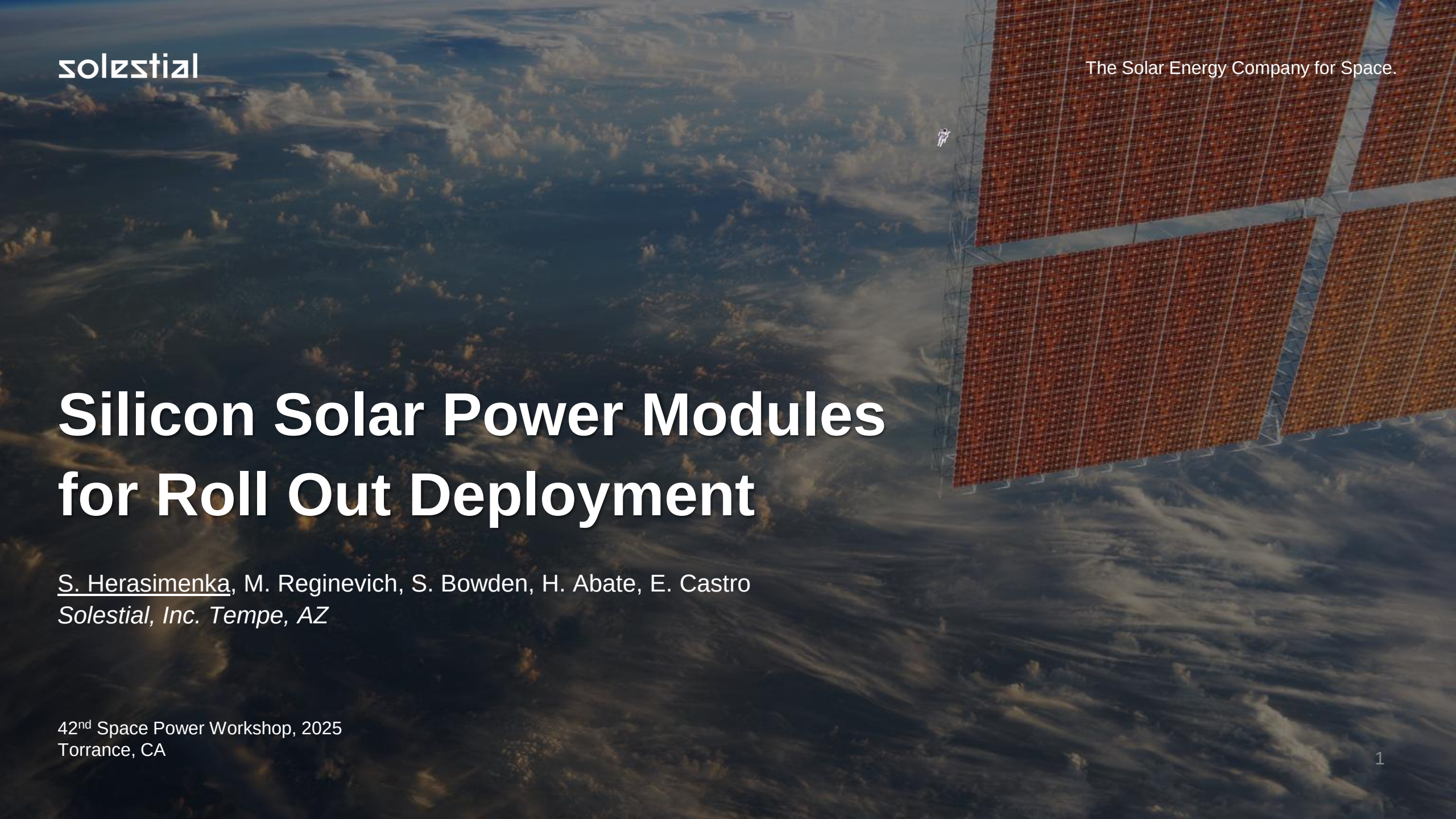
solestial

The Solar Energy Company for Space.



Silicon Solar Power Modules for Roll Out Deployment

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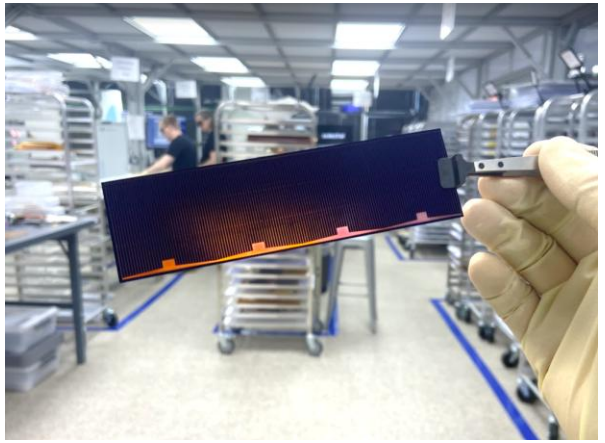
Solestial, Inc. Tempe, AZ

42nd Space Power Workshop, 2025
Torrance, CA

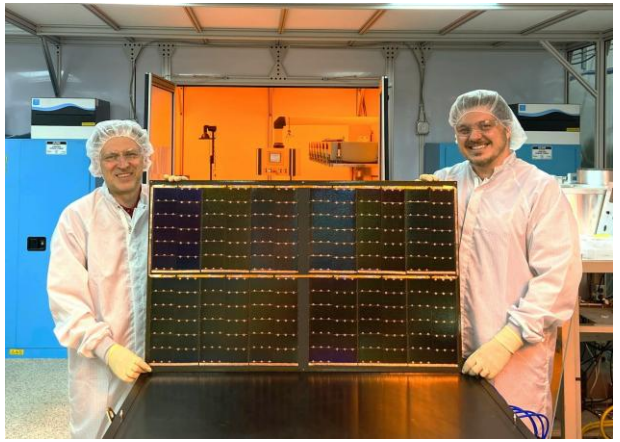
Contents

Company Overview

- **Mission:** deliver abundant energy in space.
- **What we do:** developing and manufacturing Si solar cells, modules and blankets optimized for space.
- **Location:** Tempe Arizona, 30,000 sq ft dedicated industrial space.
- **Team:** 45 full time employees.



