Structural Health Monitoring – Mechanical and impact damage detection via fluorescent coatings

OBJECTIVE:

Improve inspection capability by developing a fluorescent coating to visually detect impact events and mechanical damage.

PARTNERS:

Flinn & Jen Research Groups, UW MSE
The Boeing Company

Contact:
Dr. Brian Flinn
bflinn@uw.edu | 206.280.8483

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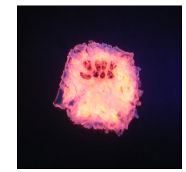
RESULTS:

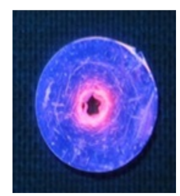
Aerospace-compatible fluorescent coatings activated by mechanical force

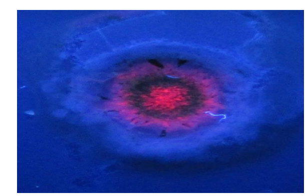
Force→



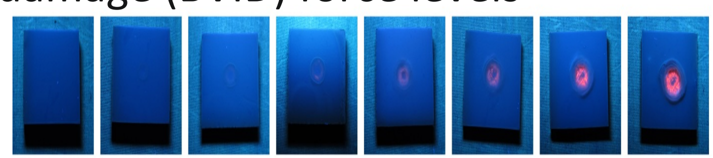
OFF ON

Coatings are activated by compression, indentation, impact events





Consistent with barely visible impact damage (BVID) force levels



Increasing impact energy→

Experimental and Numerical Study on Low-Velocity Impact on Composite Laminate Structures

OBJECTIVE:

Develop numerical models to predict low velocity impact of composite laminate structures

- Impact response & damage
- Compressive strength after impact

PARTNERS:

Boeing Company, Research and Technology, Seattle & St. Louis

Contact:

Solver I Thorsson (PhD Candidate)

solitor@uw.edu | 734.604.3843

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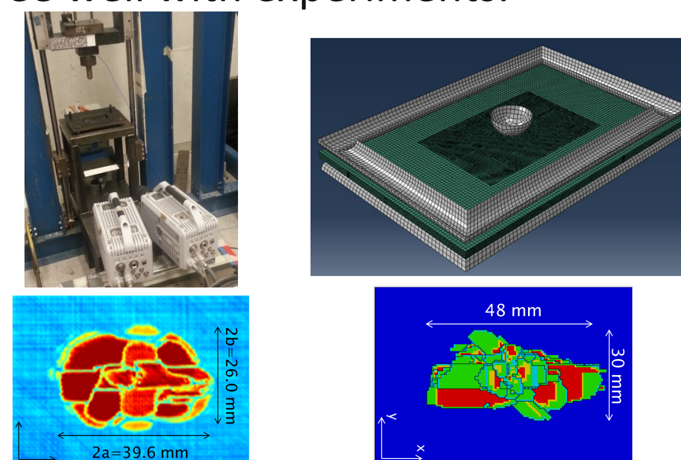
RESULTS:

Low-velocity impact experiments were done with face-on and edge-on impact. Finite elements models using Enhanced Schapery Theory (EST) and Discrete Cohesive Zone Method (DCZM) elements for in-plane and out-of-plane damage and failure, respectfully. Results agree well with experiments.



Face-on impact, experiments (left) and simulations (right)

Structural Health Monitoring – Thermal monitoring & damage detection via fluorescent coatings

OBJECTIVE:

Improve inspection capability by developing a fluorescent coating to quantify thermal exposures and identify damaged areas.

PARTNERS:

Flinn & Jen Research Groups, UW MSE

The Boeing Company

Contact:

Dr. Brian Flinn

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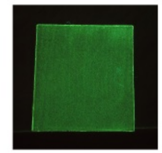
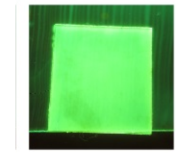
RESULTS:

Fluorescent coatings activated by thermal exposure developed



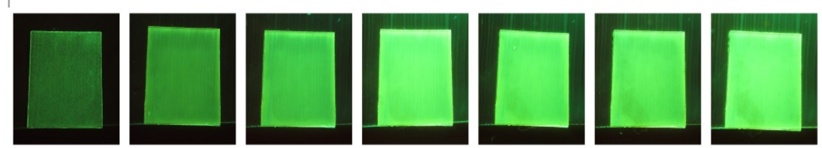
Heat→



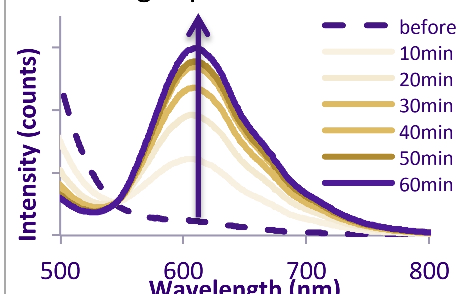
OFF ON

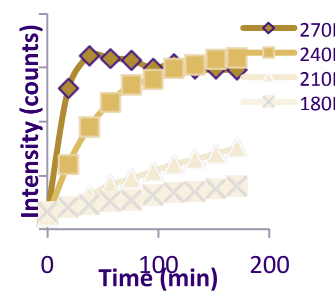
Wide temp range (175-450F)

Capable of quantifying exposure times



Increasing exposure time→



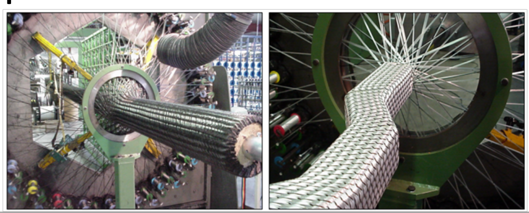


Applications: fire/ exhaust/ lightning damage, repair/cure monitoring

Braid Your Airplane: Rapid Manufacturing and Insertion of Composites in Flying Vehicles

