

# Outdoor Accelerated Testing of PV Modules

Fall 2019 DuraMAT Workshop

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Avon, Colorado

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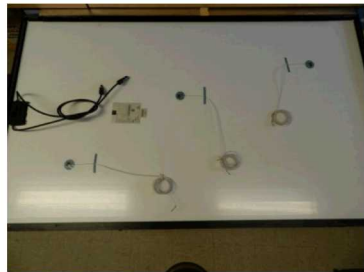
Sandia National Laboratories

# Outdoor Accelerated Testing of PV Modules - SPARK

Joshua S. Stein– Sandia National Laboratories

## Demonstration Project Areas

- **Low-cost accelerated testing of full sized modules**
- Multi-stressor acceleration demonstration on four modules
  1. Reference module
  2. Insulated back
  3. Insulated back with active heating
  4. Active heating and humidity
- All modules will be grid connected.
- Monitoring will include: Module temperature, DC current and voltage.
- Modules flash tested and EL imaged at start of test



RTDs on module backsheet



Heater blankets installed behind module



Insulation and backing over heat blankets

## Capability Area & Teaming

Capability Area(s): Accelerated Testing

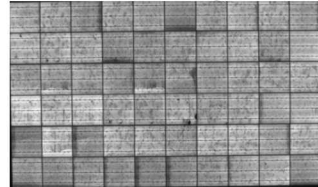
Team: Craig Carmignani, Craig One Feather, Doug Robb, Don Ellibee, Charles Robinson

## Technology Summary & Impact

Update and Status:

- Four Solar World 260 W poly modules selected
- Modules flashed, EL and UVF imaged before testing
- RTDs, insulation, and heaters installed
- Module 1-3 deployed and grid connected
- Module 4 setup (heat and humidity) is being being developed

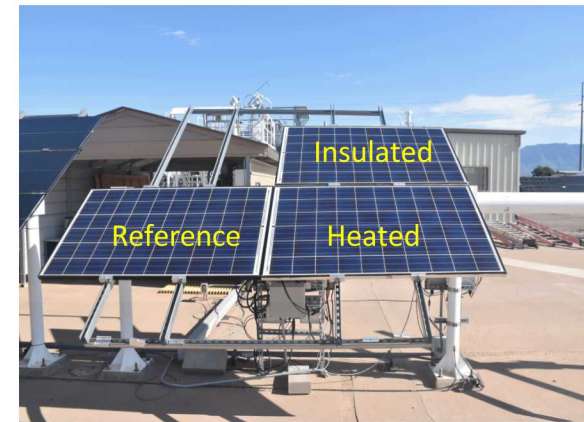
EL image



Back view with three modules installed



Front view with two modules installed



## Resources (\$)

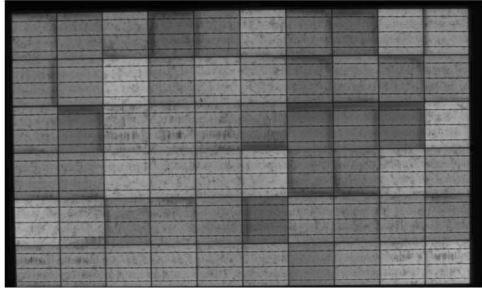
Period of Performance: 9 Months

Total Budget (per year): \$50,000

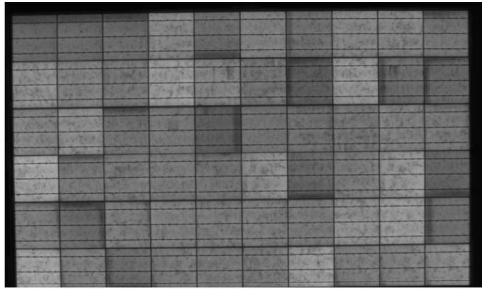


# Initial Module Characterization

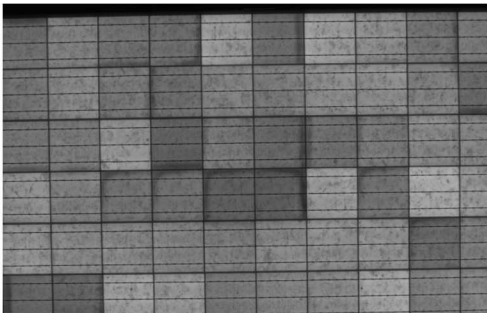
## EL (6/3/2019)



