



FUTURE NUCLEAR FUEL CYCLES : PROSPECTS AND CHALLENGES

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- 1 – Main achievement in the frame of 1991 Act**
- 2 – P and T in the 2006 Act**
- 3 – Fuel cycle possible options**
- 4 – On going R and D programs**



Atalante in Marcoule

The 1991 French Act: frame of the Program



◆ 3 Research thematics:

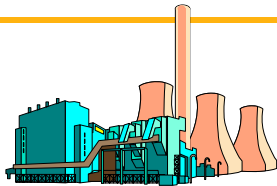
- *partitioning and transmutation of LLRNs*
- *deep repository*
- *confinement and interim storage*

◆ Deadline : final report in 2006



December 30, 1991

Minor Actinide Partitioning strategy

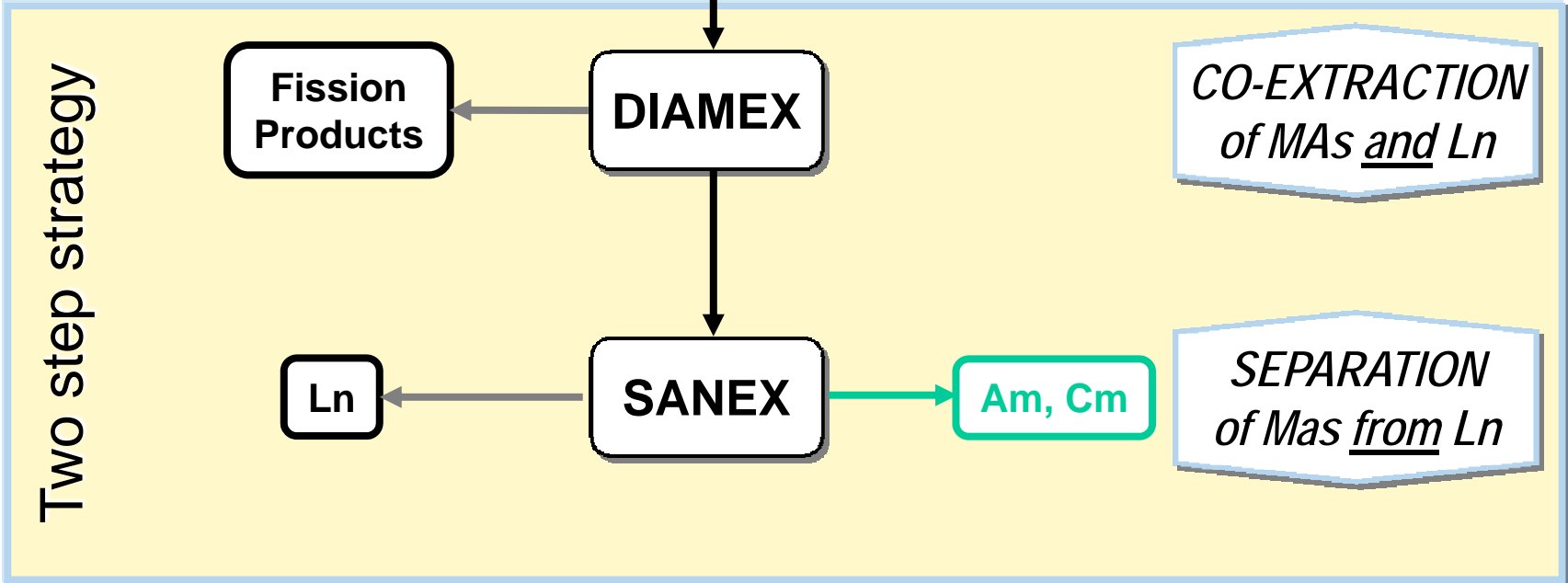
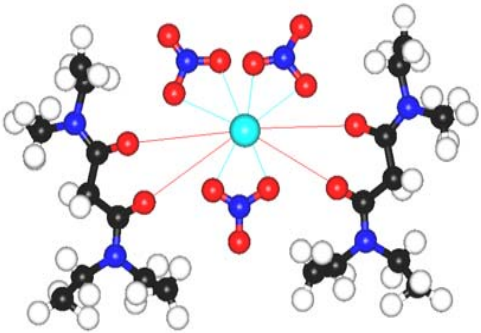


