Solar Cell CIC Optimization and Factorization for CXBN-2

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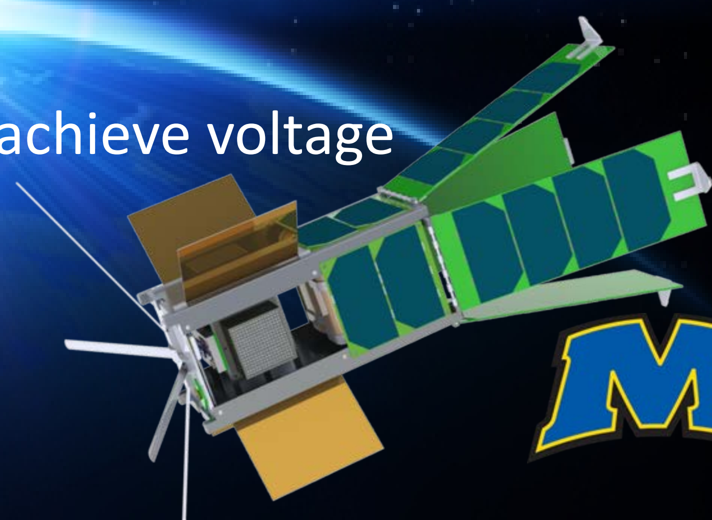
Why?

Dicing solar cells can be an effective method of optimizing surface area and packing factor on CubeSats , while providing the necessary wattage.

CXBN2’s solar panels will be tested to see if dicing solar cells and electrically connecting the string of diced cells in series will keep a positive power output for mission success.

Need to dice solar cells in order to achieve voltage matching for each string of cells.



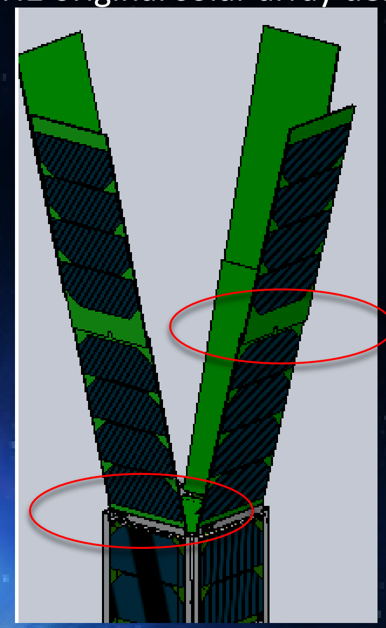
Purpose of CIC Dicing

<u>CIC</u>- Solar Cell Interconnects Coverglass

This project will involve dicing the solar cell CIC to satisfy the small satellite system requirements while having the most effective surface area and providing the necessary wattage.

CXBN-2 Solar Cell System

CXBN2 original solar array design

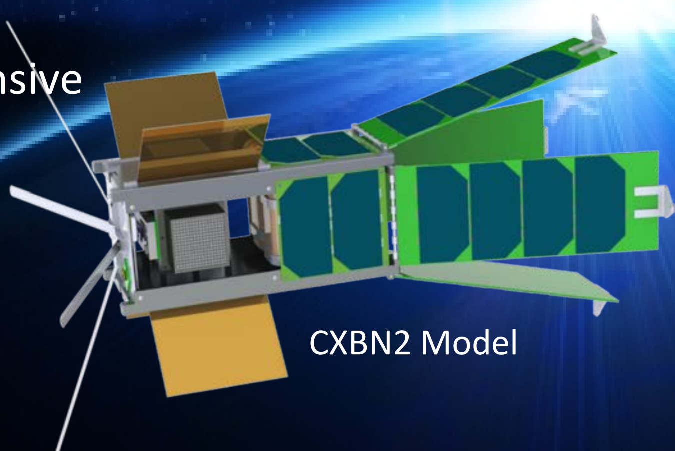


Original Mission

- Double fold out solar panels have a double hinge system

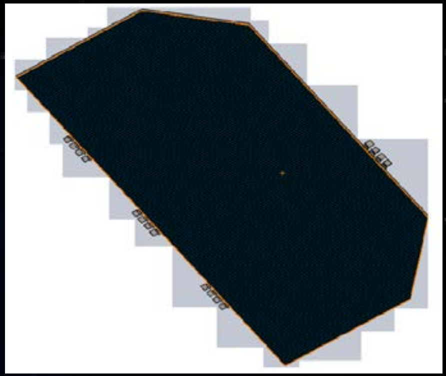
Single Fold Out Design

- Payload power requirement is less, each payload reduced to ~1 watt each.
- Less Risk
- Less Expensive



CXBN2 Model

Solar Cell



(Solid works Model)

- Solar Cells are from Azur Space.
- **Approximately 30% Triple Junction GaAs Solar Cell**
- Type: TJ Solar Cell 3G30C - Advanced
- Equipped with an integrated bypass diode, which protects the adjacent cell in the string.

