DE LA RECHERCHE À L'INDUSTRIE

TRANSMEETS,

a H2020 project proposal

for investigation of **TRANS**mutation fuels in generation 4 reactors: **M**odeling, **E**xperim**E**ntal da**T**a and **S**imulation

www.cea.fr

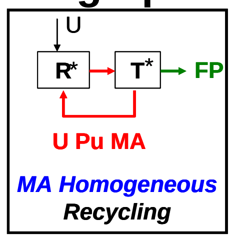
Outline

- **Context**
- **TRANSMEETS scientific and technical content**
  - **Objectives**
  - **3 pillars**
  - **4 scientific and technical Work Packages**
- **Current status**

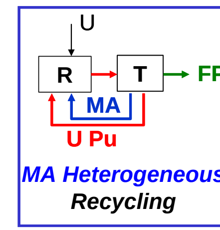
Context: Previous PELGRIMM FP7 project

- PELlets versus GRanulates: Irradiation, Manufacturing and Modelling
- FP7 European project carried out from 2012 to 2017
- Main objectives
  - **Consider 2 MA-recycling options**

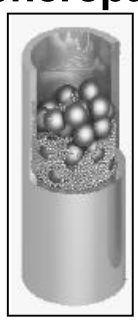
MA homogeneous recycling
MA bearing Driver Fuels (MADF):
$(U,Pu,MA)O_{2-x}$, MA < 5%



MA heterogeneous recycling
MA Bearing Blankets (MABB):
(U,MA)O2-x, MA ~10-20%



  - **Compare spherepacked and pelletized MA-bearing oxide fuels**



- A new stage has been reached in Am-bearing fuel developments :
  Fabrication process developments, Behaviour under irradiation, Modelling and simulation, Preliminary core design & safety performance

Context: Still some gaps …

…to demonstrate the compliance of MA-bearing fuels with the stringent safety requirements of Gen IV fast reactors and ESNII prototypes:

- $(U,Pu,MA)O_{2-x}$ and $(U, MA)O_{2-x}$ still at an early stage of qualification / development
- Consequences on safety of their very specific behaviour and properties, still to be determined: mainly the **risk of cladding failure and of fuel melting**
  - MA ⇒ high He production during (and after) irradiation ⇒ swelling and/or release ⇒ FCMI
  + Actinides and FP redistribution ⇒ JOG ⇒ FCCI
  - MA ⇒ lower melting temperature + thermal conductivity ⇒ lower margin to melt.
- Need for further improvement of **Fuel Performance Codes (FPC):** cornerstone of fuel behaviour evaluation and safety analyses
  - Models relevant for the assessment of the **risk of cladding failure** and to a first evaluation of the **source term** in case of a hypothetical accident :
  - Models relevant for the assessment of the **risk of fuel melting**
  - **Reliable data** necessary for models and code development and validation
  - **Multiphysics simulation**
  - **Specific tests in off-normal / accidental situations** to support safety assessments

How to address the aforementioned key issues: the TRANSMEETS European project proposal

