Solid State Structural Repair (S3R) for Naval Aircraft

CSAT 2022

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What is S3R?

- The ability to repair aluminum (and other metals) using non-melting processes
  - Builds upon dimensional repair knowledge and capability
  - Recovery of structural life is goal
  - Anticipated (for now) to only be a depot-level repair
- NAVAIR is supporting the development of two processes to enable S3R:
  - Cold spray (high-pressure systems)
  - Friction stir deposition (FSD) and related methods
- Focus is on three repair scenarios:
  - Blended surface repairs (typically from corrosion damage)
  - Edges
  - Holes
- Current investment is focused on 7050 and 7075 aluminum alloys based on prevalence in aircraft structure
  - Current TRL is 5 for structural repair cold spray and 4 for FSD
  - On- and off-aircraft options being pursued

S3R Objective

Impact: Improved Fleet Readiness

Develop and transition structural repairs for aluminum alloys using cold spray and friction stir deposition processes

Benefits

- Component life extension
- Time and cost savings compared to new component purchase or manufacture at FRC
- Repair on Aircraft, Turn Around Time reduction
- Key process enabler for reliability degraders

Desired Outcomes

- ❑ Demonstrate ability to apply repair onto H-1, V-22 and F/A-18 prototypes
- ❑ Determine and provide fixed process parameters for
  - ✓ Fixed HP cold spray
  - ❑ Portable HP cold spray
- ❑ Achieve threshold repair requirements to enable prototype repairs
  - ✓ 7050-T7451/HP cold spray
  - ✓ 7075-T641/HP cold spray
  - ❑ 7050-T7451/Friction stir process (new for FY22)

S3R Team

Government

PMA276 (H-1), PMA275 (V-22) and PMA265 (F/A-18) programs and FSTs

- User, part identification and repair certification

Fleet Readiness Center- East (FRCE), FRC-Southwest (FRCSW) & FRC Southeast (FRCSE)

- Process implementation, repair design and certification

NAWC-AD and NSWC-CD

- Project and technical coordinator, technical warrant holders for structures, metals processes, NDI, corrosion and coatings
- Mechanical and corrosion testing, NDI development, certification software tools

Government

ONR

- Sponsor, programmatic and technical coordination and guidance

Partners

SAFE

- Mechanical properties, test requirements, component repair prototyping

Penn State- ARL

- Process parameters and optimization; NDI

University of Alabama

- Powder improvements, LACS, and process optimization

Extended Team

SBIRs

GEM/Va Tech

- Develop Friction Stir Deposition for divot and hole repair

VRC/SDSM&T

- Develop High-Pressure Cold Spray Deposition for divot and hole repair

Phase II efforts underway

S3R Friction Stir Aluminum Repair Thrust

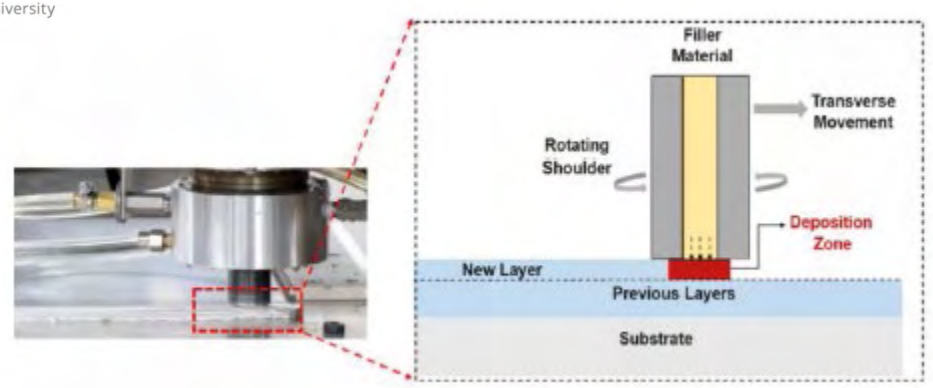
BYU

- Develop multiple Friction Stir methods for divot and hole repairs

MELD

- Develop MELD FSD to meet NAVAIR S3R requirements
- Deliver L3 system at the end of the contract

