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DEVELOPMENT OF VVER-1000 FUEL ASSEMBLY

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Motivation

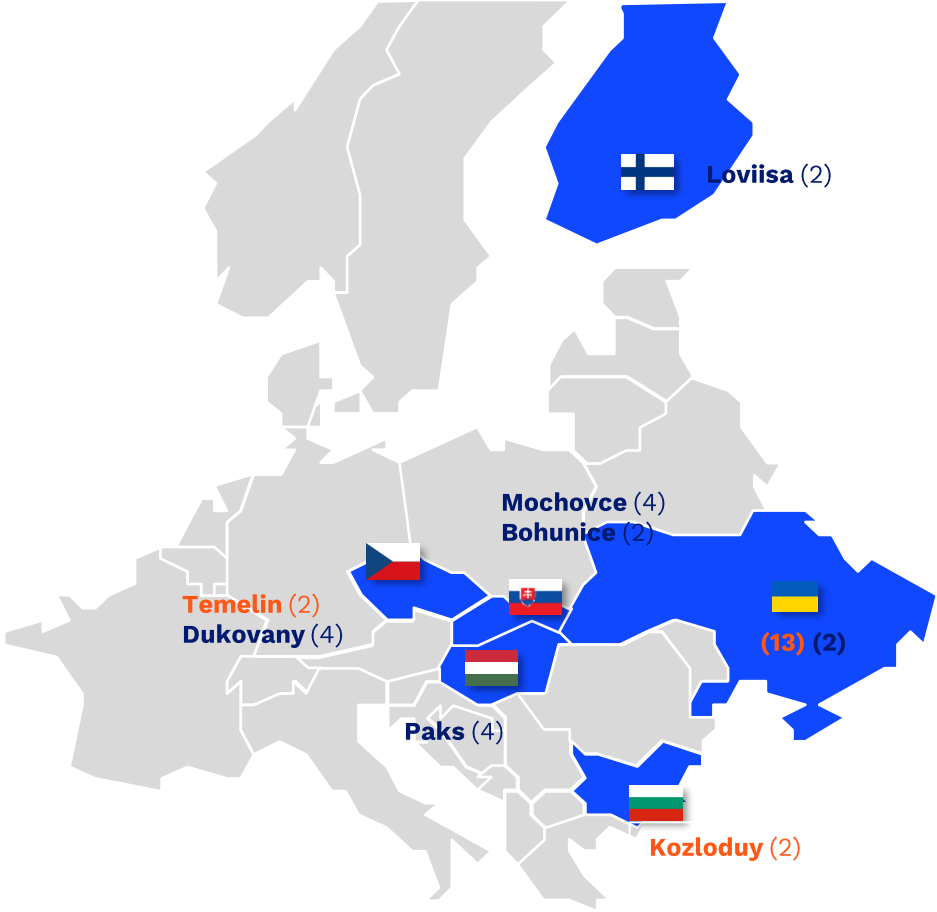
Framatome Ambition

- **Secure Nuclear energy safety and performance:**
  - Provide services to VVER Nuclear Power Plant (NPP)
  - Supply fuel assemblies to VVER-1000 and VVER-440 reactors.

Framatome Objectives

- Develop and qualify **100% European sovereign VVER-1000 and VVER-440** Fuel Assemblies
- Ensure **Fuel assembly manufacturing and shipment** to NPP
- Schedule: **Be ready for the early 2030's**

European VVER fuel market
Framatome dual-track approach



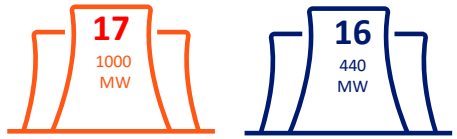
Two parallel approaches:

