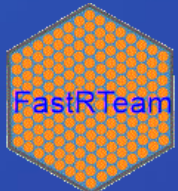


# IAEA Activities on Fast Reactors Technology



*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**

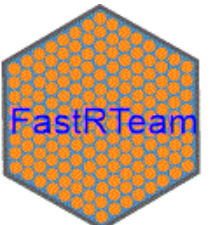
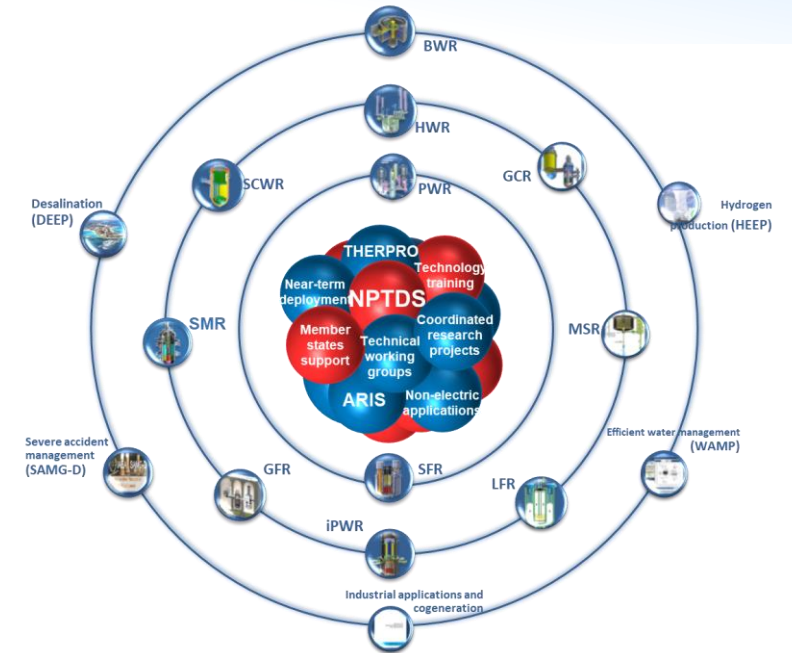
# IAEA Fast Reactor Technology Development Team



