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ADVANCED MATERIALS IN  
TRANSPORT AIRCRAFT STRUCTURES

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NATIONAL INSTITUTE FOR  
AVIATION RESEARCH

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CECAM featured project

## "Crashworthiness of Composites – Material Dynamic Properties"

### Principal Investigator(s):

Dr. K.S. Raju, *Department of Aerospace Engineering, Wichita State University*

Dr. H. Lankarani, *Department of Mechanical Engineering, Wichita State University*

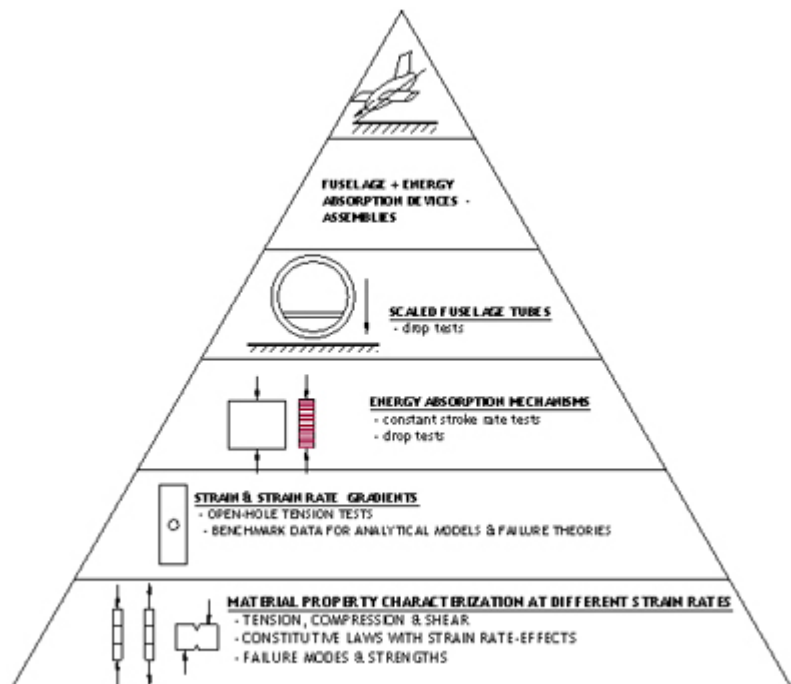
### Overview:

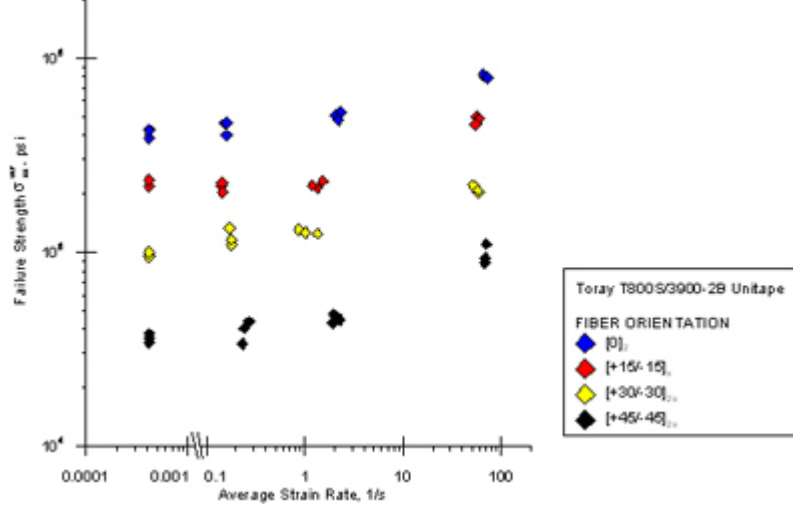
The use of composite materials for airframe structural applications is widespread in commercial, business and general aviation industries. Some of the aircraft models that use composite materials for their primary structures include the Boeing 787 and Raytheon Horizon Hawker and Premier-I. Composites' tailorability, high strength-to-weight and stiffness-to-weight ratios, corrosion resistance and superior fatigue properties have made them appealing in for structural applications, and in particular in the development of new composite fuselages. The crashworthiness of metallic airframe structures has been widely investigated using experiments at coupon, sub-component and large-scale structural levels. Considerable documentation on the modeling of the metallic dynamic impact event exists in open literature. A limited number of dynamic and drop-tests performed on fully composite fuselage structures have indicated differences in the crush patterns/failure modes, stiffness and other structural properties, compared with the metallic

fuselage structures. The differences observed between the metallic and composite structures under dynamic loads have been attributed to the strain-rate sensitivity of composites. A good understanding of the strain-rate effects at the material level is necessary for facilitating a building-block approach for designing crashworthy airframe structures. The inclusion of dynamic material properties in the analysis of airframe structures under crash loads will decrease the amount of large-scale testing required to understand the behavior of such structures, which is expensive and time consuming.

### Objective:

A building block approach, as illustrated in figure below, has been embraced to study the rate effects on the behavior of composite airframe structures. The rate effects strain rate effects will be characterized at the fundamental ply level because for most numerical analysis, the material properties are specified at this level. The material testing at this level includes the characterization along the primary ply directions and off-axis specimen testing. The off-axis specimen tests are intended to simulate a combined stress state in the plies and not to characterize a material property. This combined stress state will be used for benchmarking material models in the future. The next level of testing will include cases where *strain* and *strain rate* gradients exist (e.g., open-hole tension), which will serve as benchmark data for the material failure models. Moving up the building blocks, small components and assembly of components will be characterized under dynamic loading, culminating in characterization of scaled aircraft structures, which would be the most expensive. The understanding of rate effects at the ply level will help identify whether the observed rate effects in structural components and their assemblies are due to geometric effects or material rate sensitivity.





**Above: Building block approach for studying strain rate effects and tensile strength of unitape material at different strain rates.**

### Expected Outcomes:

The testing of large articles for crashworthiness evaluation is expensive, making the use of numerical models desirable. The understanding of material behavior under high strain rates is crucial to the prediction capabilities of the numerical models. The present investigation will generate ply-level material properties under tension, compression and shear loading at different strain rates. The test data from off-axis coupon and simple component testing can be used for benchmarking material models used in the numerical analysis. The significance of material rate effects and geometric effects will become evident as the investigation proceeds up the building blocks.

### Next Featured Project:

"Thermal Modeling for Composite Airframe Structures"



NATIONAL INSTITUTE FOR AVIATION RESEARCH  
at Wichita State University

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