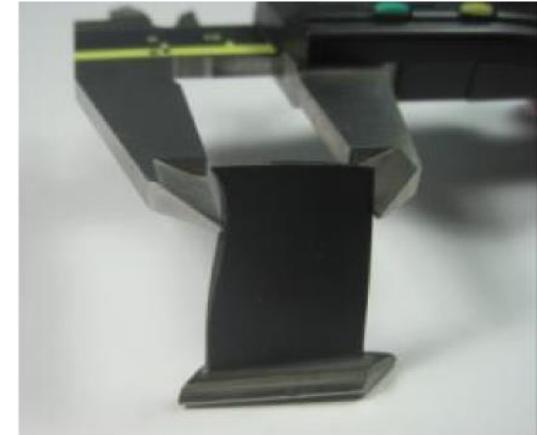
- Measurement location at the point of highest erosion
- as per NMWR 9-2835-255-2
- (National Maintenance Work Requirement)

## Equipment

- Digital caliper, 0.0005 inch resolution, 0.001 inch accuracy

## Output

- Improvement factor based on how much more sand
- is required to reach the Chord Maintenance Limit
- (CML) as compared to uncoated





## Purpose

- Determine material loss due to erosion

## Procedure

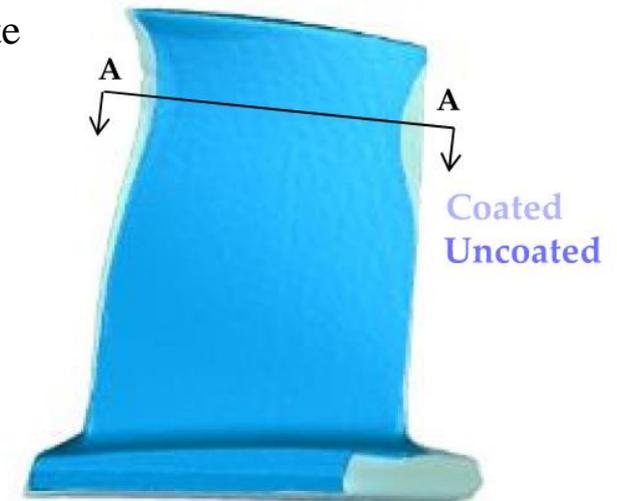
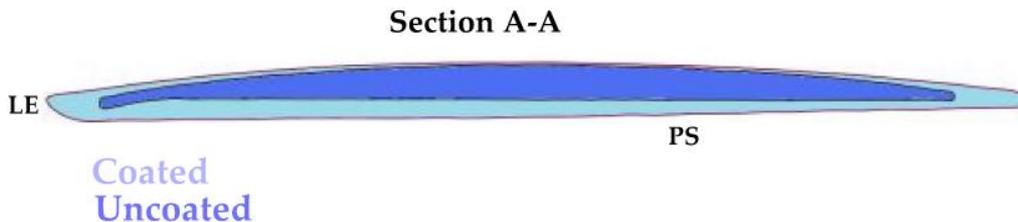
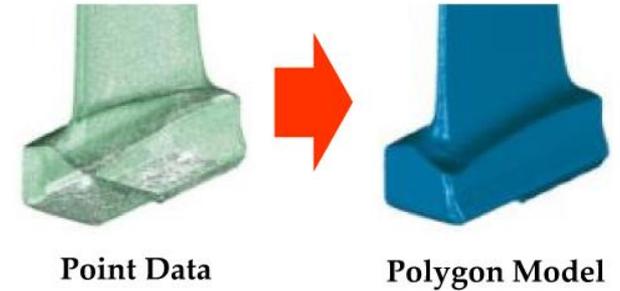
- Geometry of airfoil transferred into 3D point data
- Point data meshed to form a polygon model

## Equipment

- ACCU3D optical scanner (accuracy of  $12.7 \mu\text{m}$  at  $2\sigma$ )

## Output

- Overlay of coated and uncoated airfoils after test to demonstrate material loss





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# Mass Loss Measurement



## Purpose

- Determine mass loss due to erosion
- Same metric used by Honeywell during 2007 sand ingestion test

