



*Infrared Reflectance Imaging for Environmentally
Friendly Corrosion Inspection Through Organic Coatings
Project Number WP-0407*

Authors:

Mr. John Weir, P.E., Northrop Grumman Corporation
Mr. Jack Benfer, NAVAIR Jacksonville FL

ESTCP Conference
Tempe, AZ

25-29 February 2008

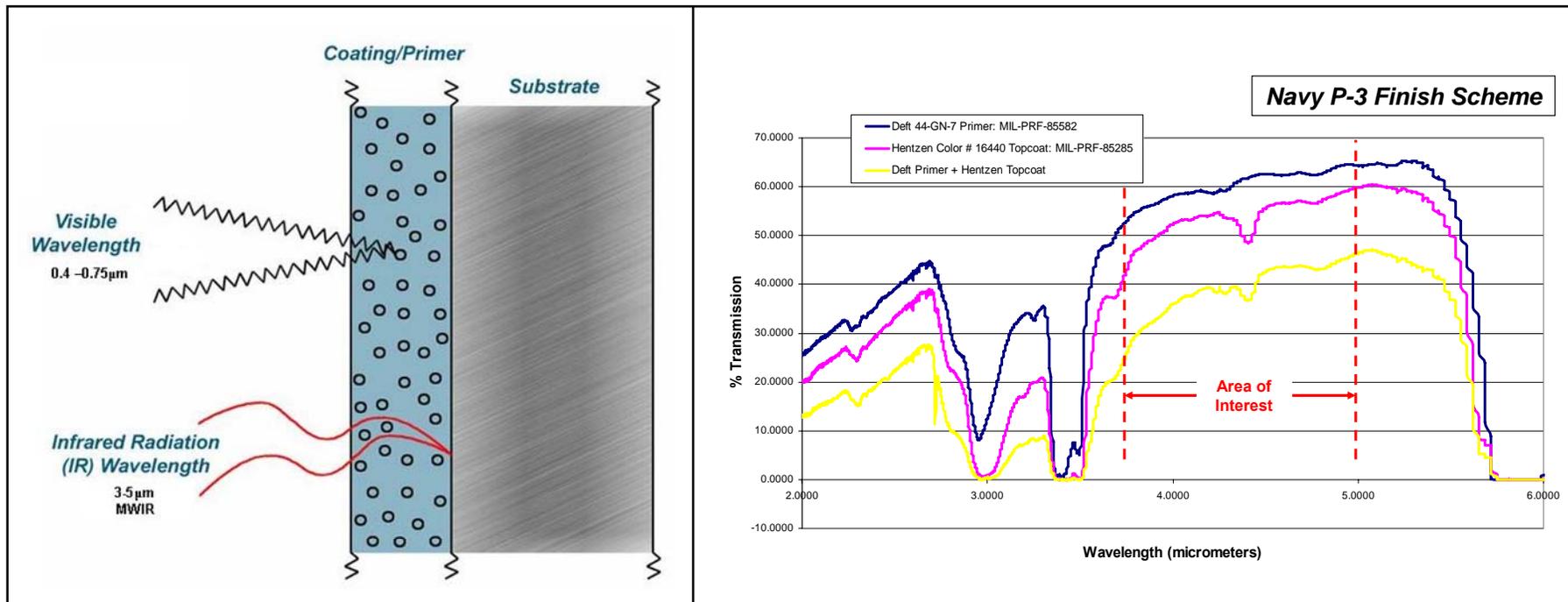
Report Documentation Page

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 FEB 2008	2. REPORT TYPE	3. DATES COVERED 00-00-2008 to 00-00-2008	
4. TITLE AND SUBTITLE Infrared Reflectance Imaging for Environmentally Friendly Corrosion Inspection Through Organic Coatings		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) Northrop Grumman Corporation, 2980 Fairview Park Drive, Falls Church, VA, 22042		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 Approved for public release; distribution unlimited			
13. SUPPLEMENTARY NOTES Surface Finishing and Repair Issues for Sustaining New Military Aircraft Workshop, February 26-28, 2008, Tempe, AZ. Sponsored by SERDP/ESTCP.			
14. ABSTRACT			
15. SUBJECT TERMS			
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified	Same as Report (SAR)
			18. NUMBER OF PAGES 44
			19a. NAME OF RESPONSIBLE PERSON

Background



Note: Typical military specification coating systems are transparent in the 3-5 micrometer wavelength.

U.S. Patent: 7,193,215

U.S. Patent: 7,164,146



Technical Objectives

- Demonstrate Infrared Reflectance Imaging Technique (IRRIT) as an enhanced inspection tool when compared to visual inspection.
- Establish and prove the technique and determine cost/waste reductions from actual maintenance operations.
- Reduce environmental impacts
 - HAZMATs
 - VOCs
 - Chromates
 - Inorganic HAPs
- Reduce costs to inspect and repair coatings by minimizing labor hours and flow/down times.

Technical Approach

NAVAIR Jacksonville, FL

P-3 OML Dem/Val



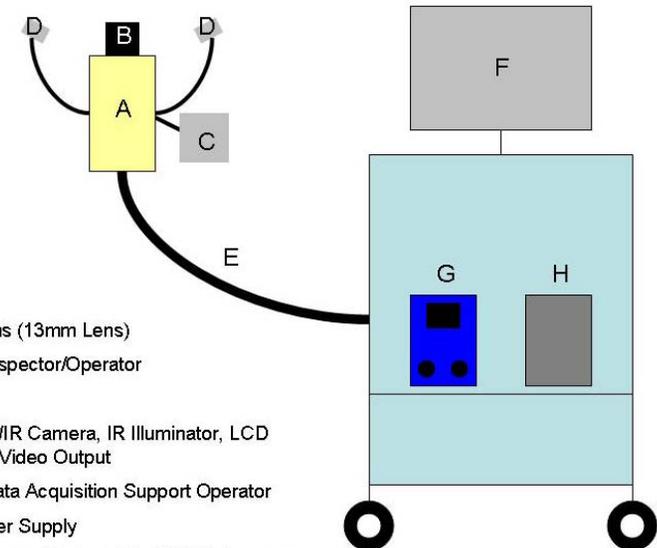
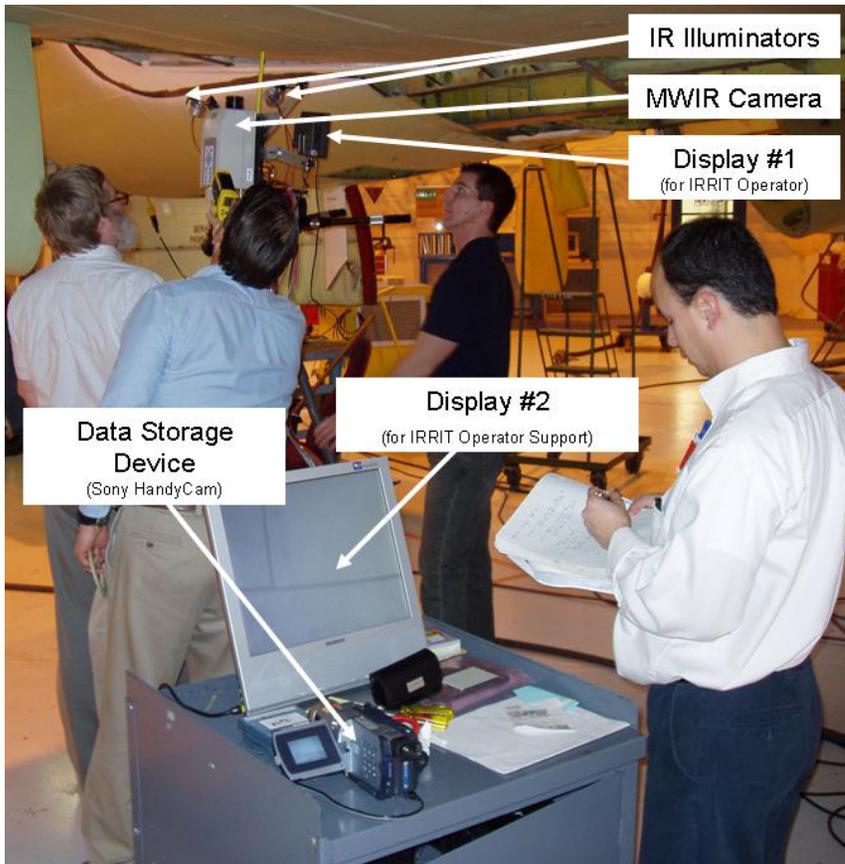
Oklahoma City ALC, OK

KC-135 and B-52 IML Dem/Val



Technical Approach

IRRIT System Components



- A = MWIR Camera
- B = MWIR Camera Lens (13mm Lens)
- C = LCD – for IRRIT Inspector/Operator
- D = IR Illuminators
- E = Cable includes MWIR Camera, IR Illuminator, LCD Power Supplies and S-Video Output
- F = LCD – for IRRIT Data Acquisition Support Operator
- G = IR Illuminator Power Supply
- H = IR Digital Data Storage (Output of the MWIR Camera - Still IR Images and IR Video, i.e., Sony HandyCam)

