National Aeronautics and Space Administration

Non-nuclear Deep Space Exploration Using Ultralight Radiation Hard Photovoltaics

Principal Investigator: Clara MacFarland (346); Co-Investigators: Tyler Colenbrander (346[1]), Dennis Thorbourn (514), Wousik Kim (513), John Brophy (312), Jonathan Grandidier (346[1])

Program: FY22 R&TD Topics
Strategic Focus Area: Power generation

[1] Previously in 346, but no longer at JPL

Objectives:
Evaluate perovskite solar cells as a potential power source for deep space missions. The specific objectives for the task this year were:
1) Determine whether perovskite solar cells are sufficiently radiation-tolerant to be used without coverglass
2) Determine whether a perovskite-based solar array could achieve a higher specific power than state-of-the-art solar arrays under Saturn and other deep-space conditions

Background:
- Solar arrays with high specific power and strong radiation tolerance have the potential to enable low-cost missions to the outer planets
- Perovskites have been identified as a new photovoltaic material of interest for their high specific power, lower cost, and anticipated radiation tolerance

Approach and Results:
- Test articles: 10 solar cells from three different collaborators (3 x CSIRO, 3 x ANU, and 4 x NREL)
- Measurements: Solar cells were irradiated to an equivalent TID for a Saturn mission (1.83e15 e^-/cm^2) at -140C. Illuminated I-V (LIV) data were taken before and after irradiation at (5.5 AU, 9.5 AU) x (28C, -50C, -100C, -140C, -165C) and (19.2 AU) x (28C, -165C)

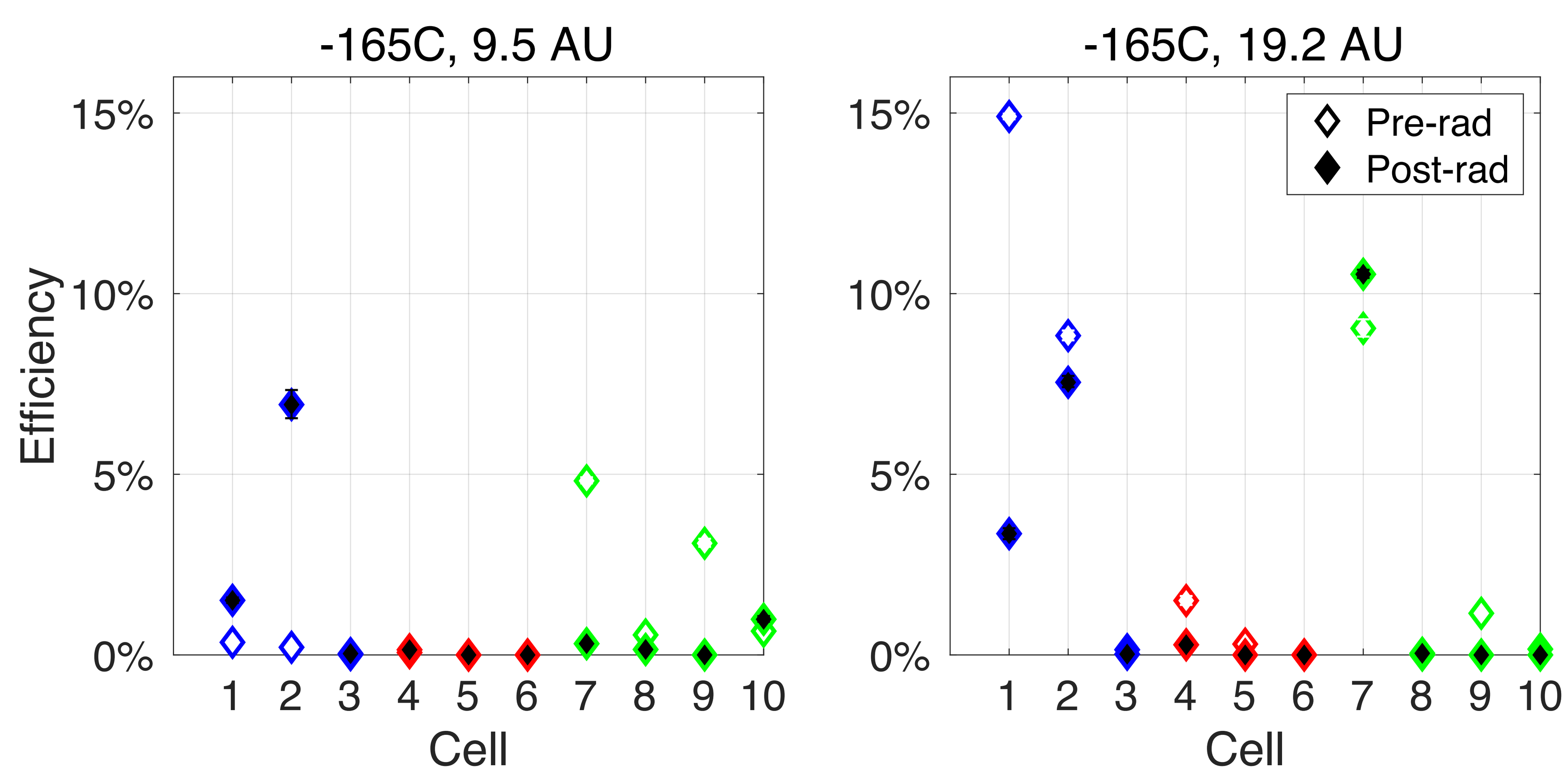

Figure 1. Cell efficiencies before and after irradiation. Pre- and post- rad efficiency, and relative change varied widely cell to cell, and changed depending on the solar irradiance.