OBJECTIVE:

Develop braided large scale unitized primary structures for air & space vehicles



PARTNERS:

National Aeronautics and Space Administration
University of Michigan

Contact:

Dr. Anthony Waas or Cyrus Kosztowny

awaas@uw.edu | 206.221.2569

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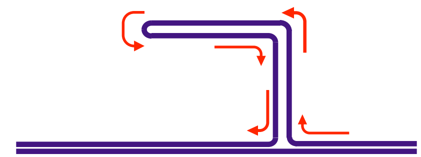
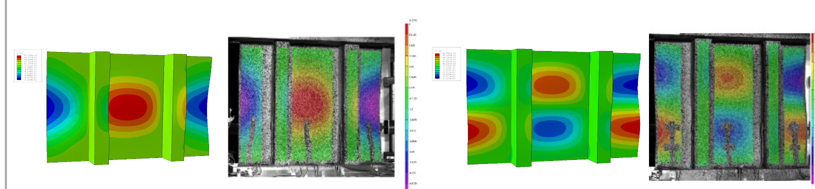
RESULTS:

- Manufactured from constituent materials in one piece



- Minimal post-manufacturing processing
- Out of autoclave capable
- Unitized stiffened panel unable to delaminate under compressive loads
- Best void volume fractions in the industry at $V_{vf} < 1\%$



Design and fabrication of self-sensing composites with embedded nanofibers

OBJECTIVE:

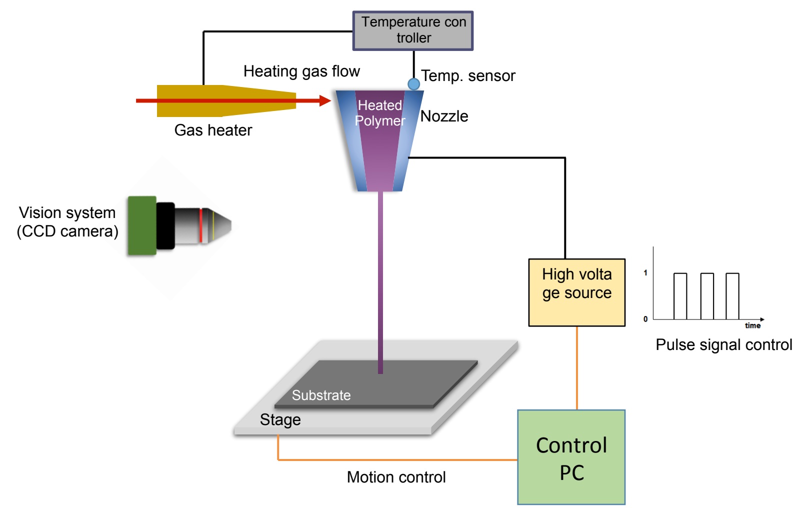
Use direct-printing technique to develop self-sensing composites with embedded multifunctional nanofiber network

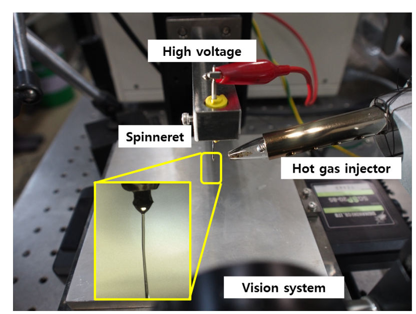
PARTNER:

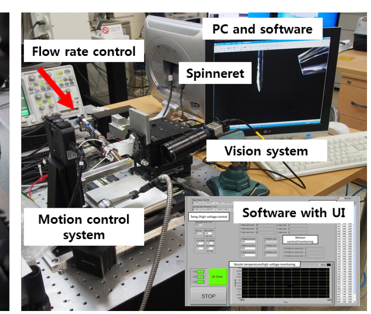
Samsung Research America

SAMSUNG

RESULTS:







Contact:

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Acoustic emission beamforming for detecting and characterizing damage in composite materials

OBJECTIVE:

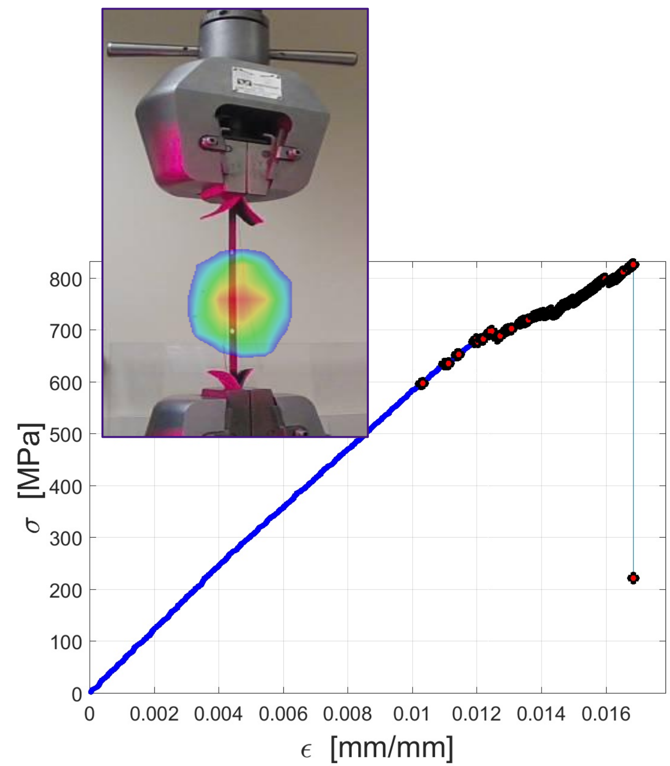
Develop a non-invasive, non-contact method for real-time monitoring of composite materials for detecting and localizing damage

PARTNERS:

SMI, Inc.