Before Dicing Full Cell Test

Azure Space Data

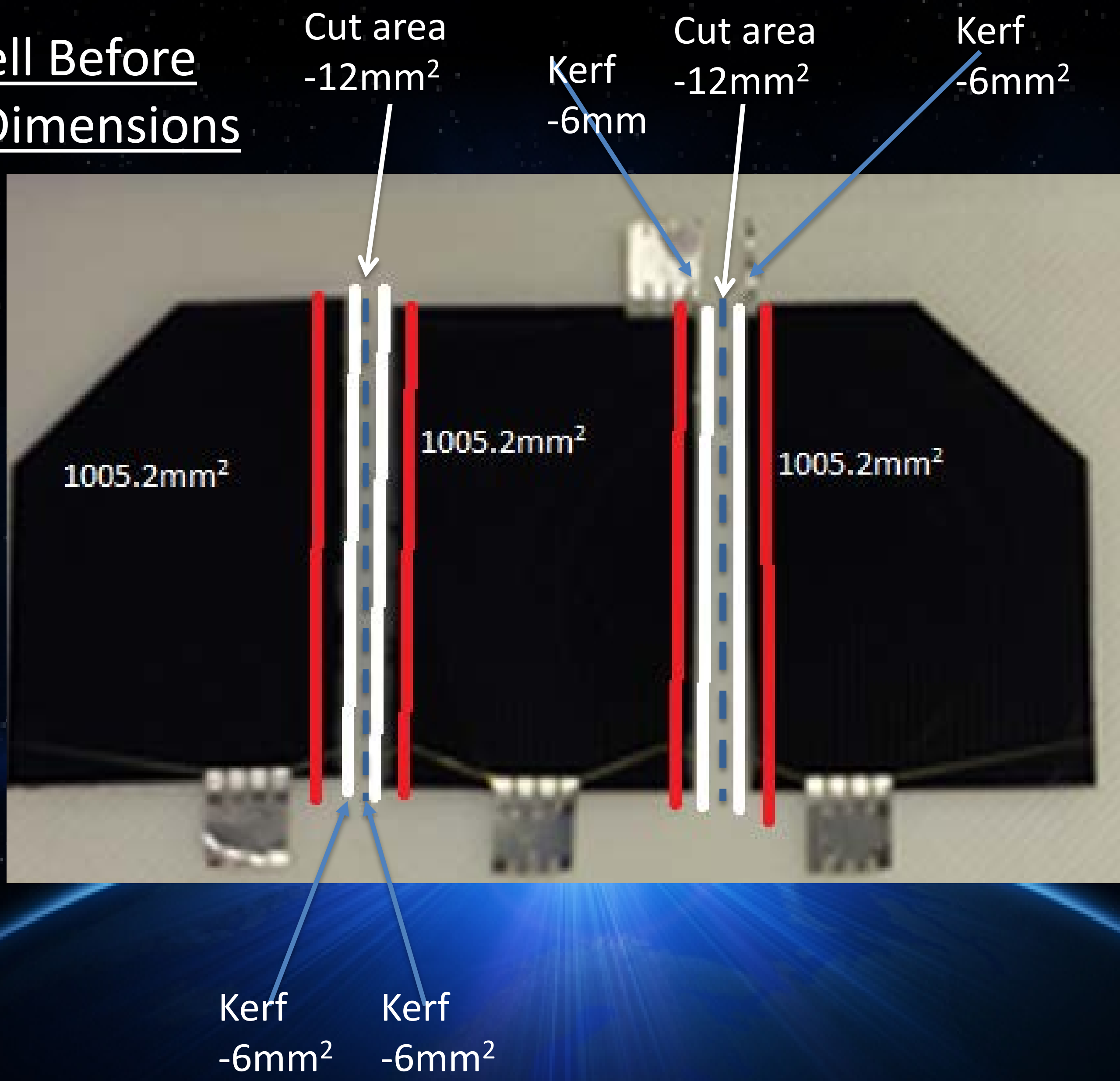
Azure Space Solar Cell Testing						
Original Cell Data From Azure Space						
Date:	3/23/15					
		Isc mA	Voc V	Max Power		
Cell:	80361 1344 58	509.3	2.694	1372.0	mW	
	80361 1344 60	512.5	2.713	1390.4	mW	

Scale Factor from Azure Space Data sheet to testing procedures by a factor of 1.05.

Full Cell Data Before Dicing

Azure Space Solar Cell Testing						
Full Cell Test Data (Measured)						
Date:	3/23/15					
		Isc mA		Voc V		Max Power
Cell:	80361 1344 58	489.5		2.46		1204.1 mW
	80361 1344 60	502.3		2.48		1245.7 mW