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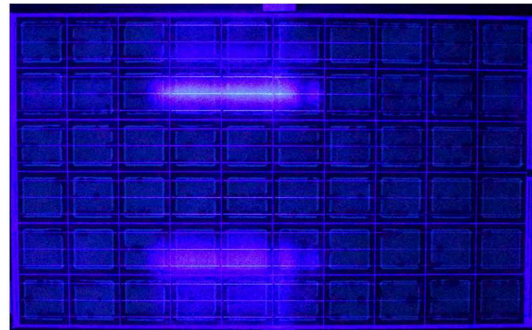
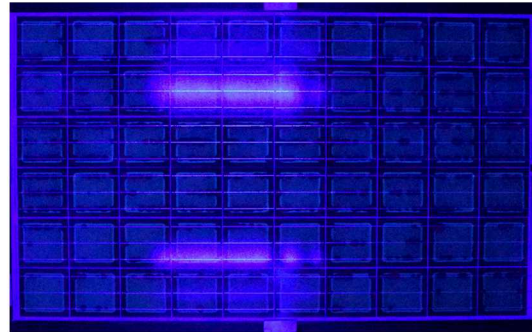
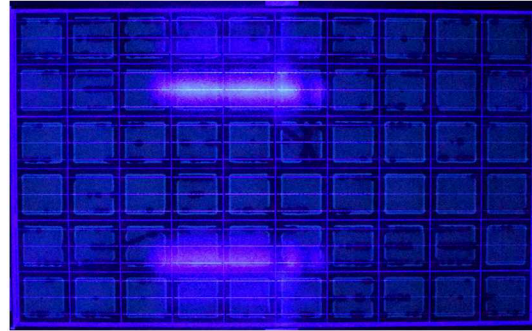


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## UVF (6/10/2019)



## Flash Tests (5/20/2019)

- $P_{max} = 257.3 \text{ W}$
- $I_{sc} = 9.05 \text{ A}$
- $V_{oc} = 37.4 \text{ V}$
- $I_{mp} = 8.54 \text{ A}$
- $V_{mp} = 30.1 \text{ V}$

- $P_{max} = 256.5 \text{ W}$
- $I_{sc} = 9.01 \text{ A}$
- $V_{oc} = 37.3 \text{ V}$
- $I_{mp} = 8.52 \text{ A}$
- $V_{mp} = 30.1 \text{ V}$

- $P_{max} = 256.8 \text{ W}$
- $I_{sc} = 9.04 \text{ A}$
- $V_{oc} = 37.3 \text{ V}$
- $I_{mp} = 8.54 \text{ A}$
- $V_{mp} = 30.1 \text{ V}$