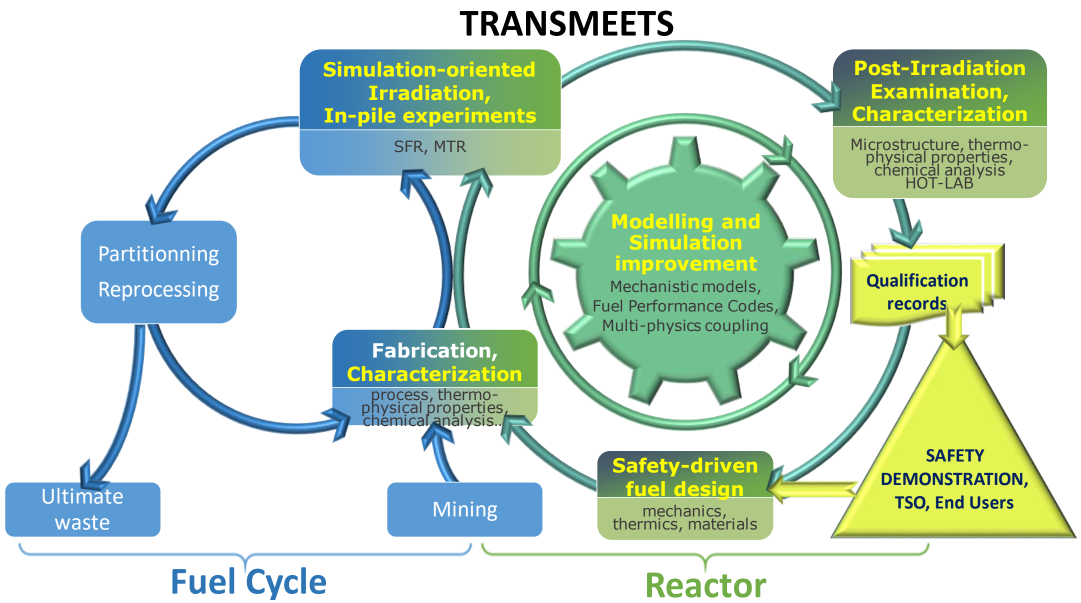
- **TRANS**mutation fuels in generation 4 reactors, **M**odeling, **E**xperim**E**ntal da**T**a and **S**imulation

- Main purpose: increase **robustness, accuracy and predictability** of **fuel performance codes** for investigation of **safety-related behaviour of Am-bearing fuels :**
  - $(U,Pu,Am)O_2$ with [Am] ~ 3% - 5%: homogeneous recycling fuels
  - $(U,Am)O_2$ with [Am] ~ 10% - 15%: heterogeneous recycling fuels

- Major objectives:
  - **Extension of the validation domain** of models/codes for $(U,Pu,Am)O_2$ & $(U,Am)O_2$
  - **Development of fuel performance codes** for normal and off-normal conditions:
  - Simulation of the behaviour of Am-bearing fuels **in normal & off-normal situations:**
  - **Train young researchers**, bring them knowledge and skills spanning the full area of simulation / qualification / safety assessment, from simulation to experiments, give them the opportunity to work in different research environments such as hot-labs or supercomputer centers

TRANSMEETS: Overall concept, 3 pillars

- TRANSMEETS : cross-road of **fuel cycle** and **reactor** challenges

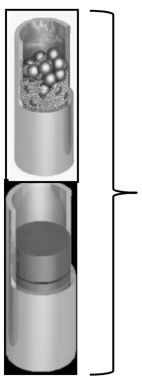


- TRANSMEETS scientific and technical content built on 3 pillars
  - **Development of simulation and modelling tools**
  - **Generation of new data : combination of experimental examinations of irradiated Am-bearing fuels, characterization of fuel properties and modelling**
  - **From normal conditions towards off-normal and accidental situations**

WP1: Investigation of helium, fission gases, fission products and actinides

- Generation of data relevant to the **risk of cladding failure** assessment
- Combination of PIE, separate effect techniques and modelling methods

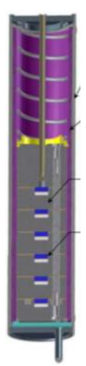
European irradiations



SPHERE: $(U,Pu,Am)O_2$

MARINE: $(U,Am)O_2$

2 pins: spherepac pellets



MARIOS: $(U,Am)O_2$

4 mini-pins
6 disks
2 microstructues
2 temperatures

Needed models/ properties	Post-Irradiation Examinations	Separate effect tests	Modelling methods
Gas (He and FG) release	Puncturing of MARINE pins	KEMS on SPHERE, MARINE and MARIOS fuels, thermal treatments on MARIOS fuels	Neutronic analysis (He & FG inventory) Atomistic calculation
Gaseous swelling	Gamma scan spectrometry of MARINE pins, Hydrostatic density measurements of DIAMINO disks		
Irradiated fuel composition	Radio-chemical analyses of SPHERE, MARINE and MARIOS fuels		Neutronic analysis (He, FG & FP inventory)
Actinide/FP redistribution/ migration	SEM, EPMA, XDS of MARINE fuel (+complement on SPHERE)		Neutronic analysis (He, FG & FP inventory)
Thermo-chemistry of fuel & FP, FP phase formation		KEMS on specifically synthetized fuels	CALPHAD modelling Empirical potential calculation