Spent Fuel

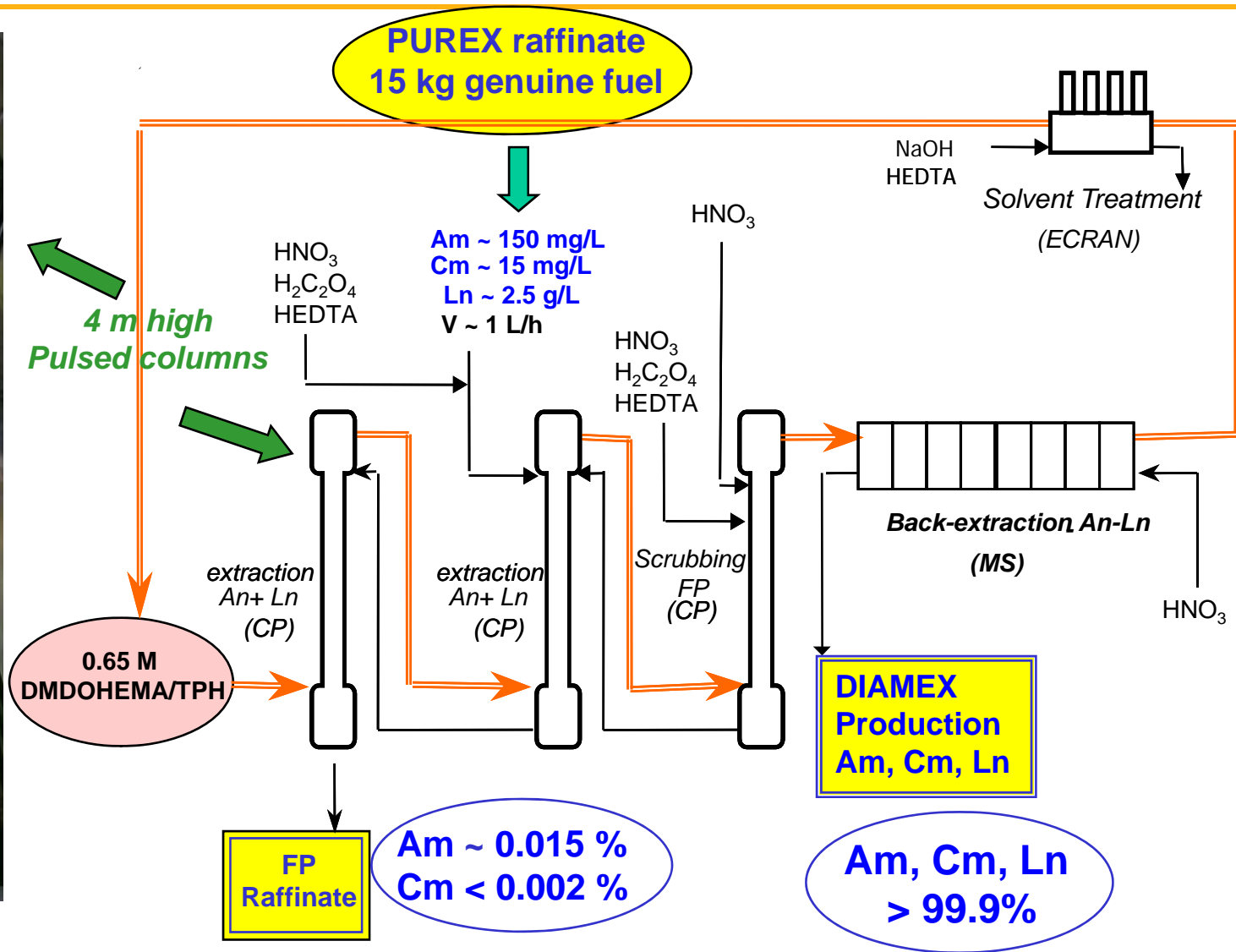
U, Pu

PUREX

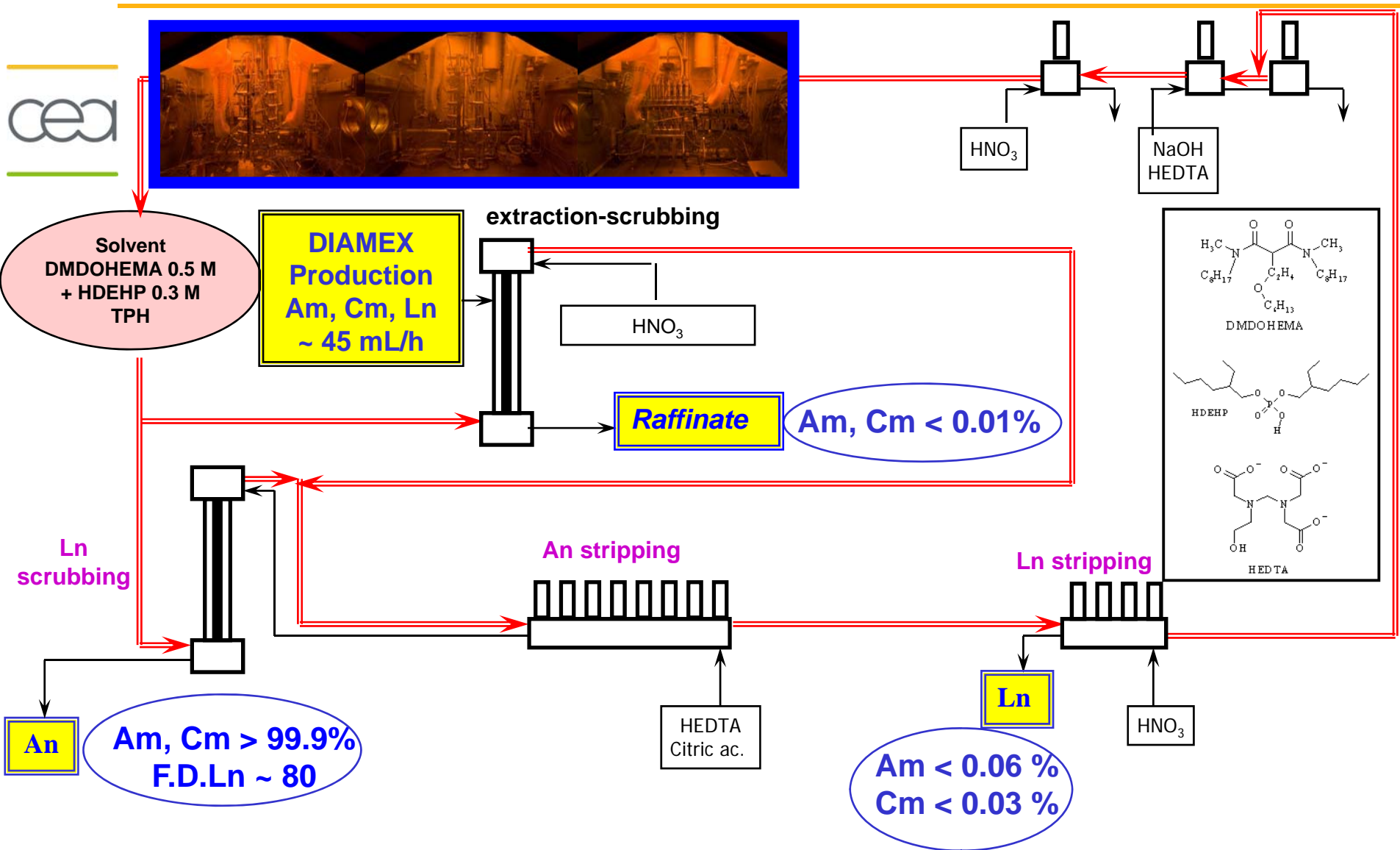
Np



DIAMEX demonstrative hot run, Nov. 2005



SANEX demonstrative hot run, December 2005



The 2006 French Act



June 28, 2006

➔ PRINCIPLES :

- Recycle (reprocess)
to decrease waste amount and toxicity
- Retrievable Geological Repository,
the reference option for ultimate waste management

➔ A « ROADMAP » :

- 2012 : *industrial potentialities of the diverse P&T options, and prototype by 2020*
- 2015 : *repository defined, and operation by 2025*