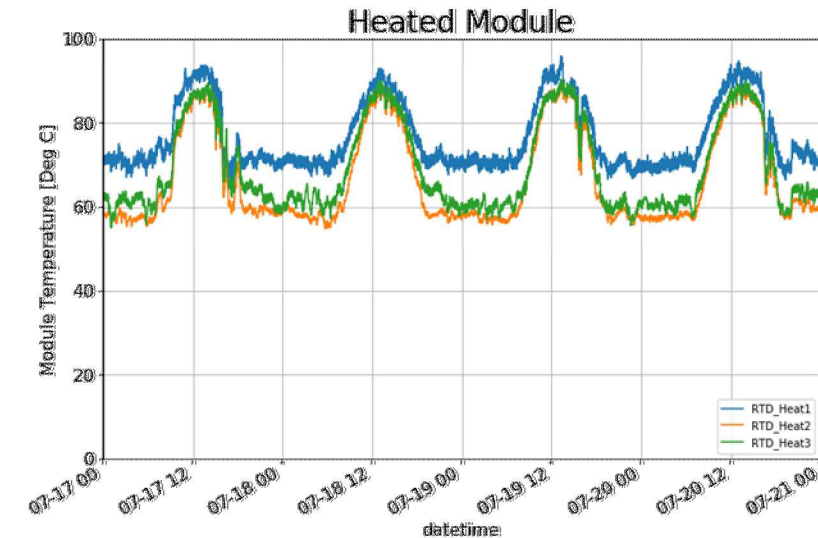
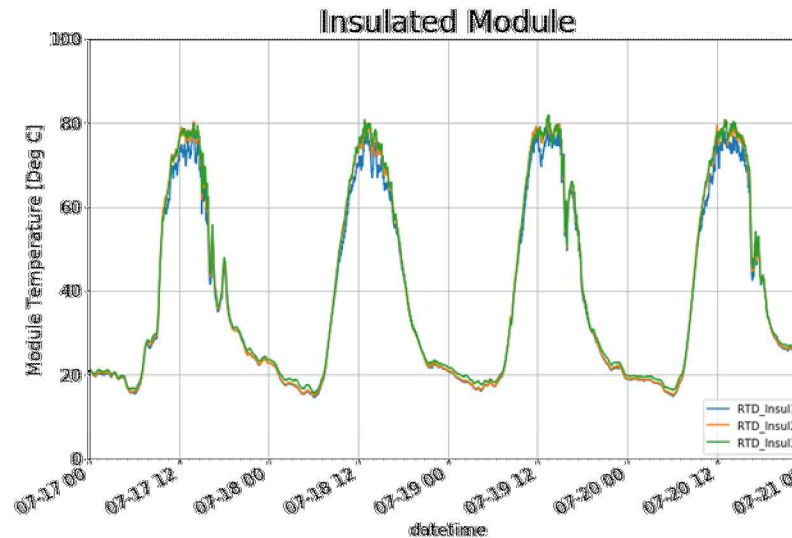
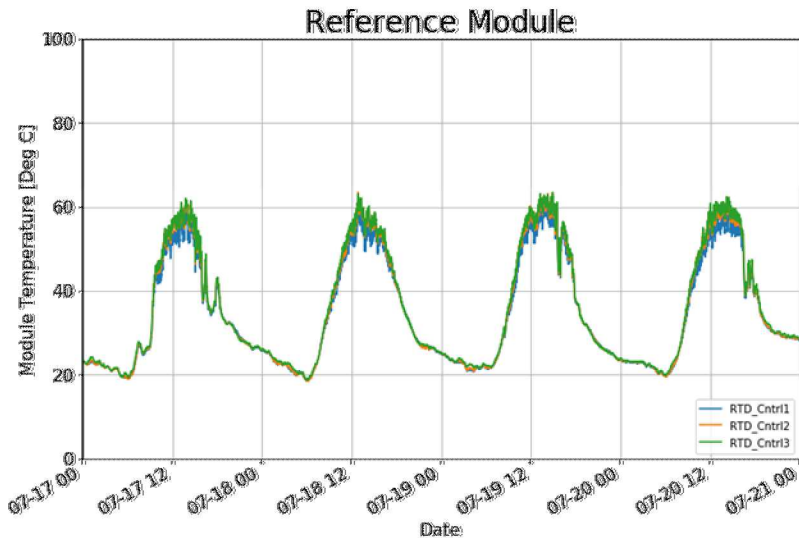
# Initial Accelerated Module Temperature Results

Test data collected since July 11, 2019 (38 days analyzed)

- Reference module exhibits max temperatures of ~60 deg C
- Insulated module exhibits max temperatures of ~85 deg C
- Insulated and heated module reaches max temperatures of ~95 deg C
  - Heater also increases temperatures at night from ~20 deg on the reference to between ~60-75 deg in the heated module.
- Heated module does exhibit variability in the measured temperatures
  - May be due to uneven thermal contact between heater and back of module.

