Solar Cell Installation Using Double Sided Polysiloxane Pressure Sensitive Adhesive (PSA) Polyimide Film

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Current Processes

- "Epoxy Method"
  - Apply polyimide sheet to the substrate
  - Mix CV-2568 (RTV silicone)
  - Create Mylar mask to contain spread of silicone
  - Apply silicone and skive excess
  - Set solar cell
  - Cure for several hours with heat in a vacuum bag

Time consuming:
Each side must cure before next side is started.

- "Solder Method"
  - Heat entire substrate
  - Apply solder
  - Set Solar cell
  - Cool

CTE Mismatch is exacerbated:
Solder joint is formed at +183°C while satellite exterior can reach large negative temperatures

What if you just wanted to get it done quickly….

Alternate Method

NuSil CV4-1161-5

- One part Pressure Sensitive Adhesive (PSA)
- 0.002” sheet of polyimide film coated on both sides with 0.015” of CV-1161 adhesive
- Total thickness: 0.005”
- Temperature range: -115°C to +260°C
- CV-1161 soluble in ethyl acetate (datasheet - to be confirmed)
  - Items can be removed, days or even weeks after bonding
- No solvents, water or heat is necessary to activate the adhesive
- Solar cell works well bonded →large ratio of bond area to weight

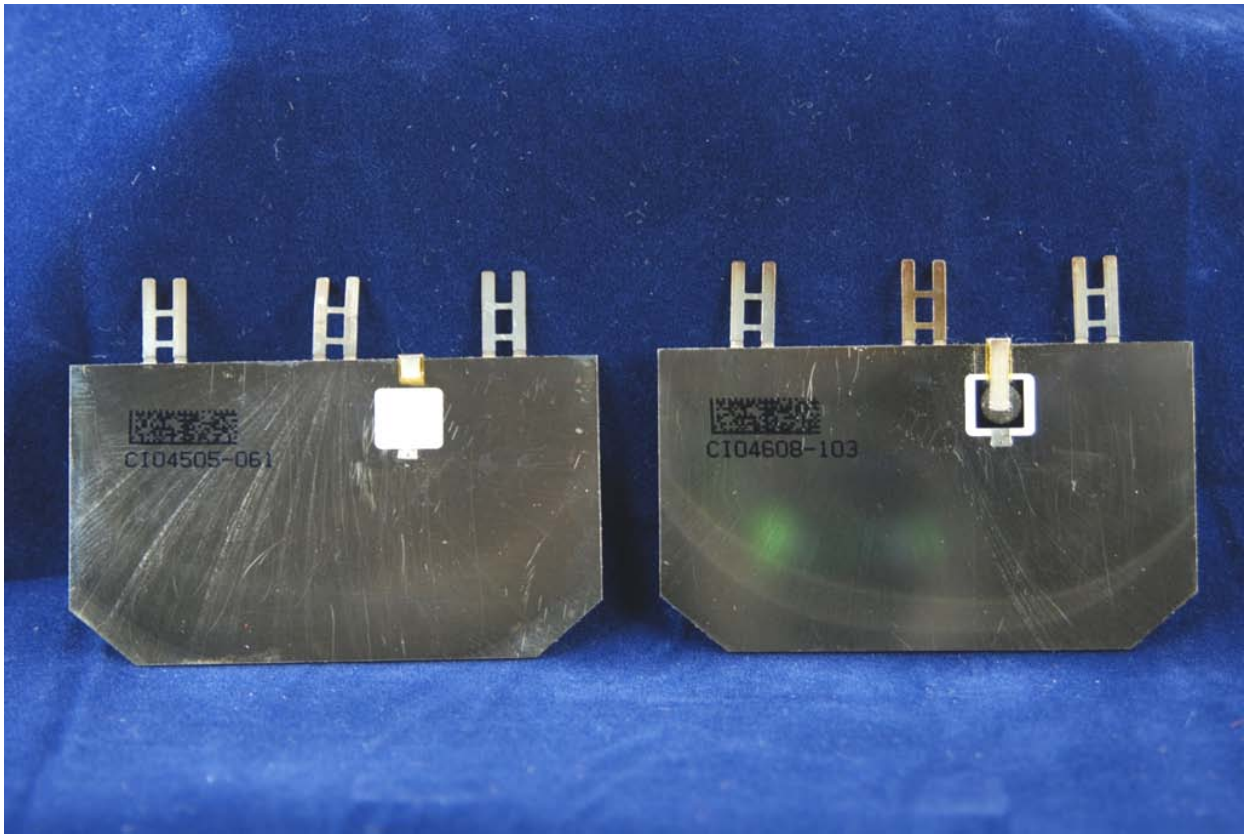
Cross Section of a Typical Assembly

Side view of associated layers (The white layers are adhesive layers present on the polyimide tape). Cutouts accommodating surface features are not shown

PSA Solar Cell Laydown – Step Summary

1. Prepare surface of substrate so that it is flat (granite block with sandpaper or lap)
2. Remove solar cell backside features
3. Bond a silver foil contact to the back of cell using silver epoxy
   - Epoxy Technology - EPO-TEK® H20E
   - Allow to cure at 80°C for 3 hours
4. Cut and apply polyimide (Kapton) to substrate
   - Ensure application is “bubble free”
   - Cut to a size larger than the solar cell to provide electrical isolation of solder tabs from substrate
5. Cut and apply PSA film equal or slightly less than the size of the solar cell
   - Create template for die or hand cutting of PSA film
   - Provide cutouts that vent to the nearest edge of solar cell to accommodate surface features
     - Diodes, tabs, etc.
     - Failure to provide cutouts will result in a non-flat surface and added stress to the solar cell
6. Remove first release liner from Nusil CV4-1161-5 PSA film and apply to the back of the solar cell
   - Again, ensure application is “bubble free”
   - “Rolling” application of film ensures less chance for bubbles to become trapped
7. Remove second release liner from Nusil CV4-1161-5 PSA film and apply to a debris free surface of polyimide tape present on substrate
   - Press firmly on cell to ensure thorough bond between solar cell and substrate layers

