MAI BA-22/BA-24: Cold Spray Repair of Aerospace Structural Components

CSAT 2020 – Update

Dr. James Castle

Approved for Public Release - Distribution Unlimited - 88ABW-2020-2102

AFRL Monitor:	Manny Gonzales	(AFRL)
AIPT Lead:	Bruno Zamorano, James Castle, Michael Nicholas, Waynie Schuette	(Boeing)
AIPT Members:	Ted Hatch, Dale Ball, Jim Sullivan, Jacob Carlson	(Lockheed Martin)
	Abby Miklas	(Honeywell)
	Peter Loftus, Matt Gold	(Rolls-Royce)
	Sesh Tamarisakandala, Michael Jacques	(Howmet)
	Isaac Nault, Aaron Nardi	(ARL)

It's all non-structural till its not

- Non-structural cold spray repairs can be done today
  - No load credit taken
  - Can be applied on structural parts
  - Still requires significant data, processes, specifications, certifications, equipment
  - Paced by the certifications necessary for each specific repair or repair class
- Non-structural repairs are usually on structural parts
  - Always a few thousandths from a non-structural repair becoming structural
  - Conversion of non-structural repairs to structural is needed

Repair opportunities seen in fleet

- Most common repair types for cold spray observed in implementation efforts
  - Corrosion
    - Upper wing skins, under skins and doors, everywhere
  - Damaged Holes
    - Access panels, doors, substructure
  - Wear Surfaces
    - Slat tracks, doors
- Every platform had needs
  - Finding applications not the problem

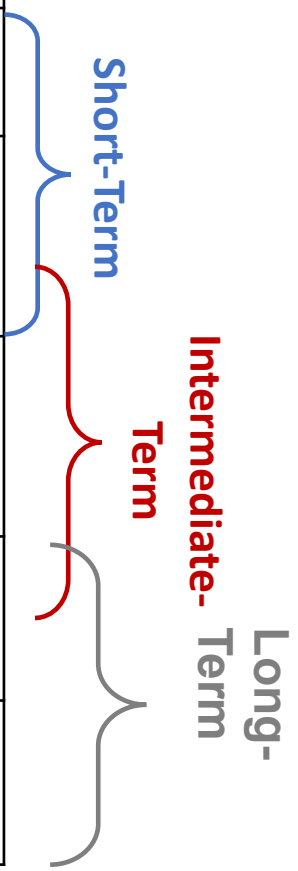
- Each has a non-structural repair opportunity and a limit beyond which it becomes structural

They all ask if they can have structural

Cold Spray Repair Classifications

- Not truly bucketized in practice
  - Continuum of load margins, criticality, purpose
  - Analyzing the continuum is a significant cost factor

Classification	Description
A	Coating restoration: • Replace cladding with cold spray
B	Non-structural dimensional restoration: • Cold Spray does not have to carry load • Could be structural part
C	Non-critical structural: • Cold Spray carries load • Platform will still operate/fly if cold spray part fails
D	Semi-critical structural: • Cold Spray carries load • Failure results in damage to aircraft and mission
E	Structural Critical: • Cold Spray carries load • Failure results in loss of platform



Certification Requirements

EZ-SB-13-001 Rev A, "*Material, Product Form, and Process Substitution Requirements for Metallic Components,*" published by AFLCMC on 1 Nov 2019

Required to Achieve 5 "Lincoln Pillars"

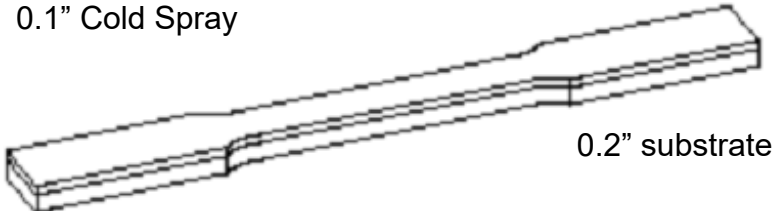
1. Stability and Producibility
   - Process, Vendor Qualification
2. Producibility / Predictability
   - Procedure Qualification
3. Predictability
   - Adhesion, Porosity, Defects, Surface Finish, Macro Process Check
4. Property Characterization
   - Mechanical, Corrosion
5. Supportability
   - Service life testing

