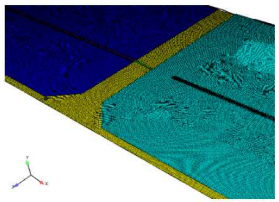
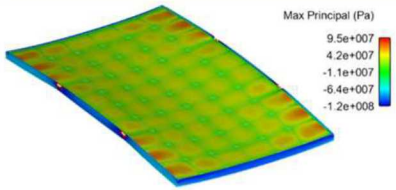
DuraMAT
Durable Module Materials Consortium

SAND2018-9242PE

Capability 2: Predictive Simulation
Progress and Updates





PRESENTED BY

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SLAC NATIONAL ACCELERATOR LABORATORY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

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Capability overview

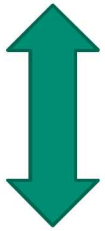
DuraMAT Capability Area 2: Predictive Simulation

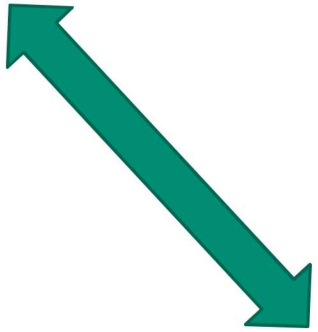
"This capability will be a suite of modeling and simulation **tools, model workflows, and a community of experts** who work in concert with experiments and data analytics… to **help interpret and enrich** existing test/experimental data, design durability-testing experiments, and help create design rules for Materials Discovery"

Capability Area 2: Predictive simulation

Module-level model (SNL)
Sub-scale models (SNL)
Materials characterization (SNL)
A Cohesive Zone model for encapsulant delamination (NREL)
A Constitutive model for ECAs (NREL)
…

Capability Area 3: Materials characterization and forensics



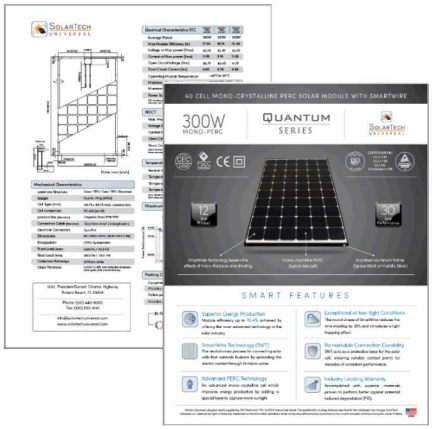


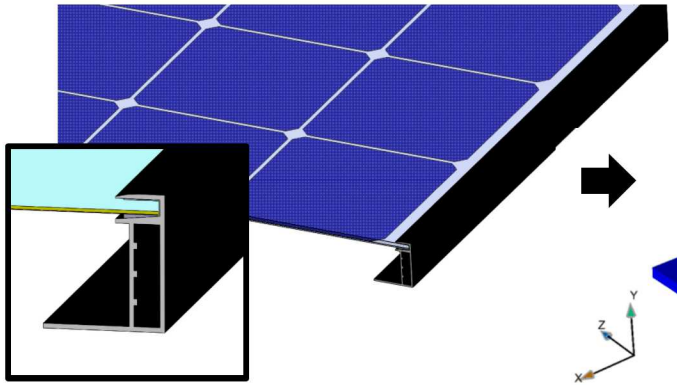
Capability Area 4: Accelerated testing

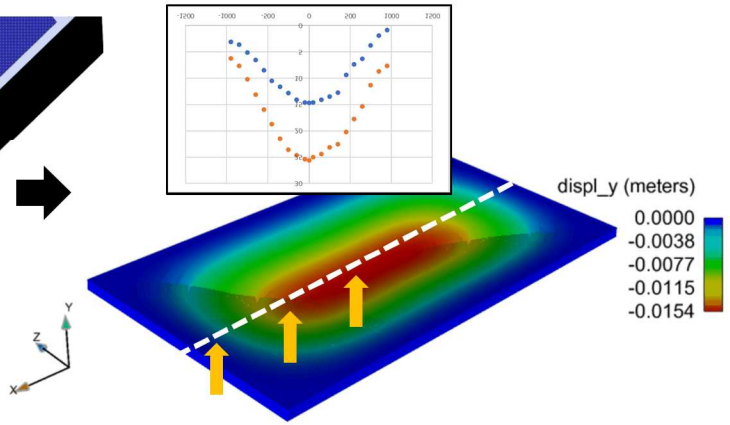
Capability Area 1: Data Management & Analytics

