IAEA
International Atomic Energy Agency

"Atoms for Peace and Development"

13th IAEA-GIF Interface Meeting
Vienna, 18 – 19 March 2019

IAEA Activities on Fast Reactors

Vladimir Kriventsev, *Chirayu Batra*
Fast Reactor Technology Development Team
Nuclear Power technology Development Section
Division of Nuclear Power
Department of Nuclear Energy
International Atomic Energy Agency
https://www.iaea.org/topics/fast-reactors

email: FR@IAEA.ORG

Main IAEA Activities on Fast Reactor Technology in 2018 - 2019

- CRPs/Benchmarks/Studies
  - **NAPRO CRP** (2013 - 2018)
  - 3 Ongoing CRPs:
    - **PSFR Source Term** (2016 - 2020)
    - **New CEFR Start-Up Tests** (2018 - 2022)
    - **New FFTF ULOF Test** (2018 - 2022)
  - 2 New CRPs proposed (to start in 2021):
    - Modelling of Total Instantaneous Blockage of SFR F/A
    - Benchmarking LOF transient test in CLEAR-S HML Pool Facility
  - Study on **Passive Shutdown Systems** for Fast Reactors (completed in 2017, NES to be published in 2019)
  - TM on **Structural Materials for HLM Reactors** (2019)
  - TM on **Benefits and Challenges of Fast SMRs** (2019)
  - TM on Economic (or Industrial) Optimization of Liquid Metal cooled Fast Reactor Designs (2020)
  - TM on Proliferation Resistant Features of Fast Reactors and Related Fuel Cycles (2020)
- Technical Working Group on Fast Reactors
  - 50th TWG-FR Meeting in Vienna, May 2017
  - 51st TWG-FR Meeting in Hefei, China, 21-25 May 2018
  - 52nd TWG-FR Meeting in Romania, 10-14 June 2019
- Joint GIF-IAEA Workshops on LMFR Safety
  - 7th GIF-IAEA Workshop on LMFR Safety: 27-29 March 2018
    - Review of GIF Report on Safety Design Guidelines on Safety Approach & Design Conditions for GEN-IV SFRs
  - **8th GIF-IAEA Workshop on LMFR Safety: 20-22 March 2019**
- LMFNS Experimental Facilities Database
- Training Courses and Workshops
  - Joint ICTP-IAEA Workshops on the Physics and Technology of Innovative Nuclear Energy Systems (2016, 2018 in Trieste, Italy)

IAEA Fast Reactor Technology Development Team







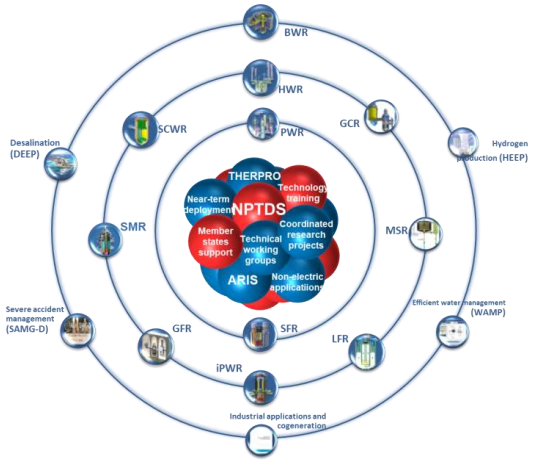




INPRO Section

Nuclear Power Technology **Development** Section **NPTDS**

"Atoms for Peace and Development"