Average Module Temperatures (including night)

| Sensor | Reference | Insulated | Heated |
|--------|-----------|-----------|--------|
| RTD1   | 31.9      | 36.1      | 73.7   |
| RTD2   | 32.6      | 37.0      | 63.3   |
| RTD3   | 33.1      | 37.1      | 64.9   |

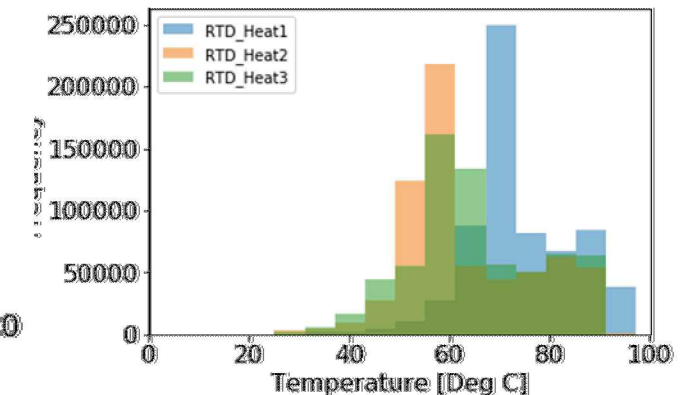
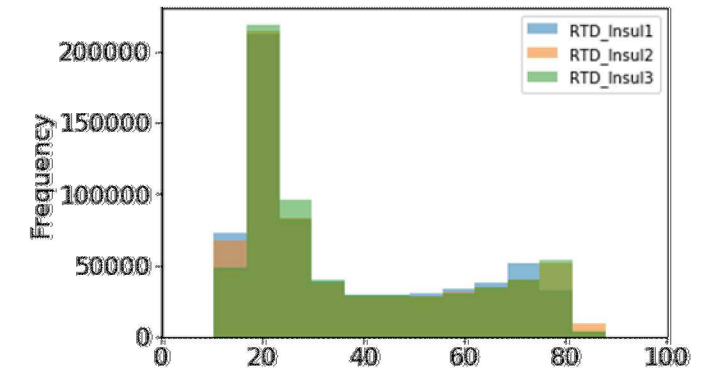
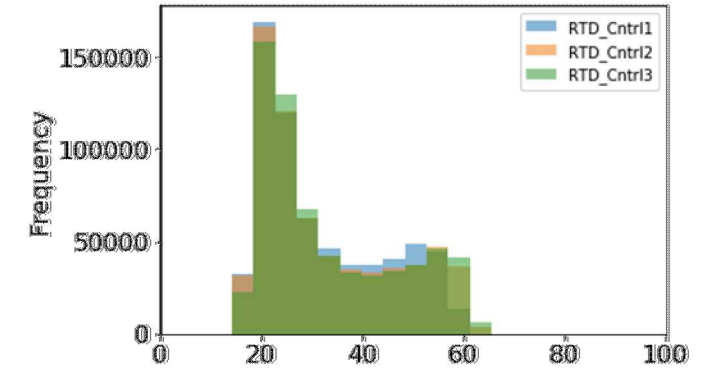
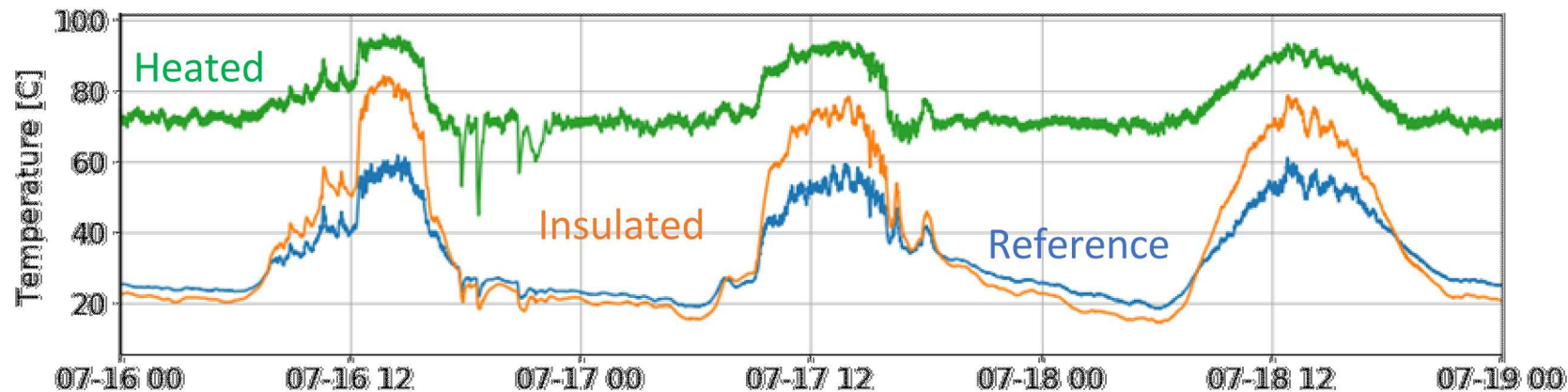




