AVT-339 Research Workshop on Robotics and laser/plasma – paint interaction in paint removal

Use of Nano-pulsed Lasers on Aircraft Structures

Casey Jones, Adapt Laser Systems, USA

29 – 30 April 2020

ADAPTLASER

Why the Interest in Lasers?

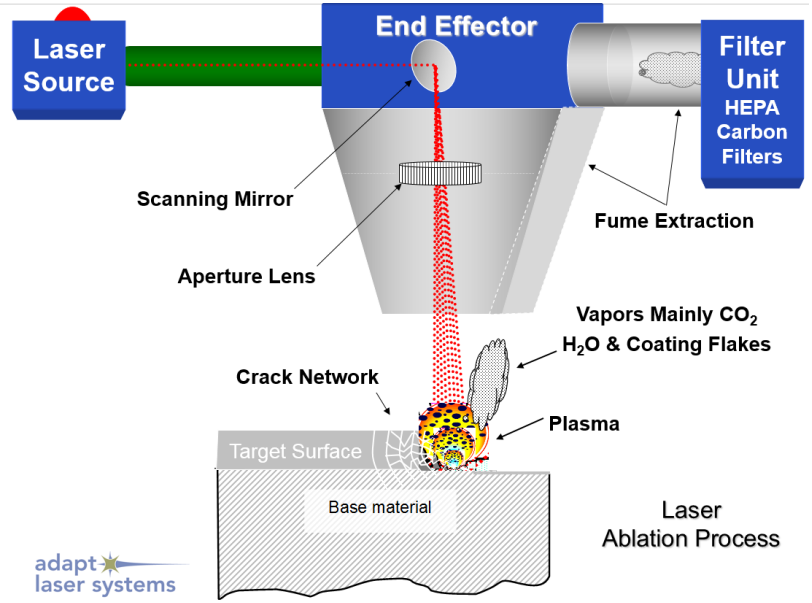
- Corrosion prevention and control (CPC) on aircraft is a nasty process!
- Many chemicals used in CPC are carcinogenic
  - Hexavalent chromium (Cr^{6+})
  - Cadmium
  - Isocyanates
  - Chemical strippers, such as methylene chloride

- These carcinogens mandate the use of personal protective equipment (PPE)
  - Full face respirators
  - Gloves
  - Tyvek suits
  - Tyvek boots

- These chemicals create large waste streams and mandate confinement of operations to certain facilities

How the Lasers Work

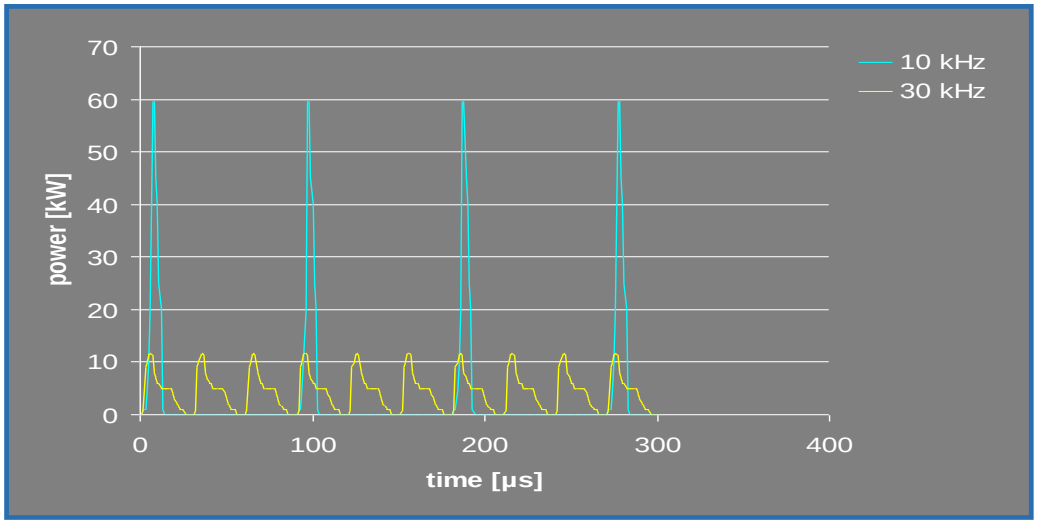
- Lasers remove coatings through ablation (essentially solid to gas vaporization or sublimation)
  - Chemicals such as strippers don't need to be captured
  - Sanding/blasting = airborne contaminants….major facility and PPE requirements!
- All contaminants are captured at the substrate…only laser safety glasses required!
- Lasers can be used outside of controlled facilities as long as all personnel are wearing the appropriate eye protection
  - This allows simultaneous maintenance operations to occur while corrosion maintenance is taking place