Radiation hardened Si solar cell



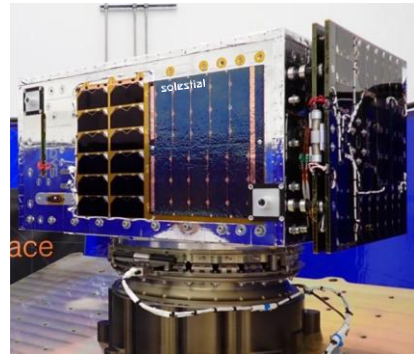
120W Si solar panel

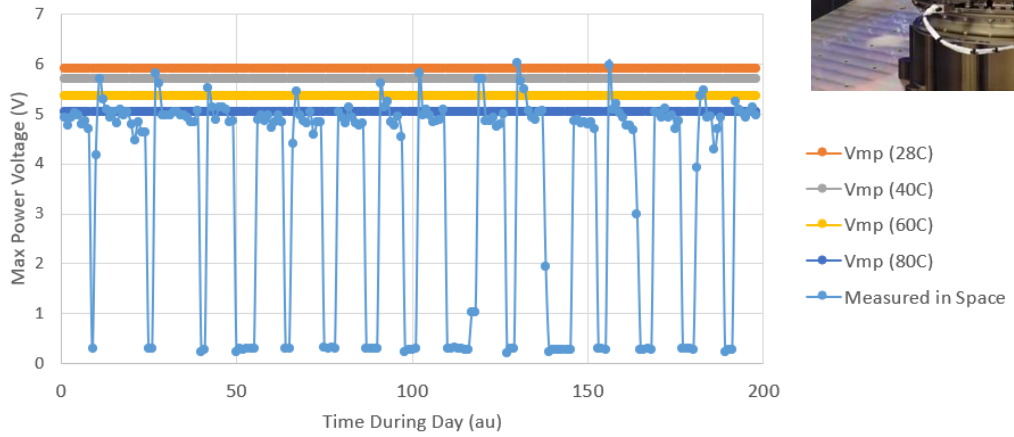
Solestial team in 2025

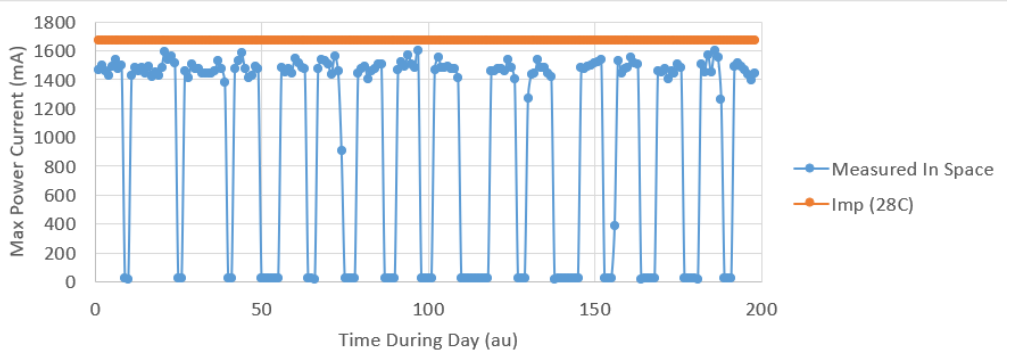
Solestial Production Facility

In-Space Performance

- **Flights**
  - Flew demo panels on 5 commercial spacecraft in LEO. Largest panel – 120 Watt.
  - None of the panels failed.
  - In-space performance data from AVS shows good correlation with ground testing.
  - We adjusted our current calibration to reproduce space measured current.
- **TRL**
  - Achieved TRL 7.
  - Transitioning to TRL 9 this year with main mission power flights.

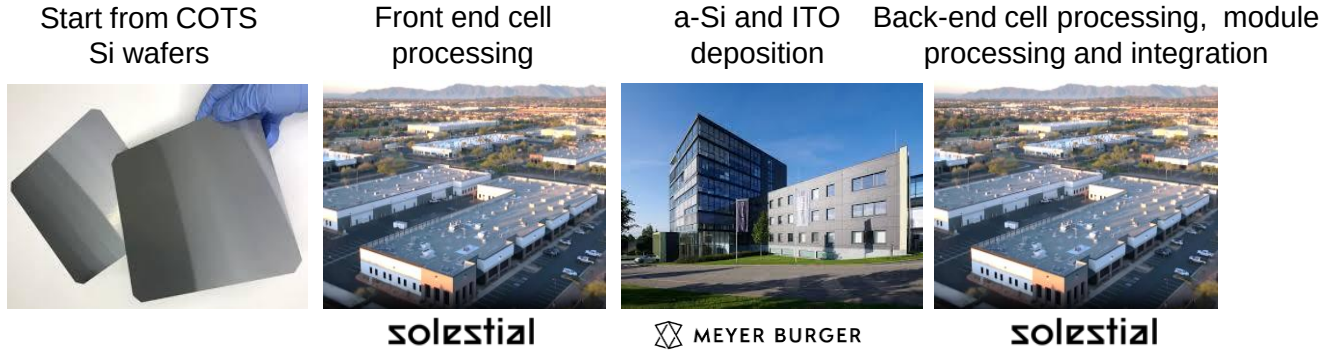


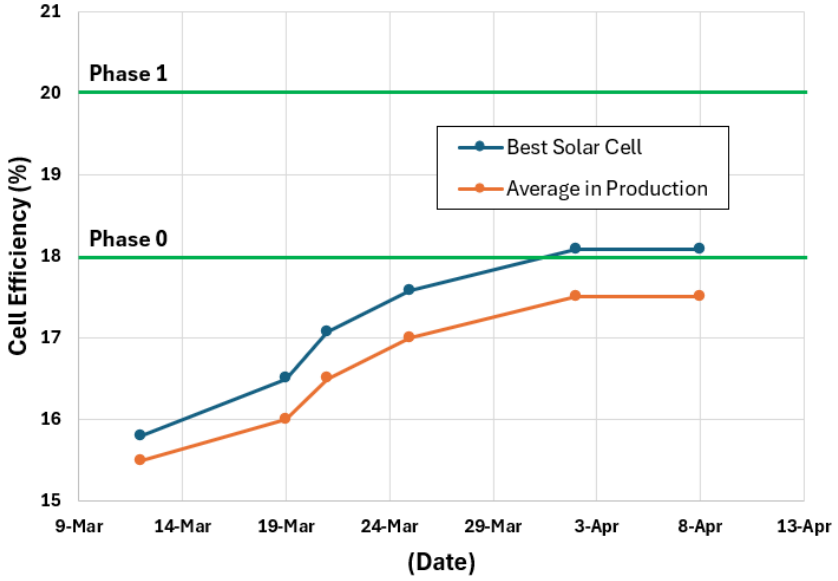


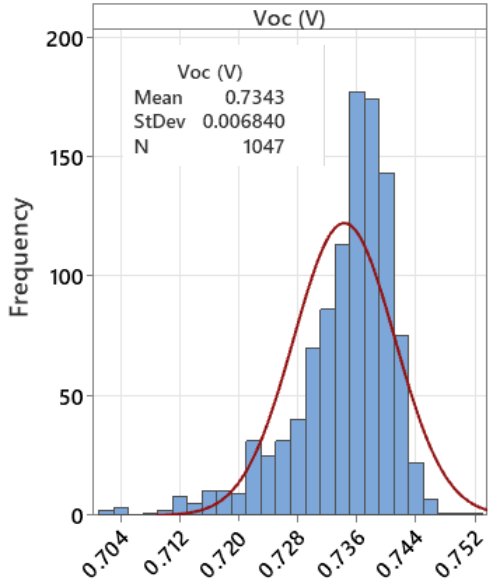


Production Ramp

- ASU => Solestial Fab in Tempe, AZ
- Production started in March 2025
- **Ramp goals:**
  - Currently running 1 kW/month
  - Summer – 8 kW/month
  - End of year – 40 kW/month
- **Performance goals:**
  - Phase 0 – 18%, 60-micron-thick
  - Phase 1 – 20%, 40-micron-thick



