Source Term Reduction

Strategies for EDF PWRs

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French RP Context

Radiation Protection Requirements Toughening

Dose Reduction ➜ Strategic stake for EDF

Productivity gains
Regulation respect
Nuclear acceptability

Collective Dose

Quasi-linear decrease for > 10 years

- 1991 ➜ 2,44 man.Sv/unit
- 2007 ➜ 0,63 man.Sv/unit
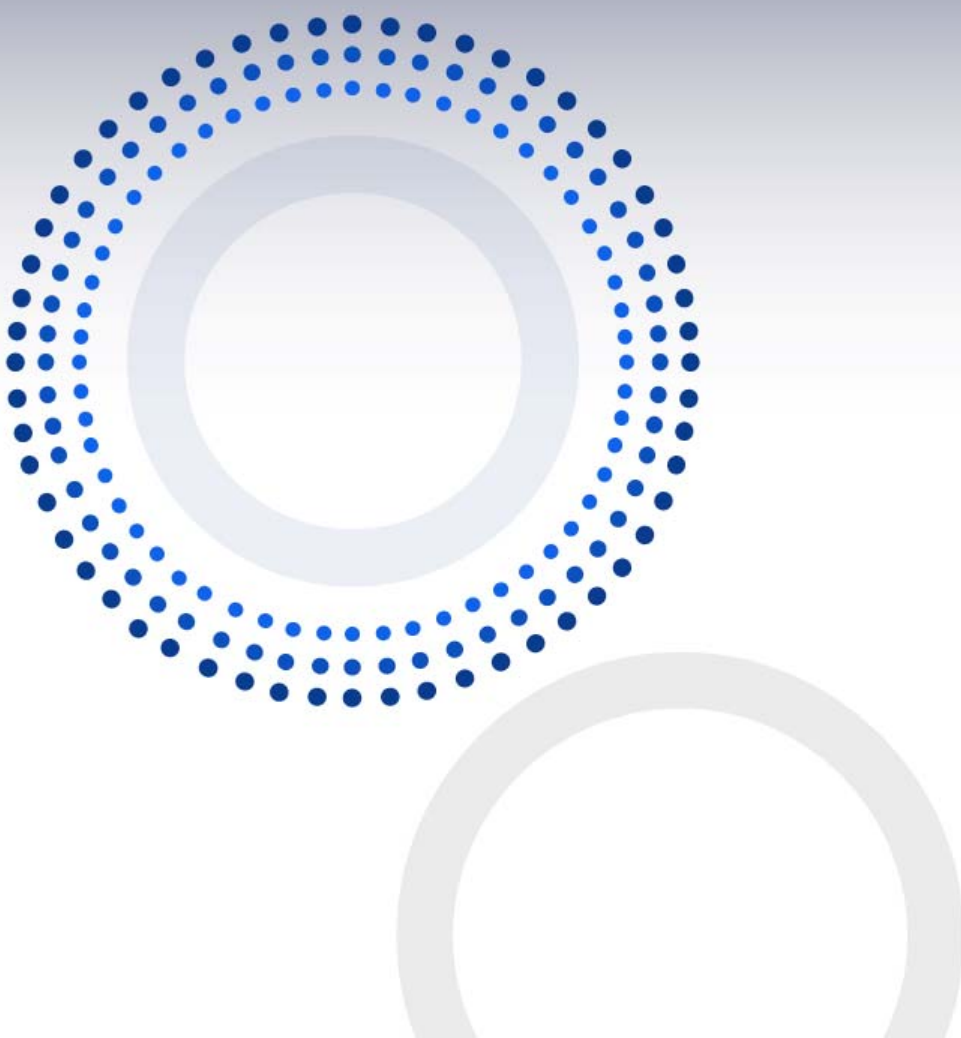- 2008 ➜ 0,65 man.Sv/unit

Personal Dose

1992 ➜ too much workers with
Dose > 20 mSv/y

2008 ➜ 0 worker with Dose > 18 mSv/y

2 ways for dose improvement

- Better organize the shutdown schedule
- Play directly on the source term

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SOURCE TERM REDUCTION Project