Remove any Surface Features



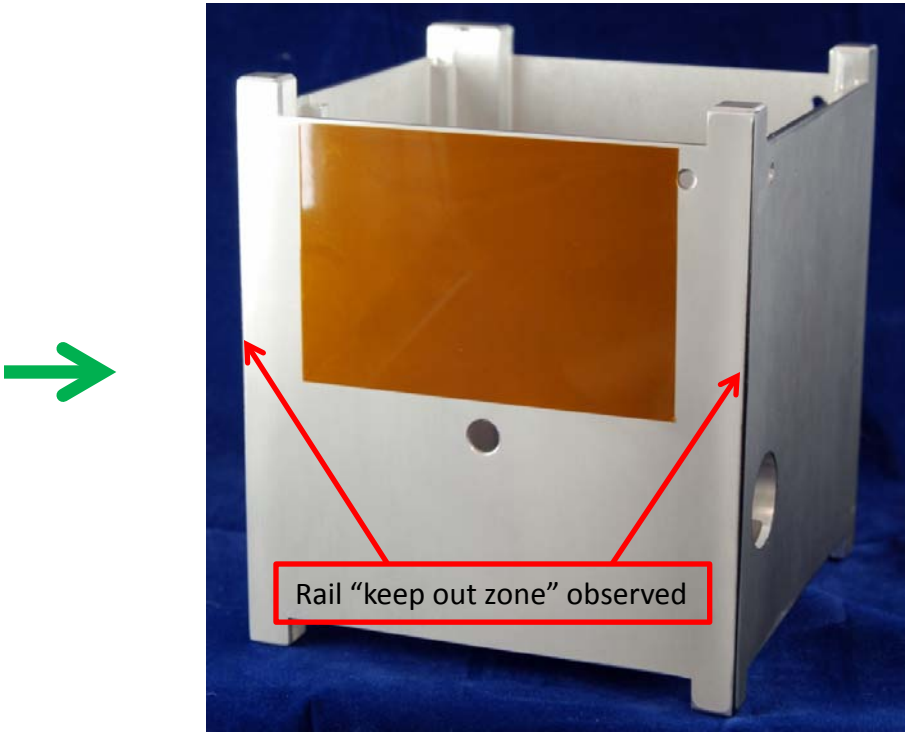
Diode removed

Diode present

Bond Silver foil Contact to Back of Solar Cell

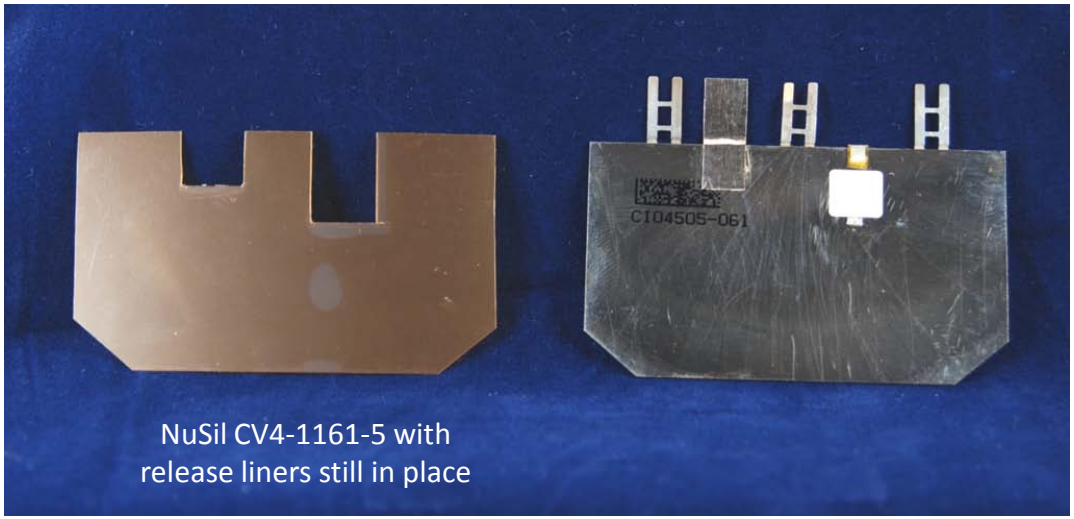
- Cut out silver tab equal to size of existing tab
- Apply to back of cell using silver epoxy (Epoxy Technology – EPO-TEK H20E)
- Allow to cure at 80°C for 3 hours
- Wipe excess epoxy to prevent unnecessary surface height that can cause distortion and stress of the solar cell surface when it is installed

Cut and Apply Polyimide Tape to Substrate



- Cut and apply polyimide (Kapton) to substrate
- Ensure application is “bubble free” using a “rolling method” of application
- Cut to a size larger than the solar cell to provide electrical isolation of solder tabs if substrate is conductive