Proven design immediately available with no licensing uncertainties

Security of supply with the OEM **proven** and **reliable** product

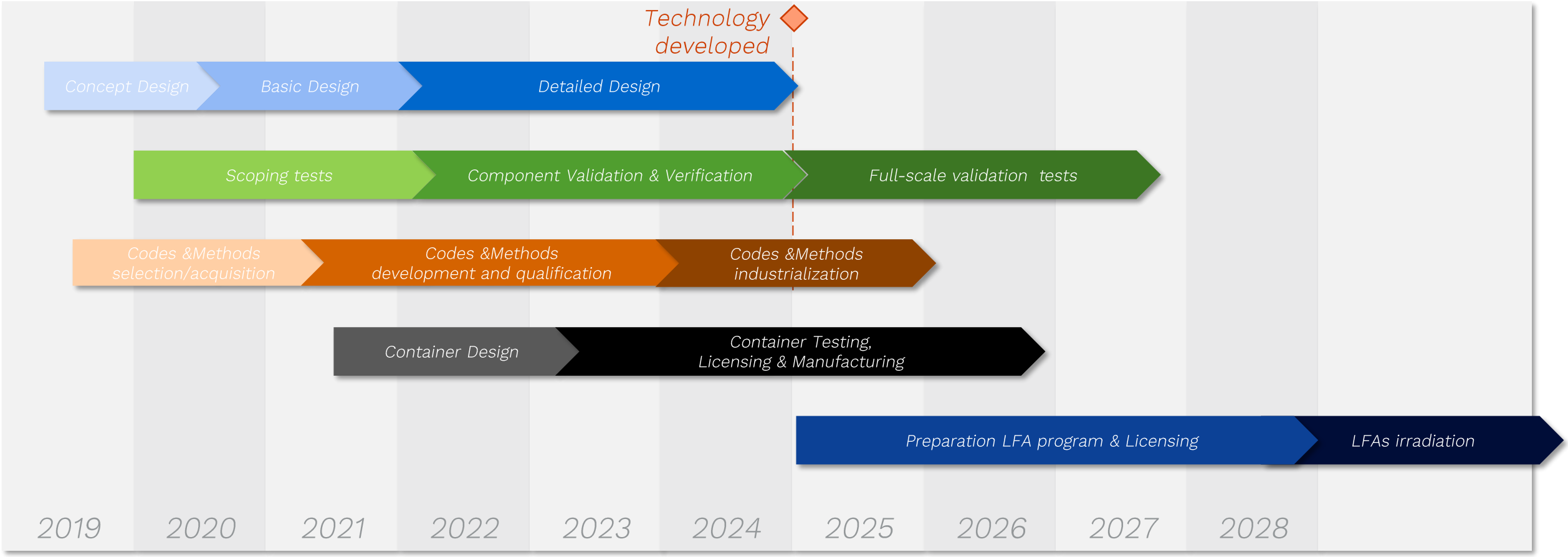
Full-speed development of a new technology to be qualified in reactors:

Diversity of supply with **the only fully European sovereign** solution



Roadmap

VVER-1000 Framatome own-design



Framatome VVER own design fuel assemblies

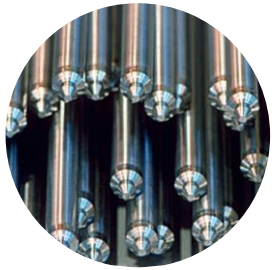
Project definition

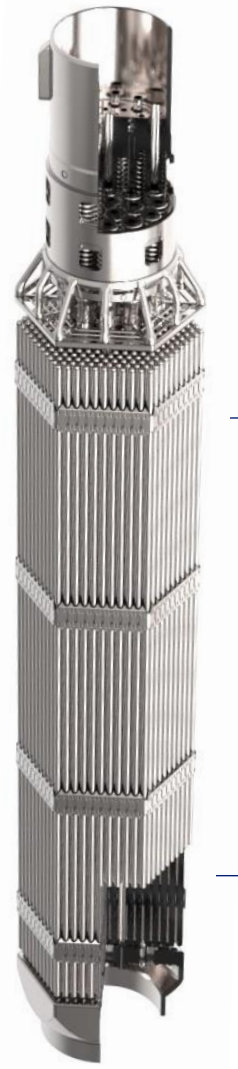
High-quality design

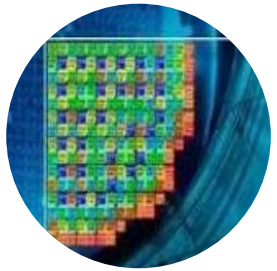
Develop a design robustness against bow and twist, Fretting, Flow induced vibration, Debris

