Virtual Research Presentation Conference

High-Efficiency Lightweight Solar Array for Deep Space Missions

PI: Andreea Boca (346)
Co-Is: Joel Schwartz (346), Jonathan Grandidier (346), Clay McPheeters (SolAero), Michael McEachen (NGIS)

Program: Strategic Initiative

Jet Propulsion Laboratory
California Institute of Technology

RPC-232

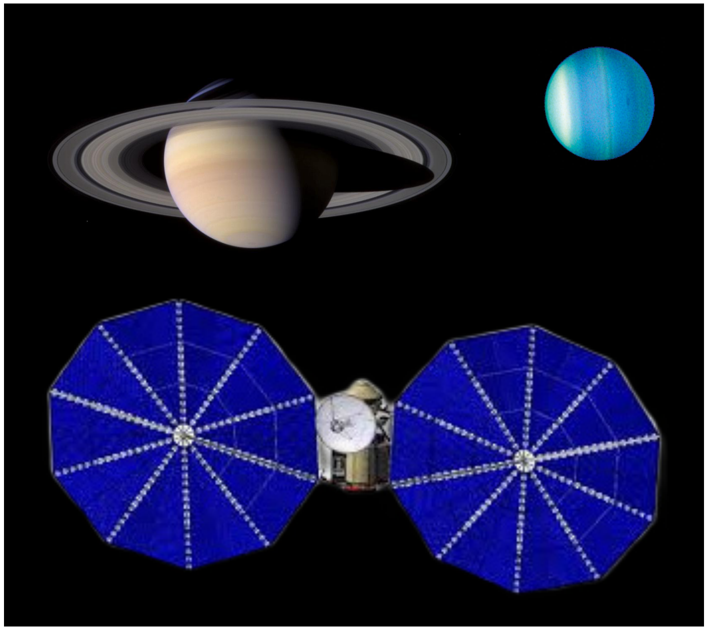
Tutorial Introduction

Abstract:

This FY19-21 task is developing a solar array that will potentially provide substantial mass and cost savings to deep space missions, when compared to currently available power sources.

Solar arrays are a low cost, readily available, and highly versatile power source, which is why most NASA missions so far have been solar powered. Deep space presents a challenging environment for solar arrays, primarily because the light intensity available for photovoltaic power conversion is low, as the solar irradiance decreases quadratically with the sun distance. It is for this reason that, until 10-15 years ago, it would have been difficult to conceive of a solar powered mission traveling as far as Jupiter (5.5AU). Now however, with Juno flying successfully and Europa Clipper in advanced stages of development, solar arrays have become a well-established power source for Jupiter missions.

Is Saturn (9.5AU) the next frontier for solar arrays? Feasibility studies [1-2] have shown no impediment to the paradigm shift to solar power occurring for Saturn missions as well. This task will contribute to extending the capability range of solar arrays beyond the Jupiter orbit where it is today, all the way out to the Saturn orbit and beyond, in the near future.



Problem Description

Context:

- The currently available, state-of-art power source for Saturn missions is the radioisotope thermoelectric generator (MMRTG), which has an end-of-design-life specific power of **1.5W/kg** for a typical 14-year mission
- No solar-powered missions have flown to Saturn yet; outside of this task, no solar array technologies have been demonstrated or ground-tested under Saturn conditions yet
- State-of-art deep-space solar arrays (such as those of Juno, Europa Clipper missions) would be relatively heavy, with end-of-mission specific power at Saturn of **0.54W/kg**

Comparison to State-of-Art (SoA):

- This new technology is a high-efficiency lightweight solar array with projected ~**3W/kg** end-of-mission specific power at Saturn
- The solar array being developed on this task offers an estimated 5x mass reduction relative to state-of-art solar array power sources; and an estimated 2x mass and 8x cost reduction relative to MMRTG power sources
- For example: 200W at Saturn require 70kg with the new technology, 135kg with MMRTGs, or 370kg with state-of-art solar arrays

Relevance to NASA and JPL:

- The deep-space solar array enables small-spacecraft missions to Saturn, and is highly enhancing even for larger missions to deep space such as Discovery, New Frontiers or Flagship class

