# Lightning Strike Effects on Full-Depth Scarf Repairs

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## Background

A scarf repair is a technique used to fix damaged composite structures and can be done on most of an aircraft's exterior.

A scarf repair results in further reduction of through thickness and in-plane electrical conductivity due to the newly introduced bonding adhesive layer.

The bonding adhesive acts as a dielectric layer, inhibiting the dissipation of energy in the event of a lightning strike. Furthermore, the adhesive prevents potential electrical surges from subsequent strikes.

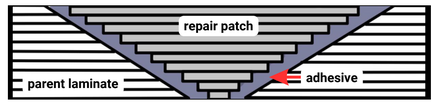


***Figure 1.*** Diagram of a composite scarf repair.

## Statement of Purpose

### Current State

There are no current additional protections being added to scarf repairs. The lightning strike protection scheme must have minimal changes to the weight and structural integrity of the component.

### Gap Analysis

There is a lack of comprehensive testing of lightning strike protection schemes for scarf repairs under realistic conditions. Additionally, some protection schemes, such as embedded metal wires, can be complex and expensive to implement.

### Objectives

- Perform scarf repairs & install lightning protection schemes
- Administer lightning strikes on the panels
- Conduct non-destructive & destructive inspections
- Compile and analyze results and report findings

### Scope

Design and characterize the performance of novel scarf repairs subject to lightning strikes (100 kA) and evaluate the effectiveness of lightning strike protection schemes/shields for fuselage panels.

### Lightning Strikes Quick Facts

> Commercial passenger planes are struck by lighting on average 1-2 times per year [1]

> The probability of a lightning strike is zoned into 3 regions of an aircraft [2]

> There are four waveforms of lightning utilized for lightning simulations [3]

> The maximum limit of a lightning strike is around 200 kA [3]

## Methodology

### Design

We prepared eight lightning strike protection scheme designs alongside a baseline panel that will be the control. These designs needed to fulfill the following criteria from our design matrix:

- Minimal service downtime
- Uses approved aerospace materials
- Minimal structural changes
- Little addition to weight
- Durable
- Affordable

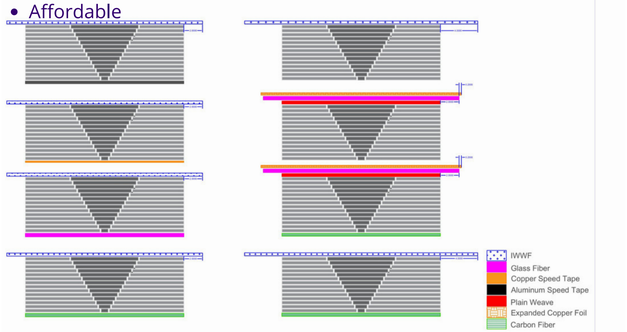


***Figure 2.*** A simple visualization of the eight lightning strike protection scheme designs.

### Experimentation

Each panel was scarfed and cured before 1of the 8 protection schemes were applied. Ultrasonic testing confirmed that there was no disbonding or delaminations of plies. Afterwards, an additional coat of paint was applied to the exterior of the panel.

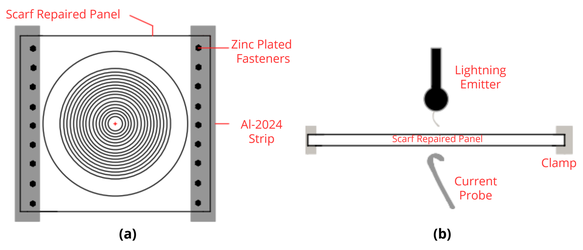


***Figure 3.*** **(a)** The grounding strap procedure for lightning testing **(b)** and the lightning test apparatus.

To simulate lightning damage, each panel was struck with 100 kilo-amperes of current at a point slightly off-center of the repair patch. At the point of contact, a nick of paint was chipped off to ensure the current interacted with the inter-woven wire fabric (IWWF). These tests were facilitated by Boeing's lightning testing lab in Seattle.

## Results

## Discussion

## Conclusion

## Acknowledgements

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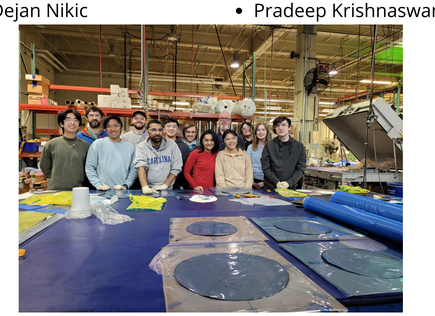

***Figure*** **.** Students and Boeing mentors at John Spalding's lab with scarfed panels ready for double vacuum debulk.

**Citations:**

1. "Lightning and Planes," National Weather Service, 20-Apr-2018. [Online]. Available: https://www.weather.gov/safety/lightning-planes#:~:text=Commercial%20transport%20passenger%20planes%20are,strike%20and%20conduct%20the%20currents. [Accessed: 07-Mar-2023].
2. "Sae Arp Lightning documents: What engineers need to know," Weather Guard Lightning Tech, 19-Oct-2020. [Online]. Available: https://weatherguardaero.com/sae-arp-lightning-document-faa-radomes/. [Accessed: 07-Mar-2023].
3. C. Karch and C. Metzner, "Lightning protection of Carbon Fibre Reinforced Plastics — an overview," 2016 33rd International Conference on Lightning Protection (ICLP), 2016.