Joint Research Centre (JRC)

Properties and Behaviour of Advanced Nuclear Fuels

J. Somers

ITU - Institute for Transuranium Elements

Karlsruhe - Germany

http://itu.jrc.ec.europa.eu/

http://www.jrc.ec.europa.eu/

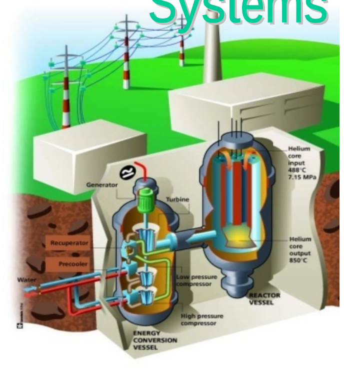
A European vision of nuclear energy development

First Reactors

Current Reactors

Advanced Reactors

Future Systems



1950 1970 1990 2010 2030 2050 2070 2090

Generation I

Dismantling & clean-up

Generation II

Produces 31% of Europe's electricity

Generation III

New build in Finland and France (EPR), other countries…

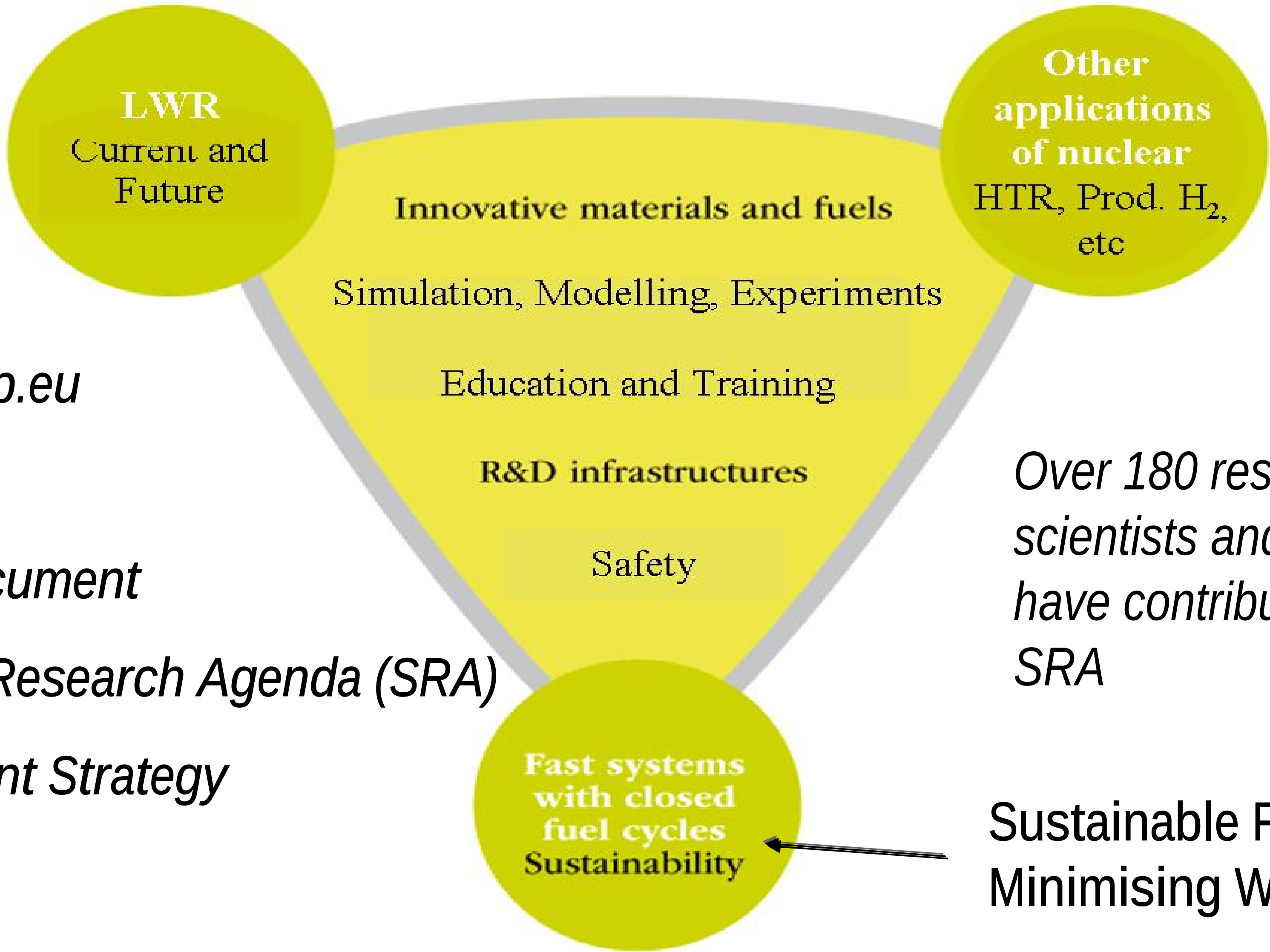
Generation IV

Start of industrial deployment in 2040-2050

The Sustainable Nuclear Energy Technology Platform (SNE-TP)

- Research to improve sustainability of nuclear energy
  - Conservation / recycling of resources
  - minimisation of radioactive waste (volume, lifetime, radio-toxicity)
  - maintaining high level of safety and favourable economics
- **Gather** all EU stakeholders involved in the nuclear sector and **structure and finance** nuclear fission R&D
- **Develop knowledge and competence** through education and training linked with a network of research infrastructures
- **Maintain Europe's leadership** in nuclear technology in the longer term by building demonstrators and prototypes for a future generation of reactors
- **Develop international cooperation** on a basis of mutual interest and benefit

