

RESUBMISSION

Purdue Workshop on Damage Mechanics Challenge

April 3, 2018

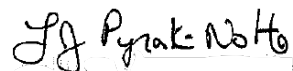
Dear Dr. Olenchak,

Attached please find a revised proposal for consideration entitled “Purdue Workshop on Damage Mechanics Challenge”.

In response to the reviews, we have reached out to the broader Purdue community to identify additional local participants in the proposed workshop. At the end of the application, I have included letters/emails of support from ME Professors Thomas Siegmund (ME, who is now a co-chair of the conference), Hector Gomez, Marisol Koslowski, Ilias Bilonis and Ganesh Subbarayan. If funded, they have suggested the inclusion of Professors Pablo Zavattieri (CE), David Bahr (MSE) and Wayne Chen (AAE). I have modified the list of conveners on page 1 to include Prof. Siegmund, the section “**Critical mass of Purdue scholars likely to participate**”, and have listed other potential professional societies for show casing the results of the workshop.

Please let me know if you need any other additional information.

Sincerely,



Laura J. Pyrak-Nolte

Distinguished Professor of Physics

Purdue Workshop on Damage Mechanics Challenge

Conveners: Laura J. Pyrak-Nolte (Physics & Astronomy), Antonio Bobet (Lyle School of Civil Engineering), Doug Schmidt (Earth, Atmospheric & Planetary Sciences), Thomas Siegmund (School of Mechanical Engineering), Hongkyu Yoon (Sandia National Laboratories), WaiChing Sun (Columbia University)

Purpose of the Conference: *To gather theorist, computational scientist, and experimentalist to define and launch a numerical challenge to predict damage evolution and signatures of failure.*

As artificial intelligence (AI) methods advance in the detection of anomalous signals in data from sensors, methods are needed to link these signatures to the underlying physics/mechanics of failure to determine if failure is imminent. This requires robust computational methods that capture the physics of failure and identify the measurable signatures of failures. The signatures of failure are required for the development of machine learning methods to quickly detect evolving failure from sensor data. While there are many computational approaches, few have been ground-truth tested with either known experimental data or with blind data sets.

The propose of this conference is to initiate a challenge to compare computational approaches on damage evolution to experimental data from laboratory experiments performed in collaboration between Purdue and Sandia National Laboratories. We propose to hold the workshop at Purdue in Fall of 2018 to

- (1) have the participants present their computational approach for numerical simulation of damage and/or their machine learning approaches for extracting information from signals with noise;
- (2) design a challenge problem that will be compared to laboratory experimental data on samples designed through advanced manufacturing methods (e.g. 3D printing) to fail in controlled ways and with increasing complexity;

(3) define a repeatable and unbiased metrics to quantitatively assess and measure the quality of the theoretical and data-driven models, given the significant influence of inherent uncertainty and variability on the onset and mode of failures.

The proposed experimental methods will generate temporal and spatial datasets that include measurements from traditional digital load-displacement sensors, 3D digital image correlation to map surface deformations, 3D X-ray microscopy to ground-truth the crack-failure geometry, and acoustic and elastic wave signals for remote monitoring.

The goal is to determine which machine learning method is the best at identifying signatures of failure and which numerical simulations provide the best interpretation of information indicating failure, or do the models show that there are other experimental measurements that are needed or better ways of performing the measurements to detect damage. The comparison of results from the challenge will be presented to the community in a special session/workshop at the June 2019 American Rock Mechanics Geomechanics Symposium in New York City, NY.

Requested Amount: We request \$25,000 to support travel and lodging of the 10-12 invited speakers, provide meals and coffee breaks for all of the participants.

Proposed extramural sponsorships: Sandia National Laboratories Geoscience Program plans to seek additional support (\$10K) through outreach funding and/or Sandia-Purdue Academic Alliance Program. Prof. Pyrak-Nolte would also seek \$10K from DOE for support of travel for post-doctoral participants to provide access to scientists and researchers in multiple disciplines that are normally outside of their current research sphere. Post-doctoral participants provide knowledge of the most recent and emerging academic developments from their research sphere.

Linkage to Purdue's Mission: Purdue is actively involved and has expanding initiatives in data science and analytics. Harnessing enormous amounts of data collected by sensors of different types is at the cusp of revolutionizing our ability to maintain the safety of our infrastructure and subsurface reservoirs. However, existing and new machine learning techniques for interrogating data often bypass the physics/mechanics that generate the signals. Computational methods are needed to generate the signals or templates that machine learning methods use to identify features in measured signals. Our goal is to advance Purdue's standing in data science through the coupling machine learning techniques and numerical simulation to make breakthroughs in the prediction, detection, and tracking of damage in materials.

Reputation of potential invited speakers/lecturers: The speakers will be drawn from the international communities of geomechanical simulation of damage, machine learning, and experimentalists.