WP2: Characterization of thermal & thermo-chemical properties and effect of irradiation

- Generation of data relevant for **risk of fuel melting** assessment
- Combination of separate effect techniques and modelling methods

Needed models/ properties	Separate effect tests	Modelling methods
Thermal conductivity	Thermal diffusivity measurements on SPHERE, MARINE and MARIOS fuels	
Melting point	Laser pyrometry on SPHERE, MARINE and MARIOS fuels	
Thermo-dynamic data for fuel phase diagram: enthalpy of reaction, heat capacity…	KEMS, drop calorimetry on specifically synthetized fuels	CALPHAD modelling atomistic calculation

- Securing and sharing knowledge: issue of a **dedicated catalogue:**

Ensure and maximize knowledge preservation at a crucial point in time : latest results obtained on performance and properties of SPHERE, MARIOS and MARINE fresh and irradiated fuels.

WP3: Improvement of Fuel Performance Codes

- Simulation tools to be developed: TRANSURANUS and GERMINAL fuel performance codes

Fuel design and qualification of the ESNII reactor concepts:

  - TRANSURANUS for the design of MYRRHA, ALFRED
  - GERMINAL developed for ASTRID design

- Mesoscopic scale:
  - transfer and integration of the results from experimental and modelling above-mentioned activities, derivation of new correlations for model parameters
  - new models for thermal, thermo-mechanical and thermochemical behaviour of Am-bearing fuels
  - upgrade of TRANSURAUS and GERMINAL FPC
  - benchmark of the improved version of FPC : SPHERE and MARINE irradiations + comparison with PIE

- Macroscopic scale:
  - new simulation methods coupling various descriptions of fuels (neutronics: SERPENT, thermo-mechanical: OpenFOAM, safety analyses: SIMMER, BELLA)
  - objective to tackle accidental situations

WP4: Application to simulation in normal conditions and off-normal conditions

- Dedicated methodology : optimization of modelling and computational time for calculations dedicated to the design and licensing of new Am-bearing fuel pins

- In normal conditions:
  - Improvement of the thermo-mechanical design of a pin for transmutation
  - thermal-hydraulic features of corresponding sub-assembly

- In off-normal conditions:
  - selection and simulation of a relevant accidental scenario and core configuration to perform representative simulations of Am-bearing fuels in off-normal situations
  - prioritization of additional R&D modelling development needed by FPC and recommendations for additional experimental needs for code validation.
  - Identification and pre-design of an irradiation experiment in transient conditions, to provide the necessary data for validation of FPC, enabling them to support safety assessments for the operation of Am-bearing fuel.

TRANSMEETS Vision and Impact

- TRANSMEETS is a relevant and innovative project to increase robustness, accuracy and predictability of Fuel Performance Codes

- Strong support for demonstration of the compliance of $(U,Pu,Am)O_2$ and $(U,Am)O_2$ fuels, with stringent safety requirements of Gen IV fast reactors and ESNII prototypes

- Outcomes of mutual benefit for:
  - Gen IV reactors safety assessments
  - In the longer term, management of ultimate radioactive wastes and reduction of the footprint impact of deep geological repositories

- Essential for improving public acceptance of nuclear energy

TRANSMEETS project proposal : Current status

- Supported by ESNII, and in line with the goals set forward by ESNII and SNETP as a whole
- Unanimously supported and endorsed by the EERA-JPNM steering committee and obtained the EERA-JPNM label
- Submitted last September in the H2020 Euratom WP 18 call, in NFRP 2 section: “Model development and safety assessments for Generation IV reactors”
- European Commission decision expected by February-March 2019

DE LA RECHERCHE À L'INDUSTRIE

Thanks to all the TRANSMEETS partners and especially to the WP leaders:

-Daniel Freis (JRC)

-Anna Smith (TUD)

-Lelio Luzzi (Polimi)

-Brian Boer (SCK•CEN)

-Sara Bortot (KTH)

-Gabor Szendro (LGI)

Thank you for your attention

www.cea.fr