CP-ESFR and ESFR-SMART projects

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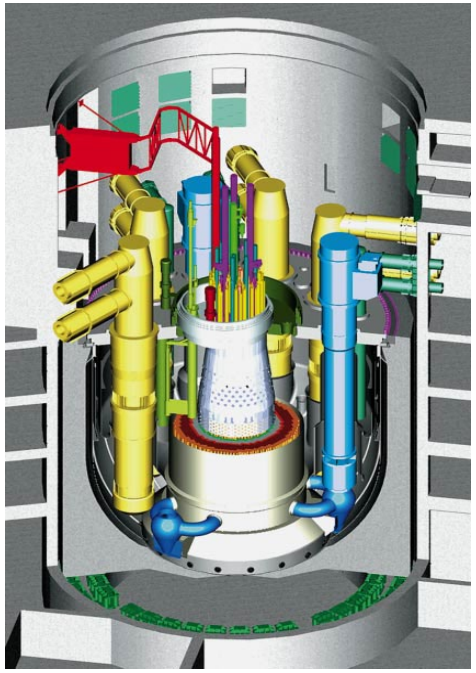
ESFR-SMART Spring School, March 29-31, 2021

European Sodium Fast Reactor: background

The reactor design has been developed taking into account SFR operation experience and multiple experiments:

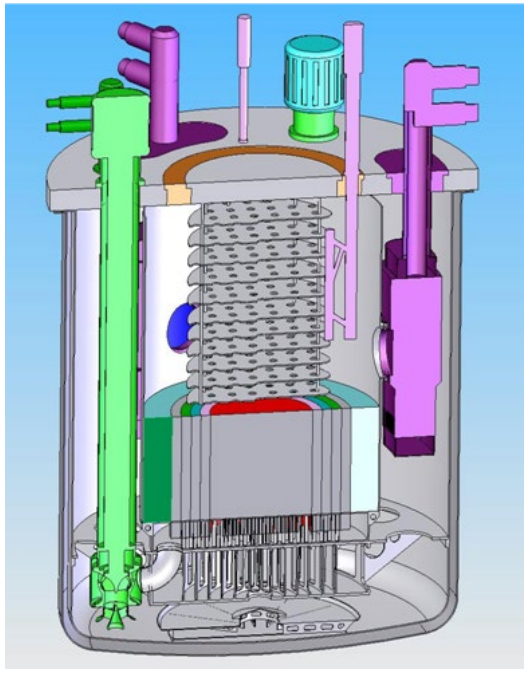
– Thermal / electrical power 3600 / 1500 MW
– Mass of sodium in the primary pool ~2500 t
– Primary sodium temperature 395ºC – 545ºC
– 6 Heat eXchangers, 3 Primary Pumps, 36 Steam Generators

