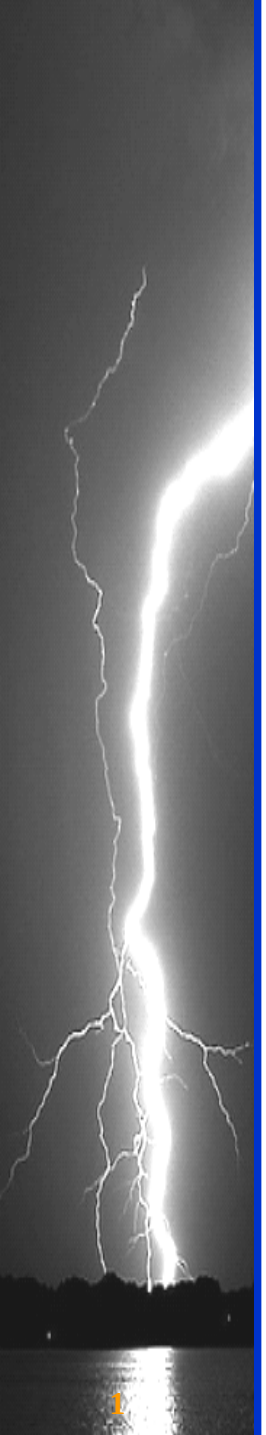


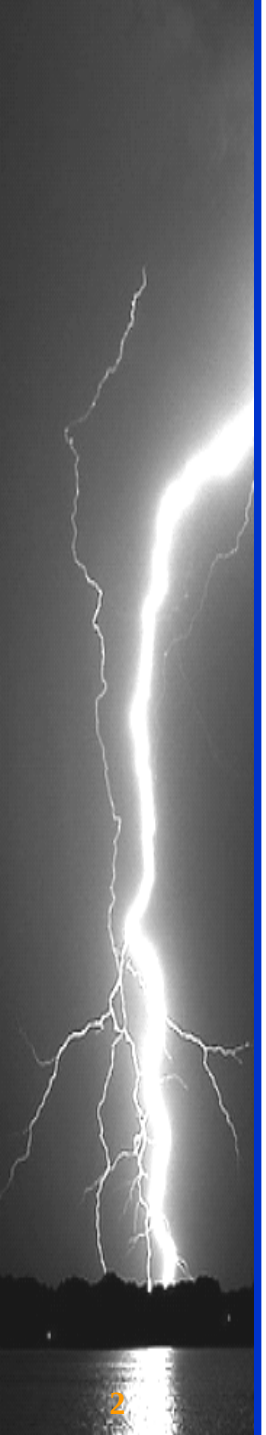
Lightning strike damage to composite structures

PI: Paolo Feraboli
Aeronautics & Astronautics
University of Washington

Boeing focal: Stan Alton
Boeing Commercial Airplanes
787 Technology Integration

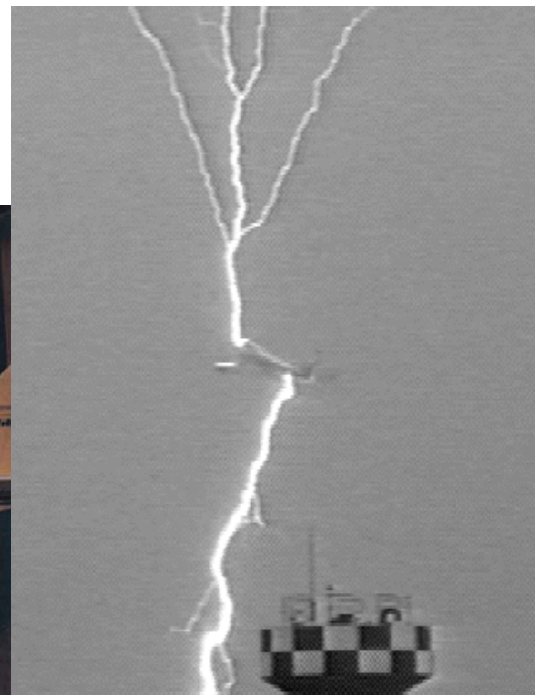
A Center of Excellence
AMTAS
Advanced Materials in Transport Aircraft Structures