PROtect features

In option to ensure Taxonomy compliance and increase safety margins in accidents







Codes and Methods

Define and deliver C&M solution for neutronic, thermo-hydraulic, thermo-mechanical, CHF correlation and associated tests to support FA licensing and reload justifications

Shipment solution

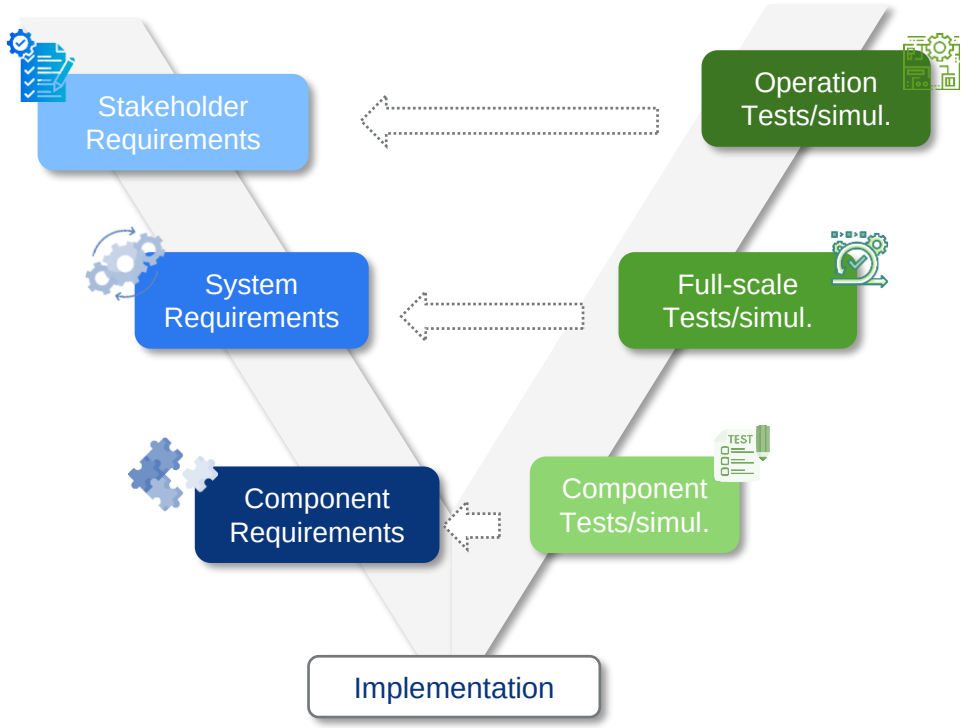
Design and license a container to ensure reliable shipment solution

Relying on the experience from decades of PWR fuel, the design offers highest levels of safety and reliability, while providing for best balance between performance and robustness