Strategic Research Agenda: 3 pillars



www.snetp.eu

Over 180 researchers, scientists and engineers have contributed to the SRA

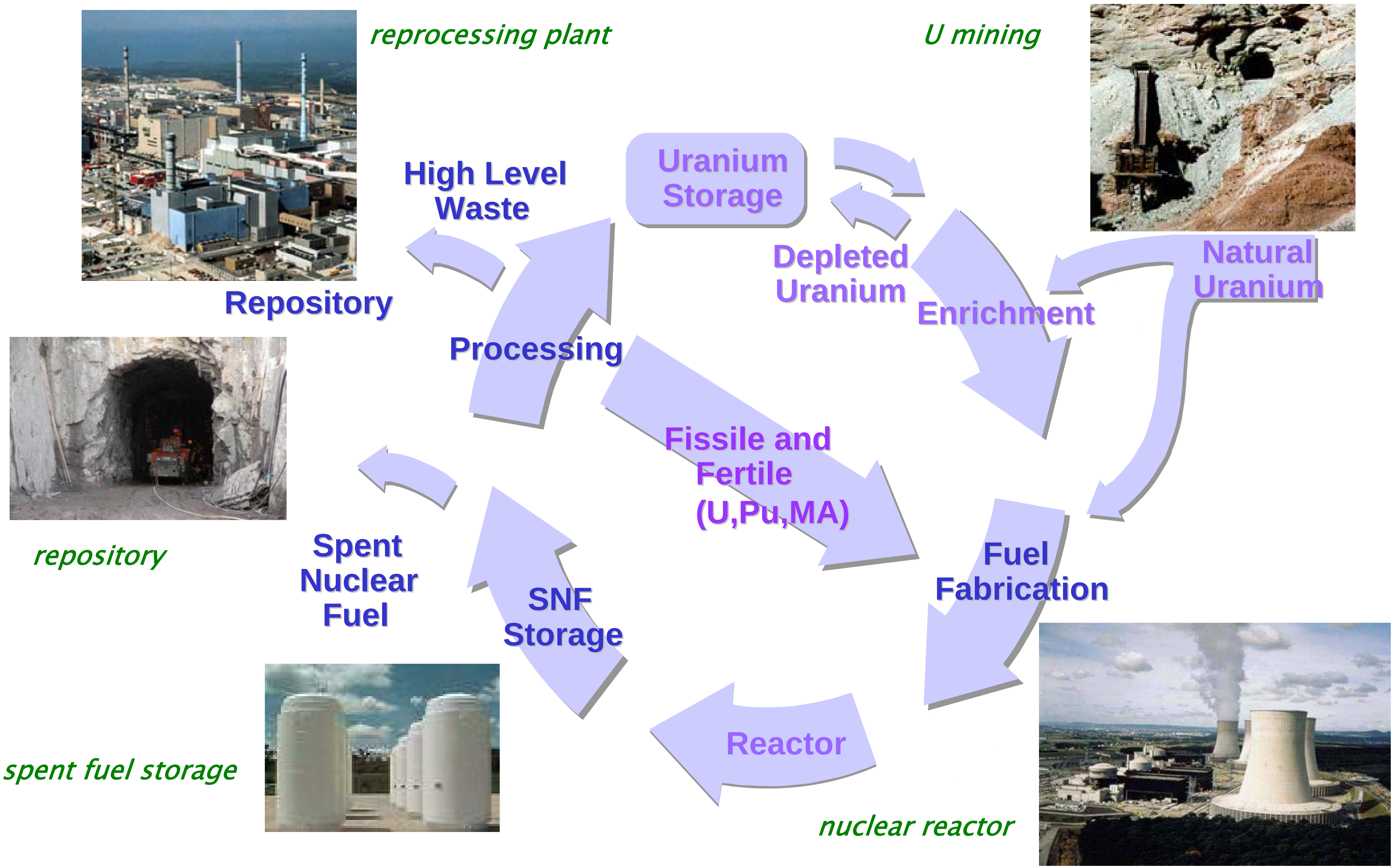
Vision document

Strategic Research Agenda (SRA)

