# Rain Erosion: from Multi-physics Modelling to Efficient & Cost-Effective Qualification

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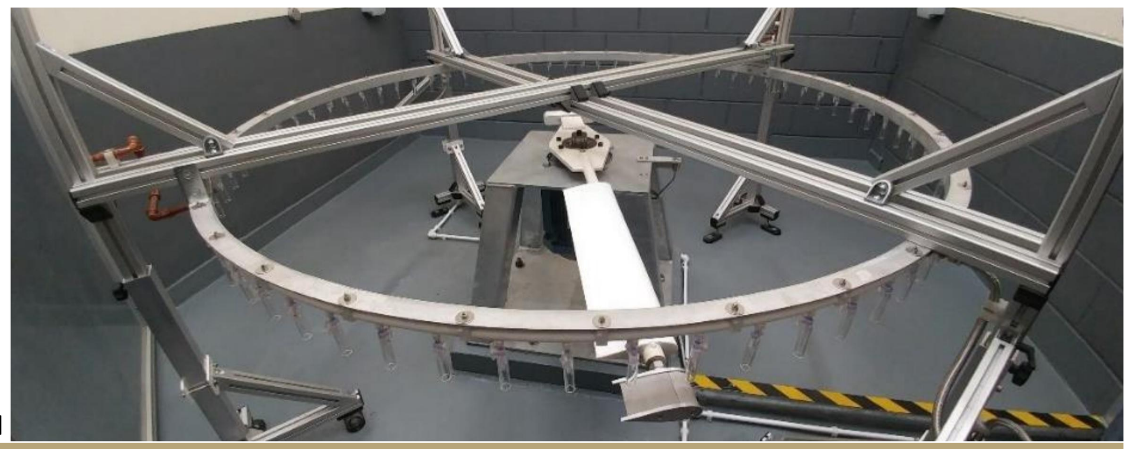
## Project Summary

The overarching goal of this project is to develop novel experimental and simulation techniques to predict rain erosion of coatings used by the aerospace industry. The new models aim at reducing the number of required tests for product development and certification

## Background and Motivation

- There is currently no accurate way to model the erosion of airplane wings by rain during flight.
- Whirling Arm tests for product development and certification are expensive and time consuming. (Large whirling arm test rig shown below)
- Computational modeling can help reducing the number of required tests lowering down costs, time-to-market of new coatings and streamlining certification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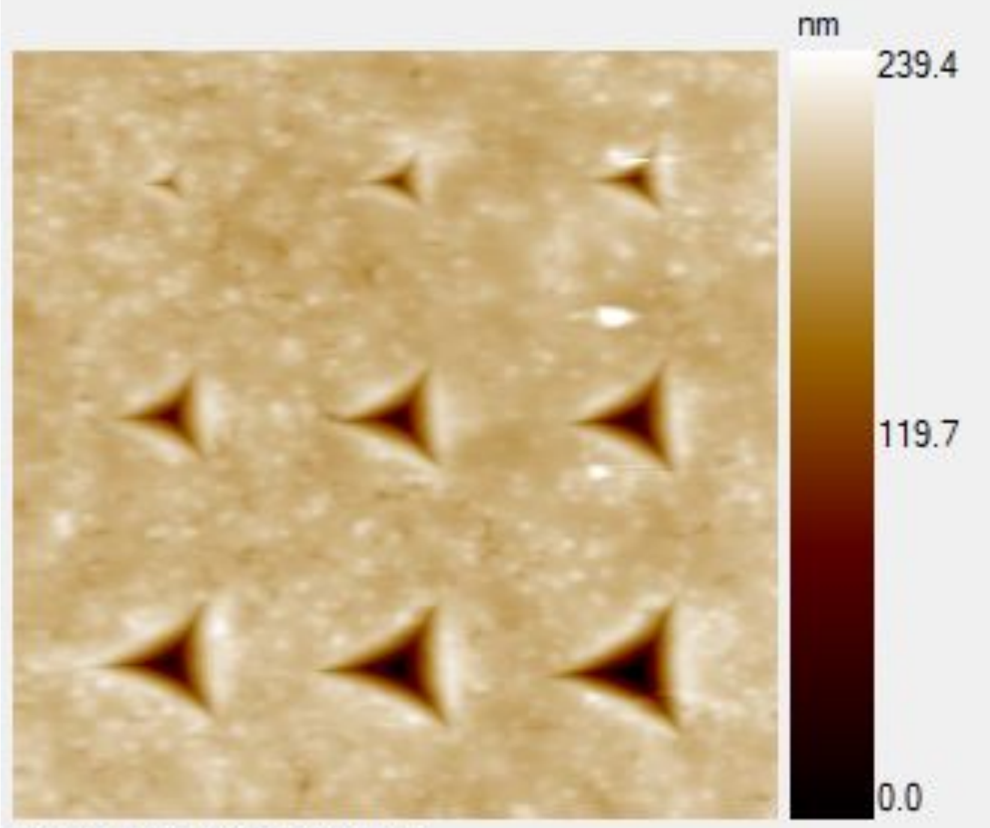
## Goals and Objectives

