EuropeaN Devices Using Radioisotope Energy (ENDURE)

Presentation @ **CLPS Survive the Night Technology Workshop 2022**

An ESA Multi-Directorate Activity:

HRE, SCI, STS, TEC

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Rationale for a European RPS capability

Exploration of the outer solar system and nighttime survival on Moon / Mars requires solar independent power

- RadioIsotope Power provides an efficient, reliable and in many cases the only solution

Europe does not have an independent RPS capability.

➢ **Any European mission requiring RPS is contingent on International partners to provide fuel, systems and launch**

ESA Exploration Missions (HRE and SCI) in the 2030's onwards require RPS

- **Moon:** *Terra Novae 2030*+ Robotic landers, payloads, surface infrastructure
- **Mars:** *Terra Novae 2030*+ Robotic surface missions, support to human missions

  Outer Solar System: *Voyage 2050* - missions to Outer planets, contributions to international outer solar system missions, Icy moons sample return Inspirator

EuropeaN Devices Using Radioisotope Energy (ENDURE)

Overall aim

Deliver an end-to-end European operational capability for RPS heat and power systems by the end of this decade

Multidirectorate rationale

- Common systems and operational solutions for different mission use cases

- Requires coordinated research, technology and capabilities development across several ESA directorates

  - HRE, SCI, STS, TEC are main stakeholders

- Requires expertise and specialised capabilities in radioisotopes at European and national level

Scope => 3 Elements

1. Fuel production and packaging capability

2. RPS system development

3. Ariane 6 Launch System and CSG Launch Range adaptations, and safety authorisation process

➤ **Procurement of RPS flight models and launch for specific missions responsibility of user programmes**

➤ **Compliant with international regulations and ESA policy for Launch Safety Assessment**
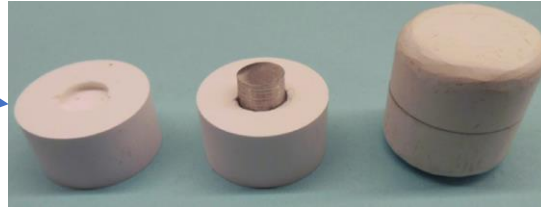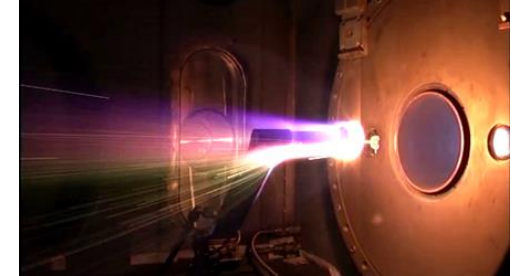
Elements of ENDURE