Toray for material support

RESULTS:



- Capable of detecting early failure of composites in real time

Contact:

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Identification of weak bond damage in composites using acoustic solitons

OBJECTIVE:

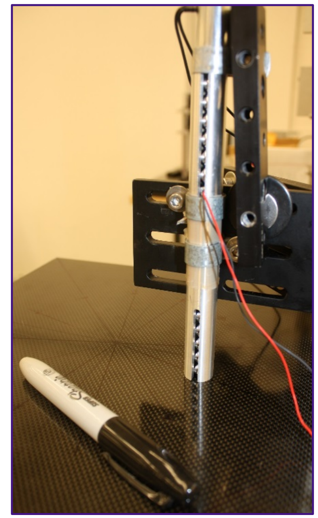
To detect the presence of weak bond in composites in two steps:

- Introduce delamination in weakly bonded composites using solitons
- Study the reflected solitons' characteristics for identifying debond

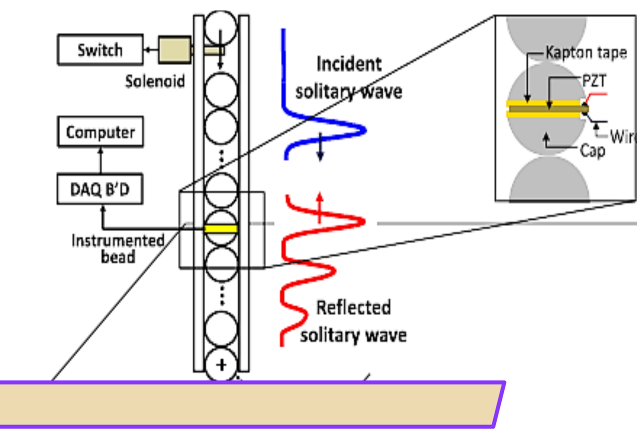
PARTNERS:

JCATI

RESULTS:



The soliton-based diagnostic technique shows promising results in terms detecting weak bonds.



Contact:

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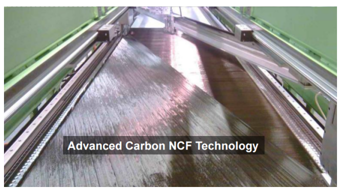
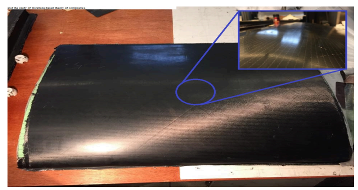
Application of shallow-angle, thin-ply laminates to composite wings

OBJECTIVE:

Investigate the effect of shallow-angle, thin-ply laminates on the structural performance of wings





PARTNERS:

Stanford University
Chomarat
JCATI

Contact:

Dr. Jinkyu "JK" Yang
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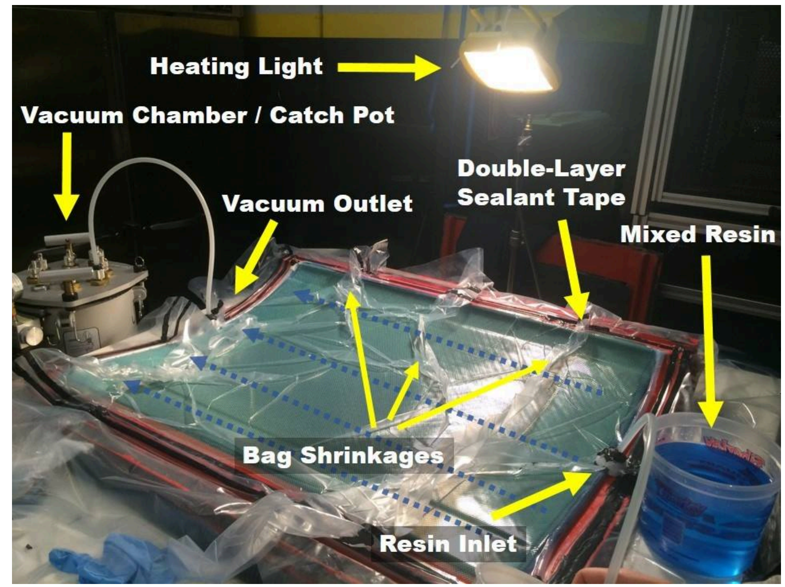
RESULTS:



64% improvement in bending stiffness-to-weight when using shallow-angle, thin-ply laminates compared to regular laminates.

Designing material properties via microstructure

OBJECTIVE:

Understand relationship between material microstructure and highly nonlinear material properties

Applications: shock mitigation, low-density materials, acoustics/structural vibration

PARTNERS:

Related wave propagation in designed materials projects (ARO/NSF):

Contact:

Dr. Nicholas Boechler

boechler@uw.edu | 206.221.6515

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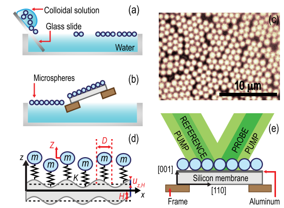
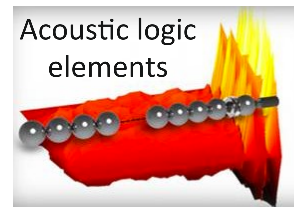
Self-assembled metamaterials