Technical Approach

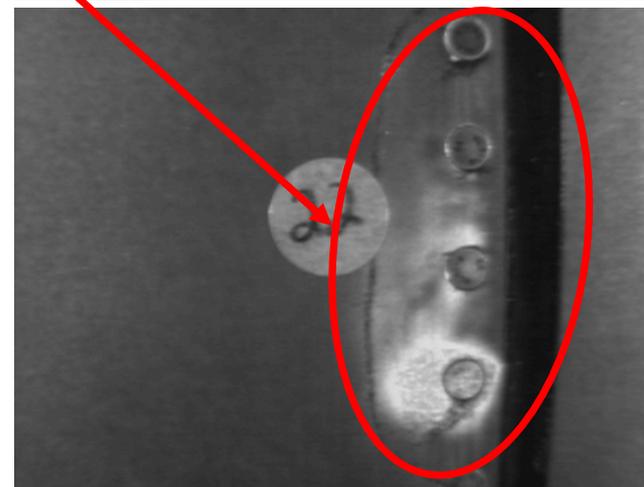
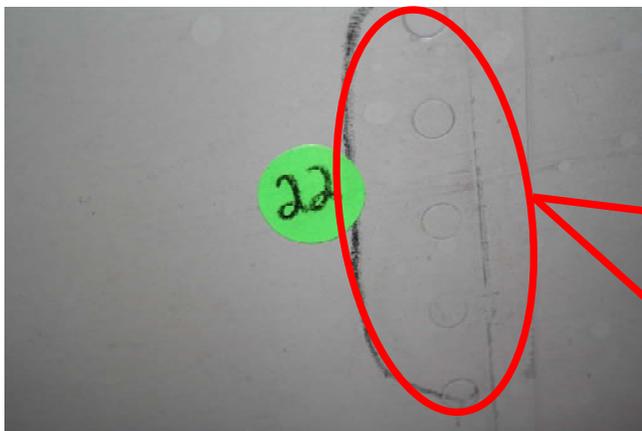
Dem/Val Process



- Consolidate and Review all data
- Statistical analysis of the number of corrosion sites identified
- Compare Visual versus IRRIT results for accuracy

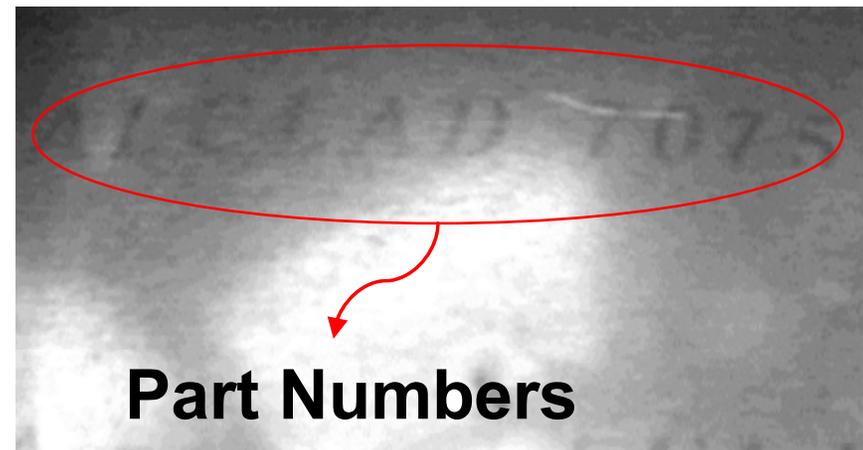
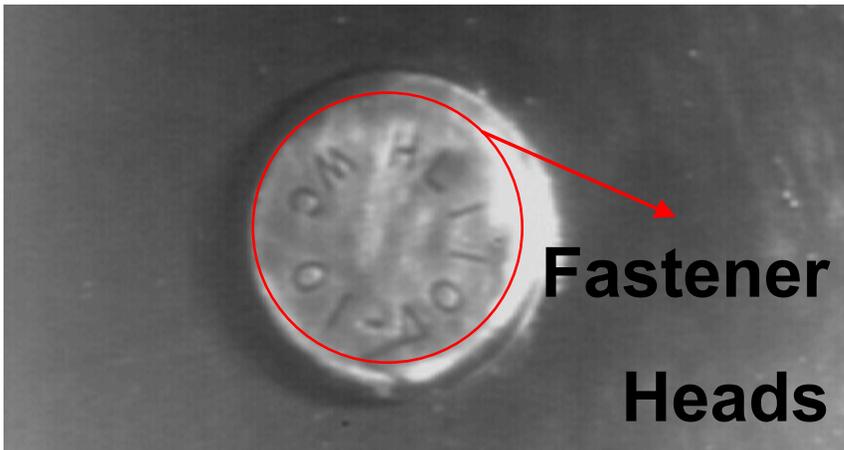
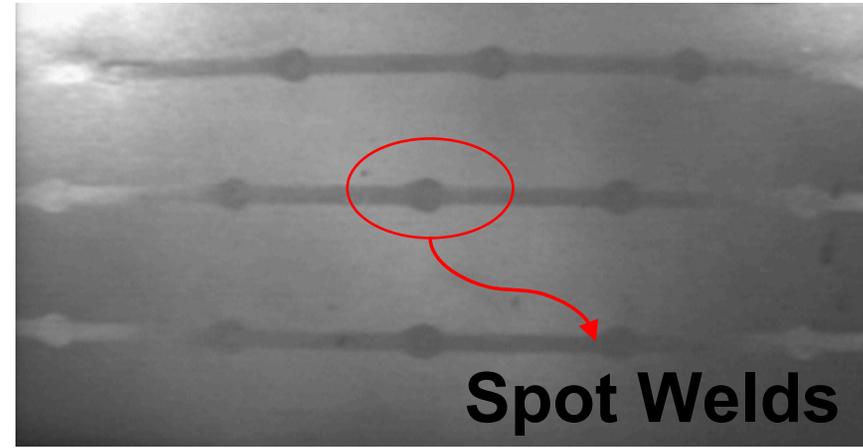
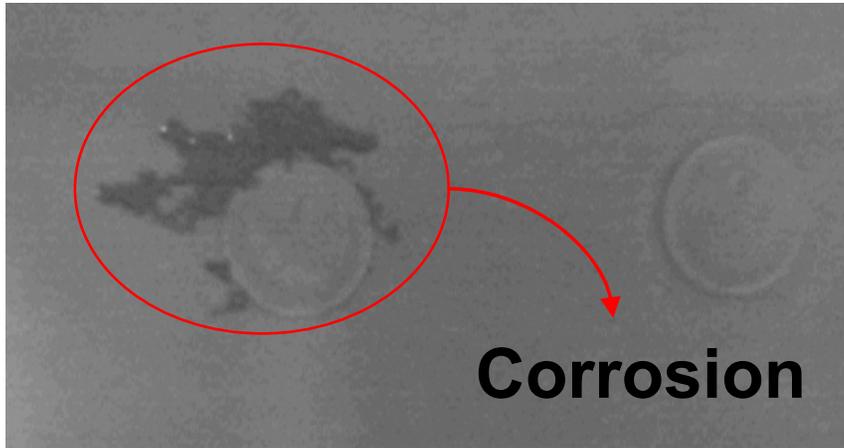
Technical Approach

IRRIT System During Dem/Val



Additional IRRIT Information

By the way....