## Procedure

- Airfoils weighed before and after test

## Equipment

- Digital scale with 0.0001 gram precision

## Output

- Mass change after sand ingestion





## Uncoated Engine

- Chord Length
- Mass

- Chord Length
- Visual Inspection
- Photographs

- Chord Length
- Mass
- Optical Scans
- Visual Inspection
- Photographs



SAND INGESTED

## Coated Engine

- Chord Length
- Mass

- Visual Inspection
- Photographs

- Chord Length
- Visual Inspection
- Photographs

- Chord Length
- Mass
- Optical Scans
- Visual Inspection
- Photographs



SAND INGESTED



## Chord Loss

After 9.5 lbm Sand Ingested

Improvement  
Factor

1.2X

2.2X

1.6X

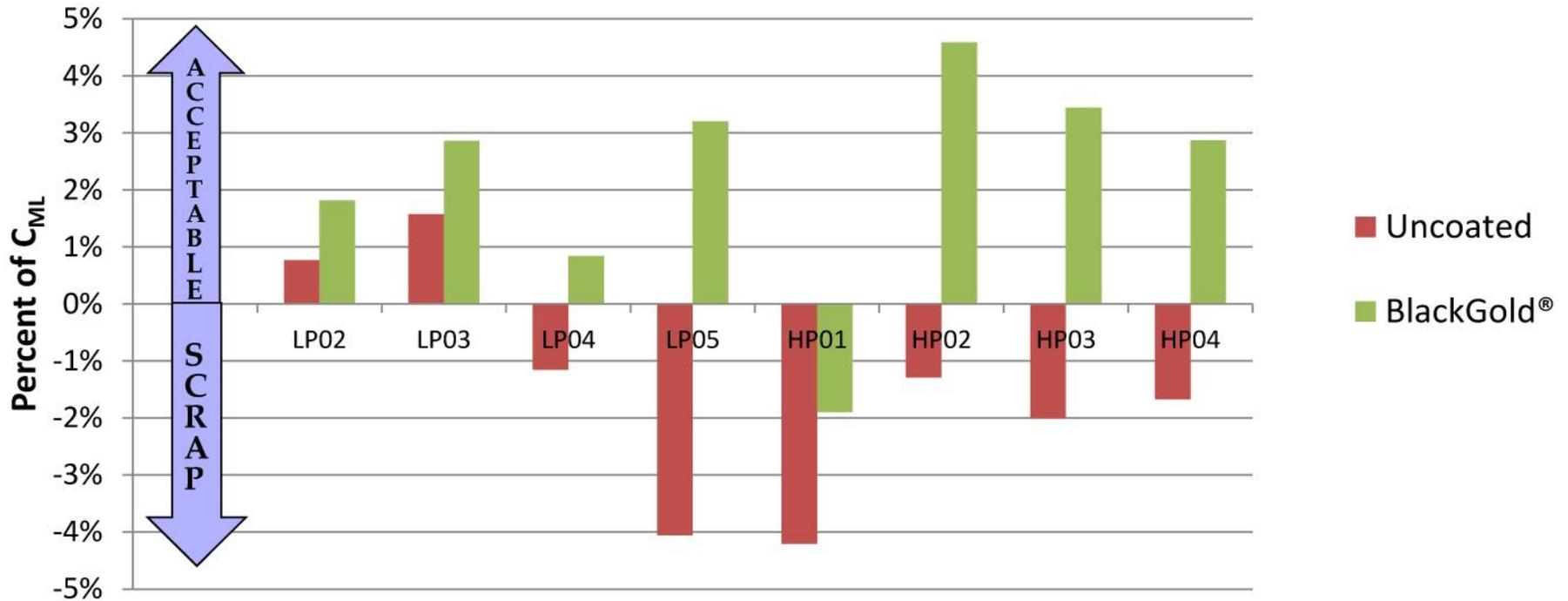
2.4X

1.4X

3.9X

7.4X

4.9X

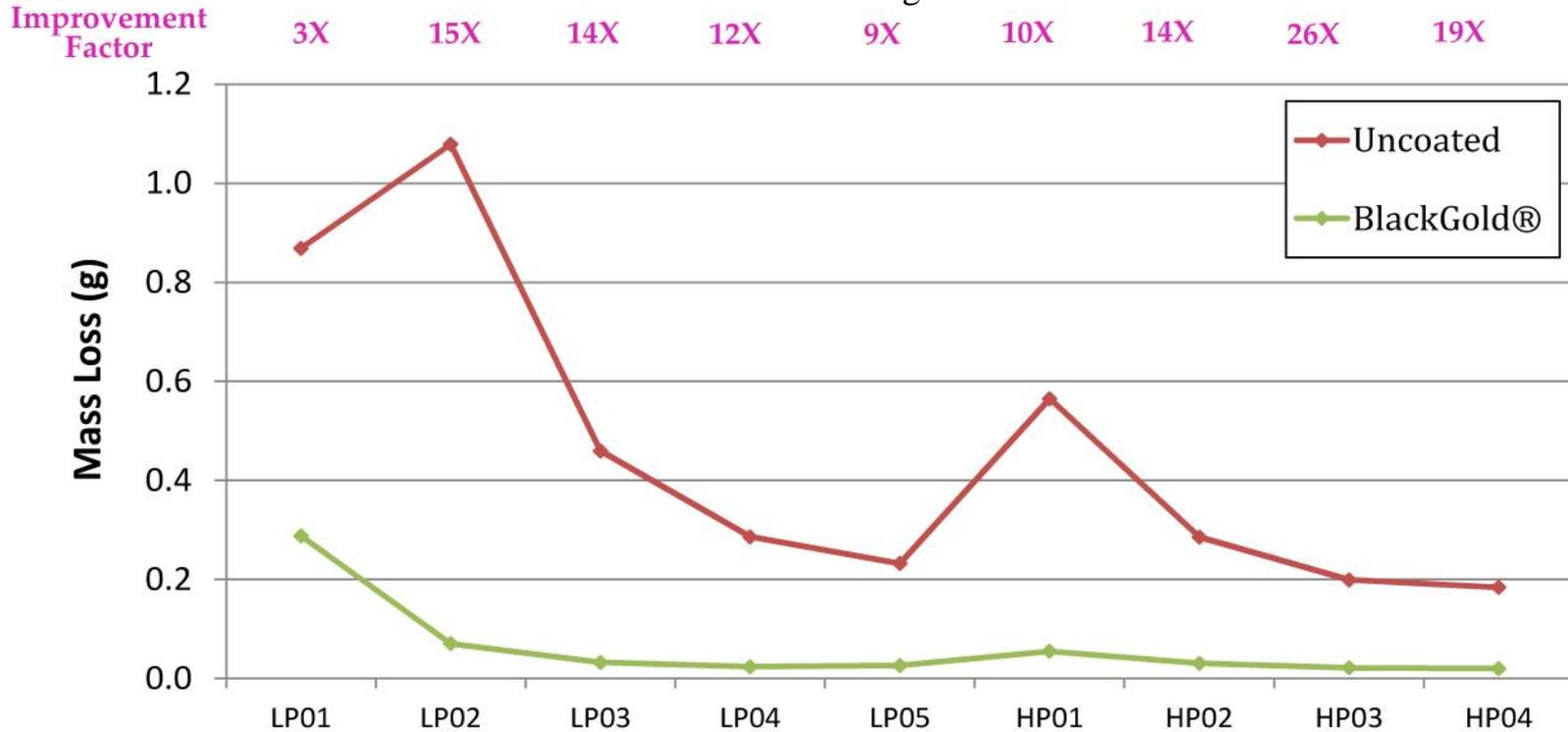


**BlackGold® v4 coating delayed parts from reaching Chord Maintenance Limits**



## Mass Loss

After 9.5 lbm Sand Ingested



**BlackGold® v4 coating significantly reduces part mass loss**



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# Sand Ingestion Test Summary Conclusions



- **BlackGold**<sup>®</sup> v4 coating delayed parts from reaching Chord Maintenance Limits
  - Between 1.2X and 7.4X improvement
- **BlackGold**<sup>®</sup> v4 coating significantly reduces part mass loss
  - Between 3X and 26X improvement



**BlackGold**<sup>®</sup> Coated  
AGT1500 Rotor Blades



**BlackGold**<sup>®</sup> Coated  
AGT1500 Impeller



# Field Evaluation



## Field evaluation of coated blades in work (400 hours)

- 2 Army vehicles at Yuma Proving Grounds (YPG)
- 2 Marine Corps vehicles at 29 Palms
- 1 National Guard vehicle at Umatilla Oregon

## Data Acquisition:

- Daily miles, total miles, engine hours, ambient temperature, test course.
- Perform Engine Health Check
- Vehicle Maximum Speed Check
- Following each month of operation download Engine Memory Unit (EMU)
- 200 and 400 hour visual and dimensional inspection

## Results to date:

- YPG                    160 hours, 70 hours, no issues (07/21/2014)
- 29 Palms            226 hours, 141 hours, no issues (06/15/2014)
- Umatilla             pending data



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# Future Events



- Completion of Field Evaluation
  - Visual inspection of compressor blades
  - Split compressor cases, measure, photograph
- Durability testing planned at Honeywell and TARDEC
  - 600 hours at Phoenix Fall 2014
  - 2400 hours at TARDEC Summer 2015
- Business case reassessment based on all test results
  - PM Abrams concurrence
  - Depot concurrence
- Final validation steps prior to implementation
  - Engineering Work Directive for OEM incorporation
  - Engineering Change Proposal
  - Full scale production site location