The 2006 French Act



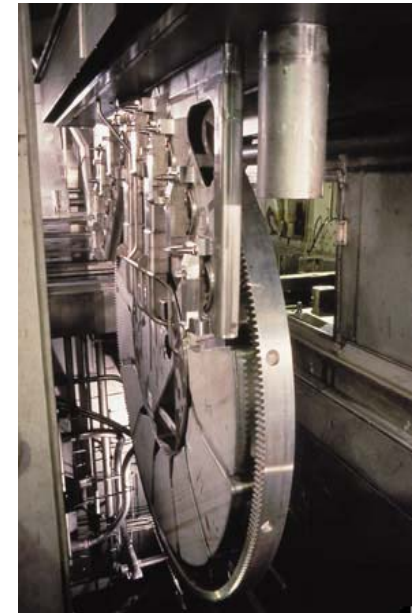
(Article 3) PARTITIONING and TRANSMUTATION OF LLRNs

« The research in this field will be connected to research concerning the new generation of nuclear reactors, as well as accelerator driven systems devoted to waste transmutation, in order to have, by 2012, an evaluation of the industrial potentialities of these concepts, and in order to start operating a prototype before December 31st, 2020... »

Minor Actinide Partitioning : what processes ?

◆ Solvent extraction, first !

- *Already developed at commercial plant scale (Industrial potentiality)*
- *high separation yields !*
- *low amount of secondary waste !*



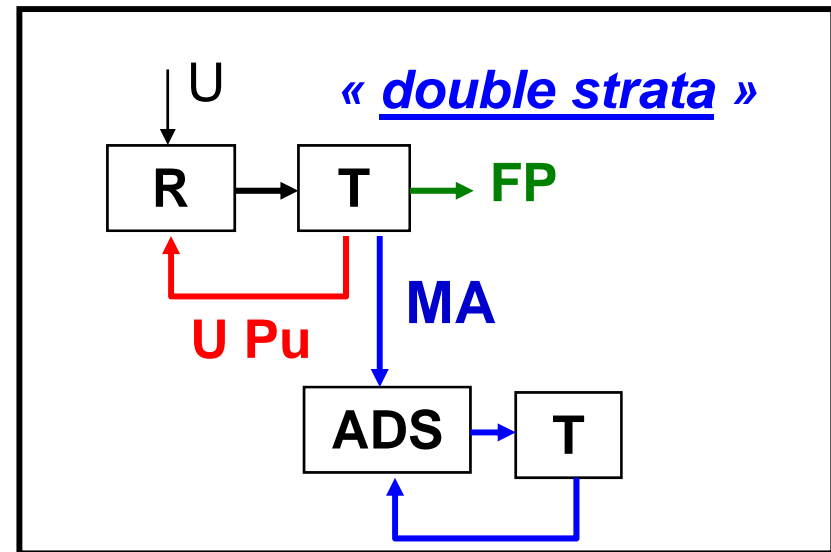
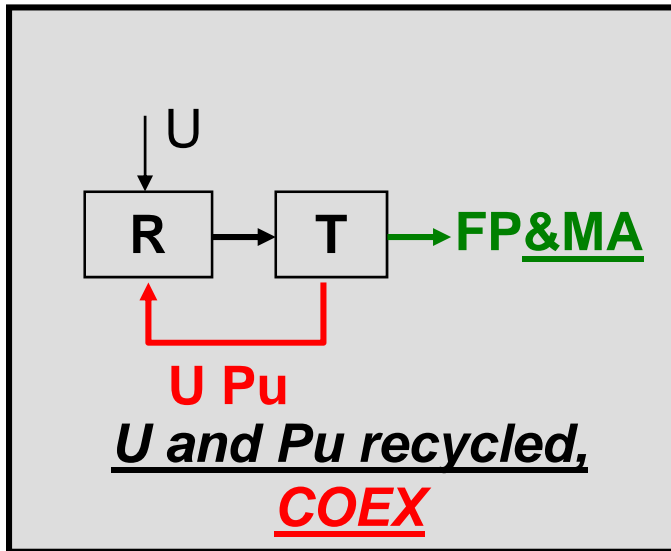
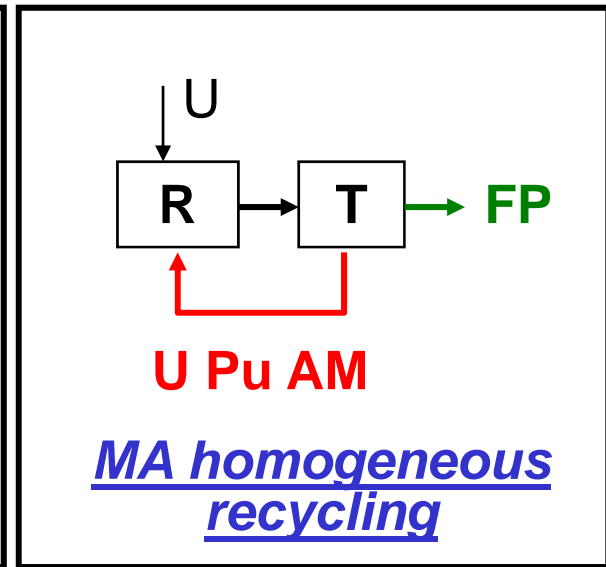
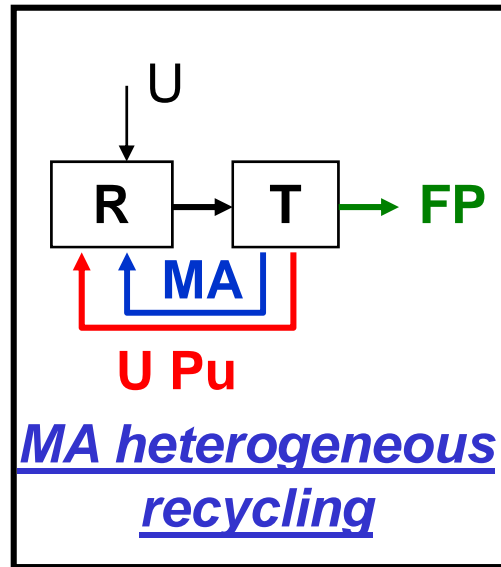
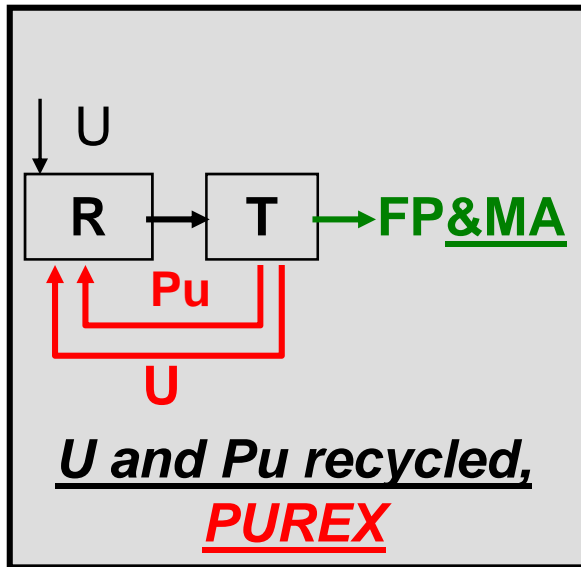
◆ *The main alternative:* ***Pyro_processes***