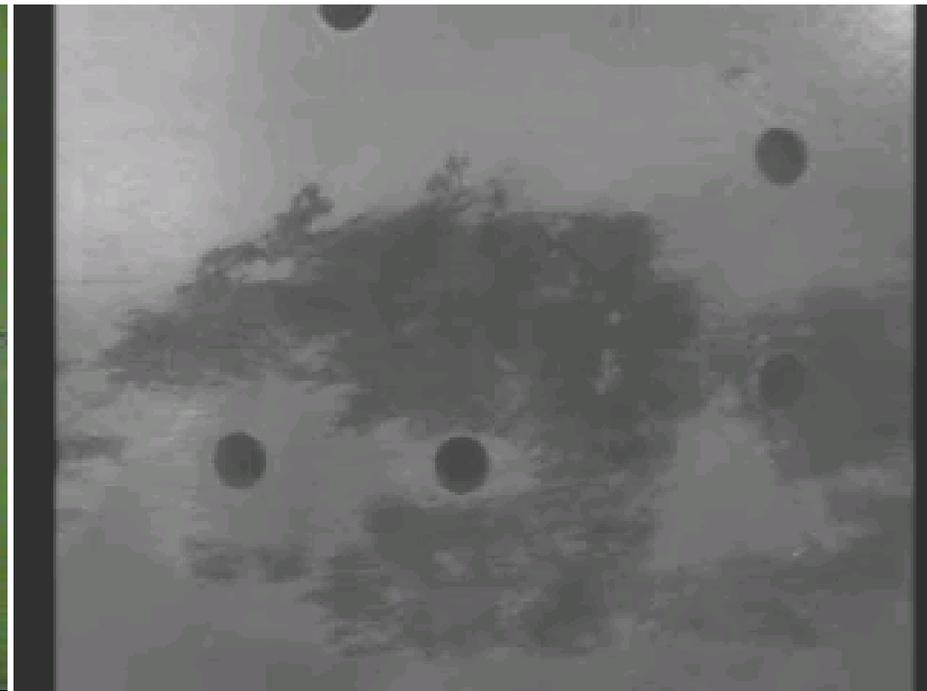


VISUAL AND IRRIT VIDEO

Visual Video



IRRIT Video



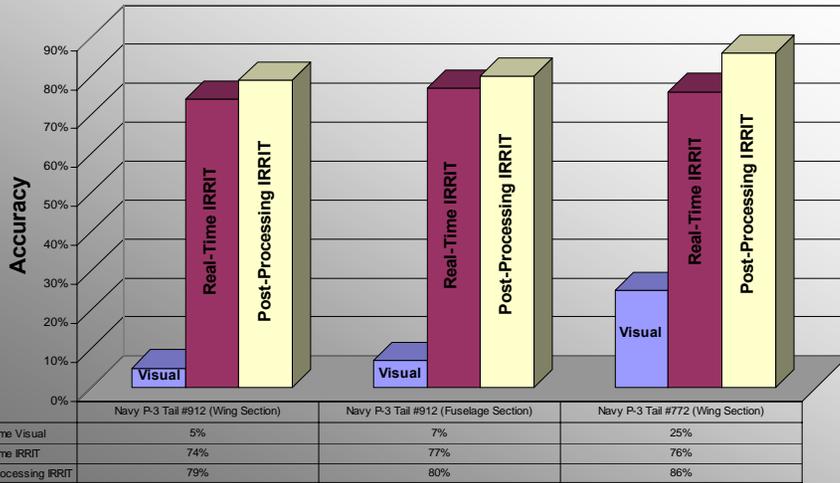


Results - IRRIT Dem/Val Data

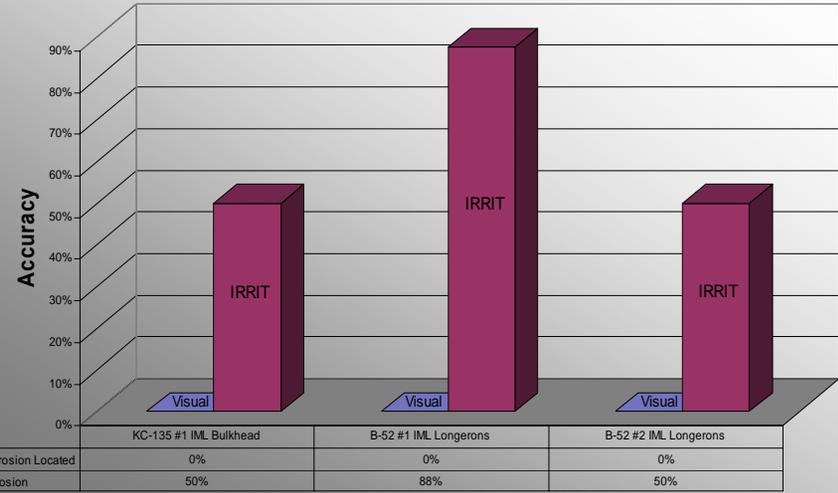
Navy P-3 OML

USAF KC-135 and B-52 IML

Accuracy: IRRIT Inspection versus Visual Inspection



Accuracy: IRRIT Inspection versus Visual Inspection



Navy P-3 OML Dem/Val Results

USAF KC-135 and B-52 IML Results

IRRIT Inspection Accuracy (Post-Processing)
79%, 80%, 86%

IRRIT Inspection Accuracy (Real-Time*)
50%, 88%, 50%

Visual Inspection Accuracy (Real-Time)
5%, 7%, 25%

Visual Inspection Accuracy (Real-Time)
0% - No Corrosion Located Visually

*Post-Processing not performed for OC-ALC IML Dem/Val due to localized stripping.

Results

Why?



1. The IR method directly images corrosion by-product through the paint system due to reflectance contrast differences of the substrate.

2. The visual method relies upon the identification of paint surface irregularities/blistering (i.e., paint degradation) as a result of substrate volume changes associated with corrosion formation.



Transition Plan

- IRRIT demonstrations and briefings occurred at multiple DoD facilities. Resulting in additional endorsements beyond the scope of the planned Dem/Val, which include:
 - USN P-3, E-6, T-45, NAVAIR Materials
 - USCG NDI Program
 - USAF Pending
- Technology Users:
 - Inspectors, quality assurance specialists, and engineers within applicable maintenance and engineering departments of the DoD.
 - Engineering Tool – RCM, E.I., Failure Analysis.
 - E&E/NDI – Conditional Based Maintenance.
 - Quality Assurance – Corrosion control program assessments.





Transition Plan

- Acquiring IRRIT System:
 - IRRIT system procurement may be performed as individual component purchases (MWIR camera) later integrated by the user community or through IRRIT System Kits produced and provided by Northrop Grumman Technical Services (Bethpage, NY).
 - MWIR Camera
 - IR Bandpass Filter
 - Data Capture/Storage System

- IRRIT System Operating Training
 - Infrared Training Center (ITC) Certification Level 1, 2, and 3
 - Currently certified trained IR Inspectors for EA-6B, NDI, Corrosion, and NATEC technicians.
 - Written practice
 - Site specific task training (IQR)
 - Northrop Grumman Technical Services (Bethpage, NY), to include, operating instructions and support for the IRRIT MWIR camera plus all required accessories.



Transition Plan

NAVAIR Materials Endorsement Letter

11 April 2007

FROM: Materials Engineering Division (AIR-4.3.4)

TO: NAVAIR JAX 4.9.7.6; John E. Benfer (WP-0407 Principle Investigator)

SUBJ: INFRARED (IR) REFLECTANCE IMAGING THROUGH AIRCRAFT PAINT SYSTEMS

1. AIR-4.3.4 has reviewed technical information and witnessed field demonstrations associated with infrared reflectance imaging of corrosion through aircraft paint systems. This technology has demonstrated capability to detect and image surface corrosion in an industrial environment while utilizing a commercially available of-the-shelf (COTS) mid-IR camera.
2. Scheduled maintenance processes that involve stripping paint from aircraft surfaces or disassembling components for corrosion inspection can be reduced or eliminated using this technology by providing enhanced inspection capability in support of ground support equipment (GSE), weapons, avionics and component product lines. The availability of a quick, reliable, and simple nondestructive technique that can detect and characterize corrosion hidden under aircraft coating systems, would reduce inspection times and costs, and reduce hazardous waste generation from paint and repaint operations.
3. This technology is also capable of providing enhanced inspection data and documentation associated with corrosion-related failure analyses, engineering investigations, and research, development, testing, and evaluation (RDT&E) programs. Continued research in this area could lead to the development of a system that significantly improves the corrosion inspection process and thereby reduces the risk of failure in aircraft structural component and ultimately improve flight safety. All new and legacy platforms can benefit from this technology; therefore, AIR-4.3.4 recommends both the continued investment into this technology, as well as, the immediate application where applicable.
4. Please contact me if further information is required. I can be reached at (904) 542-4521 x101 or by e-mail at john.yadon@navy.mil.

John L. Yadon
Materials Engineering (AIR-4.3.4)

Draft Technical Manual

MID WAVE INFRARED INSPECTION OF CORROSION UNDER PAINTED AIRCRAFT COMPONENTS

GENERAL THEORY AND INSTRUCTIONS

Reference Material

Aircraft Weapons System Cleaning and Corrosion Control.....	NAVAIR 01-1A-509
Infrared Training Center.....	TTC Level 1 Course Manual
FLIR Systems MilCAM RECON Operators Manual	17485-000 Rev C

Index

Subject	Page
Infrared Thermography Defined.....	2
Infrared Thermography Techniques	2
Passive Thermography	2
Reflectance Thermography	2
Flash Thermography	2
Thermal Energy Concepts	2
Energy	2
Heat	2
Temperature	2
IR Science Fundamentals	2
The Electromagnetic Spectrum	2
IR Waves.....	2
Visible Light	3
Conservation of Energy.....	3
Absorption	3
Transmissivity.....	3
Reflectance.....	3
Emissivity	3
Corrosion	3
Corrosion Defined	3
Effect on Military Aircraft	3
Infrared Inspection of Corrosion	4
IRRIT	4
IRRIT Background	4
Inspection Intervals	4
Recommendations Based on Inspections.....	5
Strip and Repaint Entire Aircraft	5
Scuff-Sand and Topcoat Small Areas	5
Spot Strip and Repaint Small Areas	5
Strip and Repaint Large Local Areas	5
Managing and Monitoring vs. Repairing Corrosion.....	6
Materials Compatibility.....	6
Aluminum Substrate	6
Procedure	6
Health, Safety, and Environmental Considerations	7
Appendix	7
Glossary of Terms	7



Transition Plan

- E-6 Technology Implementation
 - As a result of successful OC-ALC Dem/Val on USAF KC-135 and B-52, the E-6 engineering office is currently planning IRRIT inspections.
 - Conditional assessment of aircraft repaint
 - Maintenance induced damage
 - Rapid inspection or surface cracks (additional program R&D may be required, program related funding)



Navy E-6 → Boeing derived the E-6A from its commercial 707 to replace the aging EC-130Q

Unit Cost: \$141.7 million

Length: 150 feet, 4 inches (45.8 meters)

Wingspan: 148 feet, 4 inches (45.2 meters)

Height: 42 feet 5 inches (12.9 meters)

Weight: Max gross, take-off. 342,000 lbs
(154,400 kg)



Transition Plan

- Future IR cameras will be smaller, lighter and more portable. These improved cameras will increase inspection rates, enhance ergonomics, and the capability for inspection of more complex geometries.
- October 2007 IR Thermography Conference – Community will be IR thermography end users and developers for technology improvement purposes.





Cost Benefit Summary

- Cost of strip and repaint for OML of a single P-3 aircraft: \$129,565
- Cost of single IRRIT Merlin camera system: \$87,600*

*10% annual maintenance cost;
\$17,000 training cost

**Based off partially burdened
\$65/hour labor rate.

Category	Baseline (per aircraft)
Labor**	\$85,397
Materials	\$21,233
Utilities	\$144
HAZMAT Disposal	\$22,791
TOTAL	\$129,565
VOC Release	3,423 lbs
Total chromates applied	24 lbs
Total hazardous waste generated	11,273 lbs



Cost Benefit Summary

- Implementation Scenarios
 - Condition-based Maintenance – Treat aircraft according to pre-induction inspection performed using IRRIT (requires two IRRIT camera systems).
 - Interval Shift – Programmatic change of paint interval resulting from increased confidence from enhanced corrosion inspection data.