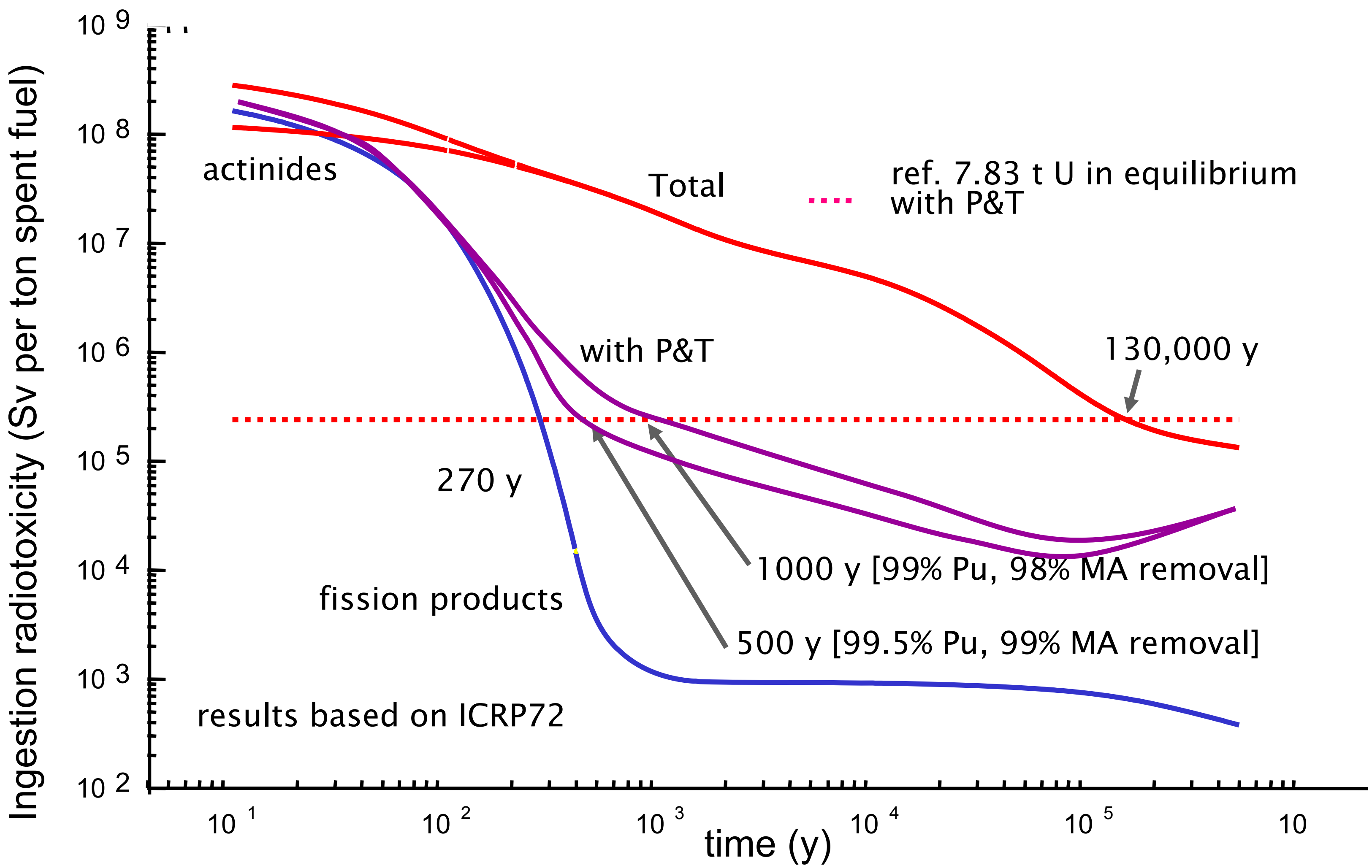
Deployment Strategy

Sustainable Fuels
Minimising Waste Issues

The Nuclear Fuel Cycle



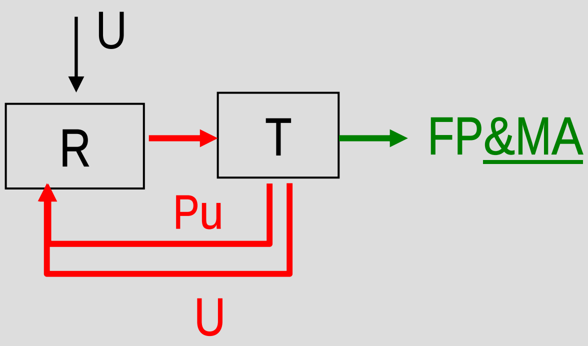
Waste Radiotoxicity Evolution



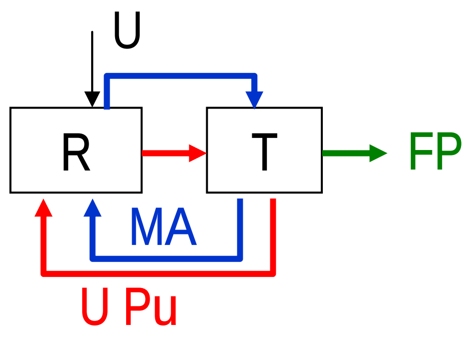
Evolution of radiotoxicity as a function of time: evaluation by CEA, FZK and ITU