(STR)

Main goals and working axis

Axis 1 : Participation to long term view about RP issues

- ❑ **National and international feedback analysis**
- ❑ **Progress lines detection and long term answers**

Axis 2 : Prediction tools development

- ❑ **Prediction tools used for operation and conception engineering**
- ❑ **Knowledge transfer to current tools for operation**

Axis 3 : Research & Development

- ❑ **Better understanding of contamination mechanisms**
- ❑ **Improvement of material RP performances**

Axis 4 : Operational support at short-term

- ❑ **Operation procedure and purification optimisation**
- ❑ **Measurement campaigns**

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Technical issues

Prediction tools

Prediction tools

OSCAR V1.1 → **Corrosion and fission products in a single calculation tool**

Prediction tools

OSCAR V1.1 → **Corrosion and fission products in a single calculation tool**

INPUT DATA

Geometry

Operation

Fuel

Material

Prediction tools

OSCAR V1.1 → **Corrosion and fission products in a single calculation tool**
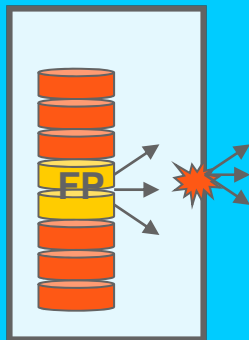
Releasing into water

INPUT DATA

Fission

Geometry

Operation

FP

Fuel

Material

PF Behaviour in fuel Thermomechanic

Releasing rate in water (ν_G)

Prediction tools

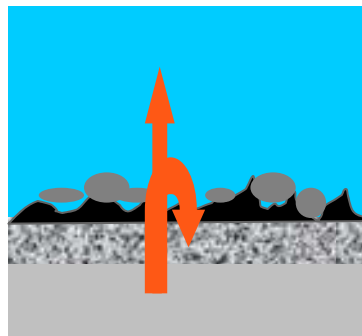| OSCAR V1.1 | → | Corrosion and fission products in a single calculation tool |

Releasing into water

INPUT DATA

| **Fission** | **Corrosion** |

- **Geometry**
- **Operation**
- **Fuel**
- **Material**

FP

PF Behaviour in fuel

Thermomechanic

Releasing rate in water (ν_G)

Releasing metal species model

Prediction tools

OSCAR V1.1 → **Corrosion and fission products in a single calculation tool**

Releasing into water

Behaviour in RCS

Fission   **Corrosion**

INPUT DATA
- **Geometry**
- **Operation**
- **Fuel**
- **Material**

Thermo-chemical Database

Solubility

Deposition

Radioactive decay

Activation under neutronic flux

PF Behaviour in fuel

Thermomechanic

Releasing rate in water (ν_G)