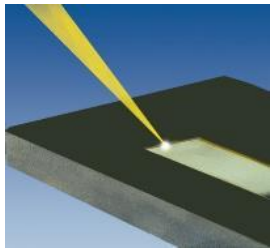
How the Lasers Work

Laser Ablation = Sublimation

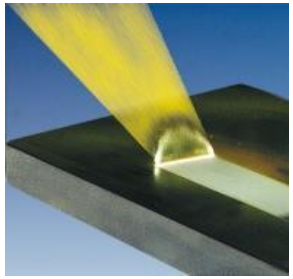
- Convert Solid To Gas
  - With Laser Energy
- Nanosecond Pulses Of Laser Energy Create
  - High Energy
  - Very Little Thermal Effect
- Metal Can Reflect The Energy
  - With Correct Parameters
- 2 Processes of Cleaning
  - Sublimation
  - Induced Pressure



PULSE



SCAN



MOVE

Health and Safety Testing Performed

- Testing by the federal government performed for nearly 2 decades
- Air sampling by 3rd party lab (MACTEC) funded by ESTCP performed 8/2002, 10/2003, 9/2004, and 2/2005; additional testing by AF Institute for Operational Health 3/2005
  - Acid gases (nitric acid, sulfuric acid, etc.)
  - Hydrogen cyanide
  - Heavy metals (hexavalent chromium, chromates, lead, etc.)
  - Cyanides and diisocyanates
  - Nitric oxide
  - CO and CO_2
  - O_3
  - SO_2
  - Organic coating VOCs
- Air sampling also performed by USAF School of Aerospace Medicine (USAFSAM)
  - April 2017 (Report available)

ALL SAMPLING WELL WITHIN OCCUPATIONAL EXPOSURE LIMITS

Health and Safety Testing Performed

- Noise sampling performed by MACTEC in 2002 - 2005
  - Below OSHA's TWA exposure limit of 90 dbA and action level of 85 dbA
  - Additional noise sampling performed in April 2017 by USAFSAM
  - Consult with local bioenvironmental to determine if hearing protection required based on other sources of noise in work area
- UV/IR exposure sampling performed by MACTEC
  - Prolonged use (up to 3 hours) could result in skin irritation
  - Never reported by USAF or commercial users
  - Easily eliminated by wearing long sleeves (or sunscreen) and gloves
- Flammability testing conducted by Science Applications International Corp. in 2004
  - Testing conducted on artificial cavity (representative of fuel tank) & contaminated surfaces
    - MIL-L-23699 lubricating oil
    - MIL-PRF-7808 lubricating oil
    - MIL-PRF-83282 hydraulic fluid
    - MIL-H-5606 hydraulic fluid
    - Skydrol LD-4
    - JP-8 Turbine Fuel