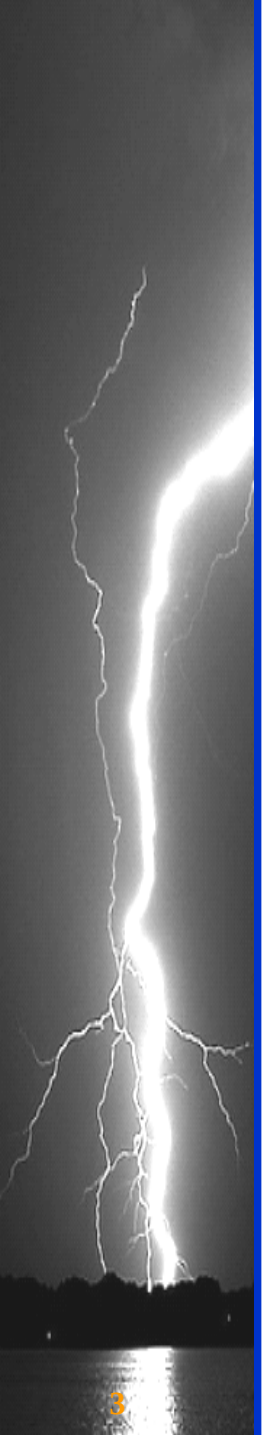
Presented at the AMTAS Spring Meeting
March 20th, 2008



Outline

- *Importance of Lightning Strike research*
- *Current Lightning Strike facilities in the US*
- *Damage tolerance requirements*
- *Proposed research*
- *Status of research at UW*
- *Acknowledgments*





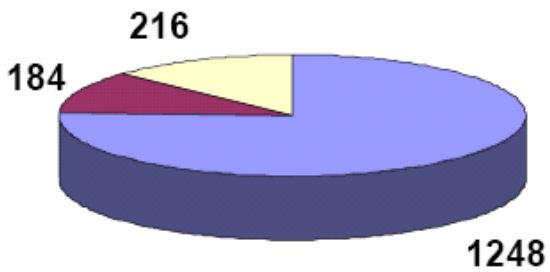
Importance of Lightning Strike research

- *Carlos Blohm (Lufthansa Technik)*
  - *Presented at the FAA/ Boeing/ Airbus/ CACRC joint damage tolerance and maintenance meeting*

