ANGSTROM DESIGNS

All-Junctions/Cells Isc Mismatch (JCM) Measurement

A Better Solar Simulator Metric

Casey Hare, Scott Ireton, Andrew Schwab - Angstrom Designs. -- Space Power Workshop, Torrance CA, April 27, 2023

Designed and manufactured in the United States

1. Motivation - Why Ask More From Illuminated Ground Testing?

- In R&D and manufacturing: “test as you fly”
- Existing methods give large errors:
  - Calibration Standards: 0.5% (for balloons) or higher
  - Spectral Match: 1% (ASTM is 25%!)
  - Spatial Uniformity: 3% (or higher for large areas)
  - Temporal Stability: 2%
- Errors mean too many cells on every array we fly
- Larger circuits = larger wings, satellites and rockets

Better Ground Testing Gives Lighter, More Efficient Satellites

2. AIAA Standards Are For Space

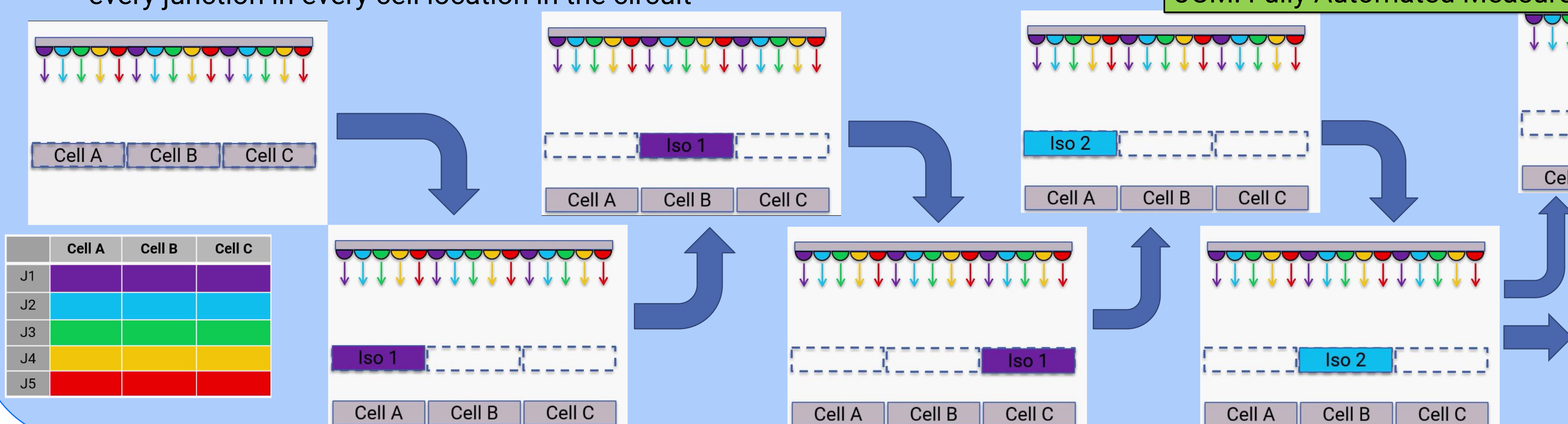
- The AIAA S111A and S112A uses isotype current matching for best accuracy
  - But includes the short-comings of pulsed, Xenon-lamp solar simulators
- AIAA recognizes that spectral binning isn’t good enough for space
- AIAA allows the E927-10 stacking of errors: 1% current match + 3% spatial nonuniformity + 2% temporal stability
- We can do better than this

Even the AIAA Standard Allows for Large 1% + 3% + 2% Error Stack

3. All-Junctions/Cells Isc Mismatch (JCM) Measurement?

- All-Junctions, All-Cells Isc Mismatch = JCM
- JCM uses isotypes to measure the short-circuit current for every junction in every cell location in the circuit
- JCM captures all the aspects of spectral binning/ matching and spatial non-uniformity at the resolution of the present test