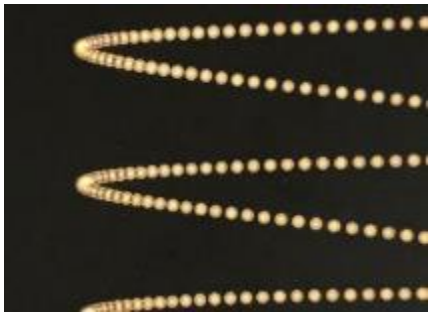
THE LASERS WERE NOT ABLE TO PRODUCE A FLAME OR EXPLOSION

Health and Safety Testing Performed

- Ergonomic assessment accomplished by AF Institute for Operational Health (Apr 2004)
  - Essentially the same as other tools in profession
  - Weight of end effector easily supported by resting fiber optic cable and vacuum hose on shoulder
  - Wheel mechanism developed to support weight of end effectors (~3 lbs for CL300 and ~7 lbs for CL1000)

Aircraft Process Controls for CL300

- Electronic Margin Shielding (EMS)
  - Surpasses edges of scan path to prevent over processing surface
- Nozzle with Wheels
  - Maintains standoff distance to ensure laser is in focus
- Motion/Distance/Thermal Sensor
  - Ensures minimum sweep speed is maintained
  - Ensure laser is in focus



Aircraft Material Testing – Coating Adhesion

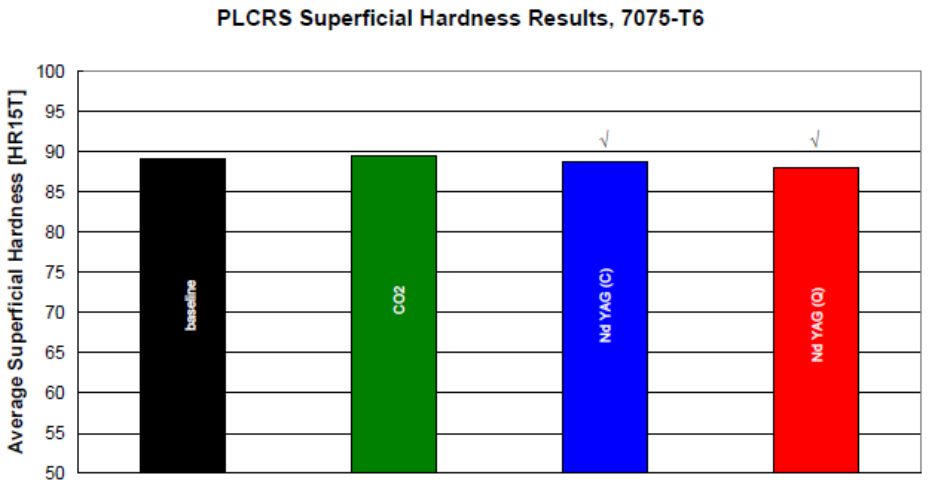
- Adhesion testing post lasing
  - A rating over 4 is considered a pass

Adhesion Ratings – Modified X.