Solar Cell Before Dicing Dimensions

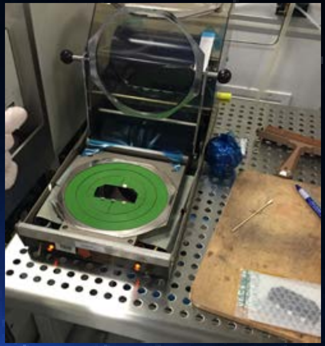


Solar Cell Dicing Process

Dicing Saw

Diamond embedded dicing saw

Vacuum Chuck

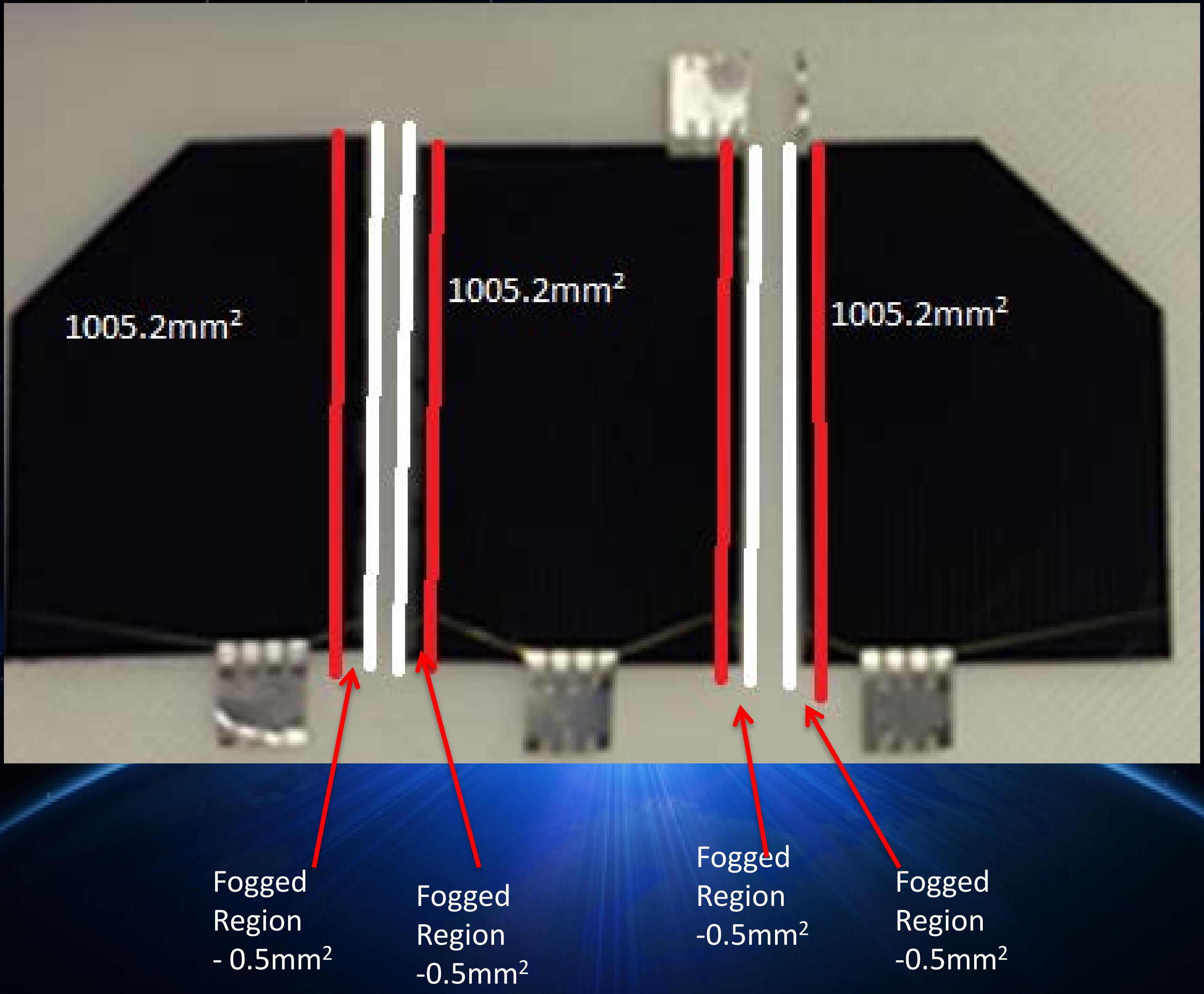


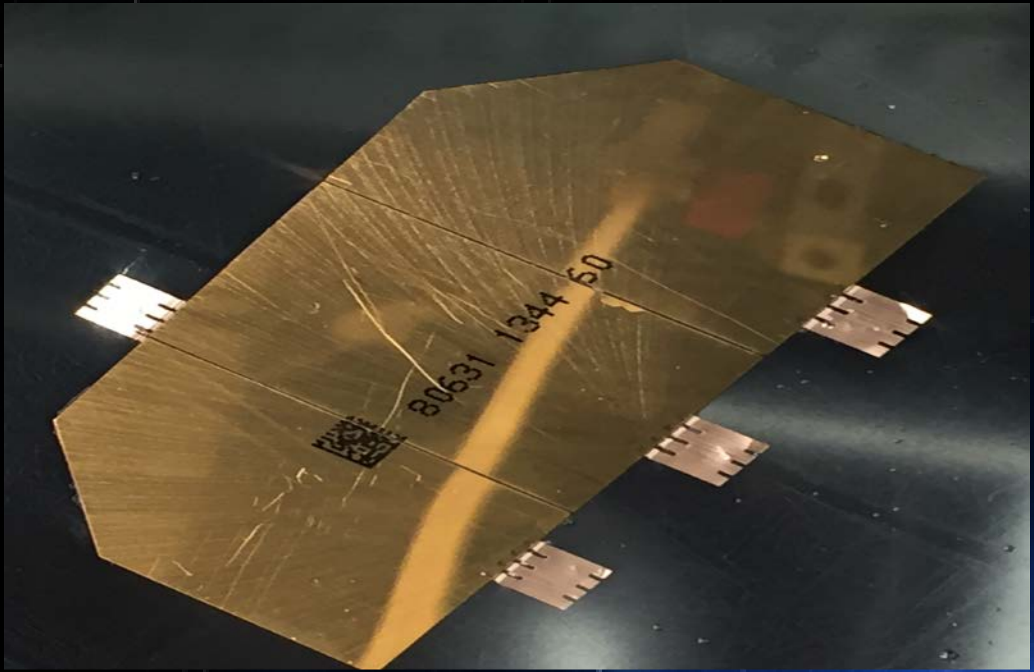
Entering in cutting dimensions

Work was performed at University of Louisville Mico Nano Technology Center
Cutting the cells in two cuts and three pieces to test efficiency.

CubeSats need specific cuts for maximum surface area and to fit to design constraints.