1990



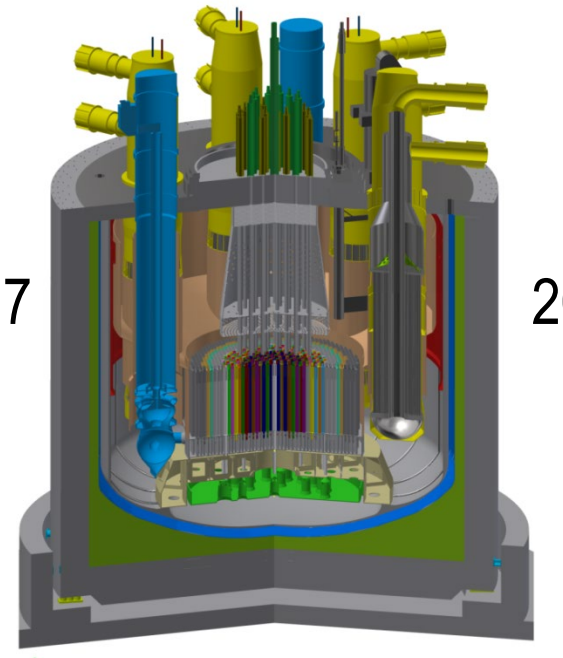
EFR

2000 ... 2008



CP ESFR

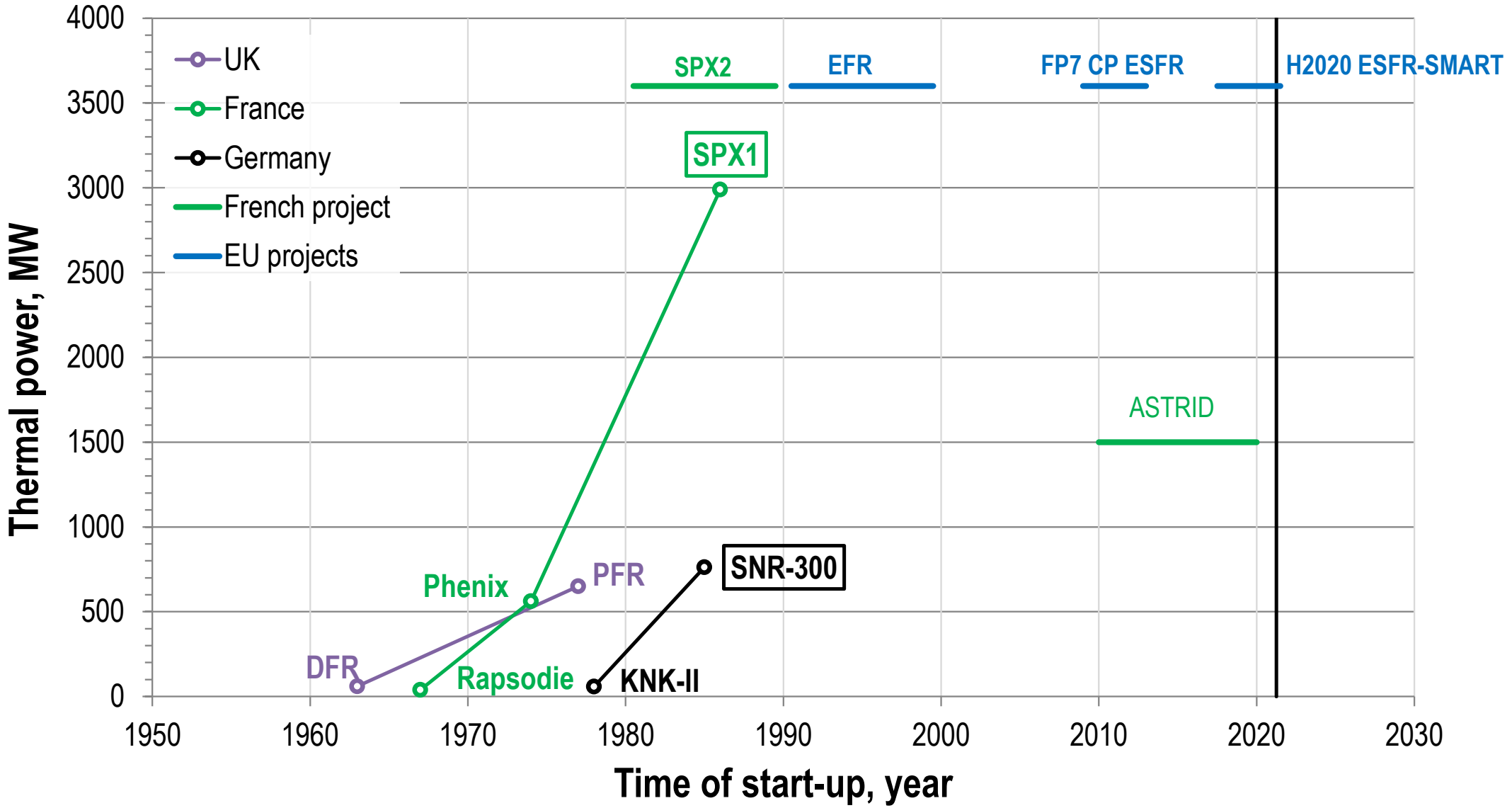
2012 ... 2017



ESFR-SMART

2021

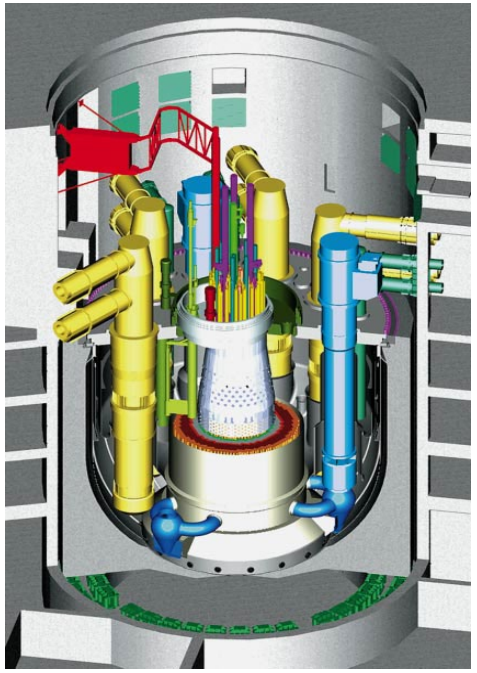
European Sodium Fast Reactor: brief history



European Sodium Fast Reactor: background

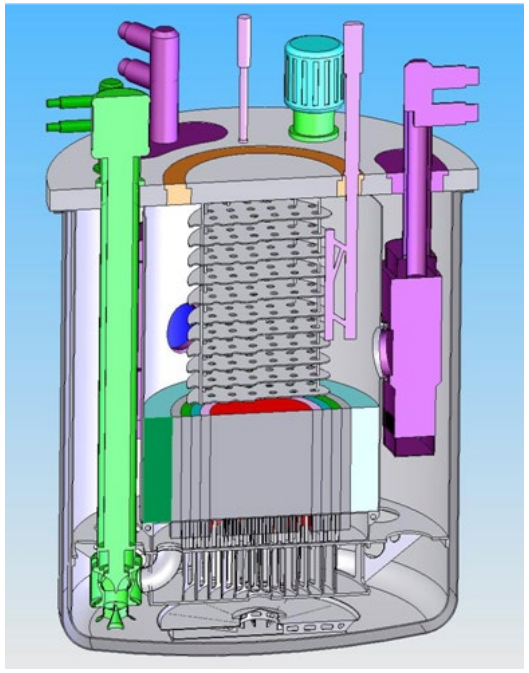
Main goals of the projects:
– Improve safety
– Improve economics
– Improve management of nuclear materials

1990



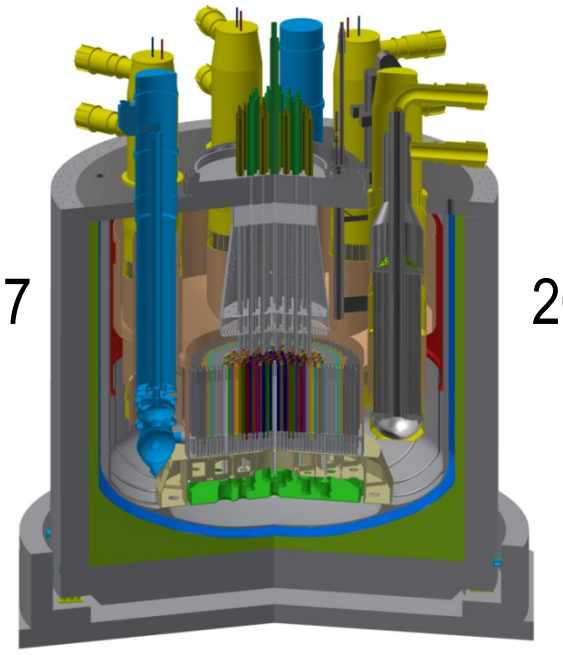
EFR

2000 ... 2008



CP ESFR

2012 ... 2017



ESFR-SMART

2021

CP-ESFR: project in a nutshell

Name:

– CP-ESFR: Collaborative Project for a European Sodium Fast Reactor

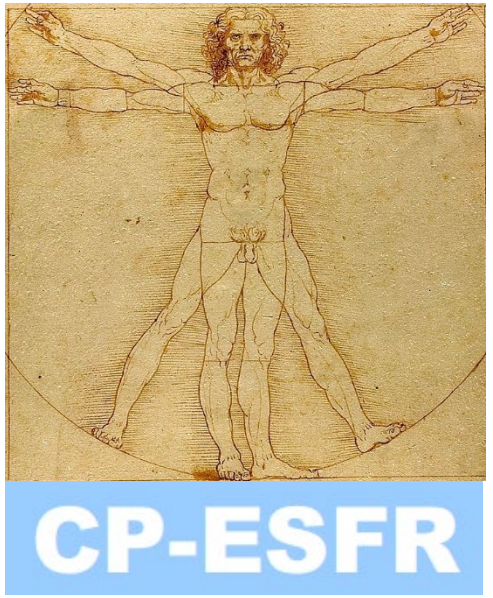
Goals:

– Assess and select innovative options for ESFR

– Confirm the performances of the selected options

Budget: 5.8 MEUR of Euratom contribution + ~5.8 MEUR of consortium's own contribution

Timeframe: 01.01.2009 – 30.06.2013



CP-ESFR: consortium

CP-ESFR: structure

SP1. Consistency & assessment (CEA)
WP1.1. Project consistency (CEA)
WP1.2. Results integration (AREVA)
WP1.3. Options assessment (CEA)

SP2. Fuel core and fuel cycle
SP2.1. Cores with optimized characteristics (CEA)
SP2.2. Fuel cycle – Fuel fabrication and properties of MA bearing carbide, nitride and oxide fuels (CEA&JRC/ITU)

- Deployment and fuel cycle scenarios (EDF)
- "Working horse" (oxide and carbide) cores (CEA)
- Optimization of feedbacks coefficients (FZK)
- Minor actinides (hom and het) recycling (CIEMAT)
- Cores with optimised characteristics (AMEC)

- Fabrication of advanced MA fuels and dedicated targets: comparison of methods, recommendations (JRC-ITU)
- Vaporisation behaviour of advanced MA carbide and nitride fuels (JRC-ITU)
- Thermal properties of oxide fuel targets for MA heterogeneous recycling (CEA)
- Comparison of past experience on carbide and nitride relocation, vaporization (NRG)
- Fabrication and determination of properties of MA bearing carbide, nitride and oxide fuels - Final report (CEA&JRC-ITU)

SP3. Safety concept options and PR & PP issues (EDF&FZK)
WP3.1. Definition of safety objectives and principles as guideline for design and assessment of different options (AREVA)
WP3.2. Implementation of a whole set of "defence-in-depth" levels and identification of representative accidents for DBA and BDBA (EDF)
WP3.3. Studies of representative transients and accident scenarios for DBA and BDBA (FZK)
WP3.4. Evaluations of provisions to decrease CDA risk and associated potential of mechanical energy releases (CEA)
WP3.5. Containment measures and core catcher designs for demonstration of long term cooling ability (EA)
WP3.6. Evaluation of modelling capabilities of accident scenarios (IRSN)