Future fuel cycle options : the 2012 milestone

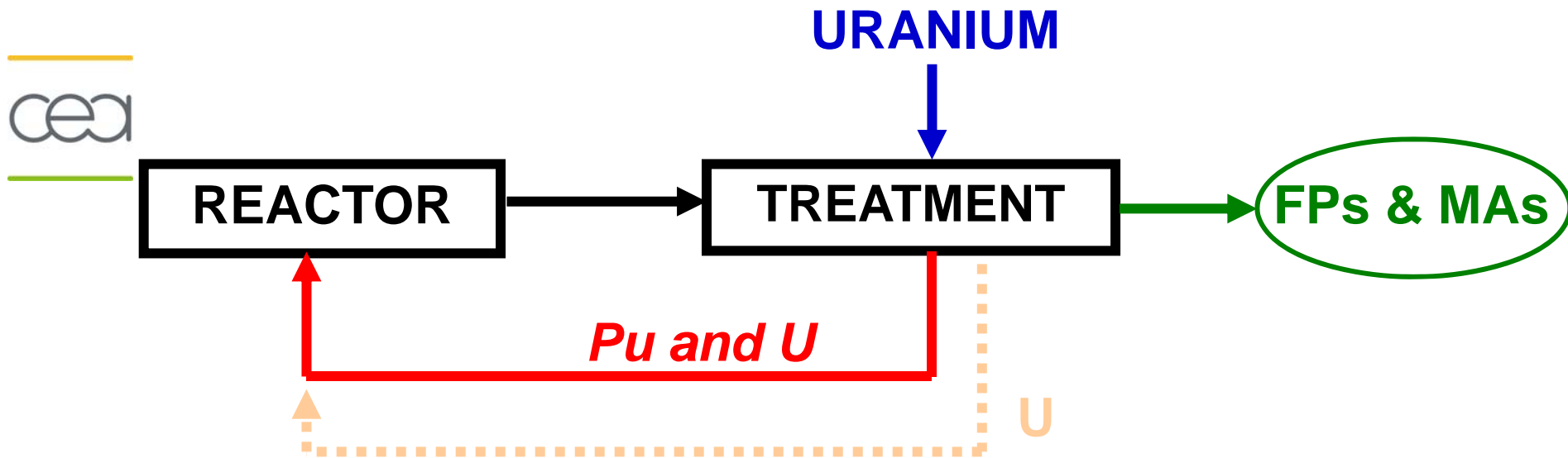


- ◆ **Define the several options** of interest, which could be successively deployed (all-actinide, Americium only, heterogeneous, homogeneous,...)
- ◆ Assess **benefits /costs ratio** for the several recycling options, considering diverse criteria and “densification” of the final storage
- ◆ **Design** / Optimize separation processes, transmutation fuels and their fabrication processes
- ◆ and gather technical elements for **industrial operation evaluation**