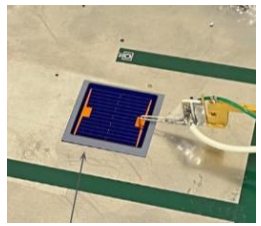


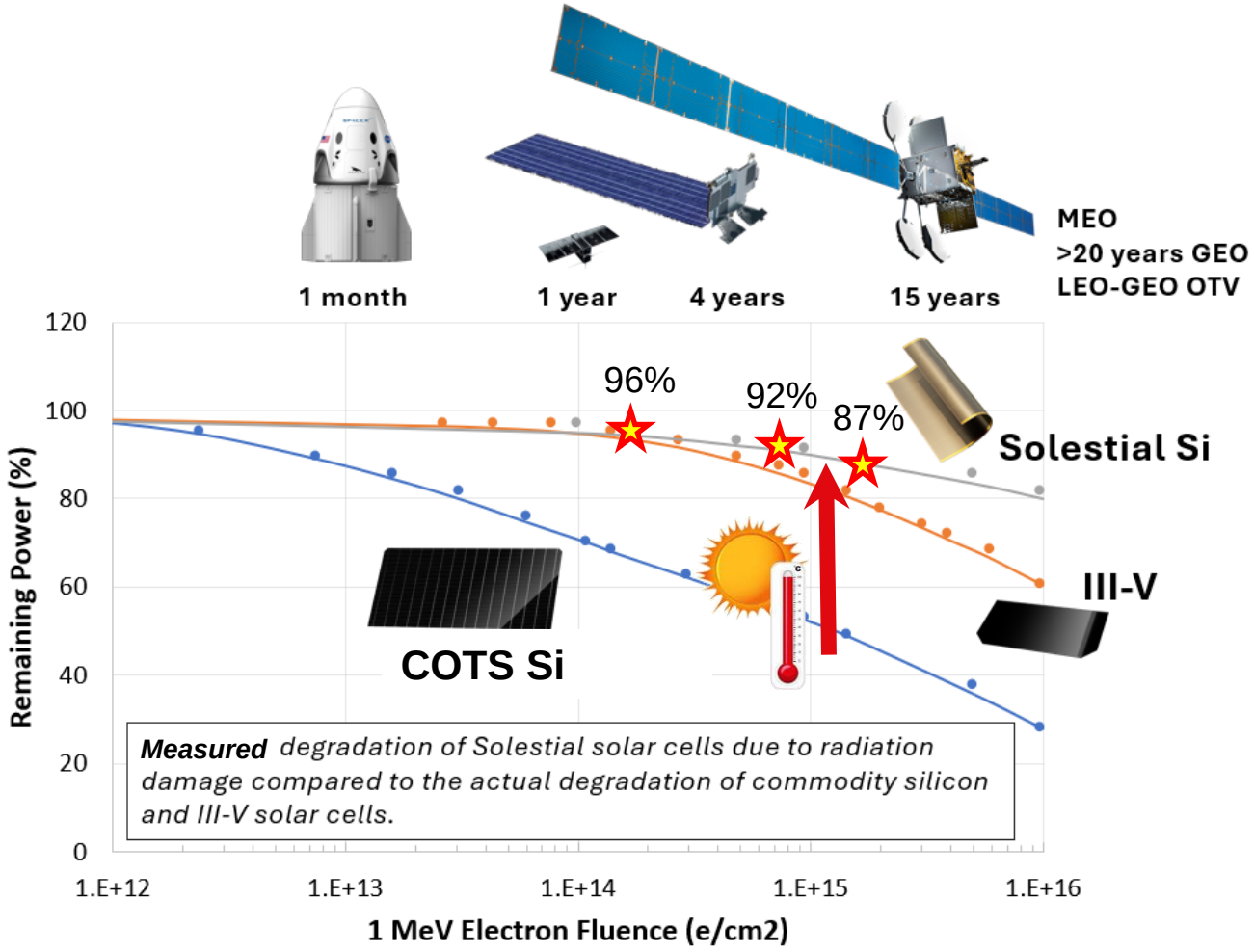


March 2025 data

Why Thin Si Cell?

1. **Enables lower radiation induced degradation**
   - 1 MeV electrons damage annealing by CEA
   - 80ºC, light, open circuit, in atmosphere, 400 hours.
   - Limitations: 15% BOL efficiency, 4 cm^2 cells, 20 um thicknss, EOL efficiency assumes no FF degradation.
   - **Next steps:** 20%, 40 um thick production cells
   - 5 cycles of 1e14 e/cm^2 irradiation and annealing.
   - Cell qualification starts in Summer 2025.

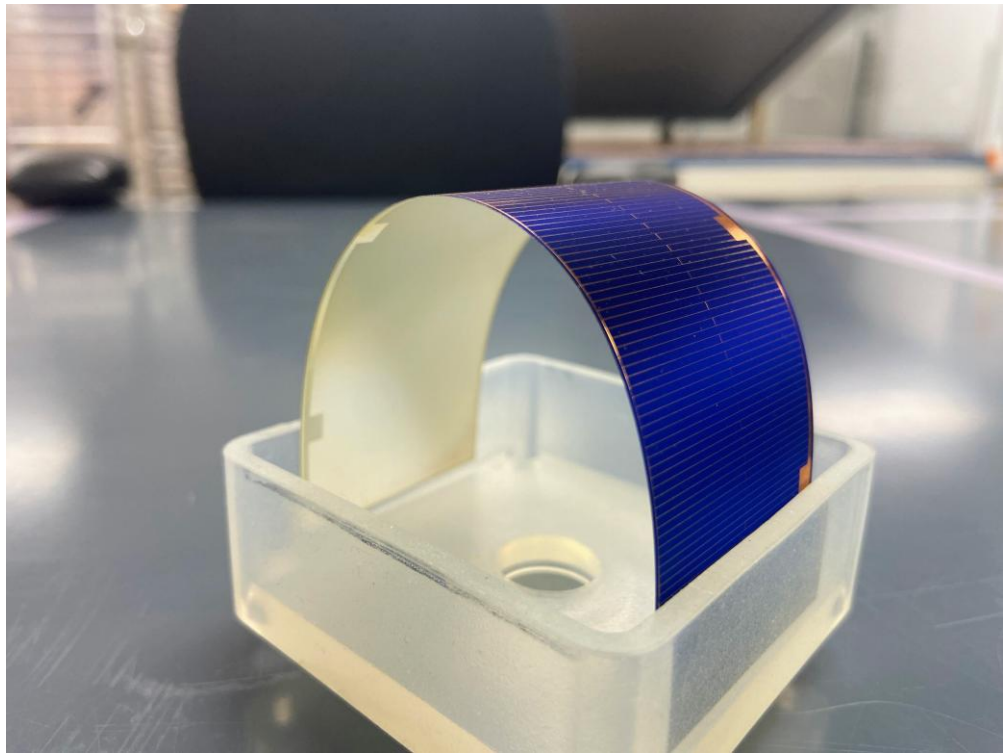




Why Thin Si Cell?