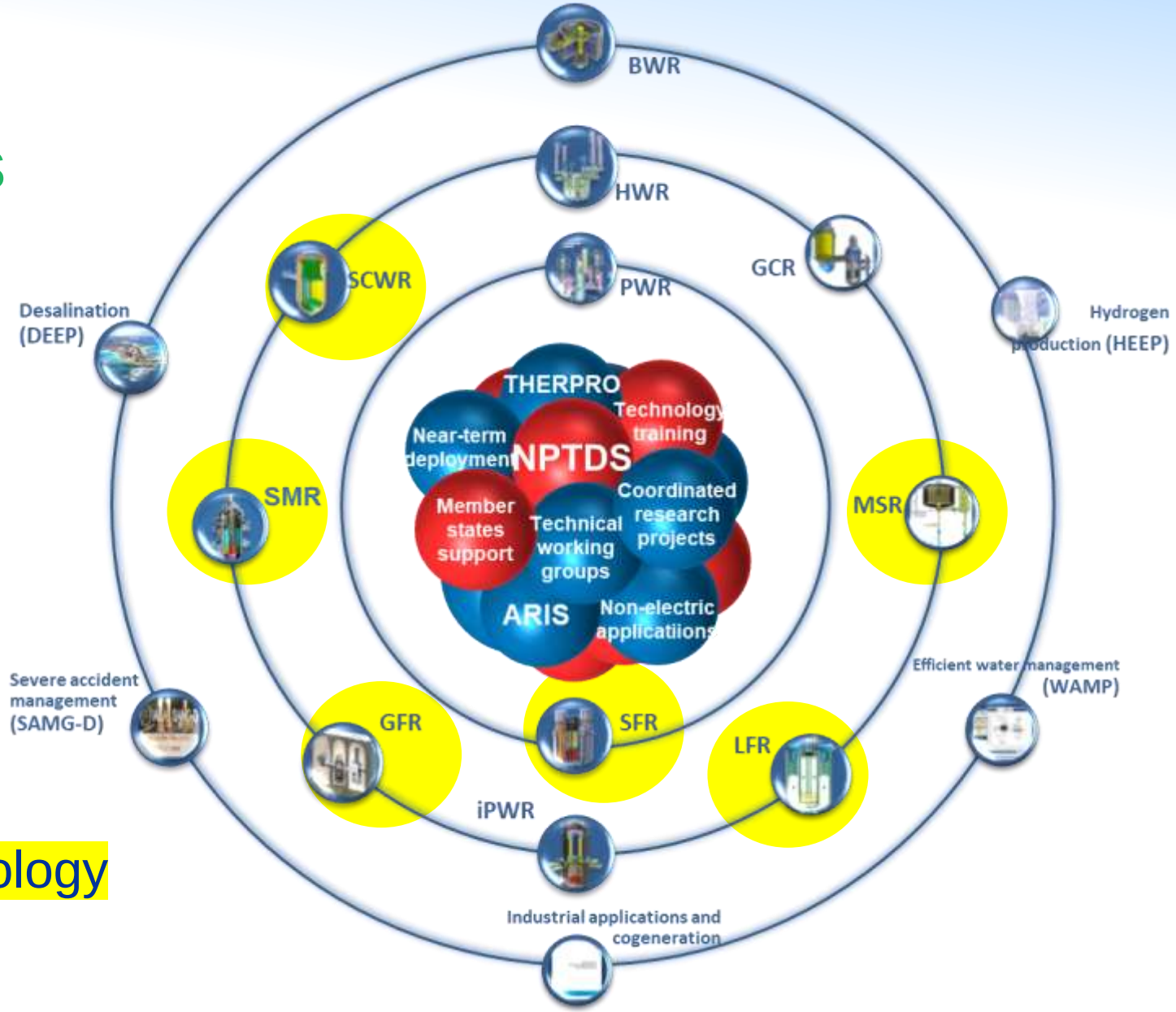


Fast Reactor Technology **Development** Team

FastRTeam

Nuclear Power Technology Development

NPTDS:
Tasks & Activities



Fast Reactors Technology

IAEA Technical Working Group on Fast Reactors (TWG-FR)

"The Driving Force…"



- Provide advice and guidance
- Forum for information exchange and knowledge sharing
- Link between IAEA activities and national communities
- Provide advice in planning and implementing of CRPs
- Develop and review selected documents
- Contribute to status report, technical meetings, topical conferences
- Identify important topics for SAGNE
- Encourage participation of young professionals in IAEA activities

Members of the IAEA Technical Working Group on Fast Reactors

Full Members

Belarus
China
Germany
Italy
Kazakhstan
Netherlands
Slovakia
Switzerland
UK
European Commission
Brazil
France
India
Japan
Korea, republic of
Russian Federation
Sweden
Ukraine
USA
OECD/NEA

Observers

Argentina
Czech Republic
Romania
Generation-IV International Forum (GIF)
Belgium
Mexico
Spain

Next, 52st TWG-FR Meeting, Pitesti, Romania, 10-14 June 2019

Fast Reactors Safety: Joint GIF-IAEA Workshops on Safety of LMFRs







1st : June 2010
2nd : Dec 2011
3rd : Feb. 2013
4th : June 2014
5th : June 2015

6th GIF-IAEA Workshop on Safety of SFR
November 2016

7th Joint GIF-IAEA Workshop on LMFR Safety
March 2018

- Final Review of GIF Report on Safety Design Guidelines on Safety Approach & Design Conditions for GEN-IV SFRs

8th GIF-IAEA Workshop on LMFR Safety
20-22 March 2019

- Discussion of GIF Report on “Safety Design Guidelines on Structures, Systems and Components for Gen-IV SFRs”

Next in 2020?

Fast Reactors: *Coordinated Research Projects*

CRPs on Fast Reactors Technology

CRP recently completed

- BN-600 MOX Core Benchmark
- Analytical and Experimental Benchmark Analysis of ADS
- PHENIX – EOL Tests
- MONJU – Na Natural Convection
- **EBR-II** Shutdown Heat Removal Tests (published in 2017)

CRP currently on-going

- **NAPRO** – Na Properties and Safe Operations of Exp. Facilities
  Ended in Sept 2018
  2 TECDOCs in Publishing
- **PSFR Source Term** – Radioactive Release Under Severe Accident Conditions