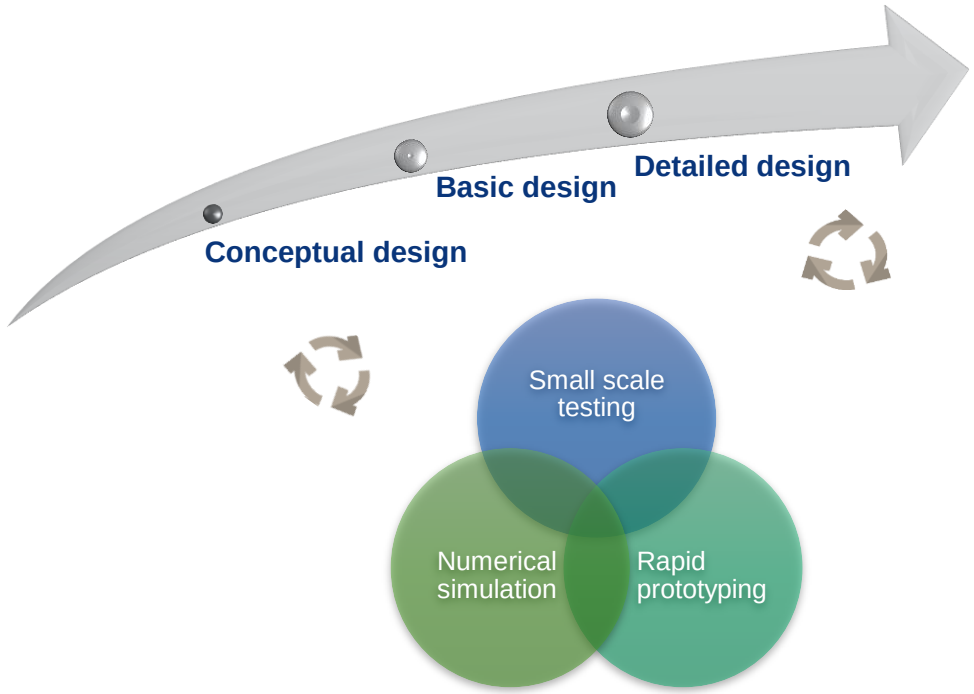
Systems Engineering approach

V-Model and design stages

The V-model in systems engineering provides a structured approach that ensures every requirement is systematically addressed and verified



Progressive elaboration, starting from broad ideas and moving towards precise, actionable plans. Adapted tools are used for each phase