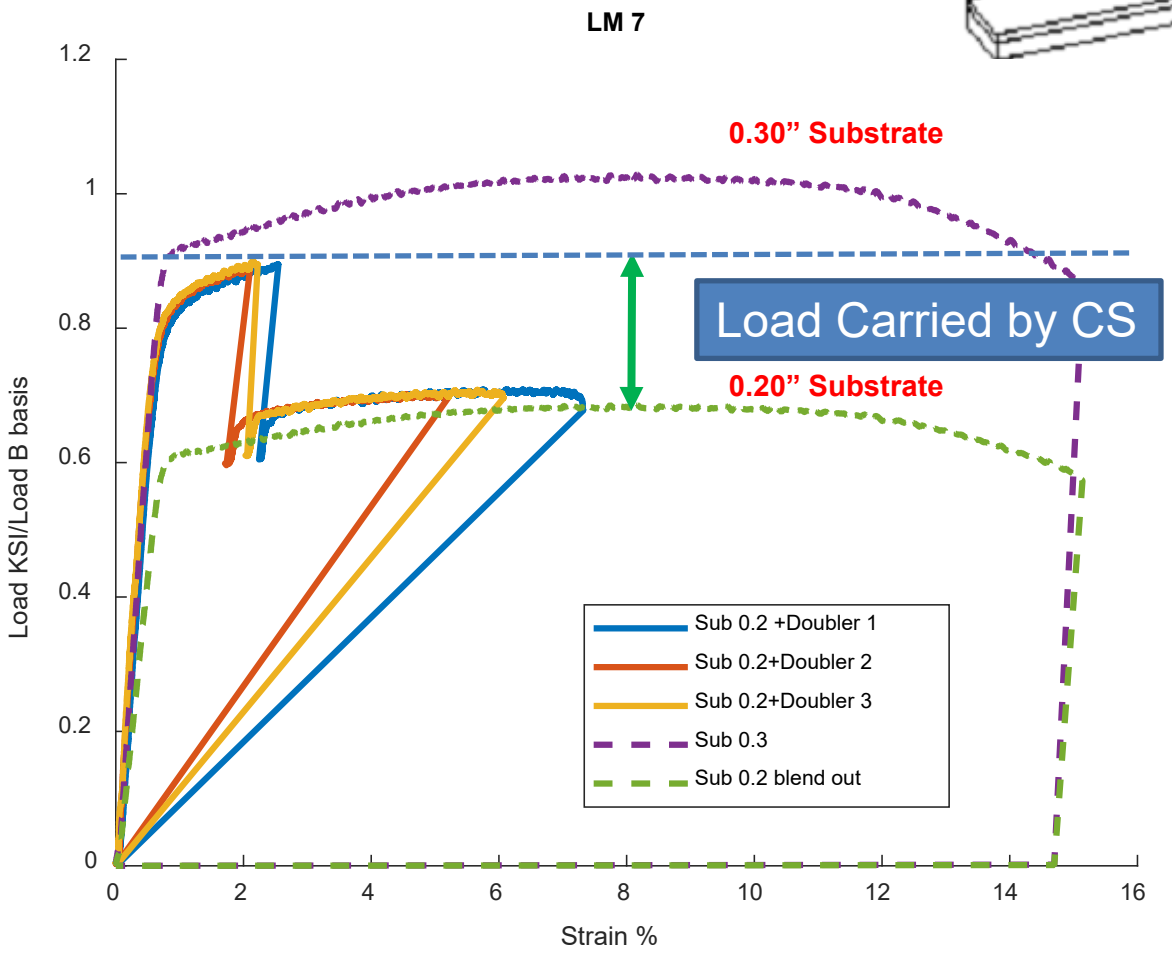
BA-24 is focused on Pillars 4-5 with BA-22 some initial work in 1-3.