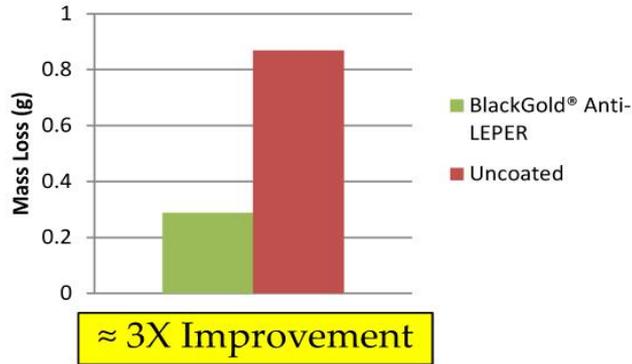


# Backup Charts





# Results – LP01 Mass Loss



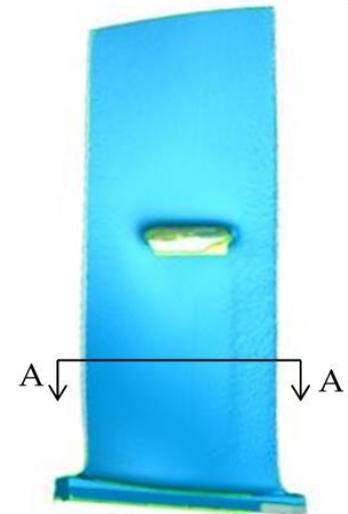
Mass loss after 15.75 lbm  
Images & Scan after 15.75 lbm



Uncoated



**BlackGold®**  
Anti-LEPER



Aligned 3D  
Models



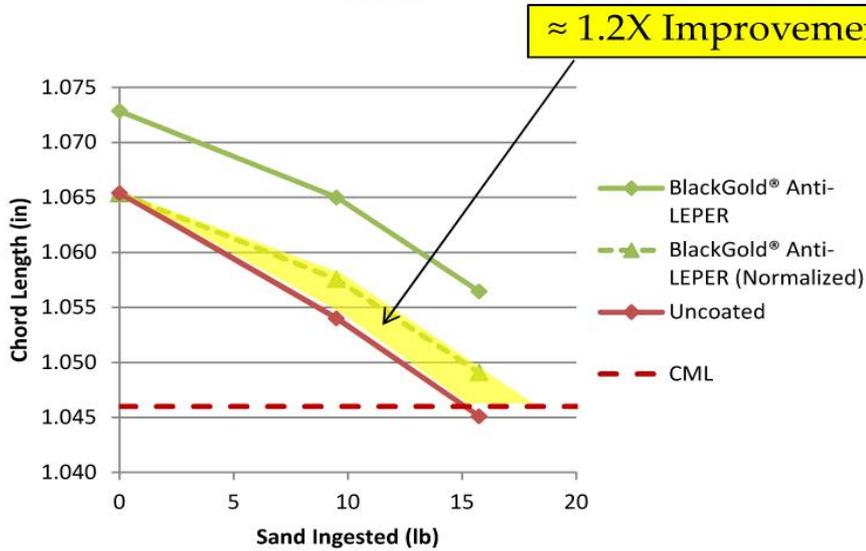
PS  
Section : A-A

Coated  
Uncoated

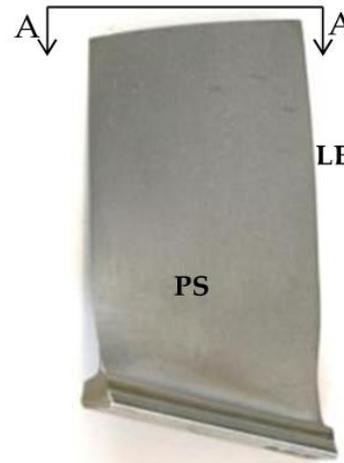
Note: Both uncoated and coated exhibited LE roughness not allowed per NMWR 9-2835-255-2