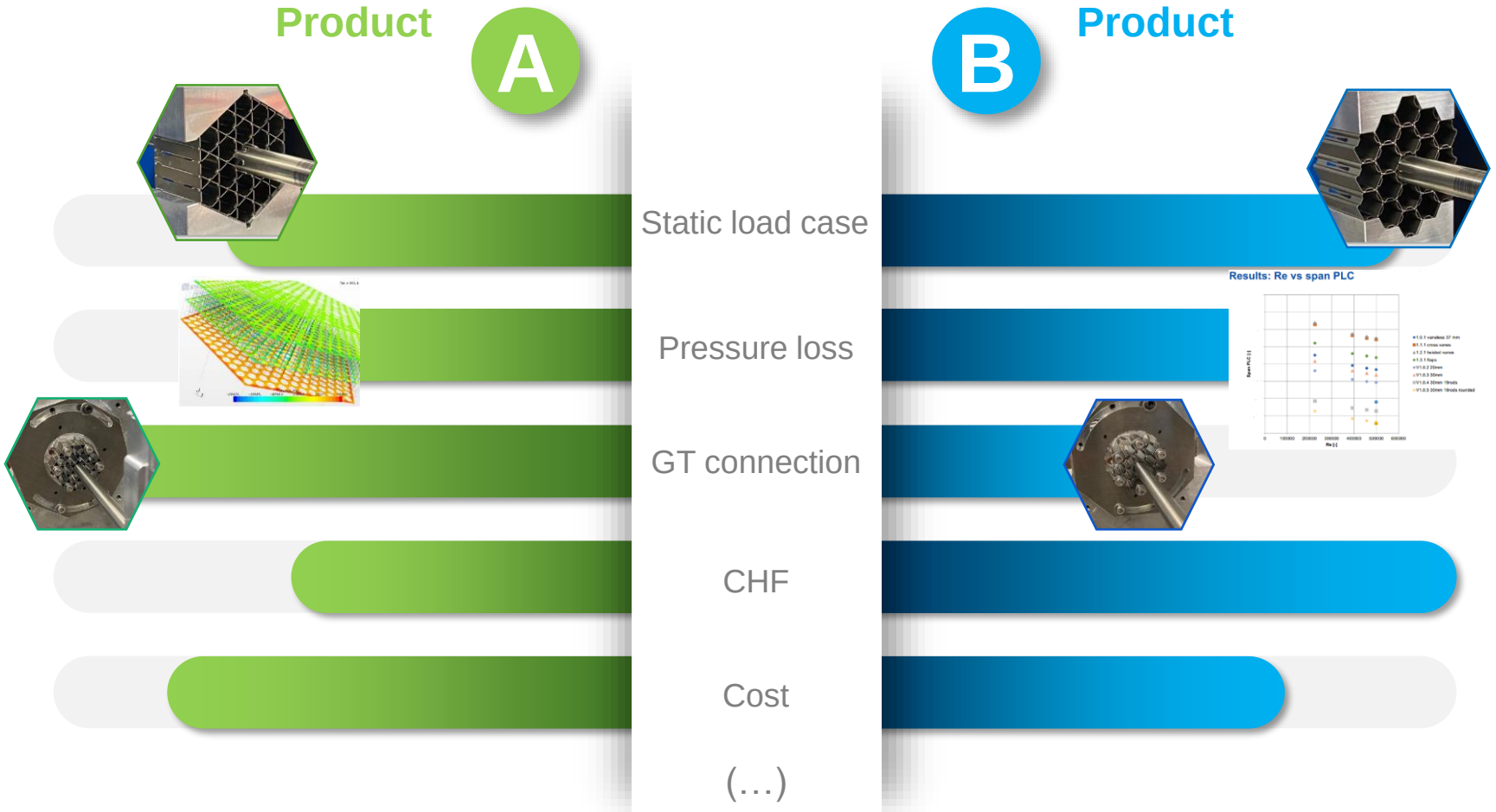


Systems Engineering: Integrating Innovation for Safer, Smarter Fuel Assemblies

Requirements and optimization process

Spacer development - Conceptual design phase

Requirements list (extract)



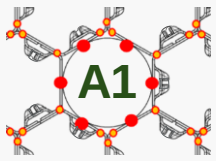
Several concepts rated using scoping tests , simulation and engineering judgment

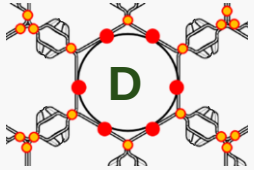
Requirements and optimization process

Spacer development - Basic design phase

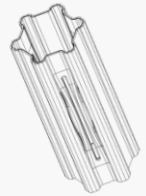
		A1	A2	B1	B2	B3	C	D
C2	Number of cell types	X	Y	X	Y	Z	X	Z
C3	Special GT sleeve	yes	yes	no	no	no	no	yes
C4	Weld tab for direct GT welding	no	no	yes	yes	yes	no	no
C5	GT welding	6+	6+	max 6	6	6	6	6
C6	Cell height	A	C	C	C	D	A	A
C7	Homogeneous Pattern	yes	yes	yes	yes	yes	no	yes
	Ranking							

Extract of the requirement file

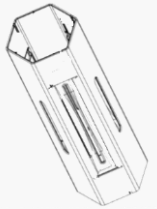




C5- Exemple of welding cell variants



C2-Number of cell type needed depends on the concept variant



One concept

Several variants

Best option selected

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Requirements and optimization process