We have additional names in case any of the above participants are unavailable in Fall 2018.

Critical mass of Purdue scholars likely to participate: At Purdue, Professors Laura Pyrak-Nolte (PHYS), Antonio Bobet (CE) and Doug Schmidt (EAPS) are 3 of the world experts in coupling geomechanics and geophysical signals to monitor damage evolution across scales. Professor Thomas Siegmund (ME) is an expert in micro-crack detection and analysis through 3D microtomography, and in computational damage mechanics. ME Professors Marisol Koslowski, Ganesh Subbarayan, Ilias Bilinonis, and Hector Gomez also support this workshop. When selected for funding, we will engage with the Rosen Center for Advance Computing, Advance Manufacturing Center, the Envision Center, Bowen Laboratory, computer sciences, and faculty in the areas of solid mechanics and data analysis in the College of Engineering (e.g. AAE-Wayne Chen, CE-Pablo Zavattieri, MSE- David Bahr) to engage a broad community.

Likelihood to attract leading scholars from elsewhere: The topic of the challenge problem is linked to damage evolution and sensing damage which has wide application in such diverse fields as hydraulic fracturing to airplane safety to civilian infrastructure. The workshop would be announced and advertised through professional societies, and through personal contacts to attract national and international participants from academia, national laboratories, and industry. In our community, challenge workshops that define current and future research needs are highly attended by leaders in their fields to ensure inclusions in future funding trends or center projects. We proposed to invite DOE and NSF program managers as observers to provide them with the

latest information computational and data sciences research, and to demonstrate Purdue's leadership role in this area.

Likelihood to showcase Purdue: The outcome of our workshop will be presented at meetings of several professional societies (American Rock Mechanics Association (ARMA), International Society of Porous Media (Interpore), ASME, ASCE, and American Geophysical Union (AGU)) and will be the basis of at least two papers: (1) on the design of the problem, and (2) the outcomes of the challenge, written by the workshop leads from Purdue, Sandia and Columbia. A recent challenge on the simulation of contacting rough surfaces was highlighted in Science (5 January 2018). In addition, a tour of our campus experimental facilities will highlight our recently acquired acoustic emission system and 3D X-ray microscope (both funded by the EVPRP at Purdue, and critical to this challenge) as well as the Envision Center and Rosen Center for Advance Computing. A website at Purdue will be used to highlight the challenge, invite submissions to the challenge, and hold a database of experimental results that can be used for benchmarking future computational and analytical methods.

Integration of networking opportunities: Design of the challenge problem will require break-out sessions and brain-storming which provides a unique opportunity for networking that does not occur at more traditional workshops where only presentations or panel sessions are given. The workshop program is designed to provide computational and data scientist speakers with a 30-minute platform to present their computational and data analytical methods, the types of results generated by the models, and what laboratory measurements are needed to confirm model/learning success. This will be followed by a poster session-lunch for early career

participants to show case their approaches. The next session is designed for experimentalist to present their methods, past results, and capabilities, followed by a 2nd poster session. On the second day, participants will divide into groups containing specialists from each area and charged to design a set of numerical challenges that can be tested experimentally. The groups will re-convened to exchange ideas and to explicitly set the challenge problem. These activities will yield maximum network opportunities over the proposed 2 days of the workshop, in addition to the dinner on the first night. This network opportunity will be re-enforced through the proposed special session several months later at the American Rock Mechanics Association Symposium in NYC in 2019; and future events at the 2020 meetings of AGU and Interpore, or other engineering professional societies.

Linkage to at least one professional association, if possible: We plan to hold a special session at the American Rock Mechanics Symposium (ARMA) in 2019. After the publication of the results, we will set a second challenge to engage an even broader community through sessions at the American Geophysical Union (AGU) Annual Fall Meeting in 2020 and at the Annual Meeting of the International Society of Porous Media (Interpore) in 2020. Professor Pyrak-Nolte (President of ARMA and President-elect of Interpore) will work with these professional societies to arrange specialty sessions. Co-convener Prof. Sun is on the organizing committee of the ARMA 2019 Annual Symposium. Dr. Yoon and Prof. Pyrak-Nolte have arranged and chaired successfully sessions at past meetings of AGU.

Value to Purdue: The proposed workshop will highlight the benefits of the strategic alliance between Sandia and Purdue (Sandia-Purdue Academic Alliance Program) and will enhance the

collaboration opportunities among the different schools at Purdue, and between the two institutions and Columbia, and potentially industries in need of the computational and data monitoring methods derived from the challenge. The workshop poises Purdue to attract funding for DOE or NSF centers by firmly establishing us as leaders in the field of damage evolution, in the applications of machine learning to multimodal data set, and establishes a relationship with Purdue colleagues that would participate in multi-investigator or multi-institution scale centers (e.g. DOE-Energy Frontier Research Centers).