Releasing metal species model

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Prediction tools

OSCAR V1.1 → **Corrosion and fission products in a single calculation tool**

Releasing into water

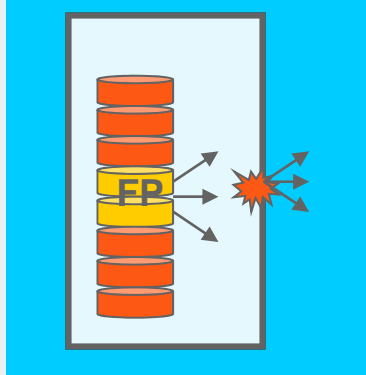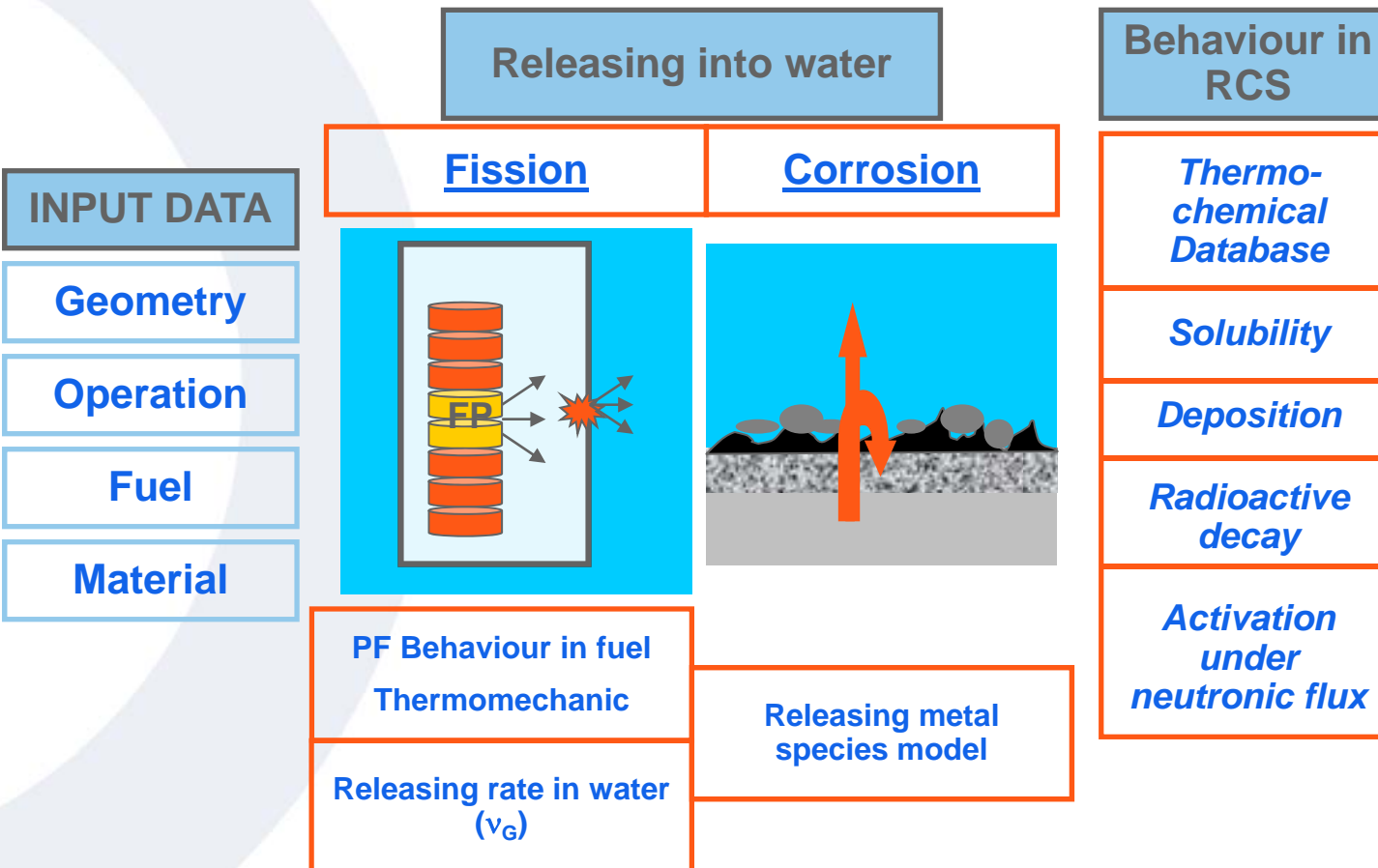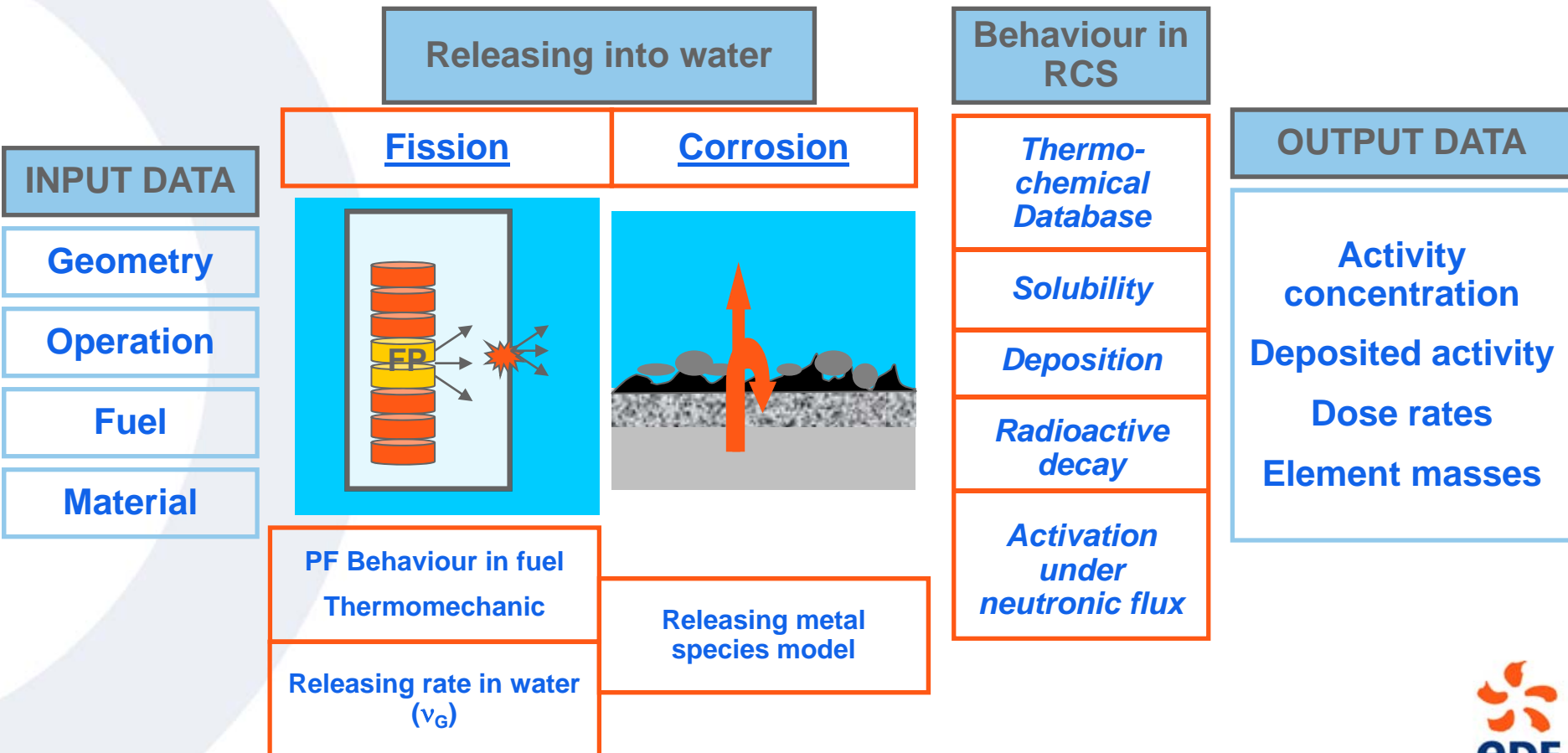**Behaviour in RCS**