Spacer development - Detailed design phase

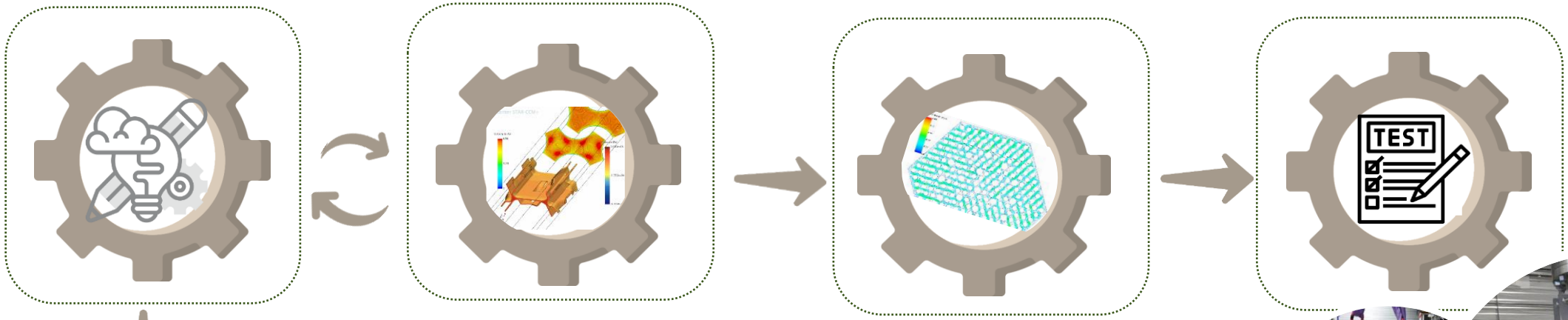
Thermo-hydraulic optimization

Design optimizations
(edges, welding points, slots…)

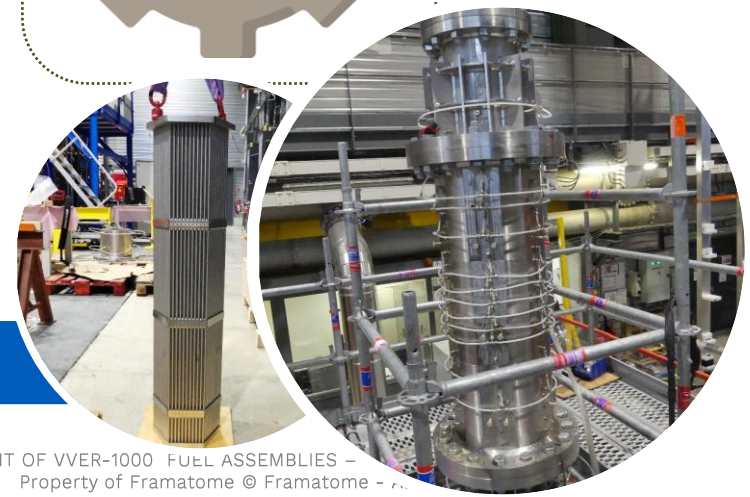
Thermo-hydraulic optimization using sub-scale models

Thermo-hydraulic validation using full-scale model

Testing in a loop



Assess impact on all criteria



Several steps to reach the best performance

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Design verification & validation (V&V)

In progress
Done
To come

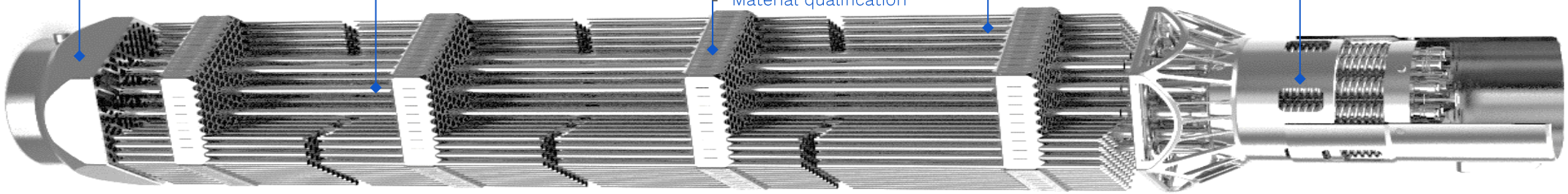
Bottom Nozzle
- PLC analyses
- Load test (strength)
- PLC testing
- Load test (connections)

Guide Tubes
- GT load, strength, buckling
- RCCA insertion and efficiency of RCCA damping
- GT connections load
- Material qualification

Spacer/mixing grid
- Spring force and contact zone
- PLC analyses
- Buckling, GT connections
- PLC testing
- Fuel rod support and fretting resistance
- Fuel rod clamping
- Material qualification

Fuel Rod
- FR Mechanical design criteria justification
- Material qualification

Top Nozzle
- Hold-down capability
- PLC analyses
- PLC testing
- Mounting functional test
- RCCA damping