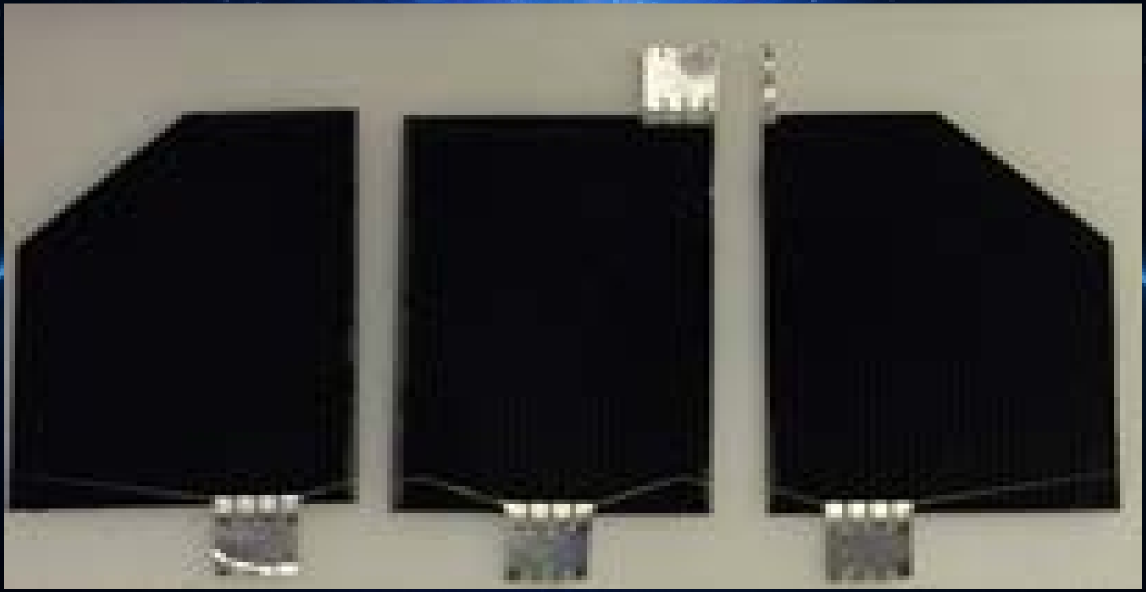
After Dicing Dimensions

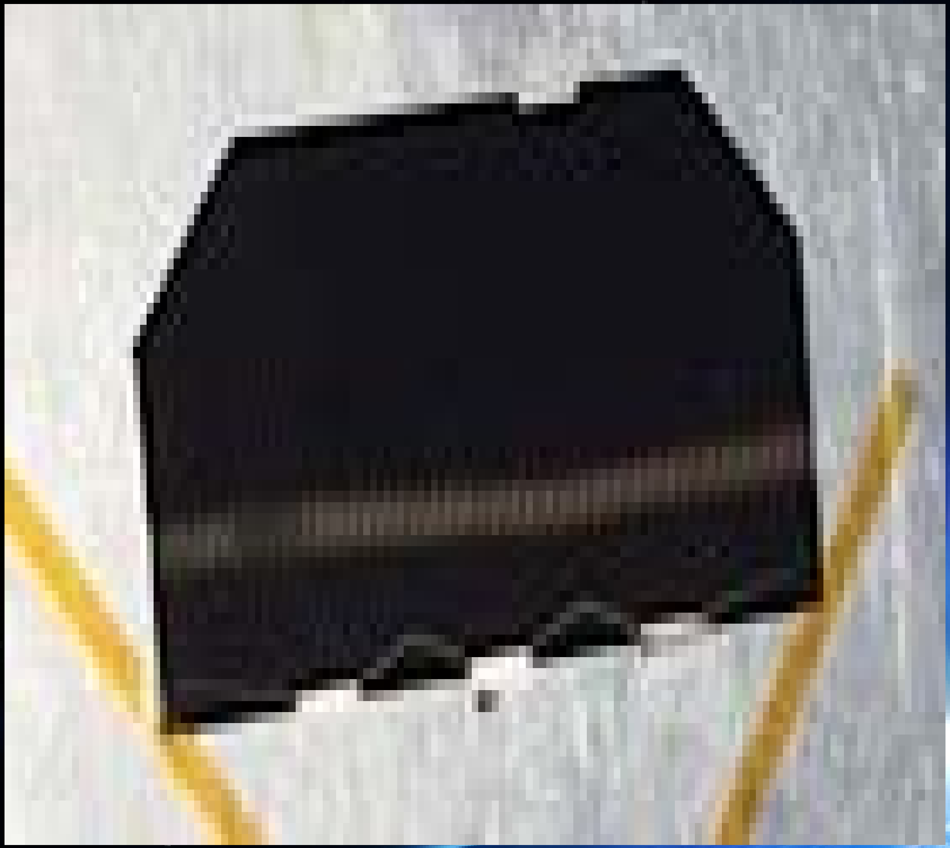




Solar Cell after dicing (backside)

Solar Cell diced and snapped for separation (front side)





