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Use of nuclear power sources in outer space

Space Nuclear Power Systems. Activities and Programmes in the United Kingdom

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* A/AC.105/C.1/L.332.
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Contents

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Introduction

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- In the context of future European space science and exploration programme radioisotope heat sources are enabling technologies for more challenging missions.
  -more capable spacecraft
  -extended lifetimes
  -vehicles and probes that can access distant and inhospitable environments
  -near sun operation
- Value for money resulting from overall longevity
- Focus on Am^{241} as heat source

Current UK activities

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- The UK is a major contributor to the ESA nuclear power programme.
- UK has a consortium of UK companies and institutes working on the ESA Programme together with other European partners
- UK organisations include, SEA, University of Leicester, Astrium, Lockheed Martin, RAL, University of Oxford
- Nuclear is seen as an enabling technology.
- Key requirement is supply of radioisotope source material.
- UK has abundant supplies of Am^{241} that can be extracted from the civil plutonium stockpile that is in storage.
- UK Government is supportive of the programme.
- NNL's Laboratory at Sellafield will house any future separation facility to make available Am^{241}.

Isotope Selection study

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- Research contracts were placed by ESA to identify and assess radioisotopes with potential use in European space NPS.
- Independent studies concluded that in the case of Europe that Am^{241} was the isotope of choice because:
  - Pu^{238} best choice for specific power W/g but an expensive production route for Europe, requiring Neptunium target fabrication, high flux reactors and reprocessing facilities.
  - UK Plutonium stockpile provides a source of Am^{241} that can be efficiently separated, with benefits to both the nuclear and space sectors.
  - Am^{241} specific power one-quarter of Pu^{238} but with manageable mass impact and more affordable to produce

Am241 Production

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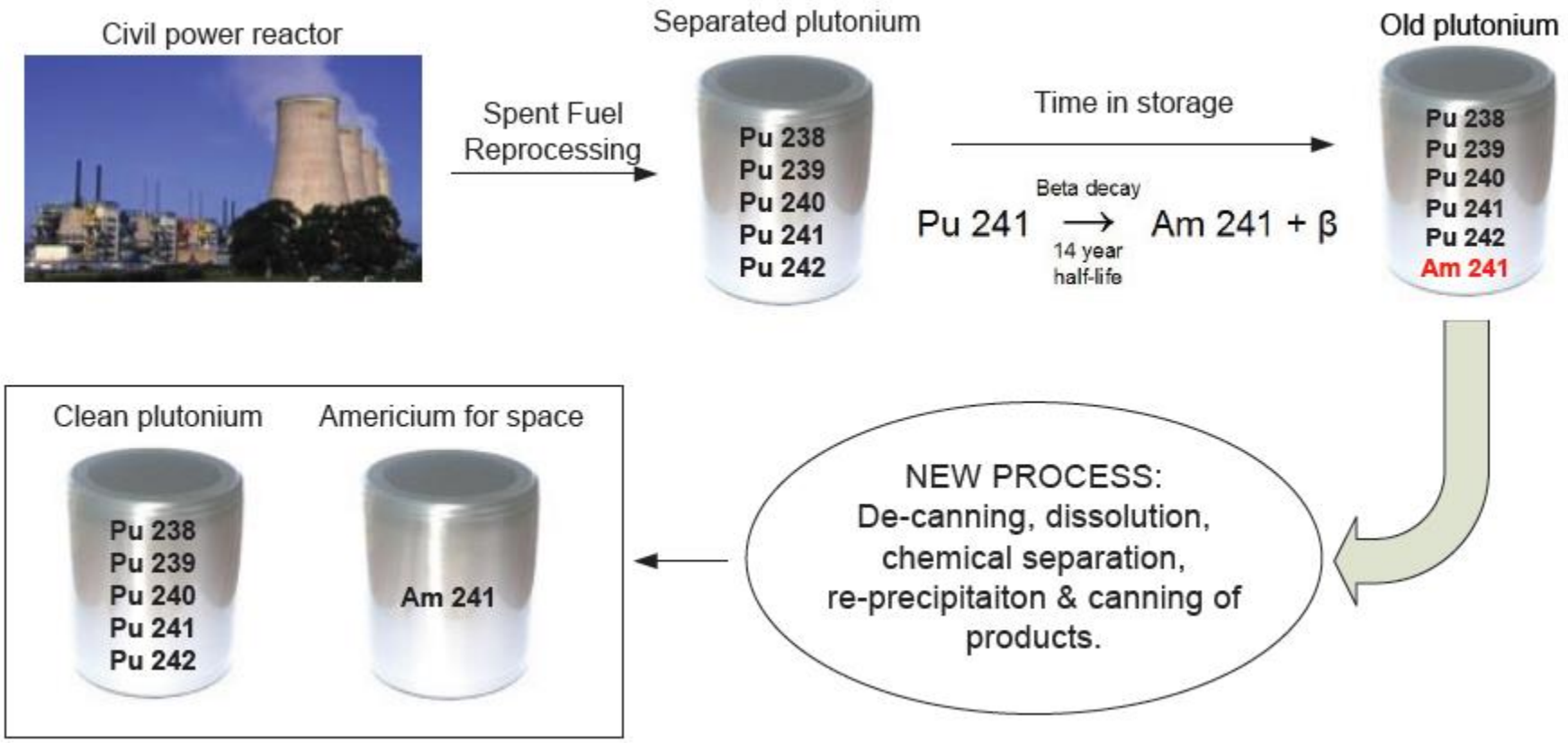
- NNL has recently completed a 2 year contract for ESA to research and design a production facility for Am^{241}.
- Outline design delivered and costed
- Discussions with Government and Nuclear Decommissioning Authority on feed material supply (civil Pu)
- First experimental runs completed, Am separated from civil Pu
- Contract extension being negotiated for a follow on 30 month programme that will increase quantity of Americium separated tenfold
- Plan to produce a RHU sized pellet