	Technology	Description	Maturity
Structures	Europa Clipper	Rigid panels	State-of-practice (SOP); will fly on Europa Clipper
	Deep Space Solar Array [1]	Ultraflex-based flexible array optimized for Saturn	State-of-the-art (SOA); achieved TRL 5 for Saturn integrated with IMM4-Saturn solar cells
	Ultralight [2]	Lighter-weight, flexible structure	Currently in development
Solar cells	3G28	Triple-junction III-V cells	State-of-practice; will fly on Europa Clipper
	IMM4-Saturn	Saturn-optimized four-junction III-V cells	State-of-the-art; achieved TRL 5 for Saturn integrated with the Deep Space Solar Array structure
	Perovskite	Currently-studied cells	Currently in development

Figure 2. Solar array structures and solar cells for deep space. A solar array consists of solar cells mounted on a mechanical structure; these options represent SOP, SOA, and potential future technologies.

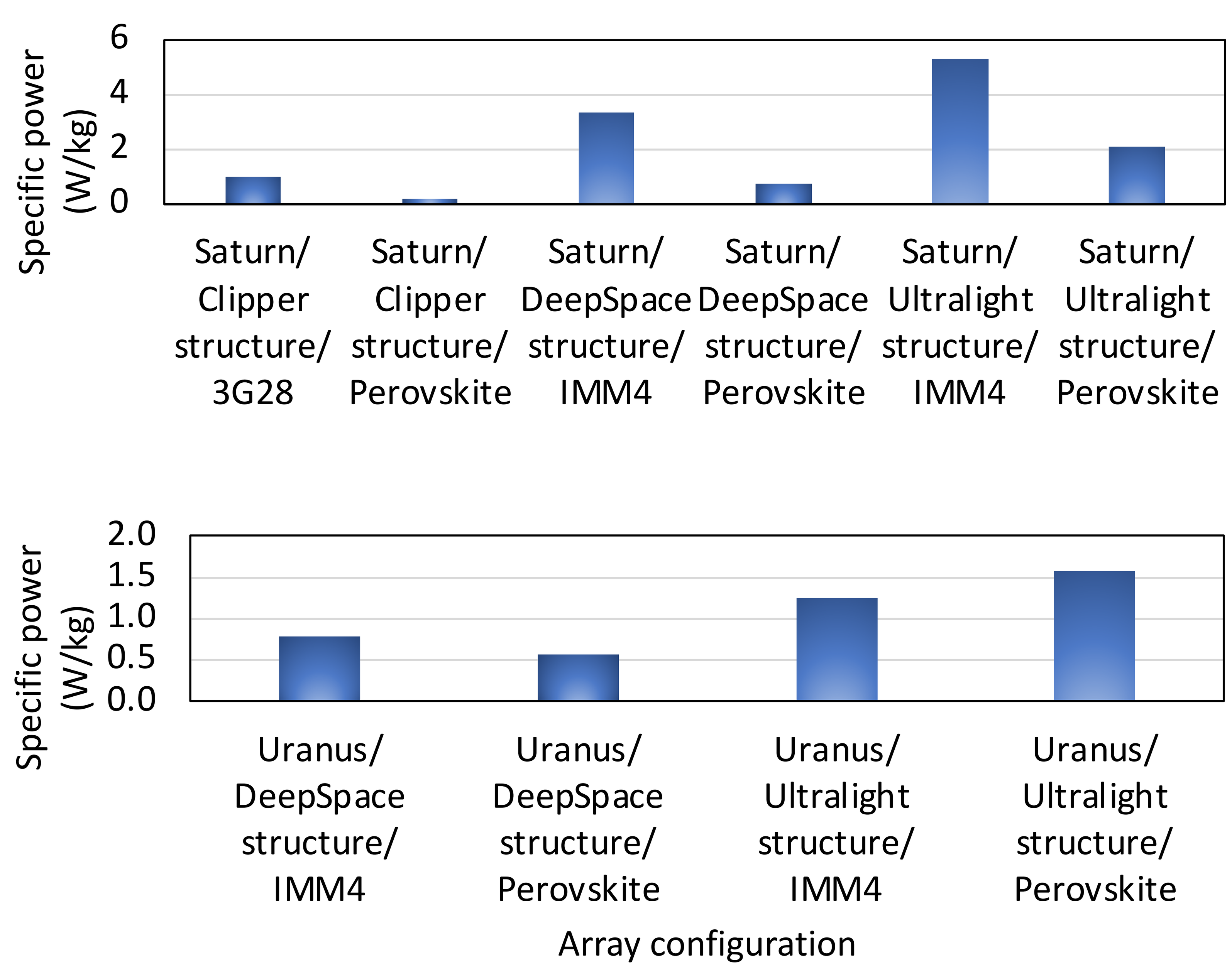

Figure 3. Specific power of solar array configurations. Perovskite solar cells only outperform traditional cells under near-Uranus conditions on a very lightweight structure.

Significance/Benefits to JPL and NASA:
We recommend that perovskite solar cells not be considered for near-term deep space applications until substantial developments are made to address the following key vulnerabilities:
- Root causes for LILT variability would need to be identified and resolved
- Efficiencies would need to be improved to at least 20% (for integration on an existing structure)
- Cell performance would need to become reproducible for large-scale production
- Cell resilience to atmospheric exposure would need to be improved

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

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PI/Task Mgr. Contact Information:
Email: clara.a.macfarland@jpl.nasa.gov

[1] Andreea Boca et al., “The Deep-Space Solar Array: a Power Source for Missions to Saturn and Beyond,” 2022 Conference on Advanced Power Systems for Deep Space Exploration (Aug 30 – Sep 1, 2022, virtual).
[2] Terry Gdoutos et al., “Ultralight Spacecraft Structure Prototype,” AIAA Scitech 2020 (6-10 January 2020, Orlando, FL), Forum AIAA-2020-0692