# Initial Accelerated Module Temperature Results

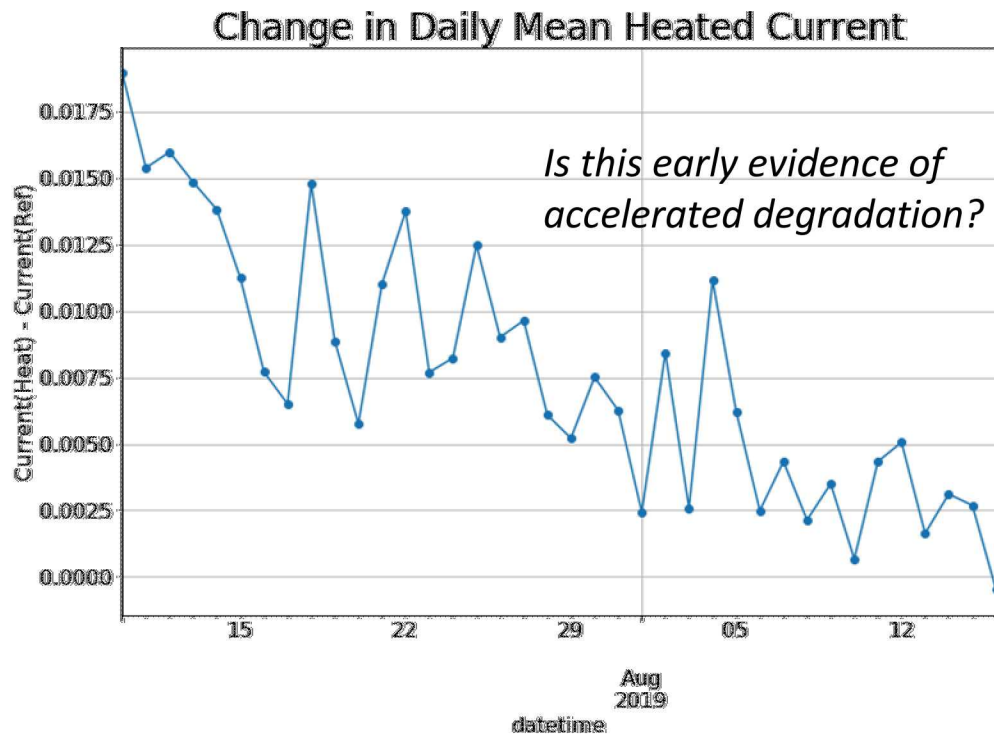
Histograms of module temperatures over 38 days

- Insulation only increases temperature during the day when sun is shining.
- Insulation also decreases temperature at night time (effect of radiance to cold sky)
- Heated module has increased temperatures all the time
- Heated module temperatures are not as uniform.

