Boeing Technology Integration

# Rapid Composite Repair Development Overview

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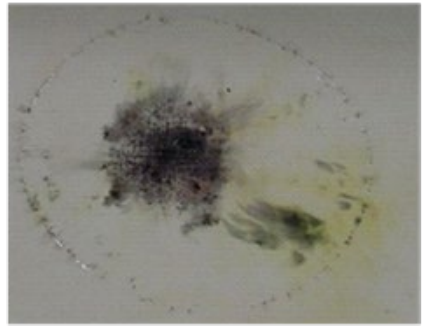
# Agenda

- Overview
- Precured Repair Solutions
- Composite Modular Bolted Repair Parts
- Rapid Tooling for Repair Part Fabrication
- Kitted Repairs / Peel and Stick Repair
- BMI Bonded Repair Development Overview
- Conclusions

# Overview

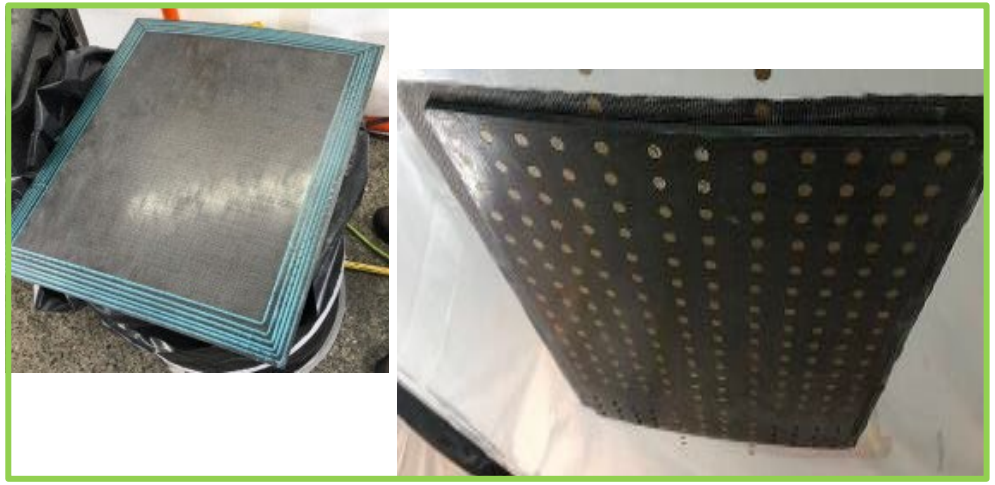
- A need exists for improved rapid repair technologies for composite structure to support Forward Deployed Combat Repair (FDCR) scenarios.
- FDCR capabilities for composites are lacking compared to metal parts.
- Needs closely align with commercial Airplane On the Ground (AOG) scenarios, allowing technologies to be leveraged.
- Along with being rapid, FDCR technologies are tailored to require a lower skill level and no cold storage for materials.

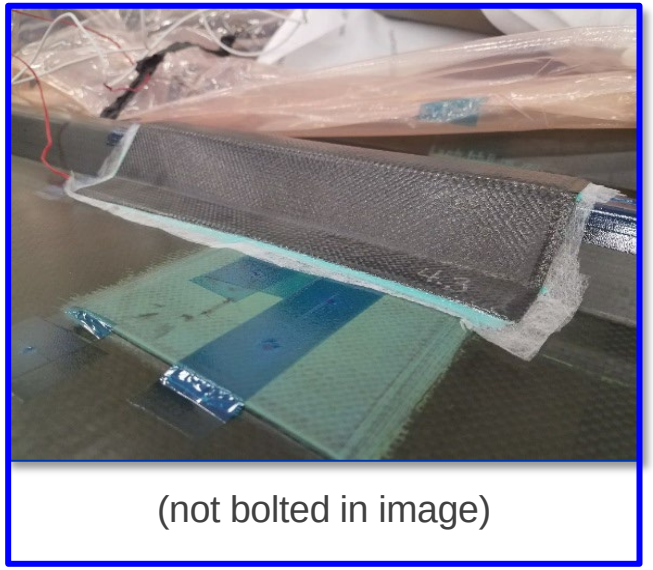


# Precured Repair Solutions

Patches/Doublers comprised of precured 2-4 ply CFRP/GFRP “books” bonded together with adhesive between each layer to match repair surface contour.

