Dr. Xu, October 30, 2018

Thank you for submitting your proposal to AFOSR for consideration (proposal number 18RT1219).

I am providing the following information in response to your recent proposal to [redacted] Portfolio. This proposal was submitted as a follow-up proposal to the effort funded in FY18.

As part of review process, we work with world class technical experts to review proposed research. Although I cannot provide their names, here are their summarized comments regarding your recent proposal:

The first reviewer thought you should narrow the research topic. They were concerned the proposal did not address the experiments capabilities for measuring viscoelasticity material effects in addition to fiber distributions at relevant length scales.

*Rebuttal ---This is reviewer's wrong understanding---our proposal is focused on fast impact behavior, not slow viscoelasticity effect.----**Roy Xu 10/31/2018***

It is not clear if nano-indentation is sufficient enough to measure moduli at the scales identified. They also thought the proposal failed to effectively address how you would translate moduli knowledge to macroscale level impact simulations.

Rebuttal --the reviewer didn't understand our proposal ("not clear"). "translate moduli knowledge to macroscale level impact simulations" is clearly expressed in session 2.3 (equations 5-8 and their texts).

In addition, the reviewer commented it is unclear from the proposal how you will transition the Hertzian contact theory information into the larger macroscale impact. For example, are you transitioning the force, contact, moduli or merely parameterizing the contact stiffness which will be utilized in the macroscale simulation. If it is the contact stiffness, then the proposal did not explain the importance of this parameter nor any other parameter and how it will be used in the macroscale simulation.

Rebuttal ---Based on several expressions "unclear or not clear", definitely, this reviewer lacks the basic technical background to understand our proposal, especially he or she doesn't understand mechanics. The most important parameter is the contact stiffness, which is well explained in the proposal. Hertzian contact theory which connects force and deformation is applicable to both small Nano-indentation and macroscale impact, and we cited several papers and books in the proposal. Obviously, this reviewer never read these classical papers and books.

They felt that although performing classical impact tests are not difficult to perform, the ASTM 7136 standard is insufficient when considering a desirable damage state. Meaning: Researchers tend to use large impact energies which create large damage states. The capability to predict large damage states is not there. However, with proper guidance, a desirable damage state could be achieved such that the problem's complexity is reduced. Additionally, although predicting

force displacement curves are getting better, predicting damage initiation and growth is a challenging endeavor. Even though the proposed numerical approach could add value, how it will be utilized is still uncertain especially when trying to predict damage is critical.

Rebuttal --Our AFRL collaborator asked us to focus on small impact energy to deal with the most important "barely visible impact damage of composites". Obviously, these reviewers don't know AFRL's missions and needs---especially composite material applications in our topic. Our first-year progress shows we can successfully predict large damage states (870 mm^2 in table 1) and damage initiation, while this reviewer just ignored. We will use large energy level also (60 J in session 6.5), so the reviewer's statement "The capability to predict large damage states is not there" and large energy level have no technical justification. These statements only demonstrated the reviewer intentionally disparaged our proposal.

They do not believe that nano-indentation can replace any simple/complicated out-of-plane experiment and were unsure why you mentioned Numerical Simulations Track II (which they thought was undesirable).

Rebuttal --The reviewer distorted our proposal. We use both 1) nano-indentation and 2) computational mechanics to replace any simple/complicated out-of-plane experiment. But the reviewer only cited " nano-indentation". The Numerical Simulations Track II produces more accurate results to be compared with Track I, fast and efficient results. This reviewer doesn't understand simulation at all.

The second reviewer had the following summarized comments:

They thought the proposal seeks to address several key issues with the mechanics of impact, but that several claims and hypothesis in the proposal are not well supported.

The reviewer did not think the proposal clearly explains how the research will address the significant length and time scale challenges with the proposed approach. For example, the proposal argues that the through thickness bulk modulus can effectively be estimated from multiple repeated surface indentations on a composite panel. However, it is not clear how averaging over 100 indentations with a 16 micron affected area constitute a sufficient sample to estimate bulk properties.

Rebuttal --The reviewer cited a wrong concept because we measure the Young's modulus , NOT bulk modulus as the reviewer mentioned. The bulk modulus includes the Poisson's ratio and the Young's modulus, and it can be found from any undergraduate-level Mechanics of Material textbook (see attached textbook photo). This reviewer's mistake is he/she didn't understand the difference between the bulk modulus and the Young's modulus. Obviously, this reviewer never learned or completely forgot basic Mechanics of Materials, how can he/she understand our advanced impact mechanics and composite materials in the proposal? Two expressions of "not clear" were mentioned, which shows this reviewer does not understand our proposal at all. Another undergraduate-level mistake by the reviewer was another comment "16 micron affected area." Our expression in the proposal was 16 micron as the diameter (length not area), and any area should be expressed in terms of "micron^2". Within five lines, we found two basic

undergraduate-level mistakes from this reviewer, so he/she is still a world class technical expert?