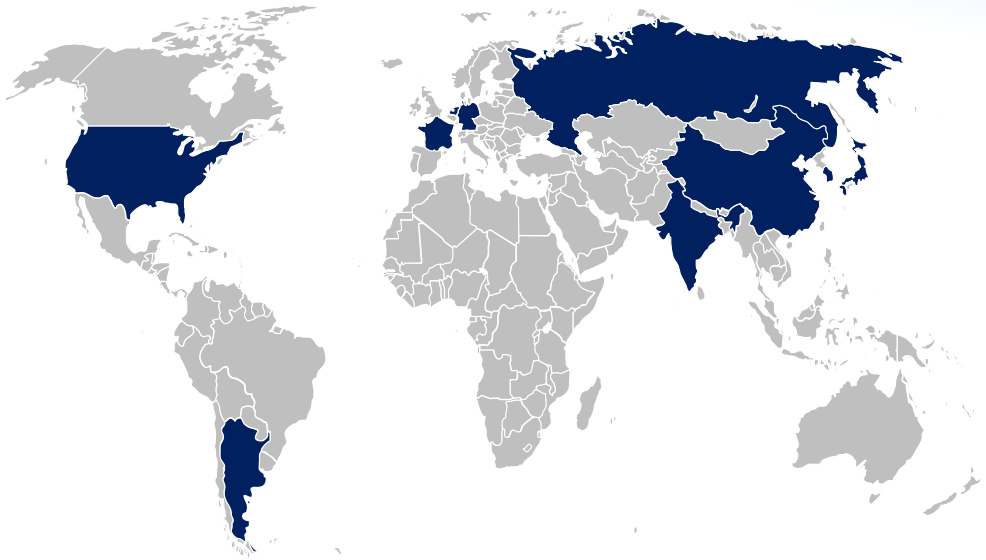
New CRPs

- MONJU – Turbine Trip Test
- **Neutronics Benchmark of CEFR Start-Up Tests** (29 participants)
- **Benchmark Analysis of FFTF Loss of Flow Without Scram Test** (25 participants)

New Proposals

- Total Instantaneous Blockage of SFR Fuel Assembly
- LOF transient test in CLEAR-S HML Pool Facility

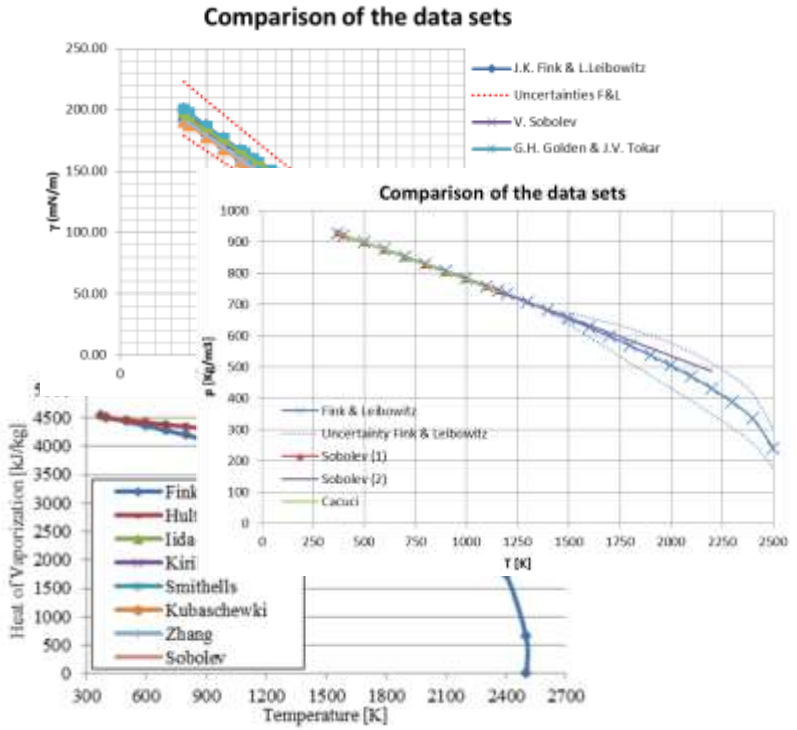
NAPRO CRP: Sodium properties and safe operation of experimental facilities in support of SFRs (2013-2018)



“Sodium properties and safe operation of experimental facilities in support of the development and deployment of SFR”

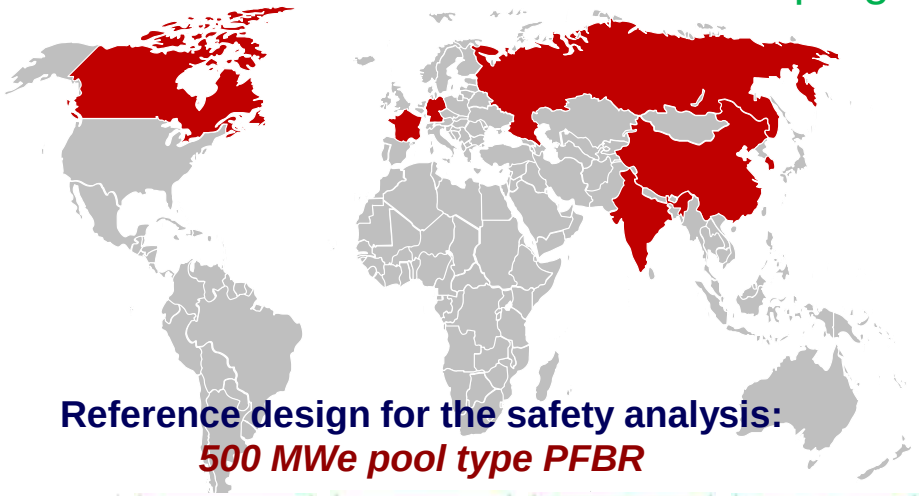
Argentina (CNEA)	China (CIAE)
France (CEA)	India (IGCAR)
Germany (KIT, HZDR)	Japan (JAEA)
Korea, Republic of (KAERI)	Netherlands (NRG)
Russian Federation (IPPE)	USA (ANL)