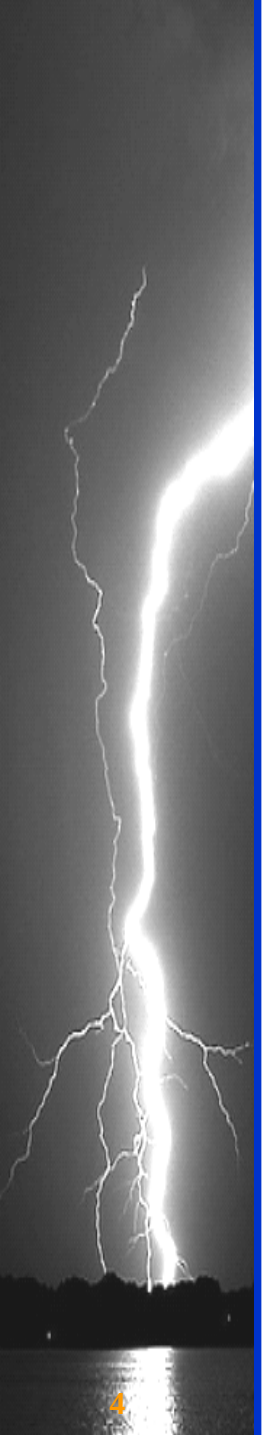
Damages on composite components

Total damages – Total fleet – Year 2006

Fleet Size: 243 a/c
Total damages: 1647 events
Repair Cost: € 33.200.000

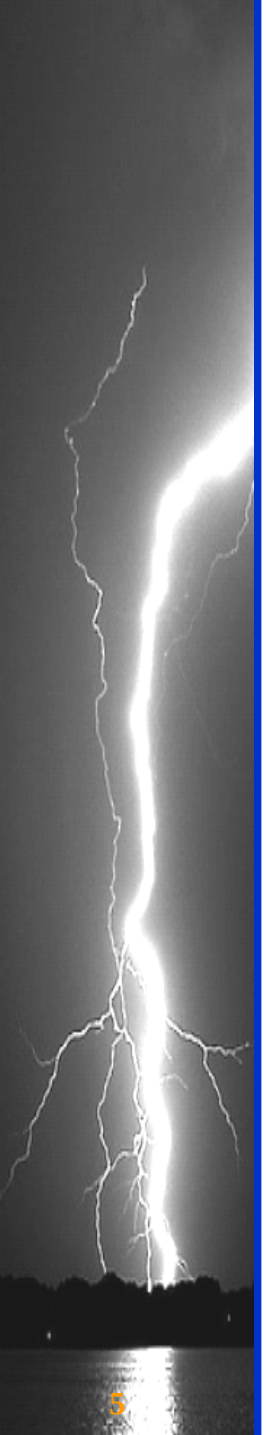


Mechanical impact



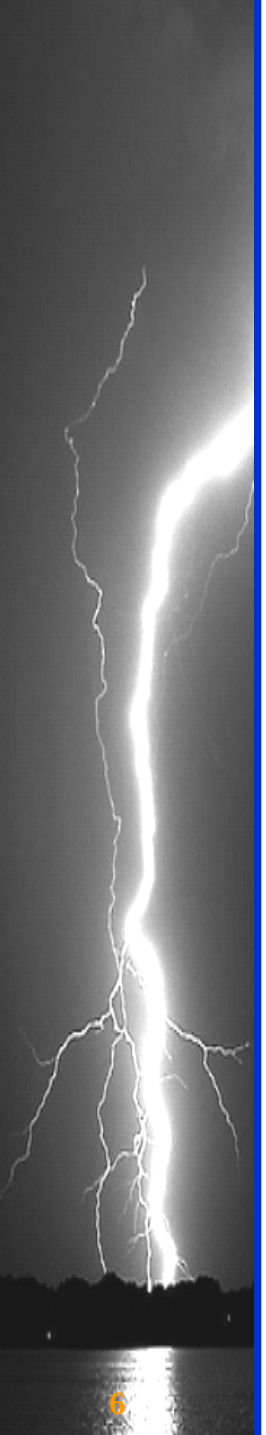
Importance of Lightning Strike research

- *Composite academic community has not addressed the issue*
  - *Non-existent literature in scholarly publications*
- *Extensive research in 1970's and 1980's*
  - *NASA, FAA and SANDIA*
- *Extensive research in proprietary domain*
  - *Boeing has active labs but highly sensitive nature of topic*
- *AGATE – delivered handbook in 2002*
  - *LTI performed contract research*
  - *Focused mostly on thin-gage sandwich*
  - *Large focus on glass fiber skins*



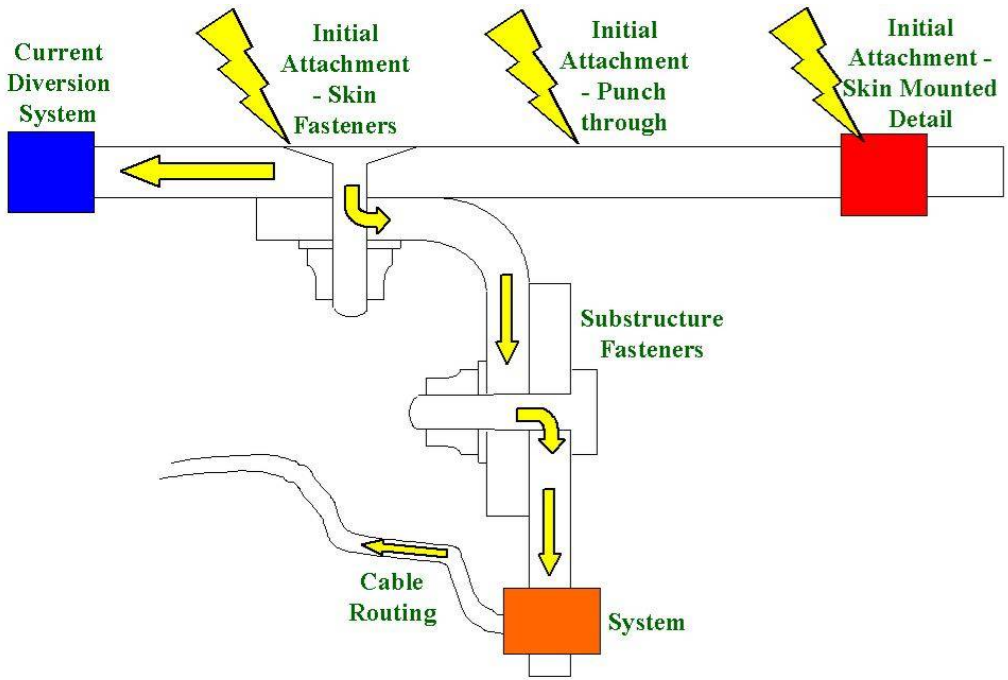
Current Lightning Strike facilities in the US

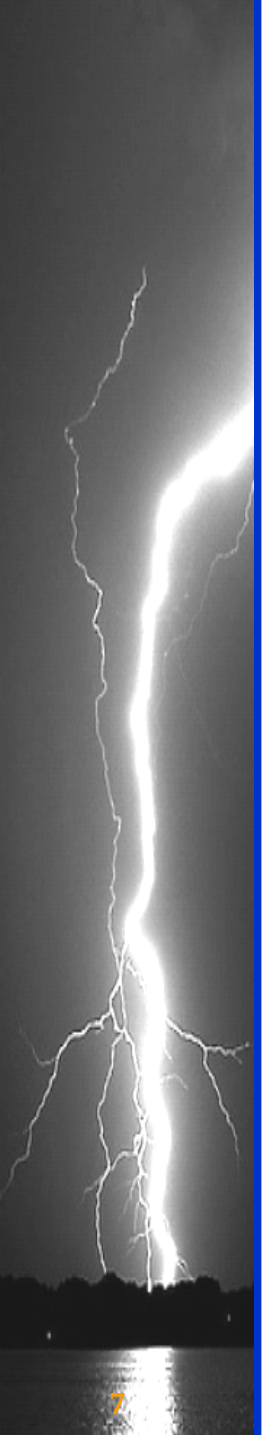
- *Full-size facilities*
  - *LTI – Pittsfield, MA*
  - *DNB – Fullerton, CA*
  - *Boeing Commercial – Seattle, WA*
  - *Shaw Aero Devices** – Naples, FL*
  - *Goodrich** – Chula Vista, CA*
  - *Red Stone/ Marshall** – Huntsville, AL*
- *Wichita State Univ. (NIAR)*
  - *Currently only indirect effects*
  - *Building facility for direct effects testing – online late 2008*
- *Caltech*
  - *Table-top generator 20kAmps for ignition studies*



