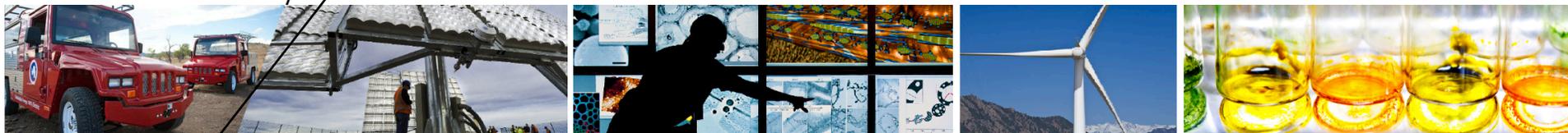




# PVQAT TG2 Update



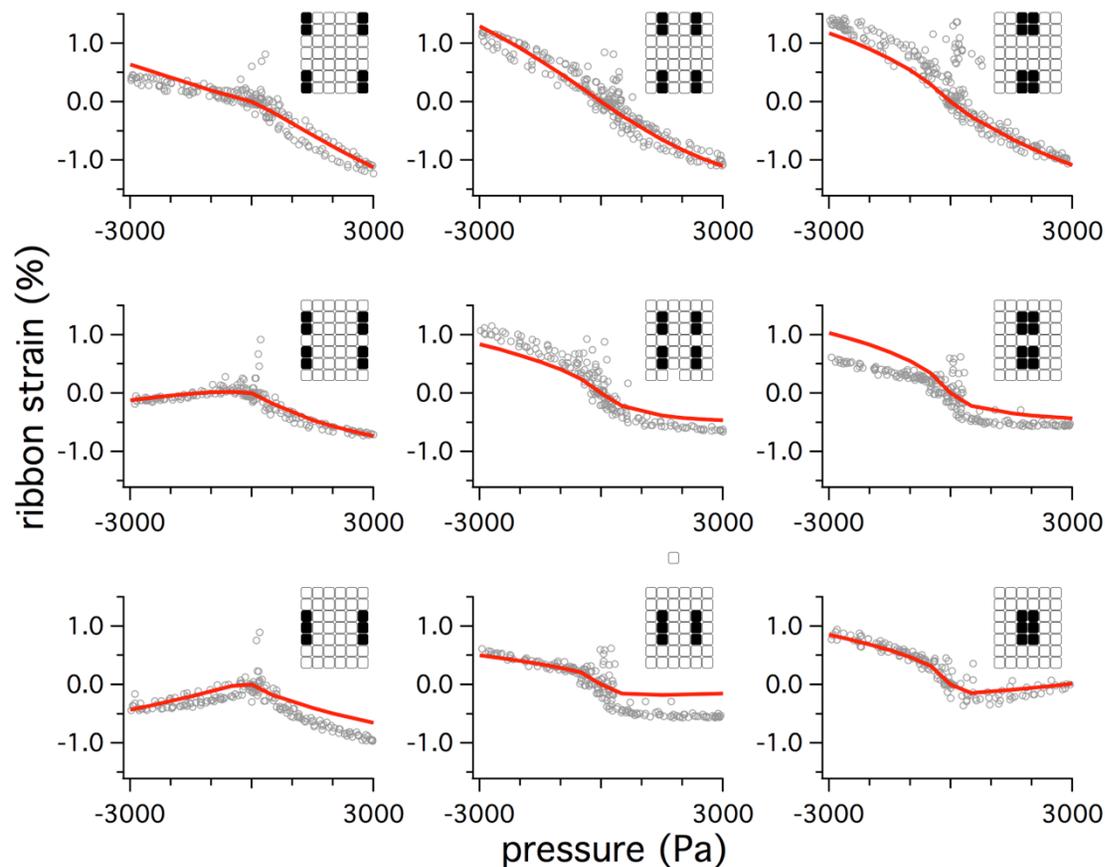
directive

## Thermal and Mechanical Fatigue

- What are the appropriate number of thermal cycles for a long-term reliability test
- Should this number be climate specific
- What is the effect and appropriate level of DML testing

