

Solar Power Modules: Flex Arrays

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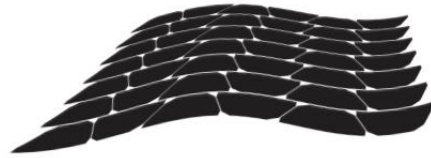
- Flex Definition
- Flex Technology Roadmap
- Flex¹ Update
 - Qual Completion
 - Production/Flight Heritage
- Flex² Update
 - Coupon testing
 - Qual Plan
 - Life Cycle Coupon
 - ESD Mitigation
 - Production Experience
- Flex on Rigid
- Conclusions

Flex Definition

- **Flex¹: String bonded to a flex carrier (without circuitry)**
- **Flex²: Cell bonded to a flex carrier + embedded circuitry**
- **Flex³: Cell bonded to a flex carrier + embedded circuitry + on-orbit reconfigurable**
- **Flex on Rigid: Any flex configuration installed on rigid substrate**

Flex Technology Roadmap

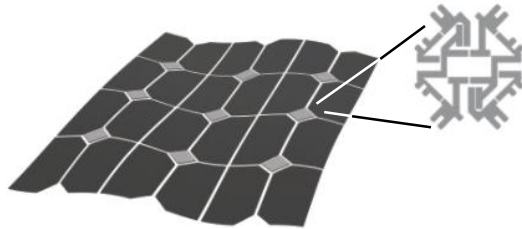
Flex¹



Flexible

	2021	2022	2023	2024	2025
	Solar Power Modules On-ISS IROSA	We're here			

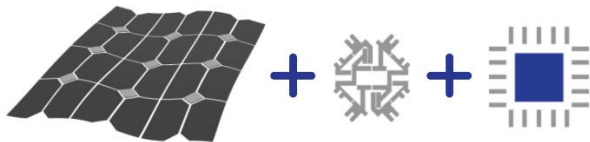
Flex²



Configurable Circuit

	Flex Circuit for CIC Connections and Wiring				
		Flex ² on Rigid			
			Flex ² on Frame		