A systems approach

- *Indirect effects*
  - *EMI shielding*
- *Direct effects*
  - *Structural damage*
  - *Sparking in fuel tank*
- *Materials, fasteners, sealants, etc. all contribute*





Spirit Aero (Wichita)

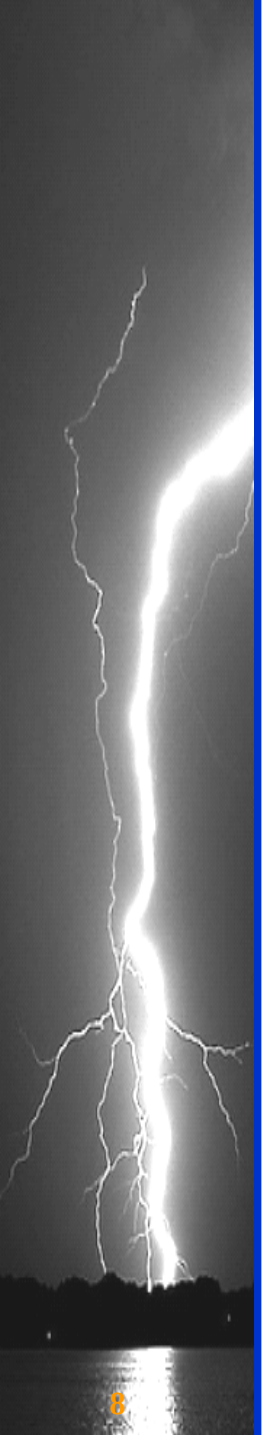
1/8 Korex core, S-2 glass skin

With Al mesh

After Zone 1A strike – LSP-001

Before Zone 1A strike

Without Al mesh



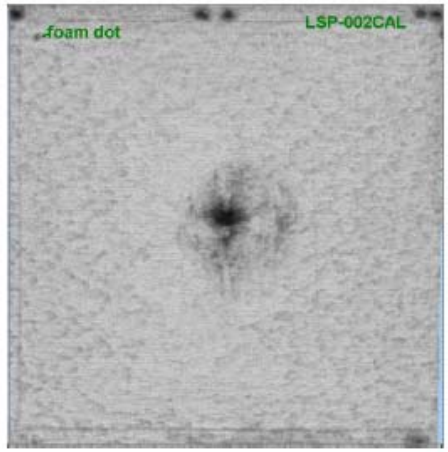
Spirit Aero (Wichita)

1/8 Korex core, S-2 glass skin

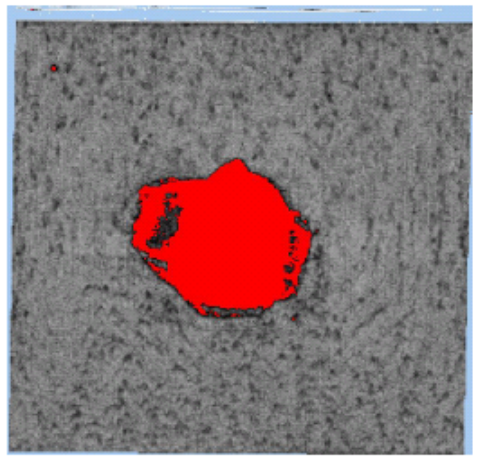
With Al mesh: 3-4 in. damage size, limited to outside mesh ply and paint