- **WP1**: Collection and assessment of sodium properties: harmonization of international data and correlations
- **WP2**: Design rules and best practice for Na exp. facilities
- **WP3**: Guidelines for the safe operation of Na exp. facilities
- 4th RCM in Vienna, 12 -14 June 2017
- Two TECDOCs and one NES to be published
  - TECDOC: Sodium Coolant Handbook: Physical and Chemical Properties (2019)
  - TECDOC: Sodium Coolant Handbook: Thermal-Hydraulic Correlations (2019)
  - NES: ~~Design, Operation and Safety of Sodium Experimental Facilities (2019)~~

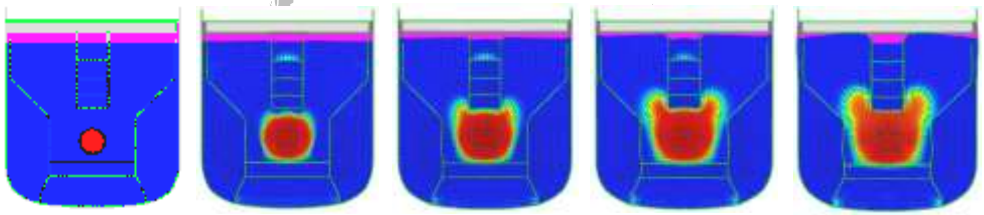


CRP on Radioactive Release from Prototype SFR under Severe Accident Conditions (2016-2020)

- 10 Organizations from 8 Countries
- CRP is in the middle of the progress



Reference design for the safety analysis:
500 MWe pool type PFBR



i. 0 ms ii. 50 ms iii. 100 ms iv. 150 ms v. 200 ms

Numerical simulation of core bubble expansions during a CDA (100 MJ)

- ✓ Transport of fission products (FP), Na and other radioactive materials from the melted core to the cover gas
- ✓ Ejection of FP, Na, fuel particles through the penetrations of the top shield reactor structure directly into the containment system and indirectly through the argon cover gas system
- ✓ Transport of fission products and other radioactive materials through the different containment compartments under various thermodynamics conditions

CRP on "Radioactive Release from the PSFR under Severe Accident Conditions"

~~*Canada (UOIT)*~~	China (*CIAE*, *NCEPU, XJTU)*
France (~~IRSN~~, CEA)	~~Germany, (KIT)~~
India, IGCAR	Korea, Republic of, KAERI
Russia (~~IPPE~~, IBRAE)	Spain (CIEMAT)
Japan (NRA)	US (*TerraPower)*

New Participants

- Japan NRA joined in 2018 (ASTERIA-FBR code)

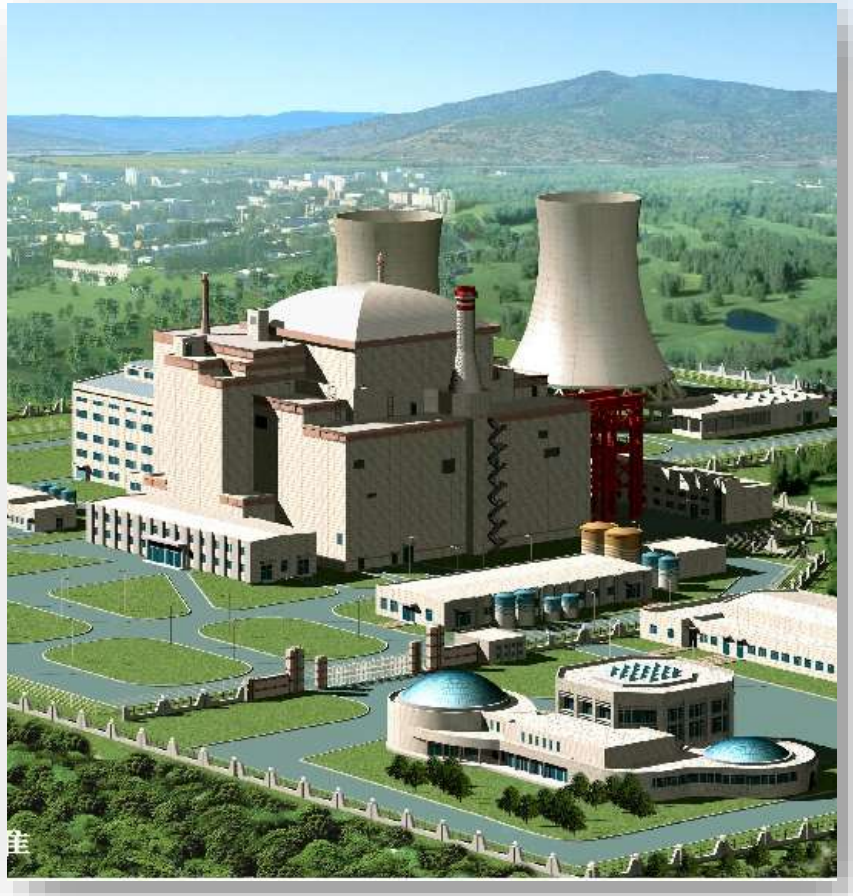
- ➢ 1st RCM: Vienna, May 2016
- ➢ 2nd RCM: IGCAR, November 2017
- ➢ 3rd RCM: Vienna, 8 -11 April 2019