“Engineers are inherently conservative with disposition requirements with insufficient data” – 707 Users Conference.

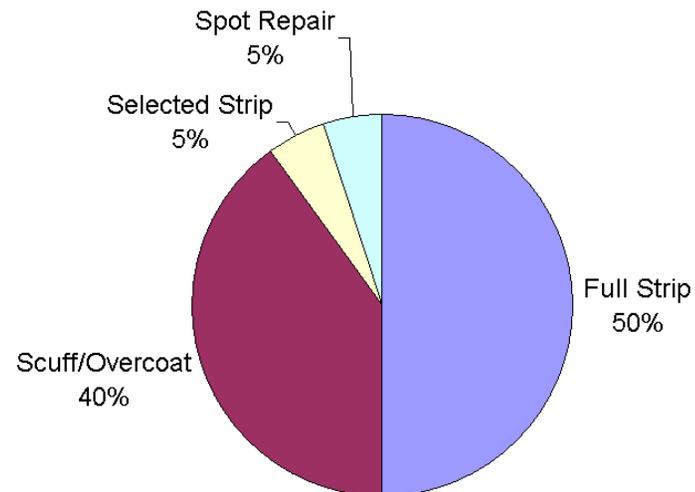


Cost Benefit Summary

Condition-based Maintenance; 25 aircraft /year

Category	Quantity
Capital Costs	
Equipment Cost	\$175,200
Training Cost	\$17,080
Total Capital Cost	\$192,290
Annual Costs	
Full Strip (50%)	\$1,645,971
Scuff/Overcoat (40%)	\$719,331
Selected Strip (5%)	\$112,913
Spot Repair (5%)	\$23,087
IRRIT Maintenance	\$17,520
Total Annual Costs	\$2,518,822

Simple Payback Period	
Baseline (per year)	\$3,239,128
Condition-based	\$2,518,822
Annual Savings	\$720,306
Simple Payback on Capital Cost (\$192,290)	0.27 years
Hazardous Waste Savings	96,502 lbs
VOC Savings	38,431 lbs



Note: %'s derived from H-53 legacy data.



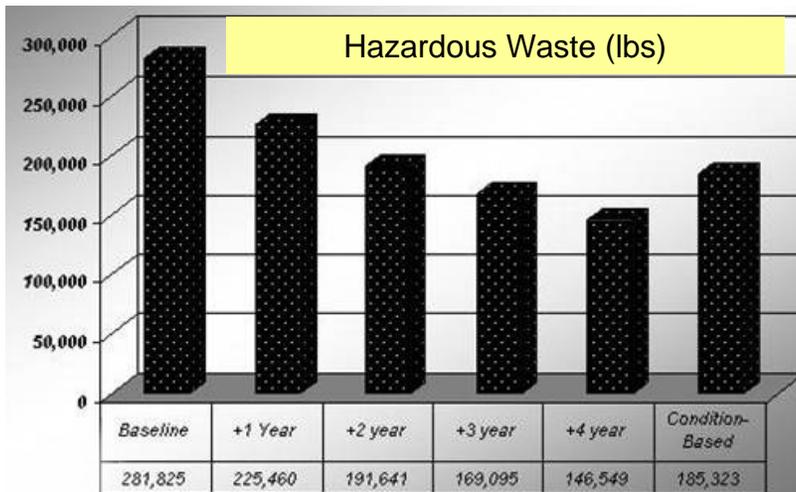
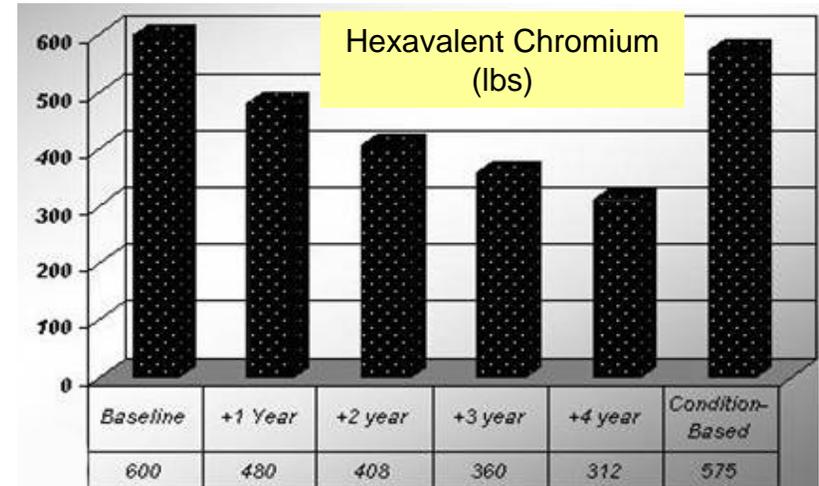
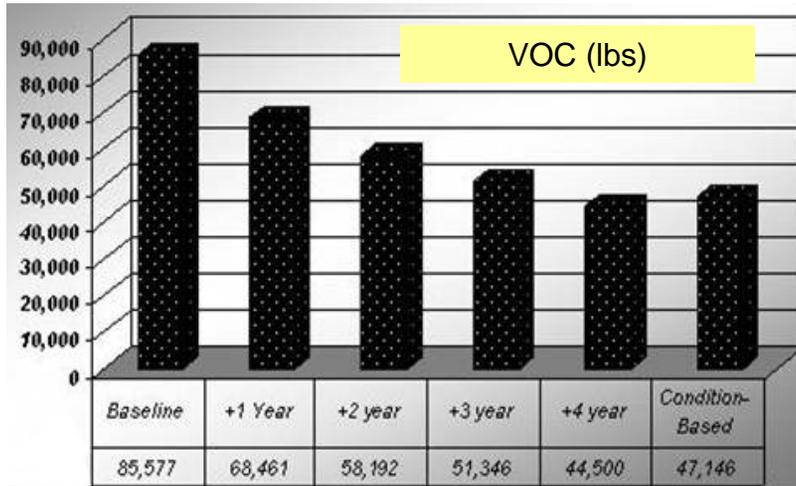
Cost Benefit Summary

Maintenance Cycle Extension

Yearly aircraft	Baseline: 25	+1 Year: 20	+2 Year: 17	+3 Year: 15	+4 Year: 13
Capital Costs					
Equipment	\$0	\$87,600	\$87,600	\$87,600	\$87,600
Training	\$0	\$17,080	\$17,080	\$17,080	\$17,080
Annual O&M Costs					
Labor/Equip.	\$2,134,925	\$1,716,700	\$1,460,509	\$1,289,715	\$1,118,921
Materials	\$530,829	\$424,663	\$360,964	\$318,498	\$276,031
Utilities	\$3,600	\$2,880	\$2,448	\$2,160	\$1,872
EHS	\$569,774	\$455,819	\$387,446	\$341,865	\$296,283
TOTAL	\$3,239,128	\$2,600,063	\$2,211,367	\$1,952,237	\$1,693,107
Annual Savings	N/A	\$639,066	\$1,027,761	\$1,286,891	\$1,546,022
Simple Payback	N/A	0.16 years	0.10 years	0.08 years	0.07 years
Hazardous Waste Savings	N/A	56,365 lbs	90,184 lbs	112,730 lbs	135,276 lbs
VOC Savings	N/A	17,116 lbs	27,385 lbs	34,231 lbs	41,077 lbs



Cost Benefit Summary

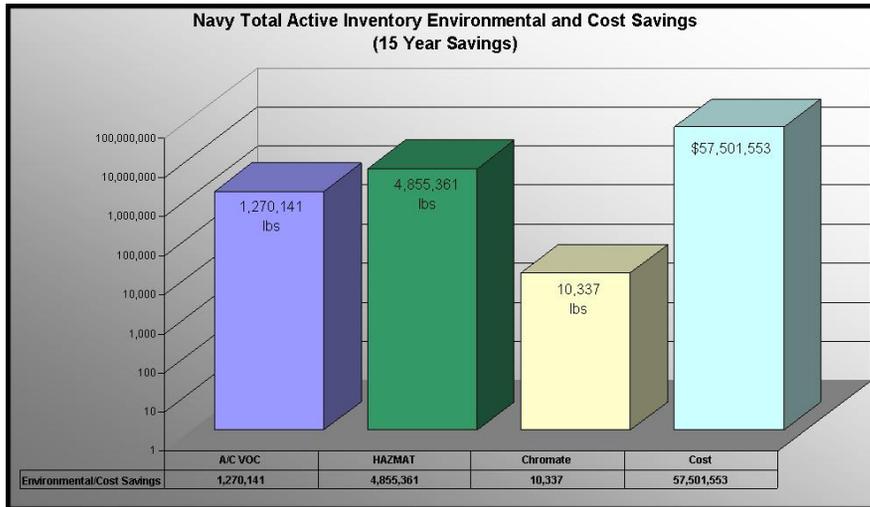


P-3 pollution prevention reductions associated with IRRIT implementation for condition based maintenance and paint interval extension.