Am241 Production



Courtesy of ESA

Encapsulation Studies

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Radioisotope fuel must be encased within a system of physical barriers to prevent fuel dispersal under accident conditions (e.g. launcher explosion, re-entry, earth impact).....

Nuclear Fuel Capsule and Aeroshell Design Study

- Contract with SEA Ltd, UK National Nuclear Laboratory (NNL), University of Leicester and Lockheed Martin UK.

Two-lane parallel approach to the low-TRL development of a European capability to encapsulate ^{241}Am radioisotope fuel:

1. A European analogue to the conventional (USA) approach of multi-layer encapsulation using refractory metals, carbon based insulators and carbon-carbon aeroshells.
2. A novel approach using ceramic-metallic (CERMET) composites manufactured with spark-plasma sintering (SPS).

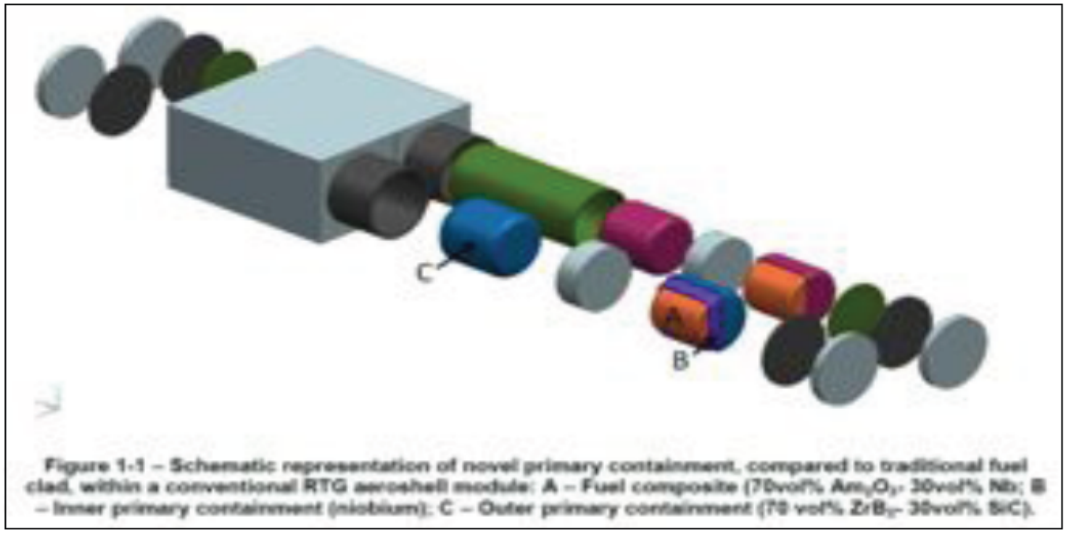

Figure 1-1 – Schematic representation of novel primary containment, compared to traditional fuel clad, within a conventional RTG aeroshell module: A – Fuel composite (70vol% Am_2O_3- 30vol% Nb; B – Inner primary containment (niobium); C – Outer primary containment (70 vol% ZrB_2- 30vol% SiC).

A wider-scope contract is now underway with a consortium led by Areva TA of France:

Nuclear Power Systems Architecture for Safety Management and Fuel Encapsulation Prototype Development (NPSAFE)

Courtesy of ESA

RTG Development

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Thermoelectric Converter System for Small-Scale RTGs ***Parallel R&D contracts:***

1.University of Leicester, Fraunhofer Institute and Astrium UK.

