Solving Long Lead Times and the High Cost of Space Solar Panels with Upgraded Silicon Technology

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Abstract

Solestial is developing 100% US made solar cells and blankets with >18% BOL efficiency, over 10 years lifespan, <3% annual degradation rate, <400 g/m² specific mass, >10 MW manufacturing capacity and $20/W price by 2025. This new solar technology will be beneficial for the projects where high cost, long lead times and low manufacturing capacity of space-grade solar cells and panels are the major barriers for implementation. Here we describe the main features of our solar cells and blankets.

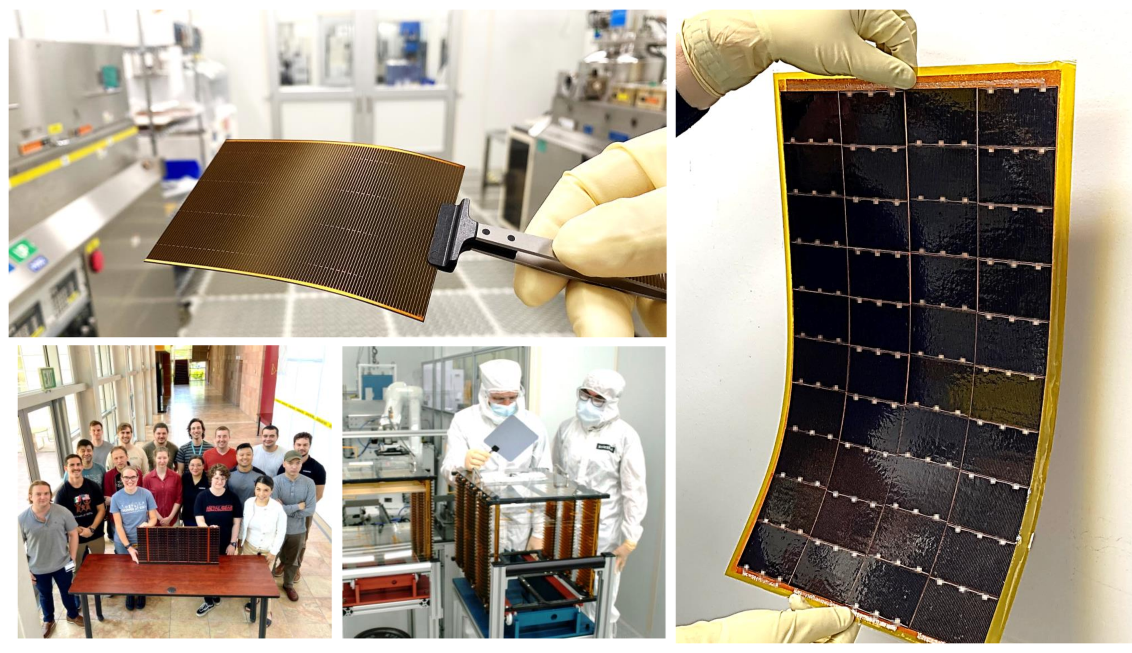


Figure 1. A thin silicon solar cell, solar blanket and Solestial team holding a blanket bonded to a 'sandwich' panel.

Si Solar Cells that Can Self-Cure Radiation Damage

- Solestial has developed ultrathin silicon heterojunction solar cells with electroplated metallization. Thinness and silicon defect engineering allow our solar cells to achieve full recovery of up to 10 years' worth of radiation damage at <90ºC temperature under full sunlight exposure[1]. This allows us to create self-curing solar cells with substantially reduced radiation induced degradation.