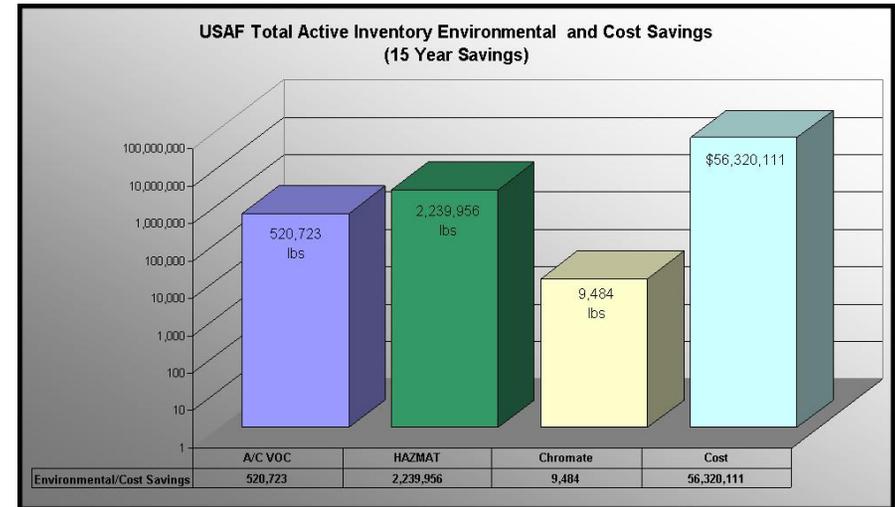


Estimated P2 Savings

Navy OML and IML



USAF OML and IML



Estimated 15 Year Savings (Navy and USAF Combined)

A/C VOC	Hazardous Waste	Chromate	Cost
1,800,000 lbs	7,100,000 lbs	20,000 lbs	\$114,000,000

Note: The above values project savings associated with full implementation of IRRIT on all applicable Navy and USAF programs.

Based on 3 year OML stripping interval shift and avoiding 100 sqft chemical stripping of IML.



Conclusions and Summary

- The IRRIT was validated as an enhanced corrosion inspection tool and consistently demonstrated greater accuracy than existing visual inspection techniques.
 - Significant pollution prevention savings can be realized for programs that implement the IRRIT technology.
-
- IRRIT inherently produces a data record to supplement engineering disposition.
 - The inspection rate of the IRRIT was approximately half the rate of visual inspection. However, improved inspection rates are expected with new generation camera systems.



Publications

- Strategic Environmental Research & Development Program (SERDP). *Final Report, "Non-Destructive Testing of Corrosion Under Coatings"*, Project Number 1137, Dated 1 September 2004.
- United States Patent 7,164,146 - System for Detecting Structural Defects and Features utilizing Blackbody Self-Illumination
- United States Patent 7,193,215 - System and Method for Imaging of Coated Substrates
- United States Patent Application 20060289766 - Spectral Filter System for Infrared Imaging of Substrates Through Coatings
- United States Patent Application – IRRIT Enhanced Imaging
- J. Steve Cargill et al., "Nondestructive Testing for Corrosion under Paint" *Materials Evaluation*, monthly periodical of American Society for Nondestructive Testing, February 2005
- Briefing, NAVAIR AUAV Engineering Conference (May 2006)



Conclusions and Summary

QUESTIONS

ESTCP

ESTCP IRRIT

***Infrared Reflectance Imaging for Environmentally Friendly Corrosion Inspection Through Organic Coatings
Project Number WP-0407***

Mr. John Weir
Northrop Grumman Corporation

ESTCP Conference
Tempe, AZ

24-29 February 2008

NAVAIR

NORTHROP GRUMMAN

CTC Concurrent Technologies Corporation

1

Mr. John Weir

Technology Development
Integrated Systems Eastern Region
Northrop Grumman Corporation
Bethpage, NY

Phone: 516-575-5422

john.weir@ngc.com

Additional contributors to this project were: Mr. Brian Pollock (WP-AFB project manager), Mr. Matthew Campbell (CTC project manager), Mr. John Benfer (NAVAIR Jacksonville, principal investigator), Mr. Steven Chu (NGC), Mr. Nils Fonneland (NGC), Mr. Dennis Leyble (NGC), Mr. Mike Miller (CTC), Mr. David Allen (ASM Management), and Mr. John Speers (WP-AFB).

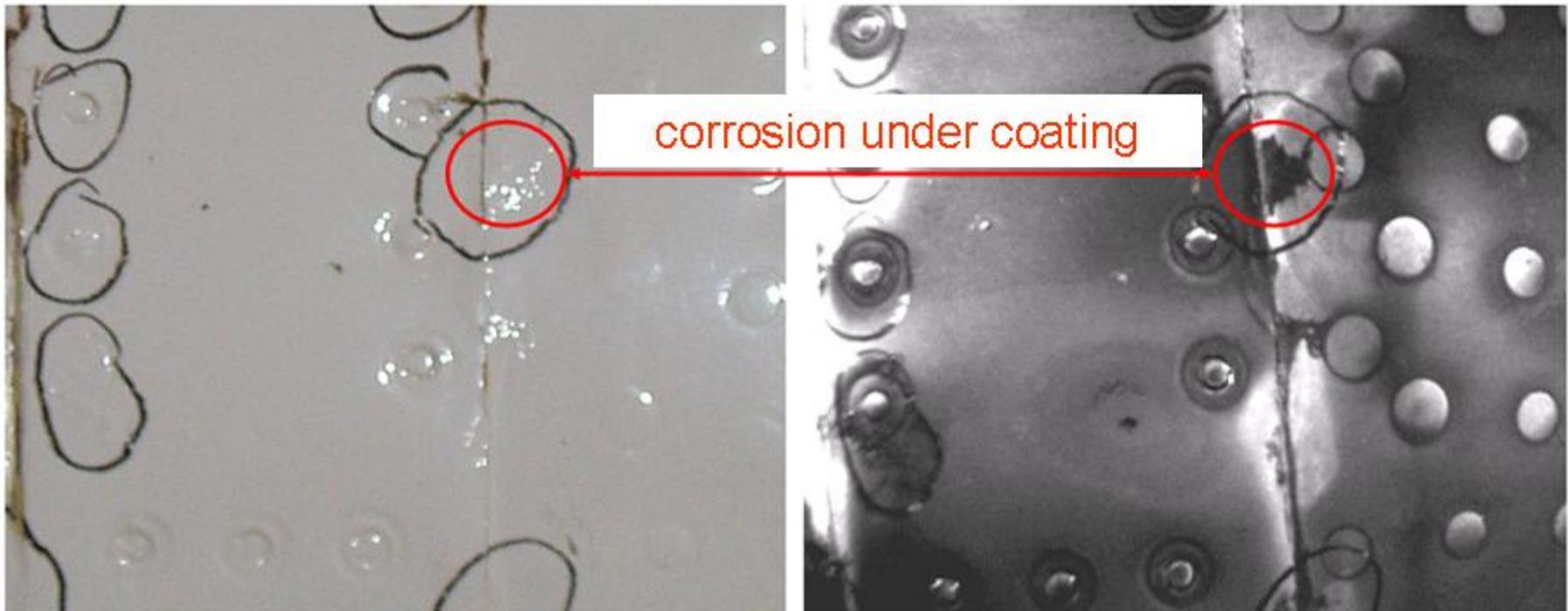


Back-Up

IRRIT Examples

Visual Image

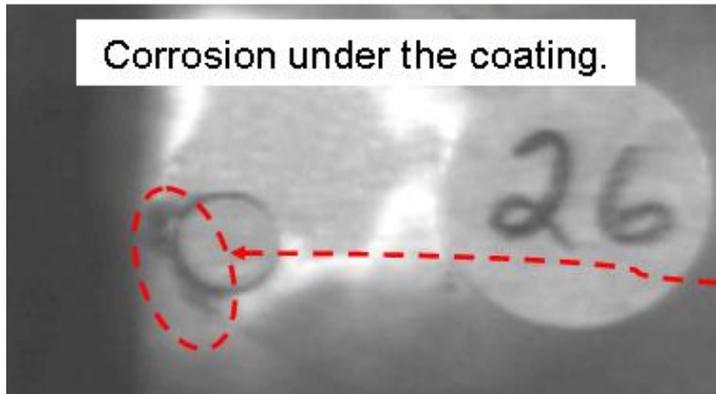
IR Image



IRRIT Examples

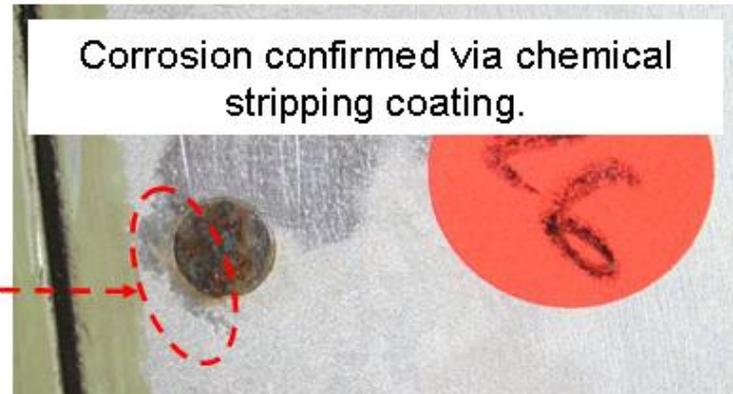
IR Painted Image

Corrosion under the coating.



Visual Stripped Image

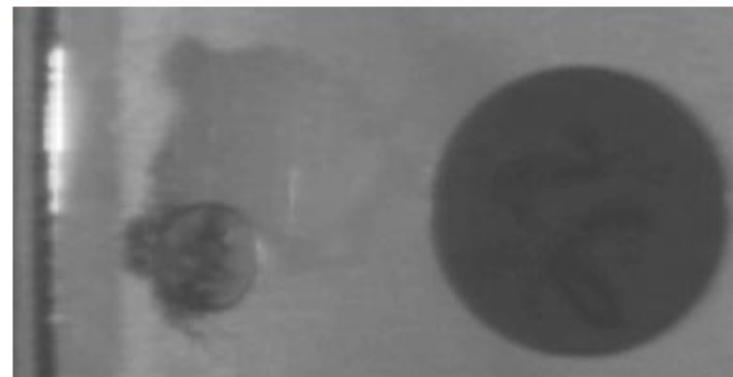
Corrosion confirmed via chemical stripping coating.



