National Aeronautics and Space Administration

RADIOISOTOPE POWER SYSTEMS PROGRAM

Technology Readiness Assessment for Stirling Power Convertor

April 30, 2026

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Why Stirling?

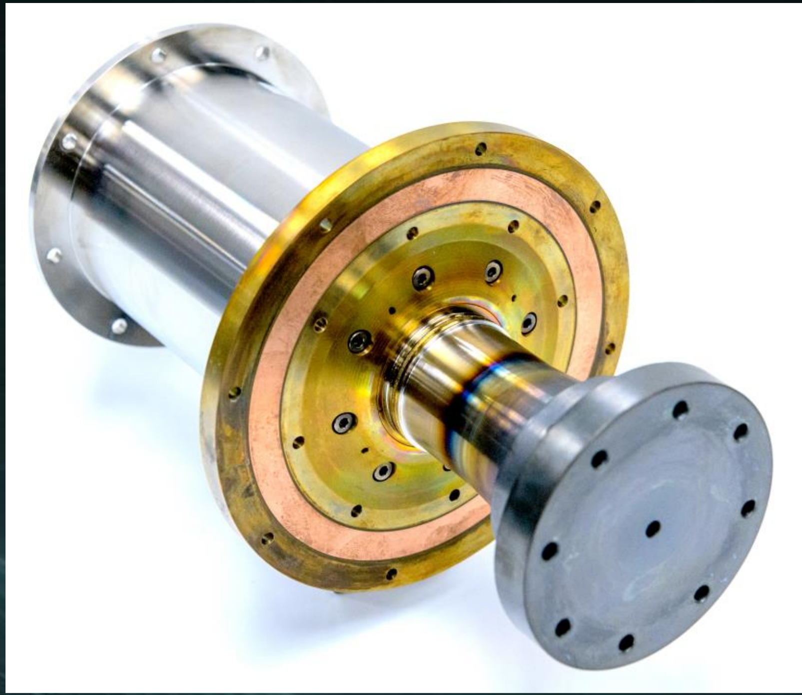
- Enables high-efficiency RPS for future NASA missions
- Higher power conversion efficiency than thermoelectric systems
- A viable path to improved power for deep space and planetary surface missions

Key Questions

- What is the current technology readiness of the Sunpower Robust Stirling Convertor (SRSC) relative to the 2022 Technology Readiness Assessment (TRA) baseline (TRL-3)?
- What progress has been made since 2022?
- What are key risks and maturation opportunities needed to advance the technology?

TRA Scope: Stirling Convertor

This TRA assesses the readiness of this thermal-to-electrical energy conversion device:



Sunpower Robust Stirling Convertor (SRSC)

TRA Methodology

- ➢ Followed standard NASA TRA process, tailored for Stirling RPS
- ➢ Streamlined delta TRA from 2022

TRA Process Steps

1. Define Requirements
2. Identify Critical Technology Elements (CTEs) / New Technology Elements (NTEs)
3. Collect evidence data
4. Assess TRL per element
5. Identify Risks & Gaps

Assessment Scope

- ➢ Convertor subassembly level
  - *(not full system)*
- ➢ Weakest-link TRL roll-up
  - *(lowest CTE/NTE TRL drives overall)*
- ➢ Investigated DRMs
  - *(Lunar, Mars, and Uranus)*
- ➢ Pu-238 fueled missions
  - *(this TRA is **not** for fission systems)*

A new question emerged | **What is the TRL for a shorter-duration, demonstration mission used to mature the technology?**

Technology Maturation Since 2022 TRA

2022 TRA BASELINE

TRL-3

Key Limitation in 2022

- Insufficient heater head creep data to support long-duration life prediction
- Focused on 17-year, long-duration mission

TRL-3 Definition

Analytical and experimental critical function proof-of-concept demonstrated in laboratory

ADVANCEMENTS SINCE 2022

Environmental Testing

Qual-level vibration, acceleration, thermal cycling

Operational Life

SRSC-4: 23,359 hours (Apr. 1, 2026) accumulated operation
(3 more units 27k, 20k, and 5k hrs)

Life Testing

New heater head creep and other component life testing

V&V Test Matrix

Applicable requirements verified to date within assessed scope

Design Refinements

Process and clearance tolerances (e.g., regenerator installation, running clearance tool, position sensor, internal fit-up interfaces)

Maturation

2026 TRA RESULT

TRL-6

Key Evidence

- ~2.5-year equivalent demonstrated operational life (electrically heated)
- Qualification-level environmental testing and existing life data

TRL-6 Definition

Subsystem/subassembly model or prototype demonstrated in a relevant environment

Focused on shorter-duration missions

TRL advanced 3 → 6 driven by | Environmental testing, accumulated operation, design refinements, and shorter mission durations

Key Findings

TRL Advancement

- <u>**TRL-6**</u> (~<u>**2.5-year electrically-heated mission**</u>)
  (~100-day radioisotope-heated mission after one-year fueled storage)
- Enabled by:
  - Environmental testing
  - > 23,359 hours of accumulated run time (as of April 1, 2026)
  - Design refinements
  - Shorter-duration missions
- Longer mission life is not yet supported by the current evidence base

Key Limitation

- Insufficient component-level life-test evidence for long-duration missions

Viable today — within a constrained mission envelope

Implications & Path Forward

What This Means

- TRL is directly driven by mission life
- Lifetime verification—not performance—is the pacing item for long-duration missions
- The technology is on a path to flight
- Short missions → **TRL-6 supported**
- Long-duration missions → **further maturation required**

Path Forward

- Expand component-level life testing
- Re-establish test-correlated life analysis models
- A near-term demo mission would build confidence toward long-duration missions
- Future TRAs will extend this assessment to the controller and integrated system

Performance is demonstrated — long-duration endurance remains to be proven

POWER TO EXPLORE

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