Future fuel cycle options, Reactor and Treatment

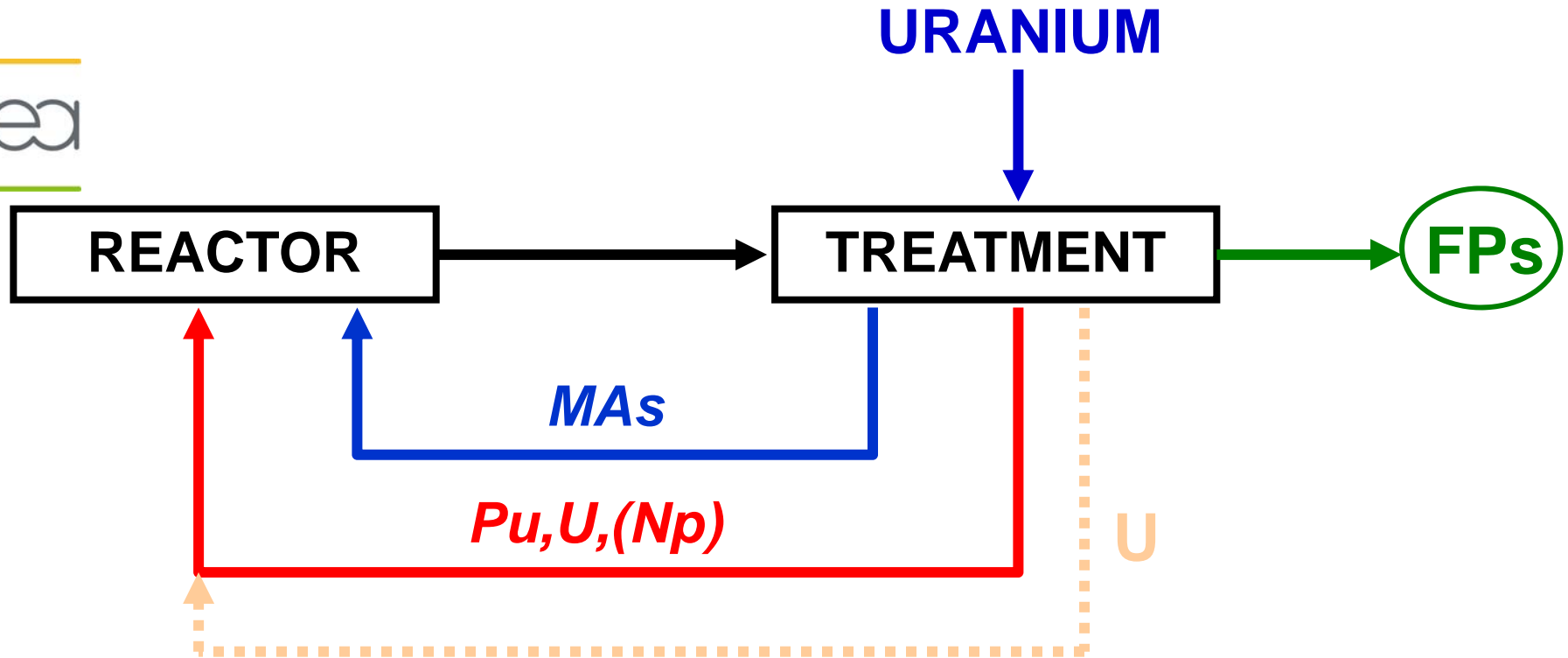


Fuel cycle, the « COEX™ » concept



- U and Pu recycling, extraction-fabrication
- *without anywhere, anytime « pure » plutonium*
- suitable for *Gen3 and MOX-LWRs*
- *a first step before more advanced options ?*

Fuel cycle, the MA heterogeneous recycling option

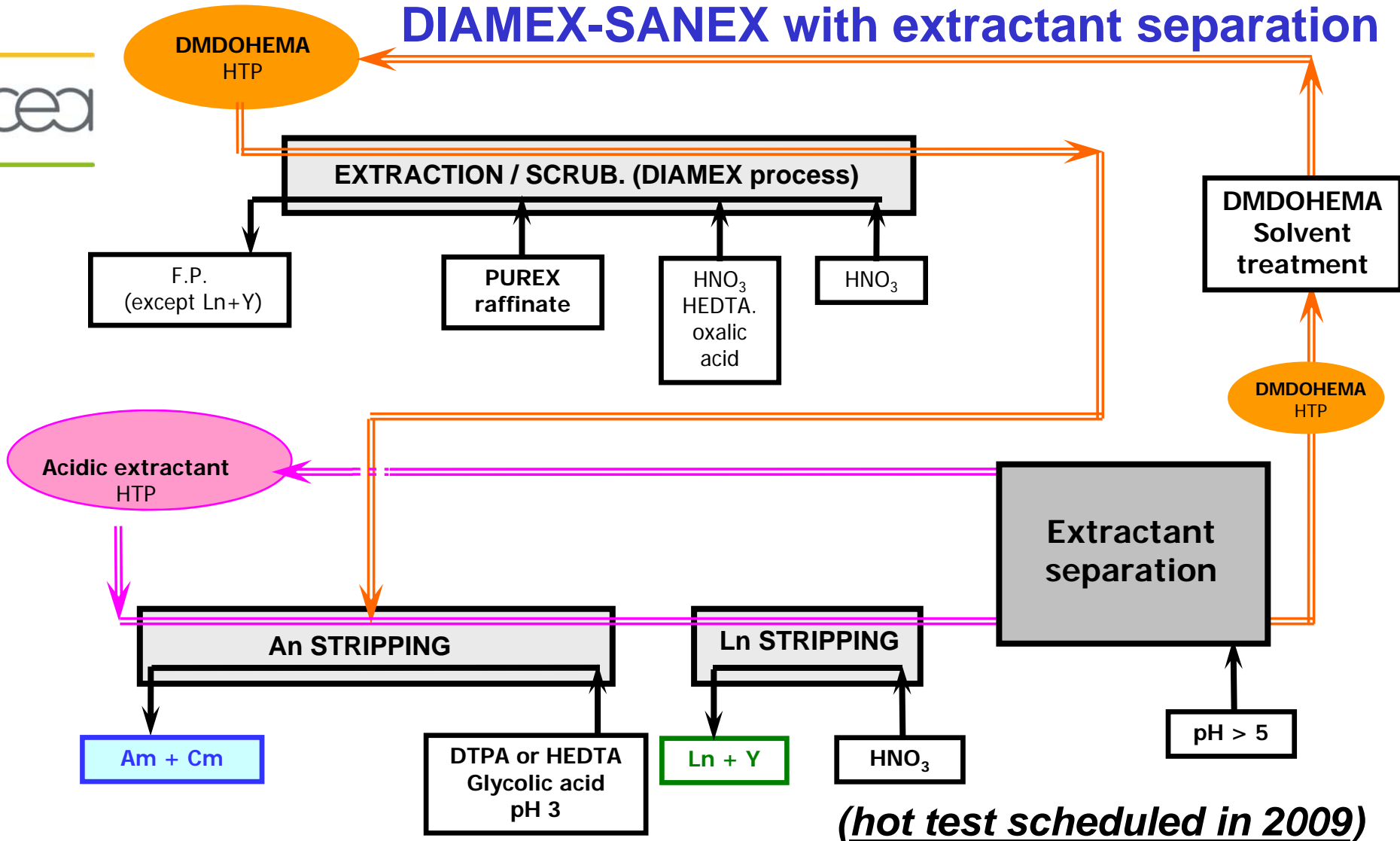


- U, Pu, Np by COEX™ (or PUREX)
- *Am (and Cm) separation* : DIAMEX, SANEX,...
- Am (and Cm) recycled on **dedicated « targets-blankets »**