2. **Lower mass of the cells**
   - 20 kW array, 220 W/m^2
   - 20 kg win on an 800 kg satellite

Wafer Thickness	Wafer Mass Density	Wafer Mass
140 microns	310 g/m^2	28.2 kg
40 microns	89 g/m^2	8.1 kg



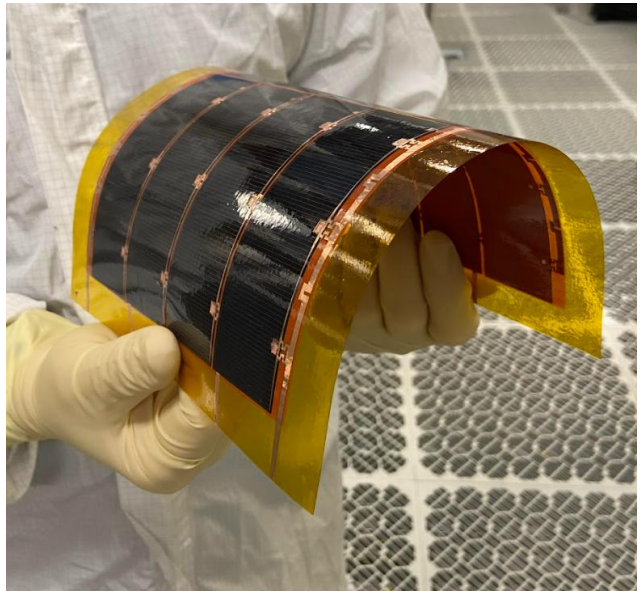
Packaging Technology for thin Si Solar Cells

2019

Mockup of the flexible blanket and soar cells

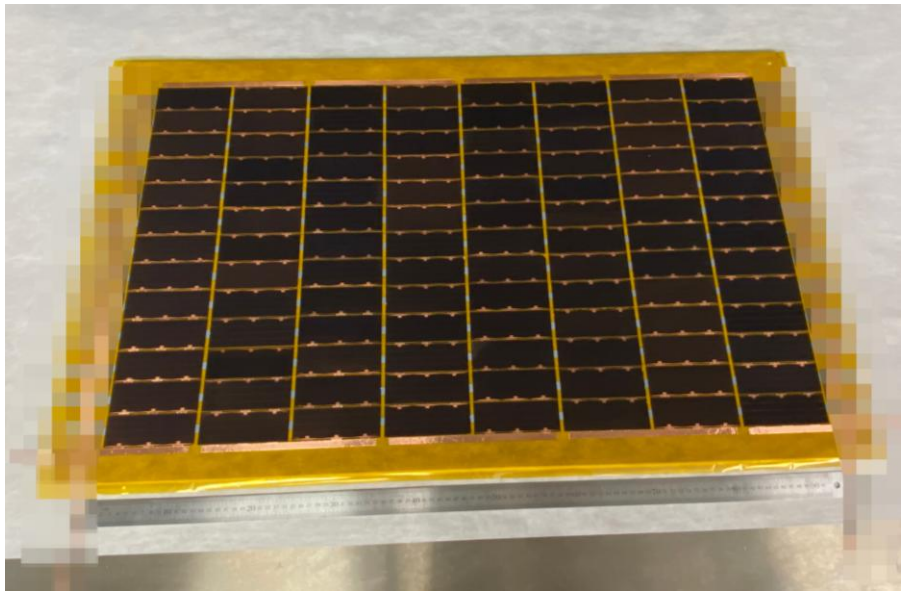
2023

A functional prototype



2025

Flight tested solar cells and solar power modules in production



Packaging Technology for thin Si Solar Cells

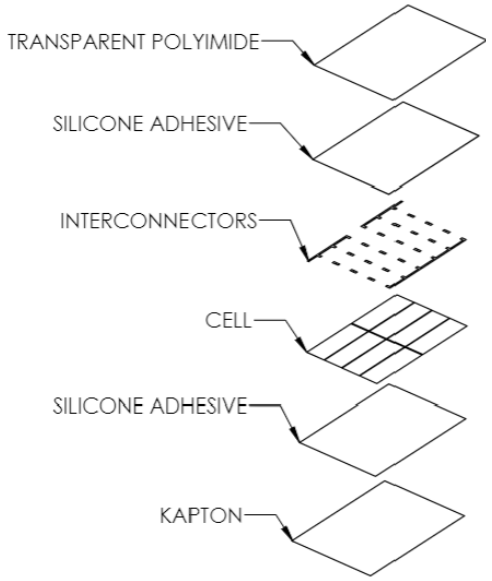
- **Features:**
  - 1 m^2 processing capability
  - Light weight and rollable
  - Fully encapsulated, no edges exposed
  - Arbitrary cell sizing and stringing
- **Module on the image:**
  - Active area: 0.9 m x 0.53 m
  - 210 g weight (350 g/m^2) w 60 um cells
- **Target specs:**
  - Voc = 72.5V, Isc = 1.8A
  - Power = 100W

Module Mass

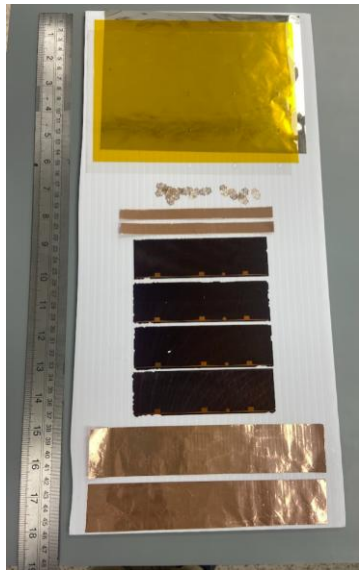
- **Model:**
  - Mass can be very accurately calculated for all components with the exception of silicone.
  - We measure the mass of silicon empirically.
- **Result:**
  - A module with a flex circuit harness weighs 500 g/m^2