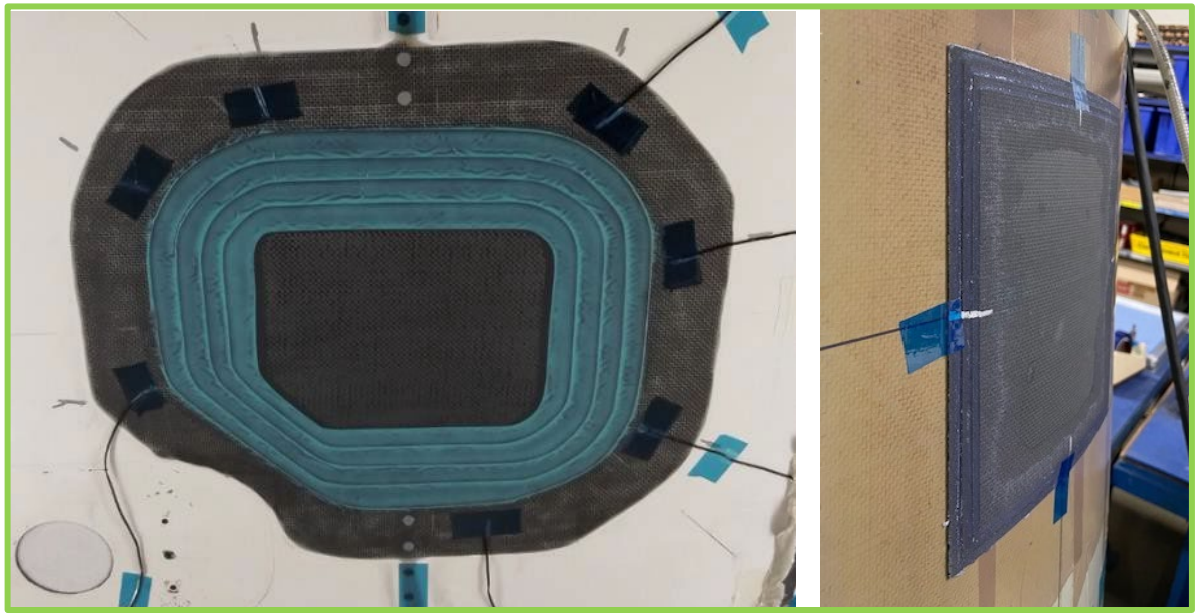

BOLTED

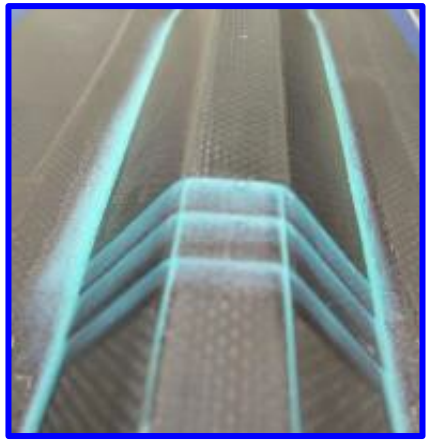




(not bolted in image)