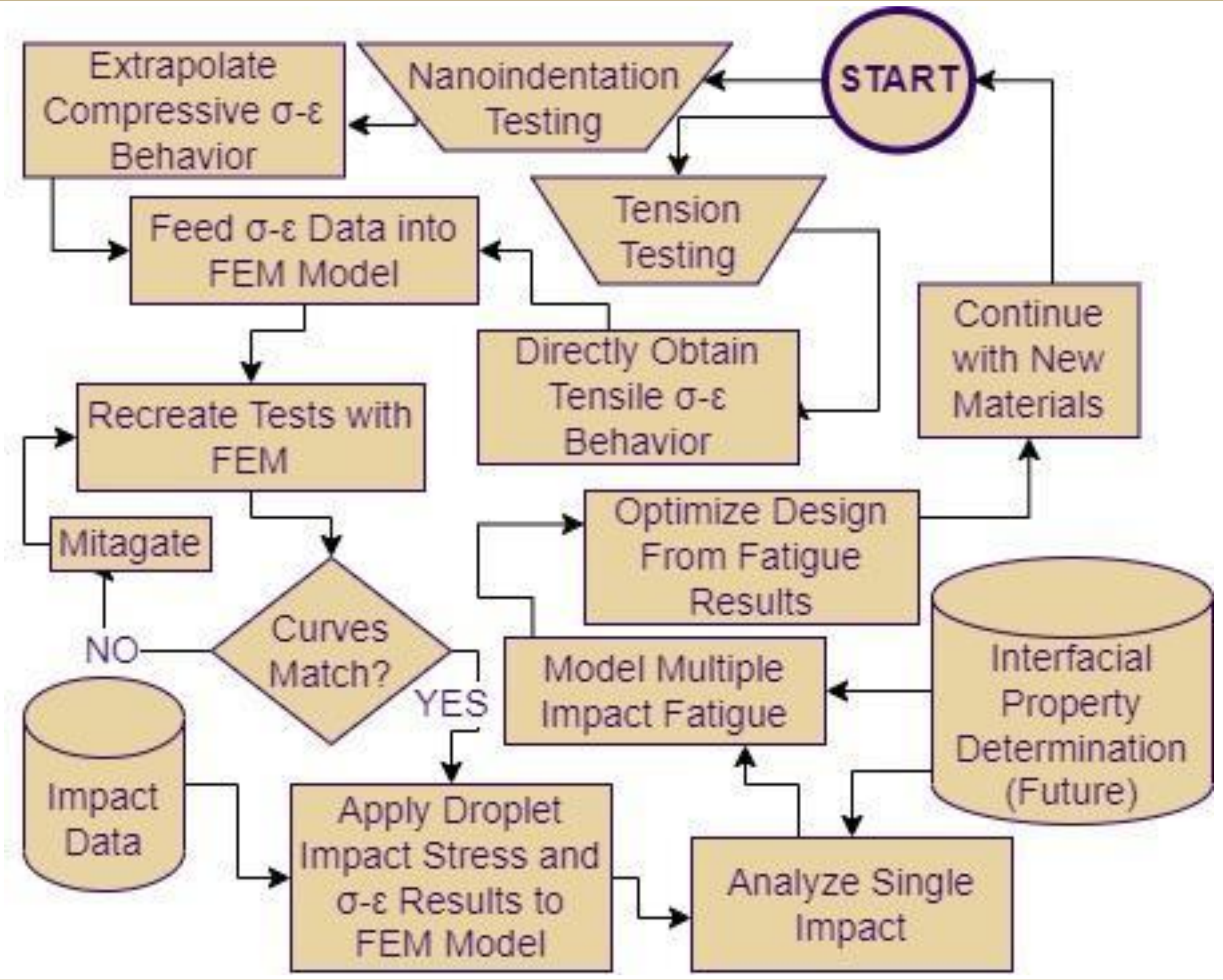
- Research & develop novel testing protocols for characterizing the mechanical properties of the coating
- Develop and validate novel computational models for rain erosion