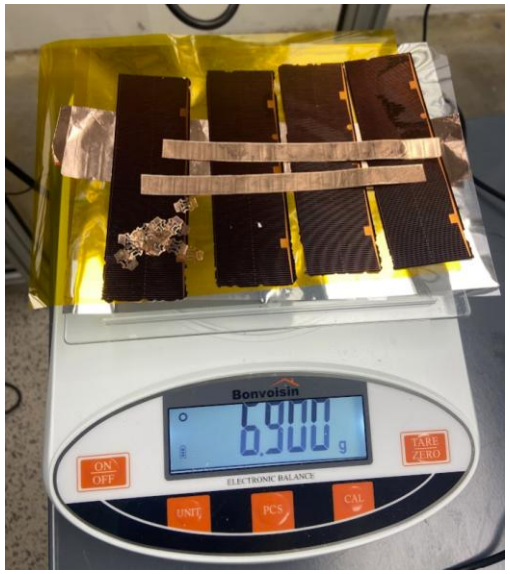
		Thickness	Coverage	Density	Volume	Mass
		(um)	Fraction	(g/cm3)	(cm3)	(g/m2)
	Mass Component					
	Ceramic coating	0.2	1	3.9	0.2	1
	Clear polyimide	25	1	1.42	25	36
	Silicone	46	1	1.05	46	48
	Copper	15	0.07	8.9	1.05	9
	Silicon	40	0.95	2.33	38	89
	Copper	15	0.07	8.9	1.05	9
	Silicone	46	1	1.05	46	48
	Polyimide	25	1	1.42	25	36
	Interconnectors	12	0.07	8.9	0.84	7
	Terminations	25	0.12	8.9	3	27
	Silicone	46	1	1.05	46	48
	Copper harness	12	1	8.9	12	107
	Polyimide	25	1	1.42	25	36
	TOTAL	332			**TOTAL**	**500**

Module Mass – Silicone Measurement

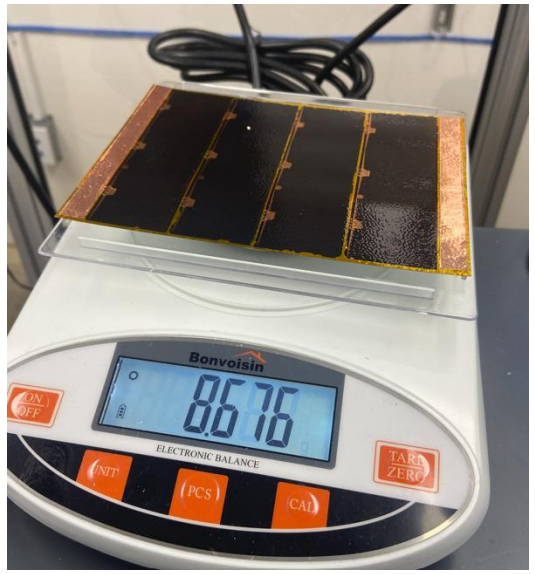


Module components without silicone

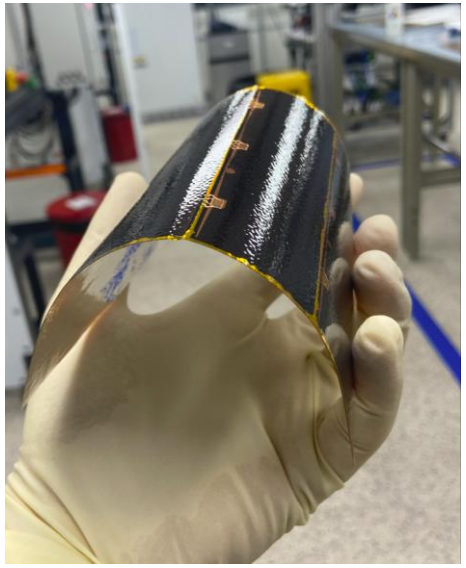




Laminated module with silicone



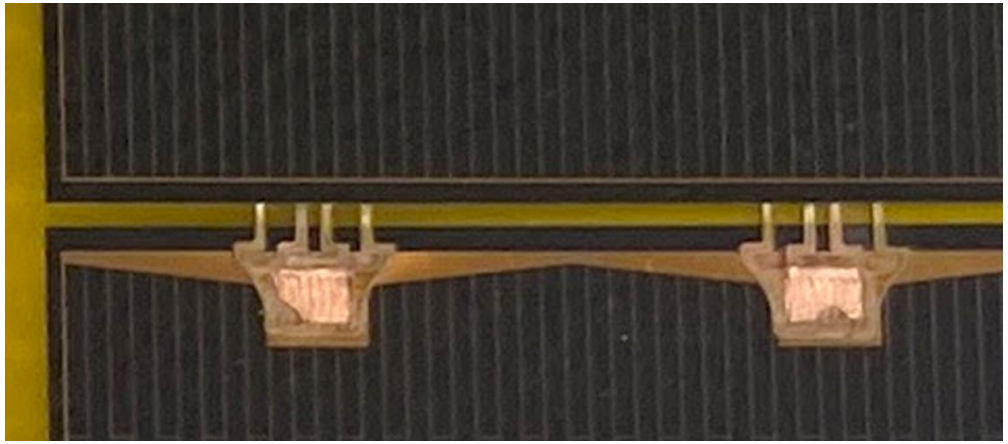
Module with built in flat copper harness remains flexible

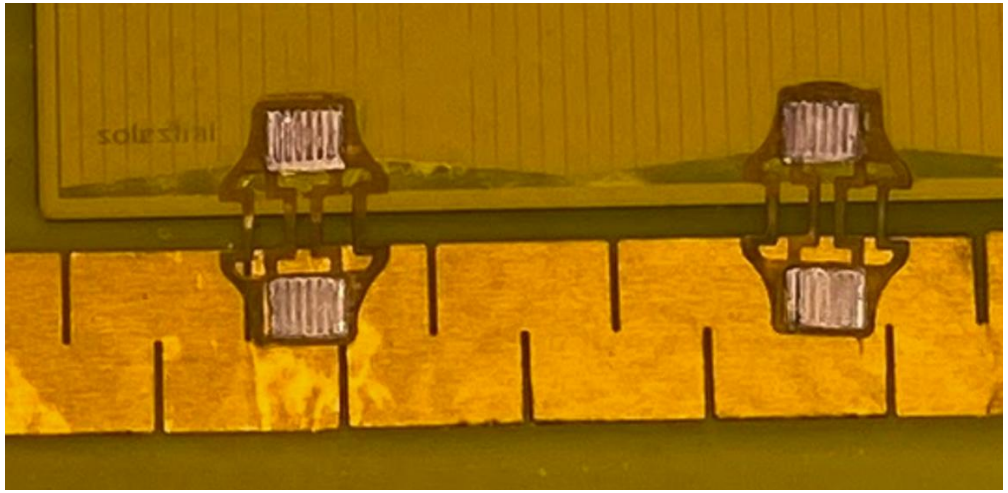


Cell to Cell Interconnection

- **Challenge:**
  - Welding cracks solar cells thinner than 60 microns.
  - Soldering and conductive adhesives have limited lifespan in space.