Fission	Corrosion

INPUT DATA

- Geometry
- Operation
- Fuel
- Material

FP

PF Behaviour in fuel
Thermomechanic

Releasing rate in water (ν_G)

Releasing metal species model

Thermo-chemical Database

Solubility

Deposition

Radioactive decay

Activation under neutronic flux

OUTPUT DATA

Activity concentration

Deposited activity

Dose rates

Element masses

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Research and Developments

R&D Actions

R&D groundwork → **Prepare further codes evolutions**

Improve contamination knowledge for everyday life in NPP
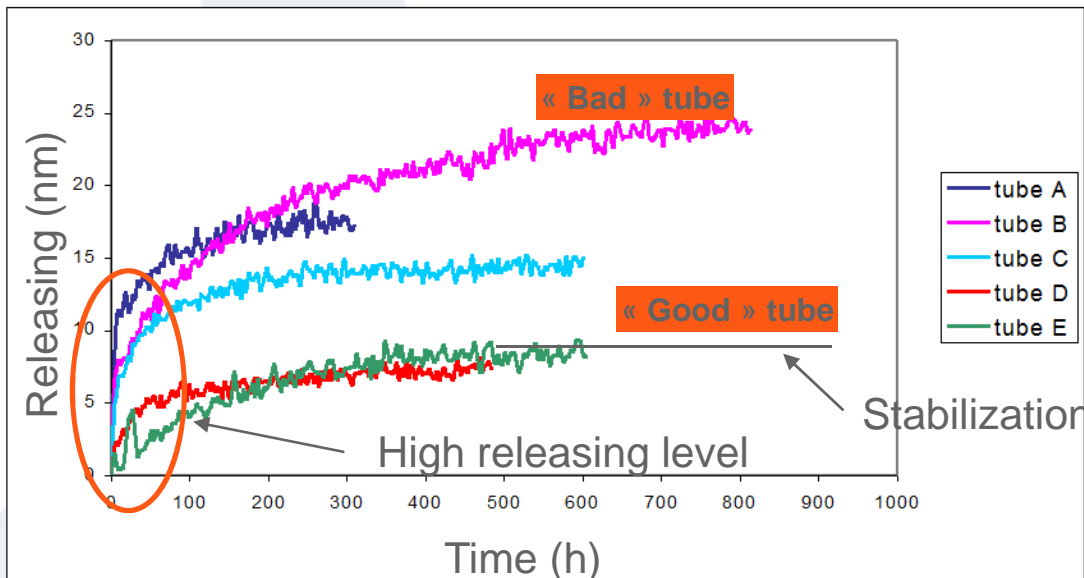
| 1 | **Releasing SG tubes characteristics** |

❑ **Releasing modeling :**   Objective → R = f (T, pH)

❑ **Tubes specifications :**   Definition of criteria to assure a low releasing rate

R&D Actions

The BOREAL Loop
(EDF/R&D/MMC)

Allow to characterize releasing properties of Steam Generator tubes vs. Time in realistic conditions

Releasing modeling

Accurate control of the quality of the SG tubes manufacturing process

« Bad » tube

« Good » tube

Stabilization

High releasing level

Releasing (nm)

Time (h)

tube A
tube B
tube C
tube D
tube E

R&D Actions

R&D groundwork	→	**Prepare further codes evolutions**
		Improve contamination knowledge for everyday life in NPP

1 Releasing metal characteristics

❑ **Releasing modeling :** Objective → R = f (T, pH) with BOREAL loop

❑ **Tubes specifications :** Definition of criteria to assure a low releasing rate

2 Colloidal particles

❑ **Colloidal particles :** Sized from 1 nm up to 1 µm (not retained by filters or resins)

❑ **Electrostatic properties of particles :** Interactions with walls pipes

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R&D Actions

R&D groundwork	→	**Prepare further codes evolutions**
		Improve contamination knowledge for everyday life in NPP

1 | **Releasing metal characteristics**

❑ **Releasing modeling :** Objective → R = f (T, pH) with BOREAL loop

❑ **Tubes specifications :** Definition of criteria to assure a low releasing rate

2 | **Colloidal particles**

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❑ **Electrostatic properties of particles :** Interactions with walls pipes

3 | **Speciation and solubility**

❑ **Solubility measurements :** Ni, NiO, $Ni_xFe_{2-x}O_4$ as a function of T, pH, redox