SP4. Innovative reactor architecture, components and BOP (AMEC&AREVA)
WP4.1. Innovative plant concept and layouts (AREVA)
WP4.2. Innovative energy conversion systems (water and gas) (AMEC)
WP4.3. Supporting crosscut activities (review of tools and experiments) (NRI)

SP5. Education & training (CEA&UNIKa)
WP5.1. Training & education courses (CEA&UNIKa)
WP5.2. Doctoral dissertations (CEA&UNIKa)

CP-ESFR: pool and loop concepts

AREVA

N° NEEL-F 2009 DC 55

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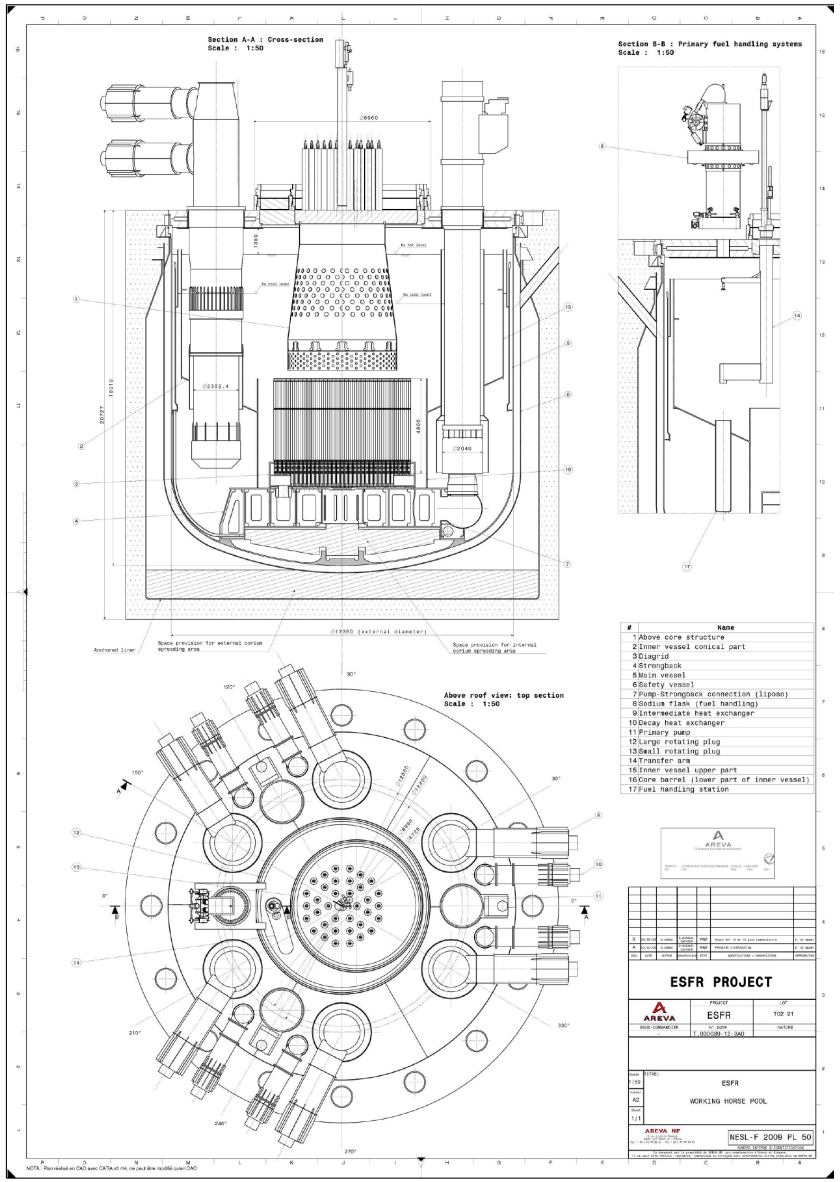

AREVA

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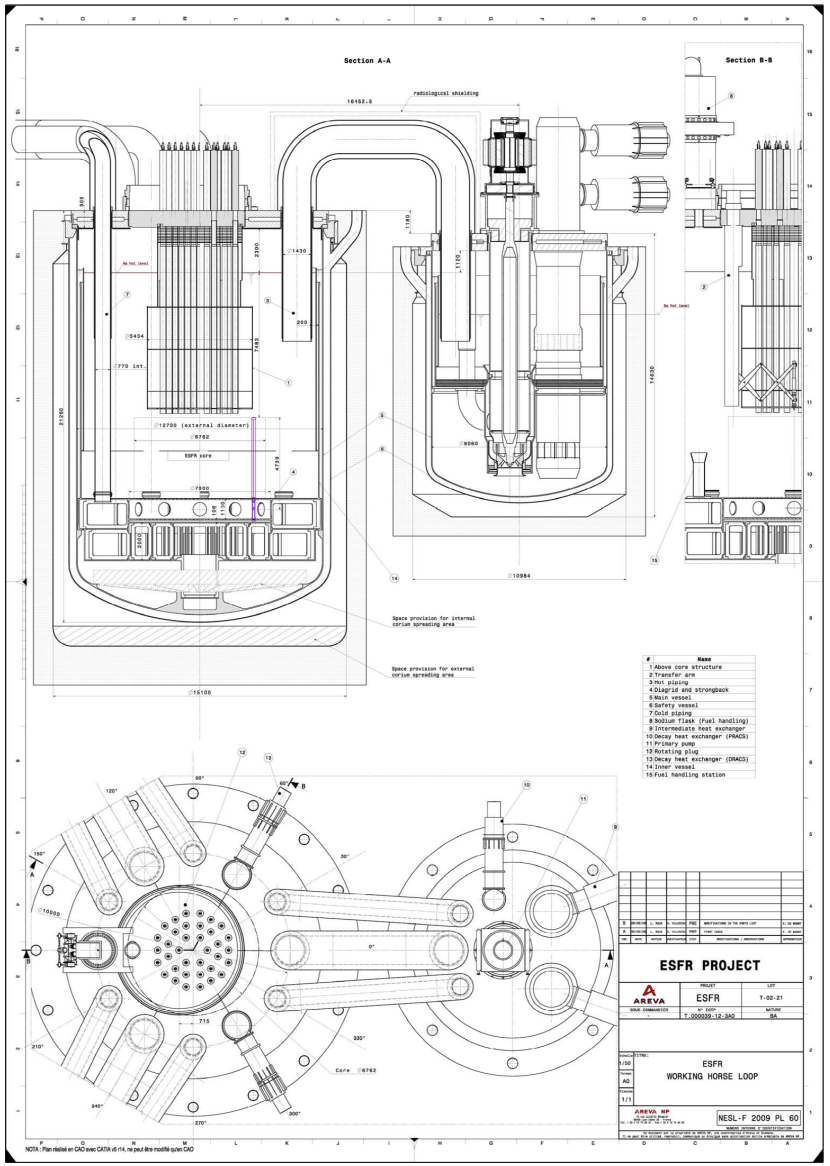


ESFR-SMART: project in a nutshell

Name:

– ESFR-SMART: European Sodium Fast Reactor Safety Measures Assessment and Research Tools

Goals:

– Select and assess innovative safety measures for European SFR concept

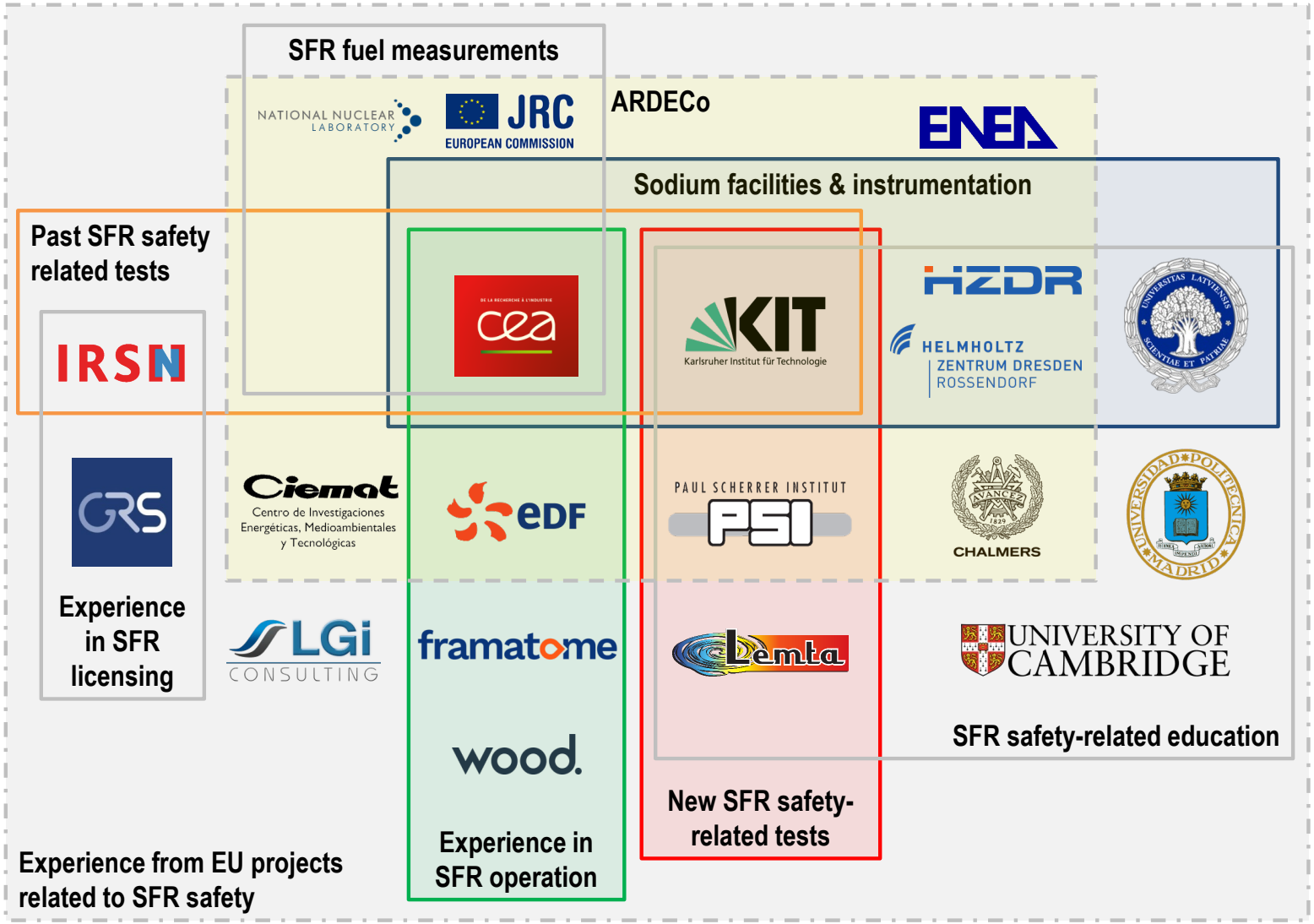
– Develop new research tools related to SFR safety (calculational codes, experimental data and facilities)

Budget: 5 MEUR of Euratom contribution + ~5 MEUR of consortium's own contribution

