DuraMAT
Durable Module Materials Consortium

Understanding PV module degradation
to enable high-energy-yield modules
with a 50-year lifespan

A fast, accurate prediction for system-wide damage due to dynamic wind loading

Ethan Young, Martin Springer, Brooke Stanislawski, Andrew Glaws, Xin He, Walid Arsalane, and Matthew Emes
Contact: ethan.young@nlr.gov NLR/PO-2C00-99438

Multi-Scale, Multi-Physics Model

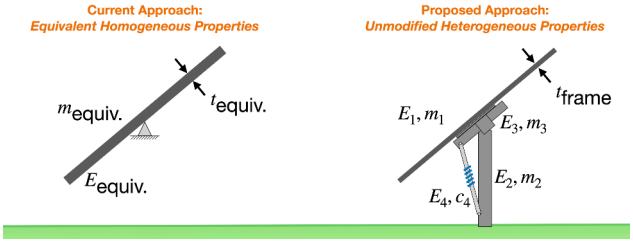
Awarded FY26
Core Modelling Call

Period of Performance: FY26-FY27
Funding: $700K

Contributing to DuraMAT Consortium Goals

We're building a fast way to predict where the wind will break things in your tracking PV system. Whether you're designing a new system, stowing your current system, or thinking of installing dampers, these models can help quantify the benefit and reduce the risk.

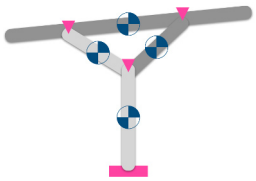
Project Overview



We are adding significant new functionality to our software tool, `PVade`[1], to **maximize the field-relevance of our results by supporting "real", unmodified system properties and dimensions**. We will use this powerful new multi-scale algorithm to **train an AI/ML model to predict locations of high stress/risk in an array** such that stakeholders can quickly predict the effect of different design or operational choices without the need for computationally expensive high-fidelity simulations. Together, these advances will enable us to **answer questions about risk and resilience not currently possible** and mitigate wind-driven degradation mechanisms.

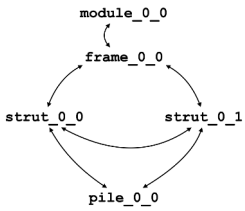
Methodology

Focus Area 1: Multi-Body Solver



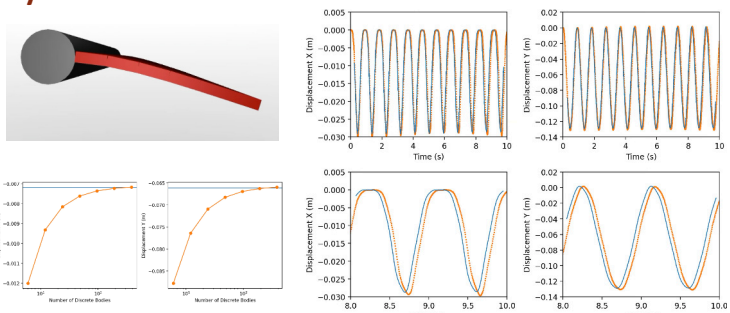
- We will implement friction hinges, bushings, pinned connections, and welds in a **simplified library of PV tracker components using MuJoCo**[2]
- This will include a set of hardware constraints and physical limits
- Demonstration of a single widely-used system **by end of year one**

Focus Area 2: Reduced Order Models



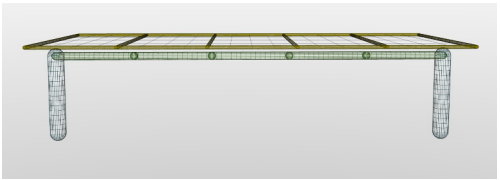
- We will **exploit the structural model's definition to build graphs**
- Components will be connected bi-directionally and transmit contact forces
- **Model inputs**: Wind speed, wind direction, tilt angle, system definitions
- **Model outputs**: Maximum force, stress, and acceleration

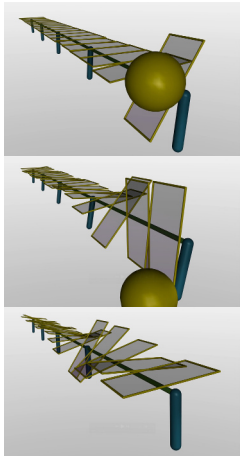
Dynamic Structural Validation



Here, we demonstrate that our implementation of multi-body algorithms can recover the expected physical behavior as predicted by a canonical finite element benchmark solution, where **our representation of the structure** via multiple rigid bodies is shown with orange markers and the **expected solution**[3] is shown as a blue line.

Preliminary PV Definitions and Tests





In the first quarter of our new project, we made significant progress toward building a multi-body PV dynamics simulation tool, including (top) **creating several proof-of-concept models** for PV structures and (right) observing their behavior under **aggressive pluck tests**. The qualitative responses to the test, the compliance in each of the joints, and the recovery of the expected angle of twist down the rotational axis of the torque tube support the fundamental multi-body approach we will employ for the remainder of the project.

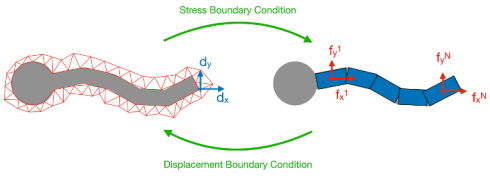
Outcome and Impact

This project is a response to the PV industry's questions about why modest wind speeds can lead to "spontaneous" cracked glass and structural damage when the system components all pass qualification testing. We will inform how effective frame and tracker stiffening measures might be and where they should be applied. These questions are becoming increasingly important as modules and frames become larger, thinner, and, in the case of glass, receive less strengthening from industry-standard heat treatments like tempering. Enhancing the tool to take in directly relevant input options, this work will enable users to test modifications to hardware features (e.g., increasing the number of dampers) and instantly act on the results (e.g., the maximum force in a joint) to improve system resilience

Scan to learn more and get started with PVade!

Future Work

In the next quarter of work, we will couple these multi-body structural models with our existing fluid-structure interaction code using the stress-displacement coupling outlined below[4].



This project will ultimately deliver a more accurate and more flexible representation of real-life systems and package key resilience predictions in surrogate models.

Acknowledgements

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References

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3. S. Turek and J. Hron, "Proposal for Numerical Benchmarking of Fluid–Structure Interaction Between an Elastic Object and Laminar Incompressible Flow," in Fluid-Structure Interaction: Modelling, Simulation, Optimisation, 2007
4. W. G. Dettmer and D. Perić, "A new staggered scheme for fluid–structure interaction," 2013