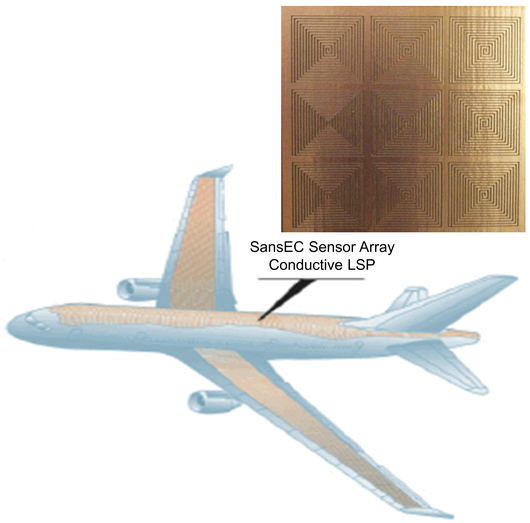
National Aeronautics and Space Administration



Lightning Mitigation

Objective

Develop innovative lightning strike mitigation technologies to minimize flight safety risks from electromagnetic environmental hazards. (Lightning & HIRF)



Technical Challenges

- **Atmospheric Hazard Sensing and Mitigation (AHSM)**
  - Improve and expand remote sensing and mitigation of hazardous atmospheric environments and phenomena
    - Lightning resilient composite aircraft
- **Lightning Mitigation**
  - Develop mitigation strategies to improve aircraft lightning protection designs through passive or active methods.
    - Investigate lightning damage mechanisms in composite materials
    - Develop composite lightning damage models.
    - Safely manage/control all aspects of lightning strike current attachment, propagation & detachment.
- **Lightning SansEC Sensors**
  - Smart Skin Technology
  - Robust, multifunctional sensors to protect & diagnose composites with single appliqué.
    - Lightning Strike Protection (LSP)
    - EM Shielding
    - Damage detection & diagnosis

Approach

- **Lightning Mitigation**
  - Establish LSP universal common practice test procedures to promote one to one correlation compatibility between future independent data.
  - Define composite matrix for universal common practice test article
  - Define Nondestructive evaluation (NDE) procedures for substrate pre-test quality assurance and post test damage assessment.
  - Define LSP test procedures to conduct lightning energy-transfer characterizations to capture mechanical, thermal, and electrical energy transfers during plasma flashover arcing events.
  - Develop lightning strike test bed to safely monitor electrical current, temperature, and mechanical shock with adequate detection thresholds to support high fidelity modeling of composite structures for direct effect lightning damage assessments.
- **Lightning SansEC Sensors**
  - Investigate lightning resilient sensors using geometry shaping & differential resistance/capacitive designs.
  - Develop designs to resonate at frequencies permeable in composite materials.

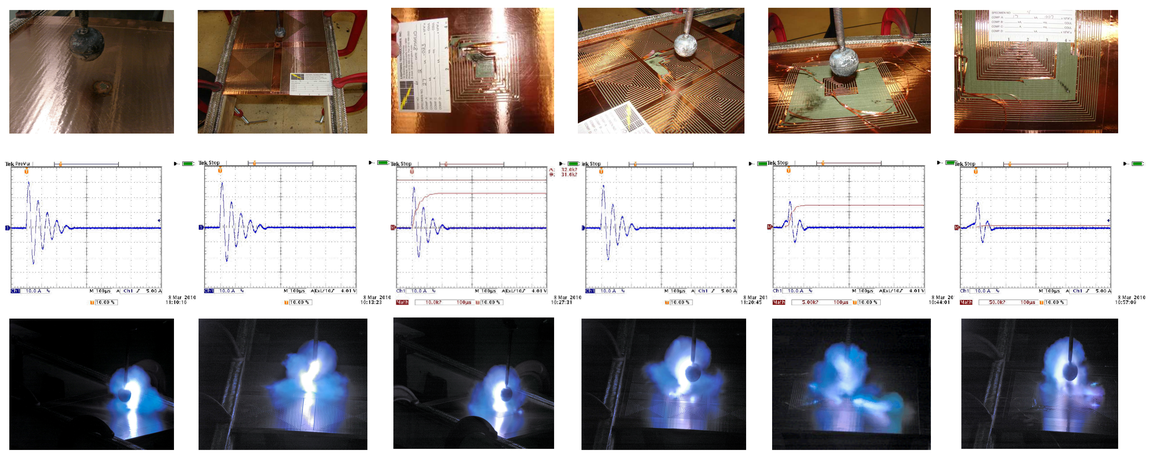
Analysis

- Aircraft in the US are struck by lightning once per year on average.
- Growth in composite aircraft manufacturing is expected to continue.
- Composite aircraft do not possess the same inherit level of lightning protection as aluminum aircraft.
- Lightning Strike Protection (LSP) conductors are used on top of composite surfaces to minimize lightning damage.
- Lightning strikes are expected to inflict an acceptable level of damage to the composite skin.
- LSP designs balance the level of protection with the increase in aircraft weight.
- Aircraft struck by lightning undergo a post-flight ground visual inspection to determine level of damage and appropriate repair procedures.
- Tap test is conducted at lighting point of entry to identify composite delamination.

Laboratory Results

Lightning Direct Effect Test

Baseline- No Sensor	6” Sensor Array	3”Sensor	3”Sensor Array	6”Sensor	9”Sensor
9 KV 30 KA Action Int. .032 x 10^6 A^2s	9 KV 30 KA Action Int. .033 x 10^6 A^2s	9 KV 27 KA Action Int. .023 x 10^6 A^2s	9 KV 28 KA Action Int. .027 x 10^6 A^2s	9 KV 17 KA Action Int. .007 x 10^6 A^2s	9 KV 17 KA Action Int. .007 x 10^6 A^2s



Solution



- **Lightning Mitigation**
  - A lightning strike test bed will be developed to conduct energy-transfer characterizations through the real time monitoring of mechanical, thermal, and electrical energy transfers during plasma flashover arcing events. Test results will be used to support identification of lightning damage mechanisms and validate composite damage modeling codes.
  - Investigate passive or active lightning mitigation approaches for composite aircraft lightning protection which provide robust lightning attachment points which can safely attract, attach and manage lightning currents to protect composite aircraft.
- **Lightning SansEC Sensors**
  - Multifunctional sensor to provide lightning strike protection, EM shielding and damage detection & diagnosis.

Conclusions

•SansEC sensors are being developed for use on composite aircraft to provide lightning strike protection, EM shielding and damage detection & diagnosis.

•Lightning test results indicate the SansEC sensors electrical impedance and intrinsic ability to steer lightning currents offer new design approaches to lightning mitigation.

•SansEC sensors can detect an abrupt change in its resonate response (frequency, amplitude, bandwidth, phase, harmonics) to support damage diagnosis.

•Lightning mitigation approaches will be explored which safely attract, attach and manage lightning currents to protect composite aircraft.



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