Timeframe: 01.09.2017 – 31.08.2021

ESFR-SMART
sodium fast reactor safety

ESFR-SMART: consortium



Work Package and Task Leaders

K. Mikityuk (PSI)
J. Krepel (PSI)
N. Chauvin (CEA)
F. Payot (PSI)
C. Latge (CEA)
E. Girardi (EDF)
E. Fridman (HZDR)
G. Gerbeth (HZDR)
L. Buligins (IPUL)
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E. Bubelis (KIT)
A . Rineiski (KIT)
S. Ehster Vignoud (Framatome)
J. Guidez (CEA)
E. Schwageraus (UCAM)
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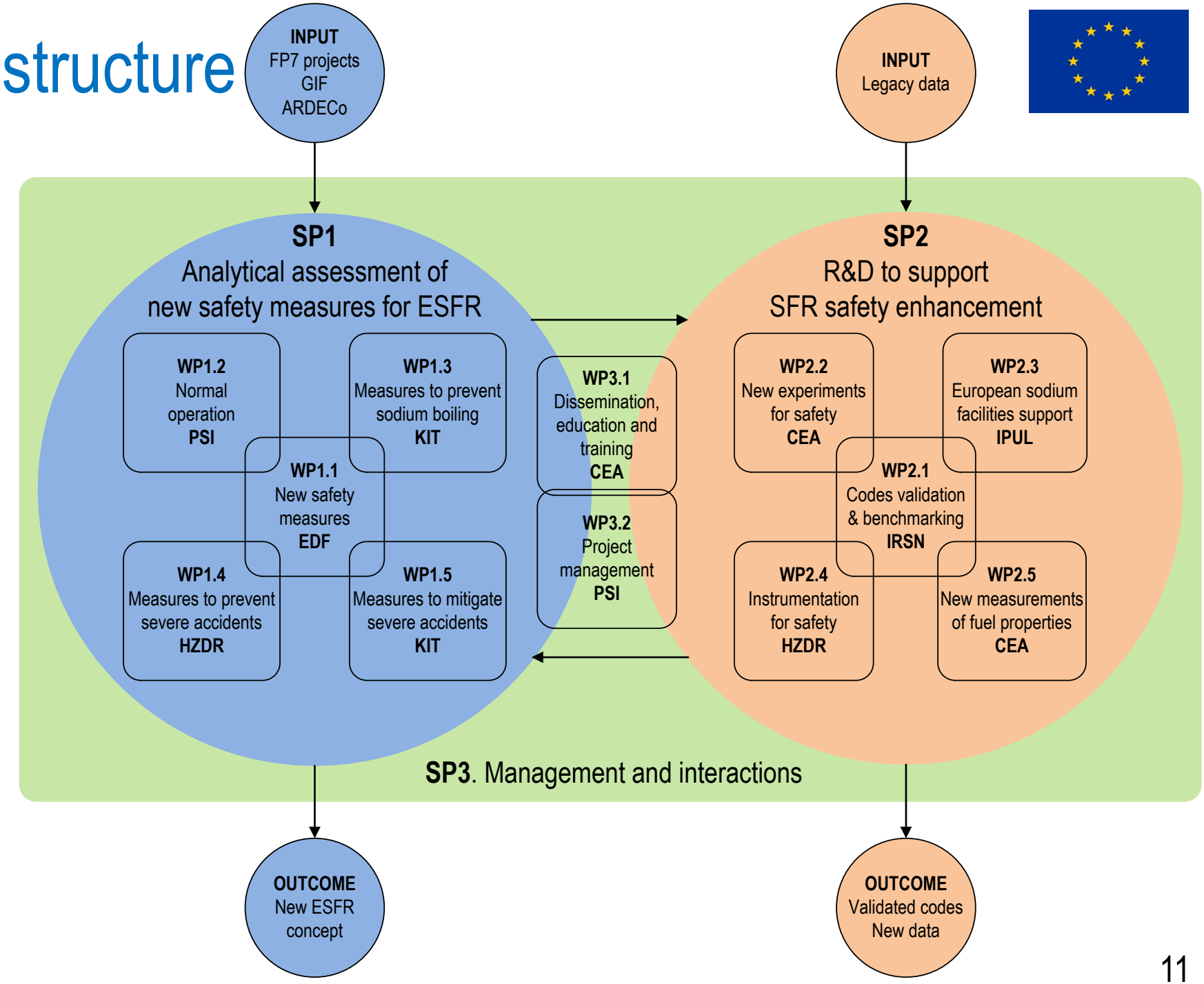
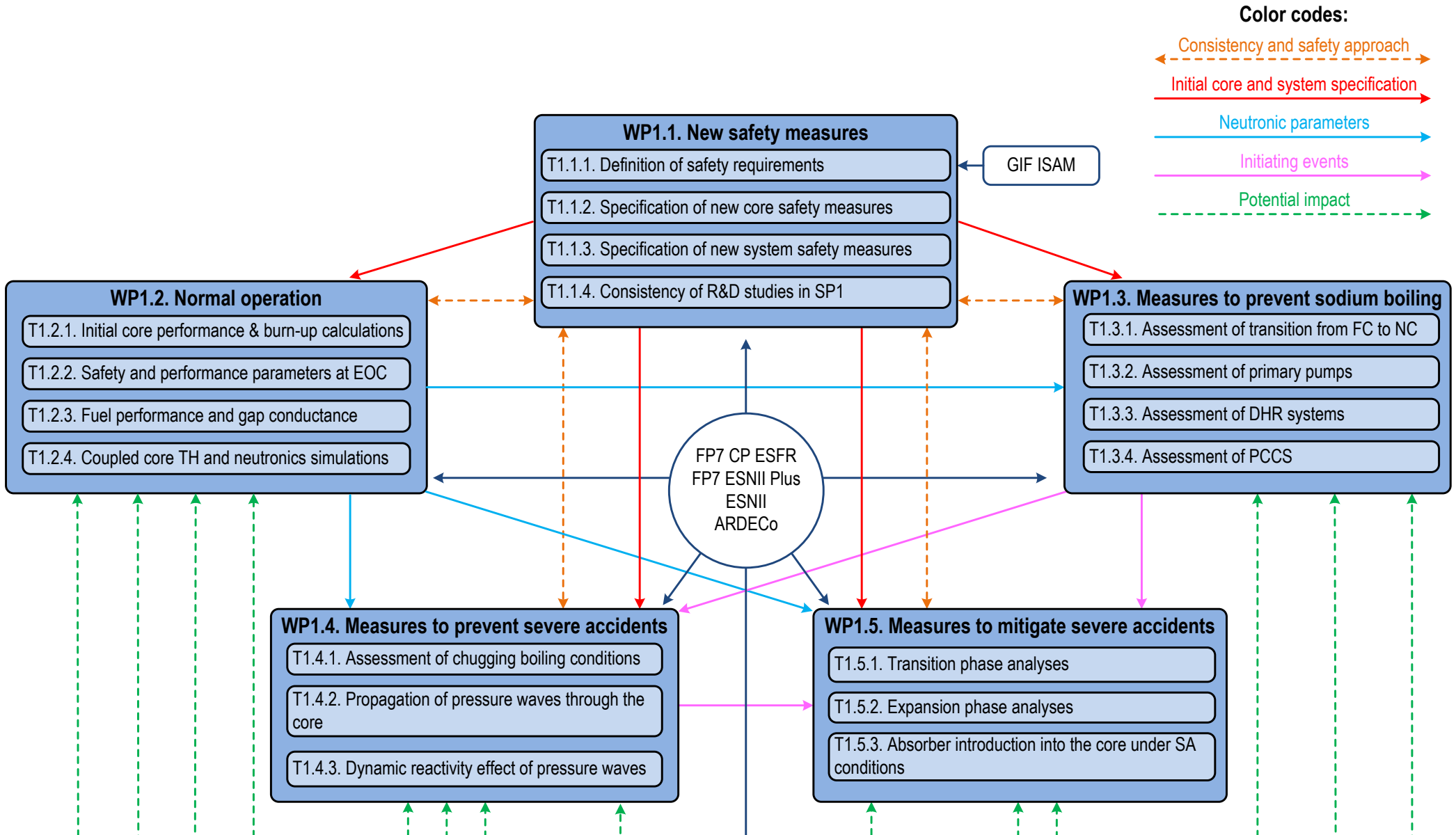
M. Gradeck (LEMTA)
X. Gaus-Liu (KIT)
L. Ayrault (CEA)
S. Eskert (HZDR)
E. Sanseigne (CEA)
W. Jager (KIT)
D. Staicu (JRC)
C. Demaziere (CHALMERS)
N. Garcia Herranz (UPM)
H. Tsige-Tamirat (JRC)
M. Bazin-Retours (LGI)