JRC EUROPEAN COMMISSION

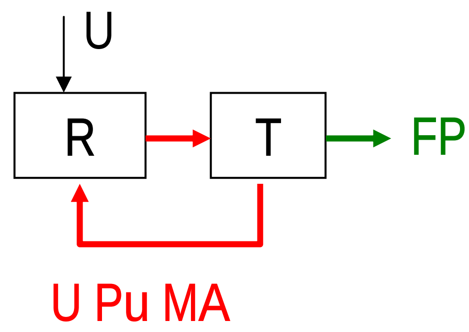
Actinide-Recycling-Schemes



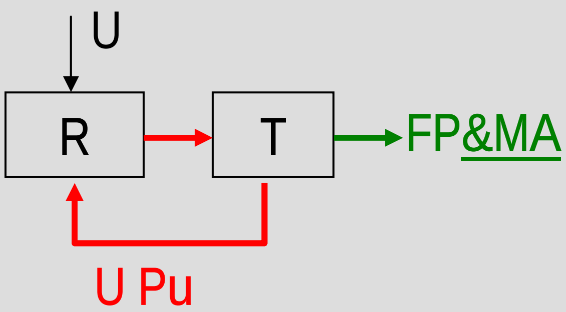
U & Pu recycling, PUREX



Heterogeneous MA recycling

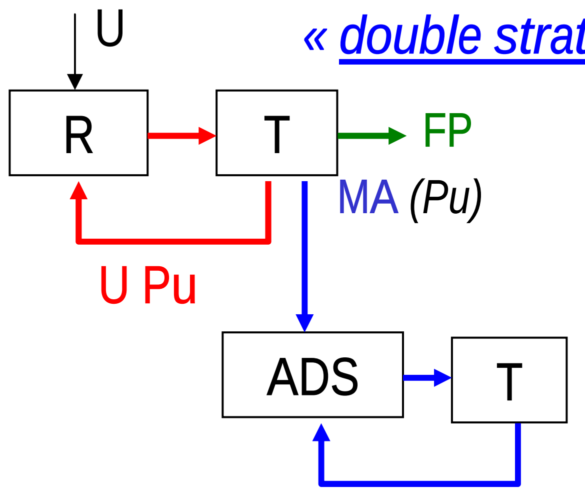


Homogeneous recycling



U & Pu recycling, COEX

« double strata »



Fuel requirements for MA Fuel Recycling

- Neutronics and core physics
  - Safe operation, Conversion ratio =1
- Material properties
  - Fabrication feasibility
  - Margin to melt (T_f, λ, C_p)
  - Mechanical properties
  - Interaction with coolant
  - Interaction with cladding (chemical and mechanical)
- Irradiation Performance
  - High burnup
  - Swelling behaviour
  - Relocation/vaporisation behaviour
  - FP retention
  - Reprocessability (or not)

Fuel properties (U,Pu)

	Metal	Oxide	Nitride	Carbide
Heavy metal density ($g.cm^{-3}$)	14.1	9.3	13.1	12.4
Melting point (K)	1350	3000	3035	2575
λ ($W.m^{-1}K^{-1}$)	16	2.3	26	20
T centreline (K)	1050	2350	1000	1000
C_p ($J.g^{-1}.K^{-1}$)	17	34	26	26

