



# Development of Forced Pulse Water Strip of Tungsten Carbide HVOF Coatings and Chrome Plating on Aircraft, Landing Gear and Propeller Components

Jay Randolph

ES3 - Georgia Technical Operations Center  
(478) 957-1278

[jay.randolph@es3inc.com](mailto:jay.randolph@es3inc.com)

Fred Laguines

ES3 - Georgia Technical Operations Center  
(478) 258-2889

[Fred.laguines@es3inc.com](mailto:Fred.laguines@es3inc.com)

Mohan Vijay

VLN – Advanced Technologies  
(613) 749-2244

[mvijay@vln-tech.com](mailto:mvijay@vln-tech.com)

Guest Speaker: Kirk Bucknor

Messier-Dowty Inc  
(905) 683-3101

[Kirk.bucknor@messier-dowty.com](mailto:Kirk.bucknor@messier-dowty.com)

**SERDP/ESTCP Workshop –  
Surface Finishing and Repair Issues  
for Sustaining New Military Aircraft**

# Report Documentation Page

*Form Approved  
OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE <b>FEB 2008</b>	2. REPORT TYPE	3. DATES COVERED <b>00-00-2008 to 00-00-2008</b>			
4. TITLE AND SUBTITLE <b>Development of Forced Pulse Water Strip of Tungsten Carbide HVOF Coatings and Chrome Plating on Aircraft, Landing Gear and Propeller Components</b>		5a. CONTRACT NUMBER			
		5b. GRANT NUMBER			
		5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S)		5d. PROJECT NUMBER			
		5e. TASK NUMBER			
		5f. WORK UNIT NUMBER			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>ES3 Inc,1346 South Legend Hills Drive,Clearfield,UT,84015</b>		8. PERFORMING ORGANIZATION REPORT NUMBER			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)			
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)			
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>Surface Finishing and Repair Issues for Sustaining New Military Aircraft Workshop, February 26-28, 2008, Tempe, AZ. Sponsored by SERDP/ESTCP.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>	<b>Same as Report (SAR)</b>	<b>20</b>	

# Agenda & Project Overview

## Agenda & Project Overview

### Objective

## USAF SBIR Phase I Awarded to ES3

USAF SBIR Number F071-317-0028

Period Of Performance: 5Jul07 to 3Apr08

### Benefits

## Joint SBIR between Hill & Robins AFB

Craig Shaw, Hill AFB

Greg Sutton, Robins AFB

### Status

## USAF Tech Leads

Ryan Josephson, Hill AFB

Richard Newton/John Jacobs, Robins AFB

### VLN - FPWJ Theory

### Phase I Test Results

## ES3 teamed with VLN Advanced Technologies

### Messier-Dowty Test Results

## Commercialization Interest:

Messier-Dowty, Boeing, Heroux-Devtek,

Goodrich, KLM, Delta Air Lines,

Tinker AFB, FRC-East/ISSC @ Cherry Pt.,

FRC-Southeast @ Jacksonville, and others

### Contact Information

### Questions



# Objective

Agenda &  
Project  
Overview

**Objective**

Benefits

Status

VLN - FPWJ  
Theory

Phase I Test  
Results

Messier-Dowty  
Test Results

Contact  
Information

Questions

**The objective of the Phase I Feasibility study was to develop the parameters that could strip both hard chrome plating and HVOF tungsten carbide coatings consistently and repeatedly, without visually or dimensionally damaging the substrate.**

**Hill AFB: Focus is Landing Gear**

**300M High Strength Steel substrates  
HVOF coating is WC-Co**

**Robins AFB: Focus is Aircraft and Propeller**

**4340 Low Strength Steel substrates  
HVOF coating is WC-Co-Cr**

**Phase II – Qualification Testing**

**Phase III – Commercialization and Technology  
Insertion**

# Benefits

Agenda &  
Project  
Overview

Objective

**Benefits**

Status

VLN - FPWJ  
Theory

Phase I Test  
Results

Messier-Dowty  
Test Results

Contact  
Information

Questions

**A process that will strip both chrome plating and HVOF tungsten carbide coatings from high & low strength steel alloys**