Am241 Fuel Process Industrialisation
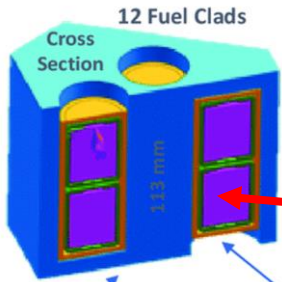

Am241 Fuel Production

Pelleting and cladding

Aeroshell development and validation

RadioIsotope Power Systems (RPS)
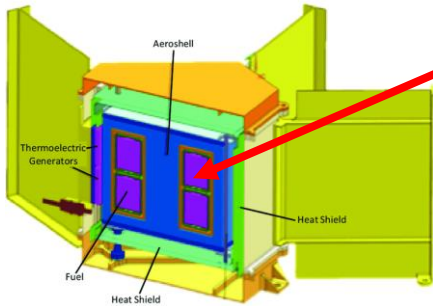

12 Fuel Clads
Cross Section
113 mm
6 clads are inserted from each end
Each aeroshell sleeve accommodates 2 clads
European Large Heating Unit (ELHS)
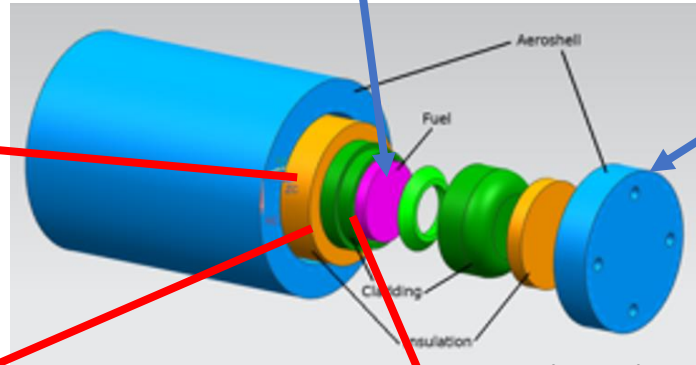
Aeroshell
Fuel
Cladding
Insulation
RadioIsotope Heating Unit (RHU)

Aeroshell
Thermoelectric Generators
Fuel
Heat Shield
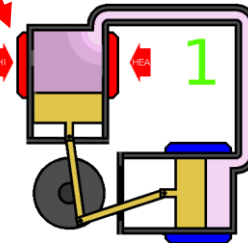Heat Shield
RadioIsotope Thermoelectric Generator(RTG)

1
Stirling Generator (SG)

Launch Safety Authorisation Process

Launch System Adaptations
CSG Adaptations

R&D activities (Pu238 production feasibility study, …)

Am241 Production Capability

- Am-241 is biproduct from civil nuclear power plant fuel utilisation and can be recovered from spent spent fuel reprocessing
- The Am-241 separation process has been demonstrated at small scale.
- Experimental Am_2O_3 pellets have been produced, further development of enhanced ceramic forms is ongoing
- The requirements for building a full scale facility (and dealing with the associated waste streams) are fully understood.
- Study of a medium scale production facility is ongoing
- Stakeholder support has been established.
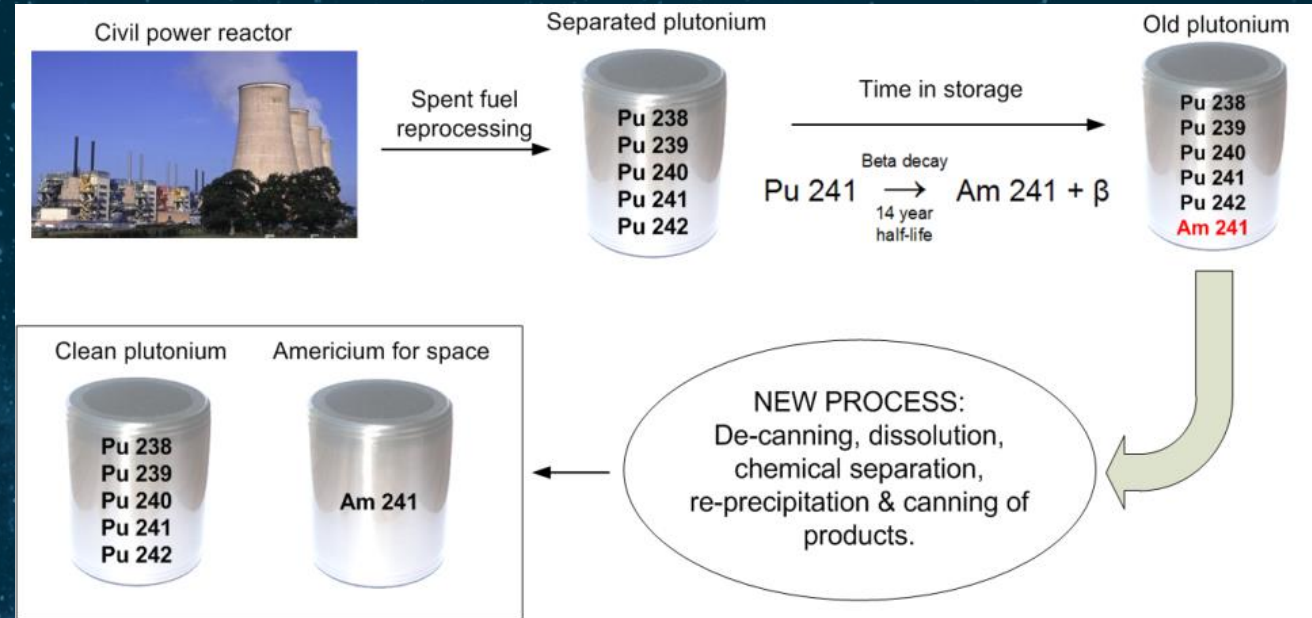
Experimental Am_2O_3 pellet