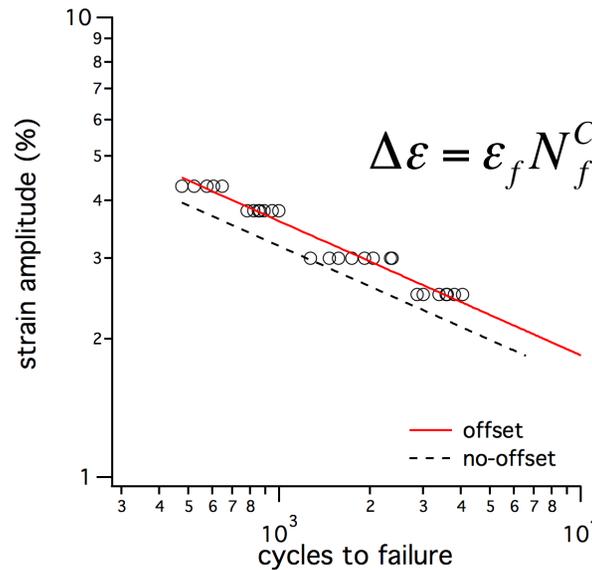
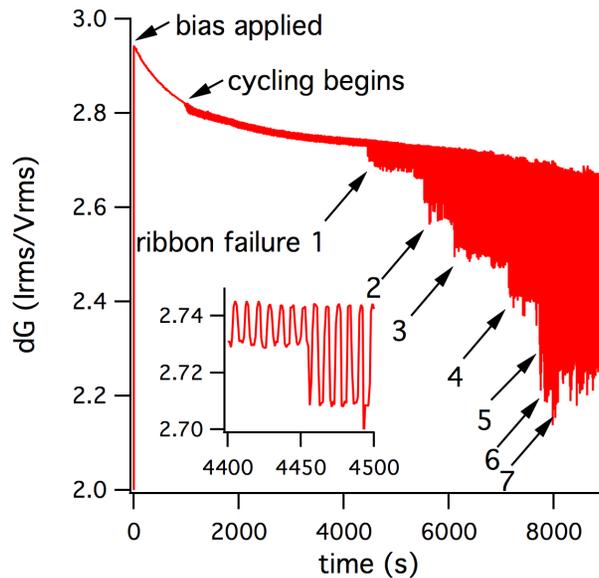
# DML: FEM and mechanical loading

## DML fatigues ribbon interconnects



cell-to-cell strain  
-3 kPa to +3 kPa  
measured and simulated

# dynamic mechanical loading



## Thermal Cycling

$$\Delta \varepsilon_{105C} = 2.5\%$$

$$N_f^{offset} = 3726$$

$$N_f^{no-offset} = 2420$$

### Poster 43:

In-situ impedance measurement in c-Si PV modules during rapid thermal cycling

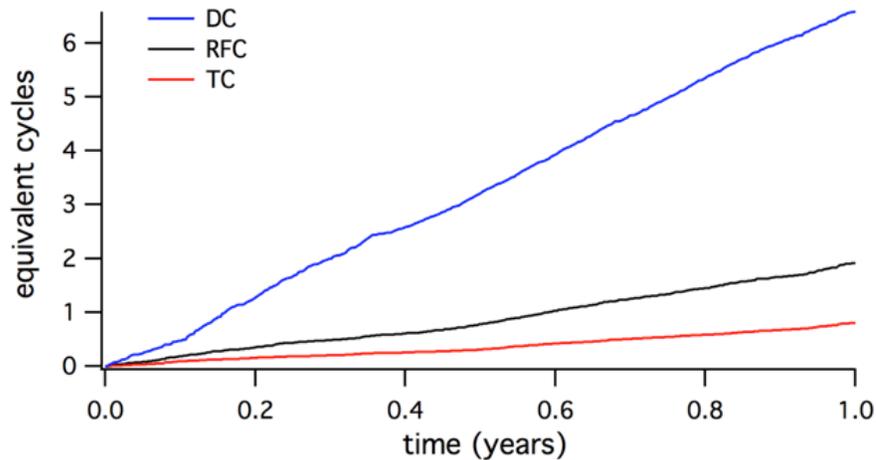
ESPEC

$$N_f \approx 3000$$

Failures only evaluated during in-situ measurement

# thermal cycling and service

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Normalize by the number of cycles to failure for the  $\pm 1$  kPa DML cycle or the IEC TC cycle

25 years is equivalent to less than 175 cycles

\*This evaluation must be qualified for the specific module evaluated.