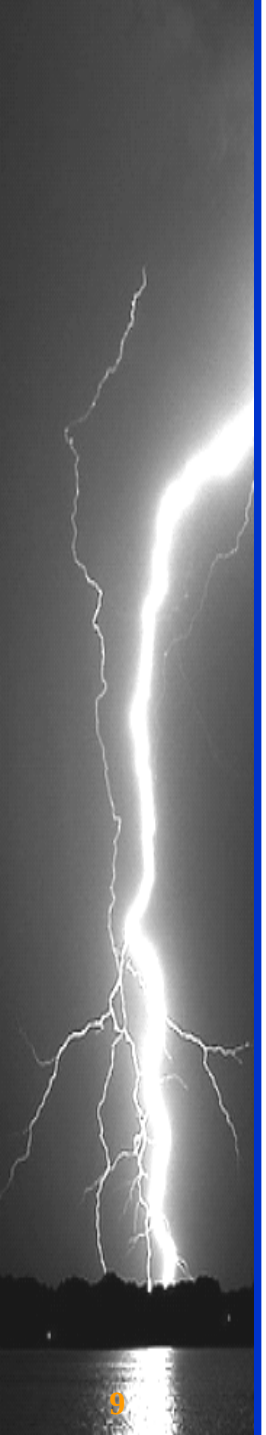
Without Al mesh: 9 in. damage size, and punctured both skins

1-2 inch damage, mesh only –validated via TTU (NDI)



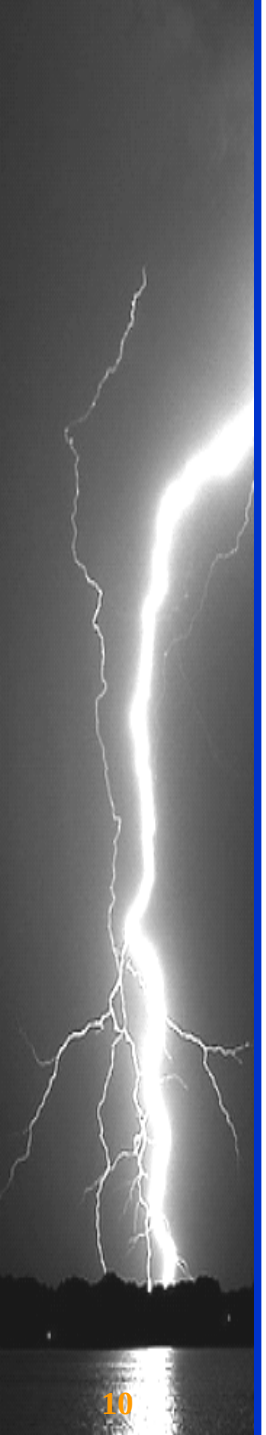
Damage area 12 inches, plus thru hole – Validated by TTU





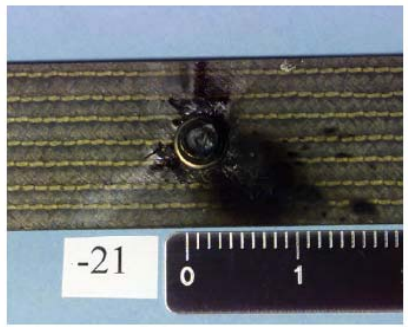
Proposed research

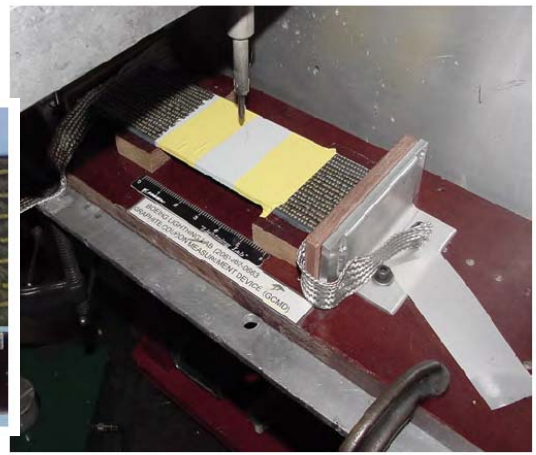
- *Current LS research almost exclusive domain of EE engineers*
- *Focus on:*
  - *Indirect effects*
  - *Sparking and fuel ignition*
  - *Systems/ certification of assemblies and components*
  - *Structures-focused work has been more superficial*