Material Property Characterization	**BA-24**
Physical	
Microstructure evaluation (Linear indications, porosity, oxides)	X
Mechanical	
Adhesion / bond strength	X
Shear adhesion strength (Three-lug shear testing)	X
Corrosion	
Salt spray corrosion testing	X
SCC susceptibility	X
Exfoliation corrosion susceptibility	X
Intergranular corrosion resistance	X
Supportability	
Tension testing (UTS, YS, elongation, modulus)	X
Fatigue crack initiation	X
Fatigue crack growth rate	X
Fracture toughness	X

Tensile Testing Curves

Repaired Specimen

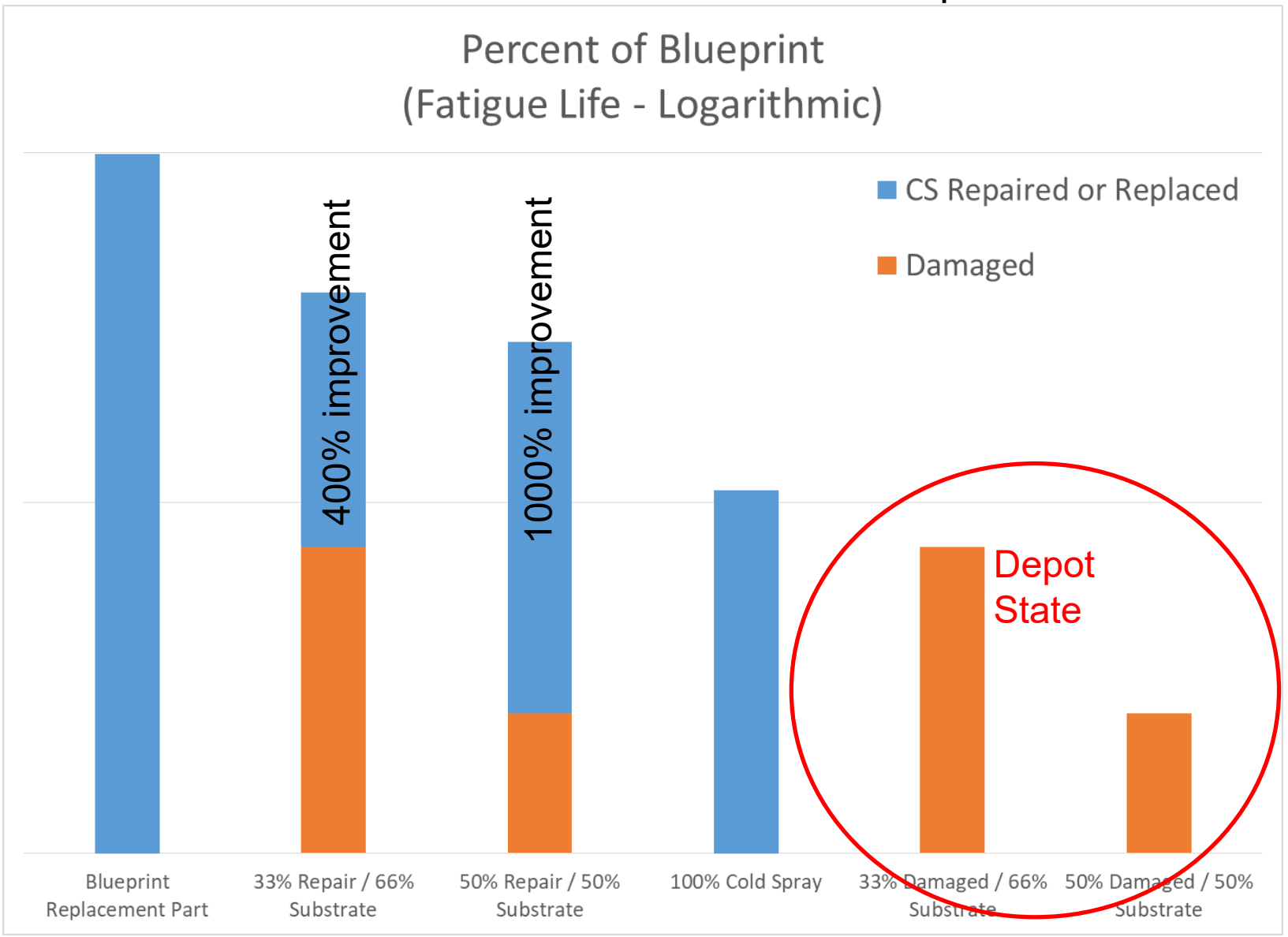




Cold Spray Doubler Carries Load

