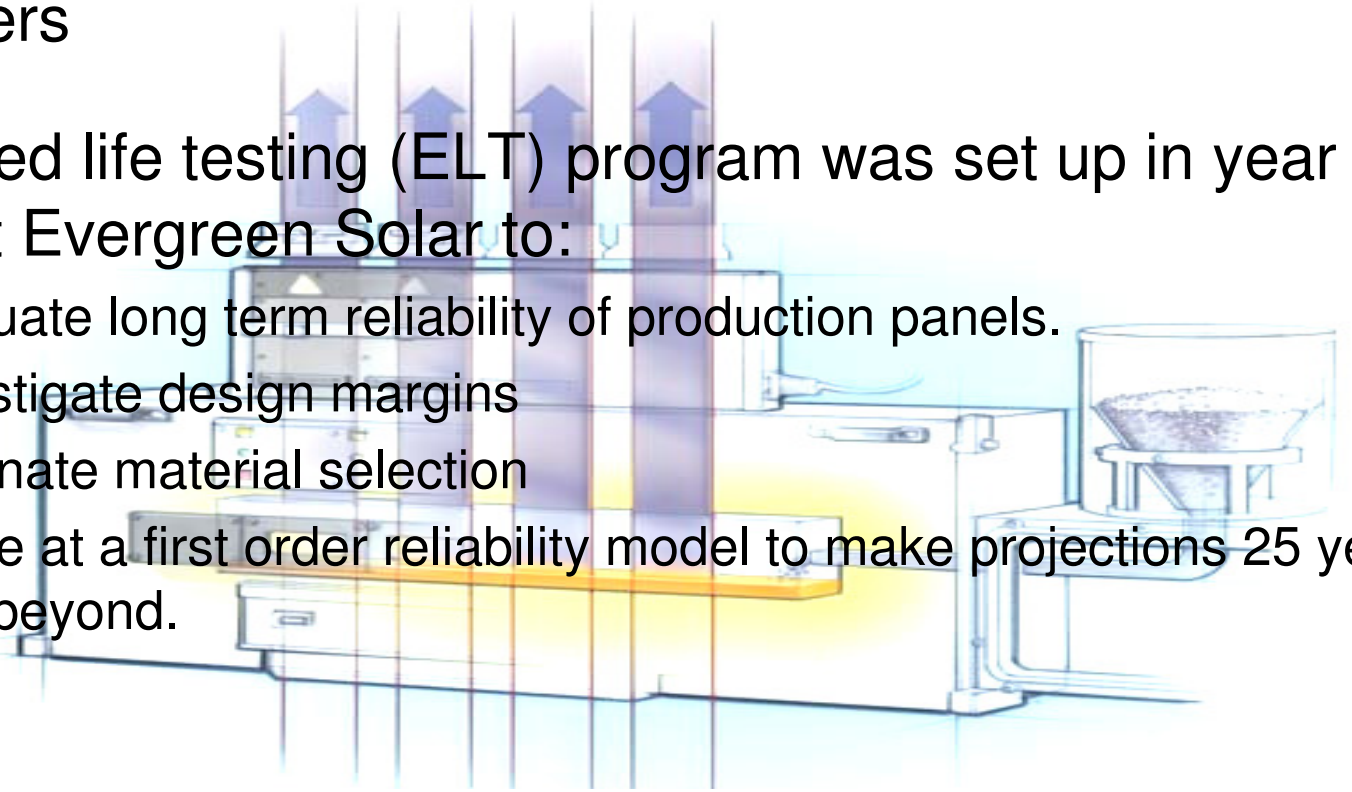
Extended Life Testing of multi-crystalline Silicon PV Modules