- **Approach:**
  - Fully laminated copper foil interconnects with in-plane stress relief.
  - Novel method to form a joint between an interconnector and a solar cell.
  - Fully laminated interconnectors.



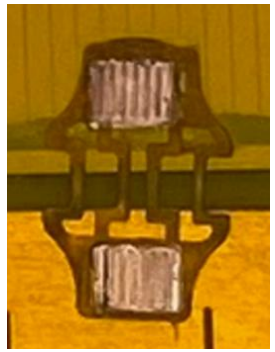


Cell to Cell Interconnection – Evolution

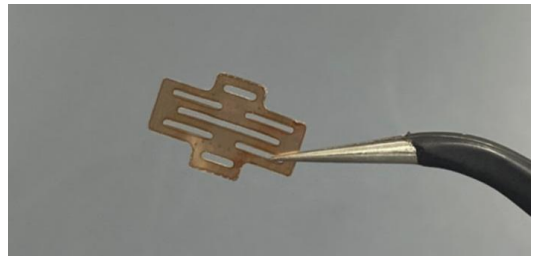
Gen 1

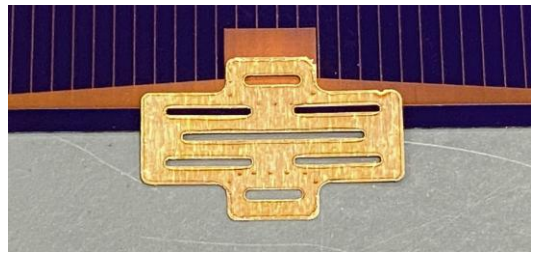
Gen 2

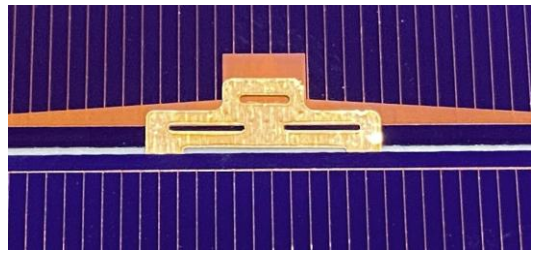
Gen 3



Gen 4

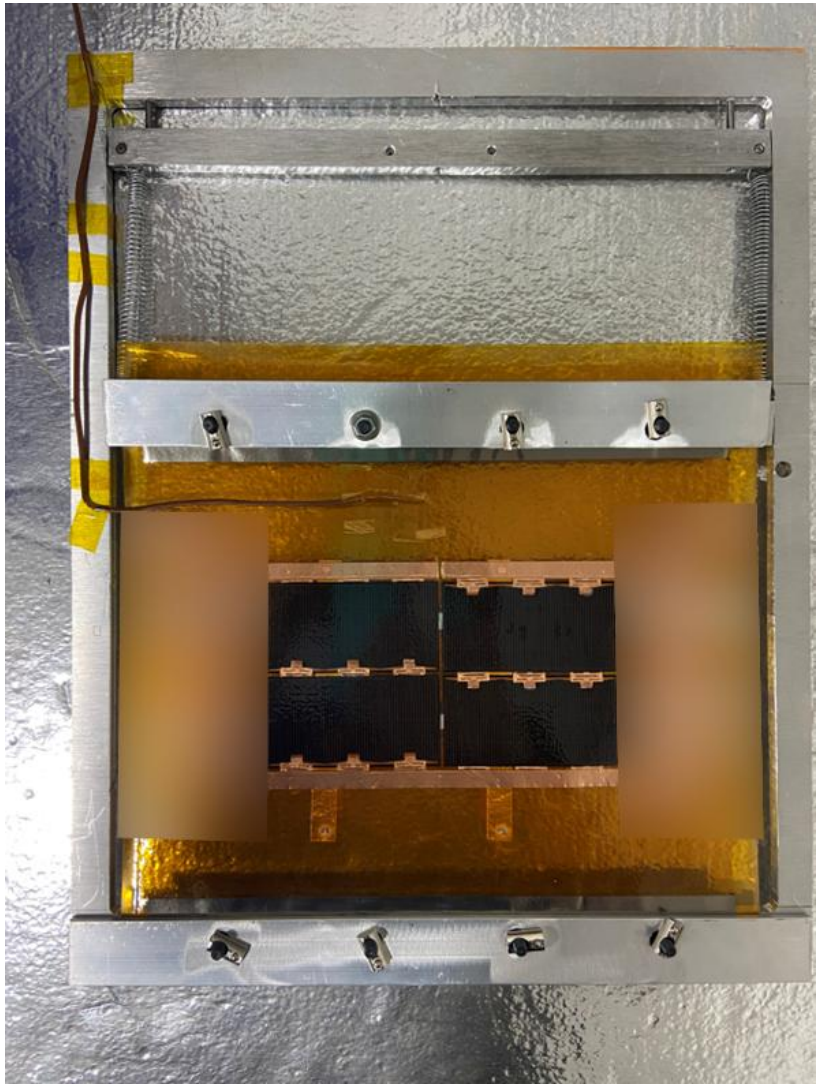






Thermal Cycling

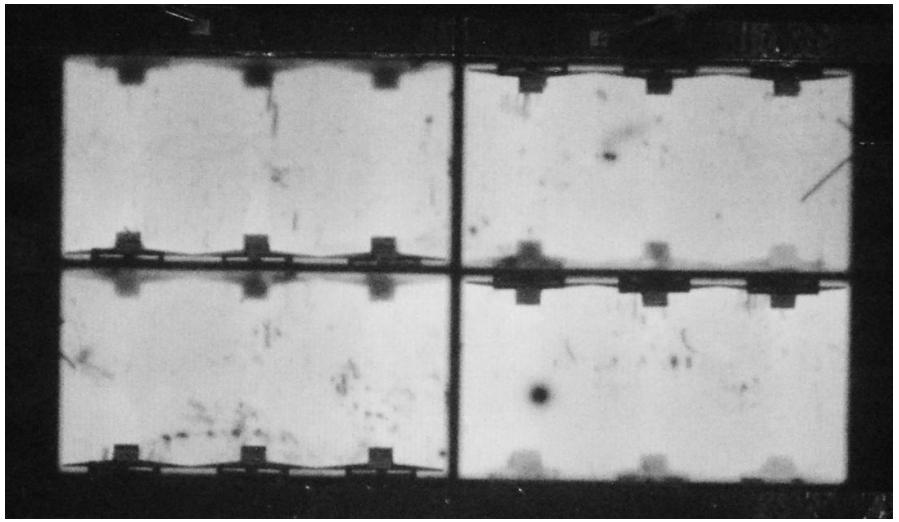
- **Test device:**
  - All components of the module have flight-ready configuration.
  - Additional titanium bars for uniform distribution of a pulling force.
  - Tension created by two springs.
- **Cycling conditions:**
  - Temperature range: -60ºC/+120ºC
  - Cycle time: 20 min, dwell time: 1 min
  - Cycling in atmosphere