Full Solar Cell

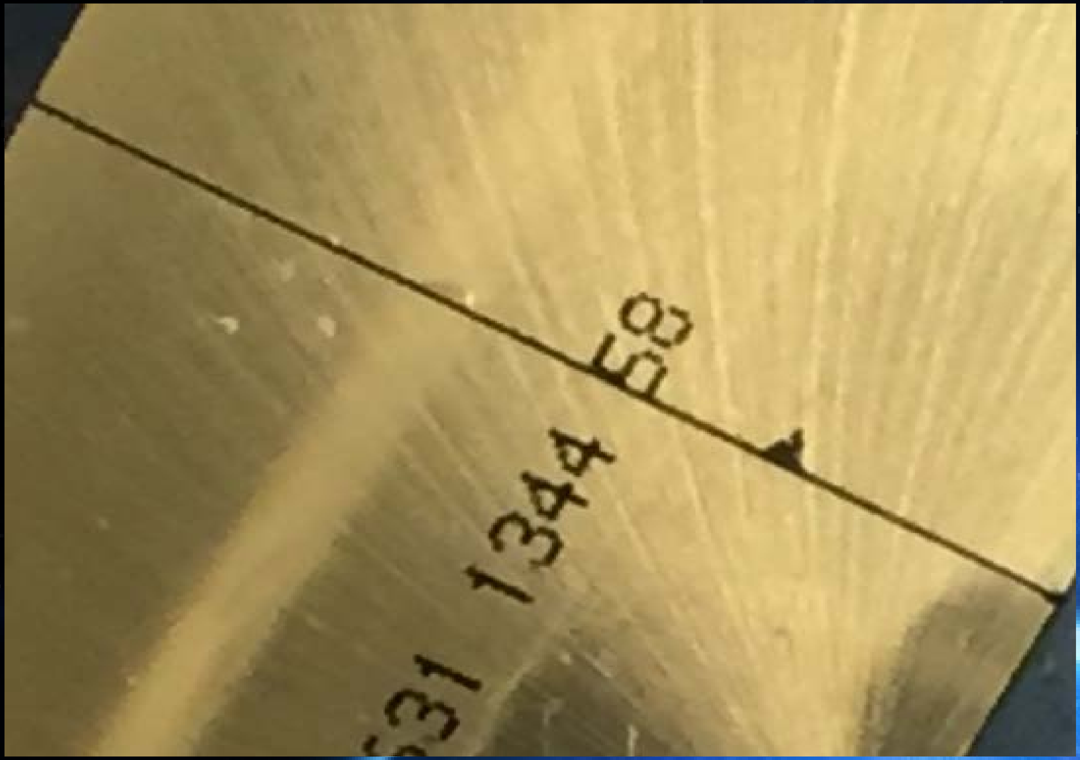
Diced Solar Cell

Testing after dicing

Azure Space Solar Cell Testing								
Original Cell Data From Azure Space								
			Isc mA		Voc V		Max Power	
Cell:	80361 1344 58		509.3		2.6		1372.0	mW
	80361 1344 60		512.5		2.7		1390.4	mW

Azure Space Solar Cell Testing								
Cut Cell Test Data (Measured)								
			Isc mA		Voc V		Max Power	
Cell:	80361 1344 58		169.6		7.8		1323.4	mW
	80361 1344 60		170.6		7.6		1297.0	mW

Dicing Issues

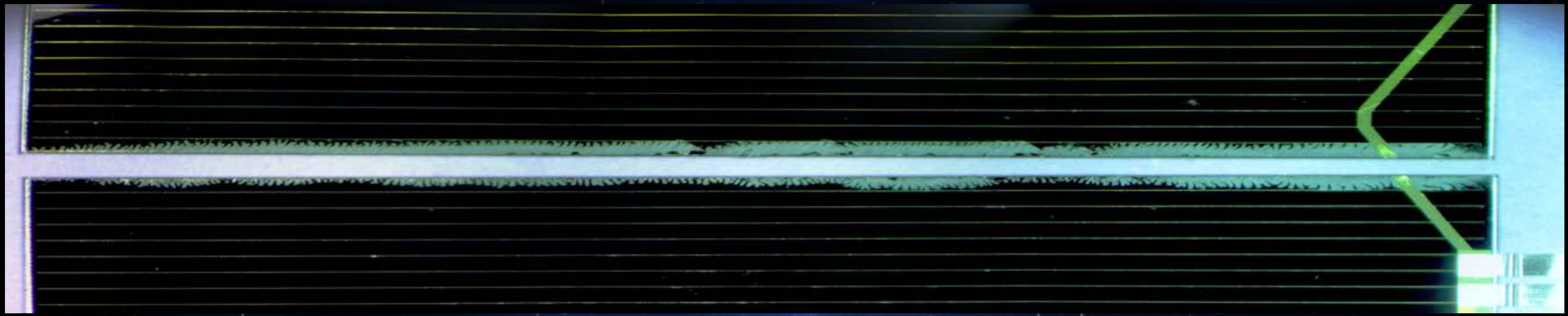


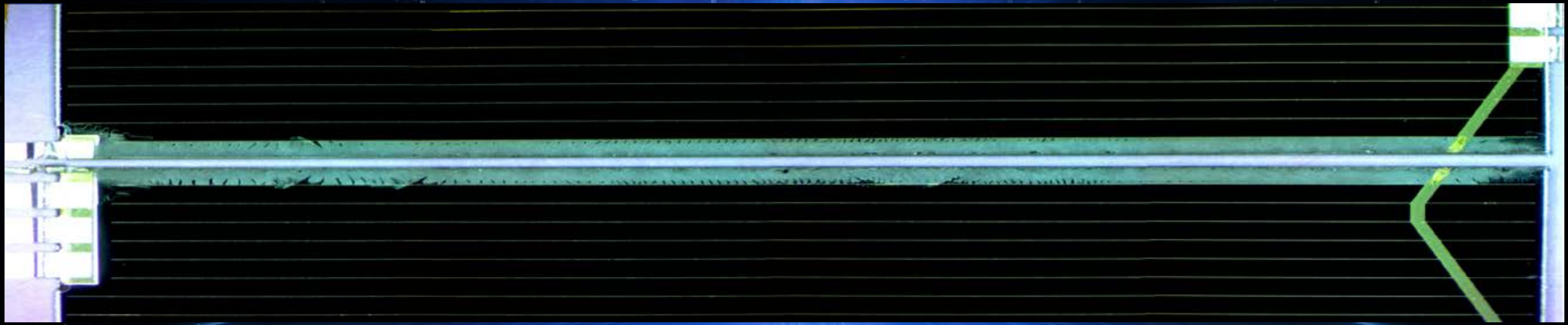
Chipped Cell after dicing

Cell Chipping and Fogging along cuts.

What caused the fogging and cracking?

Solar Cell Cuts with fogging





Cut Direction →

Possible Causes of fogging damage

- Speed rate of dicing saw.
- Vibrations from saw.
- Temperature increase.
- Water might not have been the best solution to dice with.