New CRP: **Neutronics Benchmark of CEFR Start-Up Tests**

中国原子能科学研究院
中核集团 CHINA INSTITUTE OF ATOMIC ENERGY

IAEA

- China Experimental Fast Reactor
  - Sodium-cooled fast reactor with nominal power of 65MW(th), 20MW(e)
  - Reached the first criticality in 2010
  - Generated electricity at 40% full power and was connected firstly to the grid in July 2011
  - Generated electricity at 100% power in December 2015 and operated for more than 40 effective full power days

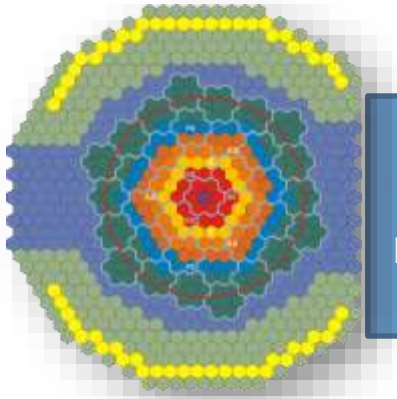


1st, Kick-Off RCM: June 2018, Vienna

CEFR Start-Up: Tests and Simulations

Experiments

1. Fuel loading and criticality	2. Measurement of control rod worth	3. Reactivity effects measurement	4. Irradiation test of foils
Net criticality	Net criticality core	**Temperature reactivity coefficient**	**Reaction rate distribution**
250℃(cold state)	**Operation loading core (250℃)**	Pressure reactivity effect	Cross-section ratio
360℃ (hot standby)	Operation loading core (300℃)	Flowrate reactivity effect	Neutron spectrum
Nuclear heating start point		**Sodium void reactivity effect**	Absolute nuclear power
		Core SA exchange reactivity effect	



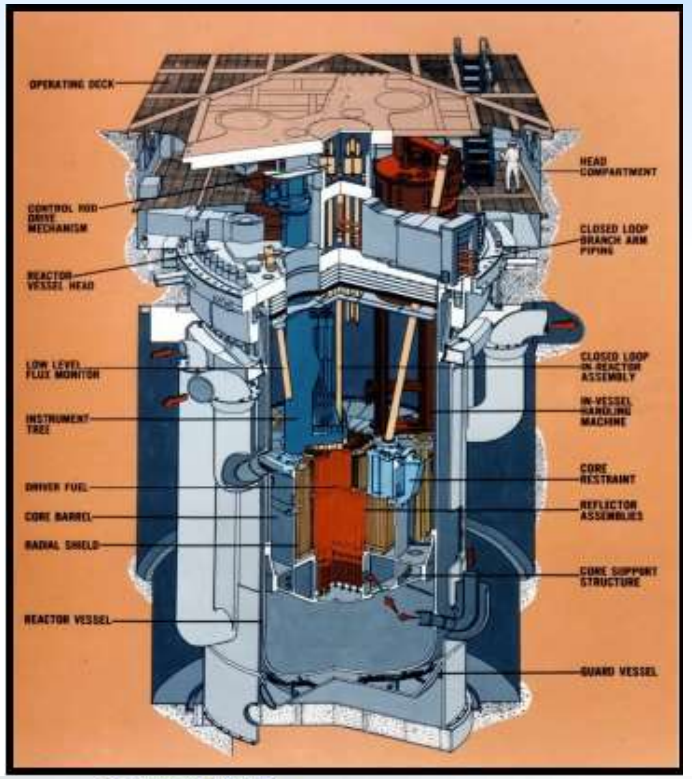
Planned duration: 2018 – 2022

Set up simplified model of CEFR core	Perform blind neutronics calculations independently	Comparison with experimental data, models update	**Refined Simulations; Publications of the results**

Kick-off RCM: 11-14 June 2018 (27 Participants from 17 MSs)

New CRP: **Benchmark Analysis of FFTF Loss of Flow Without Scram Test**

- FFTF Reactor:
  - 400 MWth sodium cooled fast test reactor
  - Mixed UO2-PuO2 (MOX) fuel
  - Loop type plant, axial and radial reflectors
  - Prototypic size
    - ~1m^3 core volume
    - ~91 cm high, ~120 cm diameter
  - Series of Passive Safety Tests
    - Demonstrated passive safety of SFRs
    - Demonstrated efficacy of negative reactivity insertion safety devises (GEMs)

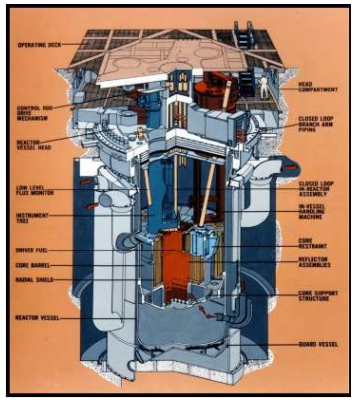




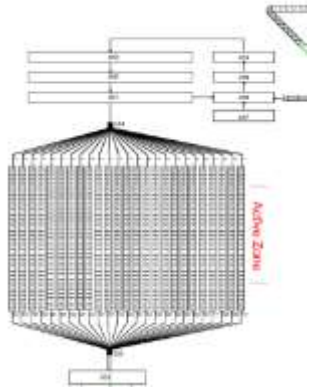
PNNL/ANL at Consultants' Meeting
November 2017, Vienna

