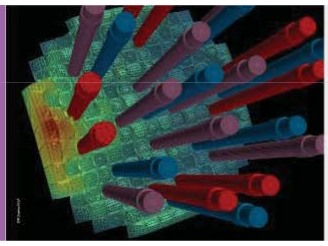


FISA 2022
30 May - 3 June 2022
Lyon, France

Review of Euratom projects on design, safety assessment, R&D and licensing for ESNII/Gen-IV reactor systems

B. Hatala (VUJE),
M. Ferreira (VTT), J.-L. Kloosterman (TU DELFT), K. Mikityuk (PSI), M. Šípová (CVŘ)

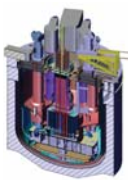
Introduction

European Sustainable Nuclear Industrial Initiative (ESNII) considers:

- Reference solution: Sodium Fast Reactor ASTRID;
- 1st alternative: Lead-cooled Fast Reactor ALFRED supported by LBE facility MYRRHA;
- 2nd alternative: Gas-cooled Fast Reactor ALLEGRO.

In addition the following Gen-IV systems are supported by Euratom:

- Gen-IV Molten Salt Fast Reactor MSFR (mentioned in SRA Annex as an attractive long-term option);
- Gen-IV Supercritical Water Cooled Reactor (SWCR);
- Gen-IV European Sodium Fast Reactor ESFR.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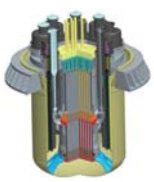
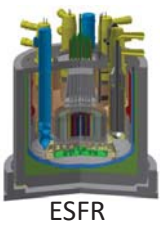
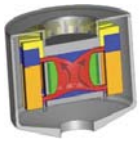

ALFRED


MYRRHA

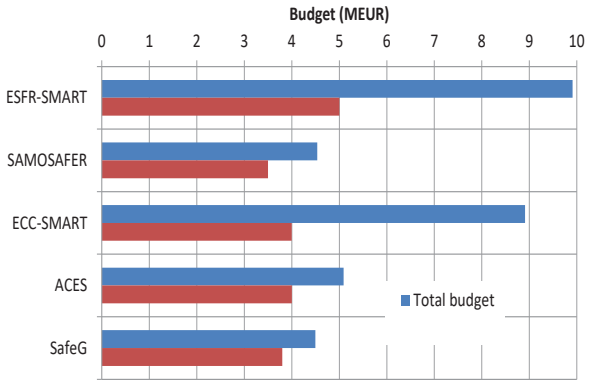

ALLEGRO

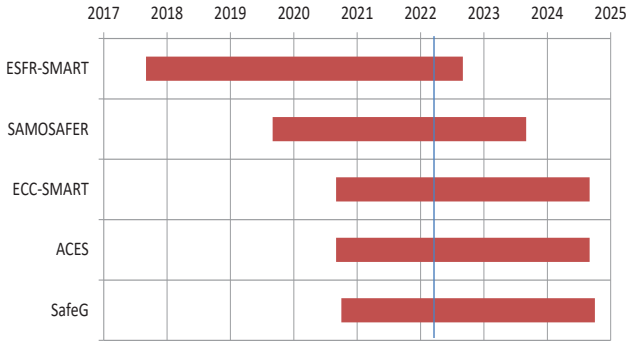

ESFR


SCW-SMR


MSFR

Four Generation-IV systems supported by the considered EU projects





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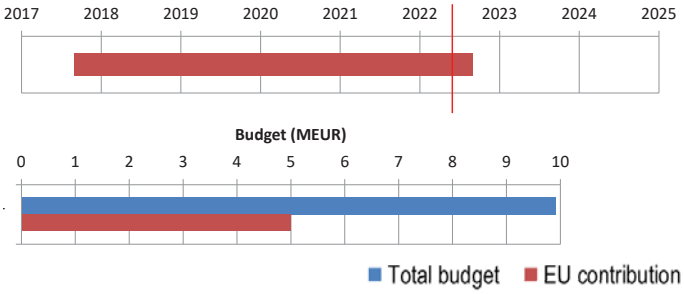
	SCK-CEN	ENGIE LABORELEC	PSI	UJV REZ	EVALION	VSCT	CTU	CV REZ	GRS	KIT	HZDR	BGF	UPM	CIEMAT	JRC	ENEN	VTT	IRSN	CEA	FRAMATOME	EDF	LGI	UNI DE LORRAINE	EK-CER	BME	ENEA	POLITO	POLIMI	UNI PISA	IPUL	NRG	TU DELFT	NCBJ	RATEN	KTH	CHALMERS	VUJE	STU	IJS	ZAG	IPP CENTRE LLC	ENERGORISK	JACOBS	UNI CAMBRIDGE	UNI NOTTINGHAM	UNI SHEFFILD	NNL	SUM
ESFR-SMART			C					x	x	x		x	x	x			x	x	x	x	x	x			x				x						x						x	x			x	19
SAMOSAFER			x				x		x						x			x	x	x	x						x	x			x	C														12
ECC-SMART						x		C		x				x	x	x	x								x				x					x	x			x	x		x	x					16
ACES	x	x					x	x									C	x	x		x																			x							10
SafeG				x	x		x	x				x							x						x	x								x			C	x				x	x		x		14