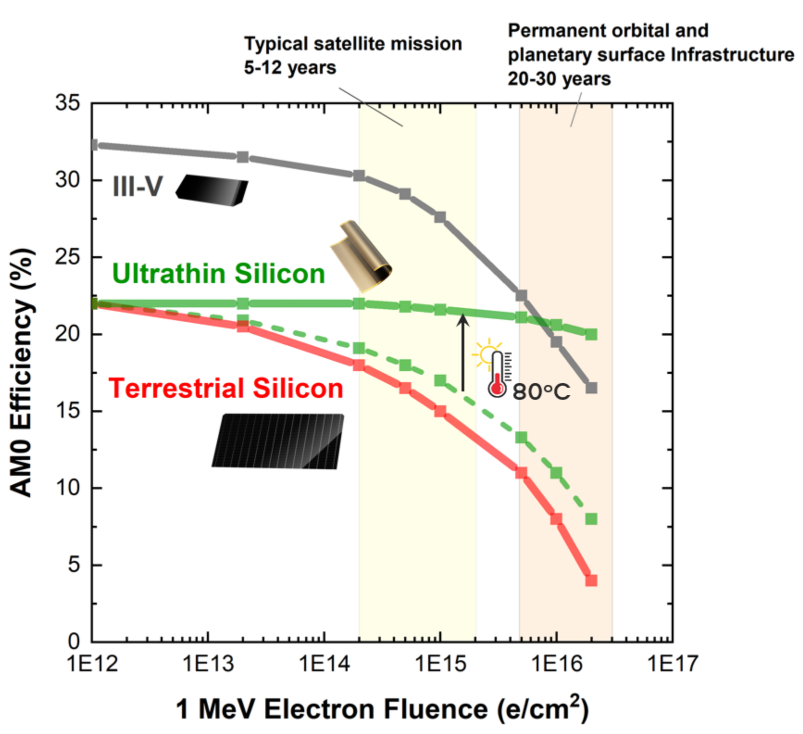


Figure 2. Projected end-of-life efficiency of ultrathin silicon solar cells providing solar cells routinely experience more than 80ºC temperature in space.

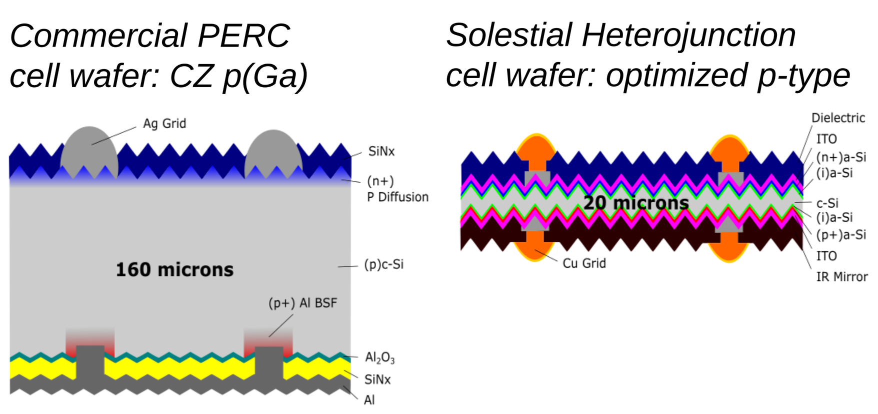


Figure 3. Schematic picture of a PERC solar cell and Solestial Ultrathin Silicon Heterojunction solar cell.

	Before Irradiation	After Irradiation	After 8hrs at 80ºC
Voc (mV)	718	614	714
Jsc (mA/cm²)	35.4	32.1	35.3
FF (%)	74.2	69.5	74
AM1.5 Eff. (%)	18.9	13.7	18.7

Table 1. Best ultrathin solar cell performance before and after 1 MeV 1e15 e/cm² irradiation and 80ºC annealing.

Novel Packaging Technology for Ultrathin Solar Cells

- We have developed a process to encapsulate and interconnect ultrathin silicon solar cells into thin and light-weight blankets. We use planar interconnectors with in-plane stress relief, polyimide substrate, silicone adhesives and transparent polyimide front cover with protective capping layers. Blankets with >19% AM 1.5 efficiency (~17% AM0) have been demonstrated.

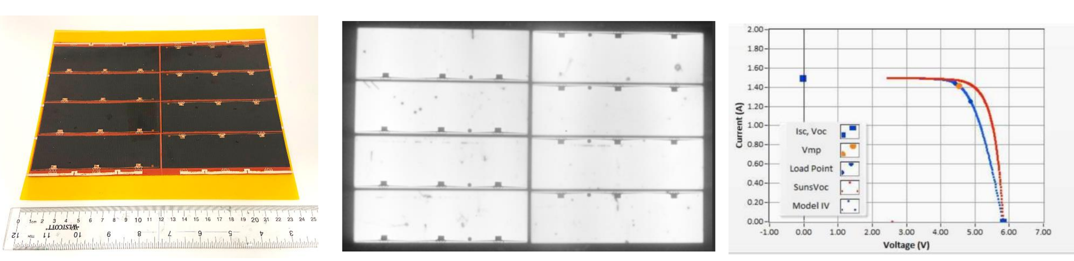


Figure 4. Photo, electroluminescence and IV curve of a mini-blanket with 19.3% AM1.5 efficiency.