Efforts underway



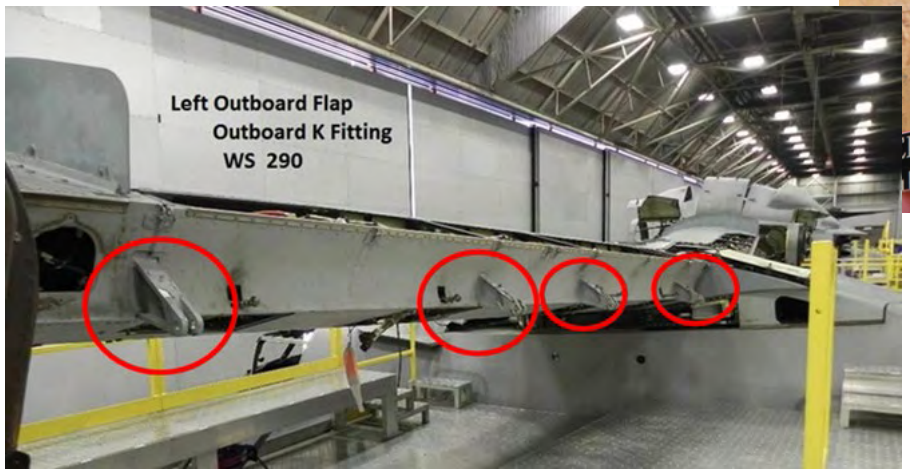
S3R Targeted Repairs

PMA276: H-1 program

- Objective: Static load requirement
  - Skid tube

PMA275: V-22 program

- Objective: Dynamic load requirement
  - K-fitting



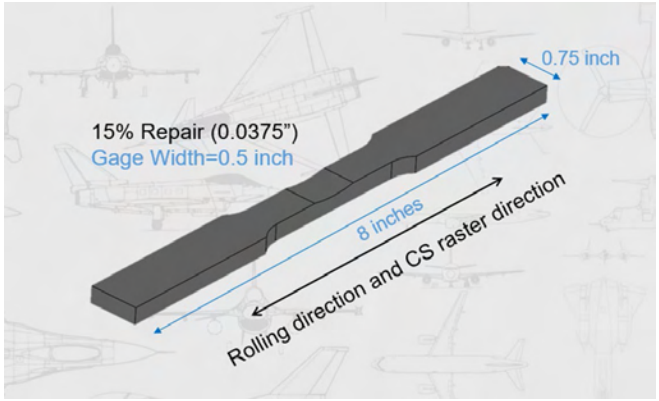
PMA265: F/A-18 program

- Objective: Dynamic load requirement
  - Trailing edge flap (TEF) hinges

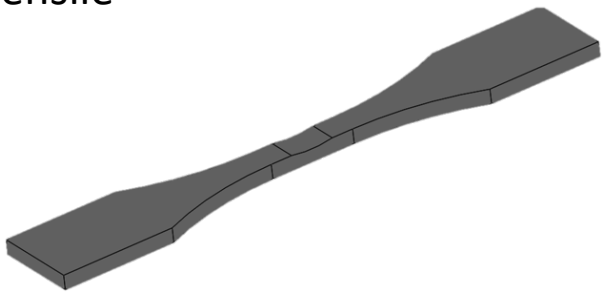
Repair Process Development

- ✓Fatigue life improvement is primary requirement used for process development
- ✓Standard coupons and test methods in place- important achievement which supports all related efforts

