Innovative De-Painting

The Laser Coating Removal Robot

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Presentation Overview

- Company introductions
- A brief look at aircraft de-painting today
- Laser paint stripping background
- Polygon laser scanner performance
- Robot concepts
- Development partners & plans
Who is EWI?

- Manufacturing technologies company
- Founded in 1984 in Columbus, Ohio
- Global thought-leader on materials joining and allied technologies
- Innovate, mature, and commercialize technologies to advance US manufacturing competitiveness
Who is SwRI?
Southwest Research Institute

- Nonprofit
- Applied R&D
- Revenue: $591M
- Staff: 2800
- Campus: 1200 Acres in San Antonio, TX
- Facilities: 2M Square Feet
- Contract Services
- Physical Sciences and Engineering
Who is LCR Systems?

- A Stratagem Group Company
- LCR System B.V. develops, tests, manufactures, and sells sustainable robotic solutions for the aircraft & helicopter MRO industry.

Mission:
- To become an incubator (knowledge center) for future robotic applications for the MRO aviation industry.
Motivation for de-painting innovation

- Reduce hazardous waste products
  - Chemicals
  - Hex-Chrome
  - Cost of disposal
Motivation for de-painting innovation

- Reduce workplace hazards
  - Chemical and hex-chrome exposure
  - Repetitive motion injury, falls
  - Cost of protection
Motivation for de-painting innovation

- **Reduce cost**
  - Reduce labor content
  - Reduce time for set-up, masking, de-masking
  - Improve productivity
Motivation for de-painting innovation

- **Improve Flexibility**
  - Avoid fixed infrastructure
  - Address wide variety of aircraft
  - Introduce de-painting in other hangers
Unbounded creativity for AF depaint

- Media blasting from a cabled cabin
Early automated de-painting

- Plastic media blasting
- SwRI first to implement

Southwest Research Institute media blasting at WRAFB
The purpose of this project is to identify and evaluate the enabling technologies required to fabricate an automated laser paint stripping (ALPS) system.
A long wish-list, 2 decades ago  
- many items still being sought today -

Process requirements for the ALPS system are as follows:

A. The robotic system shall not damage the aircraft through physical contact or overexposure to the laser.
B. Stripping shall take less than one week.
C. A removal rate of 2-4 ft²/minute shall be achieved.
D. The system shall accommodate a laser pulse rate of 300 pulses/second.
E. Based on the pulse rate and average number of pulses required, a sensor feedback rate of 1/30 second shall be provided.
F. The robot shall be capable of transmitting the laser beam to the surface of the airplane and then of positioning the laser so that the pattern, over which the laser is incident differs from the target pattern by less than 0.040 inches at all points.
G. The robot shall accommodate a payload capacity of 100 lbs.
H. The robotic system shall be capable of paint stripping, partial paint stripping, and surface inspection.
I. Global positioning and relative positioning shall be provided.
J. A standoff distance of 12 inches shall be maintained during stripping.
K. The stripped area shall be at least 90% of the total surface area.
L. The system shall be able to differentiate between stripped and nonstripped surfaces.
M. Composites shall be stripped to primer only.
N. Metal surfaces shall be stripped to bare substrate.
O. A user-friendly programming language shall be used.
P. The robot controller shall be capable of receiving inputs from all sensor systems.
Previous ASAF efforts

- LPS demonstration systems at USAF bases
- CO$_2$ lasers in each case

Tinker AFB

Hill AFB
More recent USAF effort

- Mobile platform
- 6kW fiber laser
- COTS robot
Scanning a beam for laser de-coating - previous “galvo” scanners -

- Typical scan speed ~ 8 m/s
- Zero scan speed near edges
- Sensitive protective window

8kW CO₂ at Hill AFB
Another way to scan a beam - polygon scanner by EWI and CWA -

- Up to 50 m/s scan speed
- All reflective optics
- One moving part
- Constant scan velocity across scan width

Rotating Polygonal Mirror
Laser Beam Source

Patented
EWI scanner in commercial use

- Polygonal laser scanner for coating removal
- US 8481886 B2
- Considerable evolution since inception
- Works with any laser type
- Power handling to 30kW
How does laser coating removal work?