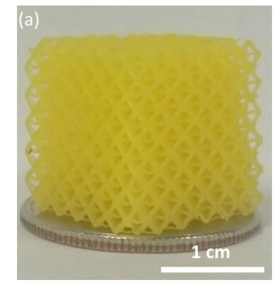


A. Khanolkar,..., N. Boechler, Appl. Phys. Lett. 107, 071903 (2015)

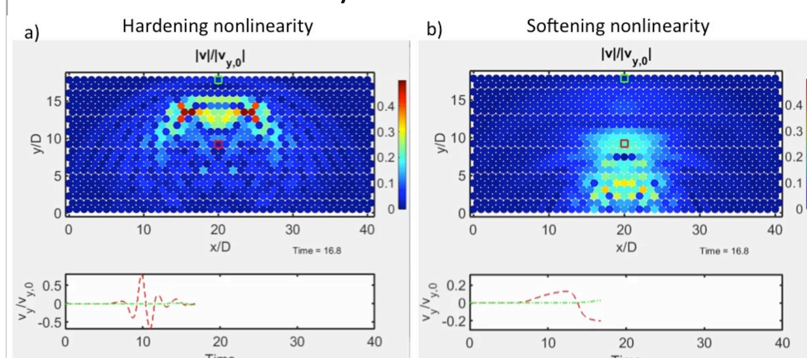


N. Boechler *et al*, Nature Materials 10, 665 (2011)

Leverage wave tailoring expertise in flexible AM-enabled material toolbox



Self-energy localization/delocalization via tailored material nonlinearity:



Web: http://faculty.washington.edu/boechler/

Crashworthiness Analysis of Textile Composites

OBJECTIVE:

1) to formulate ***multiscale models*** for effective crashworthiness ***design of textile composite structures***;
2) to develop ***new experiments*** for material characterization and ***scaling from lab to structure***

PARTNERS:

Dept. of Energy, GM, Ford, Chrysler

Contact:
Dr. Marco Salviato
salviato@uw.edu | 206.543.2170

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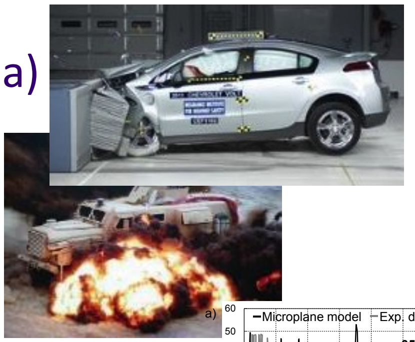
RESULTS:

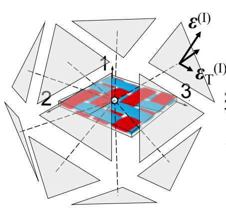
1) Effective ***multiscale model*** based on ***microplane decomposition*** (b) with excellent agreement with experimental data (d);
2) ***mesostructural optimization*** enabled by the proposed multiscale framework

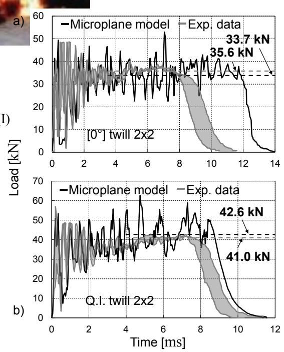
(a)

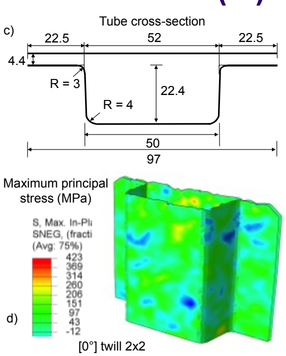


(c)

(d)







(b)

Durability of Textile Composite Structures: Experimental and Computational Analysis

OBJECTIVE:

1) To provide ***experimental and computational tools*** to asses the **durability of large textile** (2D and 3D) composite **structures;** 2) To provide tools for **mesostructural optimization for *durability***;

PARTNERS:

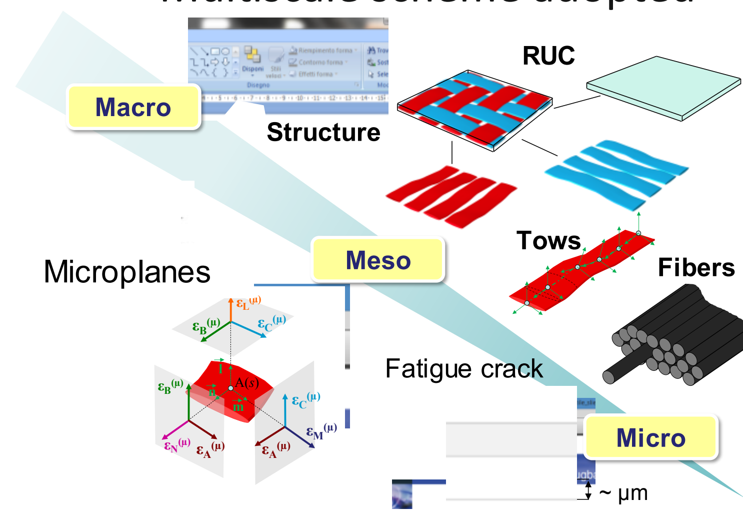
NSF (pending), Albany Composites

RESULTS (ongoing):

1) A general computational framework is under development to account for (a) ***fatigue***, (b) ***matrix degradation***, (c) ***randomness*** of material properties*;*

2) A new set of experimental protocols is under study to characterize ***material degradation from lab to large structures***

Multiscale scheme adopted



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Nanocomposites for Large Lightweight Structures: Experiments and Modeling

OBJECTIVE:

1) To develop ***new nanocomposites*** with ***enhanced quasi-static and fatigue behavior***;
2) To formulate models for **material and structural optimization**