BONDED

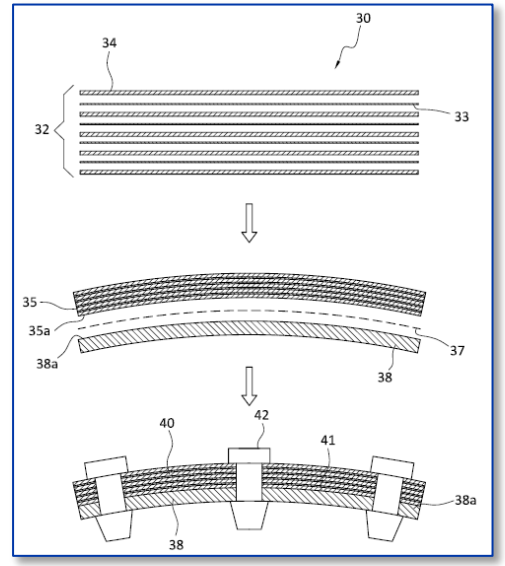


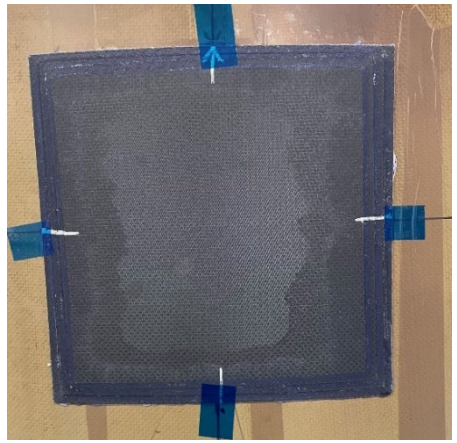


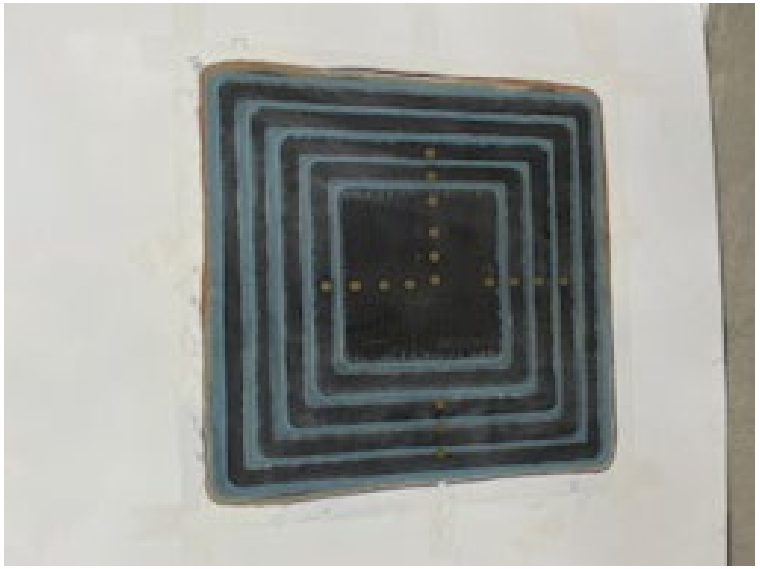
# Precured Repair Solutions

## Advantages:

- Autoclave patch properties.
- Can use a lower temp cure while still utilizing a 350F cure CFRP/GFRP.
- Bolted version only requires limited or no damage clean-up, and no moisture removal.
- Permanent repairs with no fatigue concerns.
- Can stock the book material so it's immediately ready for use. Eliminates prepreg storage constraints.
- Uses peel ply on book surfaces for fast surface prep.
- Significantly faster than a traditional composite repair. Comparable timewise to a metallic doubler, but without the fatigue or corrosion concerns.
- Depot level repairs can utilize a film adhesive for bonding, while FDCR can use a room temp storable paste adhesive or 2-part resin.