The reviewer also questioned claims in section 2.3, that a composite with a 50% volume fracture has a 12.5 micro representative volume element without providing a definition of what is meant by representative volume element (RVE) or what specific properties this RVE entails. They commented that whenever an RVE is defined, it must be defined in terms of a specific property. For example, an RVE for the modulus is very different for an RVE for fracture toughness, for example. The reviewer thought it is not clear that an RVE on the scale of 12.5 microns would give an adequate representation of the stiffness. Instead the RVE for the elastic stiffness of the bulk composite would be at a minimum be on the order of multiple plies to account for the changing ply orientations on modulus.

Rebuttal --- Definition of the representative volume element (RVE) is seen in any Mechanics of Composite Material textbook. Our RVE is a square element with a circular fiber. We didn't explain our RVE since this is a very simple concept from any textbook—not for an advanced proposal. If the reviewer thinks our REV is not right, he/she should tell us a right RVE. The reviewer has a wrong statement of RVE in fracture toughness. I was the chair of ASME Fracture and Failure Mechanics Committee and I never heard about this RVE in fracture toughness. The reviewer also has another wrong statement of using RVE to account for the changing ply orientations on modulus. Ply orientations on modulus must be obtained sin lamination theory, not RVE. All my impression is he/she doesn't understand RVE.

The reviewer also questioned the use of variables in equations which were not defined. For example, what is the h with the double dot in equation 5? They commented that the proposal needs to better describe the theoretical development. In addition, the reviewer commented that the although the proposal claims in section 2.2 to estimate damage initiation without meso-scale impact experiments, it is not clear from the theoretical development that researchers will be able to get information on damage initiation. For example, per the theoretical development, the proposal predicts a dynamic contact stiffness of impact as given in equation 8. How does this impact stiffness translate into damage initiation? It is not clear from the proposal.

Rebuttal--Again, the reviewer used several expressions of "not clear", which means he/she didn't have the required technical background to review our proposal, or even read our proposal carefully. For example---"what is the h with the double dot in equation 5? This "h" is clearly defined in equation 1 and its texts ---"impact stiffness translate into damage initiation? It's well explained using equations 7-8 and 13 and their texts. This reviewer didn't understand our equations at all.

The connection of this research to aircraft certification requirements raised some comments. The reviewer questioned the claims that safety due to impact of current material systems is not well quantified, instead referencing there are a myriad of certification requirements for military systems including impact resistance. They also felt that while the physics of such events are not always well understood, certification requires sufficient empirical data to support flight safety of any certified structure.

Rebuttal—This reviewer discussed some applied work without any specific details. Our proposal is a basic research proposal and our first-year work led to three journal papers under review. The reviewers don't understand AFOSR's mission to support basic research, and this is an unreasonable comment to our basic research proposal.

Finally, the reviewer did not think the proposed modeling in section 7 was clearly connected to the experiments in the rest of the proposal. Specifically, how exactly will the previously described experiments with nano-indentation be related to the simulations? Also, they thought the proposal failed to clearly describe the how research will compare the homogenized and discrete damage modeling approaches, or how the simulations will be verified and validated.

Rebuttal ---- Again the reviewer used several expressions of "not clear", which means he/she didn't have the technical expertise to review our proposal. The connection between the nano-indentation to the simulations was clearly explained by equations 8, 11-13 and their texts. The reviewer mentioned "homogenized and discrete damage modeling", but our damage modeling was described in 5.4.1. The reviewer didn't understand damage modeling at all. Our simulation validation was clearly described in sections 5.4, 6.4. The reviewer either ignored or didn't understand.

------In summary, our proposal includes three major topics: 1) nanoindentation experiments , 2) impact experiments and 3) computational mechanics. We find these two reviewers never worked on any topic in our proposal, because they failed to use the right technical expressions and parameters when they commented on our proposal. Moreover, we clearly wrote some key parts such as multiscale indentation mechanics using some equations and texts, however, they simply don't understand any equation, and even made undergraduate-level mistakes. These reviewers also failed to understand ARFL's missions and needs for composite material applications. Therefore, these reviewers don't have the right technical expertise to review our proposal. But they still propose many "technical concerns", so we have to question their motivation other than objective technical reason. ----------Roy Xu 10/31/2018

In summary, I think you have a good research concept, although it may be better suited for an applied research area. However, there are several issues which should be addressed to improve the document for consideration as basic science. These include the comments above, as well as the overall issue of linking microstructure features to deformation mechanisms across multiple temporal and spatial scales, and how such models will be verified and validated. Because of these reasons, your proposal as currently written was not selected for funding.

Sincerely,

[redacted]