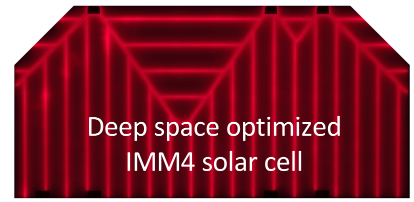
Methodology

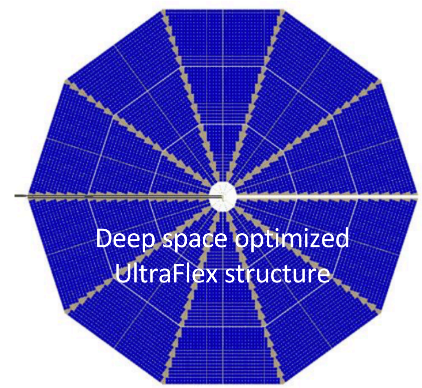
Formulation, theory or experiment description:

- The deep-space solar array is a system which integrates two high-performance components:
  - the high-efficiency, lightweight deep-space-optimized IMM4 solar cell, and
  - a deep-space-optimized version of the lightweight UltraFlex mechanical structure and harness
- The objective is to bring this solar array system to TRL-5 within the time frame of the task
  - test article is a reduced-scale but otherwise fully representative solar array prototype coupon
  - two hardware iterations: FY20 Pilot coupon ~2.7W/kg, then FY21 Final coupon 2.9-3.0W/kg
  - prototypes being ground-tested (thermal cycling) in relevant environment for a Saturn mission
- During the FY20 period, the team's primary focus has been on fabricating and testing the Pilot coupon and on developing the build processes and conceptual designs for the Final coupon

Innovation, advancement:

- Very high specific power at the solar array system level is achieved through a combination of high efficiency and low mass at the component (solar cell and mechanical structure) level
- This approach leads to system-level specific power that is a five-fold improvement over SoA solar arrays, and two-fold over SoA radioisotope power sources

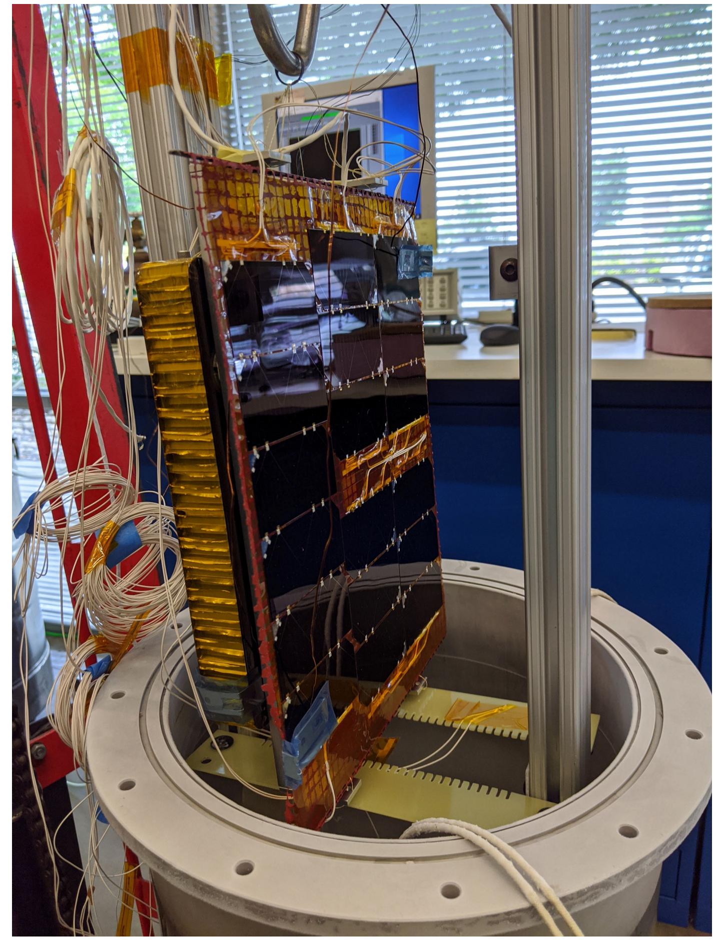




Results

Accomplishments versus goals (1 of 2):

- All proposed FY20 milestones have been met
- One key goal for this period has been to fabricate the Pilot-coupon test article
- The Pilot coupon is of reduced scale (10"x 12") but otherwise representative of a full-scale solar array with 2.7W/kg end-of-mission specific power at Saturn
  - flight-like materials, interfaces and electrical/mechanical components
  - flexible and rigid substrates plus test fixturing fabricated by NGIS
  - electrical components laid down onto the substrates by SolAero
- Hardware specifications were released in an interface control document (ICD)
  - e.g. 3 series strings of six 27.56cm^2 solar cells each, in various geometries
- Components included: solar cells, bypass diodes, interconnects, coverglass, harness wires, blocking diodes, adhesives, PRT temperature sensor, rigid panel substrate, flexible scrim substrate, fold-line sparlets, tensioning flexures, etc.
- The Pilot coupon build and assembly were completed successfully