# Results – LP02 Chord Loss



Mass loss after 15.75 lbm  
Images after 15.75 lbm

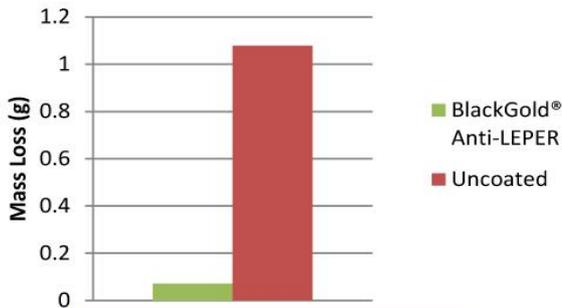


Uncoated

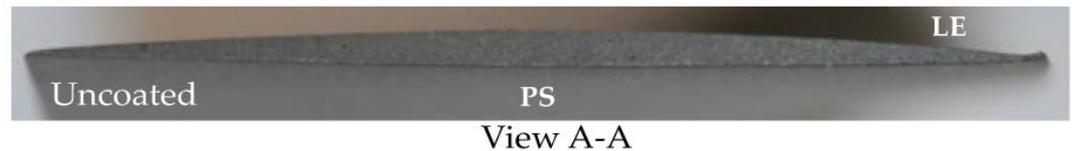


**BlackGold®**  
Anti-LEPER

## Mass Loss



**≈ 15X Improvement**



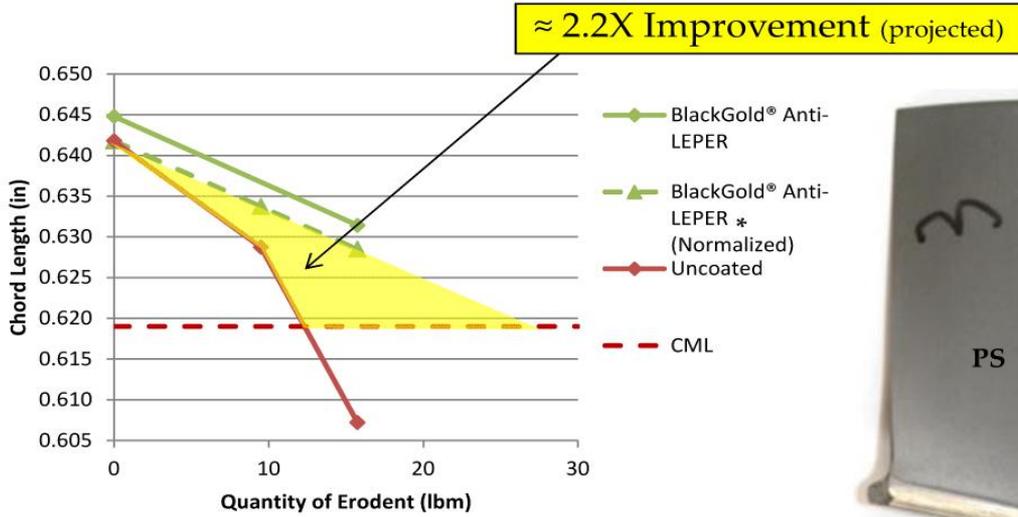
View A-A



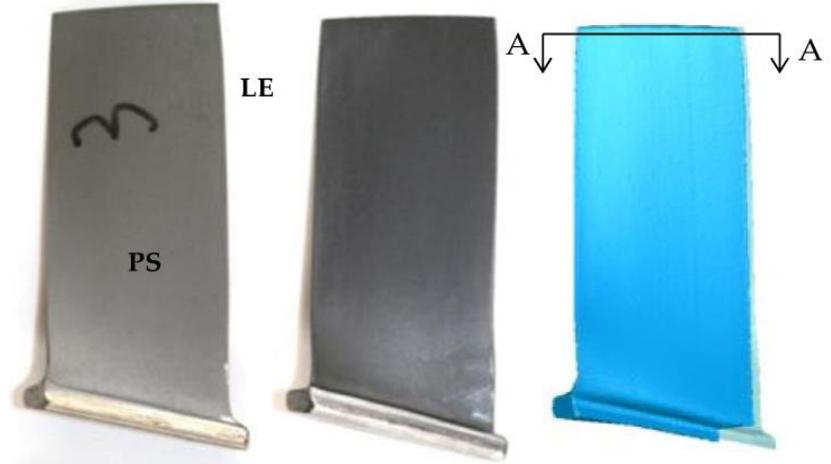
View B-B



# Results – LP03 Chord Loss



Mass loss after 15.75 lbm  
Images & Scan after 15.75 lbm

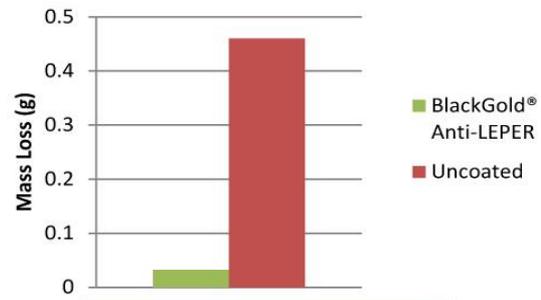


Uncoated

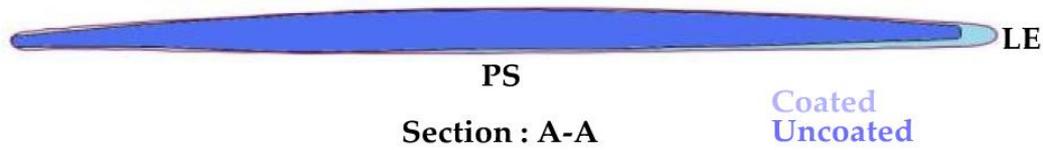
**BlackGold®**  
Anti-LEPER

Aligned 3D  
Models

## Mass Loss



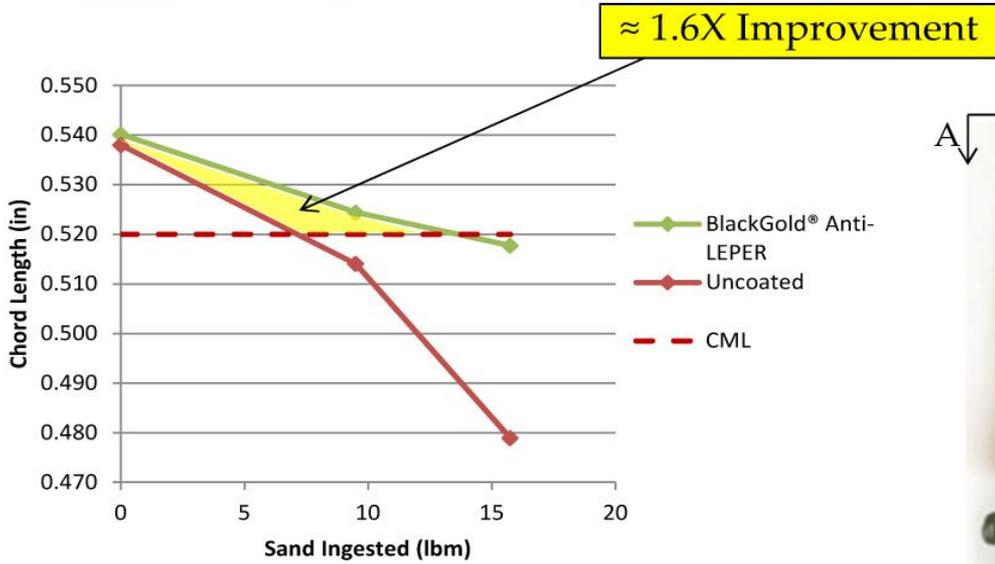
**≈ 14X Improvement**



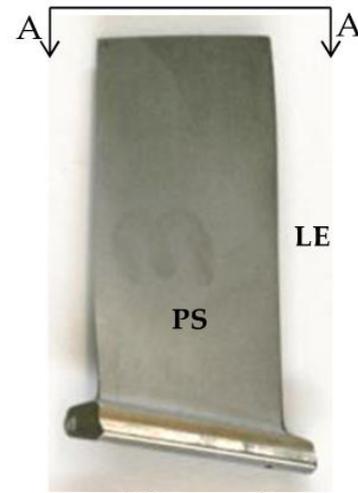
\*9.5lbm Anti-LEPER data point not recorded



# Results – LP04 Chord Loss



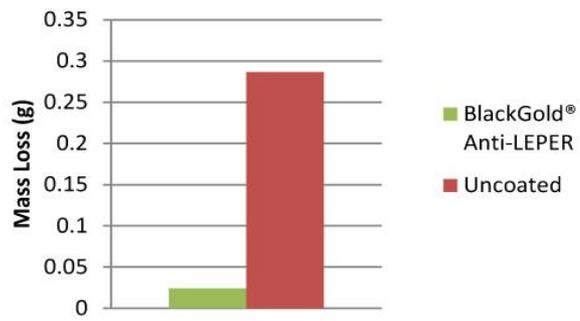
Mass loss after 15.75 lbm  
Images after 15.75 lbm