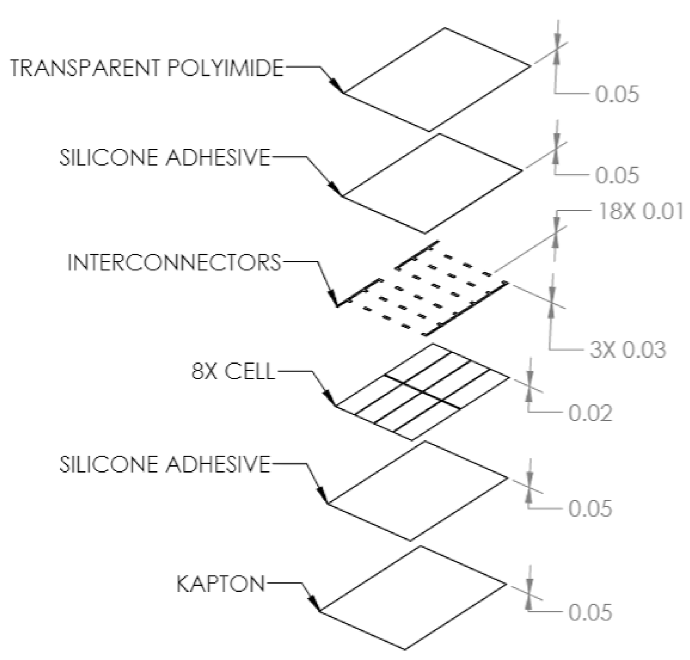


Figure 5. Schematic diagram of the layers comprising Solestial blankets.

Full Customization

- Unlike incumbent space solar panels, we begin the design process with panel drawings and adjust solar cell size to cover the available area. This method increases packing density to partially compensate for the efficiency difference between III-V and Si space solar cells.

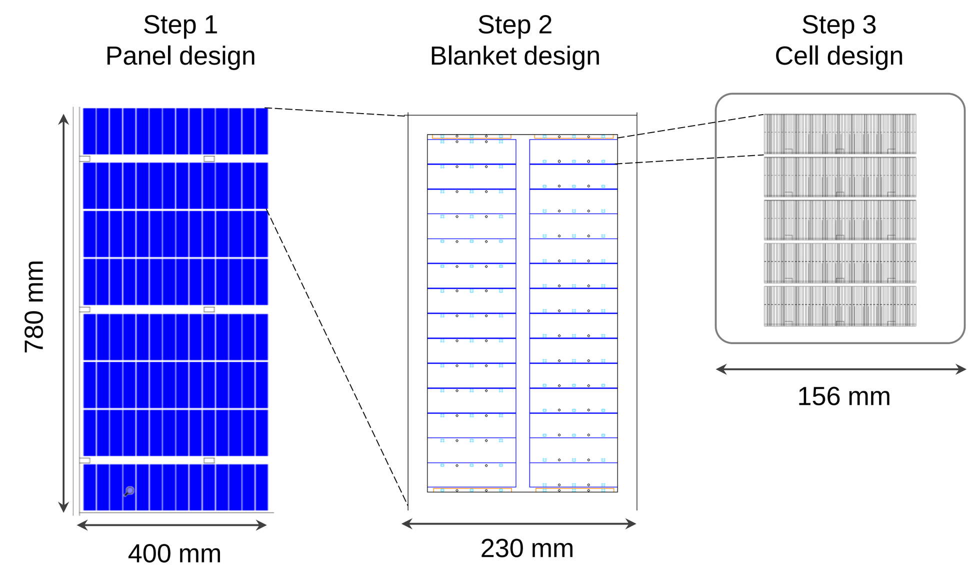


Figure 6. Schematic representation of the process of panel design which starts from adjusting the cells to achieve a packing density, followed by blanket design and fitting solar cells on a wafer.