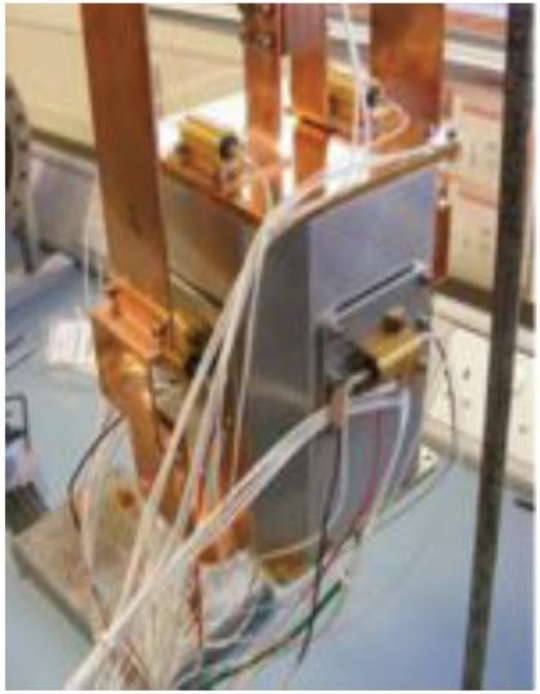
2.Areva TA, Ecole des Mines de Nancy, SEA Ltd, TAS-I and Babrow Consulting

Innovative Mg-Si / Mn-Si-Ge thermoelectric module by Ecole des Mines de Nancy

Both of these contracts have been succeeding in manufacturing and testing electrically heated RTG prototypes.

Work continues under contract extension in both cases.

ESA's strategy is to develop RTGs in the lower power range (few We few tens of We for acceptable mass, robust system with no moving parts).



Prototype RTG (electrically heated) prepared for testing at the University of Leicester

Courtesy of ESA & UOL

Stirling Radioisotope Generator Development

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In the larger power range (above few tens of W_e), an engine is used to efficiently convert heat into electrical power for limiting the size, weight and fuel requirements of an RPS, especially given the lower specific power of Am241 as compared to Pu238.

Stirling Engine Radioisotope Power System (SRG) Requirements Study:

SEA Ltd, Rutherford Appleton Lab, and Oxford University.

This 1st-stage paper study derived the detailed system requirements for a European space SRG.

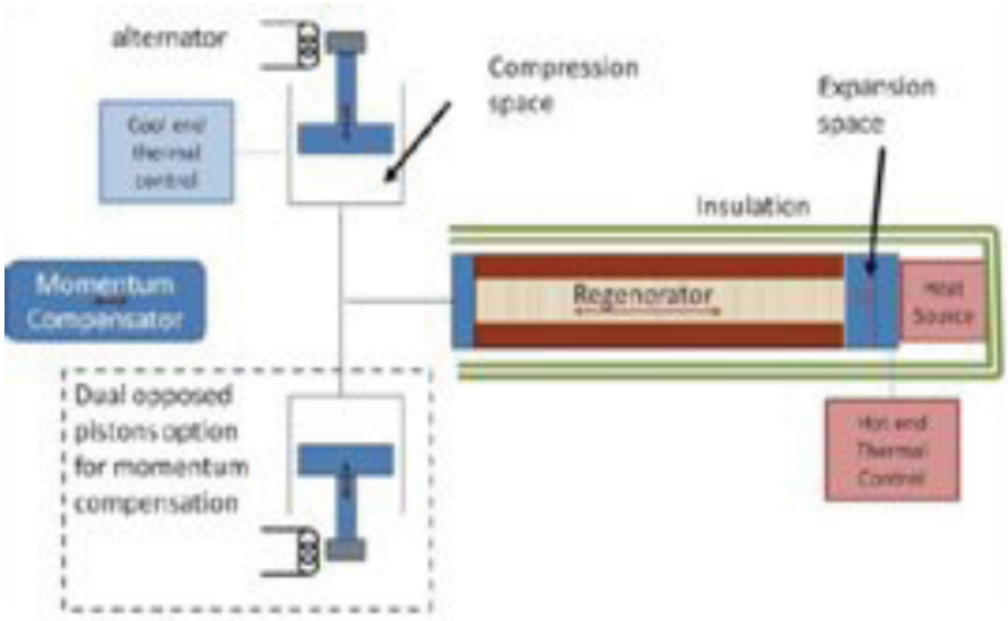
It highlighted the potential to exploit the existing UK expertise in long life space Stirling coolers using the flexure bearing "Oxford Mechanism" .