Vivek Gade
John Wilson

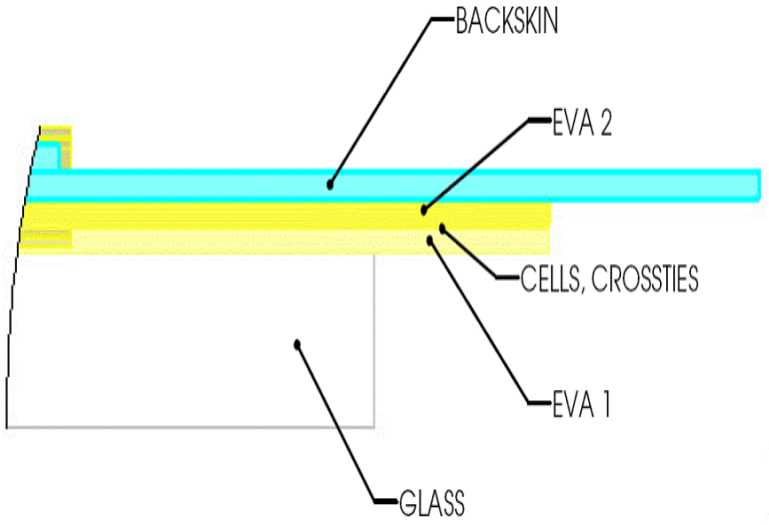
Goal & Background

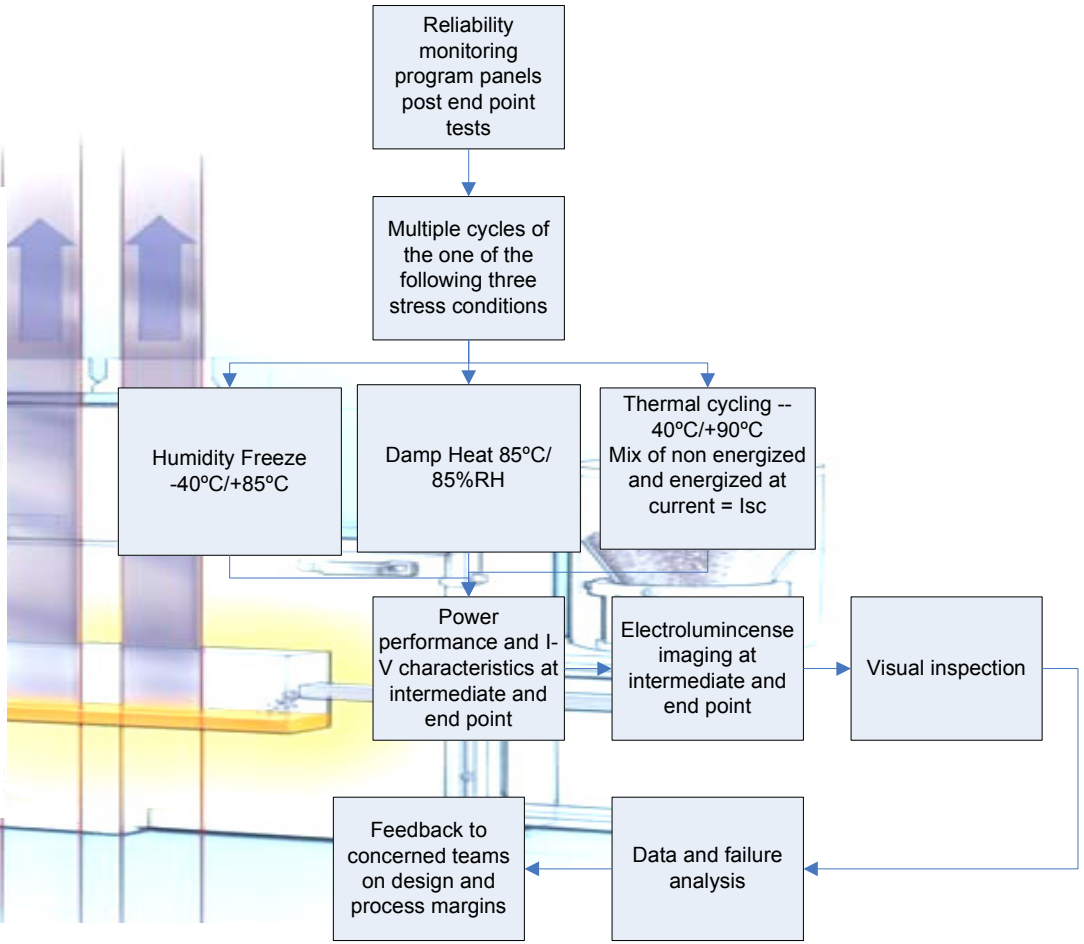
- Obtain quantitative information about long term reliability of Crystalline Si photovoltaic (PV) modules using accelerated testing in environmental temperature-humidity chambers

- Extended life testing (ELT) program was set up in year 2009 at Evergreen Solar to:
  - Evaluate long term reliability of production panels.
  - Investigate design margins
  - Alternate material selection
  - Arrive at a first order reliability model to make projections 25 years and beyond.