CRP Benchmark: FFTF ULOF Test

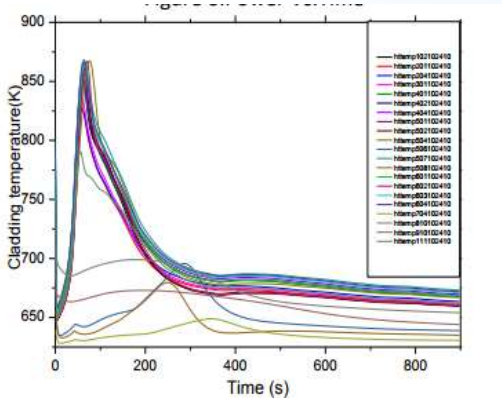
Coupled Neutronic, Thermalhydraulic and System Codes



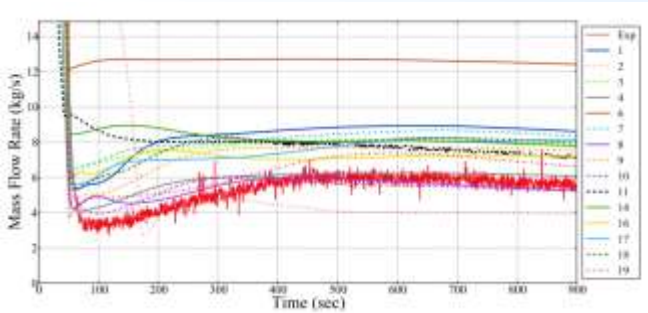
Plant Data



Modelling



Simulations



Comparison

ULOF Transient from 50% Power; Reactor Survives (thanks to GEM)

Benchmark Specifications	Blind Simulations performed independently	Sharing of results and comparison with Experimental Data	Uncertainties Qualification and Results Validation	Publication of IAEA document

Planned duration: 2018 – 2022

Kick-off RCM: 22-25 October 2018

Knowledge Preservation

Storing CRP data

New IAEA CRPs on Fast Reactors (Initiated in 2018)

Neutronics Benchmark of **CEFR Start-Up Tests**

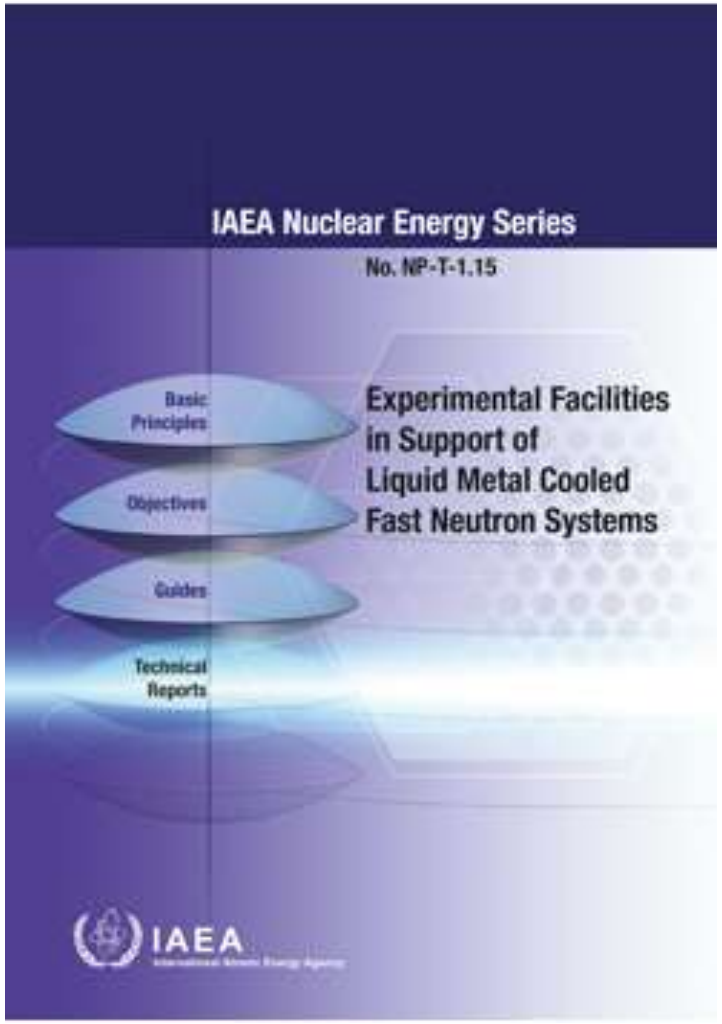
Country	Organization(s)
Belgium	SCK•CEN
China	CIAE, INEST, SNERDI, XJTU
France	CEA
Germany	KIT, HZDR, GRS
Hungary	BME, EK
India	IGCAR
Italy	NINE/UNIPI
Japan	JAEA
Rep. of Korea	KAERI, UNIST
Mexico	ININ
Romania	RATEN
Russia	IPPE, IBRAE, SSL, Kurchatov Inst.
Slovakia	VUJE
Switzerland	PSI
Ukraine	KIPT
UK	Cambridge
USA	ANL, NRC, INL
17 Countries	**29 Organizations**