**Elimination of multiple wet chemical strip tanks**

**Elimination of hydrogen embrittlement issues that are associated with the wet chemical strip process**

**Elimination of embrittlement relief bakes**

**Reduced process time**

**Environmentally friendly process**

**Utilization of basic water (no abrasives) in a recycled system**

# Project Status

Agenda &  
Project  
Overview

**Phase I Feasibility testing successfully completed and report submitted to the USAF.**

Objective

**Phase II is being initiated and scheduled to start at conclusion of Phase I PoP, Apr08.**

Benefits

**Project Status**

**Other DoD Repair Depots contacted and invited to join Phase II testing.**

VLN - FPWJ  
Theory

**Incorporate specific depot or weapon system test requirements with same plating/coatings and substrate combinations.**

Phase I Test  
Results

**Add test programs for other finishes and / or substrate combinations.**

Messier-Dowty  
Test Results

Contact  
Information

Questions

**OEM's being contacted or in discussions for complimentary test programs.**

# VLN – FPWJ Theory

**FORMATION OF FORCED PULSED WATERJET**



**HIGH-FREQUENCY PULSES OF WATER ARE GENERATED BY MODULATING A CONTINUOUS STREAM OF WATER**

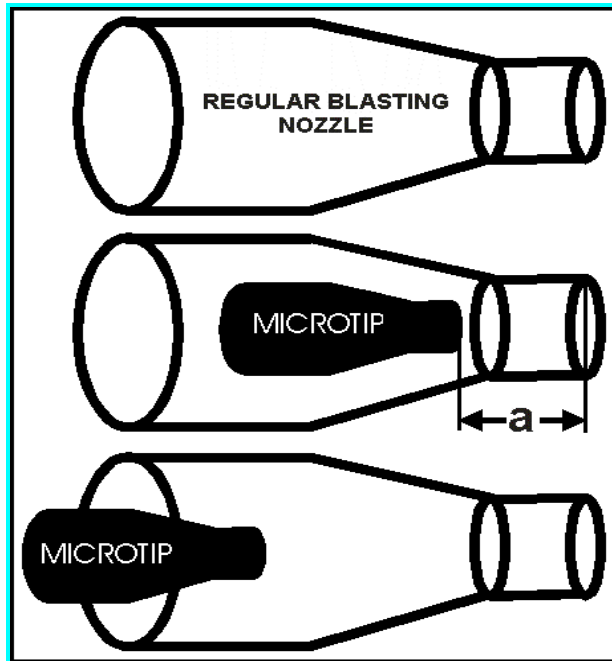


**AS SHOWN IN THE NEXT SLIDE, MODULATION IS ACHIVED BY INDUCING ULTRASONIC WAVES USING A MICROTIP IN THE NOZZLE**

- Agenda & Project Overview
- Objective
- Benefits
- Project Status
- VLN - FPWJ Theory**
- Phase I Test Results
- Messier-Dowty Test Results
- Contact Information
- Questions

# VLN – FPWJ Theory

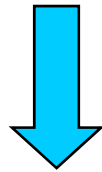
- Agenda & Project Overview
- Objective
- Benefits
- Project Status
- VLN - FPWJ Theory**
- Phase I Test Results
- Messier-Dowty Test Results
- Contact Information
- Questions



# VLN – FPWJ Theory

- Agenda & Project Overview
- Objective
- Benefits
- Project Status
- VLN - FPWJ Theory**
- Phase I Test Results
- Messier-Dowty Test Results
- Contact Information
- Questions

**FULLY DEVELOPED  
HIGHLY EFFICIENT  
PULSED WATERJET  
IS PRODUCED WHEN**



**'a' VALUE IS OPTIMUM  
FOR GIVEN VALUES OF**

**PRESSURE  
FLOW  
AND  
ULTRASONIC POWER  
INPUT**



# Phase I Test Results

Agenda &  
Project  
Overview

Objective

Benefits

Project Status

VLN - FPWJ  
Theory

**Phase I Test  
Results**

Messier-Dowty  
Test Results

Contact  
Information

Questions



**Left: View of Chrome plated, HSS coupon prior to pulse waterstrip.**

**Right: View of the coupon after complete chrome plating removal by pulse waterstrip.**

**View typical for LSS. Process time was approximately 60 seconds to remove 0.005 inch thick chrome plating along the length of a 1 inch diameter, eight inch long coupon. There is no visual or dimensional damage to the HSS substrate.**

# Phase I Test Results

Agenda &  
Project  
Overview

Objective

Benefits

Project Status

VLN - FPWJ  
Theory

**Phase I Test  
Results**

Messier-Dowty  
Test Results

Contact  
Information

Questions



**Left: View of HVOF WC-Co-Cr coated, LSS coupon prior to pulse waterstrip.**

**Right: View of the coupon after complete coating removal by pulse waterstrip.**

**View typical for HSS with HVOF WC-Co coating. Process time was approximately 120 seconds to remove 0.005 inch thick HVOF coating along the length of a 1 inch diameter, eight inch long coupon. There is no visual or dimensional damage to the LSS substrate.**

# Phase I Test Results

Agenda &  
Project  
Overview

Objective

Benefits

Project Status

VLN - FPWJ  
Theory

**Phase I Test  
Results**

Messier-Dowty  
Test Results

Contact  
Information

Questions

Surfaces were visually inspected under 25X magnification to observe surface texture characteristics.