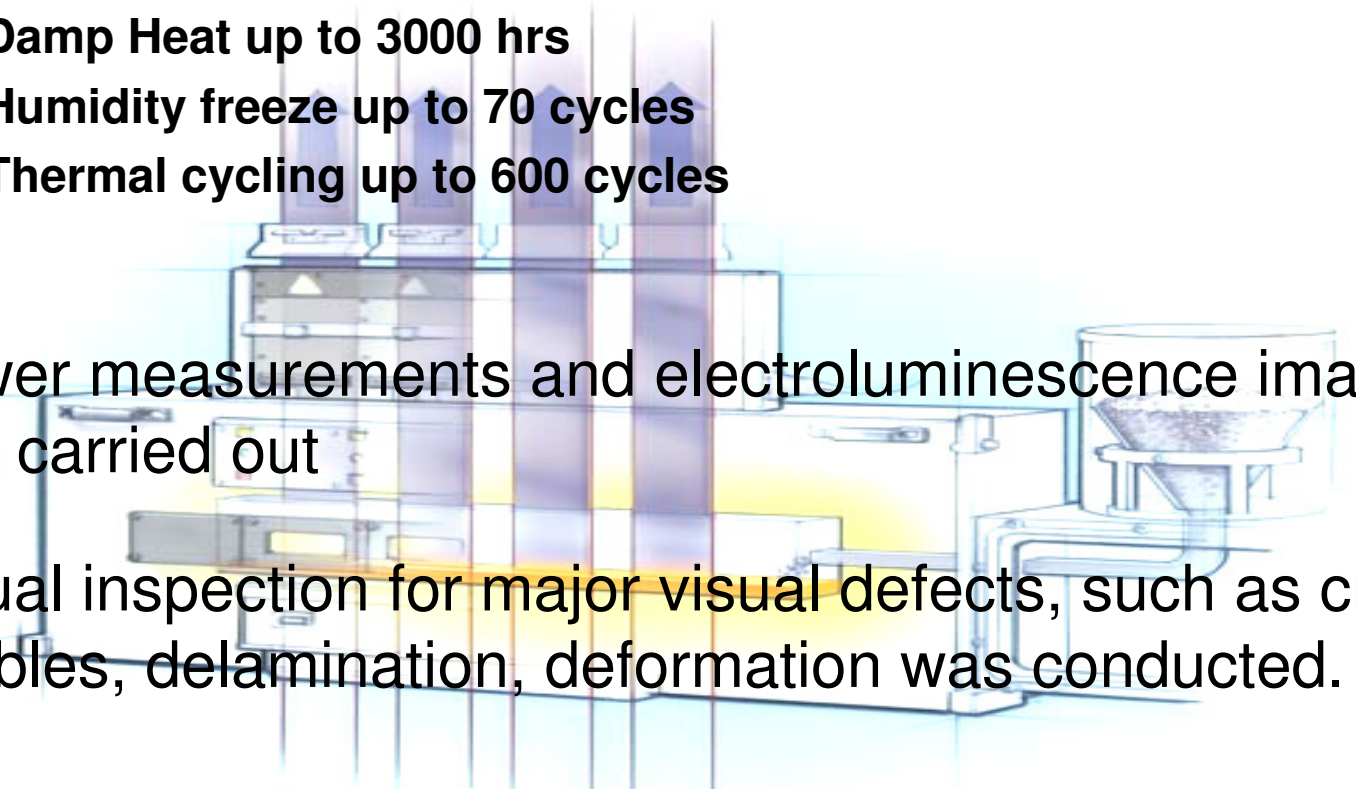
Solar module stack up and ELT flowchart





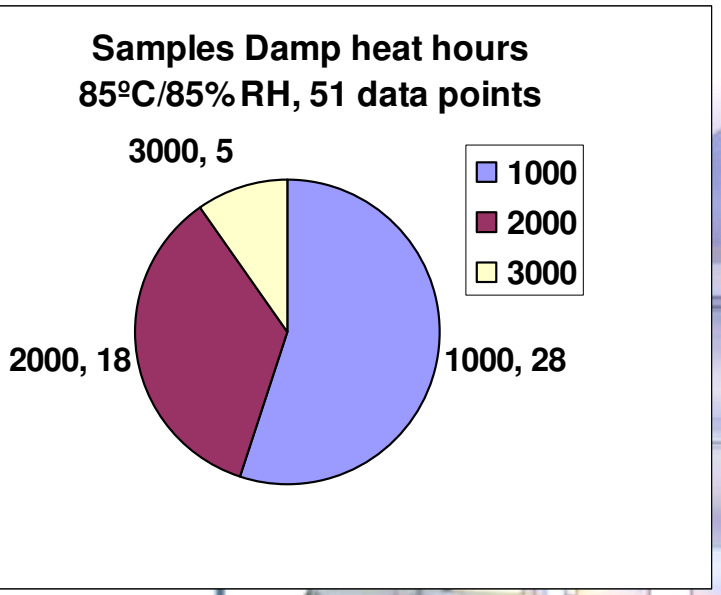
Experiments

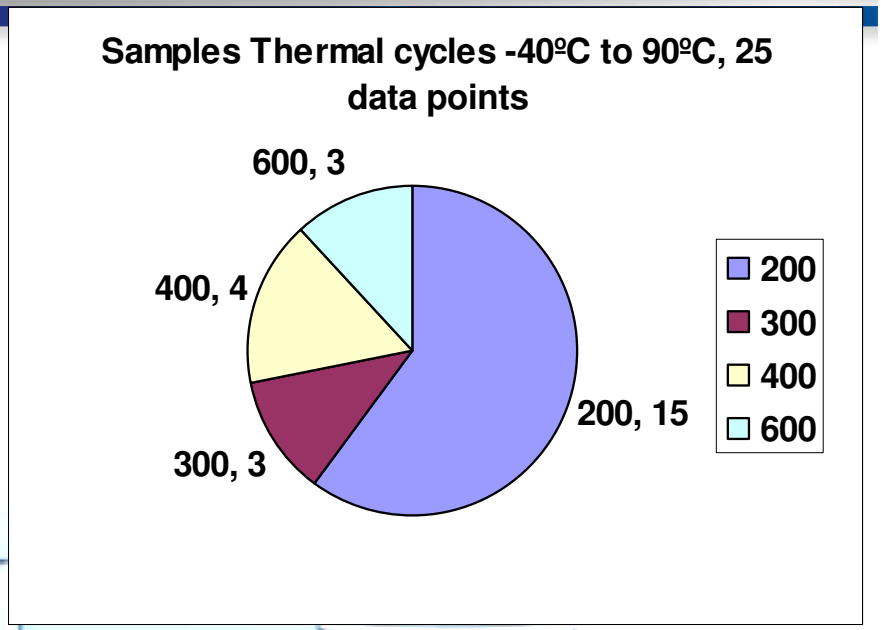
- Panels picked at random from production line were subjected to following tests as a part for extended life testing program at Evergreensolar:
  - **Damp Heat up to 3000 hrs**
  - **Humidity freeze up to 70 cycles**
  - **Thermal cycling up to 600 cycles**