- Will thermal bake and vacuum remove fogging?

Testing at MSU

- After cells are diced they under went performance testing determining
- Power output and voltage max power, to Azure Space datasheet measured under AM0.
- Extrapolate Cut Cell Power Output @ AM0?
- Compare Efficiency of cells at max power.

Testing Model (Indoor and Outdoor)

Conditions:
Indoor under Halide and Flood lamps to simulate part of the visible light solar spectrum from 500nm-700nm.
Humidity= 0%   Room Temp= 20°C

Outside: AM1.0-1.2;
Sunny (No Clouds)
Region Forecast- 26.6 - 31.6°C
Temp. Measured- 31.1°C
Humidity 88%
Wind @ 2MPH (TWC)
Time: 12:51 AM - 1:51 PM

Cells were placed onto 3D printed plates

Testing Performance after dicing at MSU

Solar Light Table- Uncalibrated but simulates solar spectrum inside.

Indoor Solar Light Table

AM0

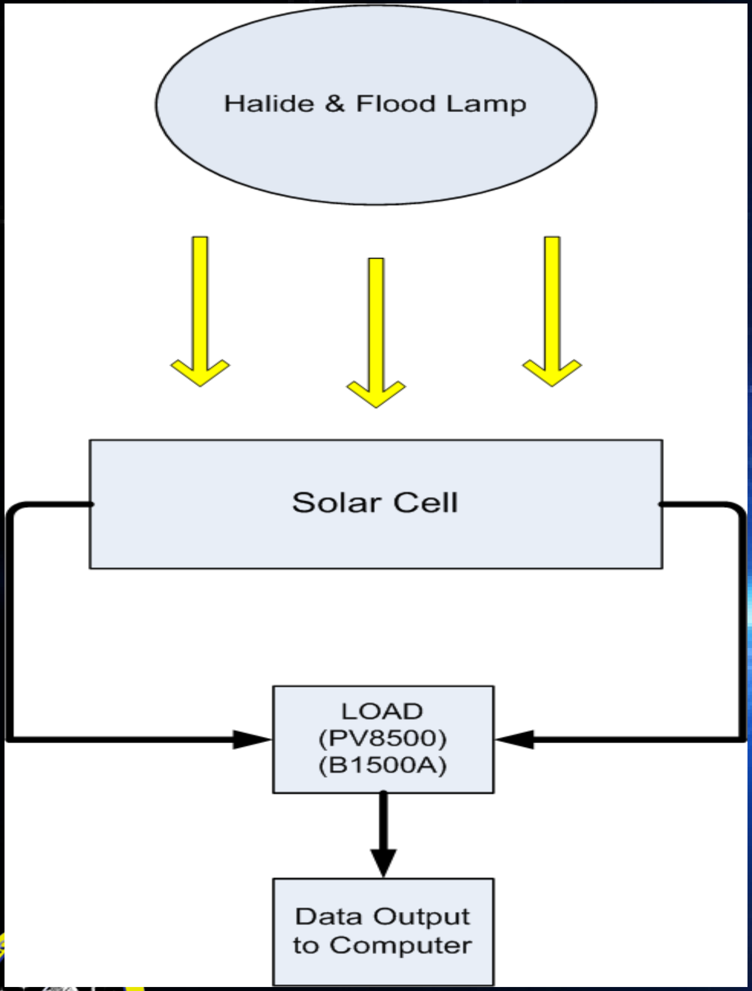
The spectrum outside the atmosphere, approximated by the 5,800 K black body, is referred to as "AM0", meaning "zero atmospheres". Solar cells used for space power applications, like those on communications satellites are generally characterized using AM0.

AM1

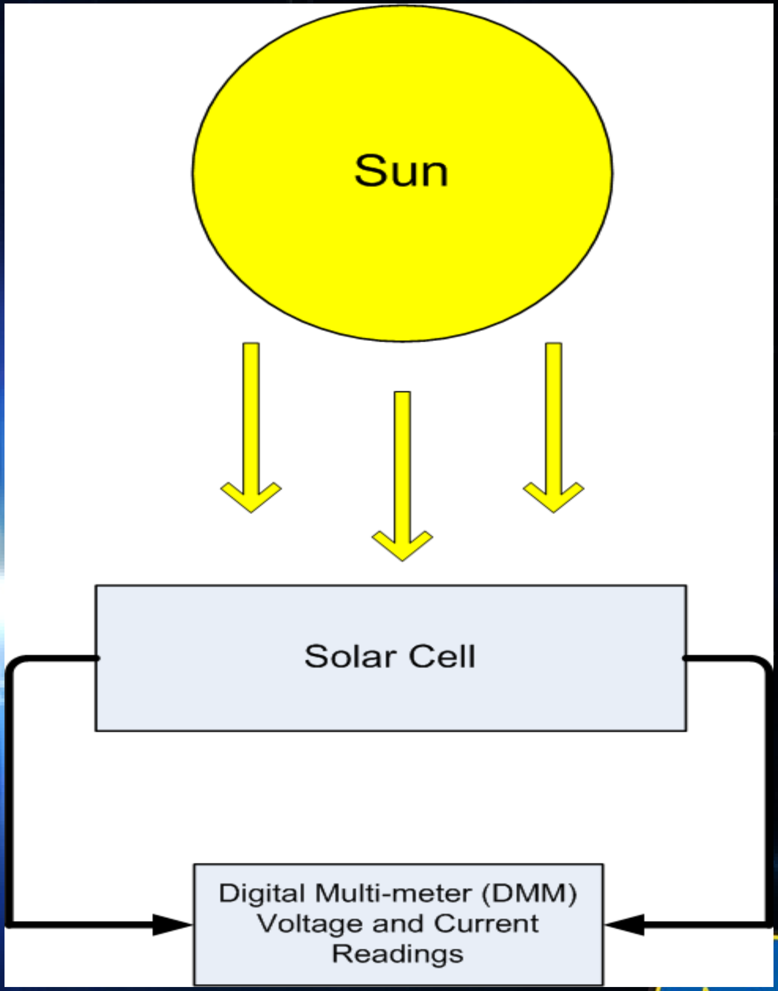
The spectrum after travelling through the atmosphere to sea level with the sun directly overhead is referred to, by definition, as "AM1". This means "one atmosphere". AM1 (z=0°) to AM1.1 (z=25°) is a useful range for estimating performance of solar cells in equatorial and tropical regions.