Uncoated

**BlackGold®**  
Anti-LEPER

## Mass Loss



**≈ 12X Improvement**



View A-A



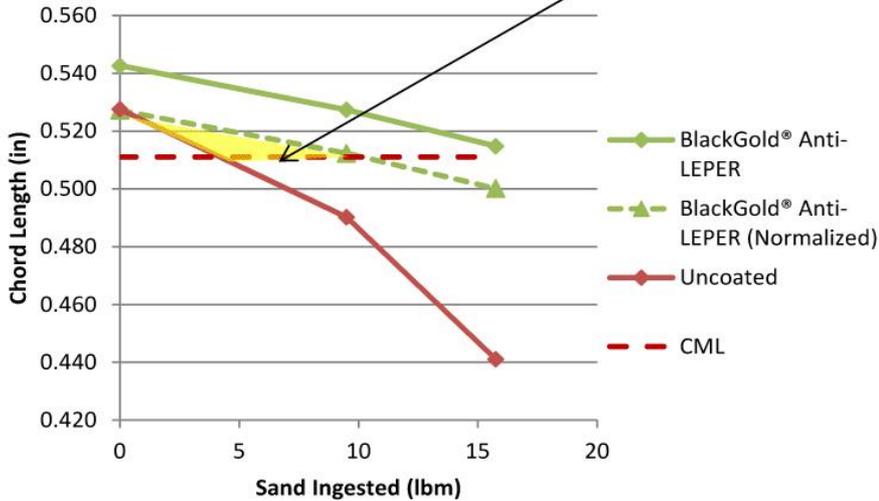
View B-B



# Results – LP05 Chord Loss



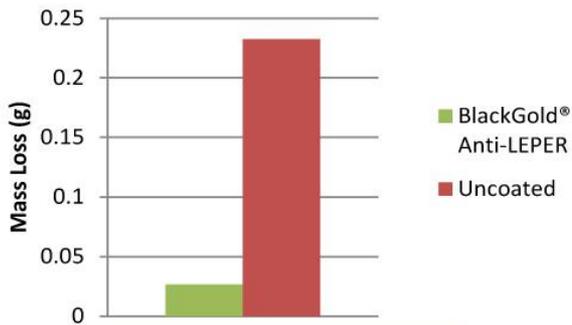
≈ 2.4X Improvement



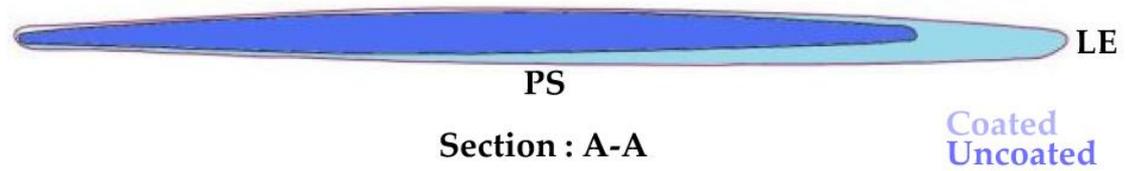
Mass loss after 15.75 lbm  
Images & Scan after 15.75 lbm