RadioIsotope Heating Systems Development

ESA

RadioIsotope Heating Unit (RHU) and European Large Heat Source (ELHS)

- Small (RHU) and large (ELHS) systems with common materials and architecture.
    - RHU provides common core element for other heating (ELHS) and electric power systems (RTG, RSG).
- Multi-layer protection for launch accident survival:
    - Pt-Rh alloy cladding; carbon felt insulation; C-C composite aeroshell.
- Preliminary performance
    - RHU: 3Wth initial thermal power
    - ELHS: 200Wth initial thermal power
- TRL5 in 2023.

RHU

ELHS

→ THE EUROPEAN SPACE AGENCY
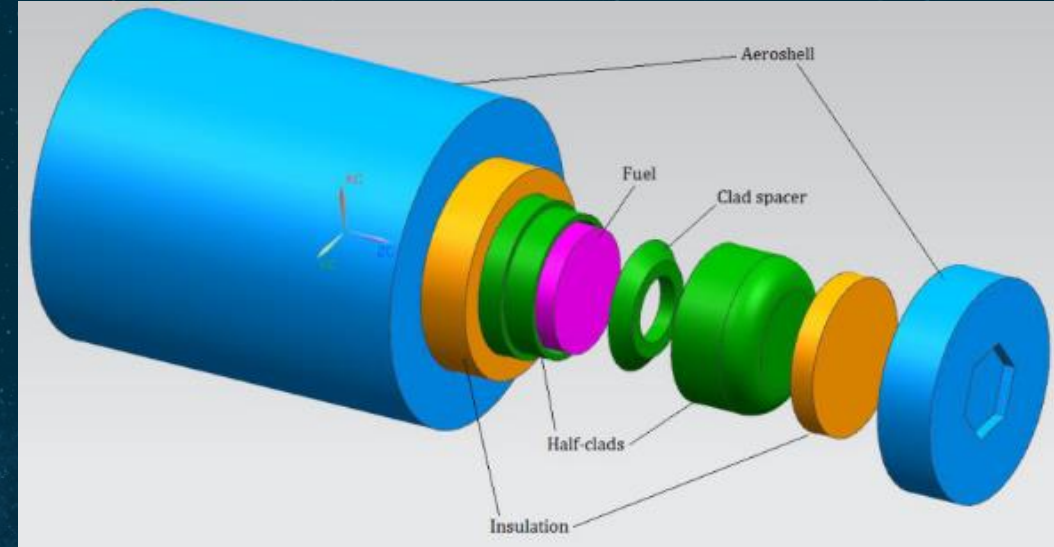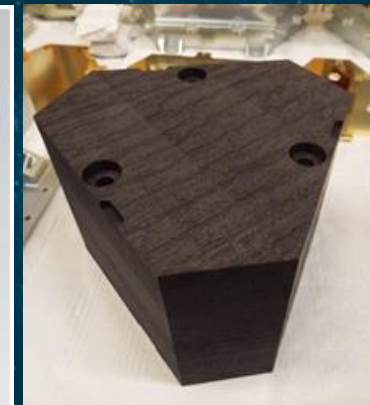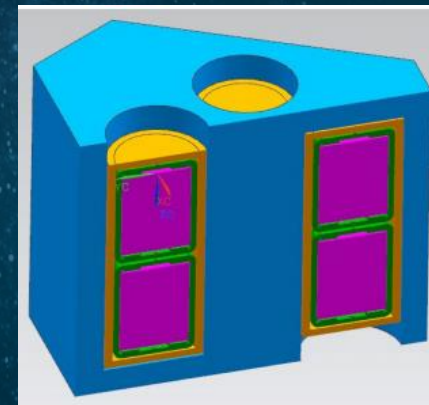
RadioIsotope Electrical Power Systems Development

RadioIsotope Thermoelectric Generator (RTG)

- RTG for use with ELHS Am241 heat source.