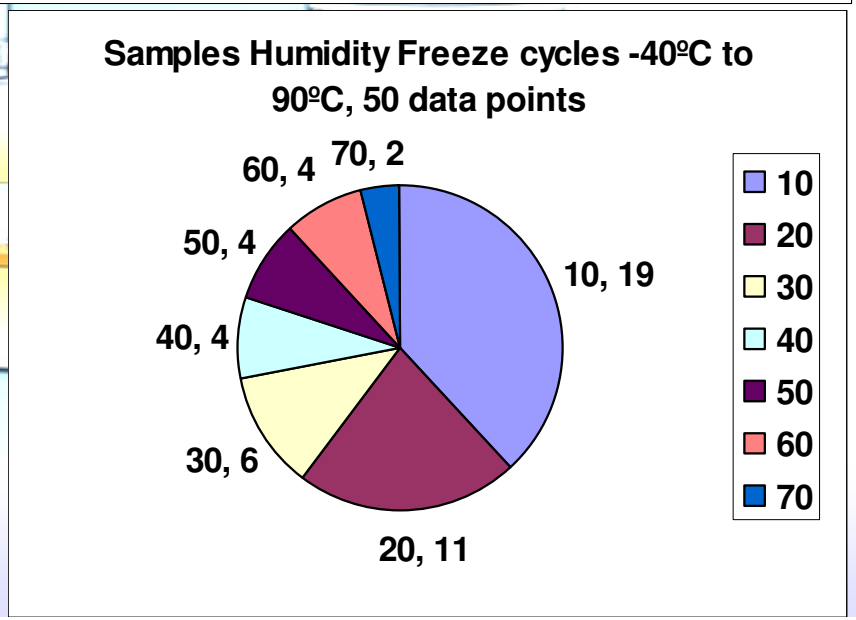


- Power measurements and electroluminescence imaging was carried out
- Visual inspection for major visual defects, such as cracks, bubbles, delamination, deformation was conducted.

Sample data points for model







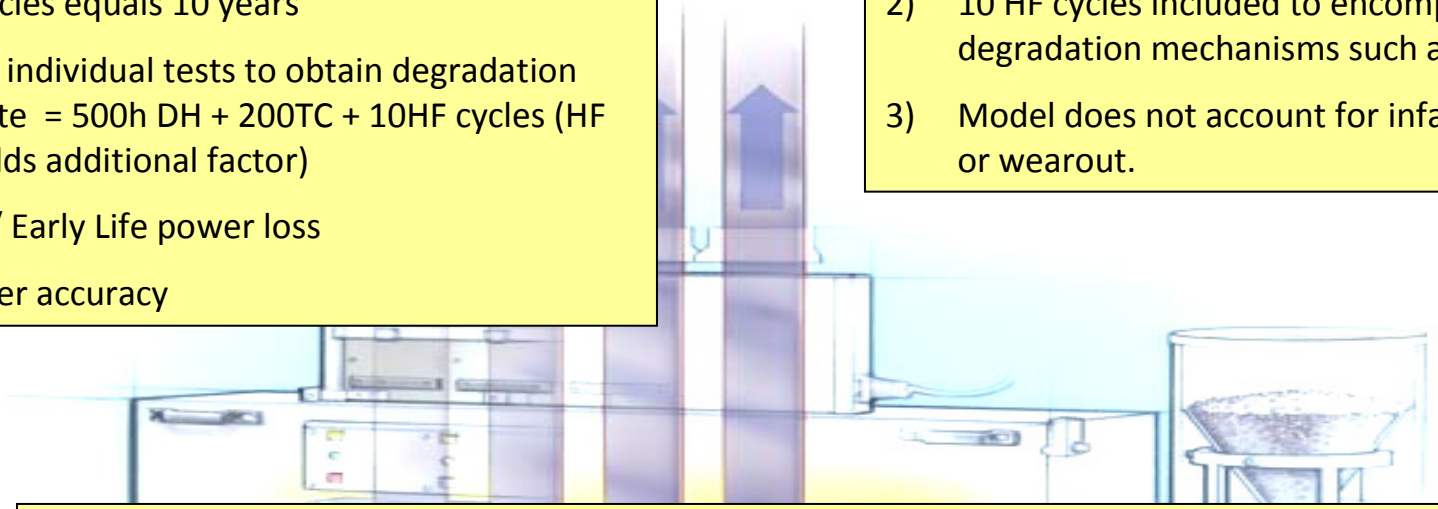
Degradation model

Model details:

1) From JPL study: 500 hrs DH equals 10 years
2) Per Industry available literature: 200 TC cycles equals 10 years
3) Sum individual tests to obtain degradation rate = 500h DH + 200TC + 10HF cycles (HF adds additional factor)
4) LID / Early Life power loss
5) Tester accuracy

Assumptions:

1) Model is based on best available industry and academic results.
2) 10 HF cycles included to encompass other degradation mechanisms such as UV
3) Model does not account for infant mortality or wearout.