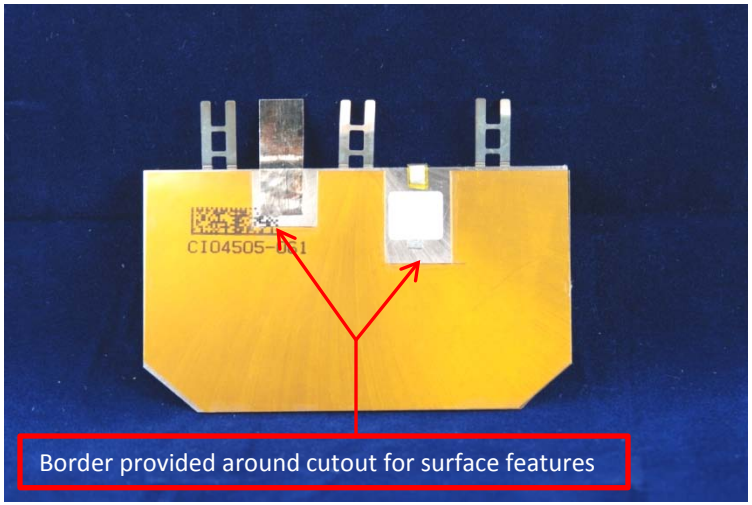
Cut PSA to Size

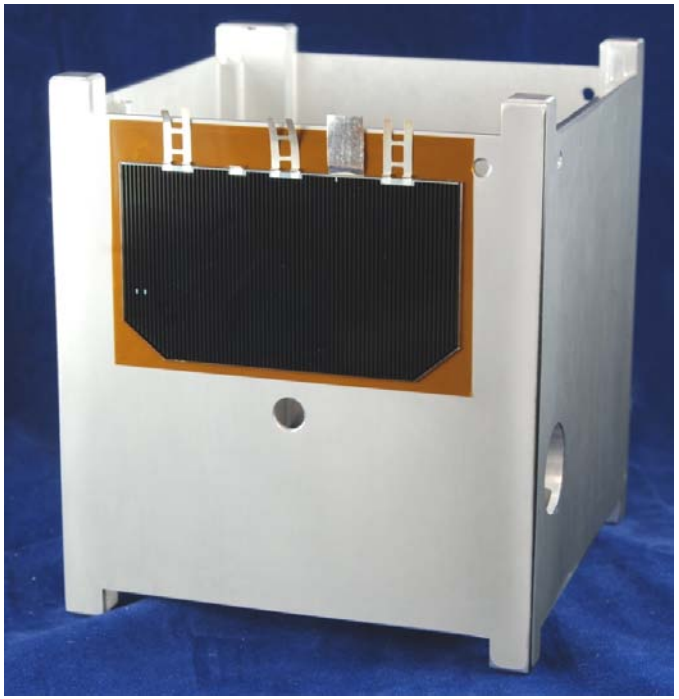


NuSil CV4-1161-5 with release liners still in place

- Cut out a sheet of NuSil CV4-1161-5 PSA film equal to the size of solar cell
- Create template
- Provide cutouts that vent to the nearest edge to accommodate surface features
- Diodes, tabs, etc.
- Failure to provide cutouts that vent will result in a non-flat surface and possibly air pockets which present a danger to “blowouts” under vacuum.