Visual Painted Image

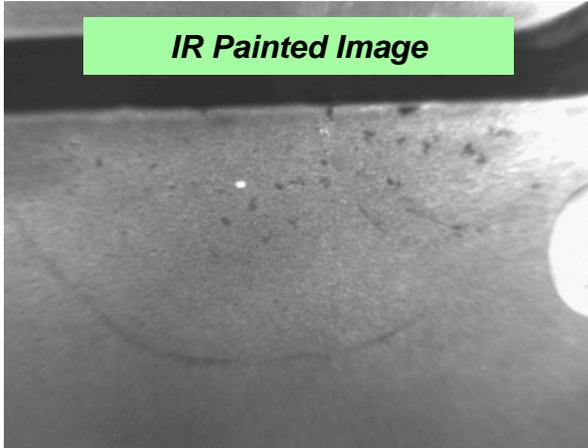


IR Stripped Image

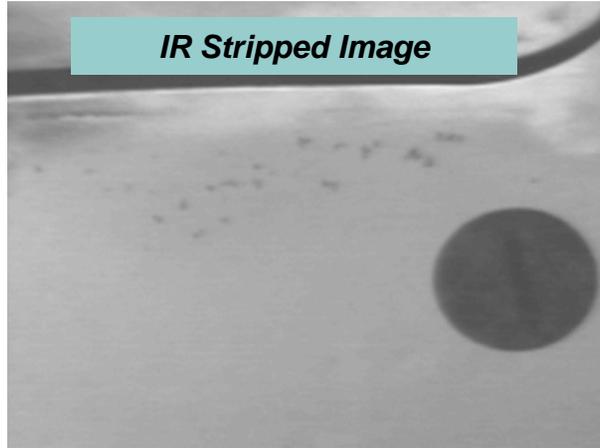


IRRIT Examples

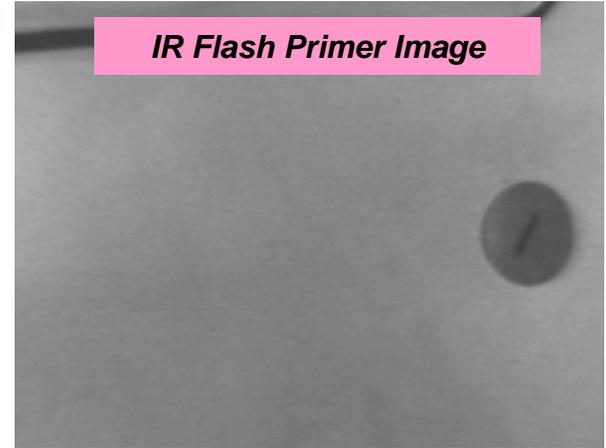
IR Painted Image



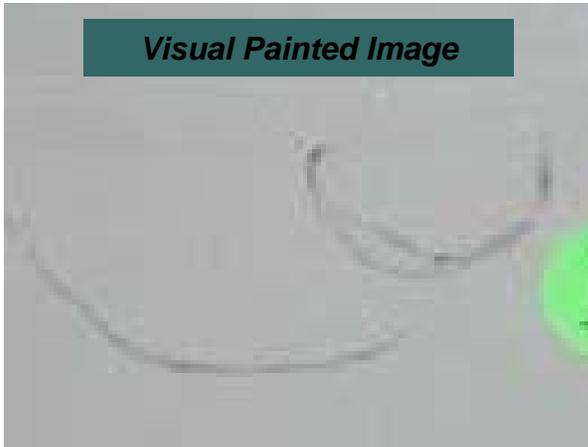
IR Stripped Image



IR Flash Primer Image



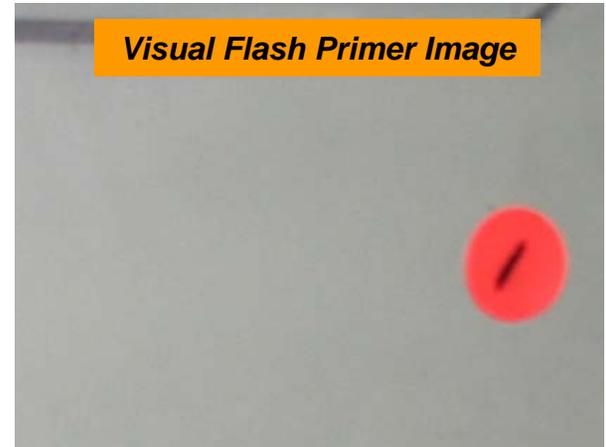
Visual Painted Image



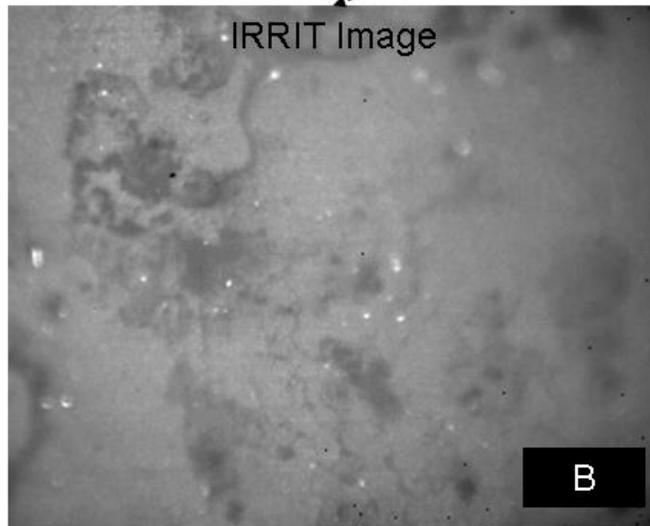
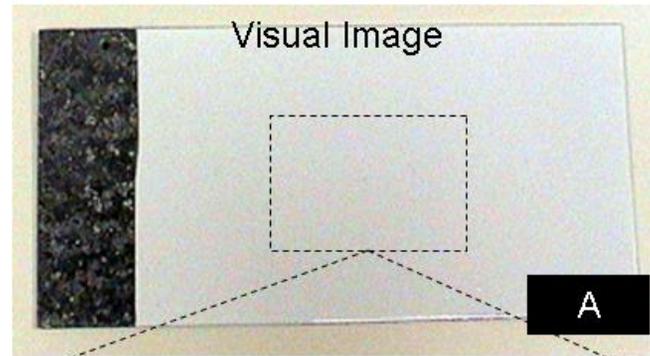
Visual Stripped Image