Testing Block Diagram

Indoor Solar Table

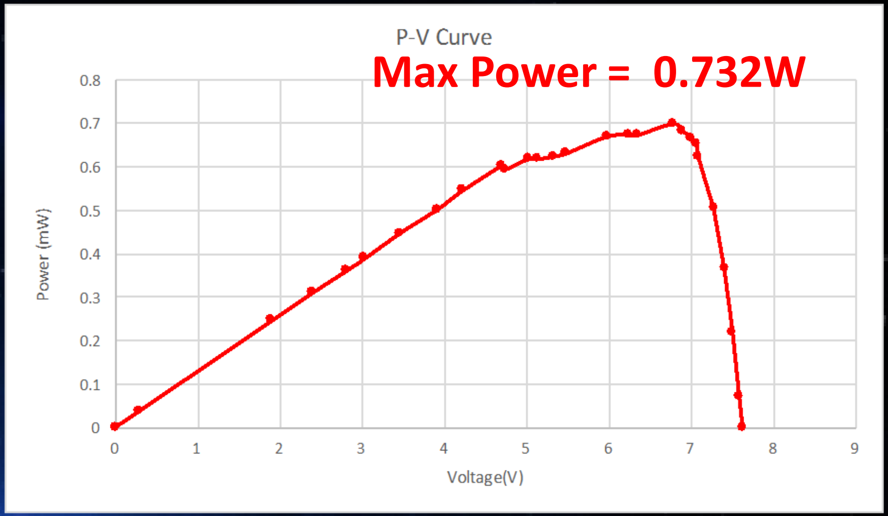


Outside testing

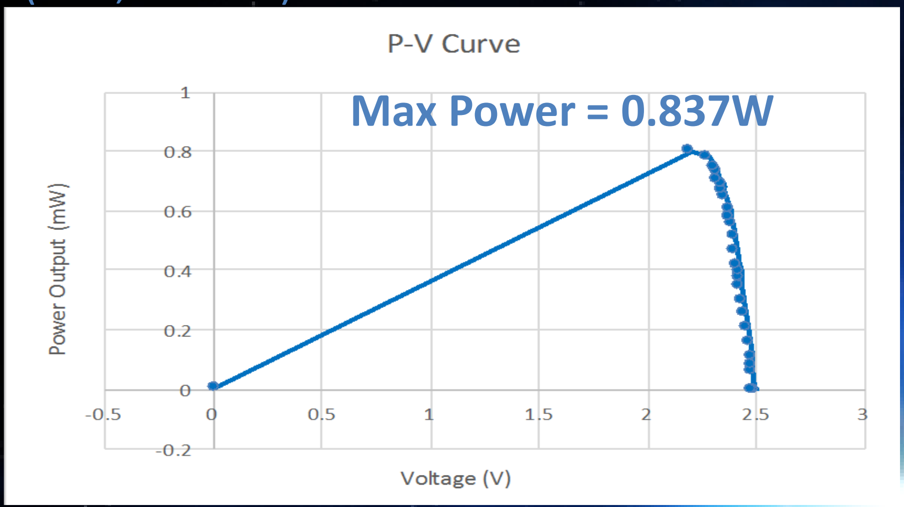


Power Output Results (AM1)

Cut Cell Test Max Power Point-
(6.78v,0.732W)



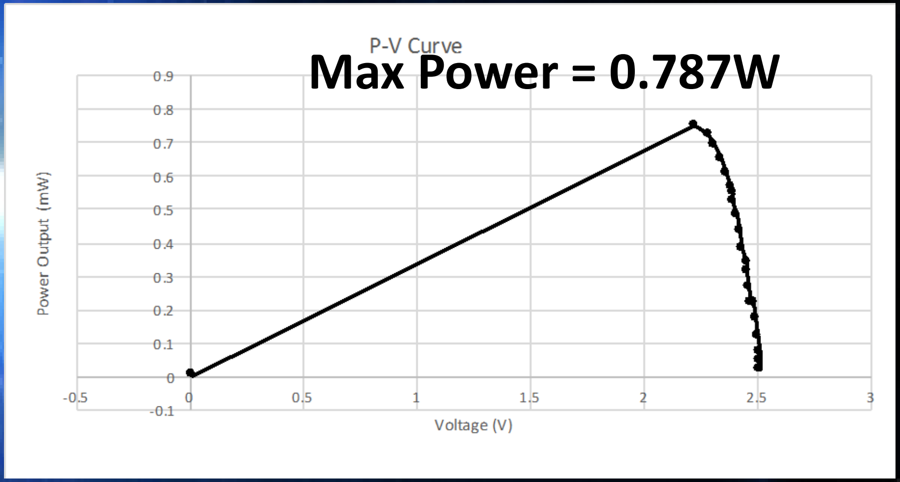
Full Cell Test 1
(2.2v,0.837W)