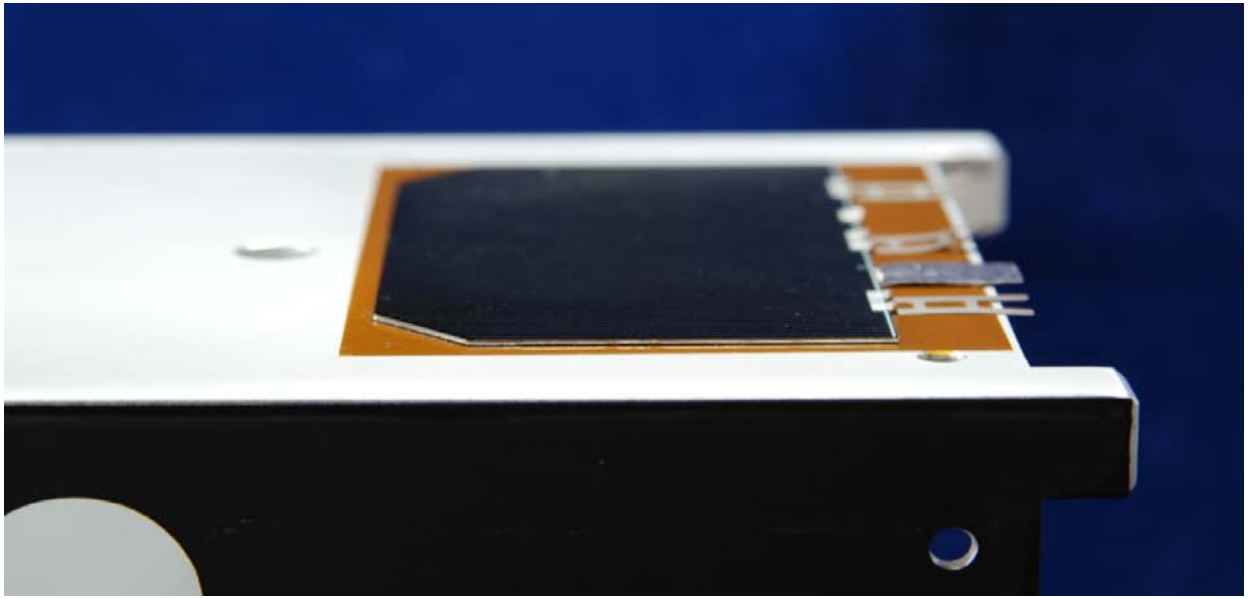
Apply Solar Cell + PSA to Substrate





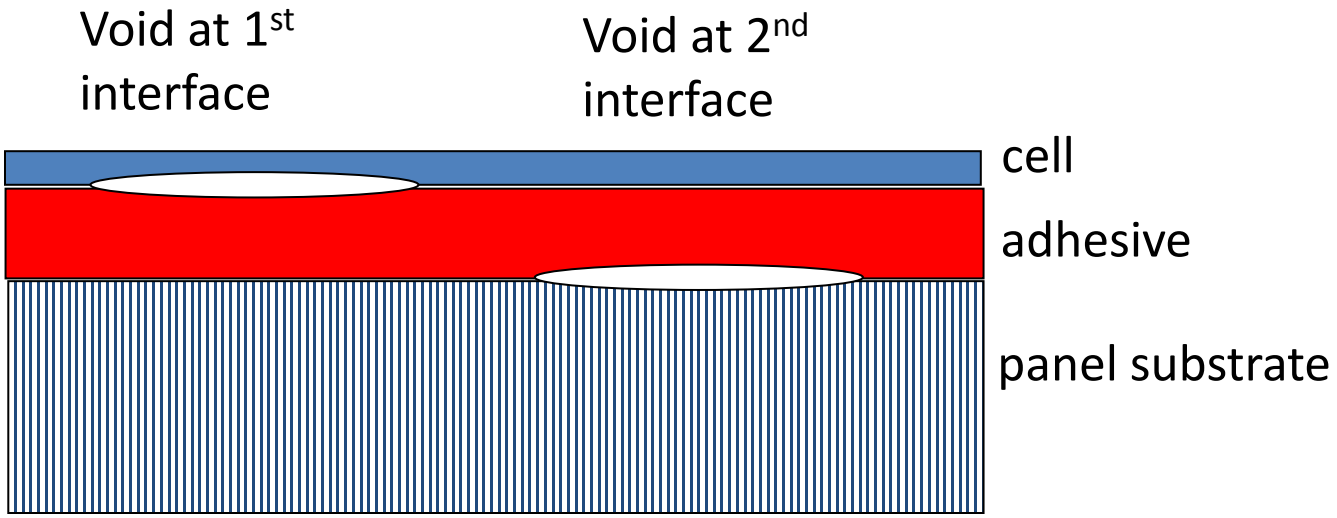
- Remove second release liner from PSA film
- Apply solar cell to the debris-free surface of polyimide tape
- Press the solar cell firmly with fingers to ensure a thorough bond
- Apply pressure across cell in the same direction to prevent creation of air pockets