Benchmark Analysis of **FFTF ULOF Test**



Country	Organization(s)
China	CIAE, NCEPU, INEST, XJTU
France	CEA
Germany	KIT, HZDR
India	IGCAR, ISSSA
Italy	NINE, Sapienza
Japan	JAEA
Rep. of Korea	KAERI
Netherlands	NRG
Russia	IPPE, IBRAE
Spain	CIEMAT
Sweden	KTH
Switzerland	PSI
USA	ANL, PNNL, TerraPower, NRC, TAMU
13 Countries	**25 Organizations**

IAEA LMFNS Online Catalogue



Experimental Facilities in Support of Liquid Metal cooled Fast Neutron Systems

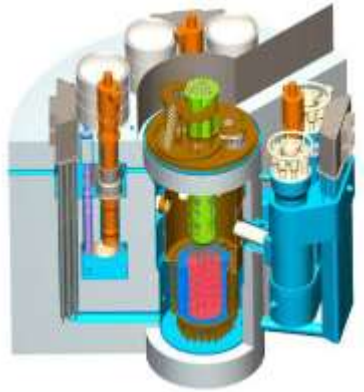
Freely Accessible:
https://nucleus.iaea.org/sites/lmfns
or google **“IAEA LMFNS”**

includes data on 150 experimental facilities under design, construction or operation

Detailed Overview Tomorrow

New Studies on Fast Reactors: Technical Meeting on Benefits and Challenges of Fast Reactors of SMR Type

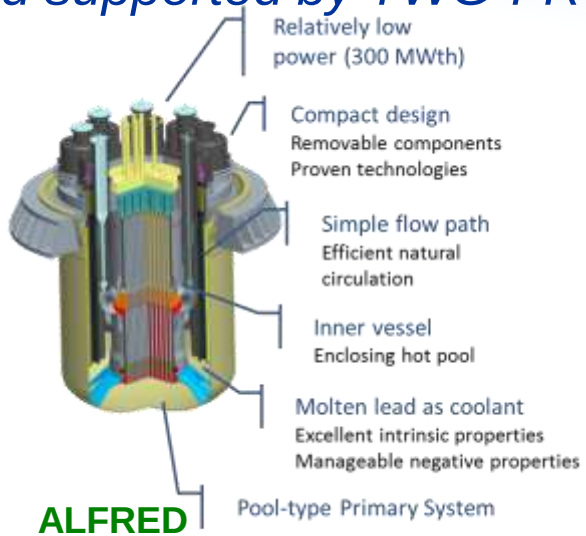
- *Proposed by Italy and supported by TWG-FR at 51st Meeting in May 2018*



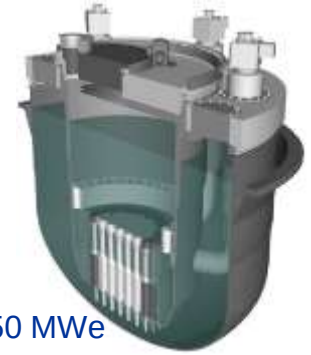
BREST-OD-300
NIKIET/Proryv



SEALER
LeadCold

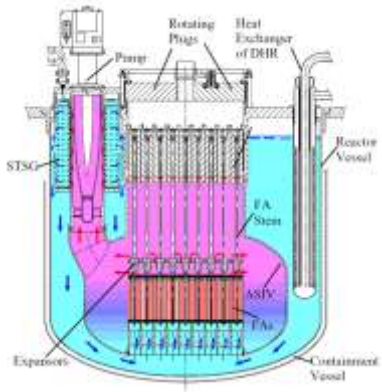


ALFRED
EU / ENEA / Ansaldo Nucleare

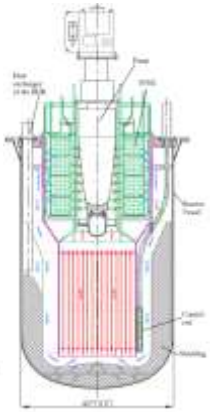


450 MWe

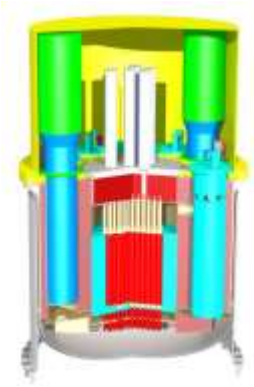
LFR Concept
Westinghouse



LFR-AS-200



LFR-10
Hydromine



CLEAR-M10
FDS/INEST

Action	Date
Announcement and Call for Papers	March 2019
Abstract submission Deadline	15 May 2019
*TWG-FR review abstracts at its 52nd Meeting and IAEA accepts **15-20** abstracts*	*June 2019*
Full paper submission deadline; Start of peer-review	August 2019
Technical Meeting in Italy	**24 - 27 September 2019**
Final Papers Deadline; Draft TM Report	December 2019
Publication of the IAEA TECDOC (or NES)	2021

New Studies on Lead/LBE: Technical Meeting on Structural Materials for Heavy Liquid Metal Cooled Fast Reactors