Value to external audiences and the media: There are many simulation and data science approaches being proposed everyday. Rarely are true code comparisons with ground-truth data testing from real measurements performed. The external audience will see that (1) which approaches truly capture the essence of the physics and can extract the signatures of damage from massive datasets; (2) provide a forum to openly discuss the approaches; (3) work towards a community that freely exchanges ideas for improvement; (4) develop new sensing or monitoring approaches that aid in detecting failure; and (5) provide a vetted computational community of scientist and engineers for addressing damage/failure issues that arise and for working with industry.

Proposed post-event impacts: As mentioned, after the workshop we will have a session at the American Rock Mechanics Symposium to compare the results of the competition and discuss the next stage of the competition (e.g. design experiments, deadline, types of failures, etc.) and then convene sessions at the Annual Meeting of the American Geophysical Union and at the Annual Meeting of the International Society of Porous Media in 2020 to present our results to a larger, more discipline-diverse community.

Thomas Siegmund
Professor of Mechanical Engineering

March 23, 2018

Purdue Workshop on Damage Mechanics Challenge

Dear Laura,

I hereby document my commitment to collaborate with you on the proposed Purdue Workshop on Damage Mechanics Challenge. I fully concur that there exists a substantive need for on-going challenge to computational models through well-defined experimental data , especially considering data from novel characterization tools. Thank you for your leadership in this effort and I am committed to working with you to make this a success such that Purdue can become a focal point in this effort.

Sincerely



Thomas Siegmund



Subject: Letter of support for the Workshop
"Damage Mechanics Challenge"

West Lafayette, IN, March 23rd, 2018

Dear Professor Pyrak-Nolte,

With this letter, I wish to express my excitement and support to the "Damage Mechanics Challenge" Workshop at Purdue. Should this workshop eventually be held at Purdue, I would be delighted to attend it and participate in the discussions.

Please, do let me know if there is anything else that I can do to support the Workshop.

Sincerely,

Hector Gomez

Dr. Hector Gomez
School of Mechanical Engineering
Purdue University
585 Purdue Mall
West Lafayette, IN 47907 USA.

Subject: Re: Damage Mechanics Workshop
From: Marisol Koslowski <marisol@purdue.edu>
Date: 3/23/18, 7:50 AM
To: Thomas Siegmund <siegmund@ecn.purdue.edu>
CC: Ale Strachan <strachan@purdue.edu>, Laura Pyrak-Nolte <ljpn@purdue.edu>

Thomas and Laura,

I will be happy to support this. Could you please sen me more information?

Marisol

Ilias Bilonis
Assistant Professor
School of Mechanical Engineering
ME 1069, 585 Purdue Mall
West Lafayette, IN 47907
Phone: (765) 496-0217
E-mail: ibilon@purdue.edu
URL: <http://www.predictivesciencelab.org>

March 25, 2018

Professor Laura J. Pyrak-Nolte
Purdue University, Department of Physics
525 Northwestern Avenue
West Lafayette, IN 47907-2036

Dear Professor Pyrak-Nolte,

I hereby document my commitment to collaborate with you on the proposed Purdue Workshop on Damage Mechanics Challenge. I fully concur that there exists a substantive need for on-going challenge to computational models through well-defined experimental data, especially considering data from novel characterization tools. Thank you for your leadership in this effort and I am committed to working with you to make this a success such that Purdue can become a focal point in this effort.

Sincerely,



Ilias Bilonis, PhD

Subject: Re: Workshop on damage mechanics challenge
From: "Ganesh Subbarayan" <ganeshs@purdue.edu>
Date: 3/23/18, 11:00 AM
To: "Thomas Siegmund" <siegmund@ecn.purdue.edu>, "" <hectorgomez@purdue.edu>, "Bilionis, Ilias" <ibilion@purdue.edu>, "" <jgibert@purdue.edu>, "" <ljpn@purdue.edu>

Thomas,

I will be happy to participate in the workshop and share my students' past work related to the area.

Thanks,
Ganesh

Ganesh Subbarayan's Contact Info

On 3/23/2018 8:46:32 AM, Thomas Siegmund <siegmund@ecn.purdue.edu> wrote:

Ilias, Hector, James, Ganesh,

I am writing to inquire about your interest in supporting a workshop on "Damage Mechanics Challenge". This is lead by Laura Pyrak-Nolte in Physics. The main idea is to build a damage mechanics challenge problem and to use current methods to give experimental (blind data) to the modeling and simulation community to test their models. This needs experiments, data and inverse methods, damage mechanics. This would be supported by the Provost Office as an on campus workshop (fall 2018).

If you are interested in supporting this and in demonstrating that there does exist a critical mass of Purdue faculty with interest and expertise in this area, please let Laura know. She can certainly answer further questions.

Regards

Thomas

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Thomas Siegmund
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Perry Excellence Scholar
School of Mechanical Engineering
Purdue University
Associate Editor Journal of Applied Mechanics
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