Inspect

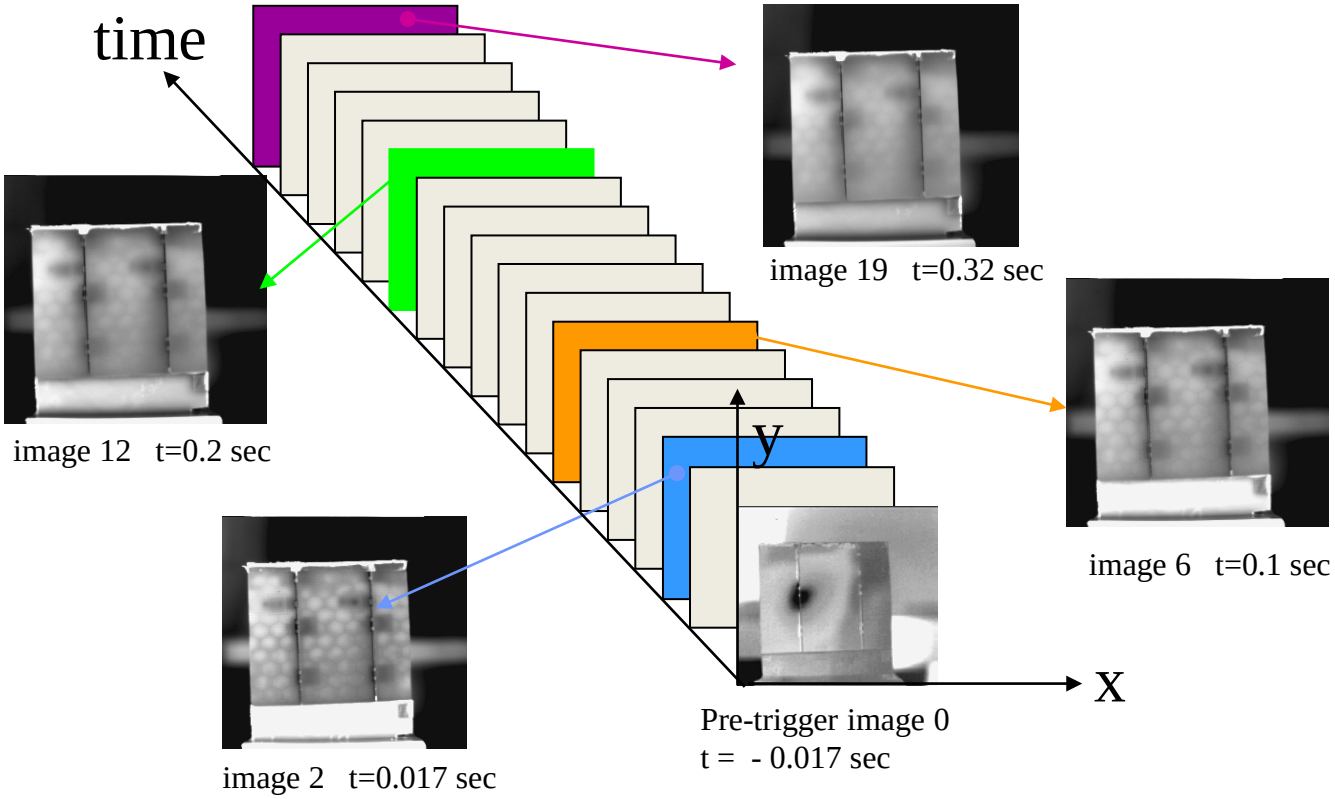


- Inspect the surface for cracks or surface distortion
- Surface distortion could mean that an air pocket may have been formed at the PSA to polyimide film interface
- Perform IR thermographic verification
- May have to remove using ethyl acetate if voids are found and process repeated

Types of Flaws

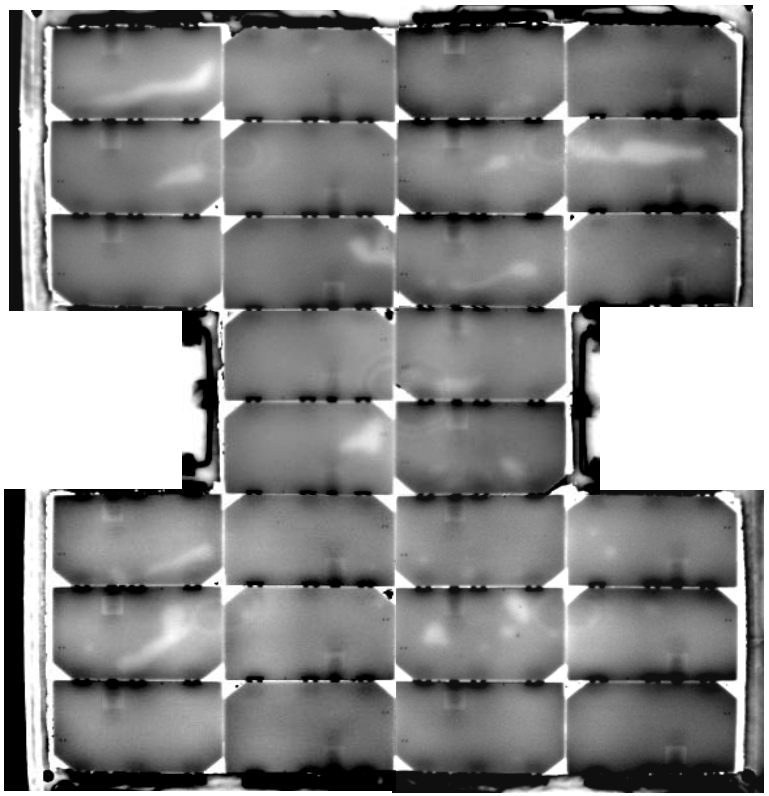


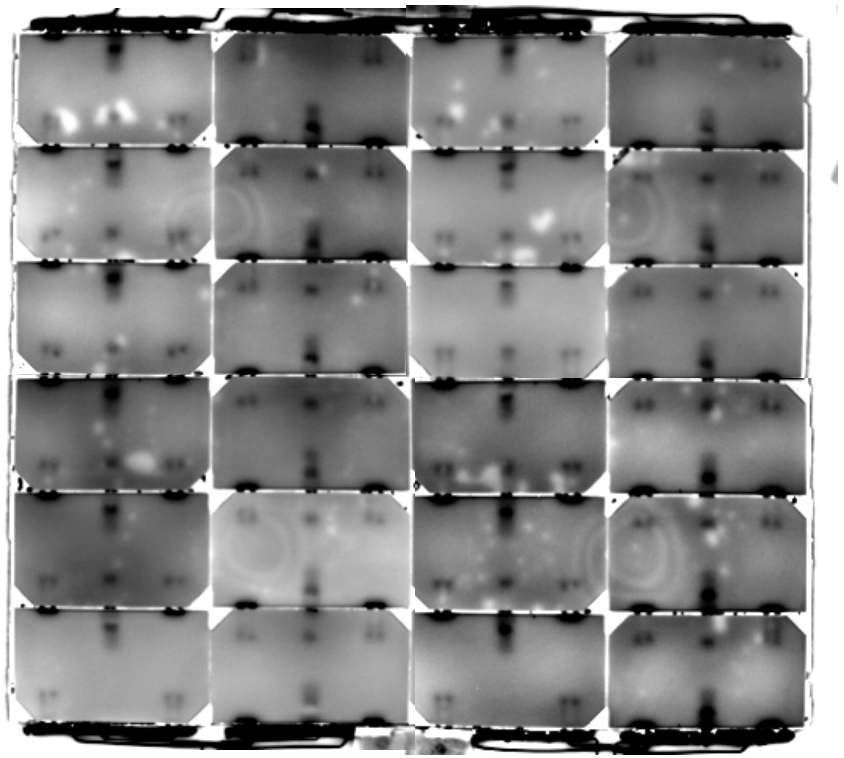
The Aerospace Corporation's (Aerospace) IR Thermography Inspection