A larger development and prototyping contract is now underway:

Stirling Converter Technology Development Phase 1

SEA, RAL, University of Oxford (UK)

QINETIQ SPACE NV, CSL (B)



Stirling converter in gamma configuration (one option under evaluation)

Courtesy of ESA

NPS Development Roadmap

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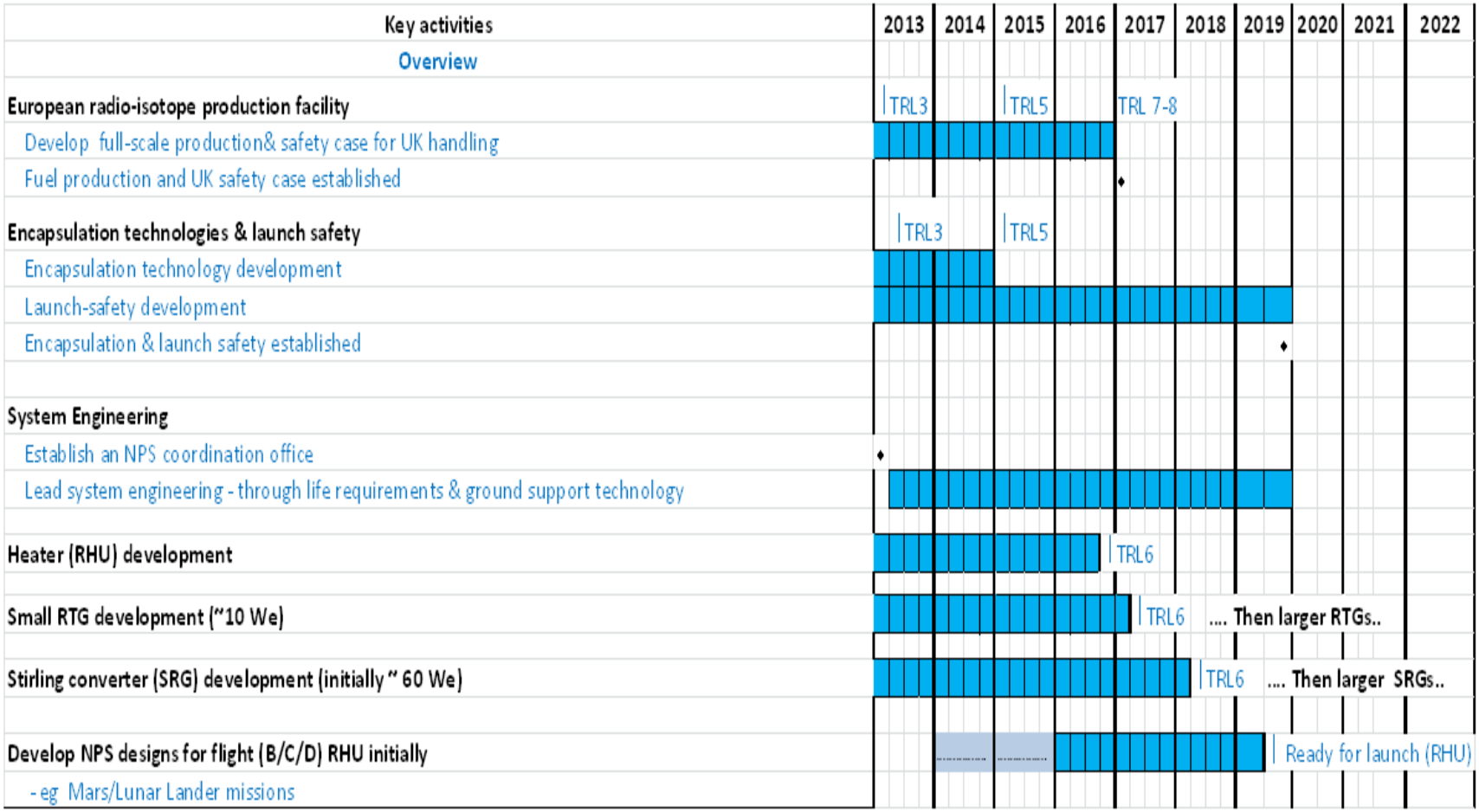

Courtesy Astrium, SEA, UOL

Interactions with US

- NNL has received valuable support from USDOE and NASA in understanding US approach to radioisotope manufacturing, facilities and safety framework.
- Several facilities visits (UK & US) have taken place.
- Exploratory discussions on US launch safety procedures including work and data requirements that underpin US Pu^{238} launch safety approach.

Summary

- UK is active on behalf of ESA in exploring the viability of using Am^{241} as a power source for space use.
- Development work on isotope separation continuing to plan, through to the pelleting stage.
- UK Government support, enabling availability of feed materials
- UK knowledge base on radioisotope systems has been increased significantly, positioning UK as intelligent user of the technology to support future European utilisation of radioisotope systems .
- UK has key technical expertise and capabilities to work with other European states to enable future deployment of radioisotope systems
- We welcome interest and collaboration from any other states.