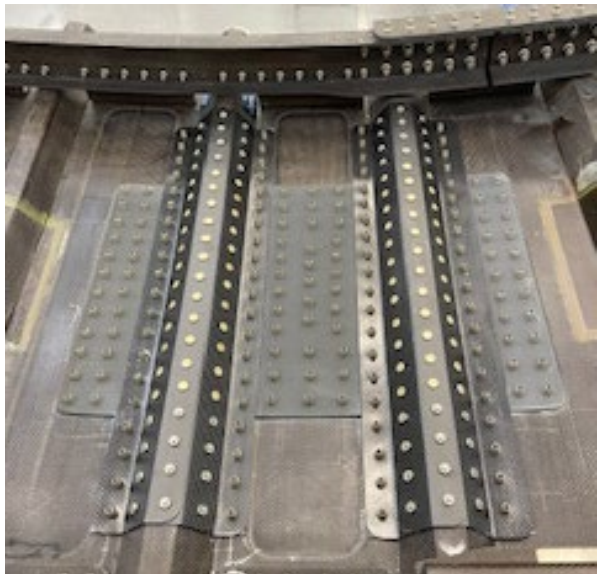


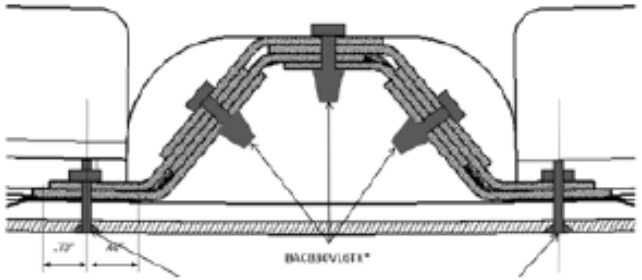



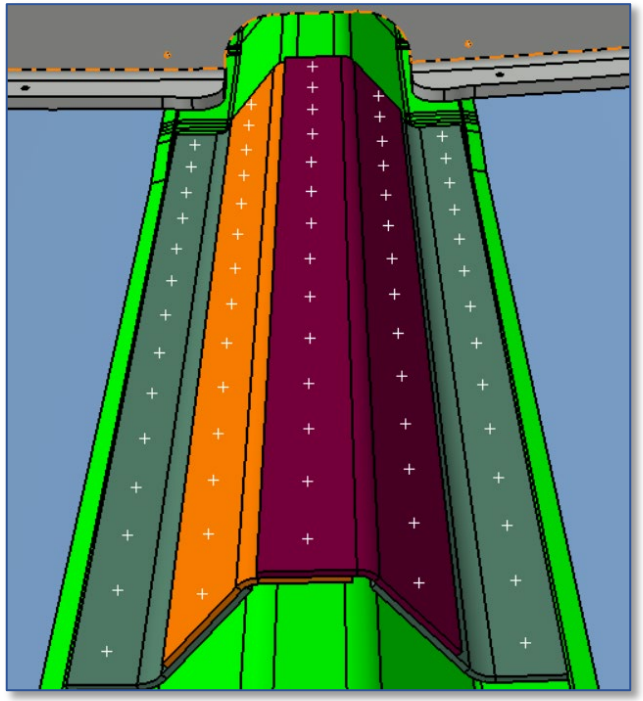


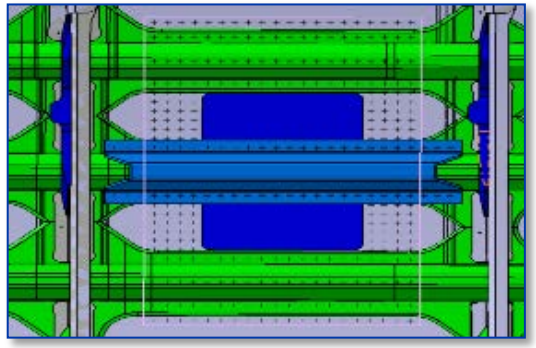
# Composite Modular Bolted Repair Parts

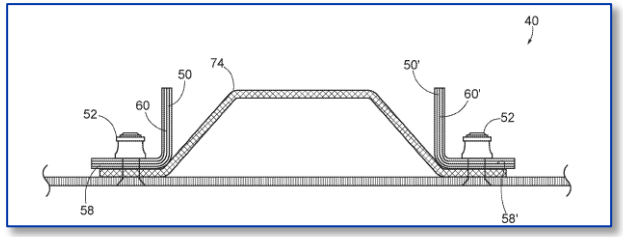
Family of off-the-shelf CFRP/GFRP repair parts that can be used to bolt onto an airframe. Parts are designed to be versatile, allowing a limited number of part types to cover a majority of the aircraft. Custom made parts are used to cover the rest.