Additional Shielding (γ,n) compared to UO2 or MOX Facilities

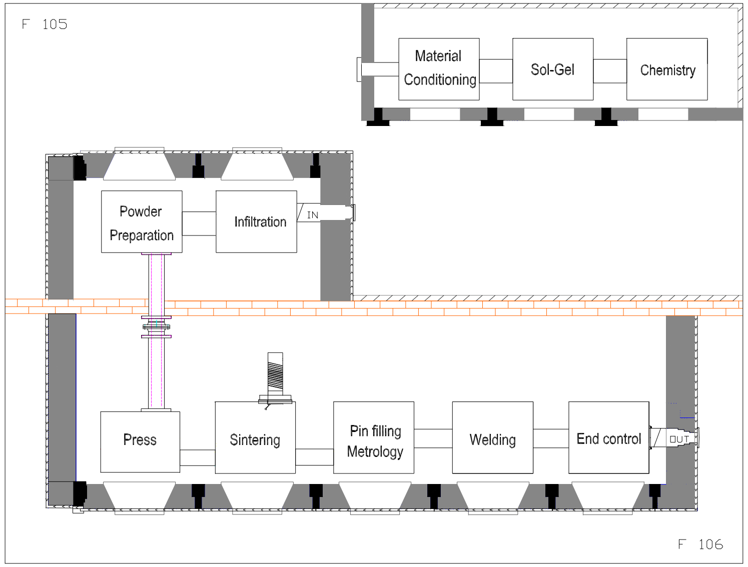
Minor Actinide Laboratory at JRC-ITU

(a) Shielded installations → remote handling

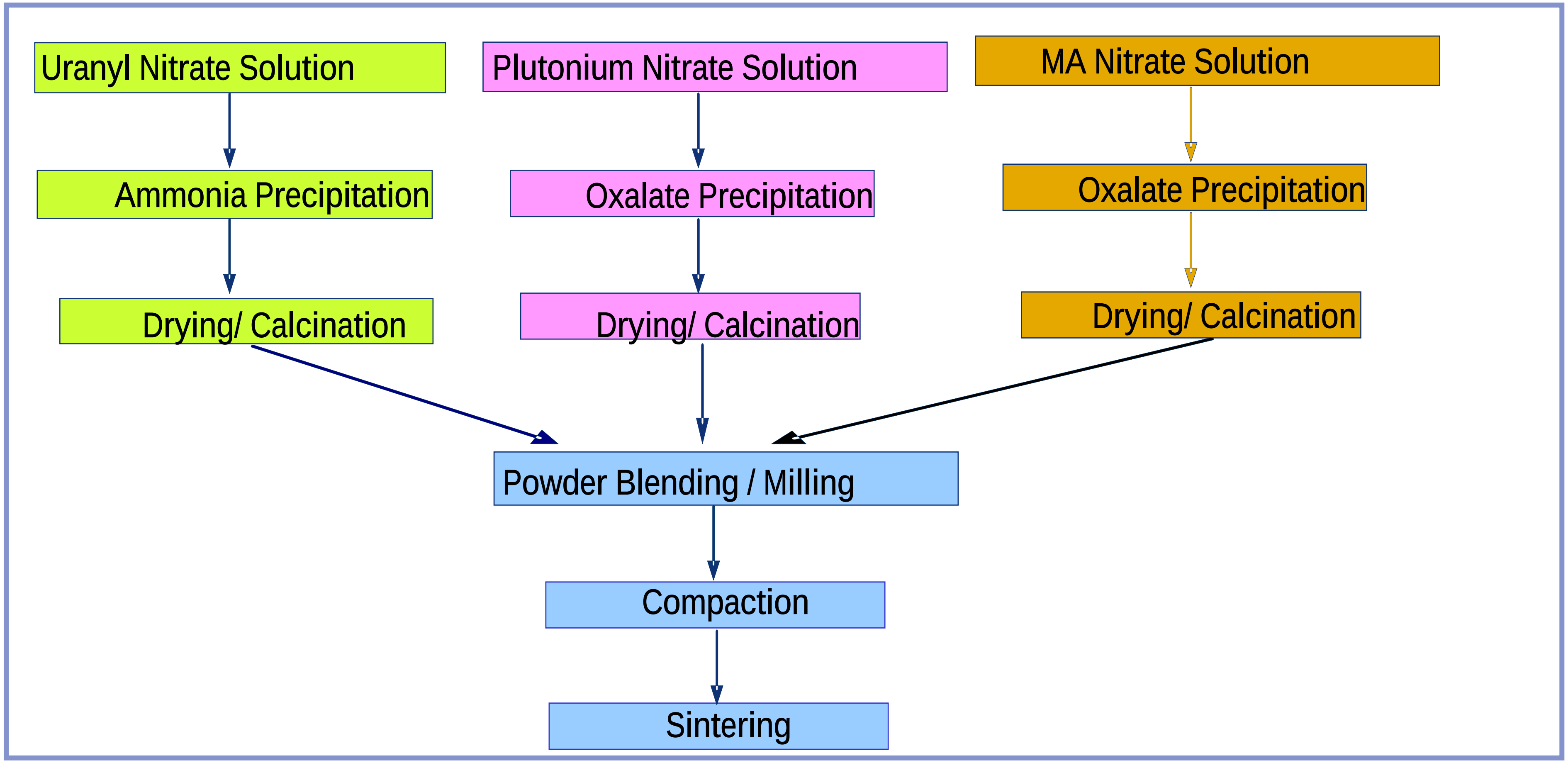
(b) Automation → use of robots

(c) dust free

(c) process simplification : minimises the (active) fabrication steps



Extension of Traditional Fabrication Technology

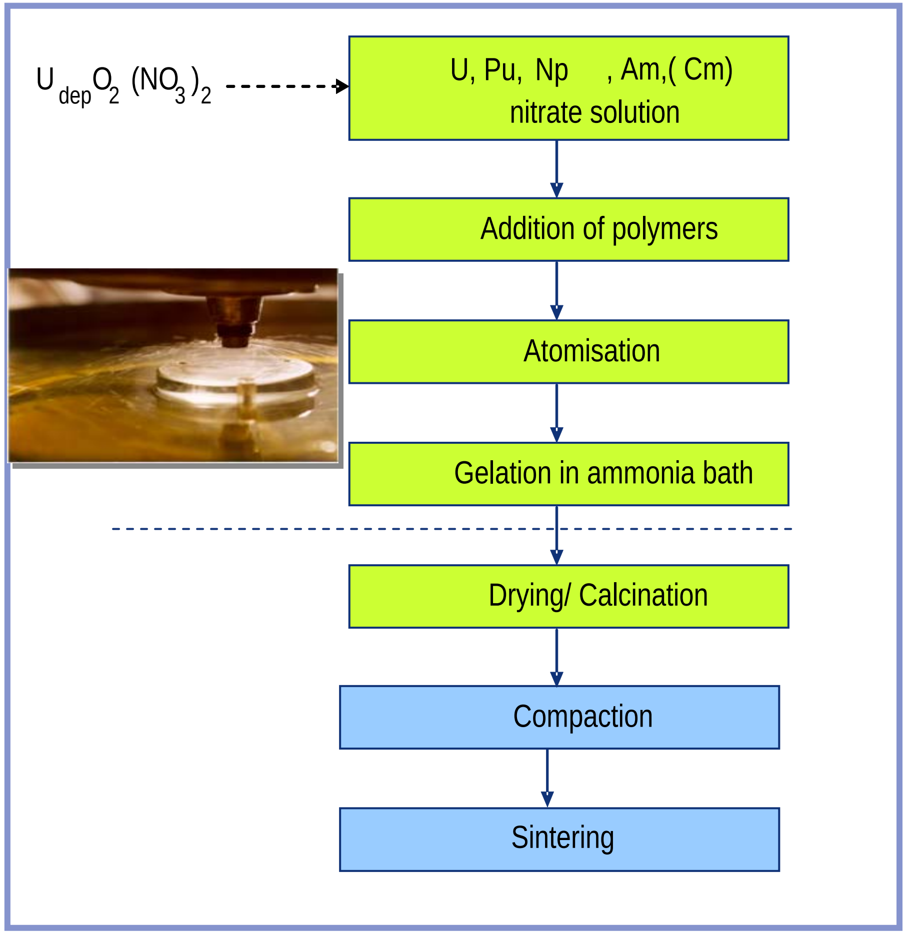


Advantages: Blend for individuals fuel pins or assemblies
Commercially use

Disadvantages: Dust with particle sizes 2-3μm or less

Liquid to solid conversion

Sol gel route for group conversion of Gen V fuels



No fine powder but *BEADS*
(Important for plant operation)

Beads diameter : 20 -600µm
(depending droplet dispersion device)