❑ **Dissolution kinetics measurements**

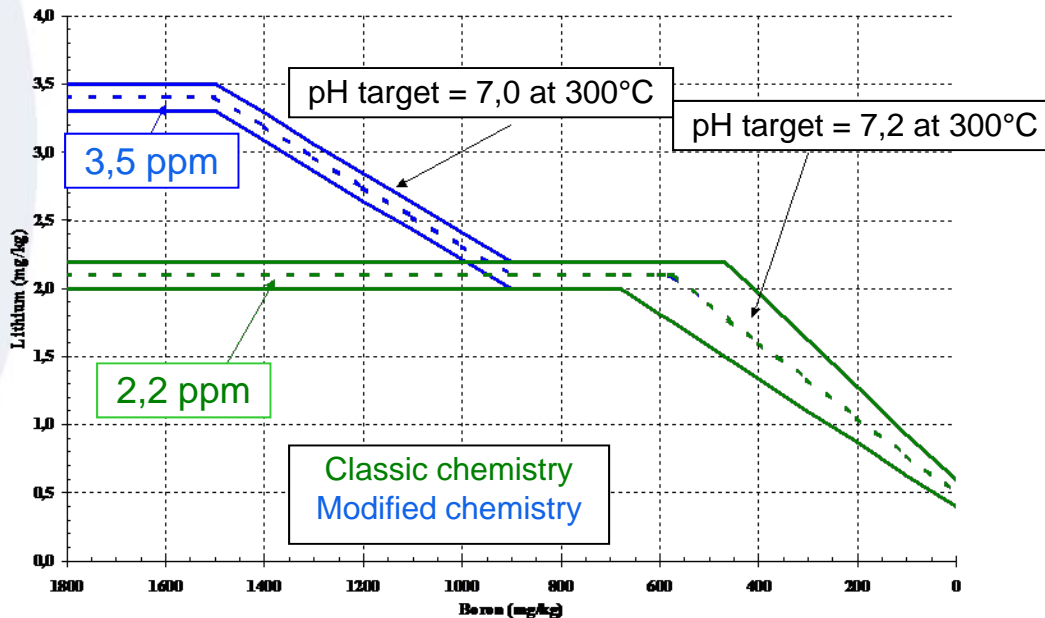# Procedures improvements

Operation improvements (1/3)

1	**Chemistry**

❑ Boron/Lithium management

- "Modified chemistry" on 5 French units for 5 years

- Extension to 1300-series units (Galice Fuel Management)

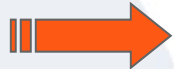- Sufficient feedback to analyse accurately the RP impact

Operation improvements (2/3)

2	Procedures improvement

☐ Zinc injection

➡ • Implemented in France in 2 units (curative and preventive aims)

• Effect not as significant as observed in foreign units
• Slight decrease however

• Pursuance on 8 new units until 2010 not only for RP issues but also for AOA and PWSCC risks

☐ Other new practices

➡ • Chemical dehydrogenation and bubble collapsing at 130°C

• Fast cooling (- 40°C/h) experimented on several 900-series units

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Operation improvements (3/3)

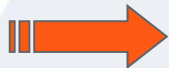| **3**	**Purification improvements**

❑ Filters : Ultrafiltration

➡ • Special membrane instead of pleated media filter in CVCS

• Experimentation in progress in laboratory (CEA) and planned on site in 2010-2011

• Technical and economic feasibility study for implementation

❑ Filters : Silica-free

➡ • Negative impact on fuel cladding during zinc injection

• Experimentation planned on site in 2011

❑ Resins : Volume reduction

➡ • Until now : use of a full resin volume for several cycles

• At the restart : Releasing of radioactive contaminant retained during previous shutdown (silver species particularly)

• Experiment : use a lower volume and change the resin every cycle

Conclusions

Source term reduction is an important matter of concern for EDF fleet performances

STR project has been launched for 6 years in order to reduce contamination levels and dose rates

Investigations about innovative technologies

Practical answers in operation

Thanks for your attention !

At your disposal for some questions !

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Operation improvements (3/4)