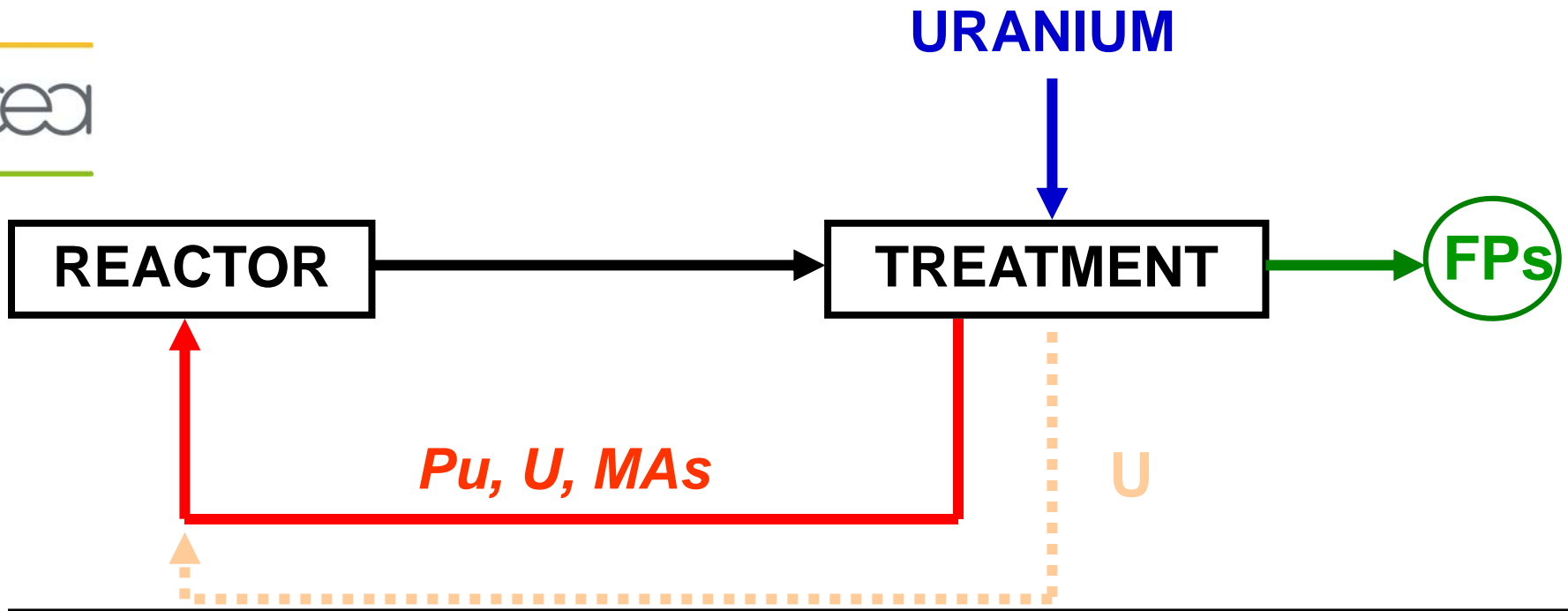
Fuel cycle, the MA heterogeneous recycling option



DIAMEX-SANEX with extractant separation

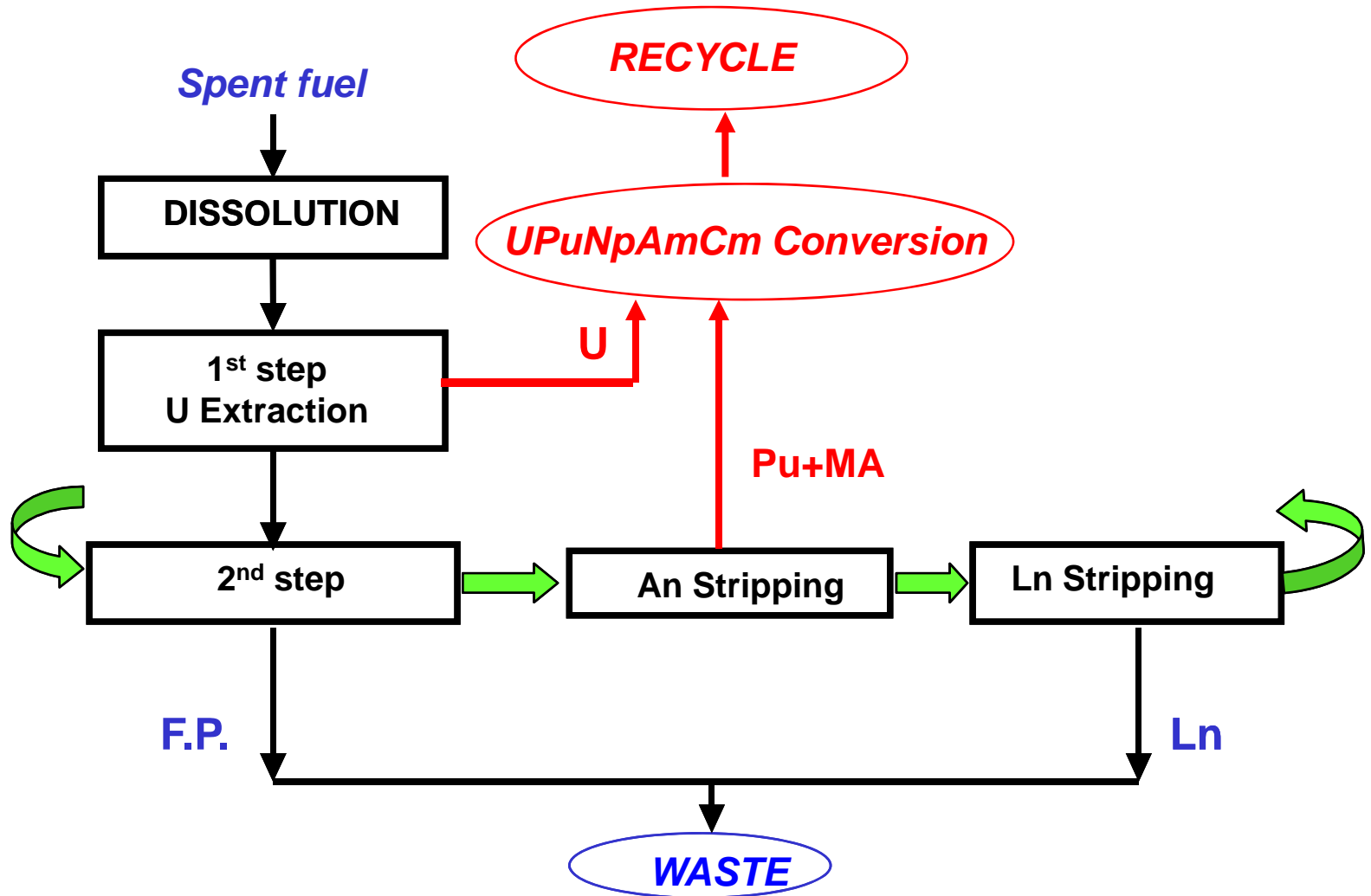


Fuel cycle, the MA homogeneous recycling option



- U, Pu, Np by COEX™ + Am (and Cm) by DIAMEX-SANEX
- or all-actinide grouped management (GANEX), the most advanced option, *but drawbacks for fuel cycle operation*