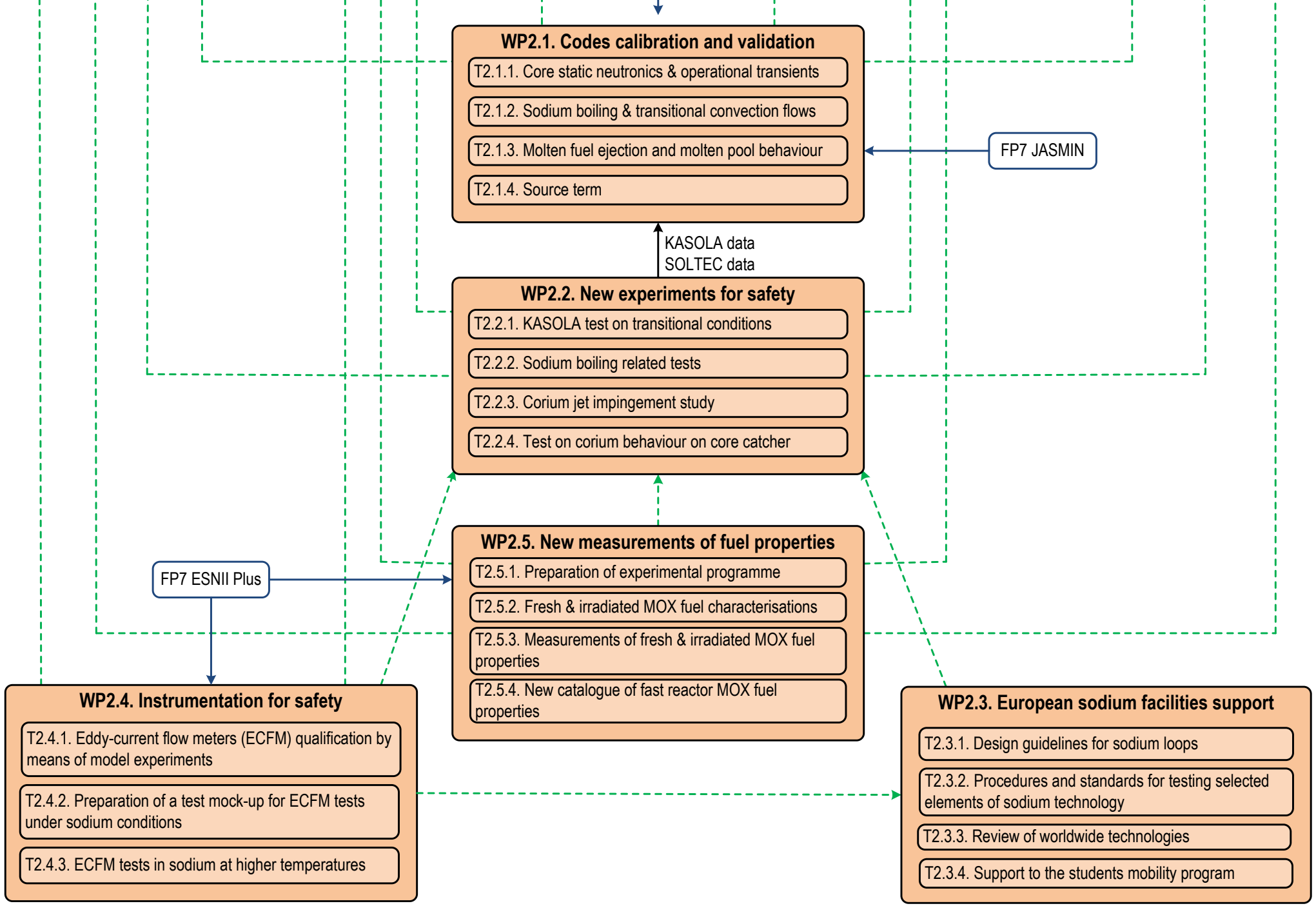
ESFR-SMART: structure

- 3 Subprojects
- 12 Work Packages
- 47 Tasks

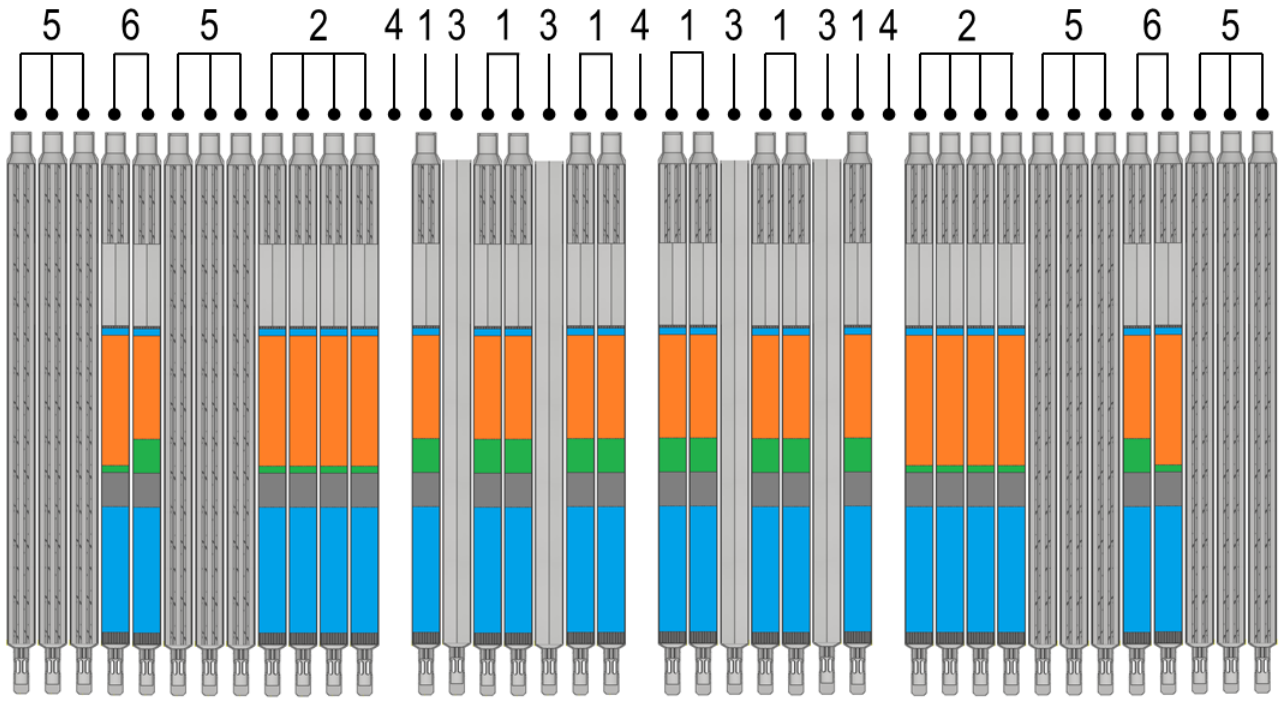


ESFR-SMART: structure



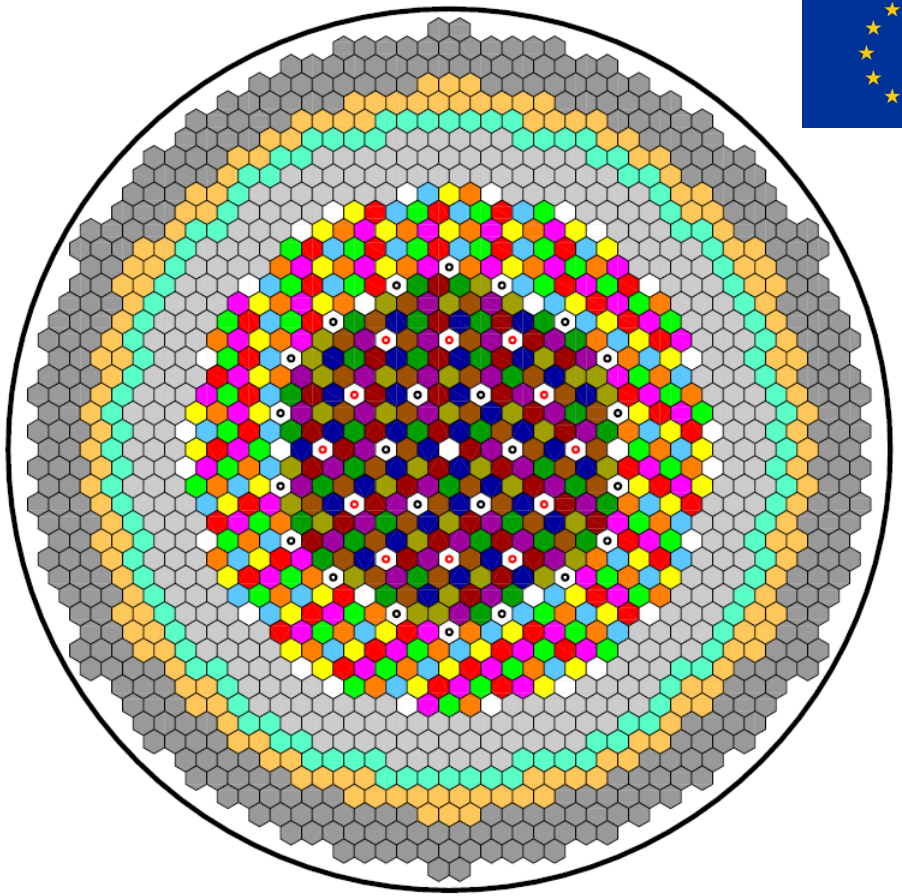

WP2.1. Codes calibration and validation
T2.1.1. Core static neutronics & operational transients
T2.1.2. Sodium boiling & transitional convection flows
T2.1.3. Molten fuel ejection and molten pool behaviour
T2.1.4. Source term
FP7 JASMIN
KASOLA data
SOLTEC data
WP2.2. New experiments for safety
T2.2.1. KASOLA test on transitional conditions
T2.2.2. Sodium boiling related tests
T2.2.3. Corium jet impingement study
T2.2.4. Test on corium behaviour on core catcher
WP2.5. New measurements of fuel properties
T2.5.1. Preparation of experimental programme
T2.5.2. Fresh & irradiated MOX fuel characterisations
T2.5.3. Measurements of fresh & irradiated MOX fuel properties