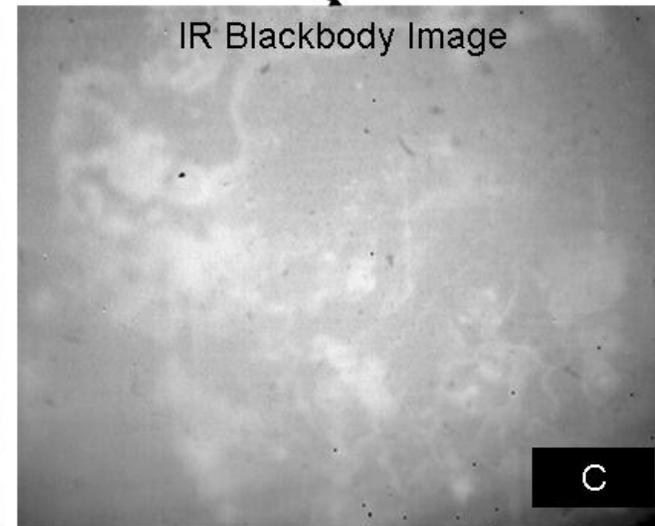
Visual Flash Primer Image



IRRIT Examples

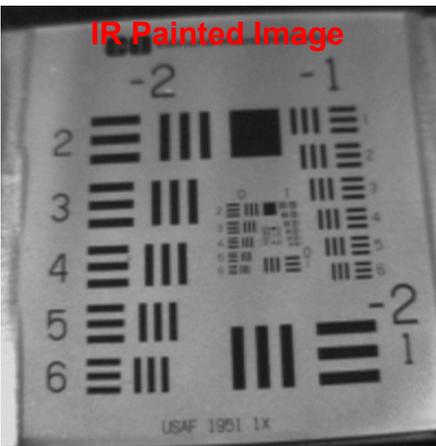


Corrosion Indicated by the Dark Areas in the IR Reflectance Mode



Corrosion Indicated by the Light Areas in the IR Blackbody Mode

IRRIT Examples



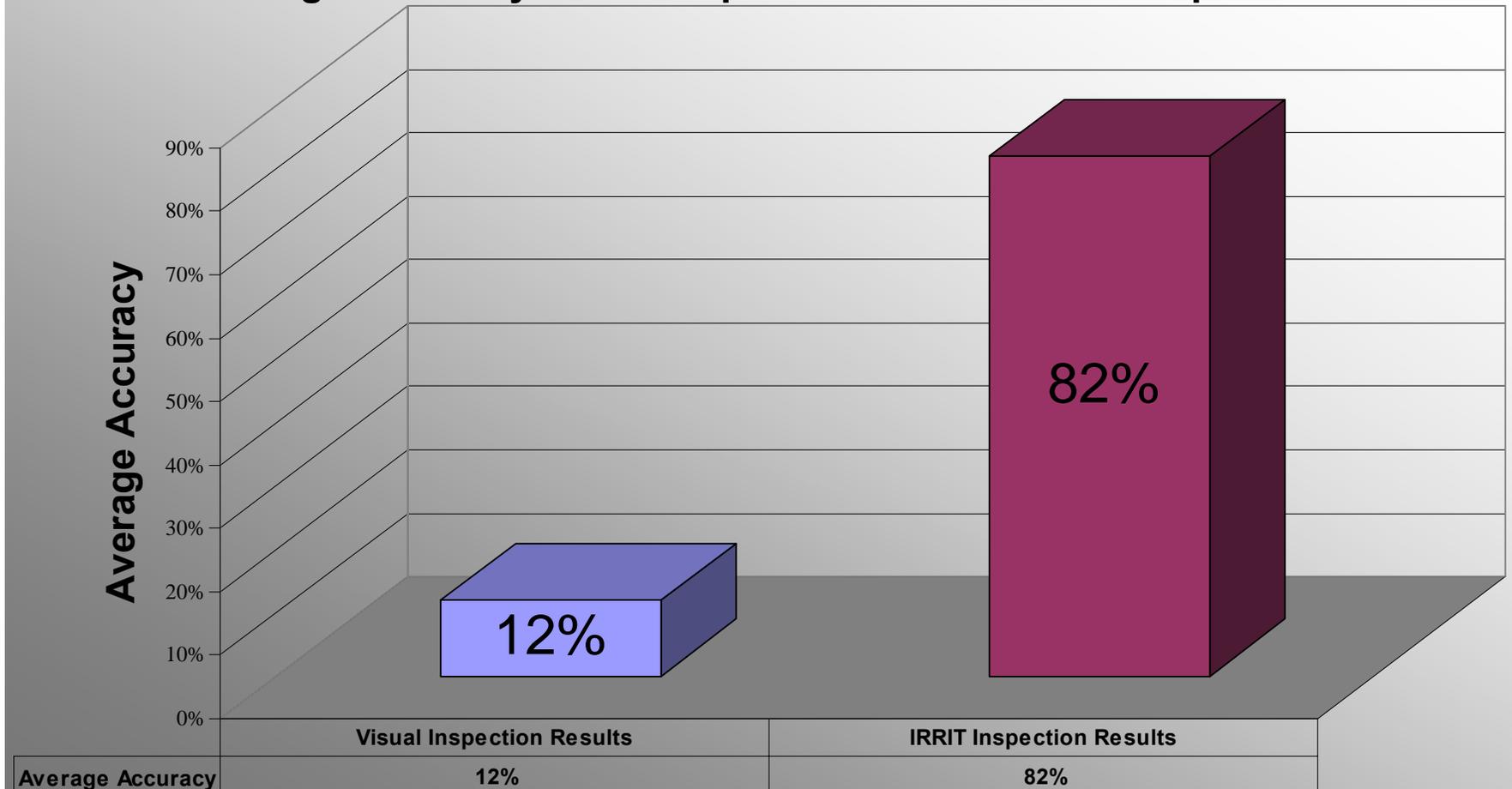
This standard was used in the laboratory to check the camera's resolution with and without various coatings applied to the surface. This standard was also checked prior and post all IRRIT inspections during the Dem/Val process. This standard ensures that the system is operating normally.

Note: This standard is painted with the same type of primer and topcoat that is on the P-3 aircraft.



Results – Weighted Average

Average Accuracy: IRRIT Inspection versus Visual Inspection





Navy P-3 Dem/Val Data Points Acquired (Raw Data)

As Received (Primer + Topcoat)							
P-3 OML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	IR Video (hour:min:sec)	Date Data Acquired
Navy P-3 Tail #912	Wing	26 Measurements (AVG = 2.44 mils)	5 Measurements (AVG = 69.1°F)	4 Measurements (AVG = 70.6°F)	375 Images	201 Images	2/7/2006
	Fuselage	24 Measurements (AVG = 3.07 mils)	3 Measurements (AVG = 70.1°F)	4 Measurements (AVG = 71.9°F)			02:29:09
Post Chemical Stripping							
P-3 OML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	IR Video (hour:min:sec)	Date Data Acquired
Navy P-3 Tail #912	Wing	<i>Not Required</i>	2 Measurements (AVG = 64.5°F)	2 Measurements (AVG = 66.8°F)	173 Images	101 Images	2/10/2006
	Fuselage	<i>Not Required</i>	1 Measurement (AVG = 71.8°F)	4 Measurements (AVG = 78°F)			01:22:51
Flash Primer							
P-3 OML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	IR Video (hour:min:sec)	Date Data Acquired
Navy P-3 Tail #912	Wing	26 Measurements (AVG = 0.79 mils)	3 Measurements (AVG = 80.5°F)	2 Measurements (AVG = 81.9°F)	60 Images	48 Images	5/8/2006
	Fuselage	9 Measurements (AVG = 0.54 mils)	2 Measurements (AVG = 85.2°F)	1 Measurement (AVG = 84.9°F)			NA



Navy P-3 Dem/Val Data Points Acquired (Raw Data)

As Received (Primer + Topcoat)							
P-3 OML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	IR Video (hour:min:sec)	Date Data Acquired
Wing	15 Measurements (AVG = 3.59 mils)	2 Measurements (AVG = 80.1°F)	2 Measurements (AVG = 79.95°F)	136 Images	100 Images	00:50:17	5/6/2006
Fuselage	<i>NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations)</i>						
Post Chemical Stripping							
P-3 OML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	IR Video (hour:min:sec)	Date Data Acquired
Wing	<i>Not Required</i>	2 Measurements (AVG = 78.55°F)	2 Measurements (AVG = 78.7°F)	125 Images	102 Images	NA	5/10/2006
Fuselage	<i>NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations)</i>						
Flash Primer							
P-3 OML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	IR Video (hour:min:sec)	Date Data Acquired
Wing	<i>NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations)</i>						
Fuselage	<i>NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations)</i>						

Navy P-3 Tail #772



Navy P-3 OML Real-Time Results vs Post-Processing Results

Real-Time Results (P-3 OML Wing Section)					
Inspection Technique	Suspected Areas of Corrosion	False Positives	Misses	Actual Corrosion Sites	% Accuracy
Visual Inspection Results	10	1	163	172	5%
IRRIT Inspection Results	128	0	44	172	74%
Post-Processing Results (P-3 OML Wing Section)					
Inspection Technique	Suspected Areas of Corrosion	False Positives	Misses	Actual Corrosion Sites	% Accuracy
Visual Inspection Results	<i>Visual inspection does not allow for post-processing results.</i>				
IRRIT Inspection Results	135	0	37	172	79%
Real-Time Results (P-3 OML Fuselage Section)					
Inspection Technique	Suspected Areas of Corrosion	False Positives	Misses	Actual Corrosion Sites	% Accuracy
Visual Inspection Results	5	0	66	71	7%
IRRIT Inspection Results	55	0	16	71	77%
Post-Processing Results (P-3 OML Fuselage Section)					
Inspection Technique	Suspected Areas of Corrosion	False Positives	Misses	Actual Corrosion Sites	% Accuracy
Visual Inspection Results	<i>Visual inspection does not allow for post-processing results.</i>				
IRRIT Inspection Results	57	0	14	71	80%

Navy P-3 Tail #912



Navy P-3 OML Real-Time Results vs Post-Processing Results

Navy P-3 Tail #772	Real-Time Results (P-3 OML Wing Section)					
	Inspection Technique	Suspected Areas of Corrosion	False Positives	Misses	Actual Corrosion Sites	% Accuracy
	Visual Inspection Results	27	2	74	99	25%
	IRRIT Inspection Results	75	0	24	99	76%
	Post-Processing Results (P-3 OML Wing Section)					
Inspection Technique	Suspected Areas of Corrosion	False Positives	Misses	Actual Corrosion Sites	% Accuracy	
Visual Inspection Results	<i>Visual inspection does not allow for post-processing results.</i>					
IRRIT Inspection Results	85	0	10	99	86%	



Navy P-3 Dem/Val IRRIT Scan Rates

Navy P-3 Tail #912	As Received (Primer + Topcoat)	
	P-3 OML Location	Scan Rate
	Wing	64 ft ² /hour
	Fuselage	73 ft ² /hour
	Post Chemical Stripping	
	P-3 OML Location	Scan Rate
	Wing	150 ft ² /hour
	Fuselage	207 ft ² /hour
	Flash Primer	
	P-3 OML Location	Scan Rate
Wing	150 ft ² /hour	
Fuselage	Scan Rate Not Recorded	
Navy P-3 Tail #772	As Received (Primer + Topcoat)	
	P-3 OML Location	Scan Rate
	Wing	120 ft ² /hour
	Fuselage	NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations)
	Post Chemical Stripping	
	P-3 OML Location	Scan Rate
	Wing	Scan Rate Not Recorded
	Fuselage	NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations)
	Flash Primer	
	P-3 OML Location	Scan Rate
Wing	NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations)	
Fuselage	NO MEASUREMENTS TAKEN – REFER TO APPENDIX F (Dem/Val Plan Deviations)	



USAF KC-135 Dem/Val Data Points Acquired (Raw Data)