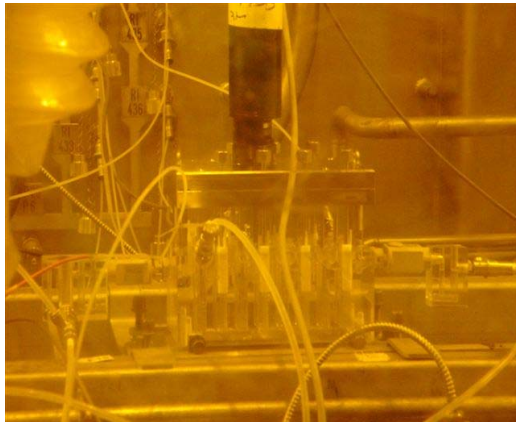
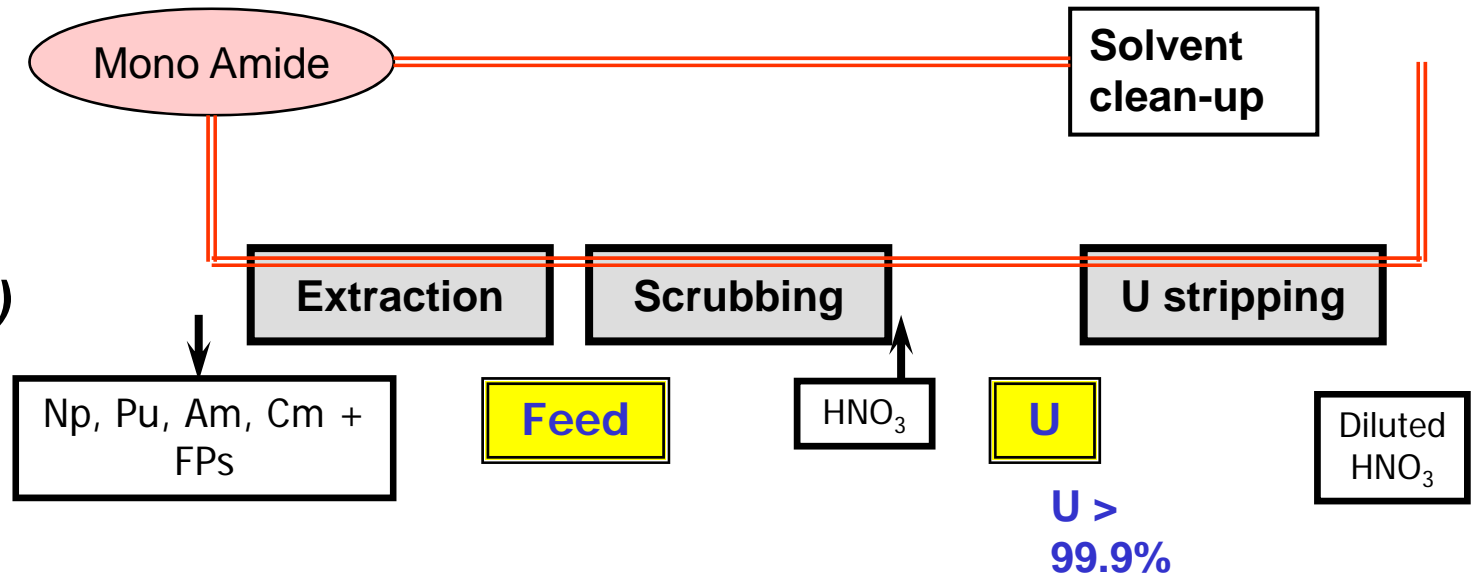
Fuel cycle, the GANEX concept



Fuel cycle, the GANEX hot runs in Atalante

1st step : *U selective extraction*

(performed successfully in June 2008)



2nd step :
Pu-Np-Am-Cm
co-recovery (diamide-based process)

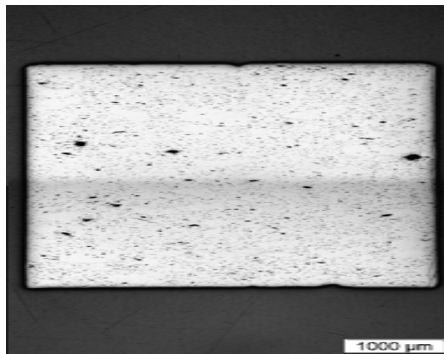
(scheduled in November 2008)

Fuel cycle, from MA solutions to fuels

Actinide oxalic co-conversion (precipitation, filtration, calcination)



U 70 % - Pu 30 %



**COPIX (UPu)O₂ irradiation test
in Phénix, 2008-2009**



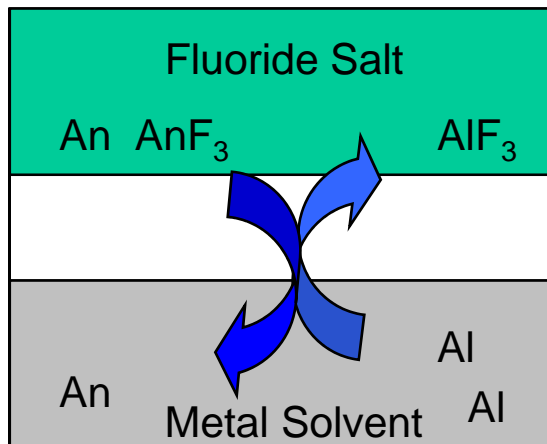
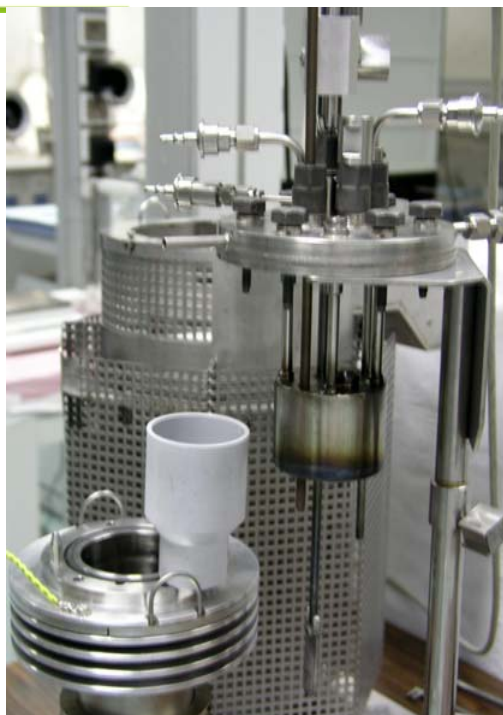
U, Pu, Np