CCAM-Lin

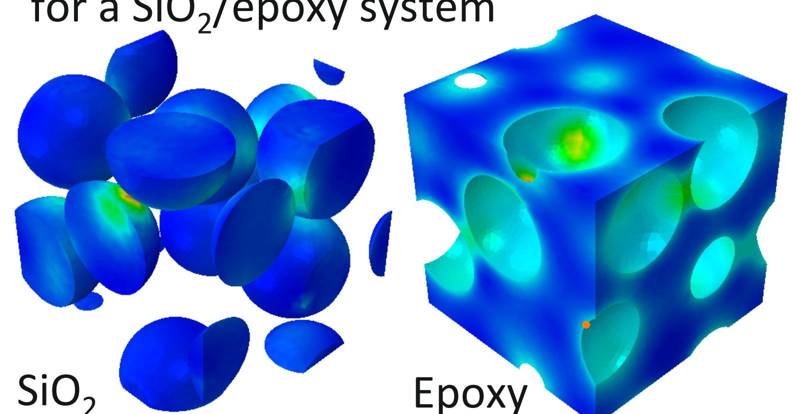
PARTNERS:

Royalty Research Funds (pending)

RESULTS (ongoing):

1) ***Strength*** and ***fatigue threshold enhanced by more than 50%*** compared to epoxy specimens;
2) Ongoing work focuses on translating these results to 3D textile composites;
3) a ***multiscale modeling*** framework is under development to describe ***fatigue damage***

Predicted fatigue damage at RVE level for a SiO_2/epoxy system



Contact:
Dr. Marco Salviato
salviato@uw.edu | 206.543.2170
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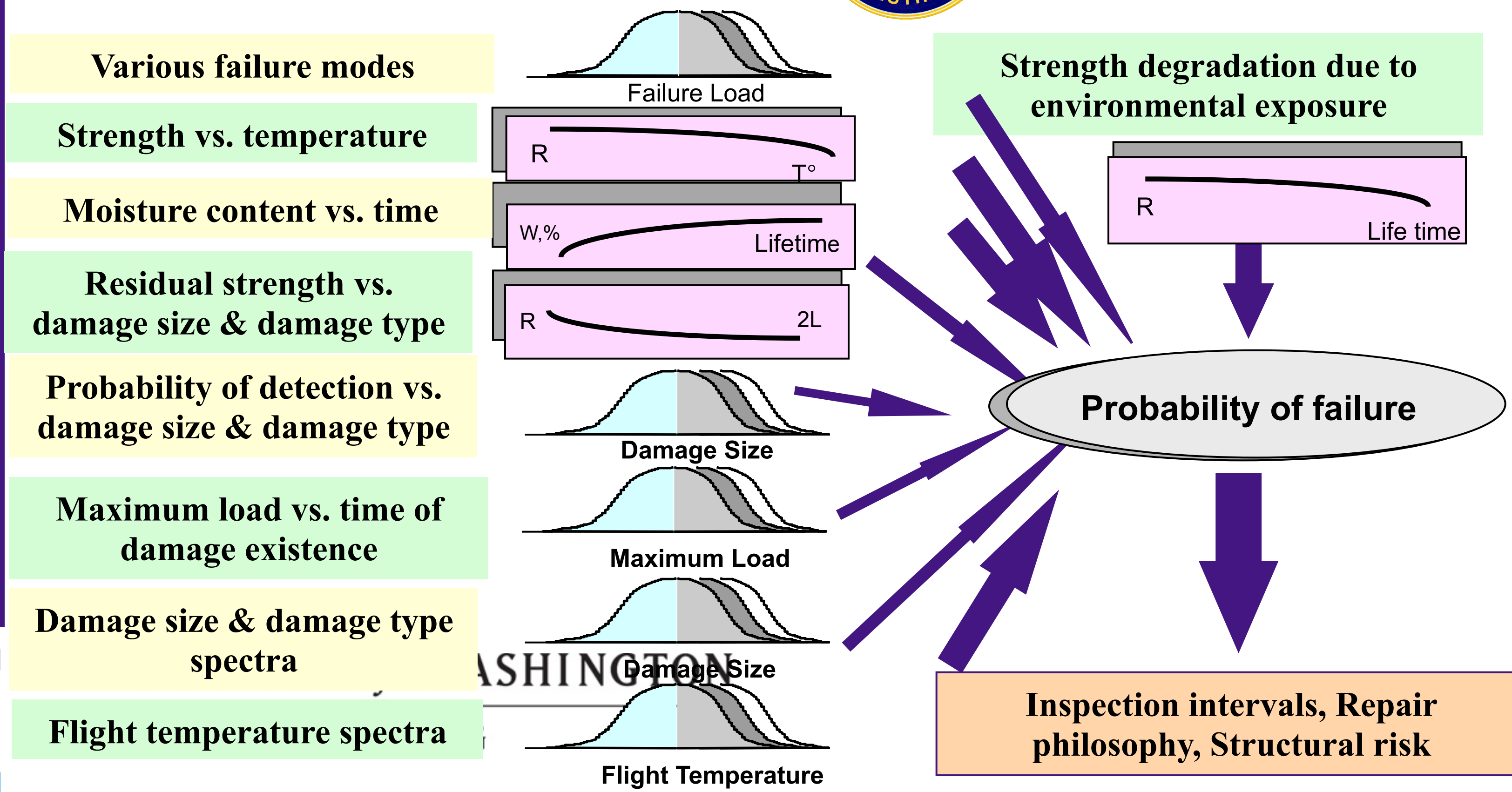
Reliability-Based Damage Tolerant Structural Design