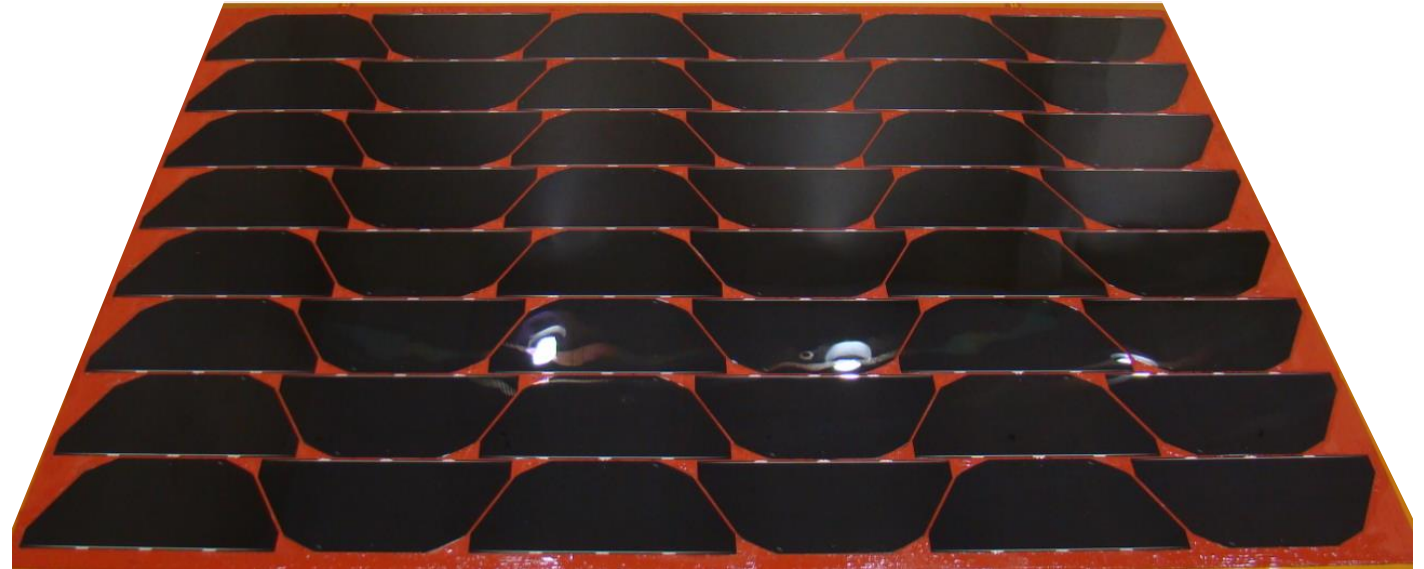
Flex³



Reconfigurable Circuit in Flight

	Active Switches on Solar Array to Reconfigure				
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- **Game Changing Impact on Cost**
- **Velocity**
 - Faster design time
 - Faster to build
 - Faster to test
- **Versatility**
 - Rigid panel
 - Flex-on-frame
 - Z-fold
 - Roll out arrays