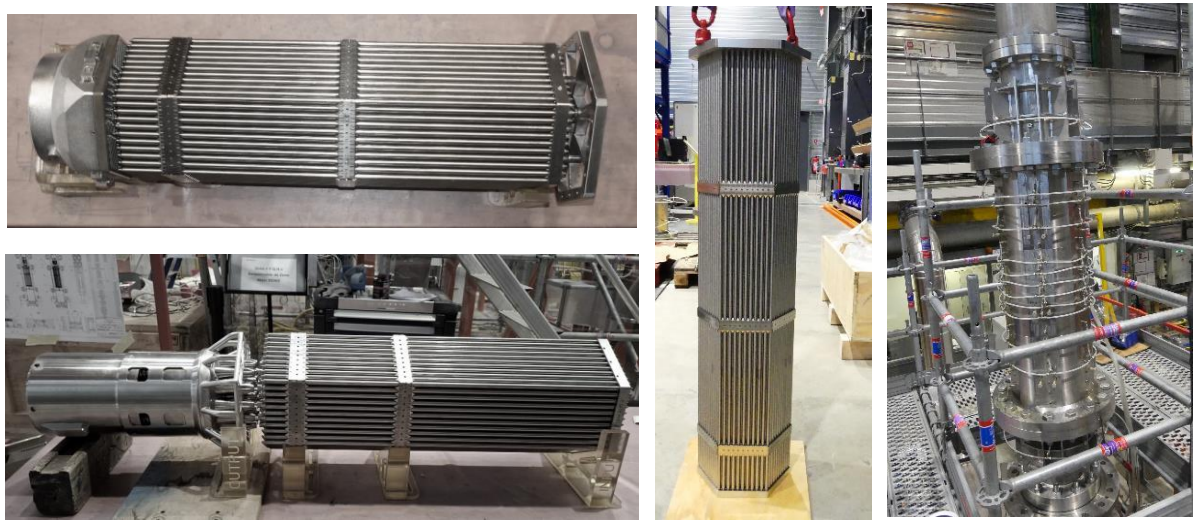
Fuel Assembly (Full Bundle)
- Full bundle stiffness measurement
- Dynamic movement/interaction in accident conditions
- Transport load simulation
- Full bundle mechanical assessment (FIV, vibration characteristics)
- CHF testing

> 85% of V&V tasks are done or on going

Framatome testing campaign

Hydraulic testing facilities:

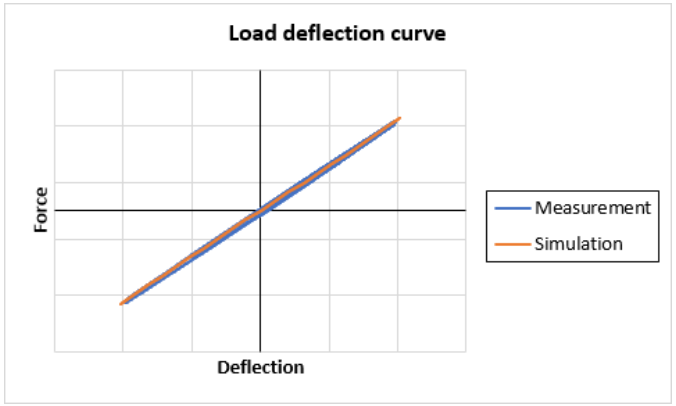
- In addition to numerical evaluation, Framatome considers as mandatory a validation PLC by hydraulic testing.
- Thus, Framatome launched the adaptation of its hydraulic loop
- All components already tested in the loop



Mock-up and FQH facility

Mechanical testing (cage & Fuel Assembly stiffness):