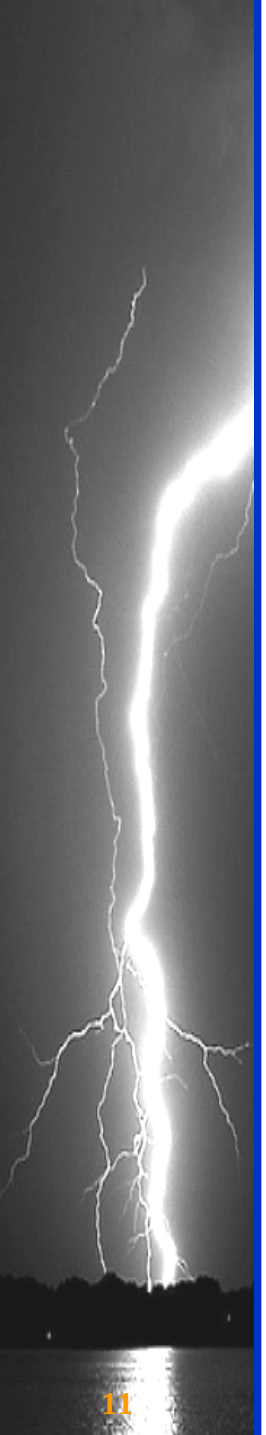


Proposed research

- *PI proposes to focus on structural aspects ONLY*
  - *Laminate carbon fiber laminates*
  - *Damage resistance (traditional and novel protection systems)*
  - *Damage tolerance (OHT/ OHC, and other residual strength)*
  - *Joint detail (effect of fastener preload, effect of fit, etc.)*
  - *Moisture and temperature effects*
  - *Different material forms (high vs. standard modulus fibers, toughening interlayer, cure temperature, stacking sequence issues)*
  - *Repair issues*







Proposed research

- *Medium size 100 kAmps, 40 kV generator that can test small test articles (up to 12 in x 12 in)*
- *Building block: certify by analysis supported by test evidence*
  - *Improve the foundations of the pyramid (basic level) in order to facilitate transition to different material forms*
  - *Standardize analysis tools to streamline certification process*

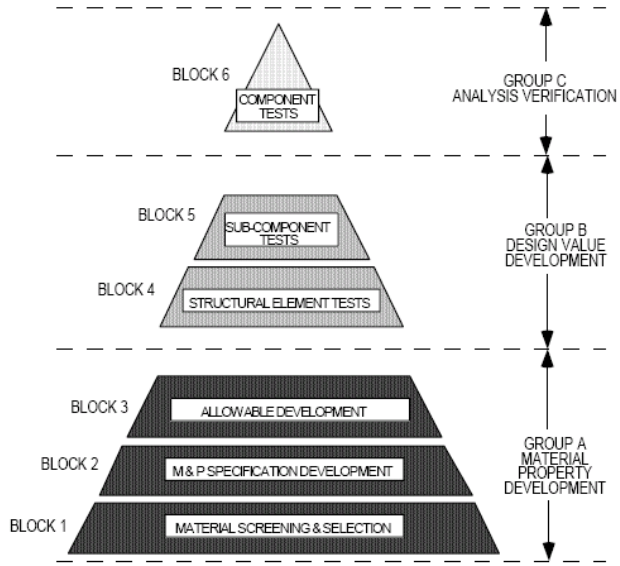
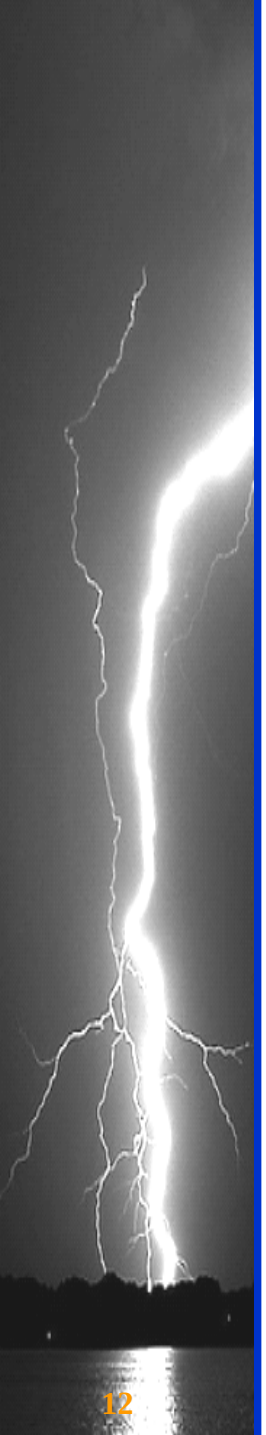
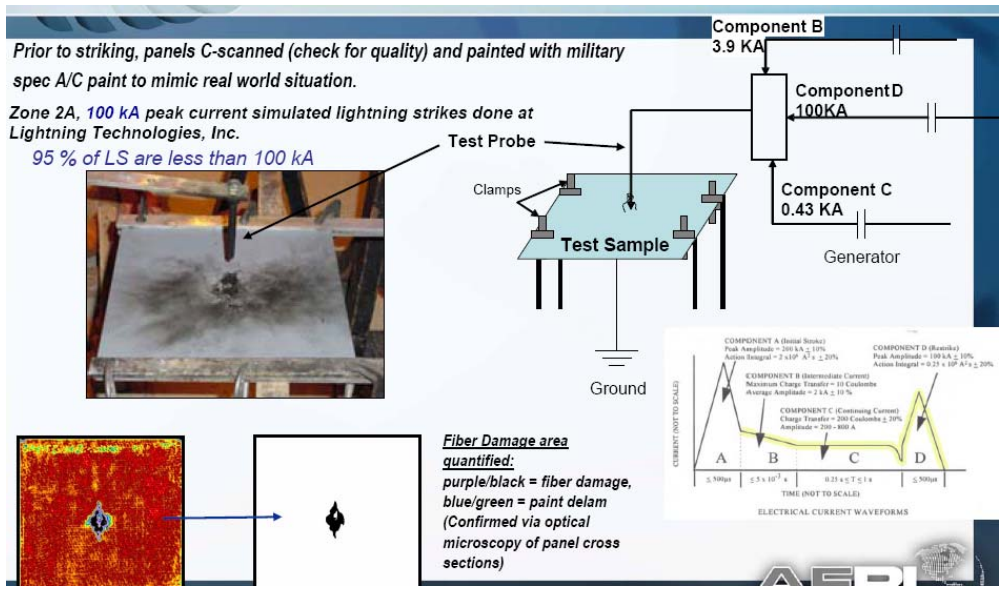