Contact: Prof. Kuen Lin
lin@aa.Washington.edu

Objective: Develop probabilistic methods for evaluating structural component reliabilities suitable for aircraft design, inspection, and regulatory compliance

Sponsors: BOEING, FEDERAL AVIATION ADMINISTRATION



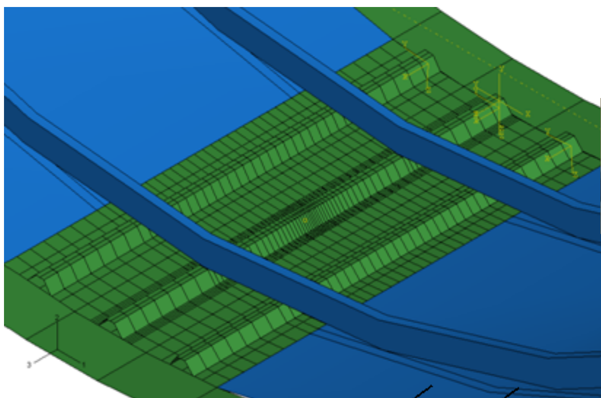
W CCAM

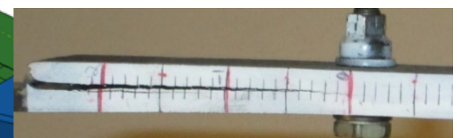
Delamination Arrest Features in Bonded Structures

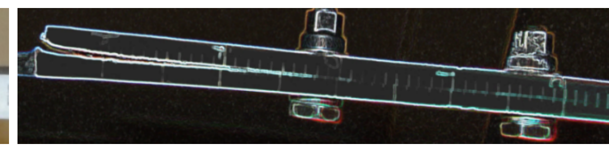
Contact: Prof. Kuen Lin
lin@aa.Washington.edu

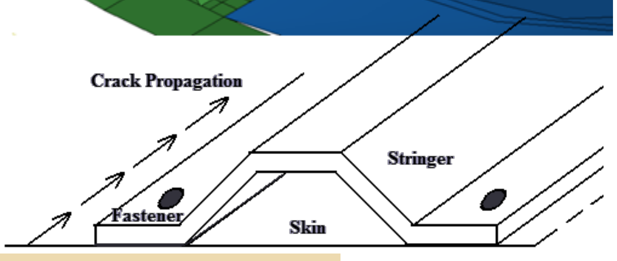
Objective: To analytically predict crack arrest capability in bonded-bolted composite structures and to verify analysis by experiments

Sponsors:

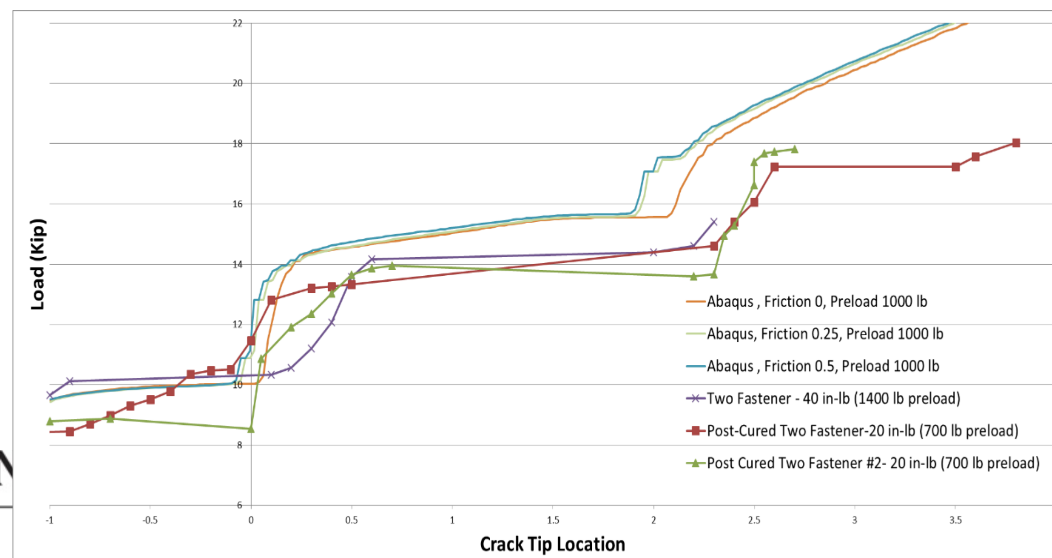








Crack propagation



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Enhanced Schapery Theory for Progressive Failure Analysis and High Fidelity Testing for Validation

OBJECTIVE:

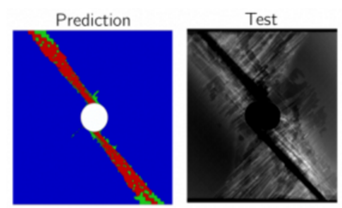
Develop and validate high fidelity, computationally efficient models for the progressive failure analysis of polymer matrix composites and make virtual testing possible.