- Uses customized Bi-Te thermoelectric modules based on COTS technology.

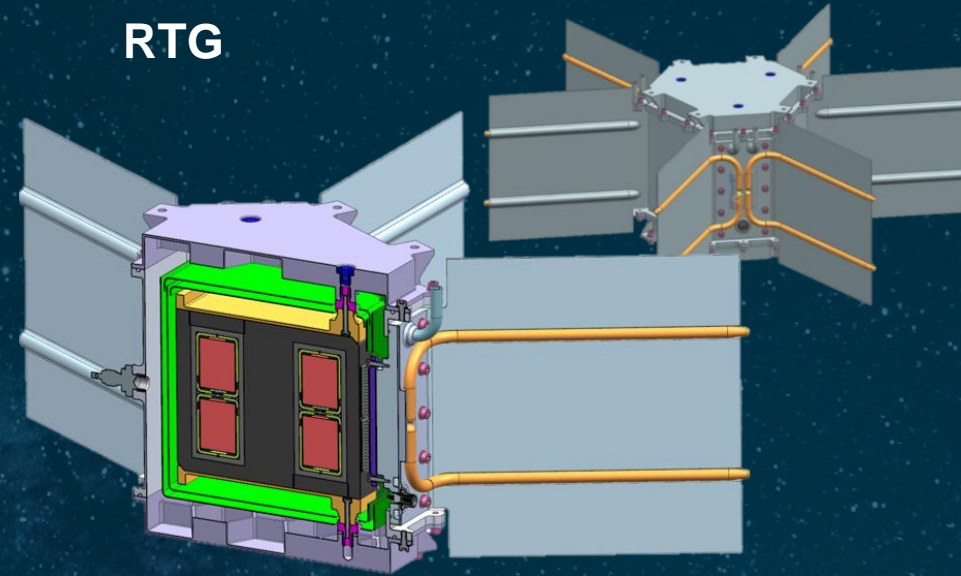- Preliminary performance estimates:

- 10 We DC output @ 5% conversion efficiency.