Tensile test coupon with field of high contrast points for DIC



Plastic indentations left behind from nanoindentation testing

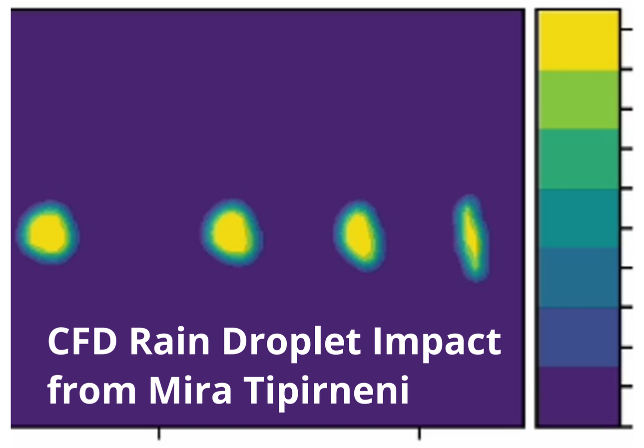
## Methodology

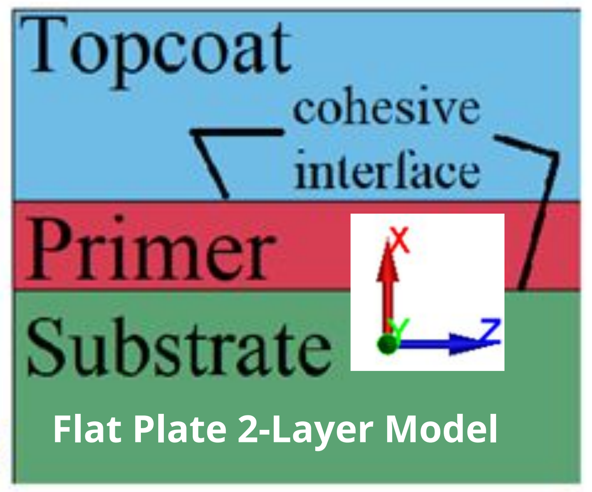


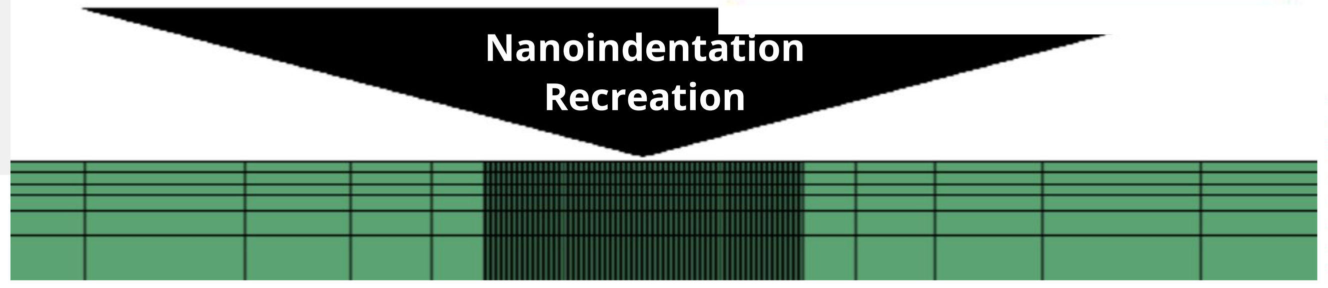

## Modelling

- Tensile Validation – Tension test results are fed into an LS-Dyna material model. The tests are then recreated in FEM to validated the model.
- Nanoindentation Recreation and Plastic Curve Extraction – Nanoindentation tests are recreated in FEM and the material's plastic curve is iterated until the load-displacement curves match.

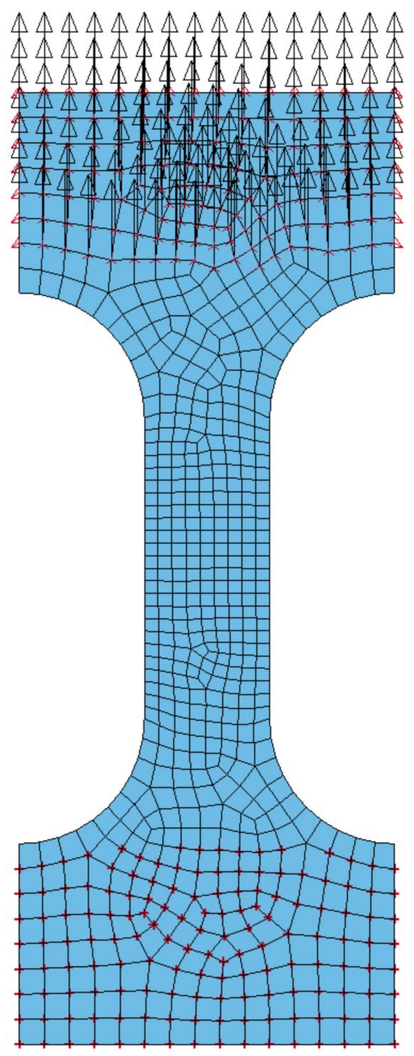
The flat plate coating uses CFD data impact data and material properties from tensile and nanoindentation testing to analyze the material response to liquid impingement.