T2.5.4. New catalogue of fast reactor MOX fuel properties
FP7 ESNII Plus
WP2.4. Instrumentation for safety
T2.4.1. Eddy-current flow meters (ECFM) qualification by means of model experiments
T2.4.2. Preparation of a test mock-up for ECFM tests under sodium conditions
T2.4.3. ECFM tests in sodium at higher temperatures
WP2.3. European sodium facilities support
T2.3.1. Design guidelines for sodium loops
T2.3.2. Procedures and standards for testing selected elements of sodium technology
T2.3.3. Review of worldwide technologies
T2.3.4. Support to the students mobility program

New core design



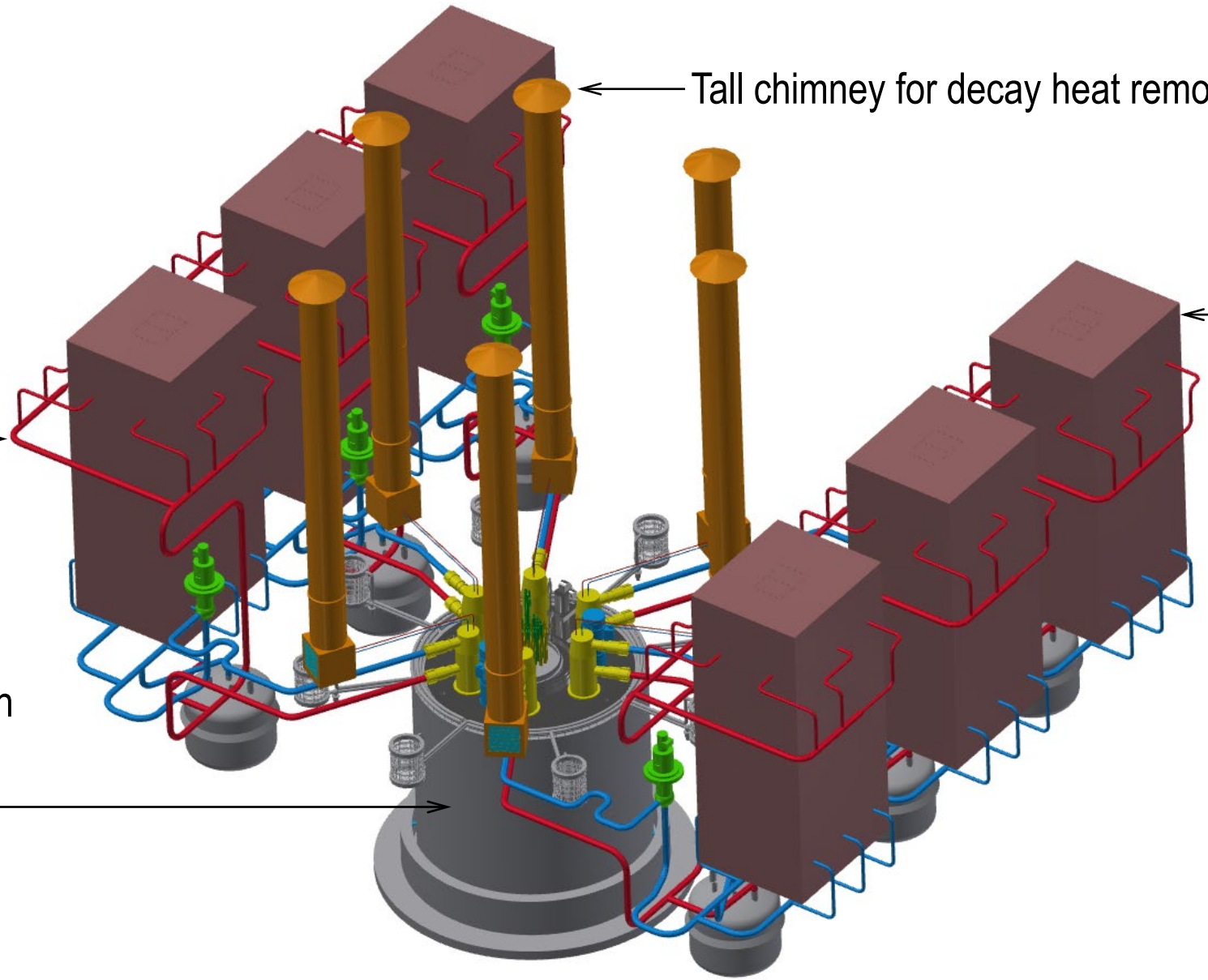
1 – Inner zone SA
2 – Outer zone SA
3 – Control assembly
4 – Corium discharge path
5 – Shielding SA
6 – Internal spent fuel storage

Fissile fuel (~18% Pu content)
Fertile blanket
Steel blanket
Fission gas plenum
Sodium plenum
Shielding (absorber)