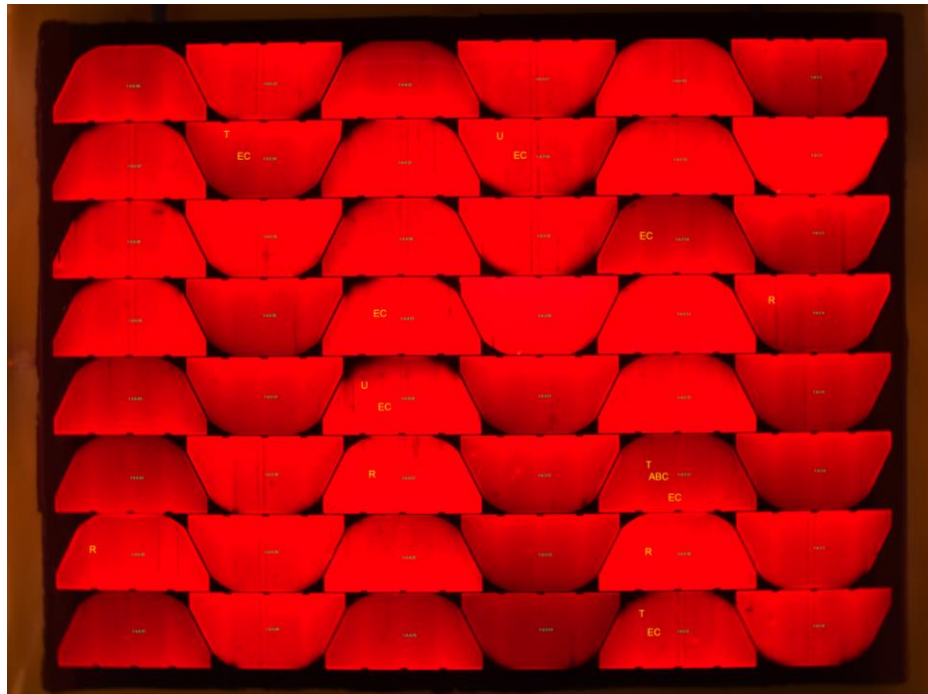


Flex SPM's Are Transforming Space Power

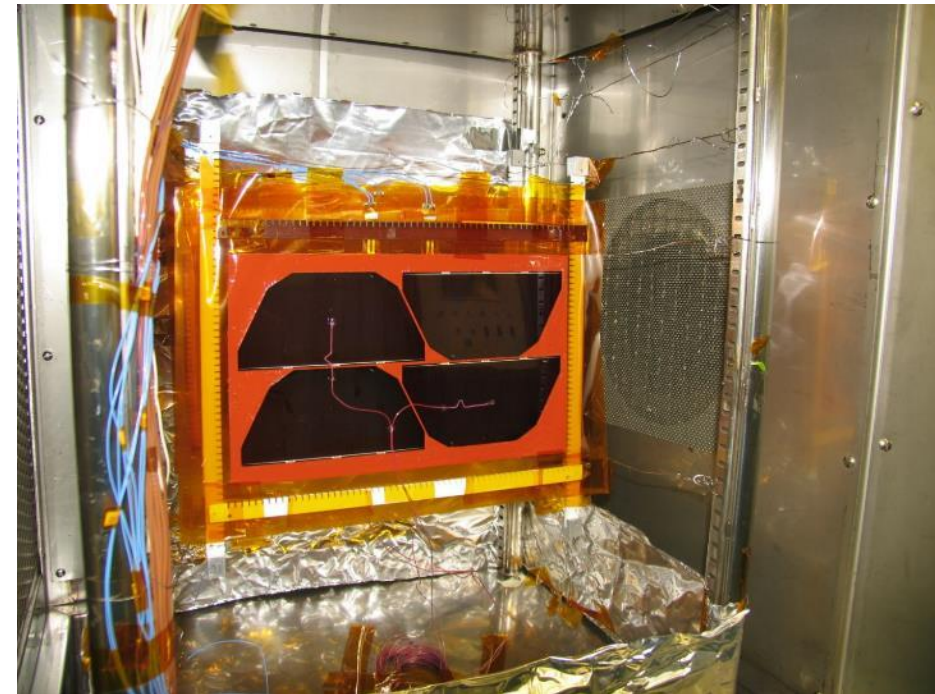
Flex¹ Qualification

Flex¹ has series welded strings with end tabs bonded to a Kapton sheet

2 Large Coupons
Completed 27,500 LEO thermal cycles
from +120°C to -65°C, TVAC, and ESD



2 Small Coupons
Completed 55,000 LEO thermal
cycles from +120°C to -65°C



Multiple
patents in-
process

Qualification Complete

Flex¹ SPM Impact on Manufacturing

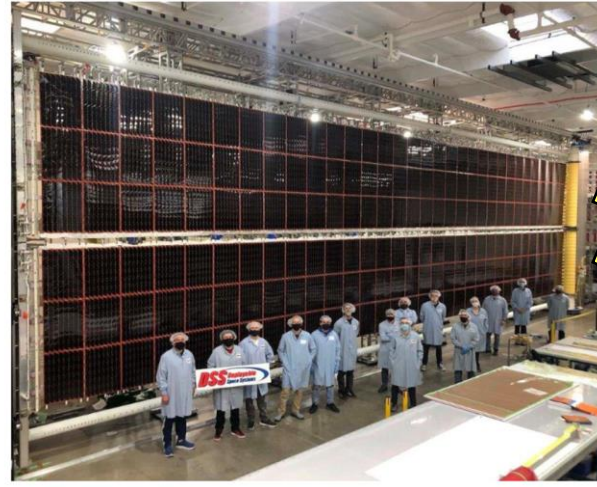
- **Simpler to build**
 - Modular design
 - Dedicated build stations
 - Automated test stations
- **Agile manufacturing (tooling/equipment) to adjust to different SPM sizes**