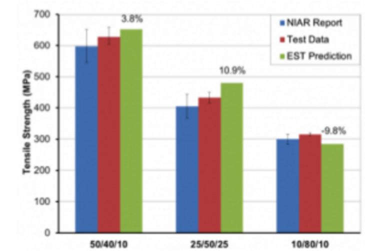
PARTNERS:

Boeing Research & Technology

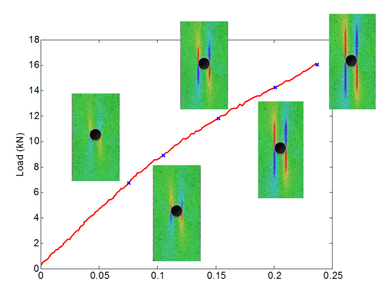
RESULTS:

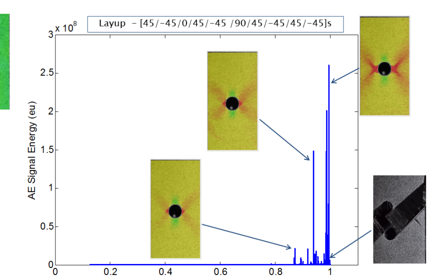
- Mesh objective predictions
- Unified approach for modeling in-plane and flexural problems
- Excellent agreement with experiments





- Digitial Image Correlation and Acoustic Emission measurements





Contact:
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awaas@uw.edu | 206-221-2569
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Development of New Material Systems for Binder Jetting AM (Powder Bed Printing)

OBJECTIVE:

To developed new powdered material systems for Binder Jet AM such as ceramics, glasses, bio-printable, cements, etc.

PARTNERS:

University of Washington (Solheim Additive Manufacturing Lab), Open3DP, Seattle Pottery, Olympic Color Rod

Contact:

Dr. M. Ganter / D. Storti

ganter@uw.edu / stori@uw.edu

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RESULTS:

To date: we have successfully tested and released more than 20 different materials systems for Powder Bed Printing.

Development of Vat Photo-Polymerization Systems – devices & materials (DLP systems)

OBJECTIVE:

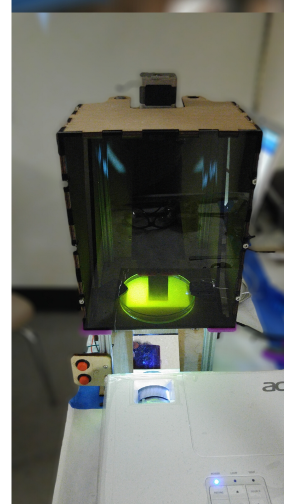
To aid in the development and adoption of vat photo-polymerization systems and materials.

PARTNERS:

University of Washington, LittleRP, LLC

RESULTS:

Autumn 2015 ME480 class fabricated, tested and printed with 10 new systems.



Tested several new photopolymers for photoelastic engineering uses.

Contact:
Dr. D. Storti / M. Ganter
stori@uw.edu / ganter@uw.edu

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Development of Mechanochromic Materials for Multi-Material AM.

OBJECTIVE:

To deploy recently developed mechanochromic materials into the 3D Printing world via Filament Printing.

PARTNERS:

UW Chemistry Department,
Research Corporation for Science Advancement (RCSA)

Contact:
Dr. A.J. Boydston / D. Storti / M. Ganter
ajb1515@uw.edu / storti@uw.edu

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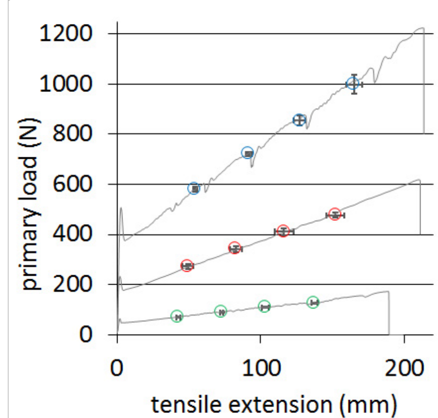
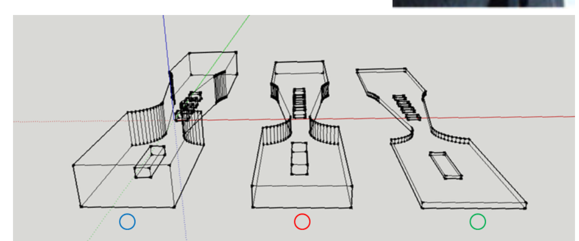
RESULTS:

New materials were successfully deployed in a multi-material AM system to create force sensors.





7 mm 4 mm 1 mm

Development of Multi-Material & Graded Property Materials via Vat Photo-Polymerization AM.

OBJECTIVE:

To modify existing Photo-polymerization system, models and materials to allow for the creation of multi-material and graded property materials.

PARTNERS:

UW Chemistry Department,
Research Corporation for Science Advancement (RCSA).

Contact:

Dr. A.J. Boydston / M. Ganter / D. Storti

ajb1515@uw.edu / ganter@uw.edu

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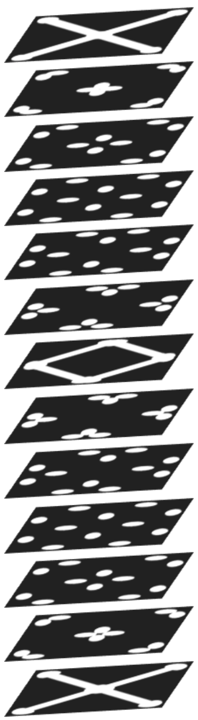
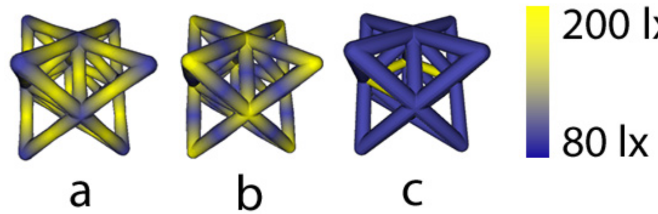
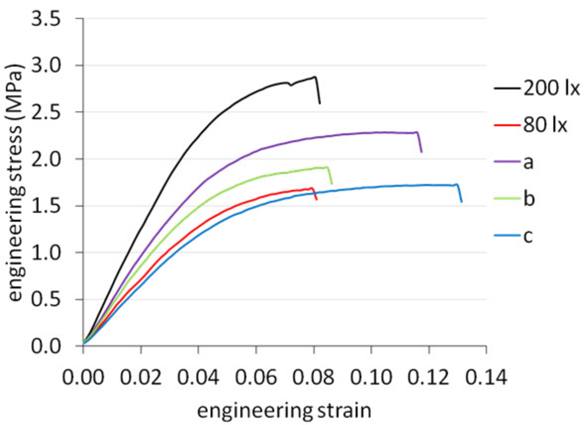
RESULTS:

Successfully demonstrated graded property objects using vat photo-polymerization AM via DLP.