Solid solution

However,

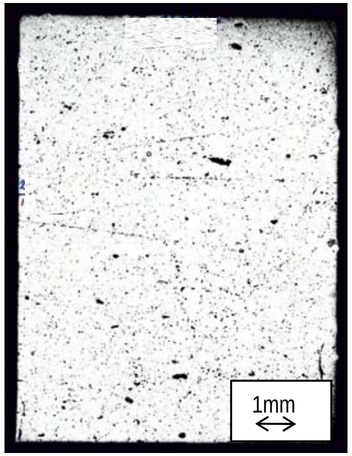
MA in all production steps

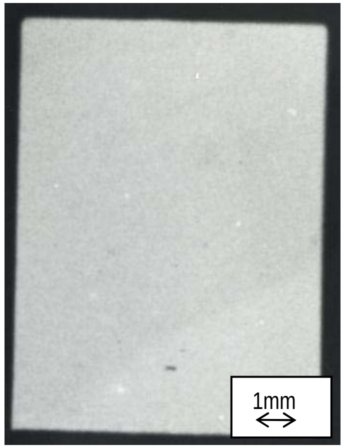
Extensive shielding,
remote operation
and automation

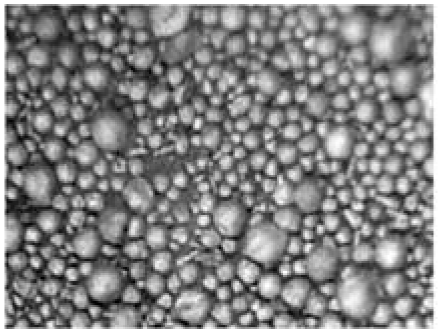
Oxide fuel: SUPERFACT

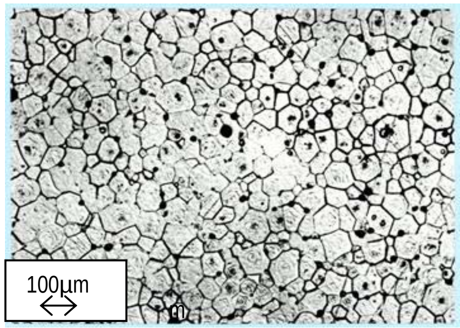
Fabrication ⇒sol gel method

$(U_{0.74}Pu_{0.24}Np_{0.02})O_2$





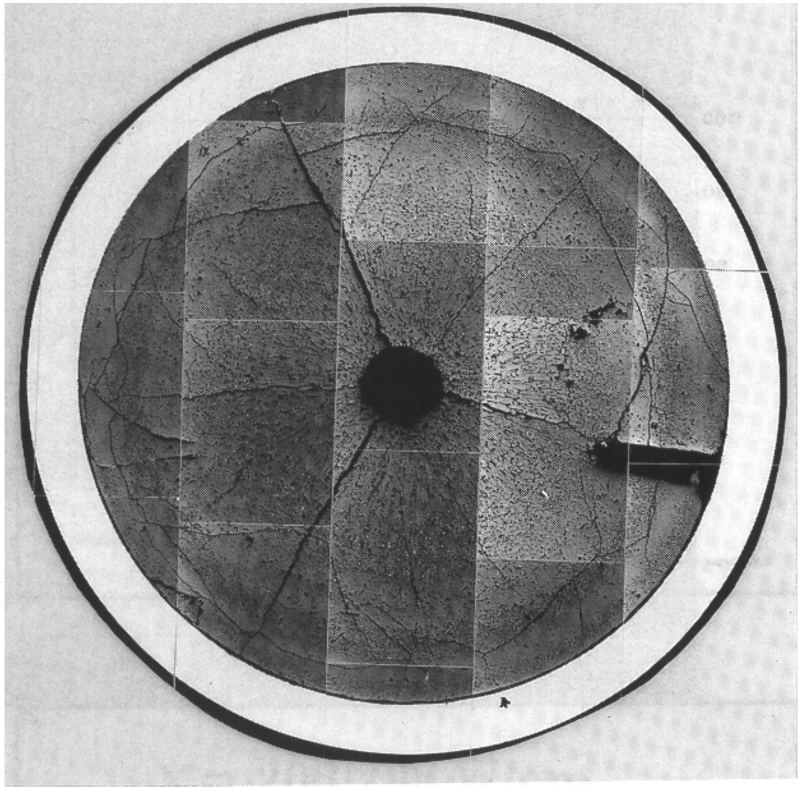




Sol-gel beads

SUPERFACT – a milestone irradiation test (CEA/ITU) Homogeneous MA Recycle in FR

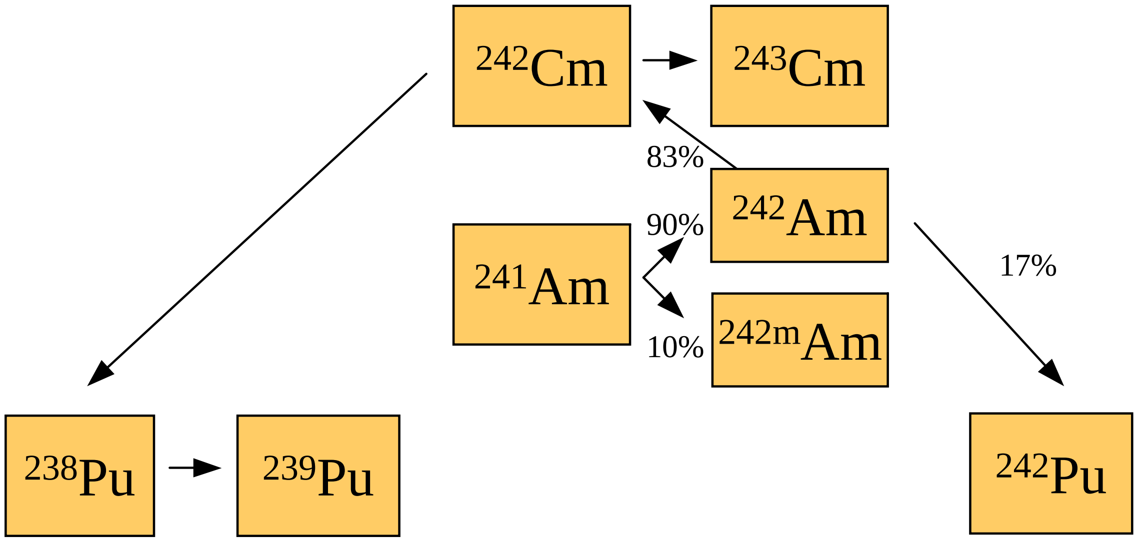
Post Irradiation Examination (PIE)