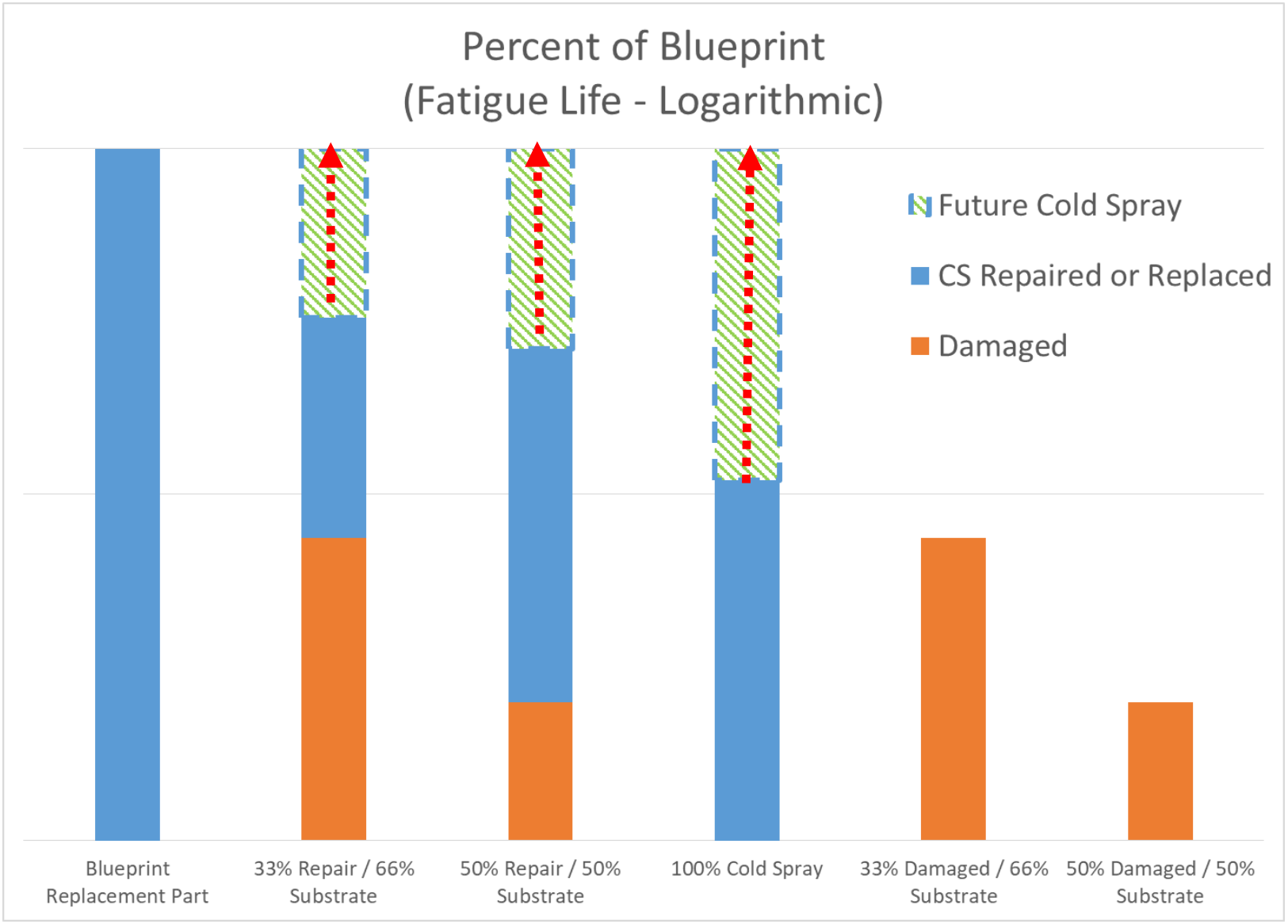
Fatigue Impact of Repair/Replace

- Relative numbers at one load level and other simplifications



Can future cold spray close the gap?

- **Equivalent cold spray performance minimizes analysis required**



What's missing in current work?

- Non-Destructive Testing / Evaluation
- A/B Basis Allowables / MMPDS
- Maturity of first 3 Lincoln pillars
  - Stability, Producibility, Predictability
  - Flaw distributions
  - BA-26 (Coming Soon)
- Low Helium / Nitrogen carrier gases
- Legacy material substrates
  - Can't make a different spray powder to match substrate for every possible aluminum in practice