- Aerospace images are 256 x 256 pixels with 14 bit resolution

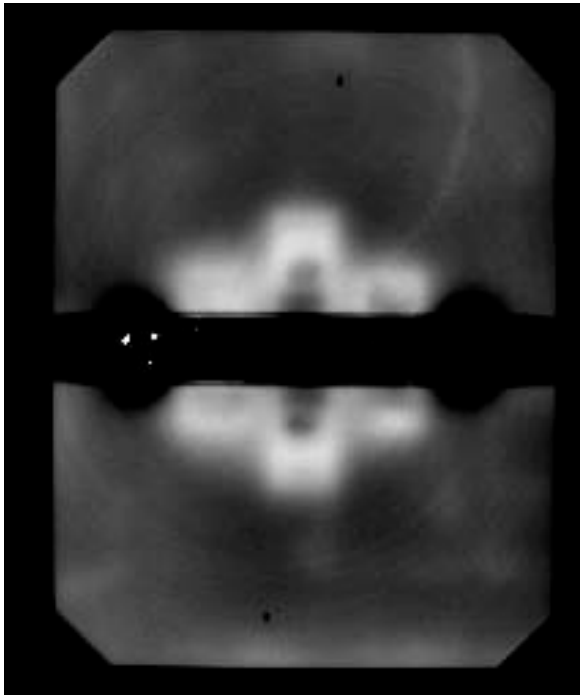
Example of Thermography (RTV silicone)



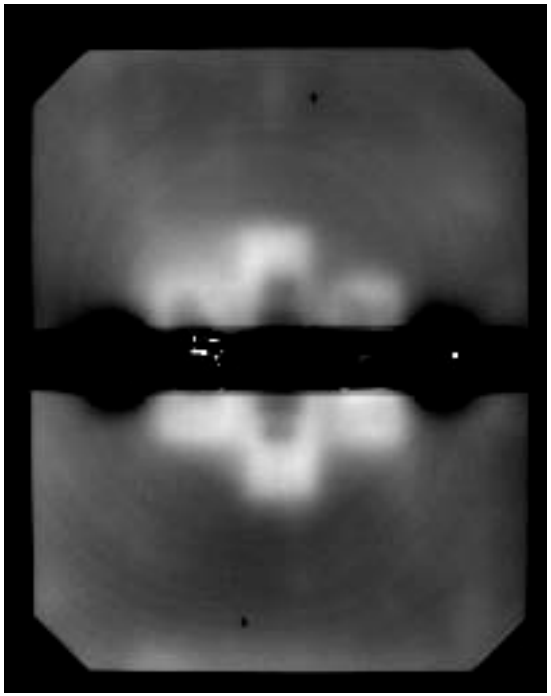


- Even the RTV silicone method by professionals, has voids.

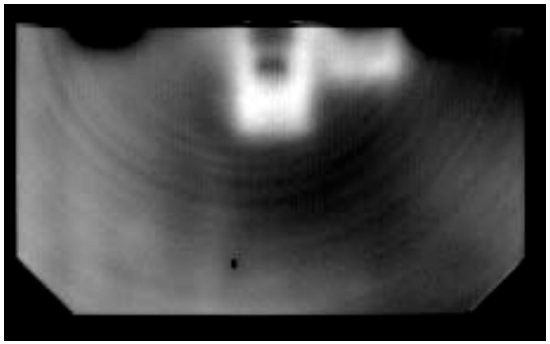
Thermography of AeroCube-3 Solar Cells



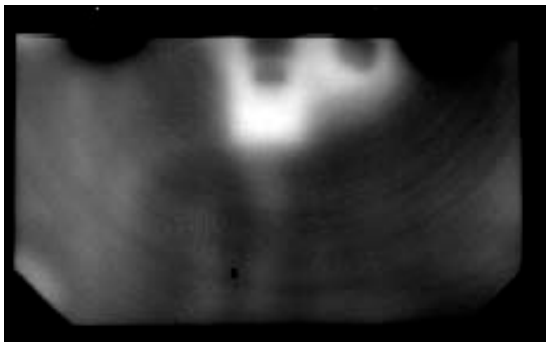
+X Face



-X Face



+Y Face



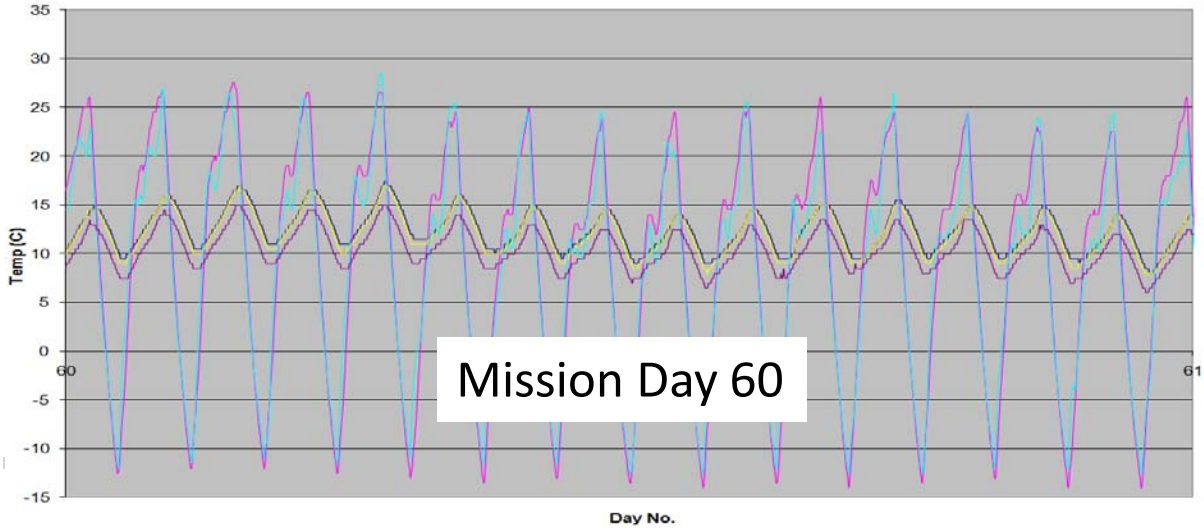
-Y Face

- White regions are areas of poor thermal conductivity (due to cutouts for diode and affixed solder tab)
- No regions of air pockets are grossly visible – Not bad!