SPM capability can be rapidly staged to support new programs

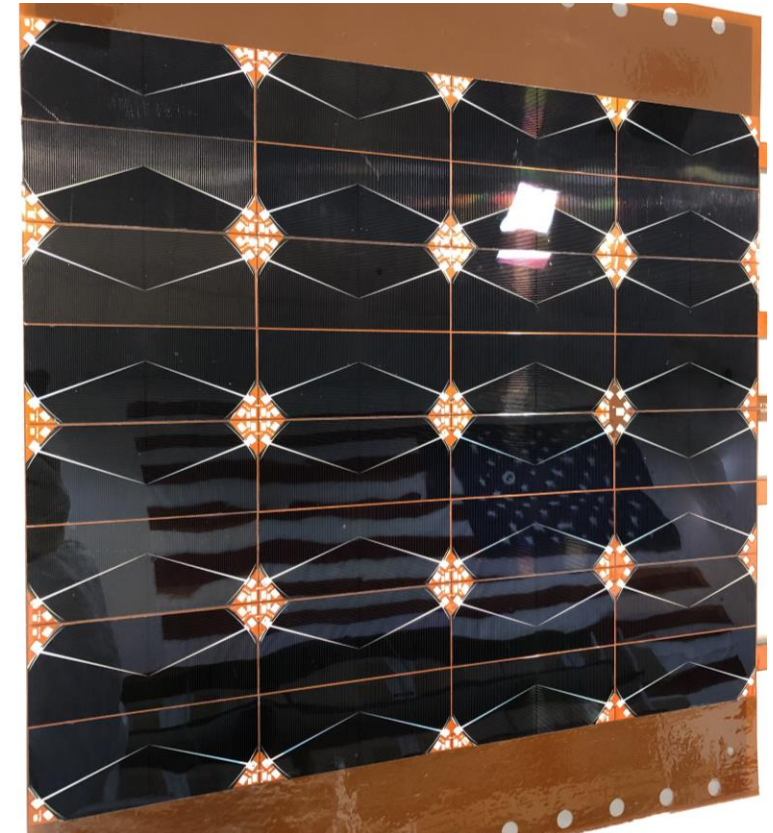
Flex¹ –High Volume Heritage

- High Volume Production Completed Ahead of Schedule (Verified Cycle Time)
- >1,153 SPMs produced, totaling over 180 kW
- Wing 1/2 installed on ISS in 6/2021
 - On-orbit electrical performing nominally
- Wings 3/4 launch ~ 10/22
- Wing 5/6 launch ~6/23



Flex² - Update

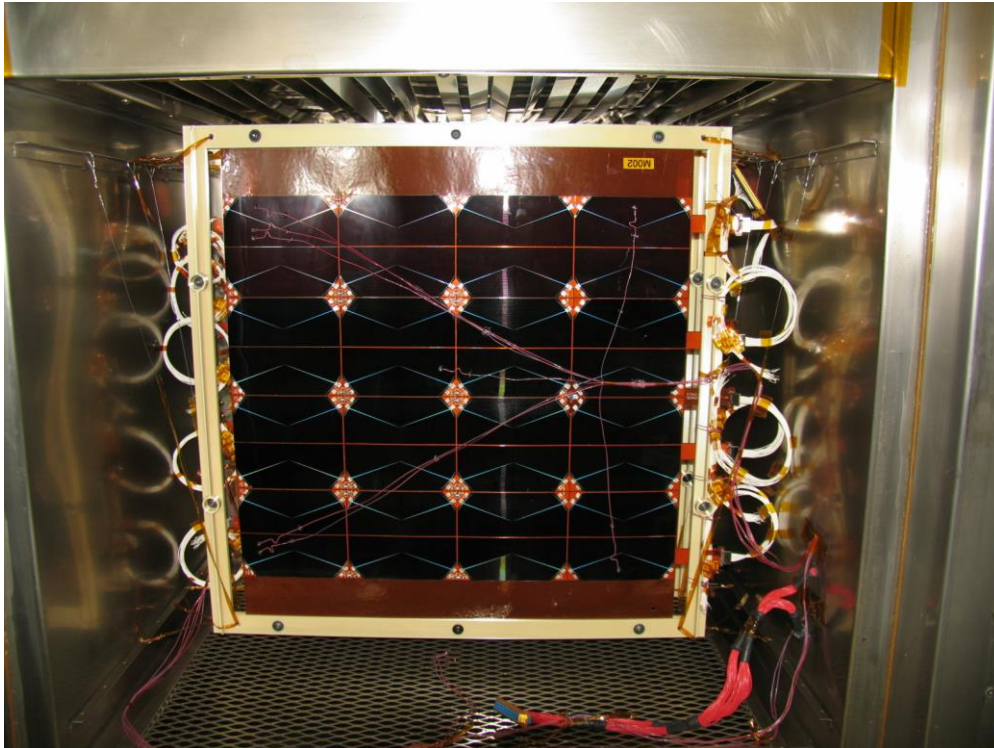
- **Lower Cost Design Phase**
 - Single structured design (multiple circuit traces layers)
 - >90% packing factor
- **Lower Cost Solar Panel Production**
 - Control schedule by decoupling solar array build from substrate delivery
 - Flex circuit wiring saves over conventional round wire
 - Structured design to speed inspection and testing processes
 - Automation friendly
- **Cycle Time**
 - Enabling staging of prebuilt solar panels that are customized in dimension and output voltage for instantaneous delivery
- **Performance**
 - Increase in packing density and power (W/m²)
 - Serpentine pattern for low cell-to-cell voltage eliminates ESD concern
 - Path to reconfigurable solar array