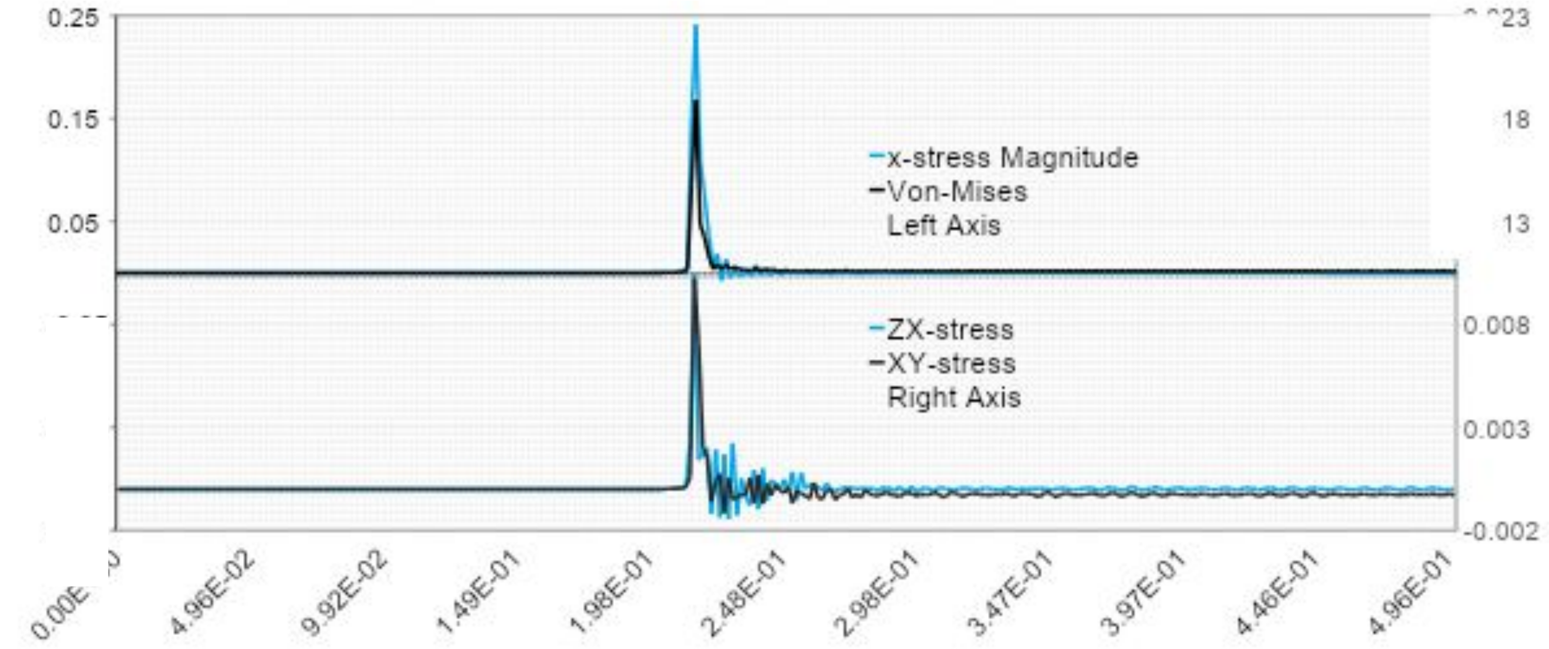



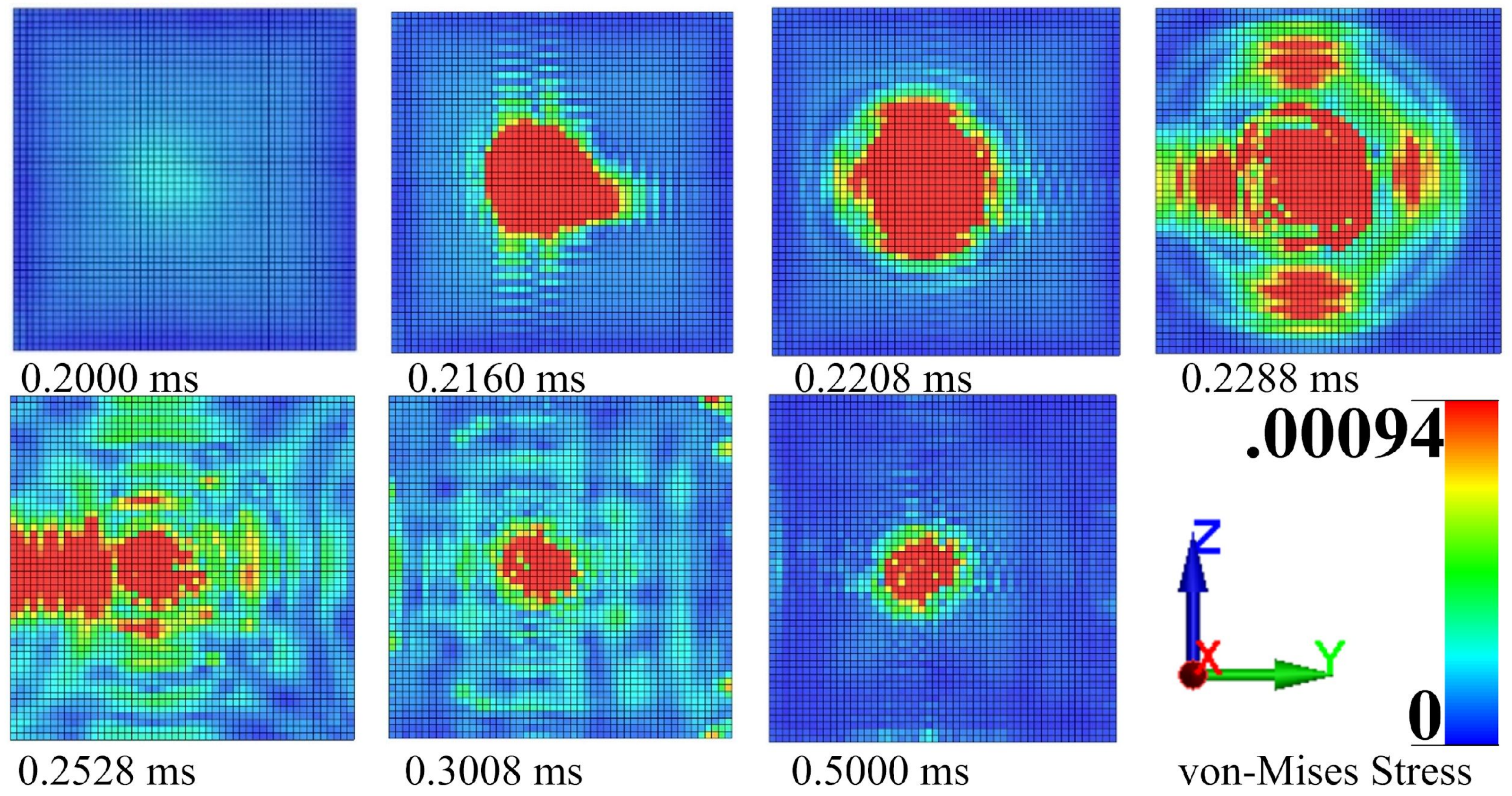

**Tensile Validation Model**



## Results

- Tensile validation models have successfully validated material models for all four materials.
- Nanoindentation models have and continue to help determine plastic compressive behavior with two materials down and two to go.
- The flat plate model is able to show material response from a single droplet impact as shown below. The stress is normalized to w.r.t. the Topcoat's ultimate strength.




## Future Work, References, and Acknowledgments

**Future Work:**

- Laser Spallation – Laser spallation can be used to determine the fracture energy of coating interfaces
- Fatigue Model – Presently, the FEM model only considers a single impact. This will be expanded to include fatigue.

**Acknowledgements to:**

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Graduate Students: Mira Tipirneni, Allen Kim

Boeing: Scott Adams

**References**

[1] Cameron Mackie, David H. Nash, Dean Boyce, Matthew Wright, and Kirsten Dyer. Characterisation of a whirling arm erosion test rig. 2018 Asian Conference on Energy, Power and Transportation Electrification (ACEPT), pages 1–6, 2018.

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