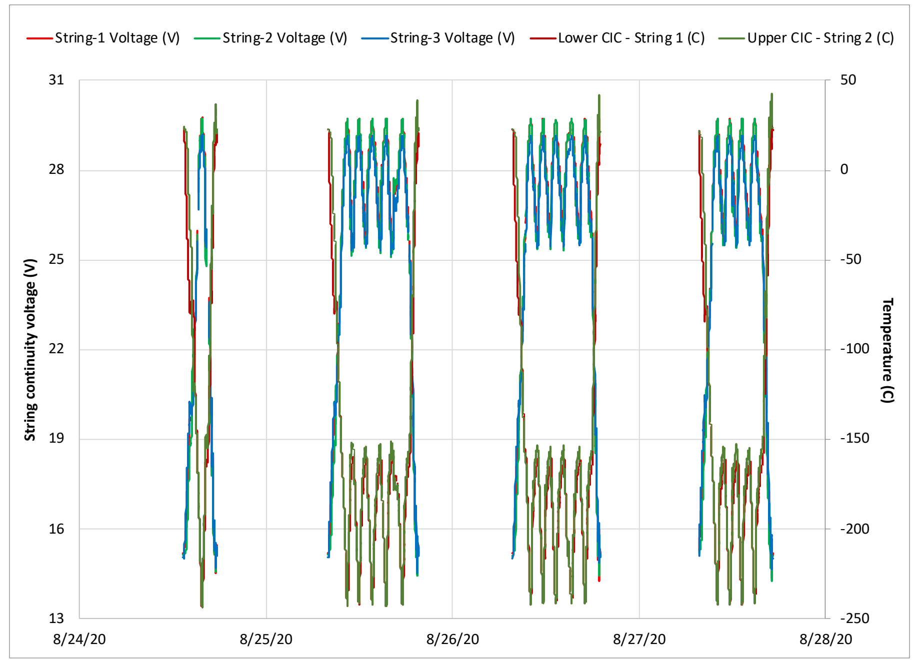


Fully assembled Pilot coupon in the test configuration

Results

Accomplishments versus goals (2 of 2):

- Another key FY20 goal has been to perform the environmental test on the Pilot coupon
- This test simulated the solar array thermal conditions during a representative Saturn mission, with 50% margin on cycle count
  - Thermal cycles: 2×(+20 to +150C) + 15×(-165 to -240C) with in-situ string continuity monitoring, periodic dark-IV sweeps
  - Visual inspection and functional testing of all electrical components before and after cycling
- The test was performed at CTD thermal test facility in Lafayette CO
  - Temperature monitoring and control provided by CTD
  - Electrical in-situ and functional testing/inspection by JPL
- Observed no loss of continuity, no significant change in dark-IV performance, and no change in functional test data
- The Pilot coupon environmental test was completed successfully



Cold cycles of Pilot coupon test: in-situ string continuity and temperature

Results

Significance

- Completing the fabrication and environmental test of the Pilot coupon constitutes an important milestone for this task
  - The Pilot coupon is representative of a solar array design with ~2.7W/kg end-of-mission specific power at Saturn
- Meeting it has significantly increased the likelihood of successfully demonstrating the overall objectives by the end of FY21

Next steps

- In the final year of this task, the team will focus on the detailed design, fabrication and test of the Final coupon, as well as on assessing the resulting readiness status for the deep-space solar array technology
  - The Final coupon will be representative of a solar array design with 2.9-3.0W/kg end-of-mission Saturn specific power
- Upon successful completion of this task, the team will seek follow-on funding from deep-space flight mission opportunities such as SIMPLEx, Discovery, New Frontiers or Flagship-class

Publications and References

[1] A. Boca, C. MacFarland, and R. Kowalczyk, "Solar power for deep-space applications: state of art and development", AIAA Propulsion-Energy Forum, 2019, DOI: 10.2514/6.2019-4236.

[2] T. J. Hendricks, A. Boca, D. F. Woerner, B. Donitz and B. K. Bairstow, "Solar power system and radioisotope thermoelectric generation technologies at Jupiter-Saturn-Uranus environments: new insights and paradigms", 70th International Astronautical Congress, 2019.