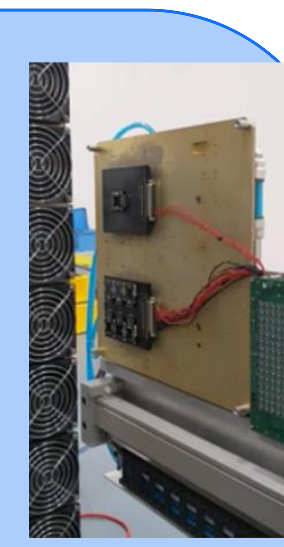
JCM: Fully Automated Measure of Present Test Needs

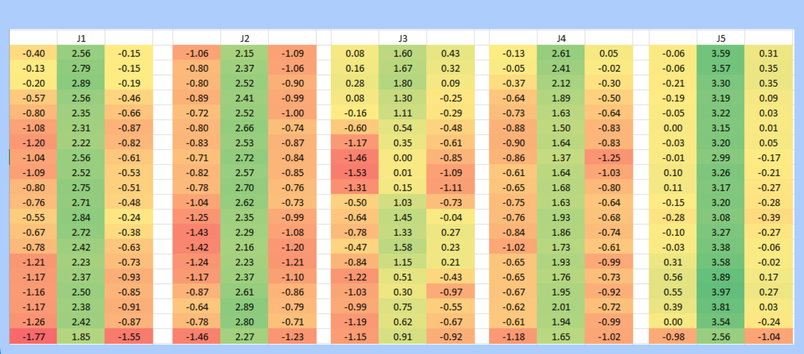


	Cell A	Cell B	Cell C
J1	+0.2%	-0.1%	+0.1%
J2	+0.1%	-0.3%	+0.2%
J3	-0.2%	+0.1%	+0.3%
J4	-0.1%	+0.2%	-0.1%
J5	-0.2%	-0.1%	+0.1%

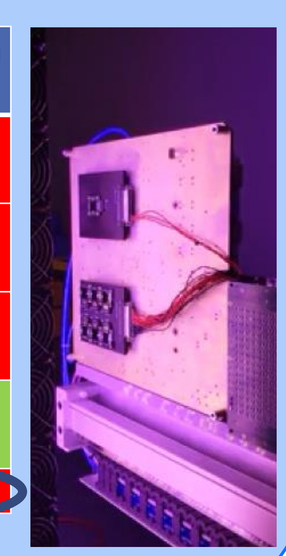
4. JCM vs AIAA on a 5J, 60 cell panel

- 3x20 circuit of 5J cells and a *partially-calibrated* 5J pLEDss
- JCM is fully automated
- AIAA current matching: doesn’t say where (in XY) in the beam
- ASTM spatial non-uniformity: sub-samples area doesn’t tell us which junction





Case	JCM Max	JCM Min	Max-Min/Max+Min	SNU small (2%)	SNU large (3%)	Current Match All (1%)
Worst-case, all junctions	3.97	-1.77	2.87	Fail	Pass	Fail
Best-case, all junctions	1.80	-0.28	1.04	Pass	Pass	Fail
Worst-case, best junction	3.81	-1.31	2.56	Fail	Pass	Fail
Best-case, best junction	1.60	-0.28	0.94	Pass	Pass	Pass
Worst-case, J1	2.89	-1.77	2.33	Fail	Pass	Fail



J1 is the BOL current limiter
(and the non-limiting JCM errors are within the J1 current margin)

5. Conclusion: JCM is a Better Metric

- JCM is measured data, in all locations critical to the test
- ASTM/ AIAA and Xenon Lamps gives errors of 6% (or more)
  - Larger error while under-sampling spatial non-uniformity
- JCM and LEDs gives errors of 2.2% (or less) for large panels
  - pLEDss has demonstrated JCM <0.3% for small coupons
- JCM is measured data rather than calibration assumptions
- Why should programs want a 4% (or more) improvement?
  - Smaller circuits, Higher confidence in on-orbit power, Lower mass, Lower MOI, Lower cost, … for every panel we fly.

JCM: strict, direct measurements

For More Information: www.AngstromDesigns.com
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