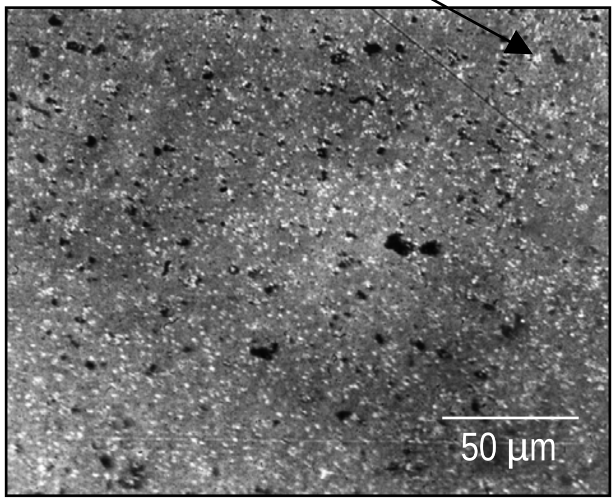


Typical observations for $(U_{0.74}Pu_{0.24}Am_{00.2})O_2$ Fuel

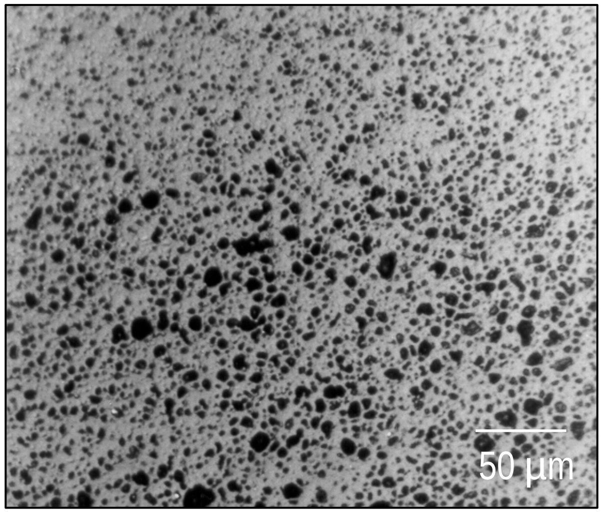
- Fuel Restructuring similar to standard MOX
- Pore migration and central hole formation
- Oxide layer (10 µm) on cladding
- Reprocessing demonstrated