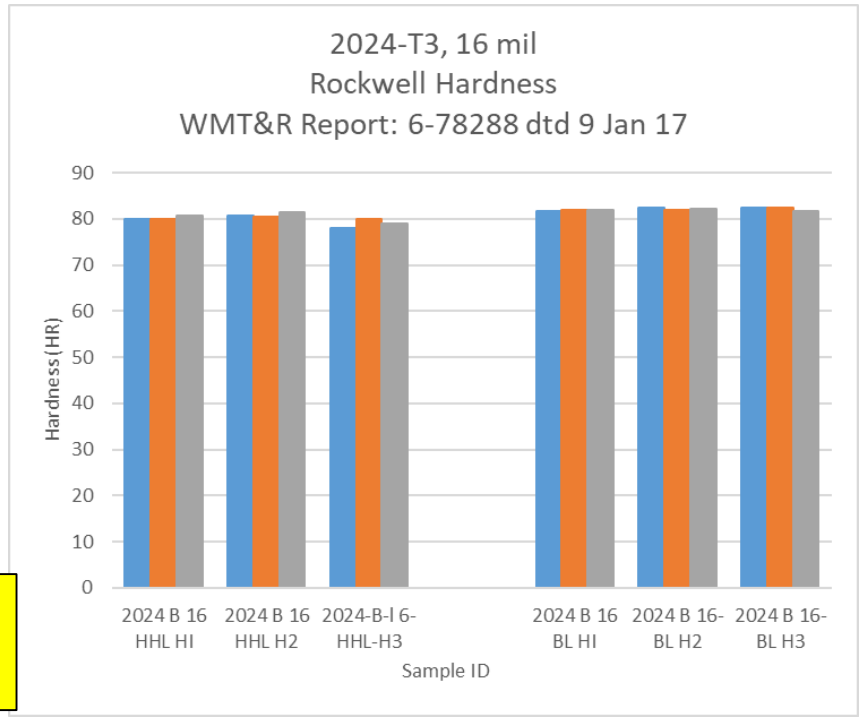
Substrate	Coating System	Rating (Avg. of 5 Panels)	Laser Used
2024 T3 Clad	MIL-PRF-23377 + MIL-PRF-85285	4.0	40 watt Nd:YAG
		4.2	120 watt Nd:YAG
		4.8	250 watt CO_2
2024 T3 Bare	MIL-PRF-23377 + MIL-PRF-85285	4.8	250 watt CO_2
		4.4	40 watt Nd:YAG
		4.6	120 watt Nd:YAG
2024 T3 Bare Chromic Acid Anodized	MIL-PRF-23377 + MIL-PRF-85285	5.0	40 watt Nd:YAG
		5.0	250 watt CO_2
		5.0	120 watt Nd:YAG
4130 Steel	MIL-PRF-23377 + MIL-C-46168 CARC)	4.4	120 watt Nd:YAG
		5.0	250 watt CO_2
		3.4	40 watt Nd:YAG

Aircraft Material Testing - Hardness

- Extensive testing has been performed by the USAF over the past 2 decades
  - Hardness testing performed by CTIO/UDRI revealed no significant impact to substrate hardness
  - (Westmoreland Mechanical Testing and Research, Jan '17)