1. ESFR-SMART: fact sheet

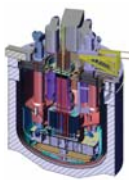
Name: European Sodium Fast Reactor Safety Measures Assessment and Research Tools



Domains:
- Design
- R&D
- Safety
- Licensing

ESFR-SMART
sodium fast reactor safety

Partners: 19
Countries: 9
Coordinator: PSI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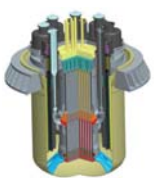
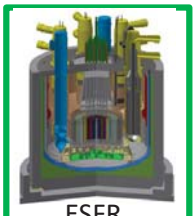

ALFRED


MYRRHA


ALLEGRO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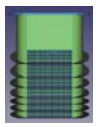
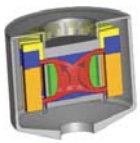

SCW-SMR

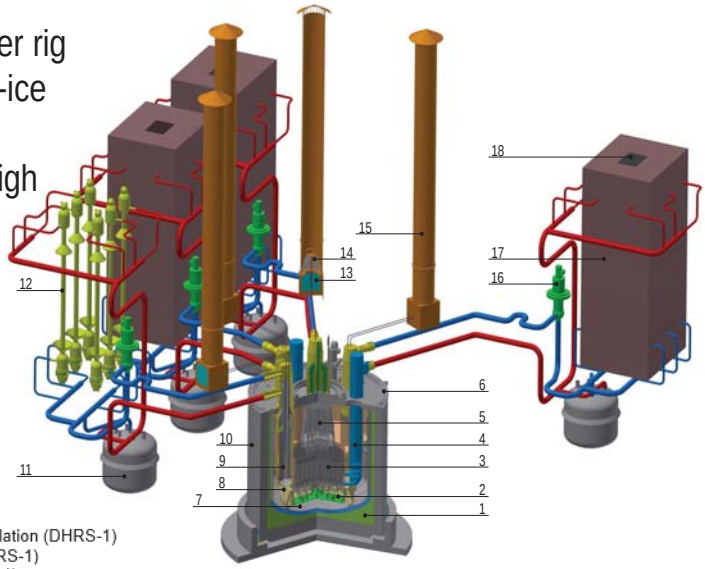

MSFR

1. ESFR-SMART: main goals

- Produce new experimental data to support calibration and validation of computational tools for each DiD level.
- Test and qualify new instrumentations to support their utilization in reactor protection system.
- Perform further calibration and validation of computational tools for each DiD level to support safety assessments of Gen-IV SFRs.
- Select, implement and assess new safety measures for commercial-size ESFR.
- Strengthen and link together new networks (sodium facilities and students).

1. ESFR-SMART: selected results

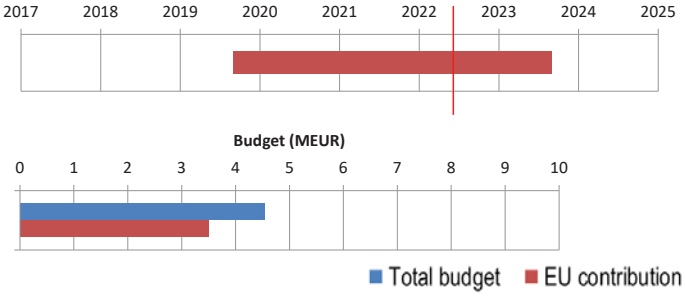
- Experimental programs:
  - CHUG: chugging boiling regime using steam-water rig
  - HAnSoLO: corium jet impingement using a water-ice system
  - JIMEC-I: ablation of a thick steel substrate with high temperature, high-velocity steel jet
- Benchmarking of codes:
  - Superphénix static and transient start-up tests
  - KNS-37 sodium boiling experiment
- Proposal of new safety measures
  - New core and system designs



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)

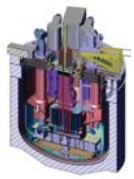
2. SAMOSAFER: fact sheet

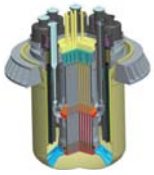
Name: Severe Accident Modeling and Safety Assessment for Fluid-fuel Energy Reactors



