

Composite Aircraft Vulnerability Testing and Modeling

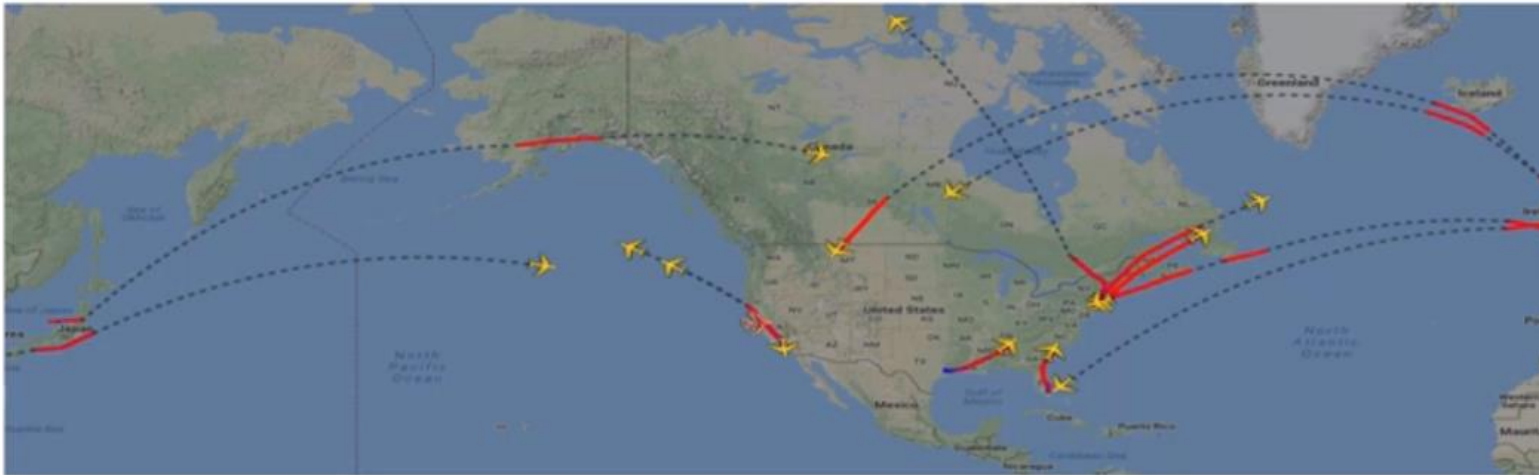
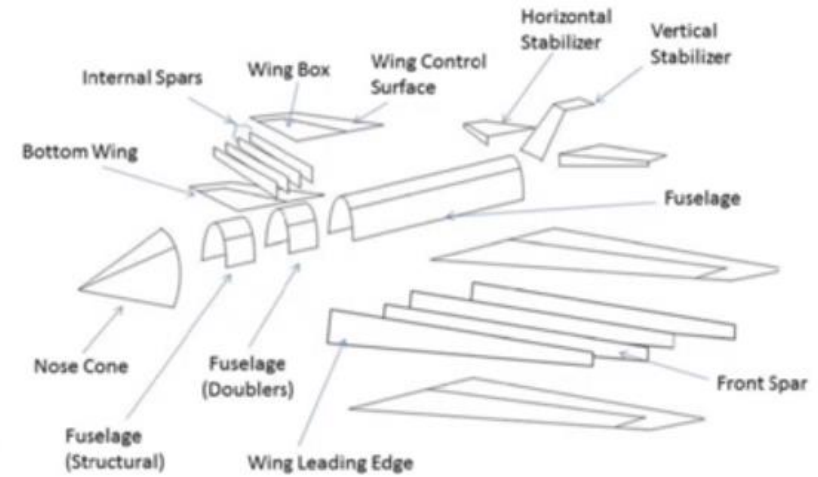
COE CST Tenth Annual Technical Meeting

Ryan Schnalzer

October 30, 2020

Agenda

- Team Members
- Task Description
- Schedule
- Goals
- Results
- Conclusions and Future Work



Team Members

- Team Members

- Ryan Schnalzer (PI)

- MS Civil Engineering, University of New Mexico
 - 10 yrs experience in Risk Engineering, Data Analysis, Hazard Analysis, Human & Structural Vulnerability

- George Lloyd, Ph.D

- B.S Petroleum Eng., M.S./Ph.D Mech Eng.
 - Research Scientist, specialty in Fast Running Model (FRM) development using Neural Networks
 - Modeling and risk assessment expertise spanning petroleum industry, civil infrastructure, DOD vulnerability & lethality, and space systems

- Industry and Research Partners

- Joseph Magallanes, P.E., S.E. of Karagozian and Case (K&C)