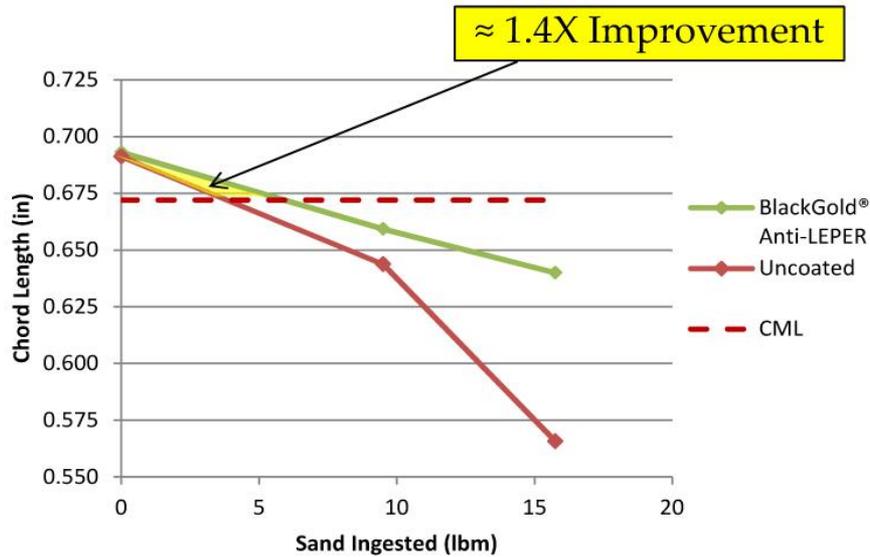


## Mass Loss

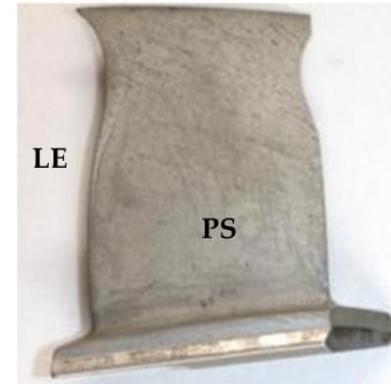


≈ 9X Improvement





Mass loss after 15.75 lbm  
Images & Scan after 15.75 lbm

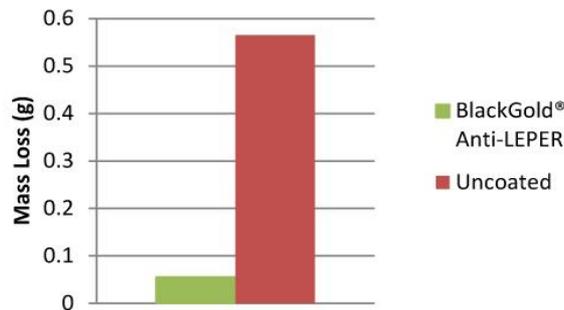


Uncoated

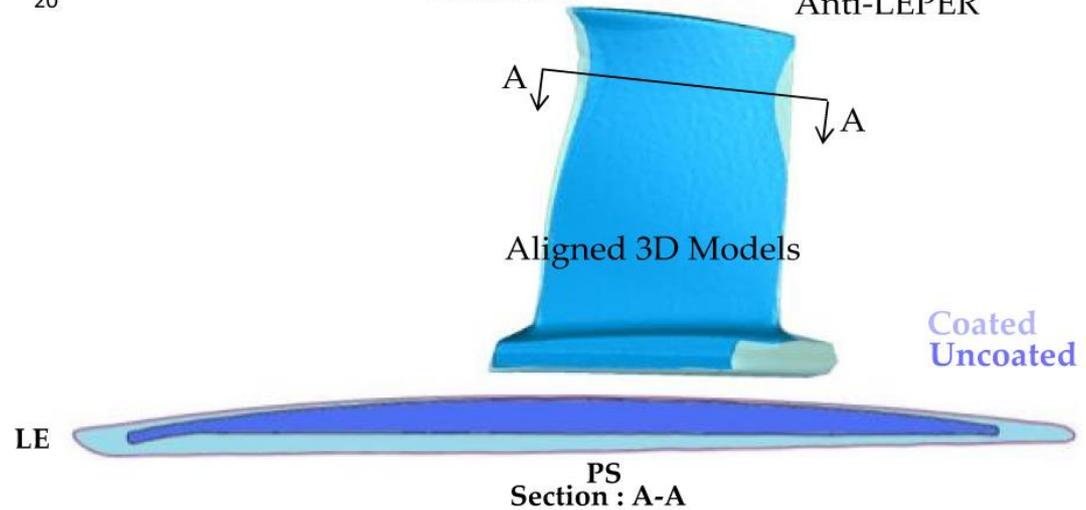


**BlackGold®**  
Anti-LEPER

## Mass Loss

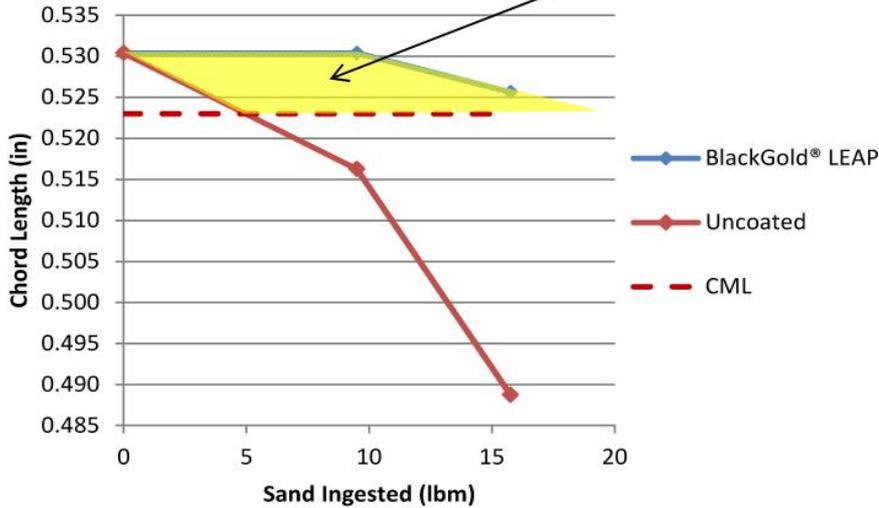


**≈ 10X Improvement**

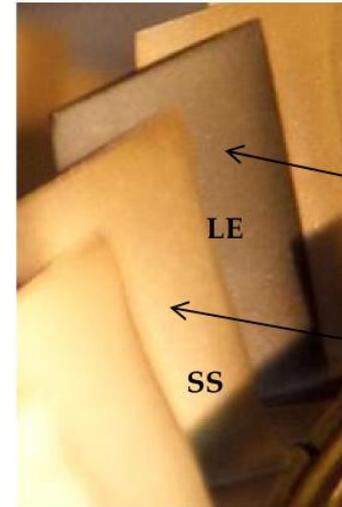




≈ 3.9X Improvement (projected)