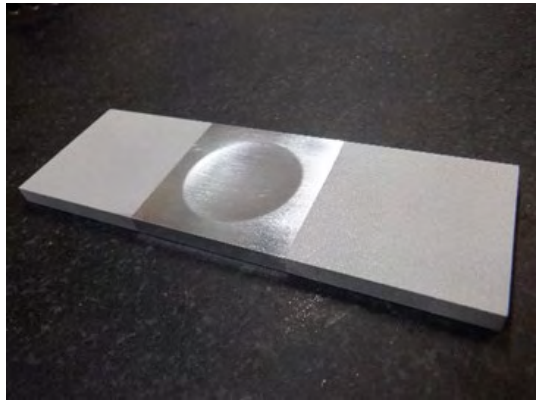
Images courtesy of SAFE



Tensile



Fatigue

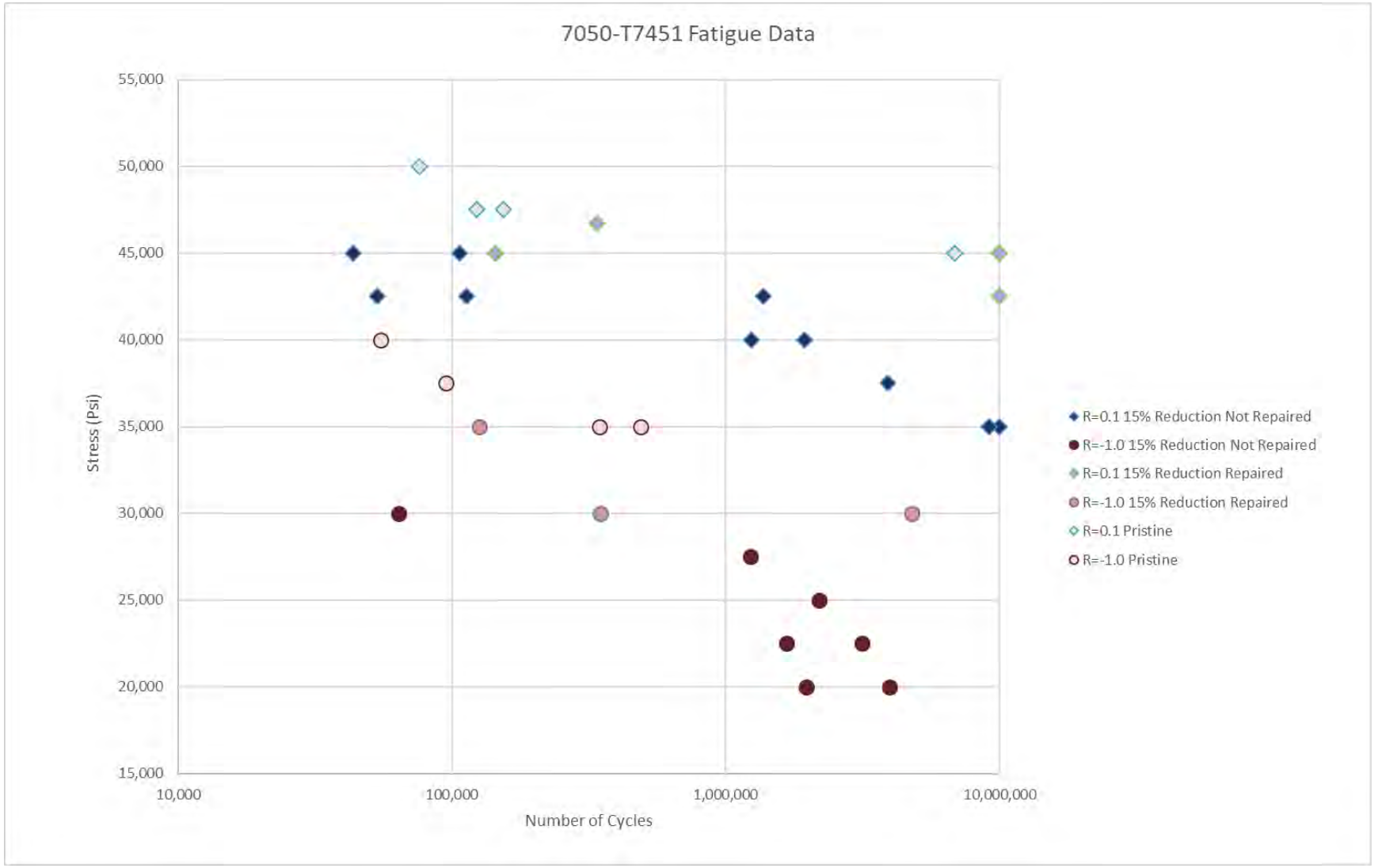


Field representative repairs (fatigue)

- 0.075 inch deep divot (30%) with 20:1 blend ratio
- 5/16” hole (first nominal oversize allowed for ¼” hole)

7050-T7451 fatigue performance
15% reduction and repair, SAFE coupon

- New lot of 7050 (SAFE and Pax)
- Repaired by Mid-American using VRC Gen III "locked" process



Prioritized Repair Requirements Status

Priority	Requirement	Minimum	Threshold	Goal
1a	Fatigue (Stress) Life Improvement: Blend Repair (@10k cycles)	10%, using maximum blend (divot) limit	25%, using maximum blend (divot) limit (30%)	Restore to original design life
1b	Fatigue (Stress) Life Improvement: Edge Repair	10%, using maximum repair limit	25%, using maximum repair limit	Restore to original design life
1c	Fatigue (Stress) Life Improvement: Hole Repair	10%, using maximum hole repair limit	25%, using maximum hole repair limit	Restore to original design life
2a	Ultimate Tensile Strength of Repaired Specimen	70% of original strength (no harm repair)	90% of original strength	Restore to original strength
2b	Yield Strength of Repaired Specimen	65% of original strength (no harm repair)	90% of original strength	Restore to original strength
2c	Modulus of Elasticity of Repaired Specimen	Similar to baseline	Similar to baseline	Similar to baseline
2d	% Elongation	TBD	TBD	TBD
3	Porosity	1%	0.50%	0.10%
4	Microhardness (of repaired substrate)	80% of base metal	90% of base metal	100% of base metal
5	Bend Adhesion	No loss of adhesion	No loss of adhesion, minor cracking	No loss of adhesion, no cracking
6	Thermal Control (if needed)	Passive/None	Active/Compressed Air	Active/Liquid/Cold plate
7	NDI detection capability	None	Partial	Full component requirement
8	Fatigue crack initiation site(s)	Will support structural analysis	Will support structural analysis	Will support structural analysis
9	Microstructure	For informational purposes	For informational purposes	For informational purposes
10	Residual Stress	For informational purposes	For informational purposes	For informational purposes

