GENERATION-IV SODIUM-COOLED FAST REACTORS AND THE ASTRID PROJECT

French-Swedish Seminar on Future Nuclear Systems

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For nuclear energy sustainability
Promotes fast neutron reactor & closed fuel cycles
No longer focused on technologies, but on existing European projects of construction

- GIF gathers 10 countries; They study 6 systems

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- Other organizations: AIEA/INPRO (+ 🇮🇳), IFNEC, OCDE/AEN

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SODIUM-COOLED FAST REACTOR SYSTEM

- "400 year-reactor" of operation for SFRs around the world

POOL Type
- China
- France
- India
- Korea
- Russia

LOOP Type
- Japan
A LONG SFR STORY: FRANCE, RUSSIA, AND OTHERS

RAPSODIE 20 MWth (1967-1983)  
BR10 (1959-2002) and BOR60 1968 →

PHENIX 250 MWe (1973-2009)  
BN350 150 MWe (1973-1999)

SUPERPHENIX 1200 MWe (1985-1998)  
BN600 600 MWe 1980 →

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WHAT DO WE EXPECT FROM GEN-IV SYSTEMS? (1/2)

• **Sustainability**
  - GEN-IV systems shall
  - Make the best use of U resource
  - Be able of Pu multi-recycling, and
  - Have the capability to transmute minor actinides
  - This calls for fast neutron reactors and a closed fuel cycle.

• **Safety**
  - Improved and robust safety demonstration compared to former Fast Reactors
  - Enhanced prevention of whole core melting accidents
  - Exclusion in a credible way energetic accident sequences
  - Prevention and mitigation of risks due to sodium chemical reactivity
  - Robustness to external hazards
  - Safety level at least equivalent to 3\(^{rd}\) generation reactors
    - And taking into account lessons learnt from Fukushima accident
• Economy
  - GENIV systems shall be competitive, for the same performance level, compared to other sources of energy at the time they will be put into operation.
  - This means a lot of efforts with regard to investment costs, but also to availability and operation costs.

• Proliferation resistance
  - Importance of intrinsic and institutional barriers
  - Safeguards have to be fully integrated from the initial planning through design, construction and operation.
**R&D OBJECTIVES AT CEA**

- Improvement of the confinement control, including Na risk (**safety**)
- Elimination of large sodium-water reactions (availability, **economics**, **safety**)
- Improvement of decay heat removal (**safety**)
- Improvement of reactivity control (**safety**)
- Optimization of handling system (availability, **economics**)
- Simplification (**economics**, ISIR)
- Avoid any corium re-criticality (**safety**)
- + Material (**performance**, lifetime, **safety**)
- + Improvement of reliability

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AN ATTRACTIVE CORE WITH ENHANCED SAFETY

Feedback for SPX and EFR: Accidents leading to core melting
- Rod withdrawal
- Unprotected Loss of Flow
  - Reduce fuel reactivity loss per cycle
  - Reduce sodium void worth

- Large pins + small-diameter spacing wire
  - Increase fuel fraction
  - Decrease sodium fraction
  - Lower voiding effect

- Heterogeneous core concept with an optimized sodium plenum
  - Global sodium void worth strongly reduced to near zero
Control Rod Withdrawal

No fuel melting

Unprotected Loss of Flow

Na temperature evolution

Standard Core

ASTRID Core

No Sodium boiling

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**Program**

- Modelling of general operation of the Nuclear Steam Supply System (CATHARE3 and TRIO-U codes)
- Study of means to remove decay heat (DHR)
- Development of models for Probabilistic Safety Assessment (PSA) in design phase
- Inclusion of external hazards (extreme situations)

**Innovations**

- DHR through the main vessel + direct DHR in cold plenum
- PSA by design
- Study of a Total Instantaneous S/A Blockage
- Modelling of fluid-structure interaction

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Program
- Enhanced resistance to severe accidents
- Consolidating expertise on severe accident codes
- Definition and realization of complex and onerous tests
- Study of equipment to mitigate consequences (core catcher)

Innovations
- Robust approach for safety demonstration
  - Evaluation of different scenario
  - Estimate of cliff-edge effects
- Core catcher that ensures:
  - No re-criticality
  - Post accident heat removal capability

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CONCLUSIONS

• Generation-IV systems call for innovation
  - To enhance safety
  - To keep economy at market level

• Astrid project is a good example of this trend through:
  - Innovation in components
  - Innovation in modelling
Thank you for your attention