Domains:
- Design
- R&D
- Safety
- Licensing

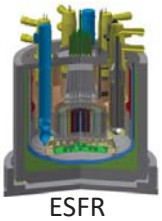
Partners: 12
Countries: 7
Coordinator: TU DELFT

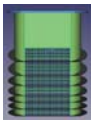

ASTRID


ALFRED


MYRRHA


ALLEGRO


ESFR


SCW-SMR


MSFR

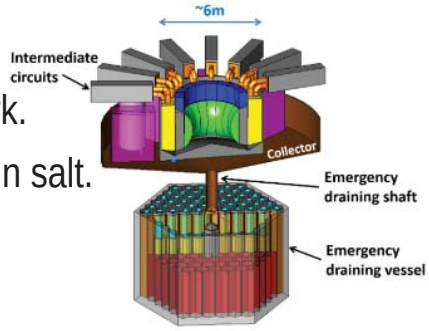
2. SAMOSAFER: main goals

Develop and demonstrate new safety barriers for more controlled behaviour of MSR in severe accidents, based on new simulation models and tools validated with experiments.

- Investigate and translate existing defence-in-depth safety approach to MSR
- Develop simulation code suite for neutronics, thermal hydraulics, thermo-physics modeling
- Develop and apply experimental setups for validation
- Design advanced barriers for severe accidents (freeze plugs, drain tanks, fission product extraction / immobilization)
- Update MSFR design

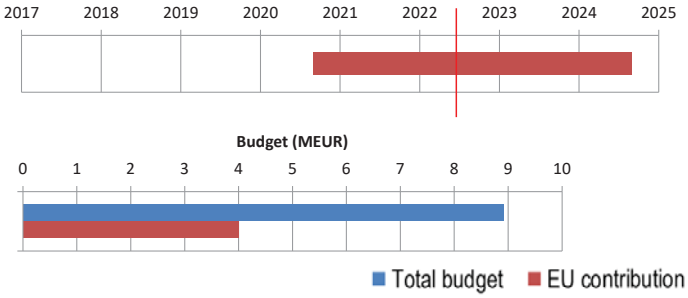
2. SAMOSAFER: selected results

- Specific MSR oriented defence in depth approach established by analysing safety functions of all fuel salt locations in reactor and by defining number of containment barriers.
- Thermochimica software coupled to JRC-Molten Salt Data Base for thermodynamic assessments of various salts.
- Molecular dynamics studies done on LiF-ThF4 using a new forced-field model.
- Preliminary scheme for reprocessing chloride salts developed.
- Salt freezing and re-melting modeling started.
- SIMMER code extended and prepared for Castillejos benchmark.
- SWATH-S facility extended to study radiation heat phenomena in salt.
- Design drawings of core and passive DHR system done.
- Summer school organized.



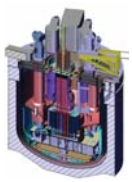
3. ECC-SMART: fact sheet

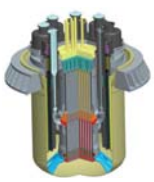
Name: Joint European Canadian Chinese development of Small Modular Reactor Technology



Domains:
- Design
- R&D
- Safety
- Licensing

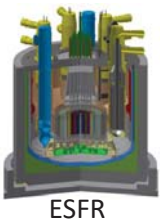
Partners: 16
Countries: 12
Coordinator: CV REZ


ASTRID


ALFRED


MYRRHA


ALLEGRO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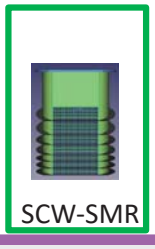
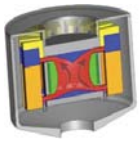

SCW-SMR


MSFR

3. ECC-SMART: main goal

Provide methodologies for safety evaluations and improvements for SCW-SMR, including experimental validation

- Assess corrosion behaviour of most promising candidates for SCW-SMR structural materials
- Define design requirements for SCW-SMR technology
- Develop and validate codes and assess proposed SCW-SMR concepts using these codes
- Provide reactor physics analysis of preliminary core layout
- Develop pre-licensing study and guidelines for safety demonstration

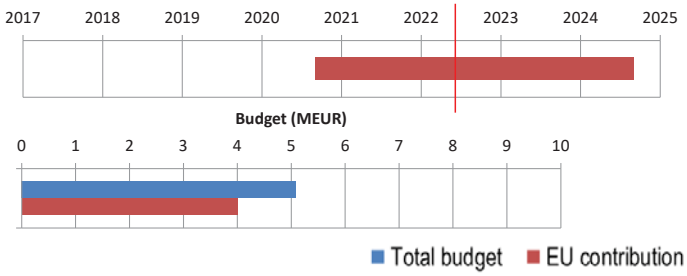
3. ECC-SMART: selected results

- Material testing: test matrix established with about 700 specimens:
  - Stainless steel 310S and alloy 800H selected as the most perspective material for fuel cladding;
  - experimental AFA (alumina forming austenitic alloy) supplied by China (USTB).
  - Most of specimens manufactured