3 | **Measurement campaigns**

EDF Strategy

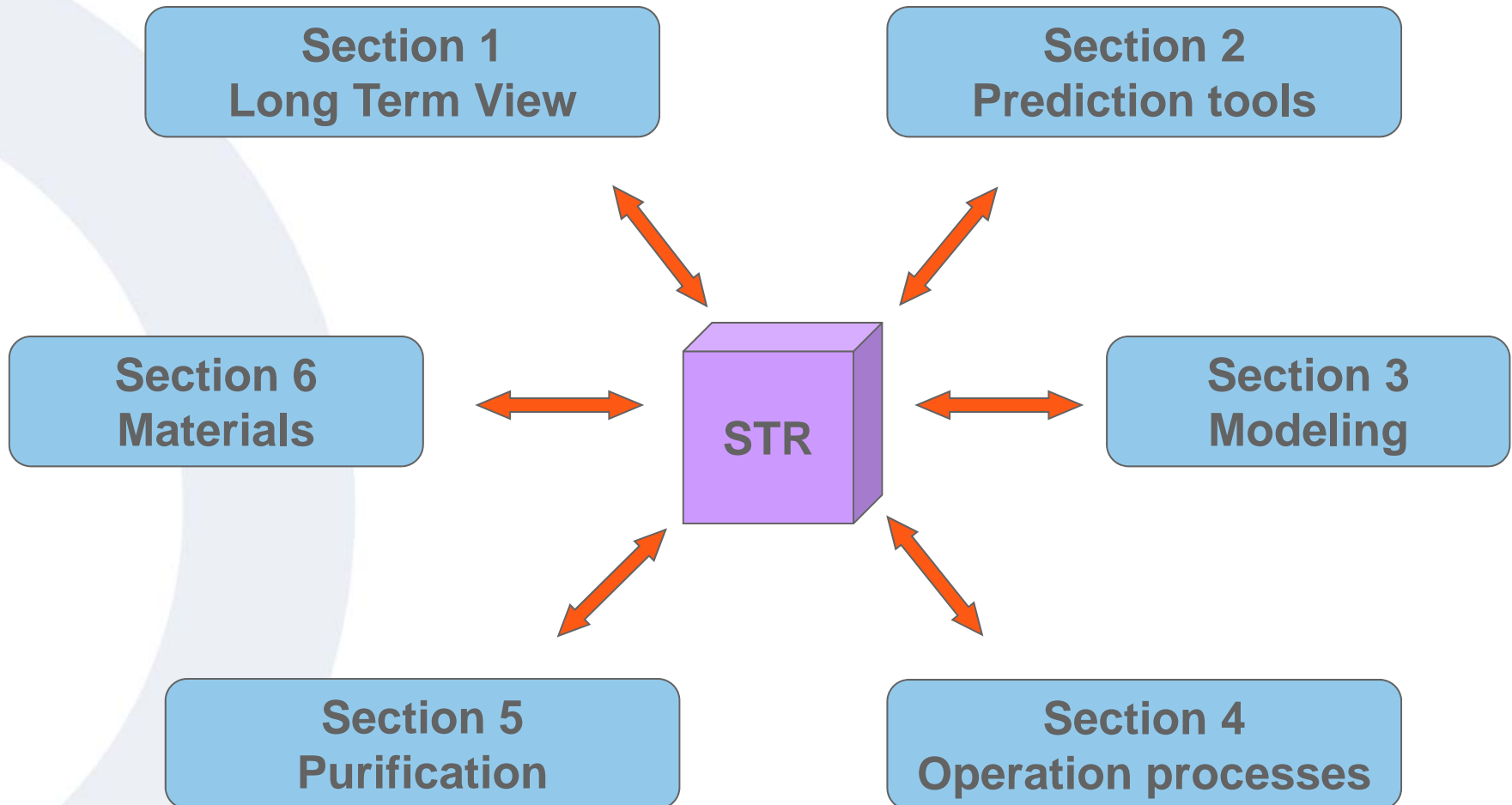|	ROUTINE DOSE RATE MEASUREMENTS	SPECIFIC CAMPAIGNS
What		
Who	RP teams in each French units	CEA (EMECC)
Why	• Calculation of RCS Index • Performance comparison • Good practices	• Accurate analysis • Specific experiments • Specific contamination

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Project segmentation

Section 1
Long Term View

Section 2
Prediction tools

Section 6
Materials

STR

Section 3
Modeling

Section 5
Purification

Section 4
Operation processes

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Prediction tools (2/2)

Current qualification scope

Fission Products	Corrosion Products
Noble gaz and iodine	^{60}Co et ^{58}Co

Reactor in « hot » steady operation

Activity concentration for Burn-Up < 35 GWd/t	Deposited Activities on legs and SG

Further developments

Corrosion products

Extension to prediction to transients and auxiliary systems

Fission products

Calibration procedure based on feedback

Integration of an actinide module

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