		Primer					
KC-135 #1	KC-135 IML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	Date Data Acquired
	Bulkheads	6 Measurements (AVG = 0.95 mils)	0 Measurements (AVG = N/A)	2 Measurements (AVG = 71.5°F)	19 Images	31 Images	10/23/2006
		Post Selected Spot Chemical Stripping					
KC-135 #1	KC-135 IML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	Date Data Acquired
	Bulkheads	<i>Not Required</i>	0 Measurements (AVG = N/A)	0 Measurements (AVG = N/A)	22 Images	9 Images	10/24/2006
		Primer					
KC-135 #2	KC-135 IML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	Date Data Acquired
	Cargo Door	11 Measurements (AVG = 1.31 mils)	4 Measurements (AVG = 75.2°F)	5 Measurements (AVG = 75.9°F)	10 Images	5 Images	10/25/2006
		Primer					
KC-135 #3	KC-135 IML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	Date Data Acquired
	Port Wing Spar	<i>NO MEASUREMENTS TAKEN – Purpose of IRRIT inspection was to show capability of the system in tight spaces.</i>					10/26/2006



USAF B-52 Dem/Val Data Points Acquired (Raw Data)

		Primer + Topcoat					
B-52 #1	B-52 IML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	Date Data Acquired
		Longerons	6 Measurements (AVG = 1.57 mils)	1 Measurement (AVG = 67°F)	3 Measurements (AVG = 67.1°F)	21 Images	17 Images
		Post Selected Spot Chemical Stripping					
B-52 #1	B-52 IML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	Date Data Acquired
	Longerons	<i>Not Required</i>	0 Measurements (AVG = N/A)	0 Measurements (AVG = N/A)	10 Images	21 Images	10/25/2006
		Primer + Topcoat					
B-52 #2	B-52 IML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	Date Data Acquired
	Longerons	7 Measurements (AVG = 3.39 mils)	1 Measurement (AVG = 70°F)	4 Measurements (AVG = 71°F)	11 Images	10 Images	10/25/2006
		Post Selected Spot Chemical Stripping					
B-52 #2	B-52 IML Location	Paint Thickness Measurements	Air Temperature Measurements	Aircraft Skin Temperature Measurements	Visible Photos	IR Photos	Date Data Acquired
	Longerons	<i>Not Required</i>	0 Measurements (AVG = N/A)	0 Measurements (AVG = N/A)	10 Images	12 Images	10/26/2006



USAF KC-135 IML Real-Time Results vs Post-Processing Results

KC-135 #1	Real-Time Results (KC-135 IML Bulkhead)					
	Inspection Technique	Suspected Areas of Corrosion	False Positives	Misses	Confirmed Corrosion Sites	% Accuracy
	Visual Inspection Results	<i>No visual corrosion sites confirmed.</i>				
IRRIT Inspection Results	4	2	*	2	**	
KC-135 #2	Real-Time Results (KC-135 IML Cargo Door)					
	Inspection Technique	Suspected Areas of Corrosion	False Positives	Misses	Confirmed Corrosion Sites	% Accuracy
	Visual Inspection Results	<i>No visual corrosion sites confirmed.</i>				
IRRIT Inspection Results	1	<i>Unknown – No selective spot stripping occurred.</i>				
KC-135 #3	Real-Time Results (KC-135 IML Port Wing Spar)					
	Inspection Technique	Suspected Areas of Corrosion	False Positives	Misses	Confirmed Corrosion Sites	% Accuracy
	Visual Inspection Results	<i>NO MEASUREMENTS TAKEN – Purpose of IRRIT inspection was to show capability of the system in tight spaces.</i>				
IRRIT Inspection Results						
Notes:	<p>* = Due to the fact that selective spot stripping occurred (only for locations that were identified by the IRRIT as having corrosion beneath the coating), it is impossible to know if any other corrosion locations were missed.</p> <p>** = Cannot determine accuracy solely based on spot stripping, because it is unknown whether or not corrosion was missed in areas that were not stripped.</p> <p>*** = Corrosion may have been removed by stripping process, mechanical abrasion may have occurred.</p>					



USAF B-52 IML Real-Time Results vs Post-Processing Results

B-52 #1	Real-Time Results (B-52 IML Longerons)					
	Inspection Technique	Suspected Areas of Corrosion	False Positives	Misses	Confirmed Corrosion Sites	% Accuracy
	Visual Inspection Results	<i>No visual corrosion sites confirmed.</i>				
	IRRIT Inspection Results	8	1 ^{***}	*	7	**
B-52 #2	Real-Time Results (B-52 IML Longerons)					
	Inspection Technique	Suspected Areas of Corrosion	False Positives	Misses	Confirmed Corrosion Sites	% Accuracy
	Visual Inspection Results	<i>No visual corrosion sites confirmed.</i>				
	IRRIT Inspection Results	2	1 ^{***}	*	1	**
Notes:	<p>* = Due to the fact that selective spot stripping occurred (only for locations that were identified by the IRRIT as having corrosion beneath the coating), it is impossible to know if any other corrosion locations were missed.</p> <p>** = Cannot determine accuracy solely based on spot stripping, because it is unknown whether or not corrosion was missed in areas that were not stripped.</p> <p>*** = Corrosion may have been removed by stripping process, mechanical abrasion may have occurred.</p>					

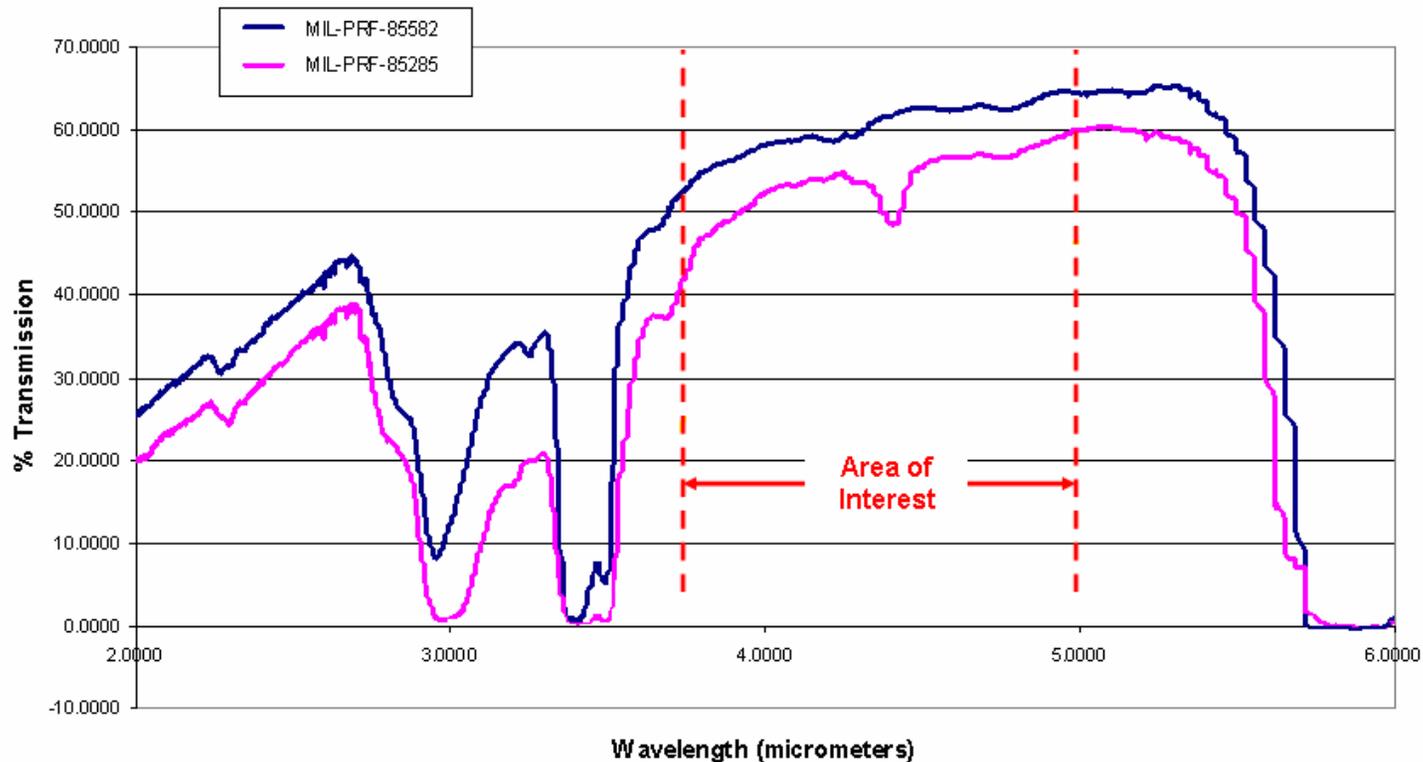


USAF KC-135 and B-52 Dem/Val IRRIT Scan Rates

KC-135 #1	Primer	
	KC-135 IML Location	Scan Rate
	Bulkheads	133 ft ² /hour
KC-135 #2	Primer	
	KC-135 IML Location	Scan Rate
	Cargo Door	150 ft ² /hour
KC-135 #3	Primer	
	KC-135 IML Location	Scan Rate
	Port Wing Spar	<i>NO MEASUREMENTS TAKEN – Purpose of IRRIT inspection was to demonstrate capability of the system in areas of limited access.</i>
B-52 #1	Primer + Topcoat	
	B-52 IML Location	Scan Rate
	Longerons	108 ft ² /hour
B-52 #2	Primer + Topcoat	
	B-52 IML Location	Scan Rate
	Longerons	135 ft ² /hour

IRRIT Examples

Optimal Wavelength Transmission Band



Note: Coatings are standard mil-spec thicknesses.

IRRIT Examples

Optimized Filter Results



3-5 μm : STANDARD FILTER



3.75-5 μm : *OPTIMIZED FILTER*

*****Received new Merlin IR camera with internal 3.75-5 micron filter.***