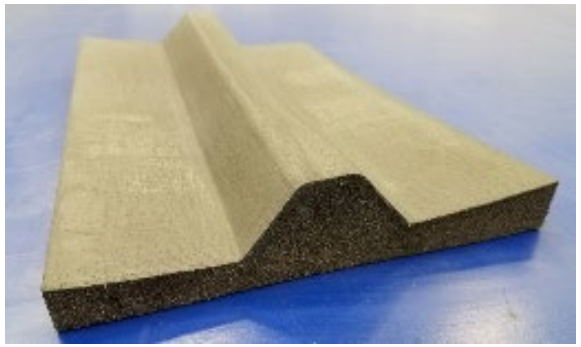






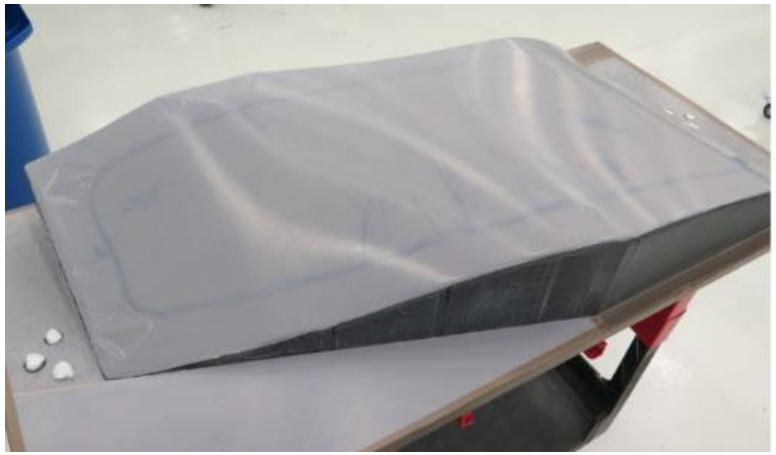


# Rapid Tooling for Repair Part Fabrication

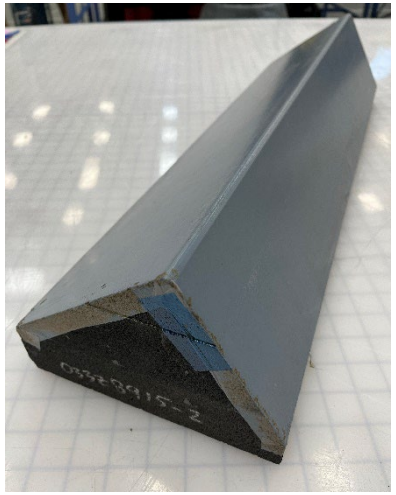


**Emergent, limited use tooling for autoclave cure**
*tested up to 25 cures showing no geometric degradation*
*(epoxy face-sheet is limiting factor for tool life)*

- Machined Carbon foam
- Non-reinforced epoxy face-sheet
- Adhesive backed release film surface
- Low CTE produces highly dimensionally accurate parts



Depending on size and complexity—fabrication ranges between 1.5-5 days



# Rapid Tooling for Repair Part Fabrication

**Production representative tooling**
*(CFRP face-sheet material is limiting factor for tool life)*

- Machined Carbon foam
- CFRP face-sheet (tooling prepreg/BMI)
- Chemically released surface

Depending on size/complexity—fabrication ranges between 2-3 weeks

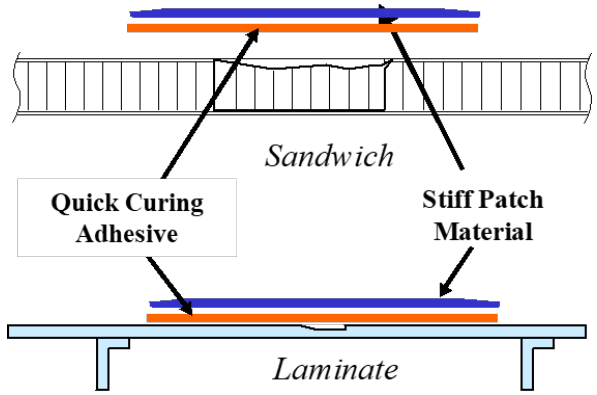
# Kitted Repairs – Quick Composite Repair (QCR) Concepts

## QCR1 (< 30 minutes):

- “Peel and stick” patch, uses pressure sensitive adhesive or rapid cure paste adhesive
- Time limited – intended to get aircraft immediately back into service but for limited amount of time
- No or minimal cure time (at room temp)