Virtual manufacturing of advanced textile composite aerostructures

OBJECTIVE:

- To numerically study the effect of processing on strength/shape of cured composite aerostructures
- To identify key processing parameters that dictate performance

PARTNERS:

GE Global Research, GE Aviation, Air Force Research Lab

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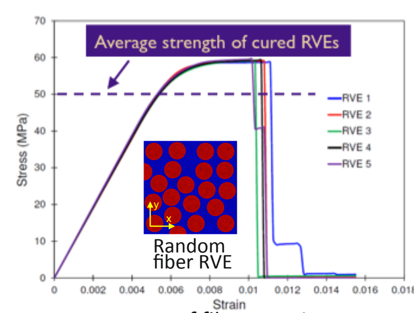
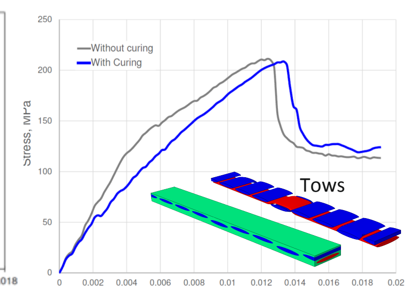
RESULTS:

- Processing induces residual stresses in the cured structure
- If stresses during curing exceed a certain limit, microcracks can form in the matrix → which can lead to reduction in stiffness and strength
- Simulations are performed with Epon 862 data on curing (i) at microscale for unidirectional laminates (ii) for textile composites such as satin weave



Response of fiber-matrix RVE under transverse tension - with and without effect of processing



Response of 8-harness satin weave strip under transverse tension - with and without effect of processing

Certification of Discontinuous Fiber Composites in Aircraft Structures: Stiffness and Strength Predictions

OBJECTIVE:

Develop statistical methods to predict stiffness & strength of chopped fiber composites such as HexMC™, leading to certification based on analysis w/modest experimental database

PARTNERS:

Ctr for Adv Materials in Transport Aircraft Structures (AMTAS), The Boeing Company, and Hexcel

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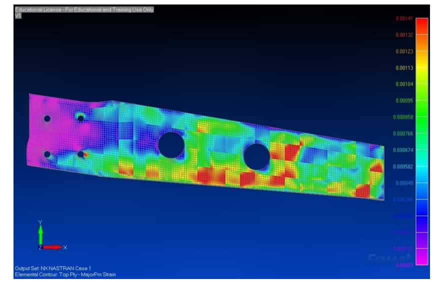
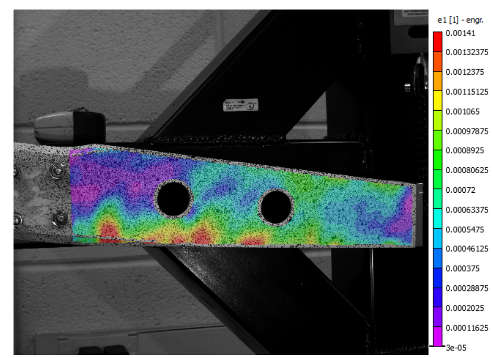
RESULTS:



Predicted



Measured

Contour Plots of Major Principal Strain in a HexMC Intercostal

Effects of Moisture Diffusion in Sandwich Composites

OBJECTIVE:

Evaluate the impact of moisture and thermal cycling (room temps to -55ºF) over long times on stiffness and fracture toughness of honeycomb core sandwich composite structures

PARTNERS:

Ctr for Adv Matl's in Trans Aircraft Str (AMTAS), Boeing , Bell Helicopters, 3M Company

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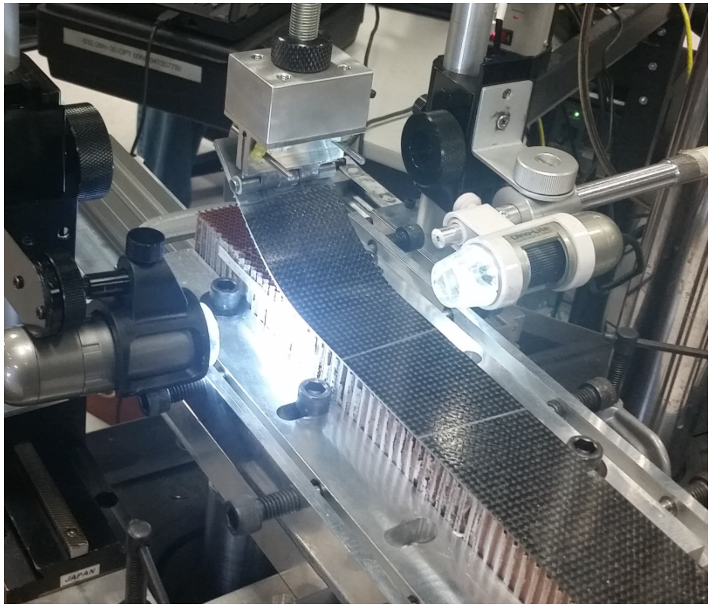
RESULTS:



Single Cantilever Beam (SCB) sandwich specimen used to measure Mode I Fracture Toughness