- *Proposed by Romania and Italy at 51st TWG-FR Meeting in May 2018*

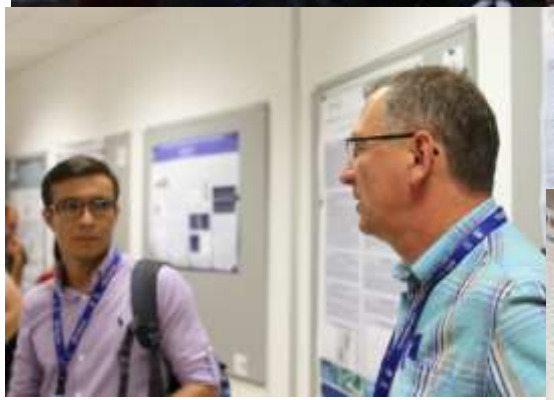
Meeting Objectives:

- Present and discuss the current status of research and development (R&D) in this field;
- Discuss and identify the R&D needs and gaps to assess the future requirements in the field;
- Enable the integration of materials research within the Member States to support development of new technologies at higher technological readiness level;
- Provide recommendations to the IAEA for future joint efforts and coordinated research activities (if required) in the field;

Action	Date
Announcement and Call for Papers	March 2019
Abstract submission Deadline	15 May 2019
*TWG-FR review abstracts at its 52nd Meeting and IAEA accepts **15-20** abstracts*	*June 2019*
Full paper submission deadline; Starting peer-review	September 2019
Technical Meeting in Vienna	**15 - 17 October 2019**
Final Papers Deadline; Draft TM Report	December 2019
Publication of the IAEA TECDOC (or NES)	2021

Joint ICTP-IAEA Workshops on Innovative Nuclear Energy Systems





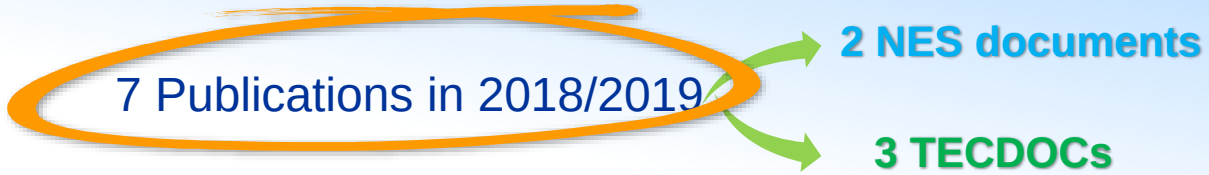




- In **2016** and in August **2018** Trieste, Italy
- Contributed by NPTDS, INPRO, GIF, and other external experts



Fast Reactors: Publications



TECDOCs and **NES** Reports:

- Analytical and Experimental Benchmark Analysis of ADS –
  - In Publishing
- Catalogue of Experimental Facilities for Liquid Metal Cooled FNSs –
  - NES Published; Database is available online and under Major Update
- ***NAPRO CRP***
  - WP1: Sodium Coolant Handbook: Physical and Chemical Properties
    - In Publishing
  - WP1: Sodium Coolant Handbook: Thermal-Hydraulic Correlations
    - In Publishing
  - WP2/3: ~~Design, Operation and Safety of Sodium Experimental Facilities - NES Report~~
    - postponed
- **Passive Shutdown Systems** for Fast Neutron Reactors
  - NES In Publishing

FRs: Completed and Scheduled Events in 2018-2019

Dates	Title	Location
27 - 29 Mar	7th Joint IAEA–GIF Workshop on LMFR Safety	Vienna
21 - 25 May	51st Meeting of the Technical Working Group on Fast Reactors (**TWG-FR**)	Hefei, China
11 - 14 Jun	1st RCM of CRP on **Neutronics Benchmark of CEFR Start-Up Tests**	Vienna
20 - 24 Aug	Joint ICTP–IAEA Workshop on Physics and Technology of Innovative NESs	Trieste, Italy
22 - 25 Oct	1st RCM of CRP on **Benchmark Analysis of FFTF Loss of Flow Without Scram Test**	Vienna
29 - 31 Jan	Consultancy Meeting on Update of the **Online Catalogue of LMFNS Facilities**	Vienna
20 - 22 Mar	8th Joint IAEA–GIF Workshop on LMFR Safety	Vienna
08 - 11 Apr	3rd RCM of CRP on **Radioactive Release from the Prototype Fast Breeder Reactor under Severe Accident Conditions**	Vienna
10 - 14 Jun	52nd Meeting of the Technical Working Group on Fast Reactors (**TWG-FR**)	Pitesti, Romania
~~18 - 20 Jun~~	~~TM on Economic and Industrial Optimization of LMFR Designs~~	~~Vienna~~
24 - 27 Sep	TM on **Benefits and Challenges of Fast Reactors of SMR Type**	Bologna, Italy
15 - 17 Oct	TM on **Structural Materials for Heavy Liquid Metal Cooled Fast Reactors**	Vienna
02 - 05 Dec	2nd RCM of CRP on **Neutronics Benchmark of CEFR Start-Up Tests**	Beijing, China

IAEA
International Atomic Energy Agency



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Thank You!

email: FR@IAEA.ORG