Process: VRC Gen III HP Cold Spray System
Substrate: 7050-T7451 aluminum

	Achieved
	In reach/additional validation needed
	Not achieved yet

Recent Progress: Skid Tubes

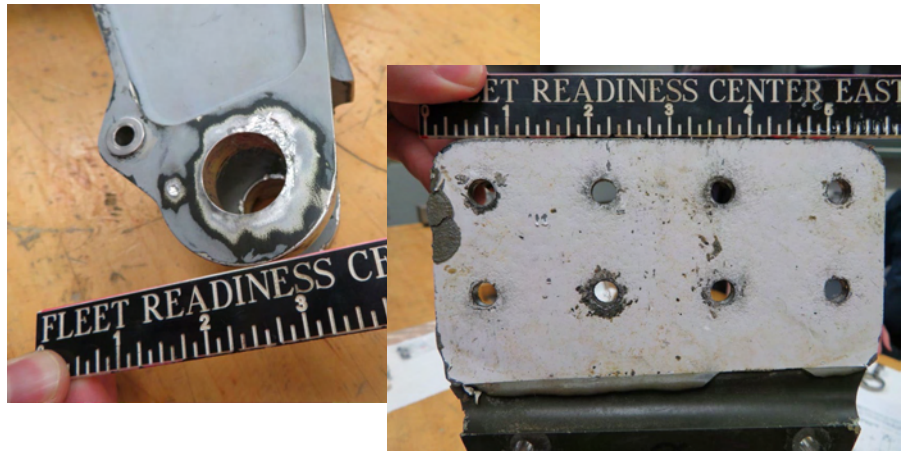
- ✓ Two scrap skid tubes sectioned for analysis and sub-scale repairs and testing
- ❑ Mid-American repair of sectioned piece(s)
- ❑ Identification of candidate full-scale skid tube(s)
- ❑ Repair of full-scale skid tube(s) at Mid-American

- ✓ Initial data requirements established to enable full-scale, on-aircraft skid tube field testing
- ❑ Data collection: coupon and sub-sections
- ❑ Tech warrant holders' review of data

Possible, pending initial data

- ❑ Tech warrant holders' approval to fly repaired skid tube(s)

K-fitting status



- ✓ Three scrap K-fittings received from FRCE
- ❑ Based on progress for fatigue life of repaired coupons, assess potential repair scenarios
- ❑ Identify prototype repair(s)
- ❑ Prototype off-aircraft repair of sub-scale or full-scale component at Mid-American or PSU-ARL

- ❑ Identify data and test requirements to verify static and dynamic performance of repairs
- ❑ Data collection
- ❑ Tech warrant holders' review of data
- ❑ Identify path to on-aircraft component testing
- ❑ Plan for on-aircraft repairs (beyond the FNC)

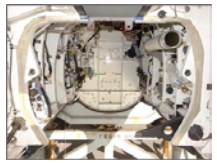
possible, pending initial data

Projected S3R Deployment Timeline

High Pressure commercial repair capability available today at MAA/VRC

Skid tube, K-fitting, Hinge prototypes

Additional prototypes

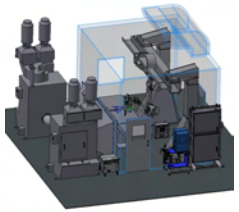


Skid tube, K-fitting, Cobox, T-64 housing

First deployed structurally repaired component

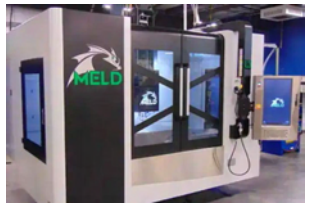
2021 2022 2023 2024

Low Pressure Systems in place at all 3 FRCs
- Supports sacrificial coating repair overlayer



High Pressure Systems planned to be in place and operational by end of CY22 for FRCE and CY23 for FRCSE

FRC validation of Prototype repairs using their CS systems



First MELD FSD system- location TBD

Portable, robotic HP cold spray system

Long Term Plan Ahead

- Continue maturing processes and developing underlying materials data to support deployment
  - ONR FNC completes ~April 2023
  - SBIR efforts- ongoing and new
  - AERMIP project in place for FY22-24 (additional prototyping and field testing)
  - Additional funds for FY23+ are in work
- Complete and promulgate 5-yr S3R plan
  - Test methods and material characterization
  - Repair methods: cold spray and friction stir deposition+
  - Analysis and modeling (including data warehousing)
  - Capability