- Scalable though stacking

- TRL 5 by 2023

RTG

UNIVERSITY OF LEICESTER

AIRBUS DEFENCE & SPACE

RadioIsotope Stirling Generator (RSG)
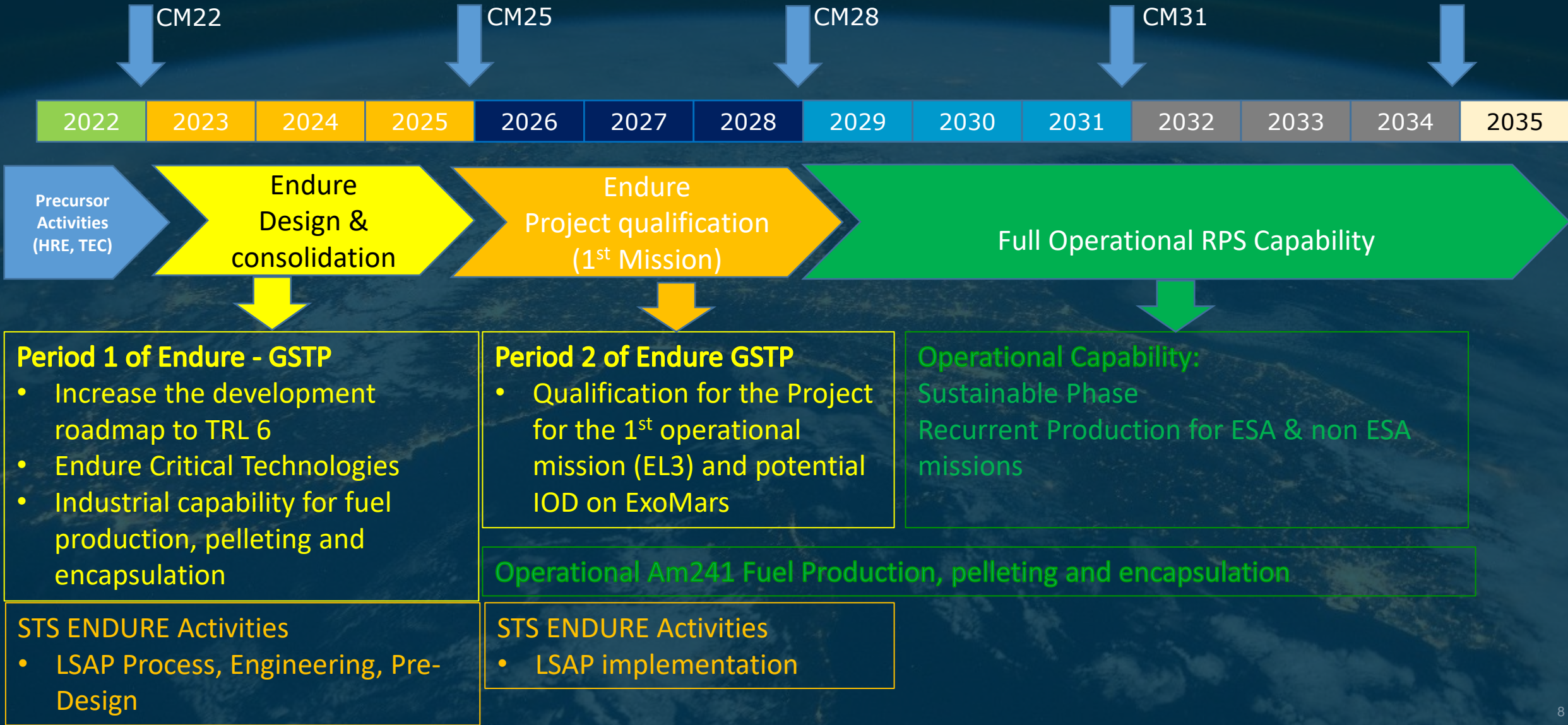
- Gamma Stirling engine @ 90Hz with back-to-back power-pistons/alternators and single displacer.

- Preliminary performance estimates: 100 We.

- TRL 4 by 2023

ERSG prototype
(Cooling system and power/control electronics not shown)

ThalesAlenia Space
A Thales / Finmeccanica Company

Science & Technology Facilities Council

UNIVERSITY OF OXFORD

CSL CENTRE SPATIAL DE LIÈGE

ENDURE Development Roadmap

CM22　　　CM25　　　CM28　　　CM31

| 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 |

Precursor Activities (HRE, TEC) → **Endure Design & consolidation** → **Endure Project qualification (1st Mission)** → **Full Operational RPS Capability**

Period 1 of Endure - GSTP
- Increase the development roadmap to TRL 6
- Endure Critical Technologies
- Industrial capability for fuel production, pelleting and encapsulation

STS ENDURE Activities
- LSAP Process, Engineering, Pre-Design

Period 2 of Endure GSTP
- Qualification for the Project for the 1st operational mission (EL3) and potential IOD on ExoMars

Operational Am241 Fuel Production, pelleting and encapsulation

STS ENDURE Activities
- LSAP implementation

Operational Capability:
Sustainable Phase
Recurrent Production for ESA & non ESA missions

Low
Earth
Orbit

Moon

Mars

esa

we explore. you benefit.

Human Spaceflight and Robotic Exploration