$Cut_{AM0} = (Cut_{AM1.5})*((Full_{AM0}) / (Full_{AM1}))$

$Cut_{AM0} = (0.837W)(1.205W)/(0.812W)$

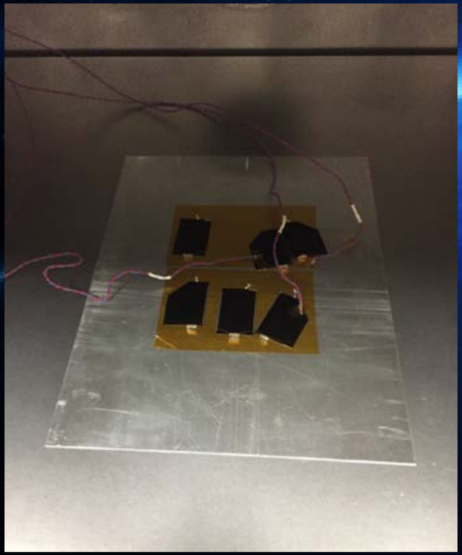
$Cut_{AM0} = 1.086W$



Full Cell Test 2-

(2.22v,0.787 W)

Thermal Vacuum Residual Gas Analysis Testing



Thermal Vacuum RGA test to determine the effect of the space environment on fogged regions on diced cells.

Start = Saturday, June 04, 2016
4:46:40 PM:000

Span = 4 Day(s) 20 Hour(s) 33 Min(s) 20 Sec(s)

Three Thermocouples (TC)

TC1– Between Aluminum plate and kapton Tape.

TC2- Cell #60 (Top Row)-Left Cut

TC3- Cell #58 (Bottom Row)-Right Cut

Other Measurements

Platen Temperature

Oven Temperature- 21.85°C - 80°C

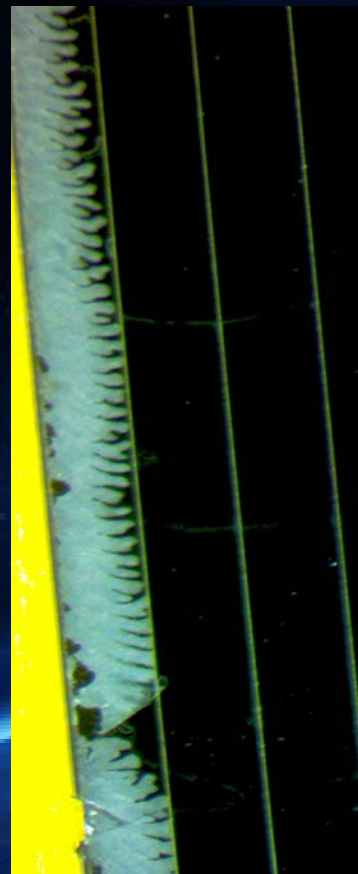
Pressure– 9.3x10^{-7} Torr

Test Conditions

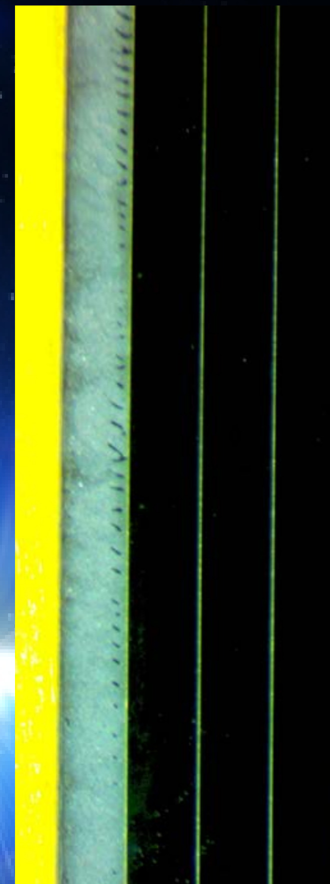
Oven Max	63.6	℃
TC1 Max	100.8	℃
TC2 Max	98.6	℃
TC3 Max	101.8	℃
Platen Max	92.3	℃
Pressure	9.98E-07	**Torr**

Post TVAC Fogging Inspection
Cut Cell

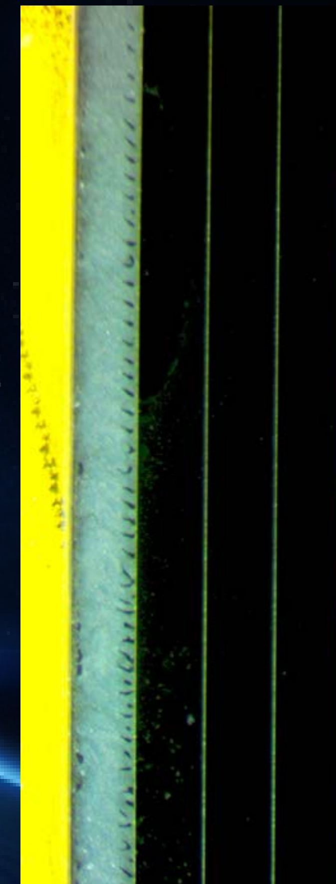
Left Cut



Left Center



Right Center



Right Cut

Full Cell vs Cut Cell CXBN2 Mission Requirements

- Full Cell is 29% efficient.
- Cut cell with no damage is 29% efficient.
- Cut cell at AM1.5 is ~28% due to fogging.
- Would have to connect two cells that are diced in series with fold out panel to keep solar array at max power output and solar efficiency.

Cut cells will provide more voltage at Vmp(Voltage Max Power) AM0 compared to full cell.

Conclusions

Dicing method is successful as long as the cut rate stays below 0.5mm/s.

Cut cells that are not damaged from dicing will keep the same efficiency and provide the mission requirements needed.

Fogging of cells is permanent damage, proof after environmental testing.

Questions/Comments