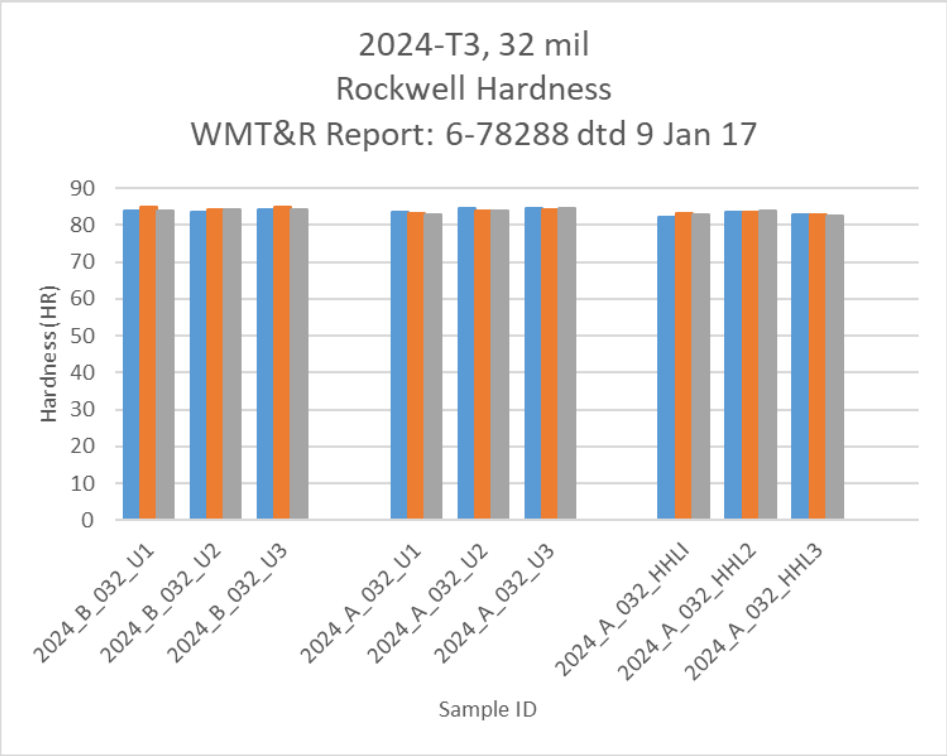


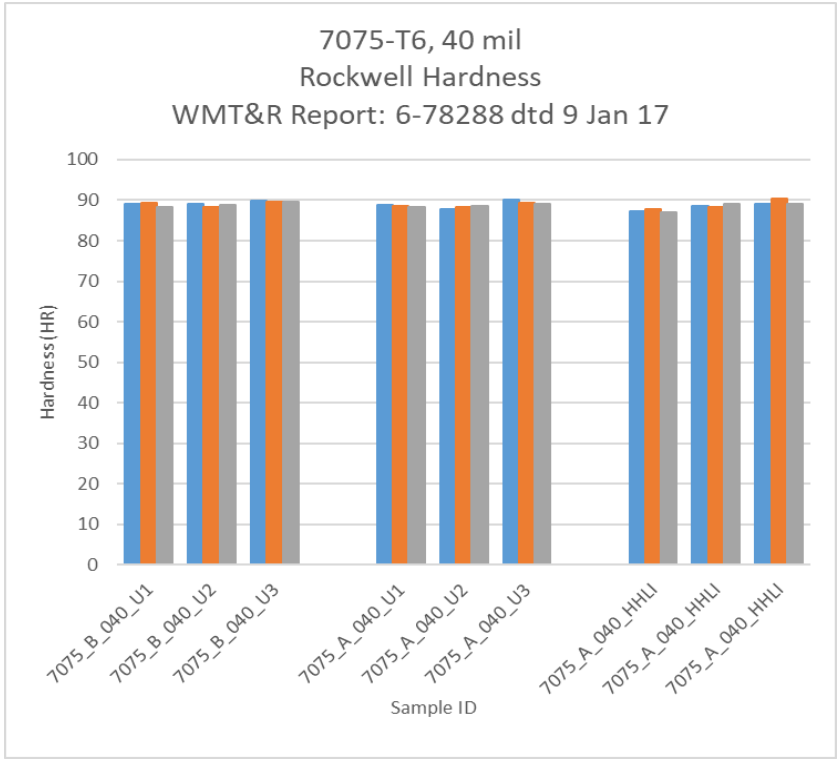
7075-T6 Clad Superficial Hardness Results.