Module-Level Modeling Efforts

- Completed scoping studies: developing **specific** module mechanical models







Module datasheet/BOM:
- First Solar Series 6
- SolarTech Quantum 300
- Yingli Solar YLM 60 40mm

CAD and discretized geometry

Predicted deflection vs. static load experiments

- **Immediate goals**
  - Validate model against static loaded deflection data
  - Parametric studies (i.e. develop “best practices” for modeling PV architectures)

- **Applications**
  - Propagating environmental loads to components or mini-modules
  - Trade studies for module design and “what-ifs”

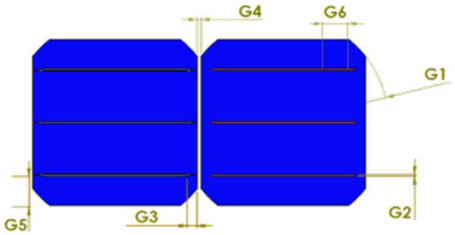
Sub-scale Modeling Efforts

- Developed parametric simulation capability to examine sensitivity of interfacial stresses to geometry, materials, environmental drivers
  - "Effects of Solar Cell Materials and Geometries on Thermally Induced Interfacial Stresses", 2018 IEEE PVSC, Waikoloa, HI

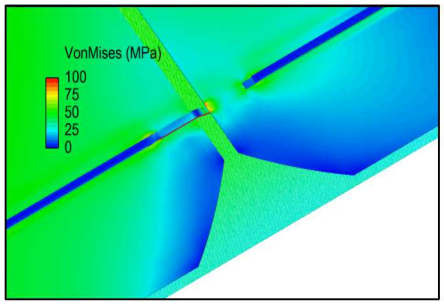
Table 1: Varied Design Parameters

#	Parameter description	Lower bound	Upper bound
G1	Cell radius	200 mm	220 mm
G2	Busbar/Ribbon width	0.5 mm	3 mm
G3	Solder pad to cell edge, front	0.5 mm	20 mm
G4	Cell spacing	1 mm	5 mm
G5	Busbar to cell edge, width	18 mm	40 mm
G6	Solder pad length, front	5 mm	13 mm
G7	[illegible]	[illegible]	[illegible]

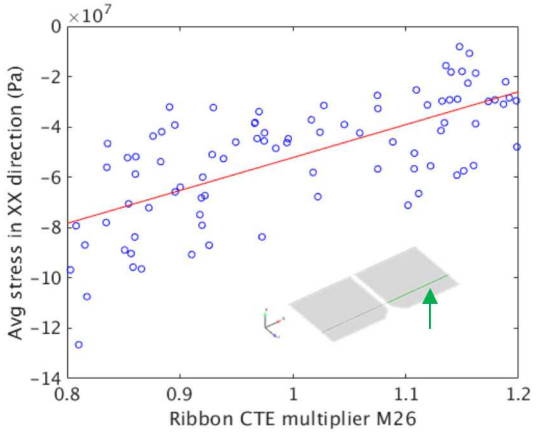
Etc. …



Parameter sampling



Simulation run
(-40° to 85°C cycle)