U, Pu, Np, Am

U 78 % - Pu 20 % - Np 1% - Am 1 %

CEA Pyro reference route: reductive extraction



Actinide distribution coefficients >100
An/Ln separation factors > 1000

- **Attractive potentialities:**

- ***Compactness***
- ***No radiolytical effects***
- ***Suitable for advanced fuels, hot fuels***
- ***...***

- **but still heavy work, still questions:**

- ***Operating pyro-processes at industrial scale ?***
- ***Technological waste amount ?***



Salt ***before*** extraction



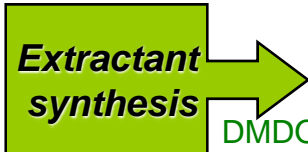
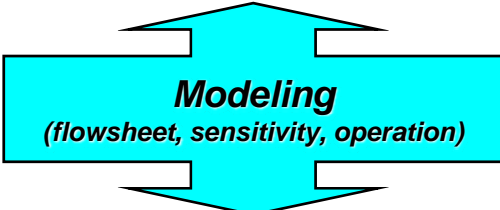
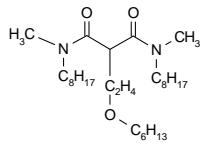
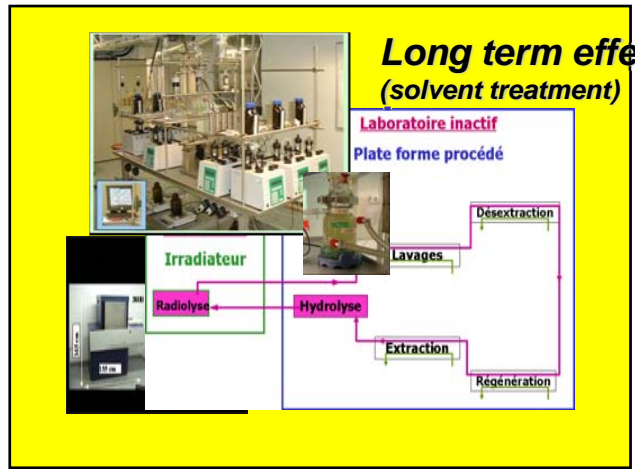
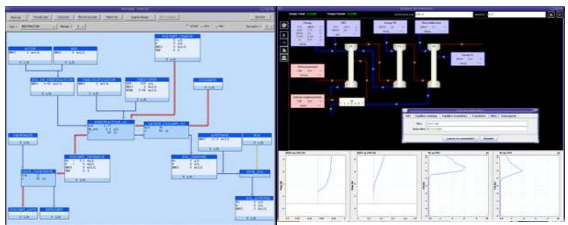
Salt ***after*** extraction

Separation process : CEA on going R and D

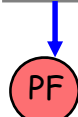
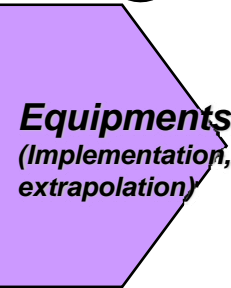


- ◆ **COEX**TM: « *Demo runs* » (*separation, conversion, COPIX*)
- ◆ **DIAMEX, SANEX** :
 - *Single cycle flowsheets*
 - « *Am only* » *recovery concepts*
- ◆ **GANEX** :
 - *1st and 2nd cycles*
 - *New flowsheets considered...*
- ◆ **Atalante new hot runs** : *from 2008 to 2012*
- ◆ **PYRO**: *Stripping in molten salts (after extraction)*

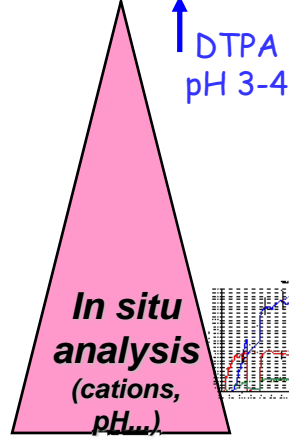
Separation process : consolidation towards industrialization



Core of the process demonstrated at small scale



Raffinat PUREX



New workshops at La Hague Areva plant ?



**SFR MOX FUEL
FABRICATION**

*(the core of SFR proto
ASTRID, tons)*

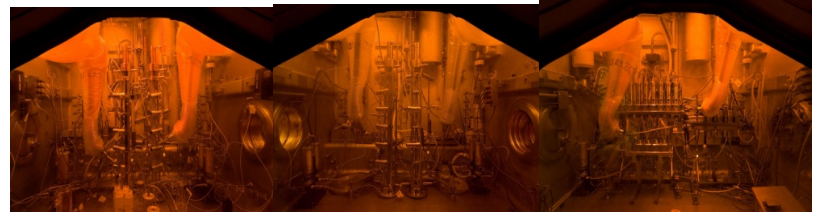
**MINOR ACTINIDE
PILOT**
(remote fabrication)

*(experimental pins,
MONJU demo, kg)*



En résumé... towards 2012 milestone

- Recycling options, for sustainable systems
- Many options still open (*what, and how*)
- A progressive step by step approach,
(*from U and Pu first, to MA recovery?*)
- A need for flexible processes?



- On-going research in the Atalante facility
(*many process options already explored*)
- A consolidation program for industrial potentiality
- Prototype(s) fuels (*driver fuel, and MA-bearing experimental fuel*):
new facilities under design, and open to international collaboration