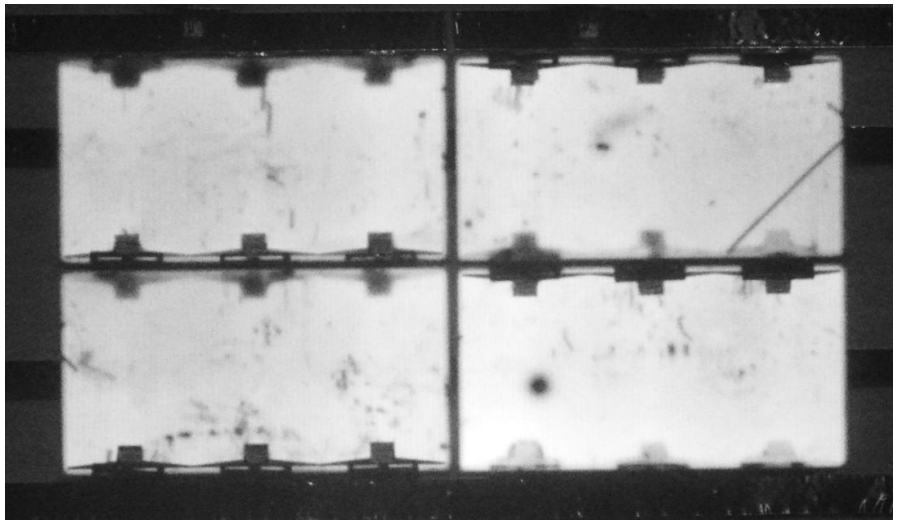
Thermal Cycling

- **Results**
  - No efficiency change after 33 cycles.
- **EL analysis:**
  - Some types of cracks can propagate as a results of thermal cycling => guides cell sorting.
  - No string failure after crack propagation.

Before cycling



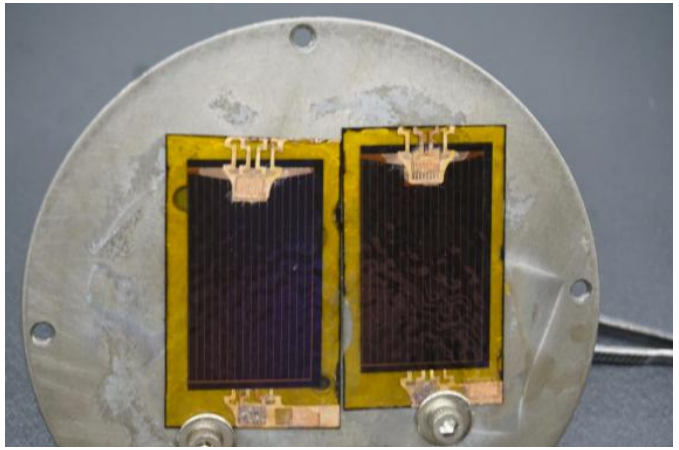
After cycling

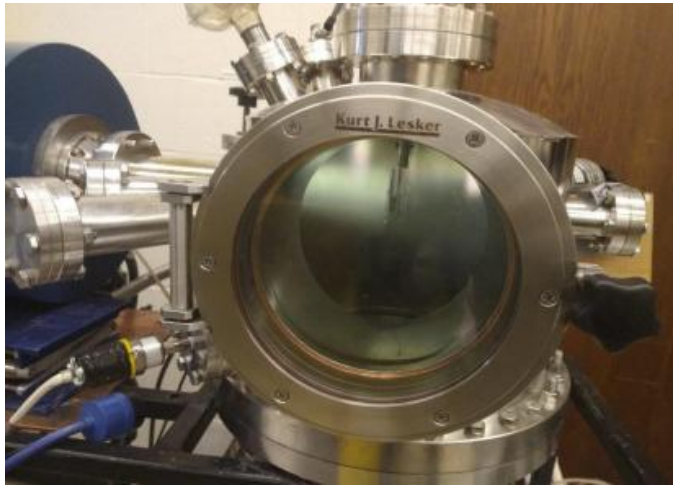


AO Exposure

- Conducted Atomic Oxygen exposure at the University of Nebraska.

- **Tests conducted:**
  - 500 km, 1 year (mid LEO)
  - 500 km, 5 years (mid LEO)
  - 375 km, 10 years (vLEO)
- **Results:**
  - No visual change of the samples after all tests. Performance degradation within 2% after AO exposure.
  - Solestial capping layers protect polyimide films from AO.





UV Exposure

- Conducted vacuum UV exposure in collaboration with a development partner.

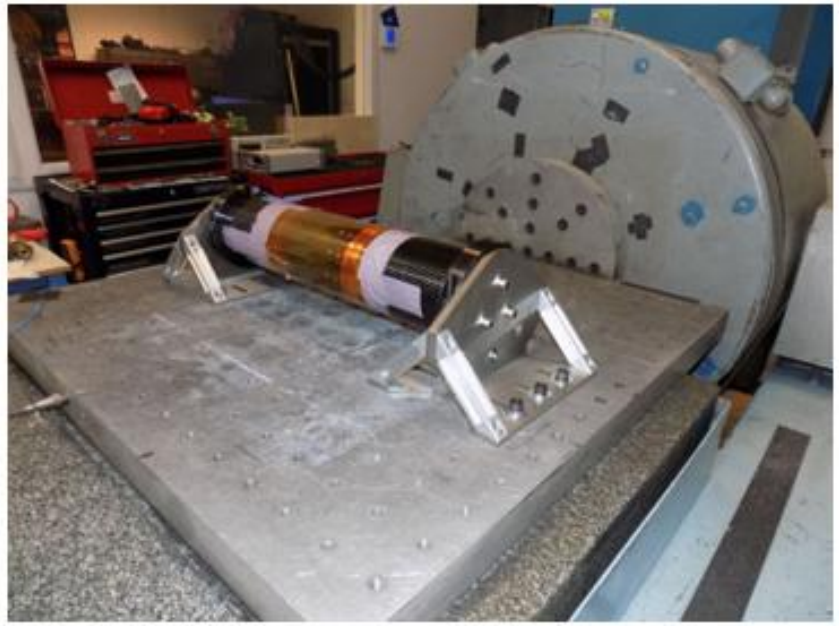
- **Tests conducted:**
  - <200 nm
  - UV flux: 2.5 W/m^2