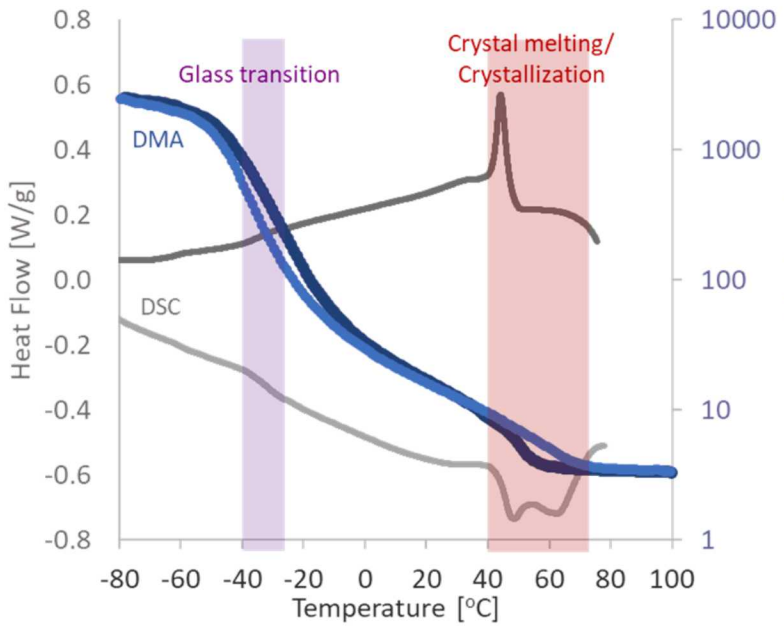
Correlating stress to individual parameters

Highly correlated parameters are candidates for further study

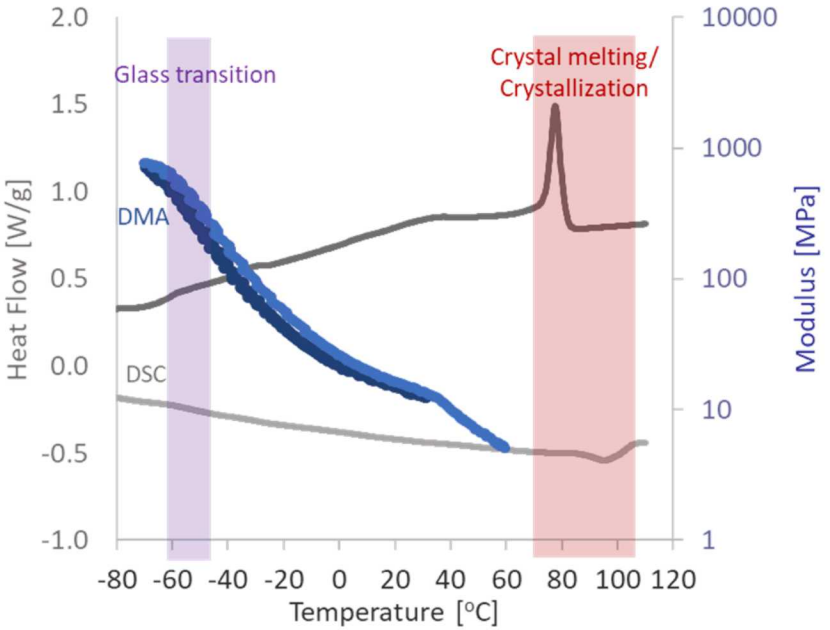
- **Applications:**
  - Determining material model needs and gaps
  - Testbed for new capabilities (cohesive zones, constitutive models)
  - Quantitative stress and fatigue life predictions for components