# Phase I Test Results

## 4340 - Stripped Chrome Plated Coupons

Serial Number	Pre-Coating Diameter (in)	Post-Strip Diameter (in)	Weight Loss/Gain (%)	Post-Strip Surface Finish ( $\mu$ in)
ES3-004	0.9937	0.9940	-0.015	87.3
ES3-005	0.9936	0.9940	-0.009	85.2
ES3-006	0.9936	0.9940	0	88.5

## 4340 - Stripped HVOF Coated Coupons

Serial Number	Pre-Coating Diameter (in)	Post-Strip Diameter (in)	Weight Loss/Gain (%)	Post-Strip Surface Finish ( $\mu$ in)
ES3-011	0.9935	0.9946	0	121.1
ES3-012	0.9935	0.9946	-0.004	120.6
ES3-013	0.9935	0.9947	+0.006	129.8

Agenda &  
Project  
Overview

Objective

Benefits

Project Status

VLN - FPWJ  
Theory

Phase I Test  
Results

Messier-Dowty  
Test Results

Contact  
Information

Questions

# Phase I Test Results

## 300M - Stripped Chrome Plated Coupons

Serial Number	Pre-Coating Diameter (in)	Post-Strip Diameter (in)	Weight Loss/Gain (%)	Post-Strip Surface Finish ( $\mu$ in)
ES3-002	0.9937	0.9940	0.235	40.7
ES3-005	0.9937	0.9940	0.164	39.6
ES3-008	0.9937	0.9940	0.201	44.6

## 300M - Stripped HVOF Coated Coupons

Serial Number	Pre-Coating Diameter (in)	Post-Strip Diameter (in)	Weight Loss/Gain (%)	Post-Strip Surface Finish ( $\mu$ in)
ES3-010	0.9935	0.9941	-0.077	109.2
ES3-011	0.9935	0.9943	-0.064	94.7
ES3-012	0.9935	0.9943	-0.083	111.7

Agenda &  
Project  
Overview

Objective

Benefits

Project Status

VLN - FPWJ  
Theory

Phase I Test  
Results

Messier-Dowty  
Test Results

Contact  
Information

Questions

# Messier-Dowty Test Results



- Agenda & Project Overview
- Objective
- Benefits
- Project Status
- VLN - FPWJ Theory
- Phase I Test Results
- Messier-Dowty Test Results**
- Contact Information
- Questions

## Water Jet Stripping of HVOF Coating



# Messier-Dowty Test Results

## Background



- Messier-Dowty (M-D) worked with VLN Advanced Technologies Inc. to optimize their forced-pulse waterjet (FPWJ) process to strip a landing gear part HVOF coated with WC-Co-Cr.
  
- All coatings stripped were in the as-sprayed condition. No tests were performed after the HVOF coating was super-finished.
  
- M-D performed a number of studies with VLN to:
  1. Assess VLN ability to strip HVOF coated parts.
  2. Strip HVOF coated parts without any visual or dimensional damage to the metal substrate.
  3. Determine the resultant surface residual stresses after stripping using x-ray diffraction (XRD).

Agenda &  
Project  
Overview

Objective

Benefits

Project Status

VLN - FPWJ  
Theory

Phase I Test  
Results

Messier-Dowty  
Test Results

Contact  
Information

Questions

# Messier-Dowty Test Results

## Experimental Part



Agenda &  
Project  
Overview

Objective

Benefits

Project Status

VLN - FPWJ  
Theory

Phase I Test  
Results

Messier-Dowty  
Test Results

Contact  
Information

Questions

- Landing Gear Pin
- 300M steel (HRc 53-55)
- HVOF coated with WC-Co-Cr
- Coating thickness = approx. 0.015"
- Length = 10"
- Diameter: Tapered



# Messier-Dowty Test Results

## ■ XRD Measurement



- One pin stripped using VLN waterjet process was examined to determine the resultant surface residual stresses after stripping.
- The intention was to determine if the resulting cyclic loading of the water pulses negate the compressive stresses induced in the pin during the shot peen operation.
- Shot peening induces compressive stresses which allows a component to carry higher cyclic stresses, thus, improving its fatigue performance.
- Any operation that decreases the shot peen effects would be considered un-acceptable.