- Testing Laboratory
 - Glendale, CA

- La Cienega Manufacturing

- Machining for tests
 - Redondo Beach, CA

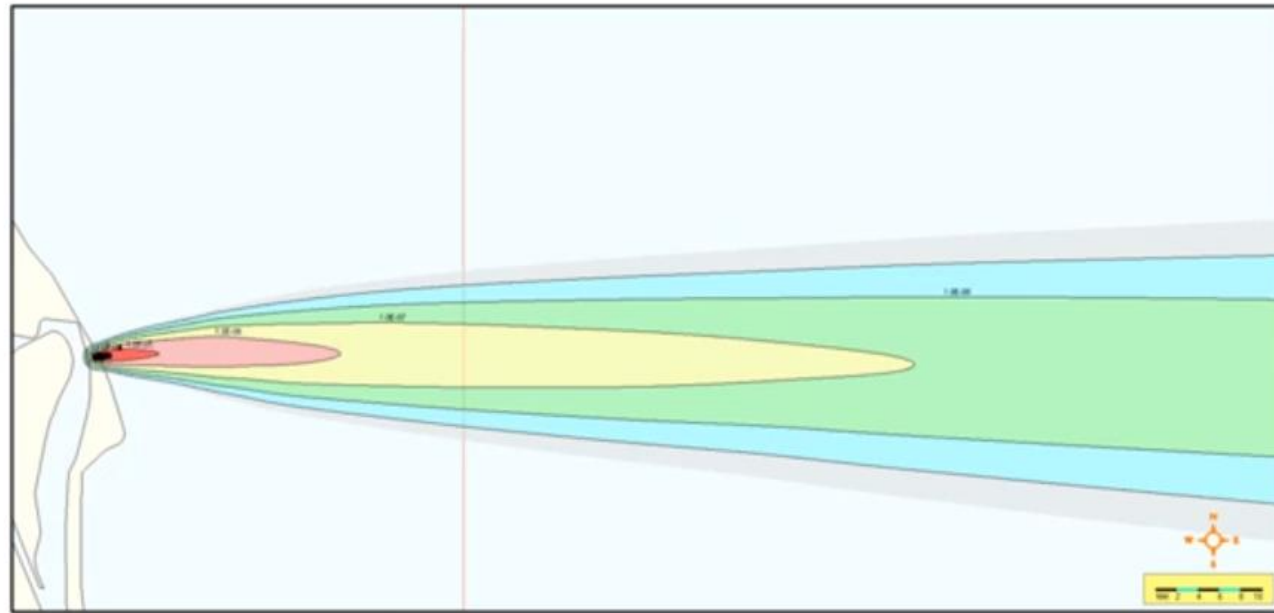
ARCTOS



**La Cienega
Manufacturing**

Task Description-Background

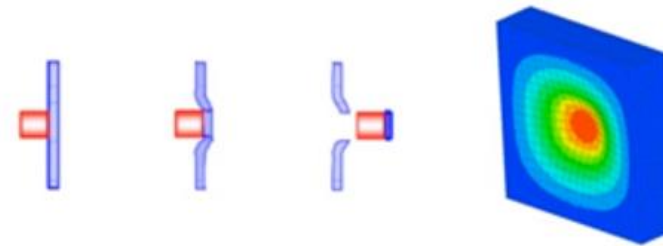
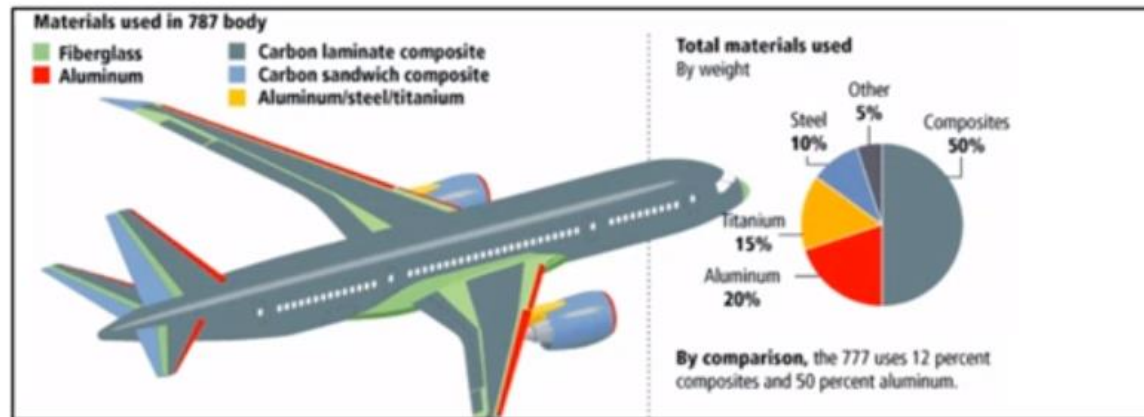
- Risk analysis programs, such as the Range Risk Analysis Tool (RRAT) provide estimates of risk posed to the public from debris from planned and malfunction rocket launches
- Risk calculations to aircraft from falling debris rely on vulnerability models



Hazard contour due to falling debris

Task Description

- Aircraft vulnerability models have been created for traditional, aluminum-based materials, but new models are needed to properly assess risk for newer, composite-based aircraft
- New composite vulnerability modeling needs to account for:
 - Different modeling geometries (Aircraft Modeling)
 - Different consequential events (Event Tree)
 - Different penetration modeling (Composite Penetration Modeling)



Shear plugging of aluminum and preliminary finite element model of a thick aluminum plate