AeroCube-3 Flight Performance Data

The Final Product – AeroCube-3

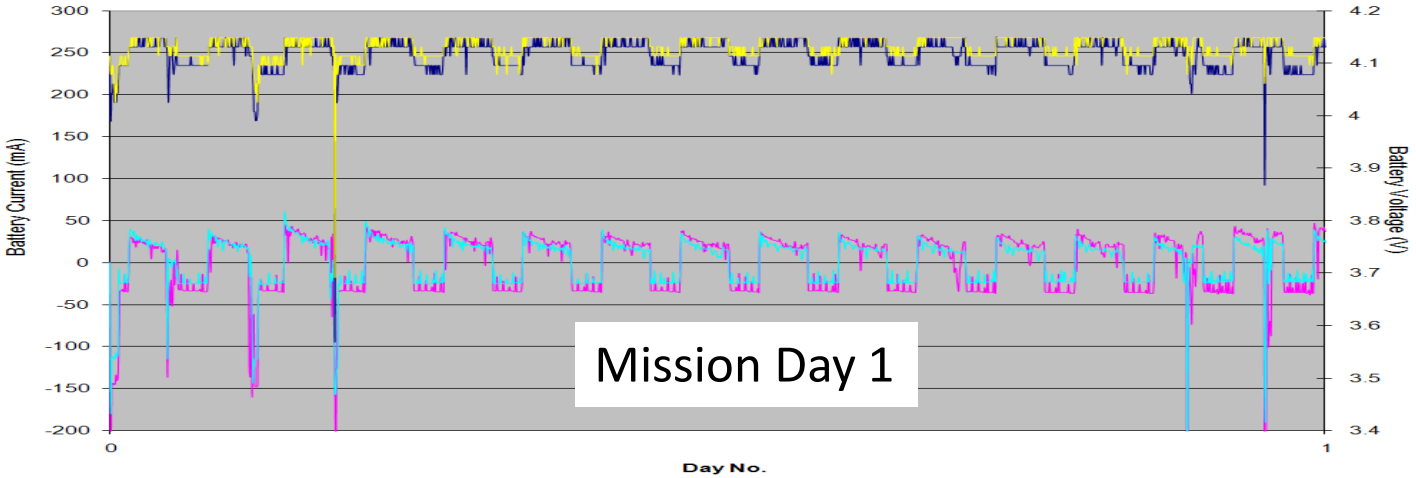
AeroCube-3 On-Orbit Temperature Data

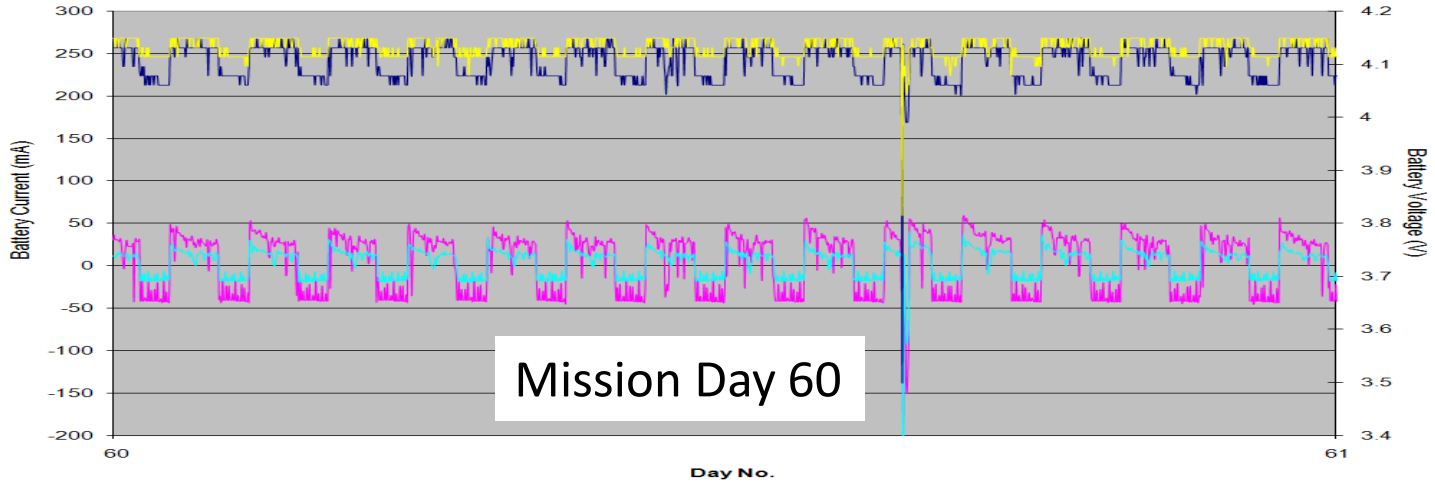


Blue / Pink lines are temperature sensors located on 2 different exterior walls of AeroCube-3