NO STATISTICALLY SIGNIFICANT CHANGE FROM UNPROCESSED BASELINE

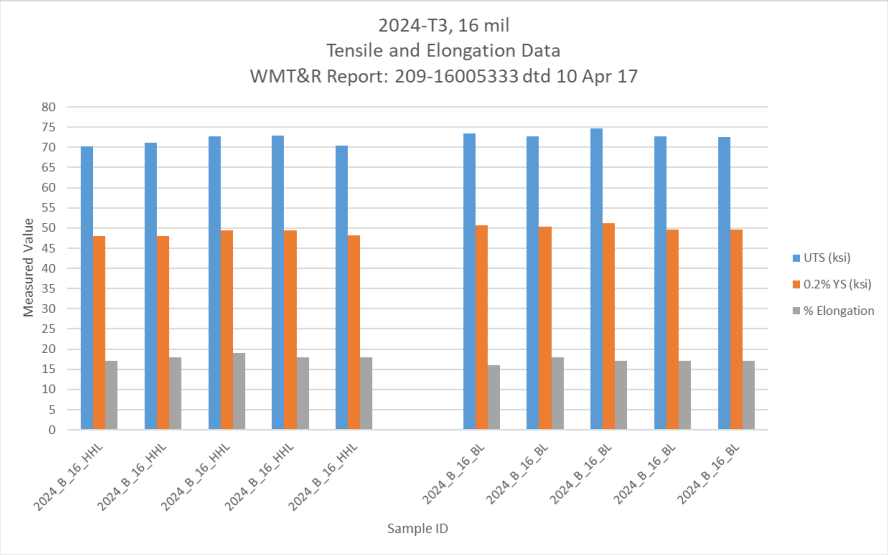
Aircraft Material Testing - Hardness

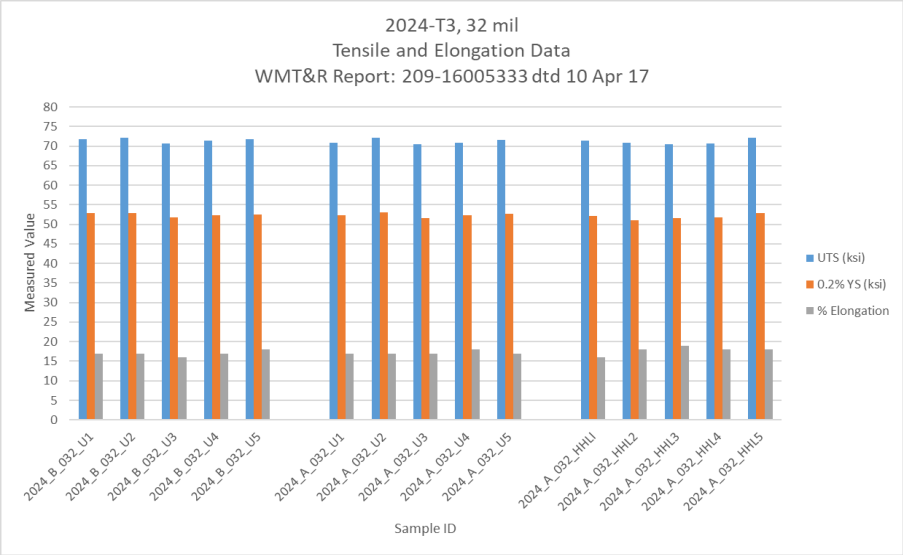




NO STATISTICALLY SIGNIFICANT CHANGE FROM UNPROCESSED BASELINE

Aircraft Material Testing - Tensile



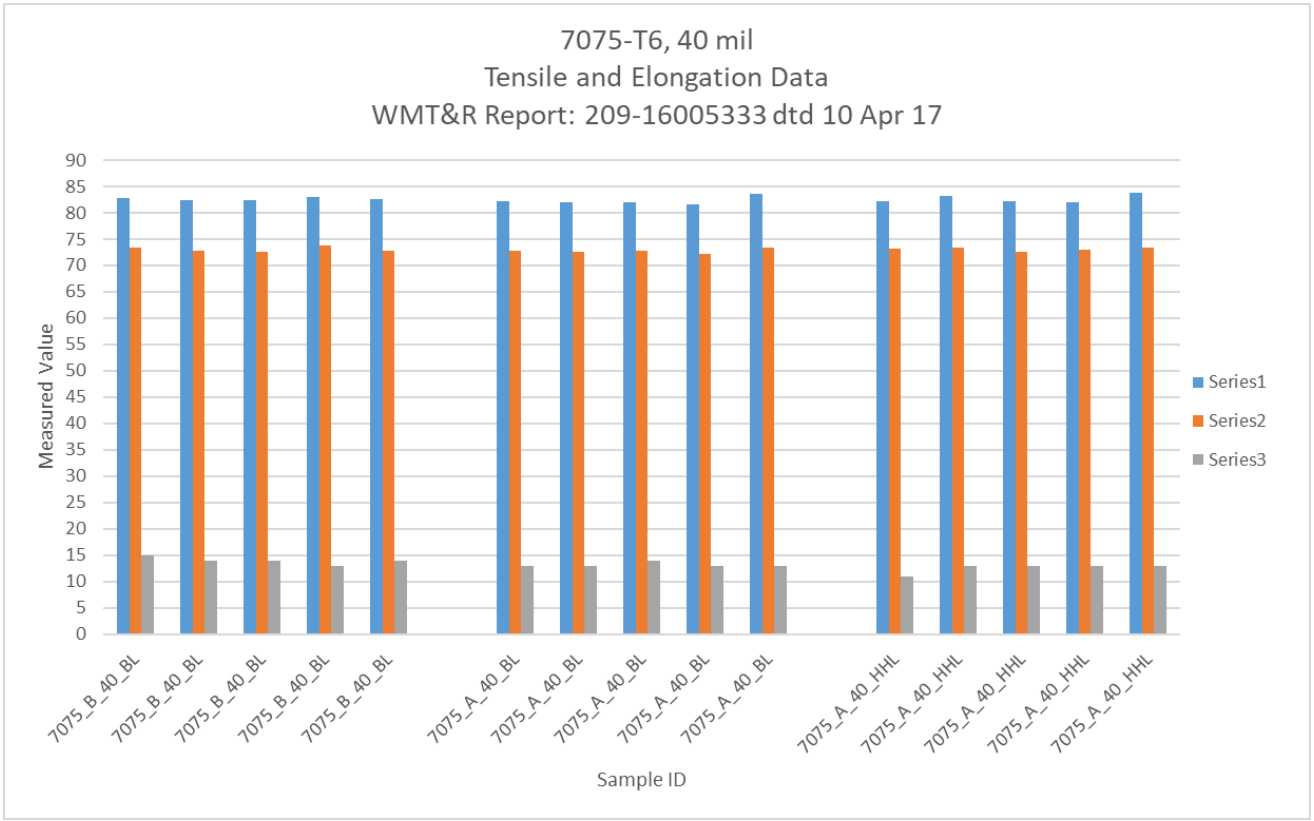


2024-T3 @ 0.016” in thickness

2024-T3 @ 0.032” in thickness

NO STATISTICALLY SIGNIFICANT CHANGE FROM UNPROCESSED BASELINE

Aircraft Material Testing - Tensile



7075-T6 @ 0.040” in thickness

NO STATISTICALLY SIGNIFICANT CHANGE FROM UNPROCESSED BASELINE

Future Aerospace Testing

- **Axial fatigue testing being accomplished by UDRI on 2024-T3 @ 0.050” and 7075-T6 @ 0.080”**
- **7075-T6 fatigue testing complete; analysis being conducted**
- **2024-T3 fatigue testing will complete in Mar 2020**
- **Pending positive results, USAF will move to qualify CL300-AF on all 7075 (0.080” and thicker) and 2024 (0.050” and thicker) substrates USAF wide**
- **Pending positive results, insertion into TO 1-1-8, “*Application and Removal of Organic Coatings, Aerospace and Non-aerospace Equipment*” expected in 2020**

Current Aerospace Usage

- Coating stripping for electrical grounding points for UH-60s
- Used by Lockheed for stripping U-2 in Palmdale, CA during depot
- Used by Lockheed for improved nut plate bonding during F-35 build
- Used by USAF to demilitarize F-22 canopy transparencies
- Airbus using for coating stripping for grounding contacts
- Inbar stainless steel tooling cleaning for composite manufacture

NORTHROP GRUMMAN

BOEING

AIRBUS

LOCKHEED MARTIN

SIKORSKY
A LOCKHEED MARTIN COMPANY

DoD Approvals

- **HHL as a coating/corrosion removal tool added to USAF TO 35-1-3 on 18 Mar 2019**
  - ***"Corrosion Prevention and Control, Cleaning, Painting, and Marking of USAF Support Equipment (SE)"***
- **HHL as a coating/corrosion removal tool added to USAF TO 36-1-191 in March 2020**
  - ***"Technical and Managerial Reference for Motor Vehicle Maintenance"***
- **HHL as a coating/corrosion removal tool added to USAF Metals Technology Office TO 34-W4-1-5 in March 2020**
  - ***"Welding Theory and Application"***

Questions?