Mass

- Solestial cells are thin and light-weight. They also don't need cover glass to protect from radiation. Thus, overall mass of the solar cells is low, and no stiff substrate is necessary to carry the cells. Solestial encapsulates solar cells between two thin polyimide films using silicone adhesives. Thus, overall mass of the package can be <400 g/m² compared to ~2,000 g/m² for standard III-V panels or glass/glass Si panels.

	Thickness (microns)	Coverage	Mass (g/m²)
Encapsulant Film	25	1	63
Front Silicone	50	1	50
Front Metal	5	0.07	3
Silicon	20	1	47
Rear Metal	5	0.3	13
Rear Silicone	50	1	63
Kapton	75	1	107
Interconnectors	40	0.1	36
TOTAL	270		380

Table 2. Mass breakdown of the layers in Solestial blankets.

Flexibility

- Low temperature annealing of ultrathin silicon solar cells under light was demonstrated. The dependence of annealing rate and temperature on cell.

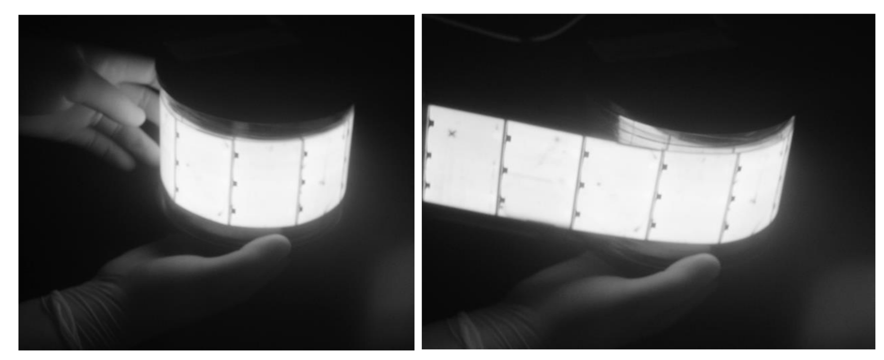
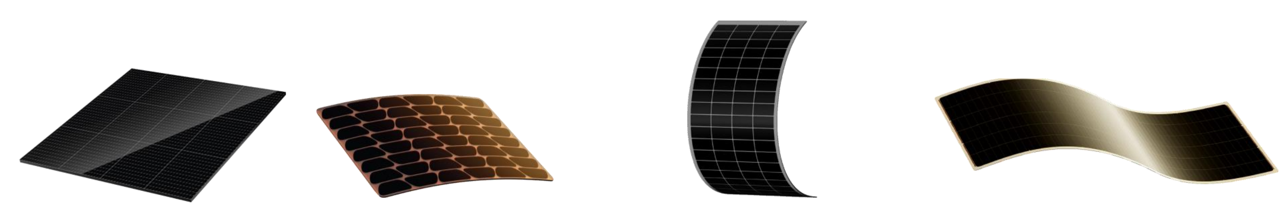


Figure 7. Electroluminescence of Solestial blanket wrapped around a spool with 15 cm diameter at room temperature.

Comparison with III-V and Terrestrial Silicon



	Space Solar Panel	Space Solar Blanket	Terrestrial Silicon Blanket	solestial
Cell efficiency (%)	29-32	29-32	22-23	22-23
EOL/BOL (Radiation)	0.9	0.9	0.65	0.9
NOCT/STC (Temperature)	0.87	0.87	0.8	0.88
Packing Density	0.8-0.9	0.8-0.9	0.95	0.95
Power Density (W/m²)	300-380	300-380	270-300	270-300
Specific Power (W/kg)	100-150	250-350	50-200	500-600
Price ($/W)	200-400	400-600	5-20	20-40
2025 Production (MW)	2	0.5	10	10
Scaling Potential (MW)	10	10	>1,000	>1,000

Acknowledgement

NASA Contract Numbers
80NSSC21C0072
80NSSC22CA123

NSF Award ID
2052381

R&D Pilot Line
Access

References

- S. Herasimenka, et al., "Full Recovery of Radiation Damage in Silicon Solar Cells at 80°C Under Light," 40th Space Power Workshop, Torrance, CA, 2023.

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