SMR Technology
The French approach

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COMBINING SKILLS OF PARTNERS FOR SMR DEVELOPMENT

Atomic Energy and Alternative Energies Commission (CEA)
- French public research institution in low-carbon energies (nuclear and renewable energies), defense and global security, information and health technologies
- A key player in research and innovation with 16,000 scientists, engineers, and support staff in 10 research centers

EDF Group
- Designs, builds and operates nuclear plants in France and abroad
- Architect Engineer for new build projects
- The World's largest nuclear operator
- Produces around 22% of the European Union’s electricity, primarily from nuclear power

- Core designer,
- Involved in the reactor design,
- Thermohydraulic codes,
- Expertise and test facilities

- NPP Architect Engineer
- Safety demonstration
- Operation & maintenance
COMBINING SKILLS OF PARTNERS FOR SMR DEVELOPMENT

An European leader in naval defence and a major player in marine renewable energies:
- designs, builds and supports submarines and surface ships.
- supplies services to shipyards and naval bases
- offers a wide range of marine renewable energy solutions.

- Specialized in the design, construction, operation and maintenance of compact nuclear reactors
- For more than 45 years, offering nuclear engineering expertise on reactors, fuel and related facilities
- Proposes solutions and products that meet the highest safety and availability standards
- About 1,500 people and operates for naval propulsion, research, nuclear medicine and energy.

- SMR reactor designer
- New technologies developer

- Steam conversion system,
- Modular concept,
- Steel containment
SMR INTERESTS & EXPECTED BENEFITS OF MULTI-REACTORS

- **Low power enabling simplified design with high level of safety**
  - Simplified and compact architecture, limiting the accident initiators and scenarios
  - Low level of residual heat, simplified and passive safety systems

- **Modular reactor, for simplified construction**
  - Limited number of modules, manufactured in factories
  - Reduction of risks related to construction on site
  - Reduction of the construction duration on site

- **Affordable nuclear for power generation**
  - Reduced investment per unit
  - Reduced Capital cost before generation of first MWh
  - Multi-unit financing scheme: first units financing the next units

- **Integration in the power network**
  - Single to multi-SMRs solutions, according to power needs
  - Flexible operation compatible with base and intermittent sources
SPECIFIC BREAKTHROUGHS TO CONSIDER

▪ Economic levers vs Scale effect
  □ Modular design and manufacturing (construction cost decrease, shortened construction duration)
  □ Series effect (In series production of components, standardisation...)
  □ Simplification of design (architecture, components, regular civil structure, easy and quick to build)

▪ Standard design and international licensing for worldwide deployment
  □ Adapted regulatory requirements
  □ In factory certification
  □ Passive systems qualification
  □ Mutualisation of systems and control room
DISRUPTIVE SOLUTIONS RELYING ON FRENCH EXPERIENCE

- **PWR Technology**
  - The most mature, spread and near term technology
  - Relying on existing capacities (supply chain, fuel cycle industries)

- **NSSS integrated design**
  - Compact primary components located inside the pressure vessel

- **Safety features**
  - GEN III+, post FKS requirements
  - Resistance to hazards
  - Passive systems with large grace period
  - Severe accident management

- **Flexible and versatile**
  - Flexible operation for power generation
  - Single to multi-SMRs facilities
FRENCH SMR DESIGN – INTEGRATED ARCHITECTURE – 170MWe

Vessel head

Electrical penetrations
PZR heaters + CRDM

Steam outlet nozzles

Feedwater inlet
nozzles

Canned Reactor
Coolant Pumps

Reactors Pressure
Vessel - RPV

Integrated Pressurizer - PZR

Integrated compact Steam Generators SG + safety exchangers

Immerged Control Rods Drive Mechanisms - CRDM

Core = Standard PWR fuel assemblies 17x17 Boron free operation
FRENCH SMR DESIGN / CONTAINMENT AND NUCLEAR ISLAND

Nuclear Island for 4 units (2 or more possible)
Partially buried/partially covered architecture

Integrated reactor located in a metallic containment shell (φ 15m), Containment immersed in a water basin
FRENCH SMR DESIGNED FOR HIGH % IN-FACTORY MANUFACTURING

All critical interfaces are metal/metal factory-made interfaces

➔ Compactness of the reactor block and its metallic containment allows innovative in-containment prefab.
➔ Pre-fabricated and pre-tested functional circuit modules (including local I&C) on skids or cradles, for inside and outside containment assembly

Components designed and selected for large series

➔ Simplified manufacturing process for newly designed components (e.g. Plate SG v/s tube SG and/or Motor-driven CRDM v/s magnetic jack)
➔ Low pressure/Low diameter pipe components (except main steam pipes)
➔ Almost undrilled vessel head

Easy and quick construction on site

➔ No need for pre-stressed concrete containment building
➔ Regular & rectangular shape buildings, with moderate excavation depth (~20m)
➔ Partially buried/partially covered architecture for efficient APC protection
➔ No need for heavy crane during site construction
➔ Disconnect (as far as possible) civil work schedule from electro-mechanical erection
FRENCH SMR DESIGNED FOR FLEXIBILITY & SIMPLICITY

Designed for flexible operation

➔ No soluble boron, small and stable core (no Xe oscillations) for easy reactivity control by control rods
➔ No thermomechanical solicitation for the NSSS from ~3% to full power

To simplify daily operation

➔ No soluble boron management ➔ easy chemistry and reduced liquid waste management
➔ Robustness to transients: large primary coolant inventory (m3/Mwe) and large pressurizer volume
➔ Passive systems, testable during operation
➔ Simple auxiliaries systems thanks to small and compact components (e.g. 400kW sealed reactor coolant pumps), simplified In-core instrumentation,…

To simplify maintenance

➔ Noria based maintenance for most primary components: CSG or reactor coolant pumps are replacable components (inspection and maintenance can be performed out of outage schedule)
➔ Reduced perimeter of 2nd regulatory barrier, few pressure retaining components for NSSS
➔ Redundant system modules on functional skids
FRENCH SMR DESIGNED FOR SAFETY

Safety design features:
➔ Simple design, large water core inventory, large operation margins
➔ Protection against external hazards (buried/under mound)
➔ Robustness against usual PWR accident initiators (Large break LOCA, spurious boron dilution, rod ejection…)

Passive DBC2-4 management:
➔ Usual gravity driven emergency shutdown
➔ Passive safety architecture to manage DBC3-4 scenarios with large grace period (several days) with no need of human action, safety classified power supply or external heat sink
➔ Large inventories for reactor coolant, water basin, containment volume
➔ Passive cooling of the spent fuel pool

Active diversified DEC-A mitigation
➔ Active high pressure boron injection for ATWS
➔ Low diameter depressurization + Mid pressure active pump from cooling pool to vessel and/or containment

Passive diversified DEC-B mitigation
➔ Passive flooding of vessel pit for In-Vessel Retention of corium
➔ Passive nitrogen injection for H2 risk
SMR : OPPORTUNITY FOR THE FUTURE

A proper response to high expectation

▪ A relevant and affordable solution for new nuclear uses
  ▪ New comers in nuclear, carbon free alternative to existing fossil
  ▪ Remote sites, isolated network, heat, steam and desalination

▪ Compatible and complementary with existing large nuclear
  ▪ Mid merit operation, complementary to large base nuclear and intermittent renewable

As world leaders in nuclear technology and operation, French partners are engaged to develop a valuable and competitive SMR solution and are opened to international cooperations.