- Innovative design of a small modular reactor cooled by SCW proposed based on HPLWR (high pressure light water reactor) using Canadian and Chinese experiences

4. ACES: fact sheet

Name: Towards improved assessment of safety performance for long-term operation of nuclear civil engineering structures



Domains:

- Design
- R&D
- Safety
- Licensing

Partners: 10
Countries: 6
Coordinator: VTT

4. ACES: main goals

- Improve understanding of ageing and deterioration of concrete for existing and next-generation NPPs
- Demonstrate and quantify inherent safety margins introduced by the conservative approaches used during design and defined by codes and standards
  - Assess corrosion of embedded liners in concrete
  - Characterise, predict and monitor ISR in concrete
  - Predict delayed strains of containment building
  - Assess performance of irradiated concrete

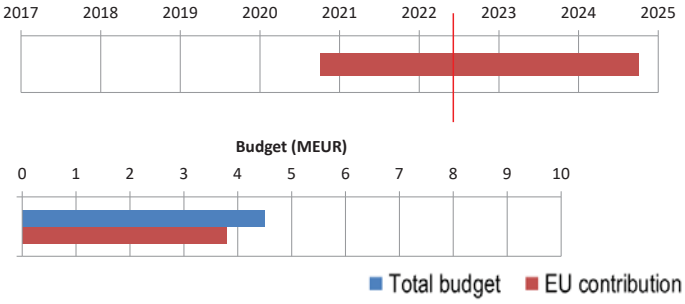
4. ACES: selected results

- Review of state-of-the-art of quantitative assessment of ageing of concrete SSC in NPPs.
- Improvement of phenomenological understanding and optimization of earlier detection of corrosion.
- Assessment of concrete structures affected by internal swelling reactions.
- Validation of existing constitutive laws and structural modelling approaches regarding the simulation of containment behaviour during operational phases.
- Generation of critical data currently missing from open literature on neutron-irradiation induced degradation of concrete aggregates relevant for European NPPs.

5. SafeG: fact sheet

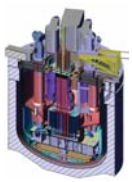
Name: Safety of GFR through innovative materials, technologies and processes

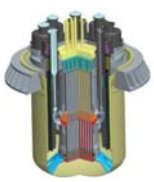
SafeG

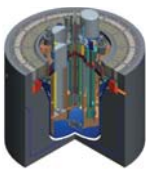


Domains:
- Design
- R&D
- Safety
- Licensing

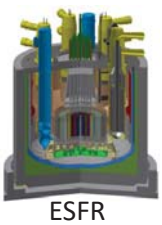
Partners: 14
Countries: 7
Coordinator: VUJE


ASTRID

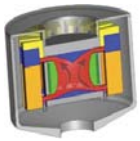

ALFRED


MYRRHA


ALLEGRO


ESFR


SCW-SMR


MSFR

5. SafeG: main goal

- Continue development of ALLEGRO for demonstration of gas-cooled fast reactor technology
- Develop driver and refractory cores satisfying performance and safety requirements
- Assess materials with better performance for primary circuit
- Assess decay heat removal capabilities
- Fuel qualification

5. SafeG: selected results

– Core safety – significant progress beyond the state of the art of GFR core safety has already been made (start-up core optimization was completed). Further work will include optimization of reactivity feedback coefficients and irradiation capabilities of the ALLEGRO core designs.

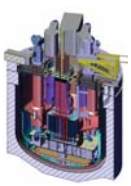
– Automatic shutdown system – Current design will be updated, using state-of-the art knowledge that is possessed by the consortium members who will work on this task.

– DHR system – So far, decay heat removal for GFRs has been solved in a very similar way for all the reference concepts. Within SafeG, effort will be put into development of innovative DHR solution based on cutting-edge technology

Summary

- 5 EU project since 2017
- 4 ESNII/Gen-IV reactor systems
- 33 MEUR of total budget including 20 MEUR of Euratom contribution.
- 47 organizations from 19 countries
- Design, R&D, safety and licensing aspects

Thank you for your attention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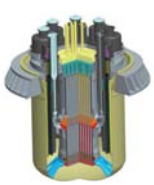
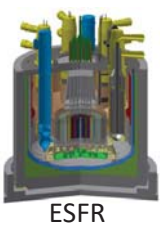
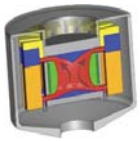

ALFRED


MYRRHA


ALLEGRO


ESFR


SCW-SMR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