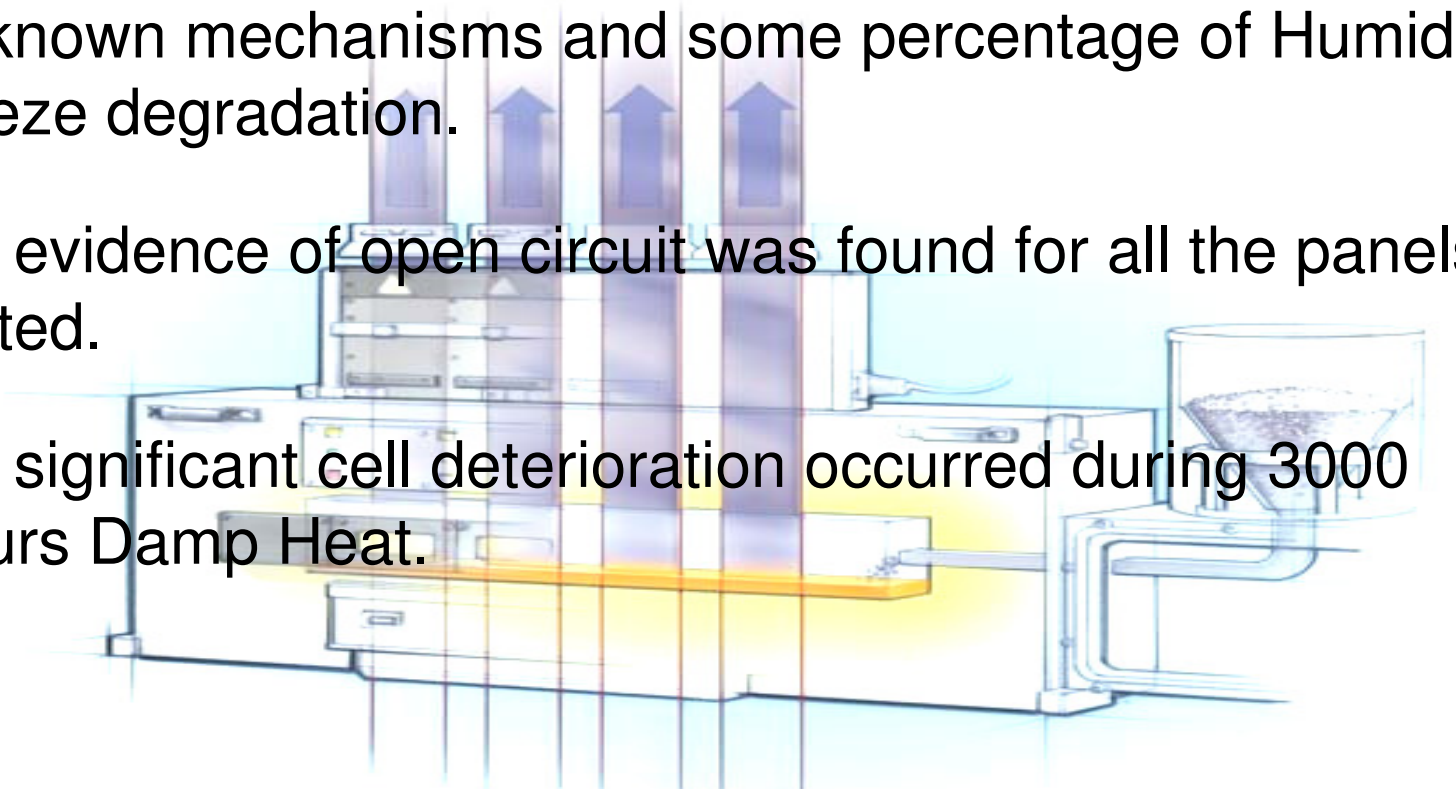


Risks & Limitations

1) Limited accelerated test data and field data on evergreen panels.
2) Data is continental / subtropical based; not to be applied to tropics
3) Model that relates accelerated tests to outdoor exposure not yet available in the industry.
4) Other unknown mechanisms may arise over the course of 25 years in field.

Conclusion and discussions

- Worst case scenario is considered in arriving at the model.
- UV related photodegradation is covered by factor for unknown mechanisms and some percentage of Humidity freeze degradation.
- No evidence of open circuit was found for all the panels tested.
- No significant cell deterioration occurred during 3000 hours Damp Heat.



Further studies

- FA is being conducted utilizing analytical techniques to investigate degradation modes.
- Cell extraction technique development is in progress to obtain complete cell for FA.
- Temperature, Humidity & Bias (THB) - Accelerated life testing including power being incorporated into program.
- HAST/HALT studies are being conducted to cut down the time and arrive at an acceleration factor.
- Combination of DH, TC and UV testing on panels is planned for year 2010.

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