Experimental Materials Characterization Efforts

- Built capability and characterized PV encapsulant bulk mechanical properties



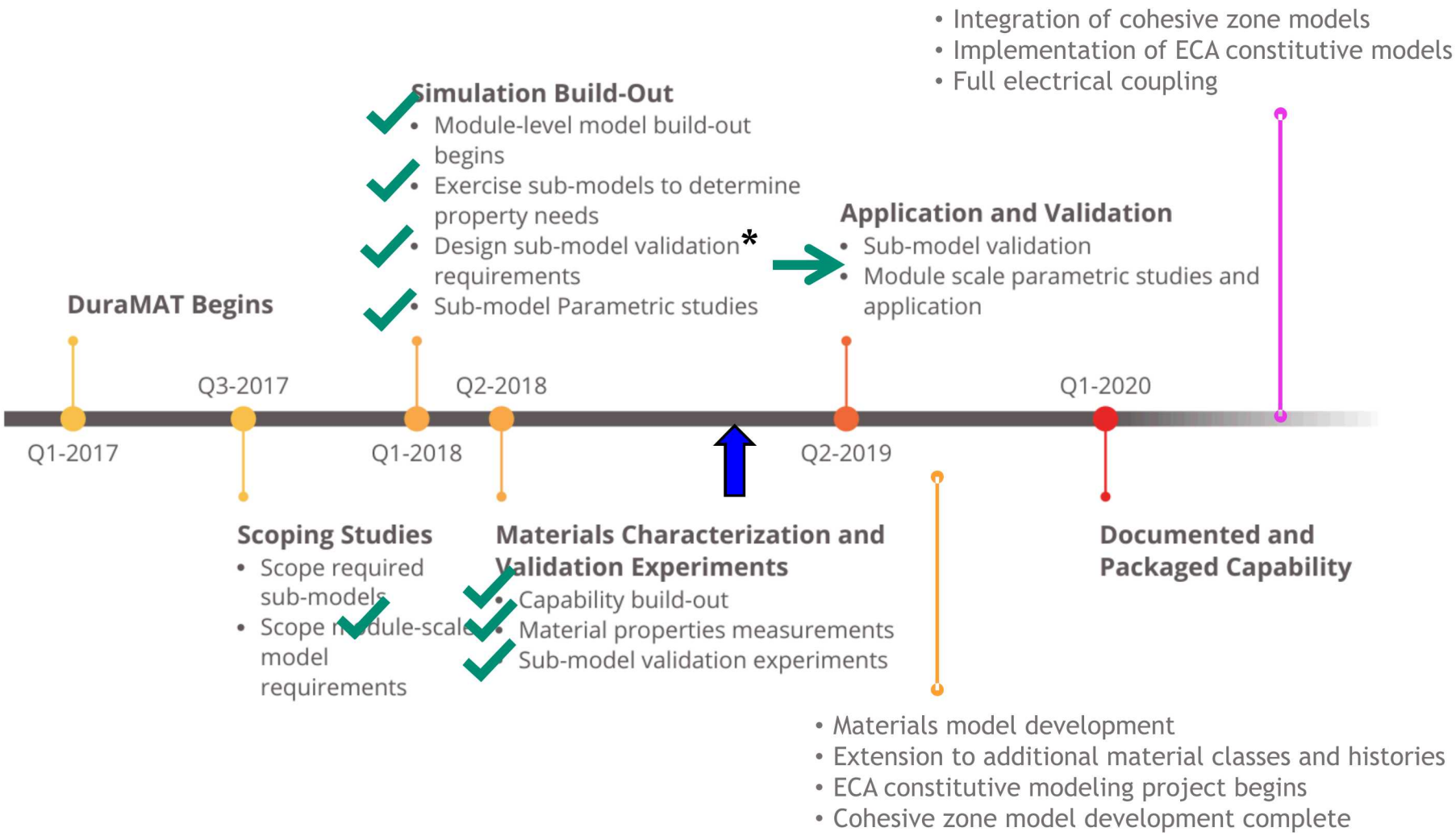
Elastic modulus vs. temperature and thermal transitions
EVA9100, 1Hz, 100% cure



Elastic modulus vs. temperature and thermal transitions
Polyolefin, 1Hz, production-like lamination

- **Immediate goals**
  - Understanding specific material variability and sensitivities
  - Constitutive models: f(T), Linear viscoelastic (Maxwell), Nonlinear viscoelastic
- **Applications**
  - Direct model input; propagation of uncertainties to model output

Predictive Simulation: Capability Development Timeline



***Sub-model:** Any sub-portion of the simulation capability, whether geometric or physical (i.e. a cell-scale model, or a module-scale model focusing on mechanical effects only)