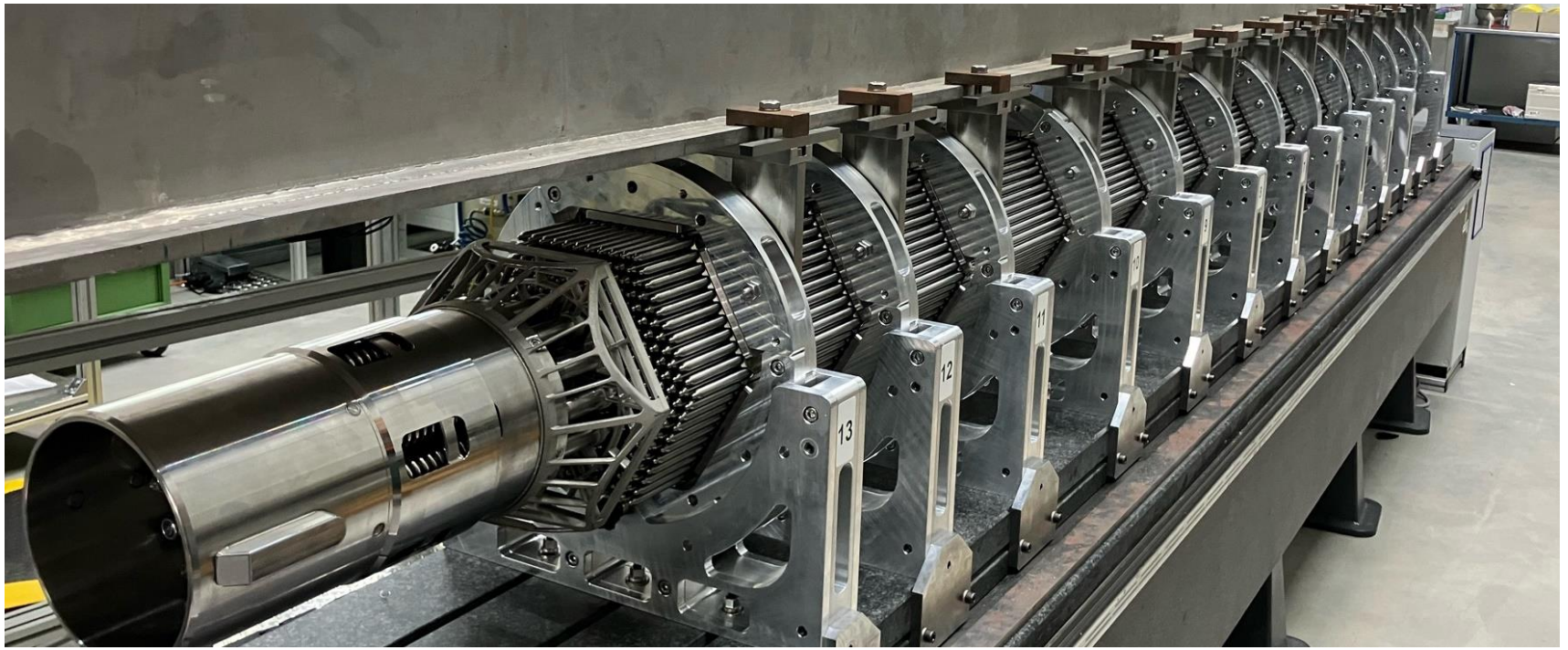
- After preliminary evaluation using FEM analysis, a mock-up is manufactured and the stiffness bench is adapted at the top and bottom part to comply with the VVER design – [2]



Stiffness test

Framatome manufacturing facilities adaptation

- Prototyping successfully demonstrated from components stage to fuel assembly



  - On-going: capability of production at Framatome European facilities

Summary

Framatome 100% sovereign European VVER fuel designs

Framatome develops 100% European sovereign VVER-1000 own-design Fuel Assemblies (FA) and dedicated containers

- VVER-1000 **Lead Fuel Assemblies readiness** targeted for **2028**
- **Reload readiness** planned for the **early 2030's**
- **Rapid prototyping & advanced simulations** are used to optimize the designs and to comply with the **ambitious timelines**
- **VVER-1000 FA "detailed design"** reached & testing of full-scale mock-up started

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Thank you