Schedule

- Period of Performance: September 2019 – September 2021
 - Testing dictates schedule
 - External review on final model will occur beginning in July 2021

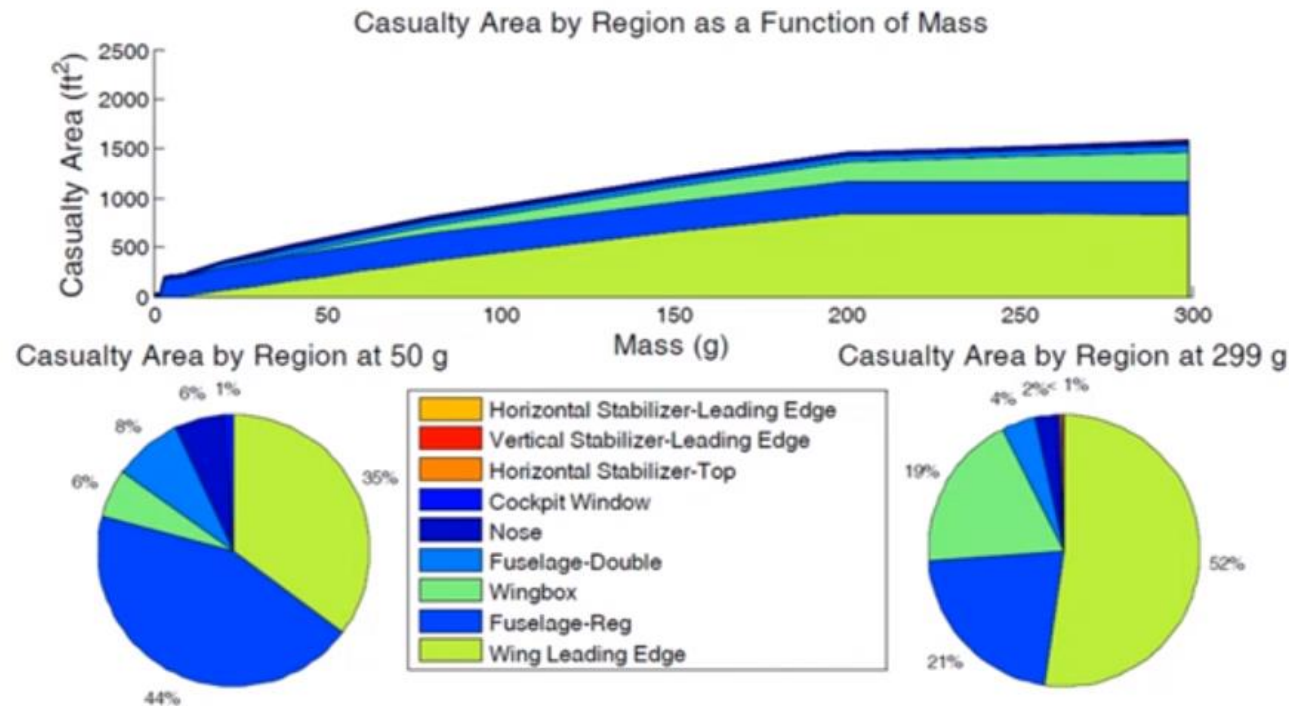
Work Area	2019				2020												2021										
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S		
Composite Aircraft Modeling	█	█	█	█	█	█	█	█	█	█	█																
Event Tree Development					█	█	█	█	█	█	█	█															
Test Preparation	█	█	█	█	█	█	█	█	█	█	█	█	█														
Composite Testing																█	█										
Test Analysis																	█	█	█								
Penetration Model Development	█	█	█														█	█	█	█	█						
Vulnerability Model Development													█	█	█						█	█	█	█	█		

Goals

- Develop a reviewed vulnerability model for composite aircraft
- Determine whether composite-based aircraft are more or less vulnerable to falling debris than traditional aluminum-based aircraft in terms of both casualty and catastrophe measures
 - Dependency on aircraft geometries (especially thickness)
 - Dependency on events resulting from impacts
 - Dependency on penetrability
- Provide clear comparison between penetrability of aluminum versus applicable composites via testing
- Improve upon a novel approach for penetration modeling using quasi-static (low strain-rate) testing and split Hopkinson pressure bar (higher strain rate) testing to understand dynamic effects on penetration

Results

- Results are still in development as testing is scheduled for November 2020
- Final vulnerability results will be provided in format analogous to prior work (vulnerability area as a function of debris mass)



Conclusions and Future Work

- The resulting vulnerability model will demonstrate if composite-based aircraft are more vulnerable than aluminum-based commercial transport aircraft
 - If more vulnerable, the vulnerability models will be recommended in place of older models to provide a conservative estimate of risk, which is bounded by criteria per RCC 321; More interaction should be sought within safety community to ensure increase in risk estimates are justified
 - If less vulnerable, updates should be made to existing vulnerability models to account for composites where applicable to reduce risk estimates
- Many complexities exist within this work ranging from proper aircraft representation, consequence modeling, and penetrability modeling; assumptions exist to bound the problem where useful
- A scientific journal paper will be created to disseminate findings and inform the community of the novel penetration test approach