## QCR2 (approximately 60 minutes):

- Composite doubler bonded w/quick cure paste adhesive
- Step up from QCR1 in terms of structural capability & repair life
- Chemical heat packs for cure; reusable vacuum bag
- Time limited – good for max 24 months with visual inspections every 90 days




## QCR3 (4-6 hours):

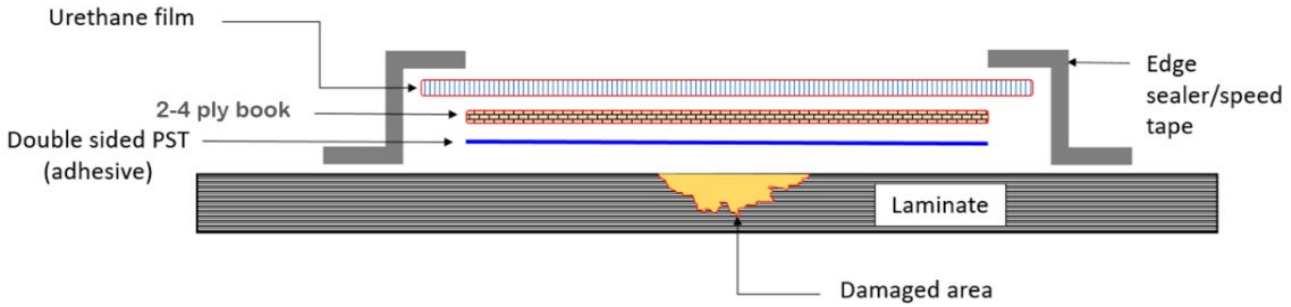
- Overnight standard hot bonded repair for damaged solid laminate or sandwich structure
- Performed by a repair mechanic with basic composite repair experience/training
- Damage removed, damage area filled, and precured patch bonded with paste adhesive
- Potential to be permanent repair

# Peel and Stick Repair

Rapid repair concept that uses a pressure sensitive adhesive (PSA) tape or rapid cure paste adhesive with a precured patch to restore structural capability for minor damage to honeycomb & solid laminate structure.

## Targets:

- Repair time of 30 minutes or less
- Time limited - 30 days / 100 flight hours min
- No cure time or a rapid room temp cure
- Service temp capability of -65F to 140F-160F
- Able to be performed by less skilled personnel
- No support equipment required



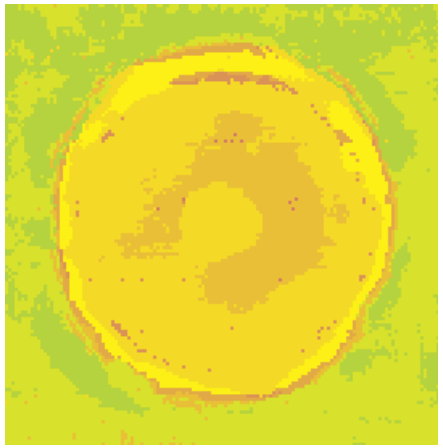
# BMI Bonded Repair Development Overview

Developed a high quality out of autoclave BMI bonded repair to fully restore structural and environmental properties. This included:

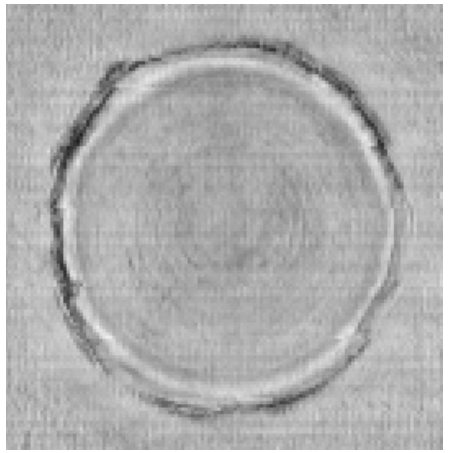
- Double vacuum debulk (DVD) process for 5250-4 & F650 fabric to consolidate patch prior to bonding.
- High quality bonding process using EA9673 BMI film adhesive.
- Design values and large panel testing to support analysis.
- NDI inspection procedure.
- Additionally, demonstrated proof of concept for a high temperature wet layup repair that processes comparably to traditional epoxy wet layup repairs.