- A high power laser beam spot travels rapidly across work surface, causing coating to heat, expand, and combust into evacuation nozzle.
- Substrate stays below allowable temperatures.
Polygon scanner advantages

- High scan speed reduces flame height
- Reduced flame height reduces beam interference
- Reduced flame height improves effluent removal
- Reduced flame height supports cleaner combustion
- Reduced flame height permits better vision

High speed video (approximately 300X) with diode laser illumination
Coating removal performance - a “standard” to compare stripping performance -

- USAF introduced this removal metric decades ago.
- Amount of paint removed per unit of energy applied

\[ R_N = \frac{\text{volume of paint}}{\text{energy incident}} = \frac{\text{ft}^2 - \text{mil}}{\text{kW} - \text{min}} \]

- Different coatings respond differently to laser types
Different LPS mechanisms
- fiber delivered vs CO\(_2\) laser -

- Long wavelengths (6-12 µm) absorbed strongly in resin
- Absorptance of CO\(_2\) laser beam is 0.9-1.0 independent of pigment

- Short wavelengths (0.4-2 µm) absorbed weakly in resin
- Absorptance of Nd:YAG or fiber laser beam is 0.2 – 0.7 dependent on color of pigment
Polygon scanner performance
- well beyond expectations -

Normalized Topcoat Strip Rate
(ft²-mil/kW-min)

CO₂ Laser

Fiber Laser

AVCO-1984
Battelle-1987
LADS-1995
RLCRS-2008
CTC/EWI-2006
ARLCRS-2007
EWI 2010

0.2 kW RP
3.0 kW CW
5.4 kW CW
4.5 kW CW
1.5 kW CW
5.6 kW CW
10.0 kW CW

We Manufacture Innovation
Polygon scanner with CO$_2$ beam

- Rail car painted panel
- Stripped at Rofin Sinar with 8kW DC laser
- Original “tooth” of grit blasted surface retained
Possible LPS application: Removal of nuclear-contaminated paint for recovery of building steel
Paint color makes a difference
- rankings from polygon testing -

Laser Paint Stripping Efficiency Ranking

Stripping Efficiency (ft²-mil/kw-min)

Q-Switch Fiber Laser on White
Fiber Laser on White*
CO2 Laser on White
CO2 laser on Gray
Fiber Laser on Gray

*Required much slower scan speed
Need for process control - more important for shorter wavelength -

- Paint thickness is not constant
- Undocumented paint layers may exist
- Overlap between passes cannot be assured
LPS Control Concept
- use paint color for process control -

- Camera
- Strobe
- Facet sync
- Exhaust
- Fiber Laser
- PC Control

Patent Pending
SwRI excels at image analysis

- 300 Hz Laser Scan
- 600 Hz Imaging Rate
- Track Laser Position
  - Surface profile
- Assess Coating State
  - Multispectral Imaging
  - Texture analysis
- Control Laser Power and Robot Speed
Large Scale Demo in Feb. 2011
- SwRI, EWI, CWA, WTT, IPG -

YOU ARE INVITED TO A
HIGH-SPEED, LARGE-SCALE,
COATING REMOVAL SYSTEM

IPG provided use of 10 kW laser for demo

Click for Video
The commercial aircraft laser de-painting dilemma

Problem
- Very wide range of sizes, many quite large
- Wide range of colors, including white
- Fiber laser cannot remove white paint.
- \( \text{CO}_2 \) are bigger, heavier, and more delicate
- \( \text{CO}_2 \) lasers require beam delivery through clean air with multiple mirrors at robot joints

Solution
- Accept that a big robot will be required.
- Solve the beam delivery challenge.
An early, but cumbersome concept