Mass loss after 15.75 lbm  
Images after 9.5 lbm

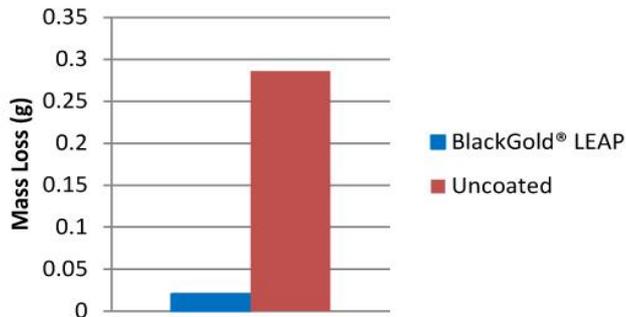


**BlackGold®**  
LEAP

Uncoated

No LEPER observed at 9.5lbm

## Mass Loss



≈ 14X Improvement



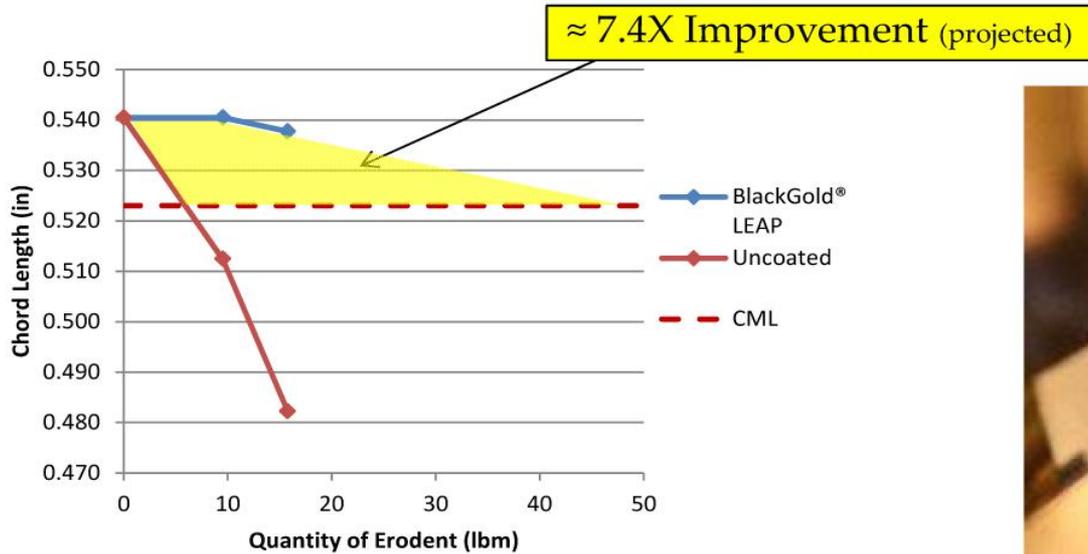
Uncoated Top View



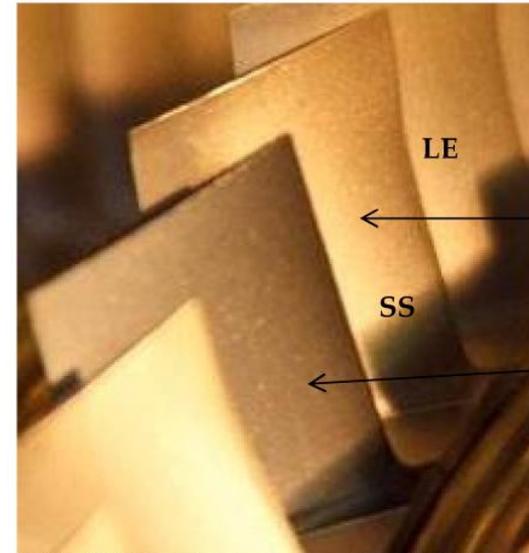
**BlackGold®** LEAP Top View



# Results – HP03 Chord Loss

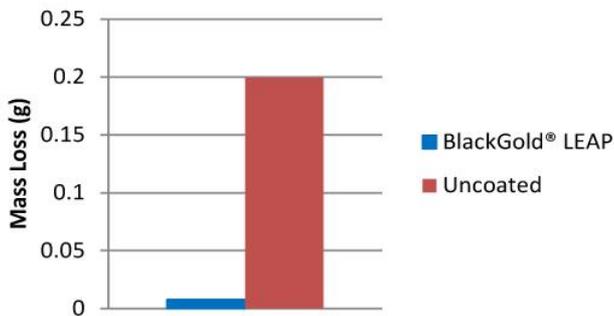


Mass loss after 15.75 lbm  
Image after 9.5 lbm  
Top view after 15.75 lbm



No LEPER observed at 9.5lbm

## Mass Loss



**≈ 26X Improvement**



Uncoated Top View – 15.75 lbm



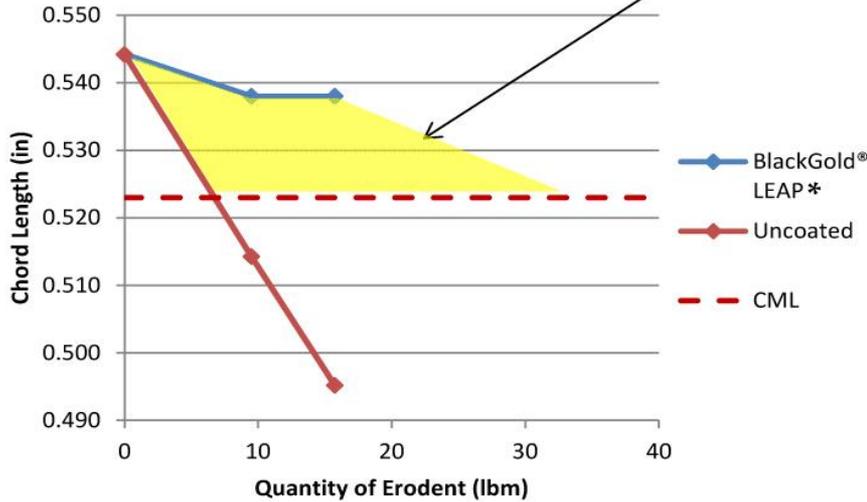
**BlackGold® LEAP** Top View – 15.75 lbm



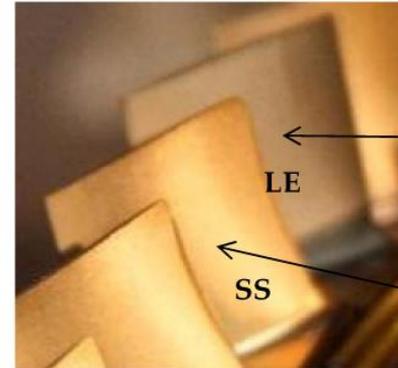
# Results – HP04 Chord Loss



≈ 4.8X Improvement (projected)



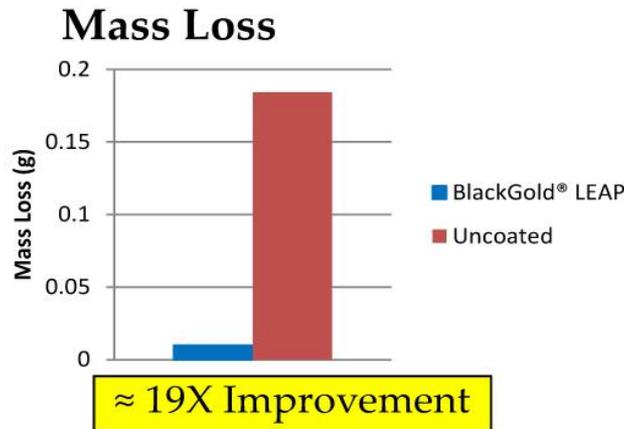
Mass loss after 15.75 lbm  
Image after 9.5 lbm  
Scan after 15.75 lbm



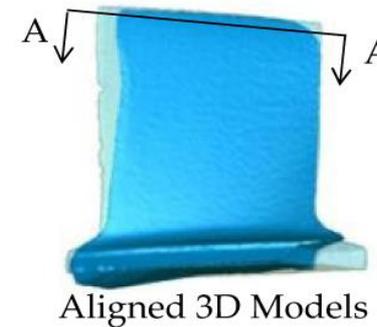
**BlackGold®**  
LEAP

Uncoated

No LEPER observed at 9.5 lbm



≈ 19X Improvement



\*Extrapolated using slope between 0 lbm and 9.5 lbm

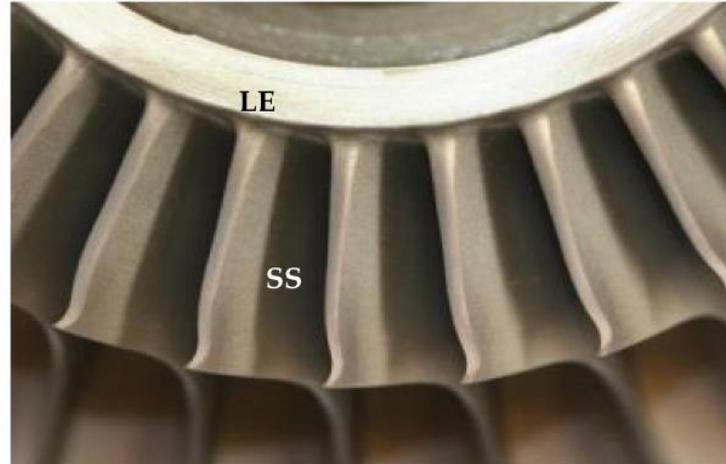
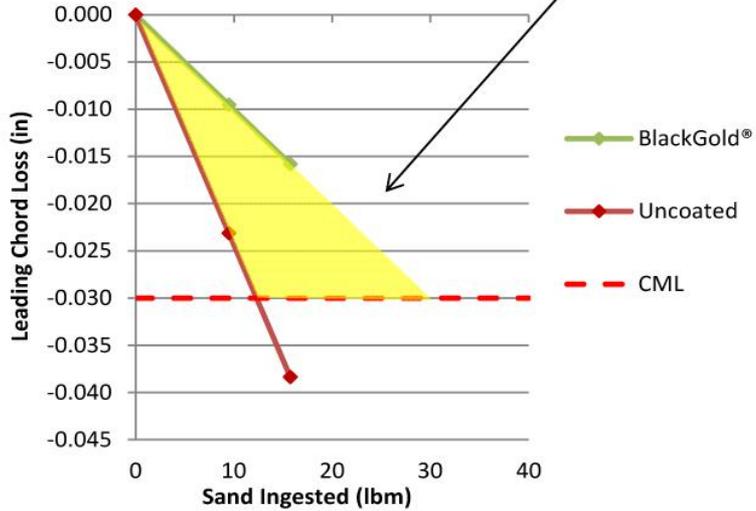