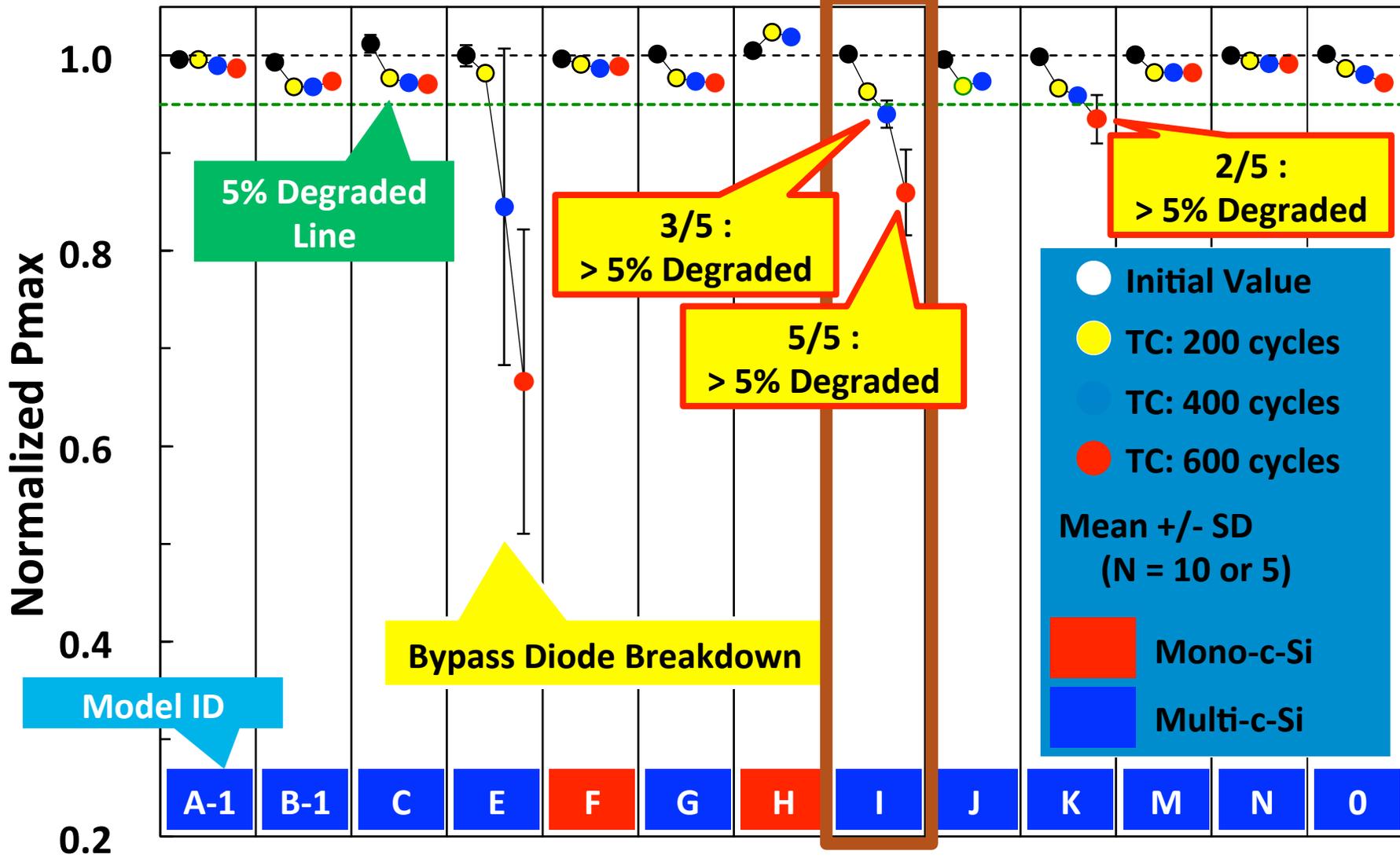


JET



ESPEC

# Extended Thermal Cycling: 13 Models (multi- / mono-c-Si, FY2011~)



Asia Standards and Conformity Assessment Promoting Project (JP), 2011-2014

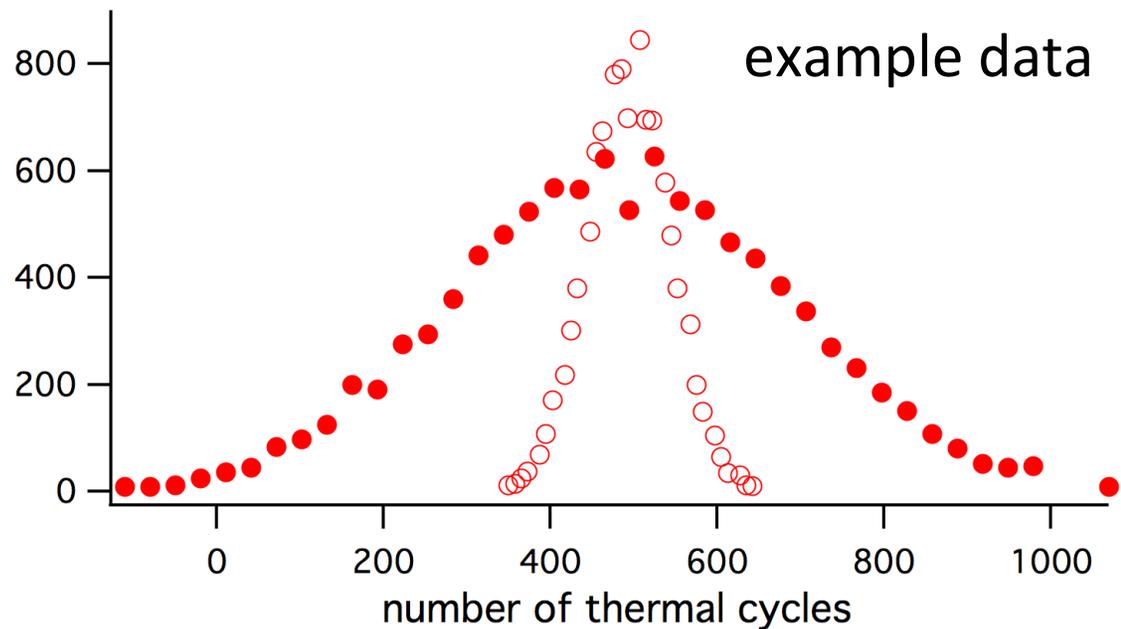
# thermal cycling: current work

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## Uncertainty analysis:

Monte Carlo simulation

Laminate material properties and geometry



# PVQAT TG2

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**TC:** 500 independent of climate zone