Yellow / Black / Purple lines are temperature sensors located on the electronics module

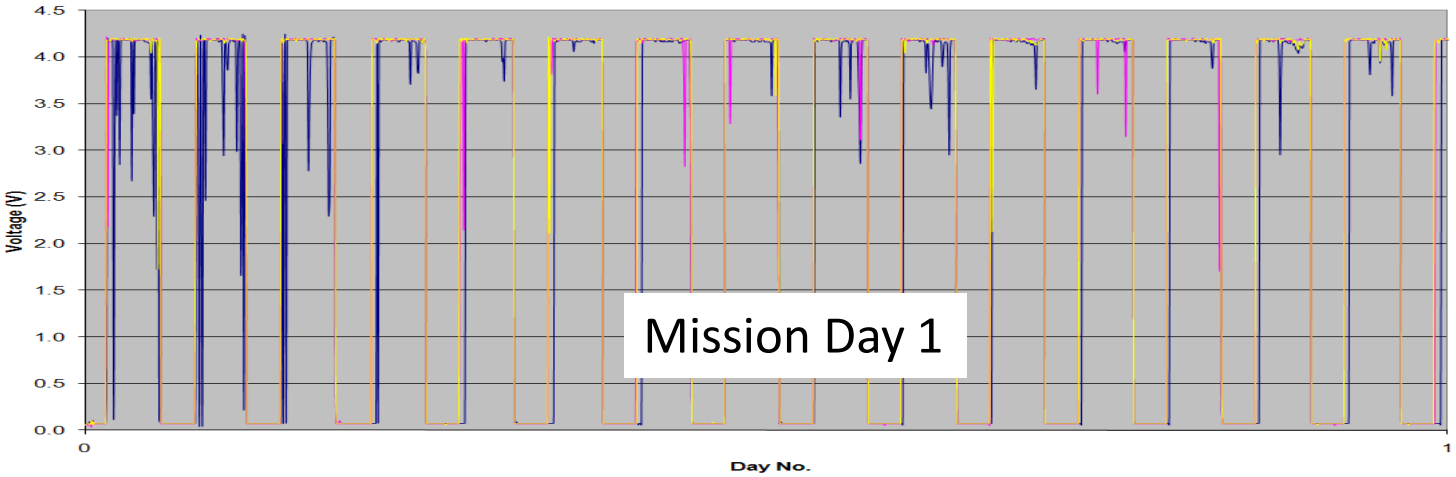
AeroCube-3 On-Orbit Battery Data

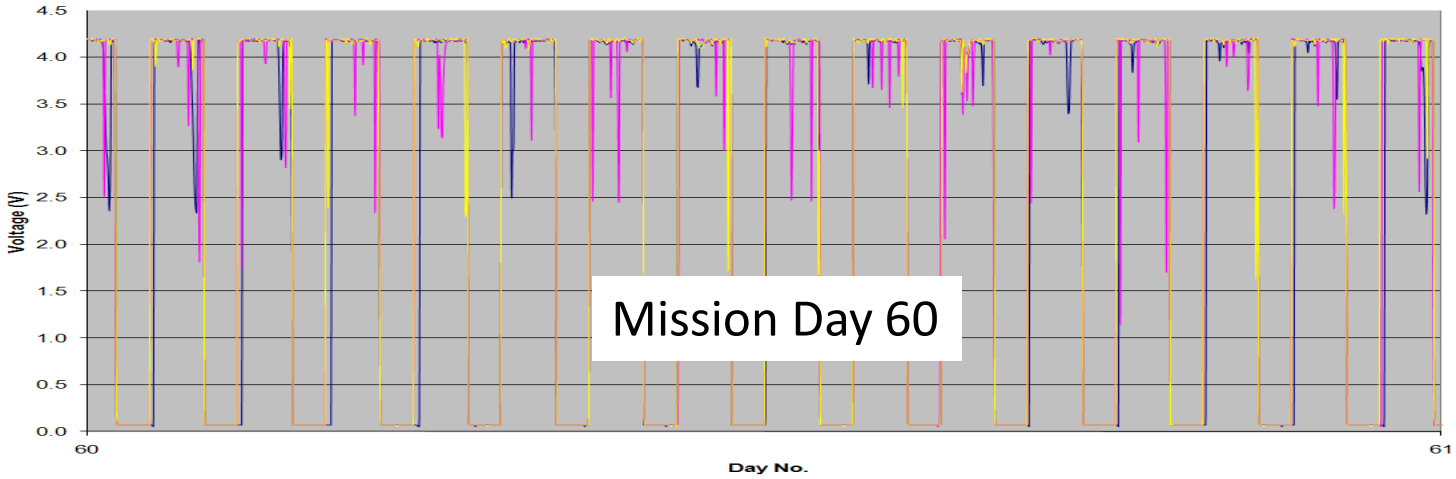




* Red circles indicate periods of contact

AeroCube-3 On-Orbit Solar Array Voltage





Summary

- PSA method is a low-tech method to install solar cells on your satellites
- No “messy” epoxies or other issues
  - Incorrectly mixed adhesives and/or incorrect cure times → premature debonding or incomplete bonding
- No long curing times under vacuum
- No exposure of panels to high temperatures
- An entire CubeSat can have solar cells assembled in 1 day

Acknowledgement

- This work was supported under the Aerospace's Independent Research and Development Program

Thank You.