HELIUM is an issue in MA fuels
Release or swelling



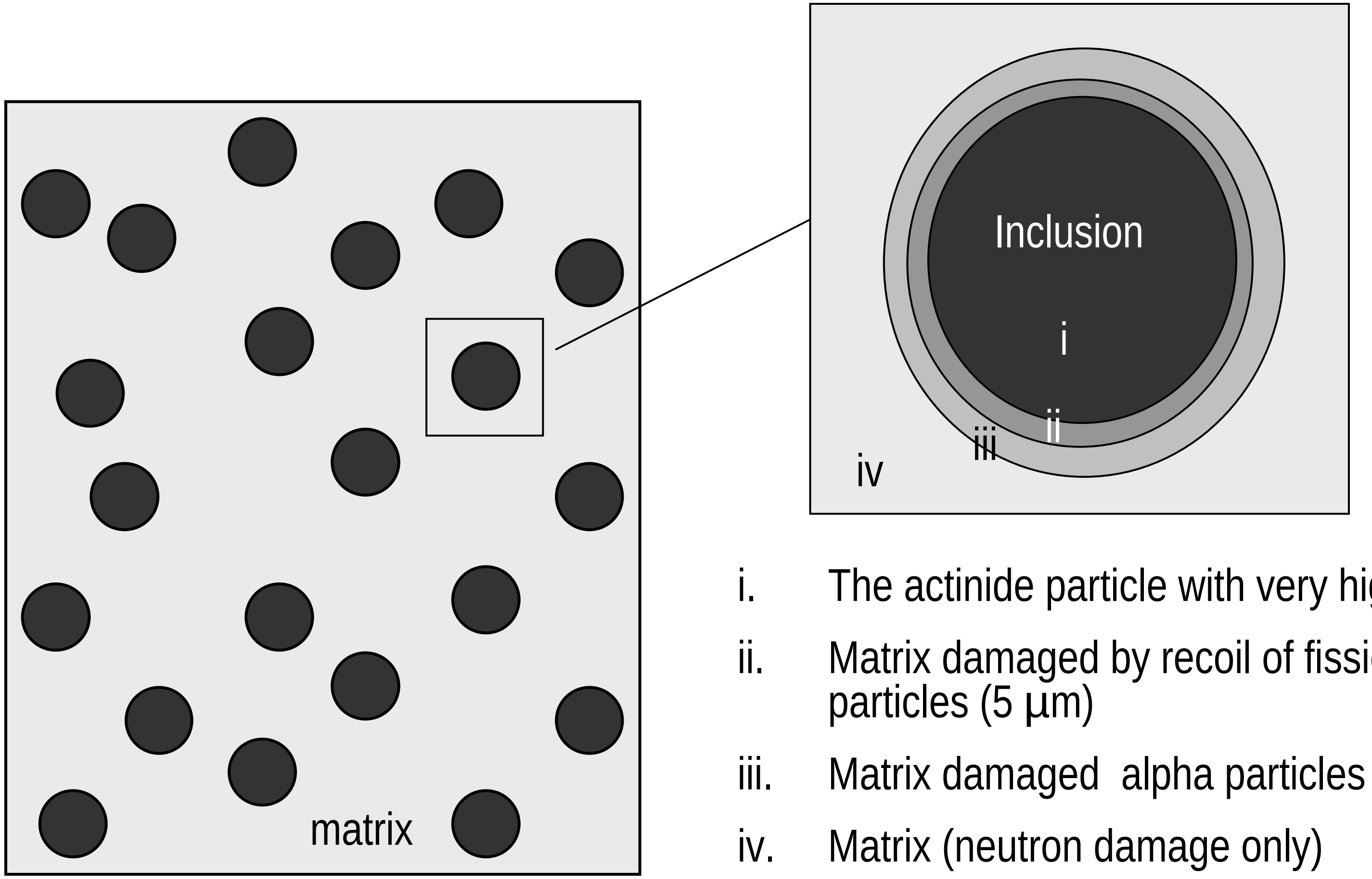


Before irradiation



After irradiation

Composite fuels for Accelerator Driven Systems



i. The actinide particle with very high displacement damage

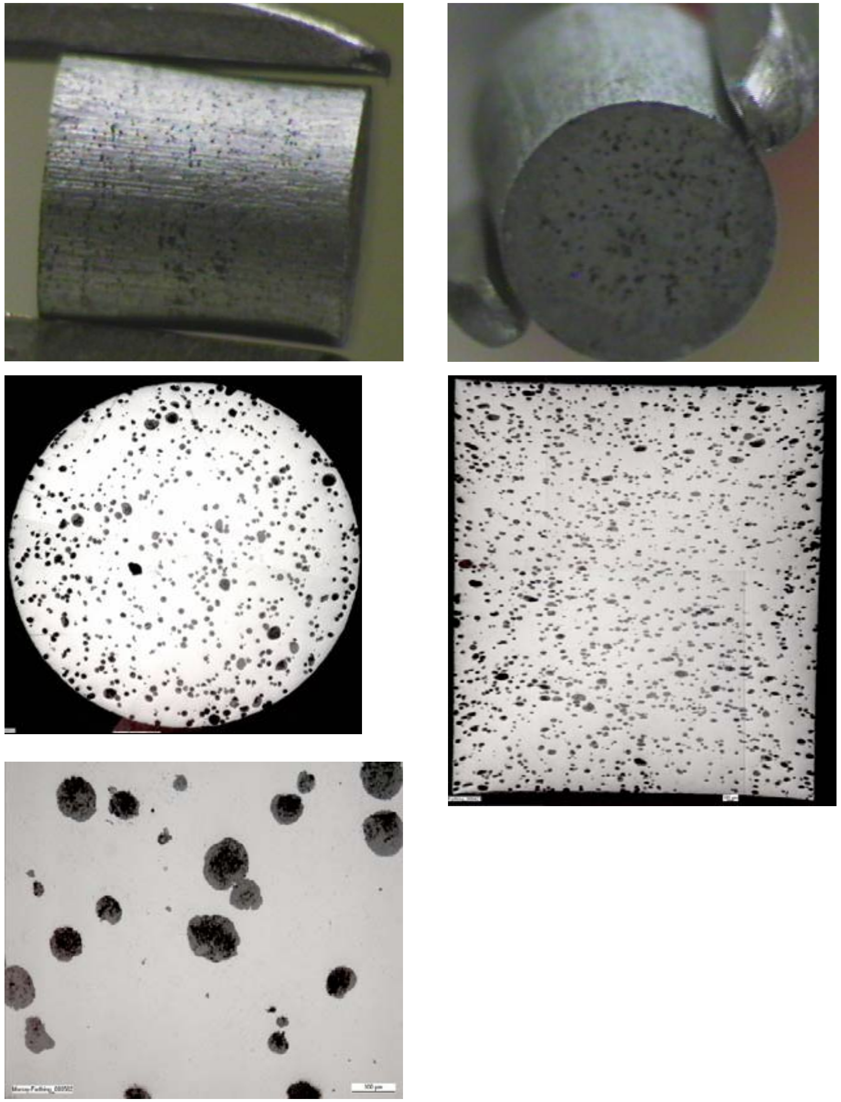
ii. Matrix damaged by recoil of fission products and energetic alpha particles (5 µm)

iii. Matrix damaged alpha particles (13 µm)

iv. Matrix (neutron damage only)

TAILOR PROPERTIES of the FUEL

CERMET Fuels



CONCLUSIONS AND OUTLOOK

- Capitalise on past programmes

- Dedicated sample fabrication and property measurement

- Separate effect studies (in and out of pile)

- Integral irradiation testing

- Improve modelling at all time and distance scales

A NEW APPROACH NOW BECOMING POSSIBLE

Thank you for your attention