FIGURE 4.4.3.2 *Building block approach.*



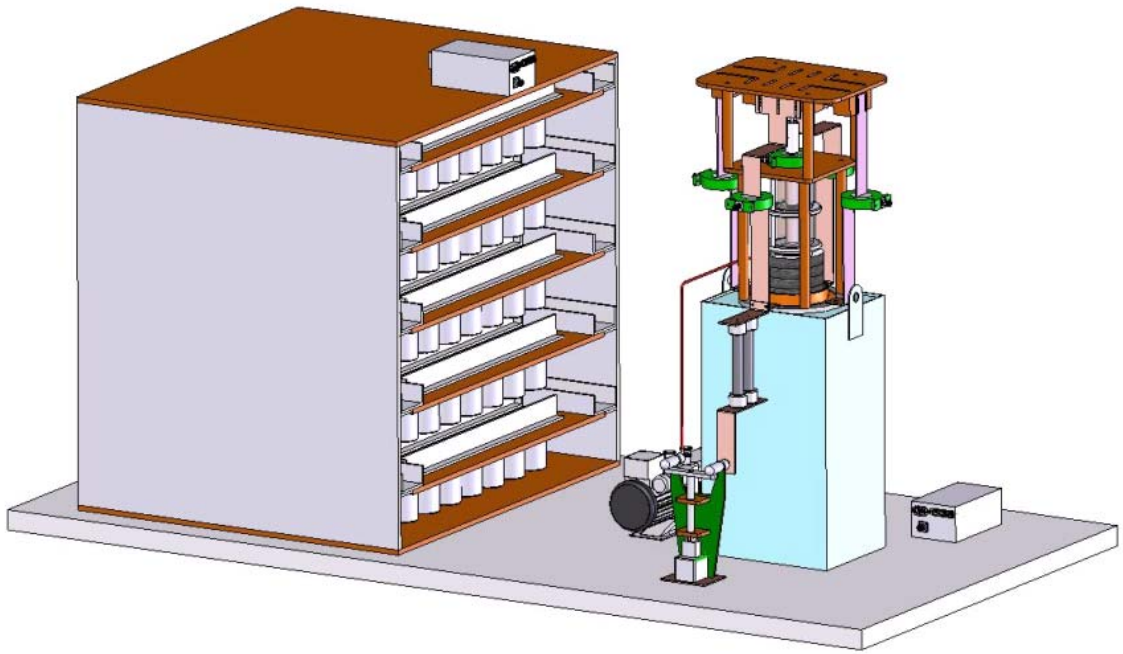
Inter-agency collaboration

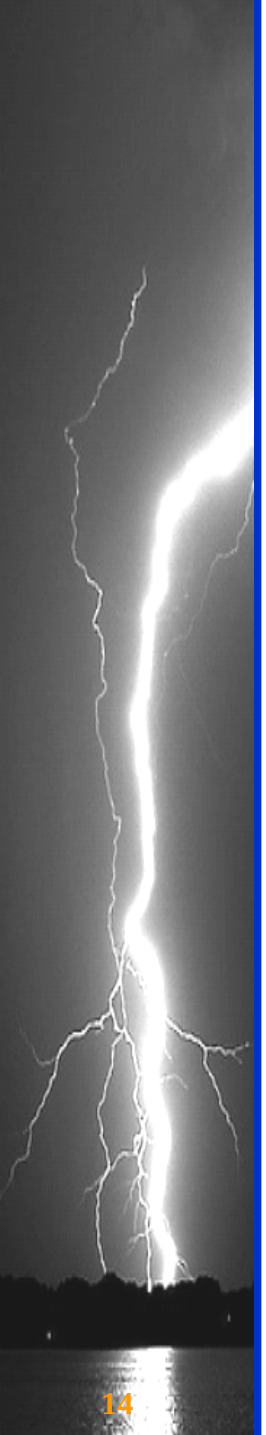
- *Air Force:*
  - *Les Lee of AFOSR and Tia Benson-Tolle of AFRL/WPAFB are currently involved in lightning activities*
  - *They use LTI test house facilities*
  - *Emphasis in multifunctional materials and structures, and nano-composite additives for improved conductivity*
- *Recent CMH-17 activities suggest expansion of participation of AFRL to safety and certification activities*