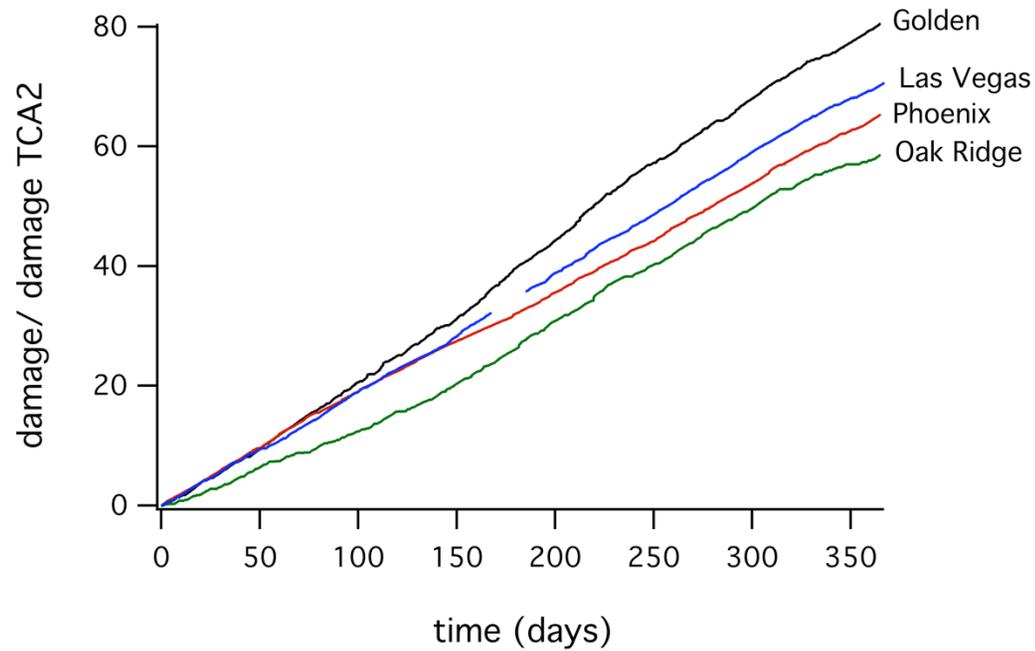
**DML:**  $\pm 1$  kPa, 1000 cycles in UV/TC/HF/DH sequence

**Challenge:** Failures are typically due to a quality excursion

\*Meier, R., et al. Reliability of copper-ribbons in photovoltaic modules under thermo-mechanical loading. Photovoltaic Specialists Conference (PVSC), 2010 35th IEEE.

# simulating an entire year

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A year in Oak Ridge, Tenn. does 70% as much damage as a year in Golden, Colo.