# BMI Bonded Repair Development Overview

## Bonded Scarf Repair Results

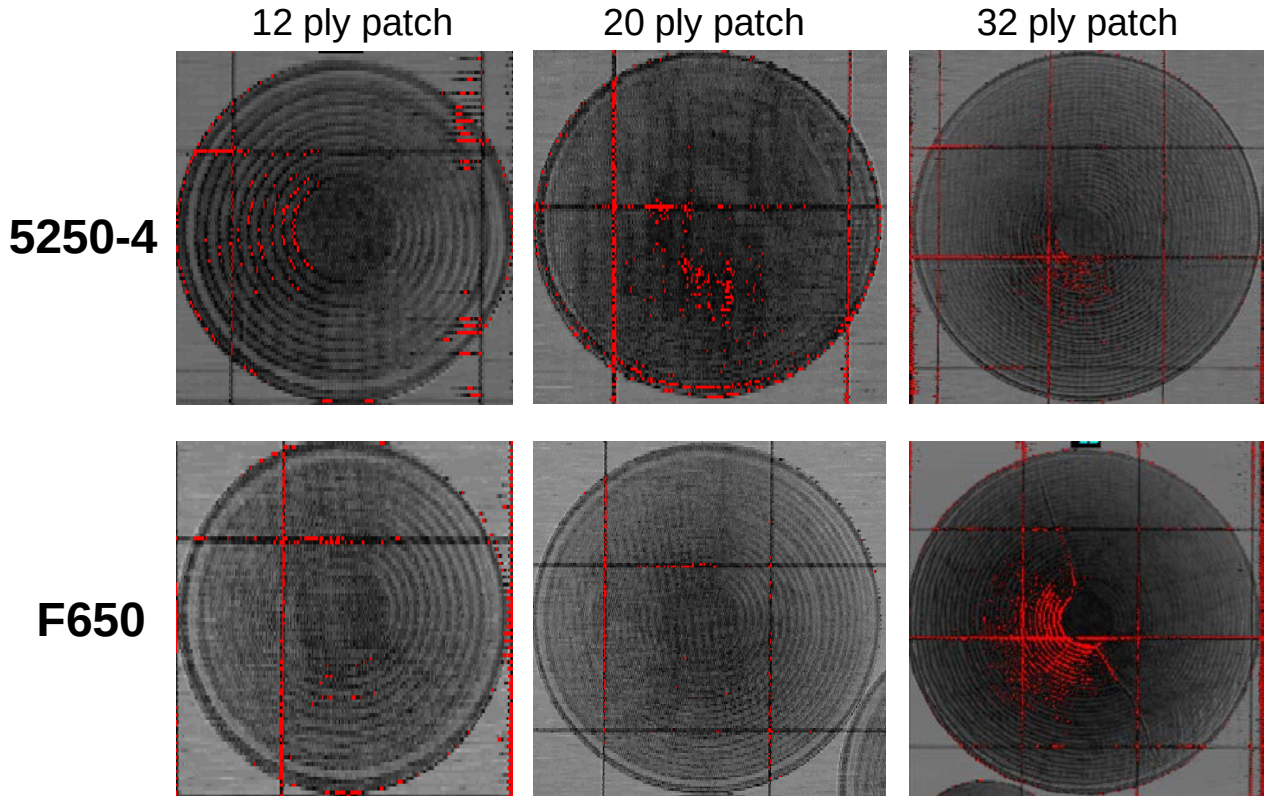


Time of Flight



Amplitude

## DVD Results




2% porosity in red (everything else < 2%)

# Conclusions

- Progress has been made in developing rapid repair processes for composite structure to address the challenging demands of AOG / FDCR scenarios.
- Rapid repair technologies developed for commercial applications can be leveraged and implemented for military applications.
- Further advancements in rapid composite repairs is needed to support the growing use of composites in aircraft.
- Standardizing repairs and using universal repair materials will help simplify repair processes in forward deployed scenarios.