# Impeller Chord Loss



Images after 15.75lbm

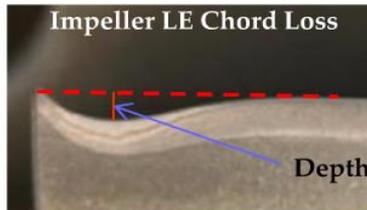
≈ 2.4X Improvement (projected)



Uncoated



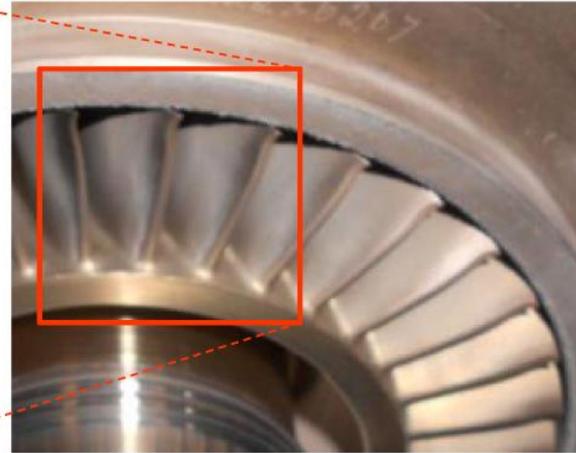
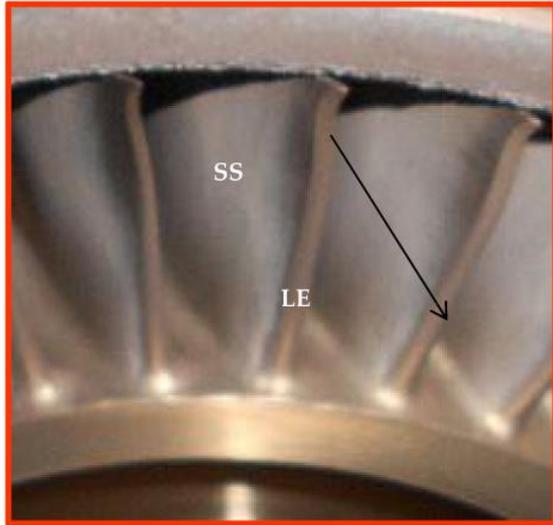
BlackGold®



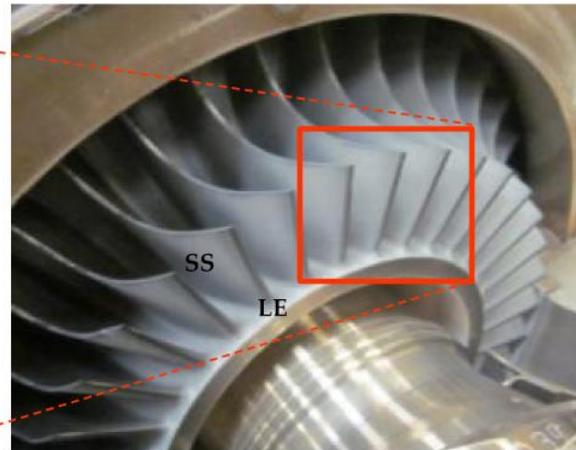
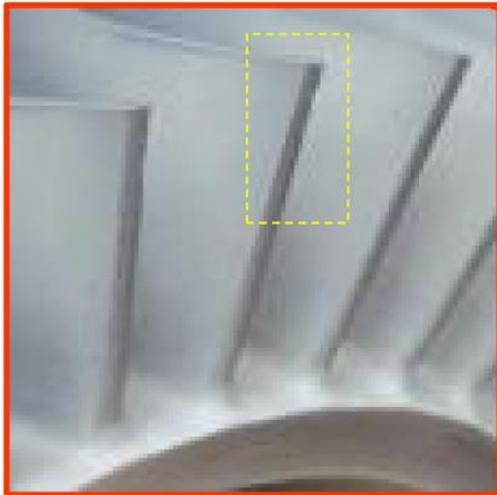


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**RDECOM**

# Impeller



**Uncoated**  
9.5 lbm  
( $\approx 0.93$  lbm/hr)



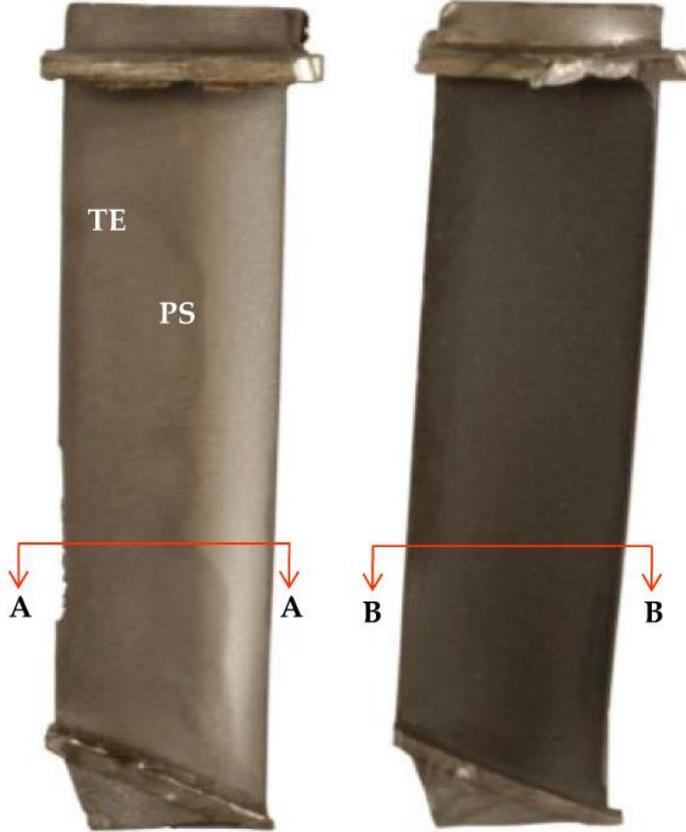
**BlackGold<sup>®</sup>**  
6.75 lbm  
( $\approx 1.41$  lbm/hr)



# LP02 Stator Vane



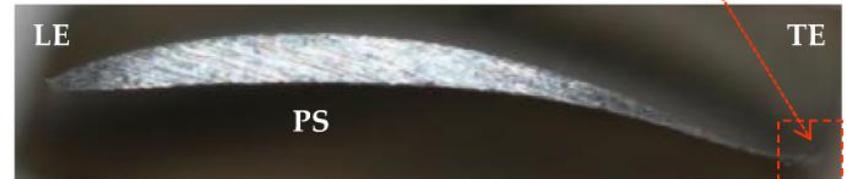
Outer Band



**Uncoated**

**BlackGold<sup>®</sup>**  
Anti-LEPER

TE Thinning



Uncoated Section A-A



**BlackGold<sup>®</sup>** Anti-LEPER Section B-B

Maintains Trailing Edge thickness



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**RDECOM**



**Thank  
You**

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