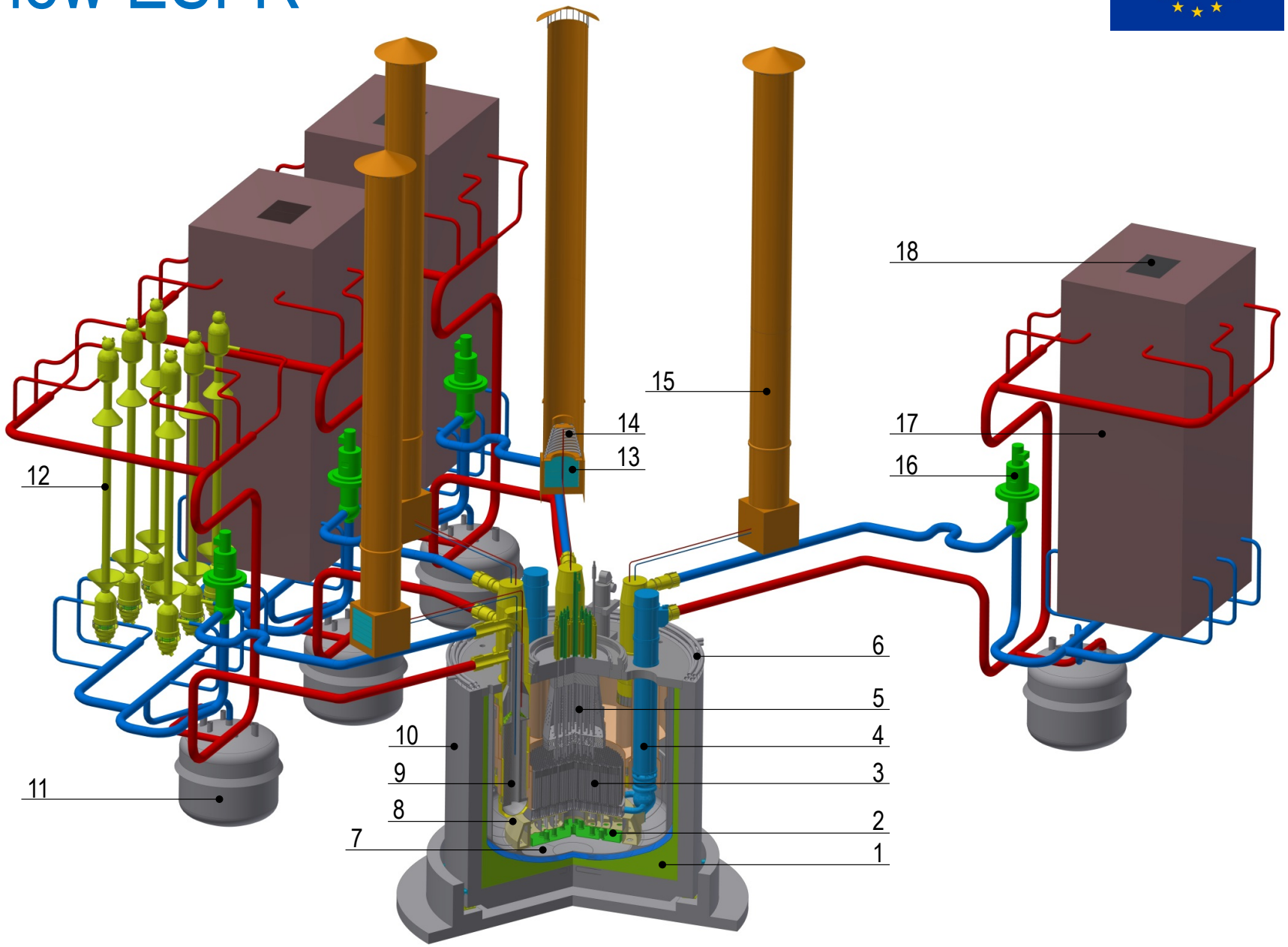
1 2 3 4 5 6	Inner zone SA	6 batches×36 = 216
1 2 3 4 5 6	Outer zone SA	6 batches×48 = 288
	CSD / DSD	24 / 12
R1 R2 R3	Reflector rings	66 / 96 / 102
S1	Spent inner fuel storage	3 batches×36 = 108
S2	Spent outer fuel storage	3 batches×48 = 144
	Corium discharge path	31

Overall view of new ESFR

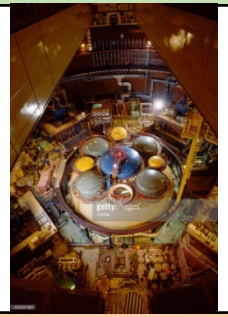
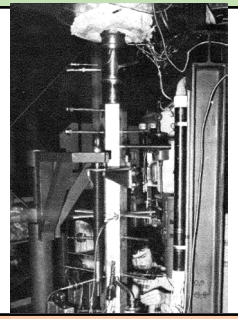
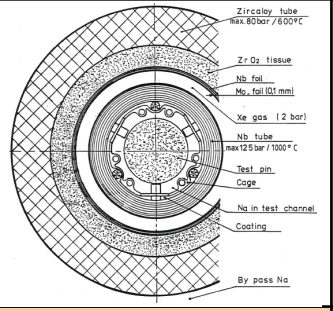
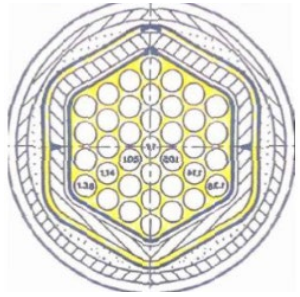
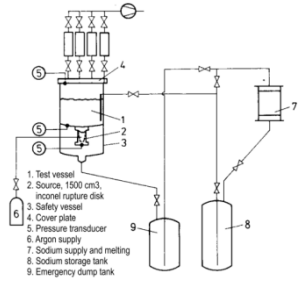
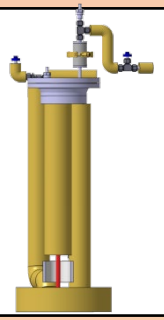
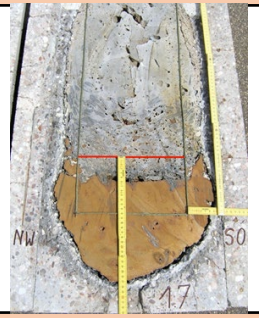
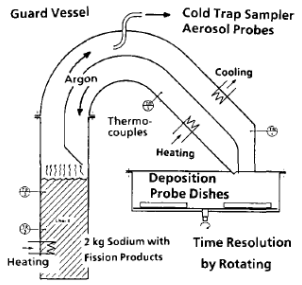
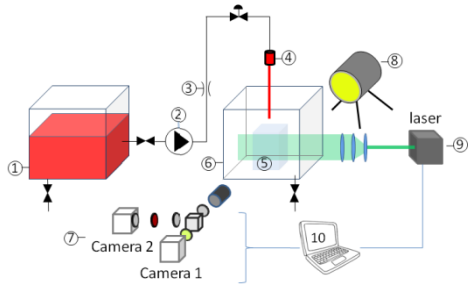
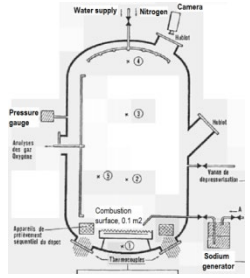


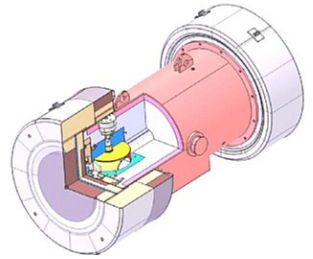
Overall view of new ESFR

1: Insulation with steel liner
2: Core catcher
3: Core
4: Primary pump
5: Above-core structure
6: Pit cooling system (DHRS-3)
7: Main vessel
8: Strongback
9: IHX
10: Reactor pit
11: Secondary sodium tank
12: Steam generator
13: Window for air circulation (DHRS-1)
14: Sodium-air HX (DHRS-1)
15: Air chimney (DHRS-1)
16: Secondary pump
17: Casing of SGs (DHRS-2)
18: Window for air circulation (DHRS-2)



ESFR-SMART: past and ongoing tests

Normal operation	Sodium boiling	Severe accident (SA) management		SA mitigation
Superphenix	KNS-37	CABRI	SCARABEE	FAUST
				
KASOLA	KARIFA	LIVE	JIMEC	NALA
				
ECFM	CHUG	HAnSOLO and JEDI		FANAL
				

MOX fuel measurements


Summary

Current achievements of the ESFR-SMART project:

- A number of design modifications aimed at ESFR design simplification and safety enhancement were selected and specified (including design drawings).
- The new ESFR core and system performance is evaluated in normal and accidental conditions. Advantages and shortcomings are identified.
- A number of calculational benchmarks and new experiments conducted.
- The fresh and irradiated MOX fuel samples were prepared for measurements of thermal properties.

Next steps:

- Ongoing benchmarks and experiments will be completed.
- The thermal properties of fresh and burned fuel samples will be measured.
- Main results of the project will be published in a Special Issue of Journal of Nuclear Engineering and Radiation Science

ESFR-SMART

Thank you!

Visit us at http://esfr-smart.eu/

The ESFR-SMART project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 754501