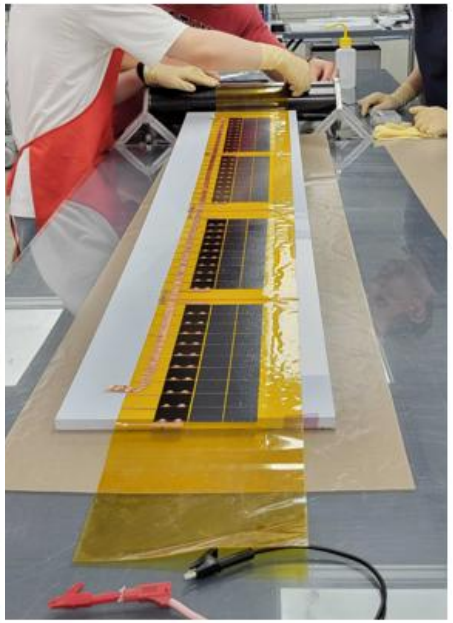
- **Results:**
  - No transmission degradation after 2,000 ESH of vacuum UV exposure.

Vibration Testing

- Conducted stowed vibration testing at NTS in Tempe, AZ

- **Tests conducted:**
  - Falcon 9 component level vibration environment.
  - No spacers between the layers of the blanket.
- **Results:**
  - No change in blanket performance after vibration test.





Frequency (Hz)	ASD Level (g^2/Hz)	
	Qualification	Acceptance
20 20-50 50-800 800-2000 2000	0.026 +6 dB/oct 0.16 -6 dB/oct 0.026	0.013 +6 dB/oct 0.08 -6 dB/oct 0.013
Overall	14.1 G_{rms}	10.0 G_{rms}

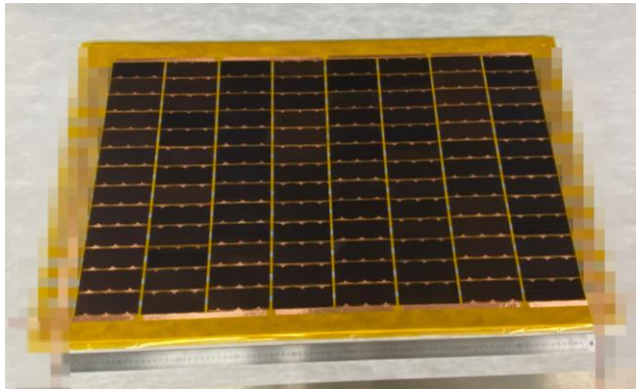
Mission Integration

- Solestial is working with Argo Space Corp. on the development of the roll out solar array for Argo's novel **space transportation and mobility vehicles**.
- We are delivering 6.8 kW of solar blankets with integrated harnessing optimized for roll out deployment in 2025.
- Argo Space Corp. is developing a novel roll out deployment mechanism and blanket tensioning system.

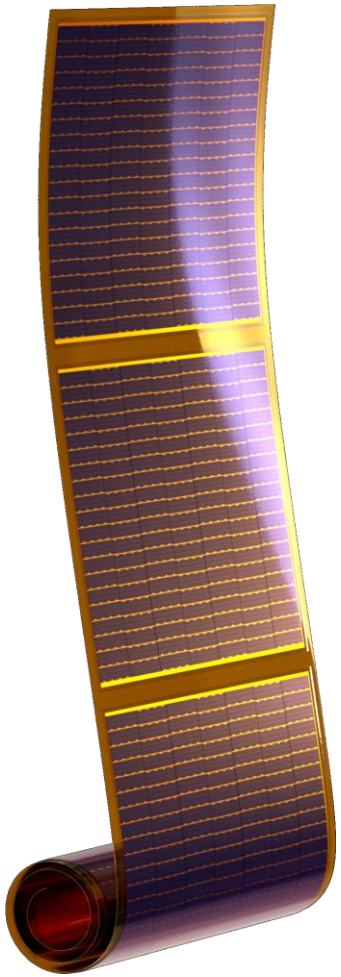
ARGO SPACE CORP

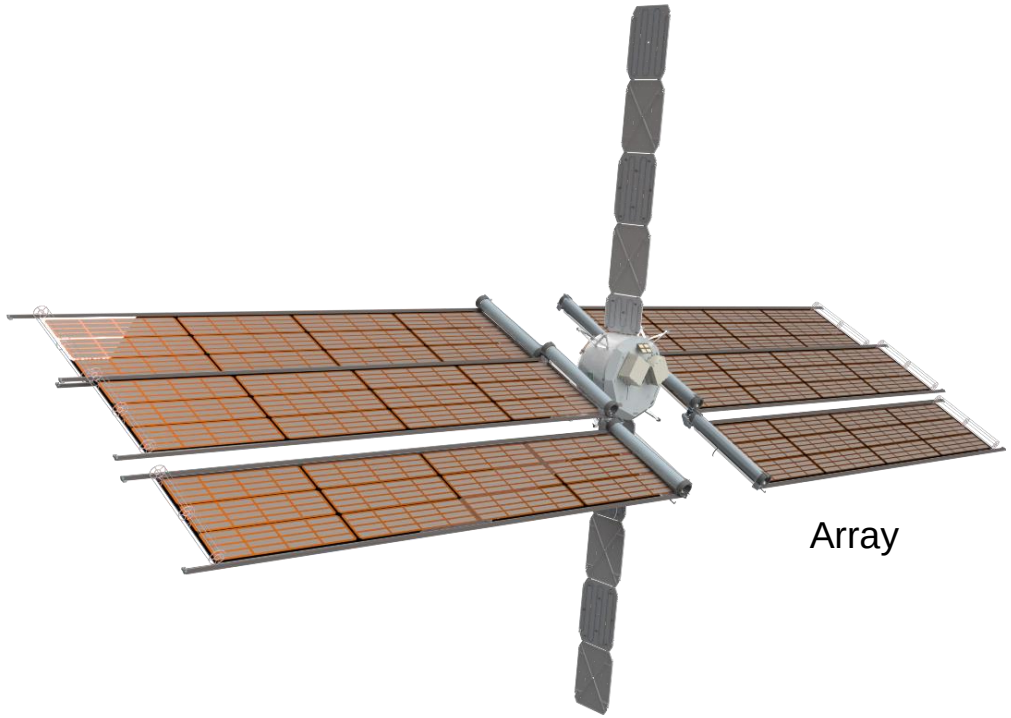
solestial

Module



Blanket





Array

Acknowledgements

- NASA SBIR Ignite, Phase 2 CN: 80NSSC23CA186

- Space Force SBIR, Phase 1 CN: FA254125PB008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