Value, Velocity, and Versatility

Flex² Coupon Testing

- **Ambient Pressure Thermal Cycling**
 - 5000+ LEO cycles in progress



Coupon To Complete 2nd Quarter

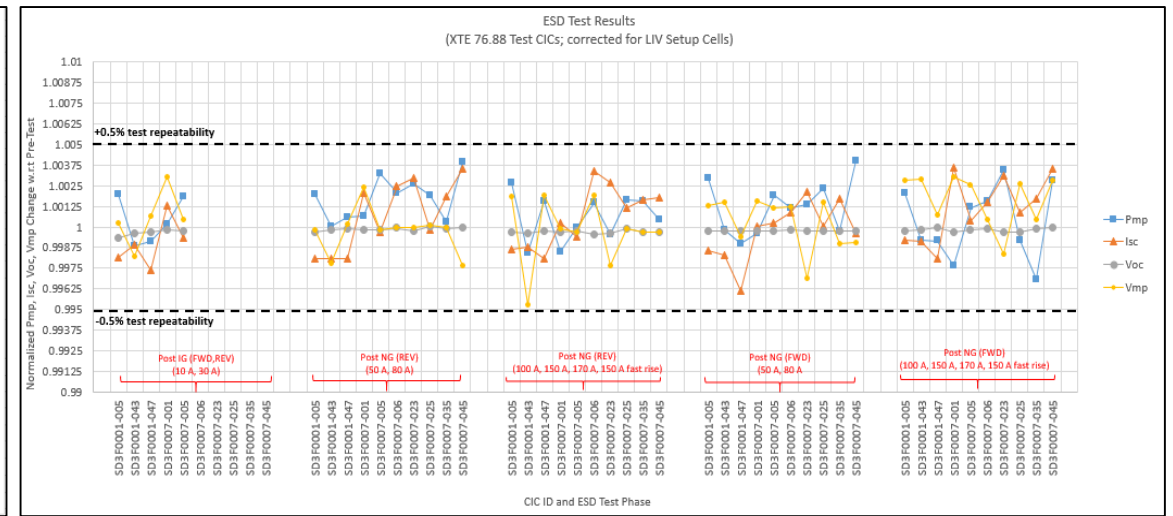
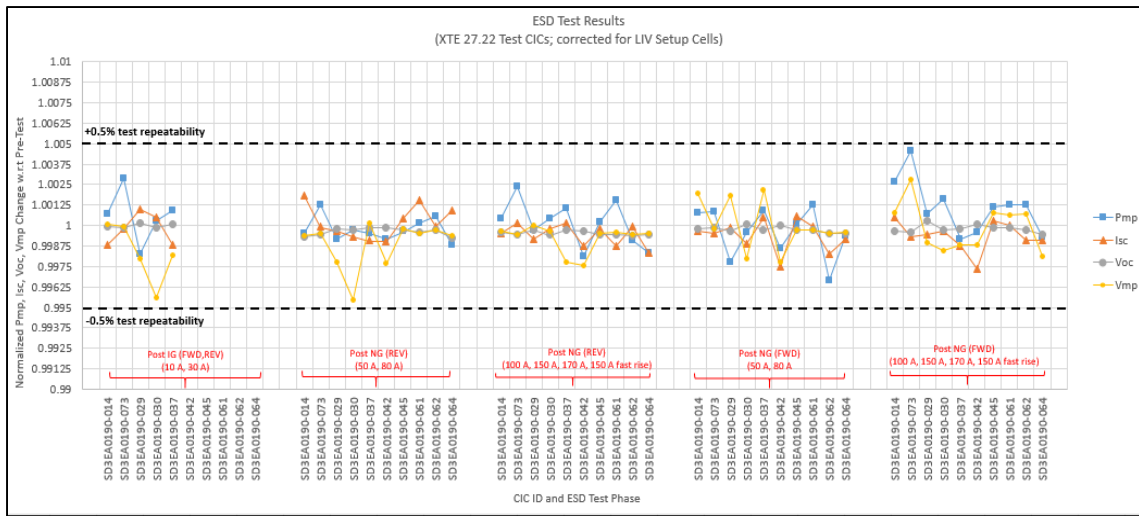
Flex² AIAA S-112A Test plan

- Humidity
- Thermal Vacuum Cycling
- Ambient Pressure Thermal Cycling
- UV Exposure
- Angle of Incidence
- Solar Absorbance
- Atomic Oxygen