Agenda &  
Project  
Overview

Objective

Benefits

Project Status

VLN - FPWJ  
Theory

Phase I Test  
Results

Messier-Dowty  
Test Results

Contact  
Information

Questions

# Messier-Dowty Test Results

## XRD Measurement – cont'd



- Agenda & Project Overview
- Objective
- Benefits
- Project Status
- VLN - FPWJ Theory
- Phase I Test Results
- Messier-Dowty Test Results
- Contact Information
- Questions

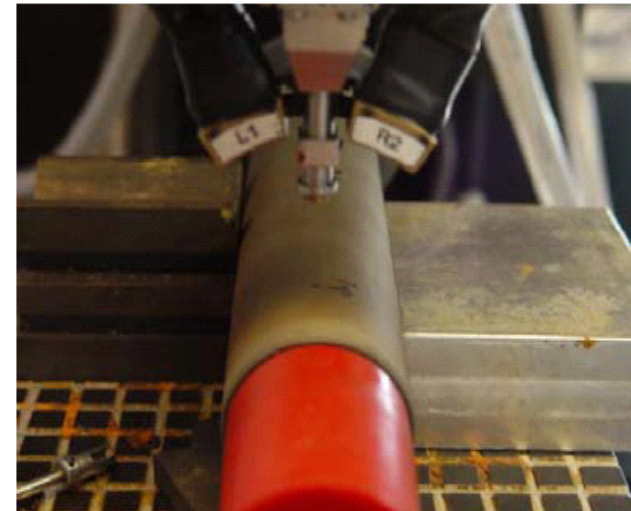
- Six(6) measurements were taken on one of the stripped pins, three(3) each in both the longitudinal and transverse grain directions of the pin.
- All measurements were compressive (-ve), ranging from -59ksi to -71ksi.
- This indicates that the cyclic loading of the waterjet pulses on the coatings did not affect the material surface stresses.

Experimental Results : Surface Residual Stress

Location: (see photograph below)

Location:	Longitudinal Stress (ksi)	Transverse Stress (ksi)
Top	-68 ± 1	-67 ± 1
Middle	-59 ± 2	-64 ± 1
Bottom	-64 ± 1	-71 ± 1

Measurement Locations & Picture:



# Contact Information

Agenda & Project Overview	<b>ES3 - Georgia Technical Operations Center</b> <b>Jay Randolph</b> <b>(478) 957-1278</b> <a href="mailto:jay.randolph@es3inc.com">jay.randolph@es3inc.com</a>	<b>Fred Laguines</b> <b>(478) 258-2889</b> <a href="mailto:fred.laguines@es3inc.com">fred.laguines@es3inc.com</a>
Objective		
Benefits	<b>ES3 – Clearfield, Utah Office</b>	
Project Status	<b>Craig Pessetto</b> <b>801-926-1150</b> <a href="mailto:craig.pessetto@es3inc.com">craig.pessetto@es3inc.com</a>	<b>Jake Merrill</b> <b>801-926-1150</b> <a href="mailto:jacob.merrill@es3inc.com">jacob.merrill@es3inc.com</a>
VLN - FPWJ Theory		
Phase I Test Results	<b>VLN – Advanced Technologies</b> <b>Mohan Vijay</b> <b>(613) 749-2244</b> <a href="mailto:mvijay@vln-tech.com">mvijay@vln-tech.com</a>	<b>Willie Bloom</b> <b>(613)-747-0107</b> <a href="mailto:wbloom@vln-tech.com">wbloom@vln-tech.com</a>
Messier-Dowty Test Results		
Contact Information	<b>Messier-Dowty Inc</b> <b>Kirk Bucknor</b> <b>(905) 683-3101</b> <a href="mailto:kirk.bucknor@messier-dowty.com">kirk.bucknor@messier-dowty.com</a>	<b>Roger Eybel</b> <b>(905) 683-3100</b> <a href="mailto:roger.eybel@messier-dowty.com">roger.eybel@messier-dowty.com</a>
Questions		

Agenda &  
Project  
Overview

Objective

Benefits

Project Status

VLN - FPWJ  
Theory

Phase I Test  
Results

Messier-Dowty  
Test Results

Contact  
Information

Questions

# Questions?