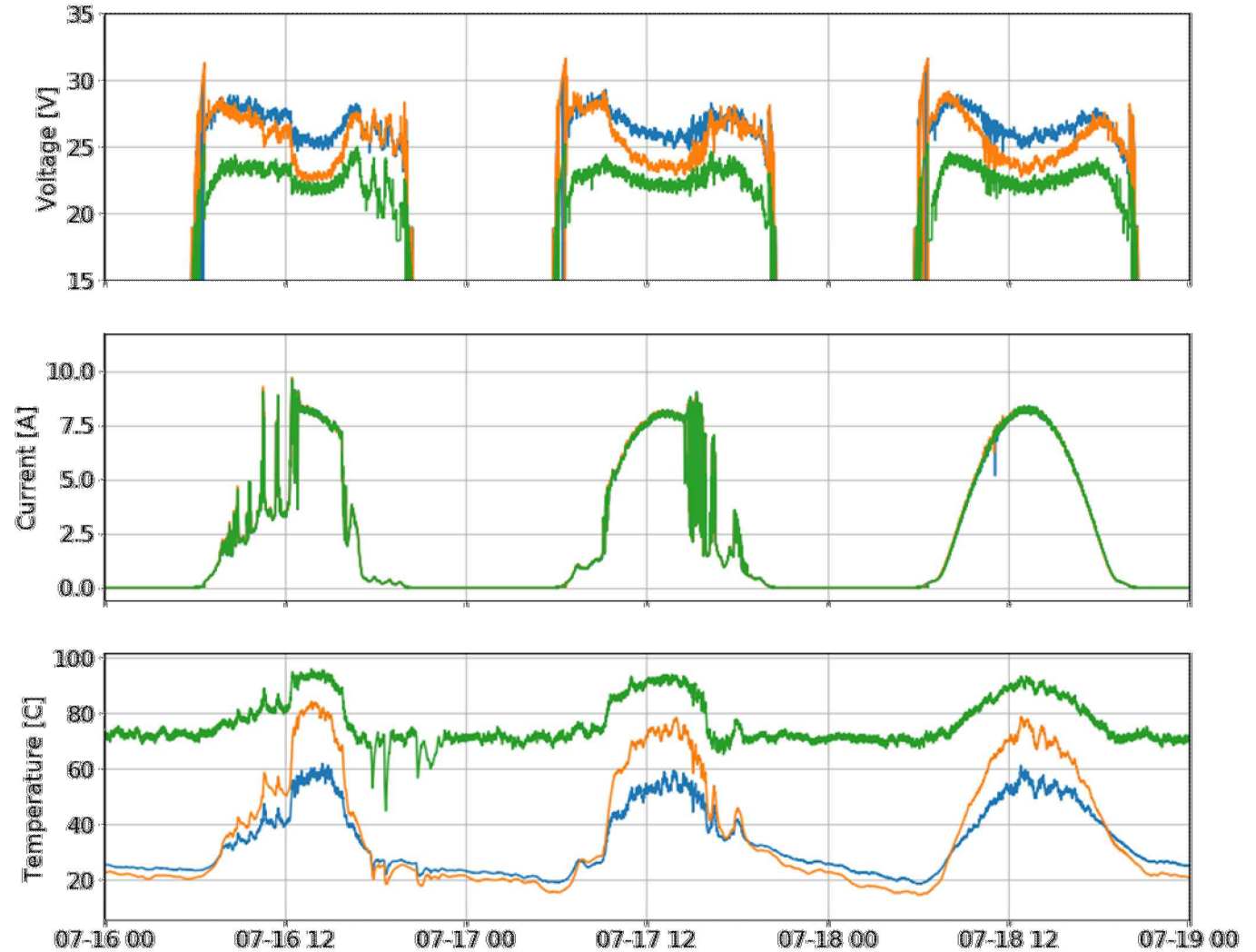


# Initial Electrical Monitoring Results

- Elevated temperatures result in lower measured voltage, as expected.
- Daily average current in the heated module appears to be decreasing faster than the reference module.



## Example Electrical Performance Results



# Next Steps and Issues

- Project has reached its budgetary limit of \$50k.
  - Re-scoped from an initially proposed project budget of \$250k.
- We have completed 3 out of 4 of the module deployments (due primarily to use of student labor)
- Elevated humidity module is nearly complete
  - Chamber is built, needs to be painted
  - Equipment (heaters, pump, tank, sensors) are purchased but need to be installed.
- Sandia will use some of its DuraMAT management budget (\$4-5k) to complete the work.