- Repositionable robot platform for CO\textsubscript{2} laser
- Technically feasible but not an attractive solution
Mobile CO$_2$ laser Platform?
- we’ll never know if we don’t ask -

- Large mobile platforms are commercially available
- Some questions about laser tolerance to motion

Image from SwRI
Laser Company is “on board”
- Trumpf confirms CO$_2$ laser compatibility -

- EWI IRD Design Study for large, white, commercial aircraft
- Beam delivery still an important question
LCR Systems Ramps Up Development Effort in 2013

- NLR observes/reviews Stratagem-sponsored 12 kW, CO₂ laser coating removal trials.

- Positive responses for:
  - Low substrate temperature
  - Removal of white paint (5-10 ft²/min)
  - Paint removal without damaging gap filler

- The National Aerospace Laboratory (NLR) is the independent knowledge enterprise in the Netherlands on aerospace.
Fast-forward to 2014 - 2015

- Stratagem establishes LCR Systems
- Brings commercialization expertise to team
LCR Systems technology advances on several fronts

- Robot solution matures
- Complex scanner & “wrist” designed
- Automatic beam alignment question solved
Business Case Analyses  
- prepared by LCR Systems & MROs -  

◆ Laser Coating Removal Saves Time

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Traditional

1.1 Masking
2.1 Add Chemical Stripper Compound
2.2 Wait time / dwell time
2.3 Paint & Compound Removal
3.1 Rinse Alkaline Soap
3.2 De-masking
3.3 Sealant Removal
4.1 Sanding Wings & Composites
5.1 Cleaning Aircraft (Scotch Brite)
5.2 Cleaning Bay
6.1 Re-Sealing
7.1 Wipe Aircraft with Grease Remover
7.2 Aircraft Masking
7.3 Start Painting Layer 1

LCR Procedure

1.1 Positioning & Masking & LCR Start-Up
2.1 Touch-Up Manually
3.1 Cleaning Aircraft (Scotch Brite)
4.1 Cleaning Aircraft (Scotch Brite)
5.1 Cleaning Aircraft (Scotch Brite)
6.1 Cleaning Aircraft (Scotch Brite)
7.1 Wipe Aircraft with Grease Remover
7.2 Aircraft Masking
7.3 Start Painting Layer 1

Conclusion: 1,3 Days Shorter Process Time
Time line for commercialization

- Summer 2014: Singapore Airlines became Launching Customer
- 15 December 2014: LCR Advisory Board Established (Civil Aviation)
- April 2015: Military Advisory Board Established
- June 2015: Test-Bed with 15kW Laser in USA (2nd Advisory Board)
- October 2015: SAE Testing Starts
- October 2015: Robot End-Effector Operational
- Summer 2016: LCR Robot – First of Series – Construction
- Q4 2016: Fabrication Testing LCR Robot
- Q4 2016: Approval OEM’s
- Q1 2017: Site Acceptance 1st LCR at SIAEC
- Q1 2017: Series Production in the Netherlands Starts
Team, partners, & advisors
- just the short list -

◆ A clear path from invention to industrialization
Summary

- After decades of “investigation,” commercial laser paint stripping technology is on the verge of reality.

- EWI’s polygon scanner sets all paint stripping records.

- SwRI’s robotic technology is solid and proven.

- LCR Systems brings commercialization expertise.

- Partners, advisors, and end-users are aligned.

- Laser coating removal makes smart sense.
EWI is the leading engineering and technology organization in North America dedicated to advanced materials joining and allied manufacturing technologies. Since 1984, EWI has provided applied research, manufacturing support, and strategic services to leaders in the aerospace, automotive, consumer products, electronics, medical, energy & chemical, government, and heavy manufacturing industries. By matching our expertise in materials joining, forming, and testing to the needs of forward-thinking manufacturers, we are successful in creating effective solutions in product design and production.

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