Status of research at UW

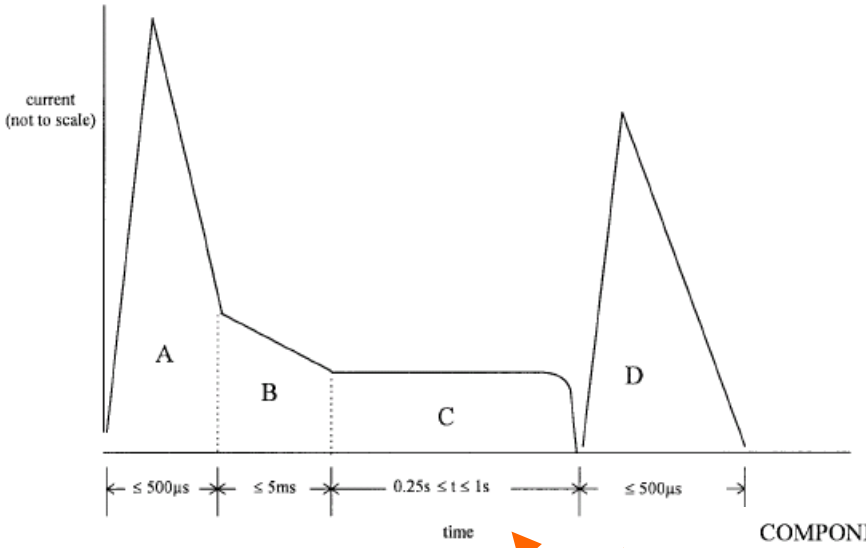
- *LS generator being built*
- *Boeing EME lab has provided guidance on lay-out and safety of circuit*





Status of research at UW

- *Waveform D demonstrated*
- *Waveform C will be online by April 2008*



COMPONENT A (First Return Stroke)

Peak Amplitude	:	200kA (± 10%)
Action Integral	:	2 x $10^6 A^2 s$ (± 20%) (in 500µs)
Time Duration	:	≤ 500µs

COMPONENT B (Intermediate Current)

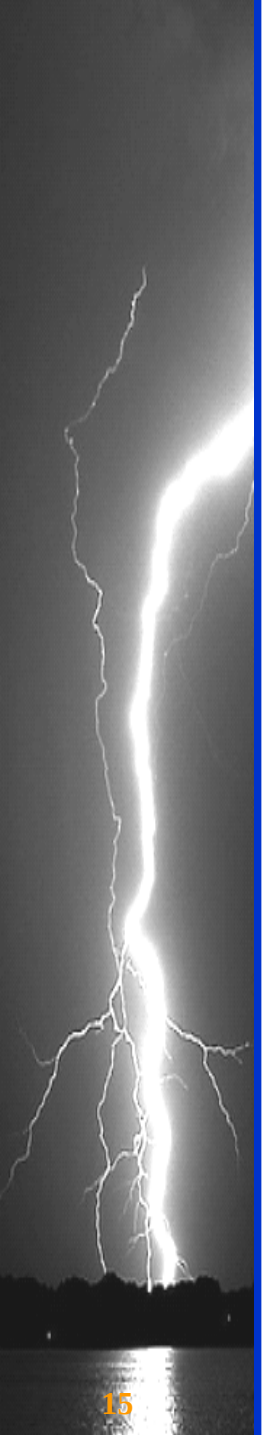
Max. Charge Transfer	:	10 Coulombs (± 10%)
Average Amplitude	:	2kA (± 20%)
Time Duration	:	≤ 5ms

COMPONENT C (Continuing Current)

Amplitude	:	200 - 800A
Charge Transfer	:	200 Coulombs (± 20%)
Time Duration	:	0.25 to 1 s

COMPONENT D (Subsequent Return Stroke)

Peak Amplitude	:	100kA (± 10%)
Action Integral	:	0.25 x $10^6 A^2 s$ (± 20%) (in 500µs)
Time Duration	:	≤ 500µs



Acknowledgments

- *The Boeing Co.*
  - *Dale Winter, Diane Heidlebaugh, Rob Steinle, and Art Day*
  - *Patrick Stickler, Al Miller*

- *UW principal researcher*
  - *Mark Miller, MS student*

- *UW support group*
  - *Dave Medendorp, Sr. student*
  - *Andrew Southworth, Sr. student*
  - *Robert Gordon, engineer*
  - *Art Blair, engineer*