AIAA S-112A Qualification To Start 2nd half of 2022

Flex² ESD Mitigation

- The greatest ESD risk to Flex solar panels is a sustained-arc discharge that can cause power reduction
- Sustained-arc mitigation techniques for Flex designs
 - Serpentine (snake-like) layout of Flex tile strings promotes immunity to sustained arcs
 - Limited grouting needed between adjacent cells of a flex tile
- Conduct pulse-injection current, ESD testing of XTE CICs representative of a generic, GEO-orbit ESD environment



XTE 27.22/76.88 cm² CICs show no measurable change (<0.5%) in Pmp, Isc, Voc, Vmp
-XTE 27.22/76.88 cm² CICs show robust immunity to generic, GEO-orbit ESD environment

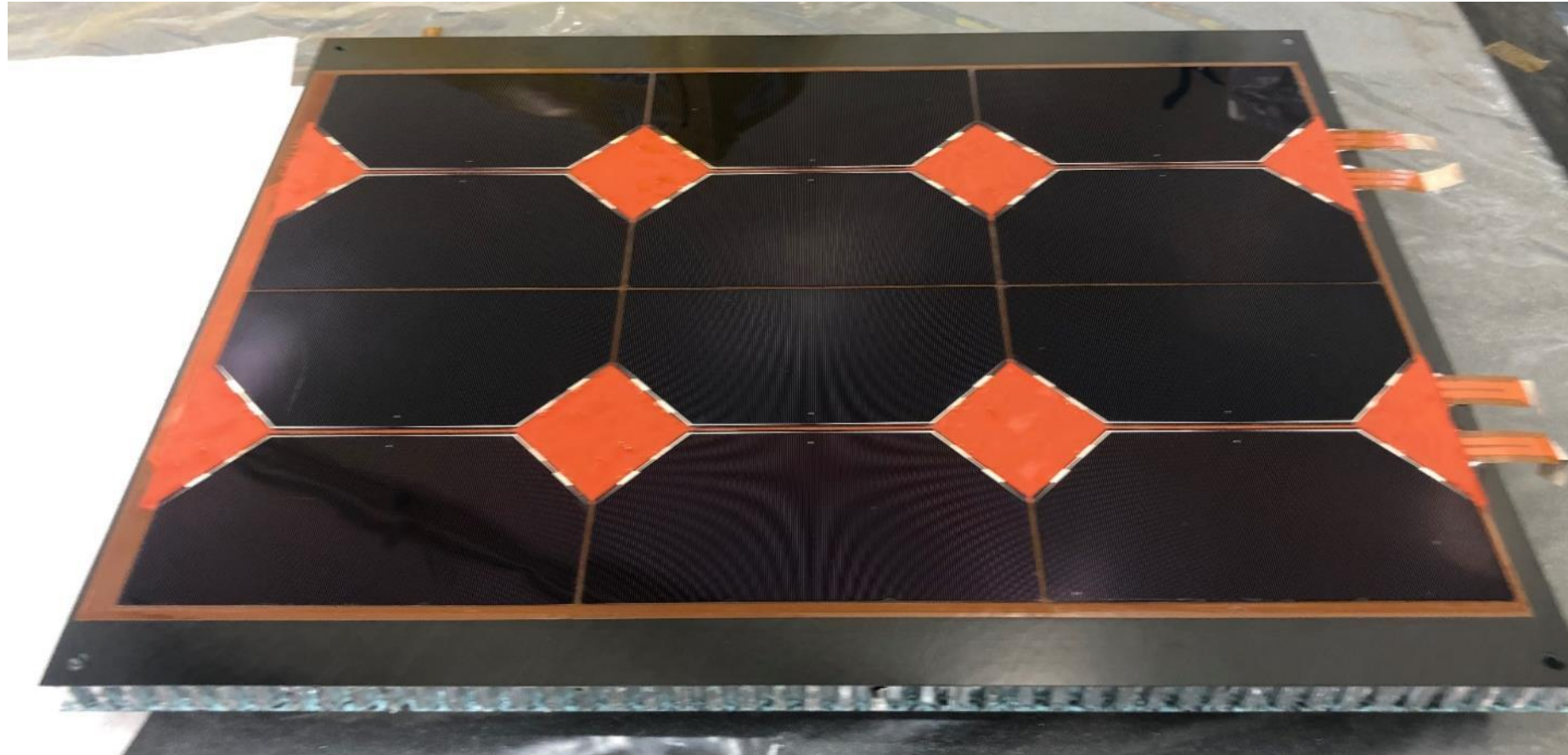
Flex² Production Experience

- Built and delivered multiple shipsets of flight SPMs

Flex³ Progress

- **Ground demonstration of concept**
- **Collecting flight-like testing data**

Flex²-on-Rigid (F²oR) Update

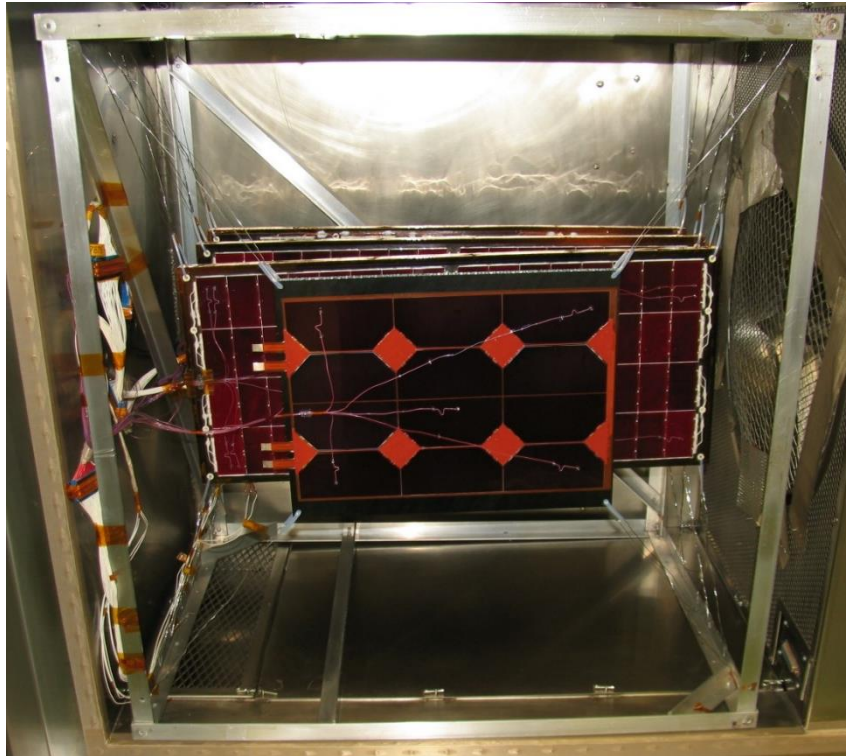


Flex² SPM successfully bonded to conventional rigid honeycomb panels

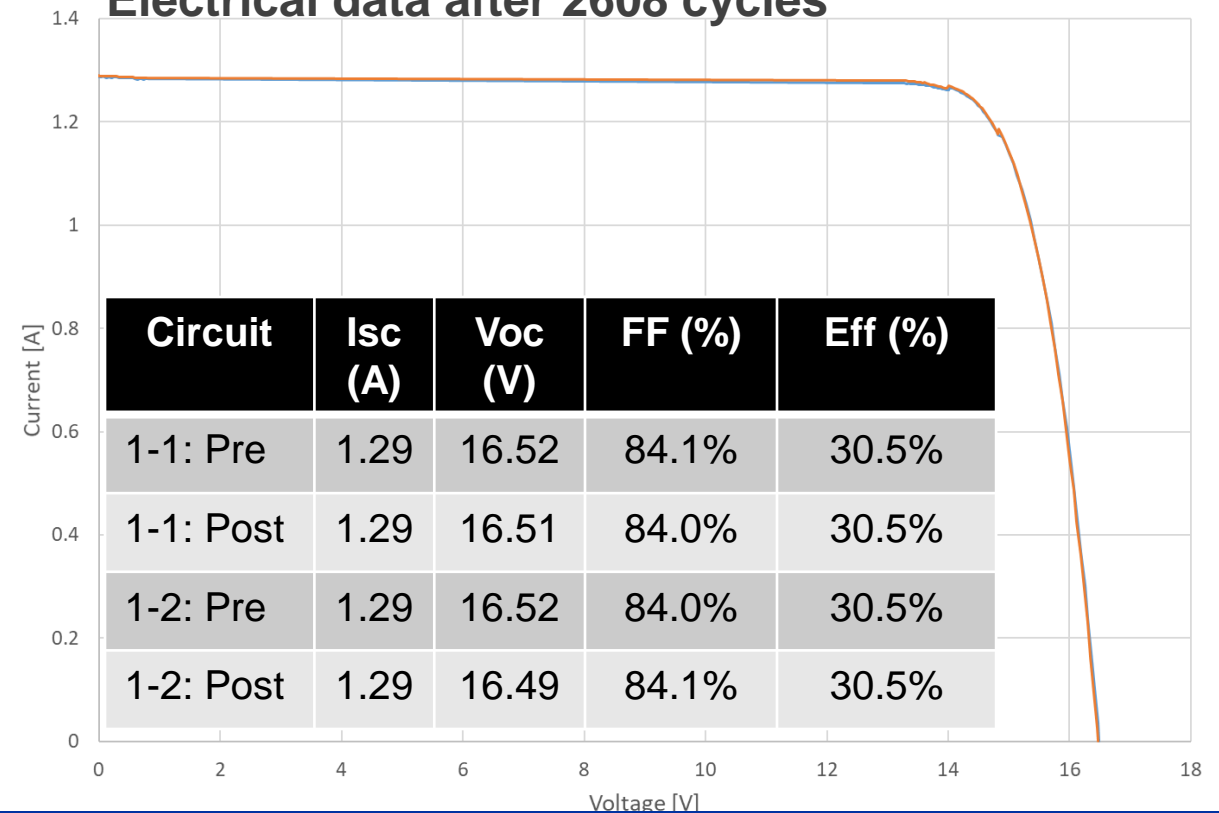
Dense Solar Cell Array On Rigid Solar Panel With No Backside Wiring

F²oR Thermal Cycling Status

Coupon has completed 2,608 cycles;
+110°C to -175°C. Completed 7 cycles:
+150°C to **-182°C**. No cracks, no delam



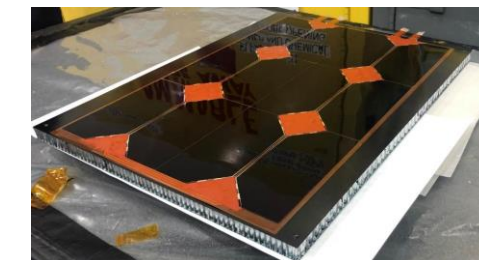
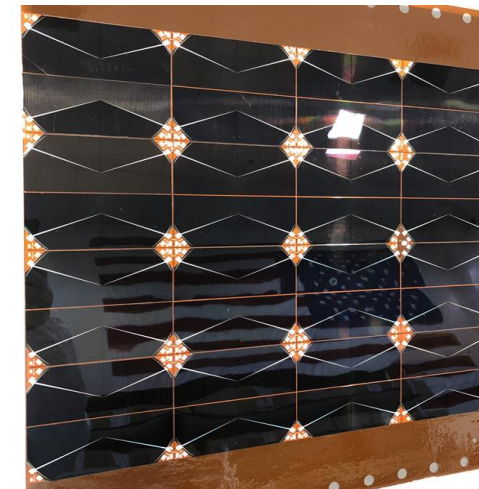
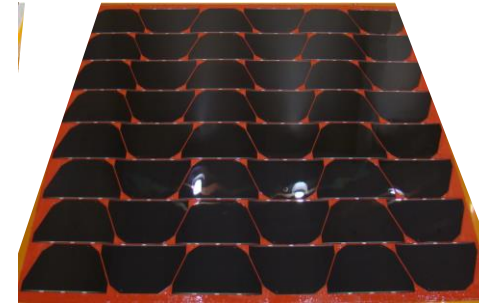
Electrical data after 2608 cycles



Flex²-on-Rigid Stable Through Thermal Cycling

Conclusions

- Flex products offer low cost design, low cost production, higher throughput, and higher performance
- Spectrolab has carried out/delivered high volume production of the Flex¹ product
- Extensively tested Flex² configuration
- Successful Flex²-on-Rigid build has reached 2,608 GEO thermal cycles



Acknowledgements



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