Nuclear Power Technology  
**Development Section NPTDS**

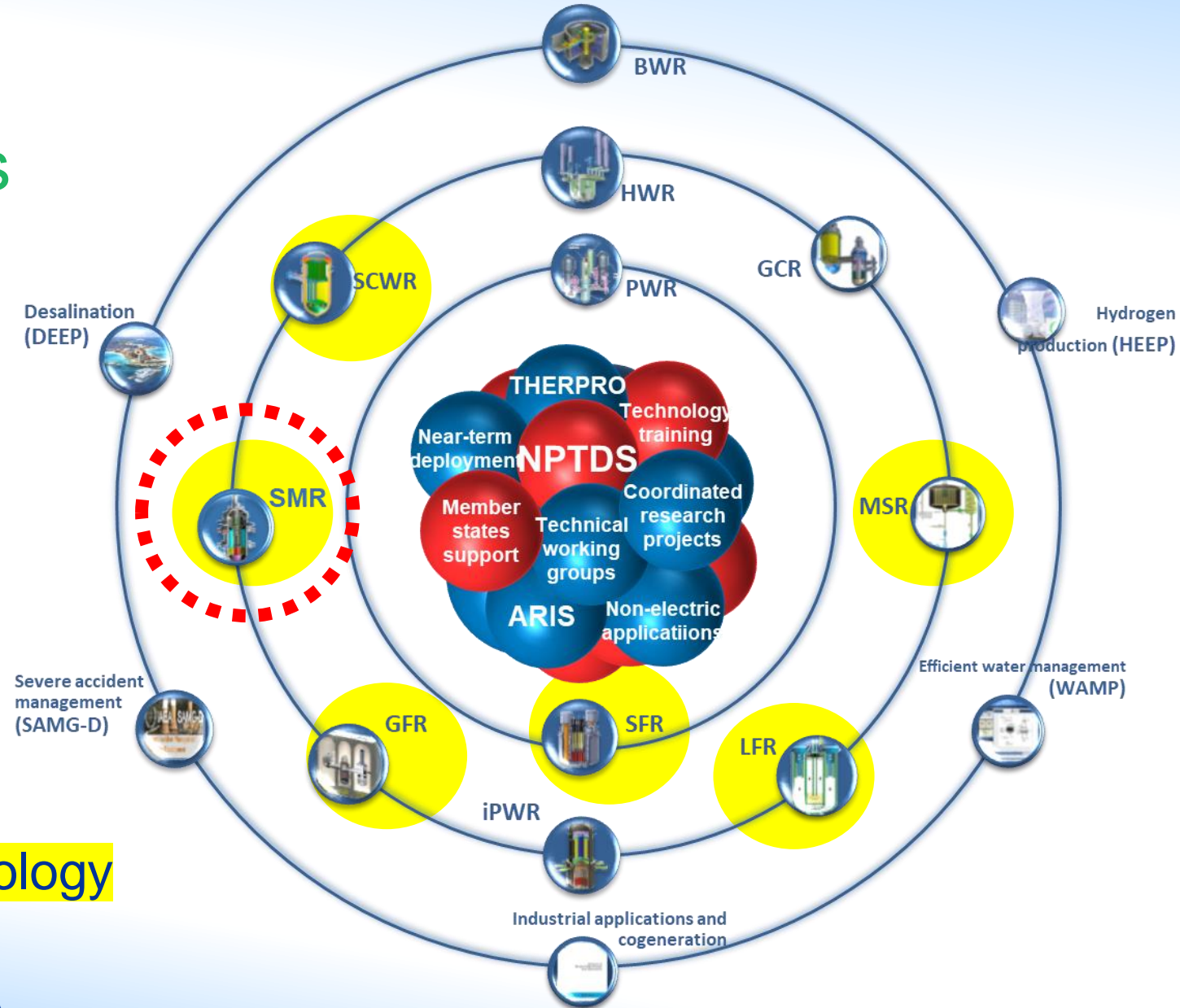
*“Atoms for Peace  
and Development”*

Fast Reactor Technology  
**Development Team**



# Nuclear Power Technology Development

## NPTDS: Tasks & Activities



## Fast Reactors Technology



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



*“The Driving Force...”*

## Members of the IAEA Technical Working Group on Fast Reactors

### Full Members

Belarus	Brazil
China	<b>Belgium</b>
<b>Czech Republic</b>	France
Germany	India
Italy	Japan
Kazakhstan	Korea, republic of
Netherlands	Russian Federation
Slovakia	Sweden
Switzerland	Ukraine
UK	USA
<i>European Commission</i>	<i>OECD/NEA</i>

### Observers

Argentina	<del>Belgium</del>
<del>Czech Republic</del>	Mexico
Romania	Spain
<i>Generation-IV International Forum (GIF)</i>	

- 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

52<sup>st</sup> TWG-FR Meeting, Pitesti, Romania, 10-14 June 2019

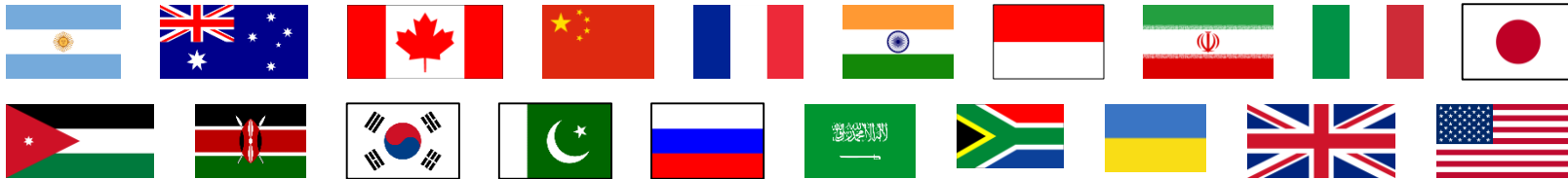


# IAEA Technical Working Group on SMR



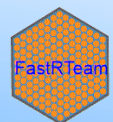
- To advice and support IAEA programmatic planning and implementation in areas related to technology development, design, deployment and economics of SMRs
- 1<sup>st</sup> meeting in 2018 with 14 Member States
- Now 20 Member States and two International Organizations: European Commission and OECD-NEA as invited observers:

Scientific Secretary:  
Mr Frederik Reitsma  
F.Reitsma@iaea.org

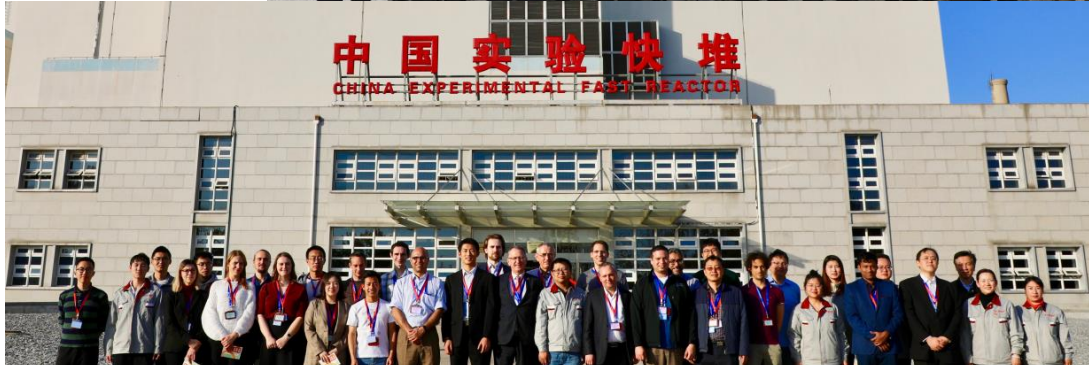


- Three technical subgroups established in 2018 / 2019:
  - **SG-1:** Development of Generic Users Requirements and Criteria (GURC)
  - **SG-2:** Research, Technology Development and Innovation; Codes and Standards
  - **SG-3:** Industrialization, design engineering, testing, manufacturing, supply chain, and construction technology
- TWG also address SMR for Non-Electric Applications and coupling with renewables
- 1<sup>st</sup> TWG Meeting held on 23 - 26 April 2018 in Vienna
- 2<sup>nd</sup> Meeting : 8 – 11 July 2019 in Vienna
- 3<sup>rd</sup> scheduled for 29 June – 2 July 2020 in Vienna

TWG-SMR Chair:  
Mr Marco Ricotti  
President of CIRTEC



# Fast Reactors: Coordinated Research Projects



## CRPs on Fast Reactors Technology

On-going CRPs

**PSFR Source Term** –  
Radioactive Release Under  
Severe Accident Conditions

Neutronics Benchmark of **CEFR**  
Start-Up Tests (29 participants)

Benchmark Analysis of **FFTF** Loss  
of Flow Without Scram Test  
(25 participants)

**NAPRO** – Na Properties and  
Safe Operations of Exp. Facilities  
Ended in Sept 2018  
2 TECDOCs in Publishing

New Proposals

Total Instantaneous Blockage  
of SFR Fuel Assembly

Simulation of **CLEAR-S**  
Loss-of-Flow Experiment

Benchmark Analysis of  
**STELLA-2** LOHS/LOF Tests



# New IAEA CRPs on Fast Reactors (Started in 2018)



## Neutronics Benchmark of CEFR Start-Up Tests

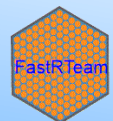


Country	Organization(s)
Belgium	SCK•CEN
China	<b>CIAE</b> , INEST, SNERDI, XJTU
France	CEA
Germany	KIT, HZDR, GRS
Hungary	BME, EK
India	IGCAR
Italy	NINE/UNIFI
Japan	JAEA
Rep. of Korea	KAERI, UNIST
Mexico	ININ
Romania	RATEN
Russia	IPPE, IBRAE, SSL, Kurchatov Inst.
Slovakia	VUJE
Switzerland	PSI
Ukraine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

## 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	<b>ANL, PNNL</b> , TerraPower, NRC, TAMU
<b>13 Countries</b>	<b>25 Organizations</b>



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

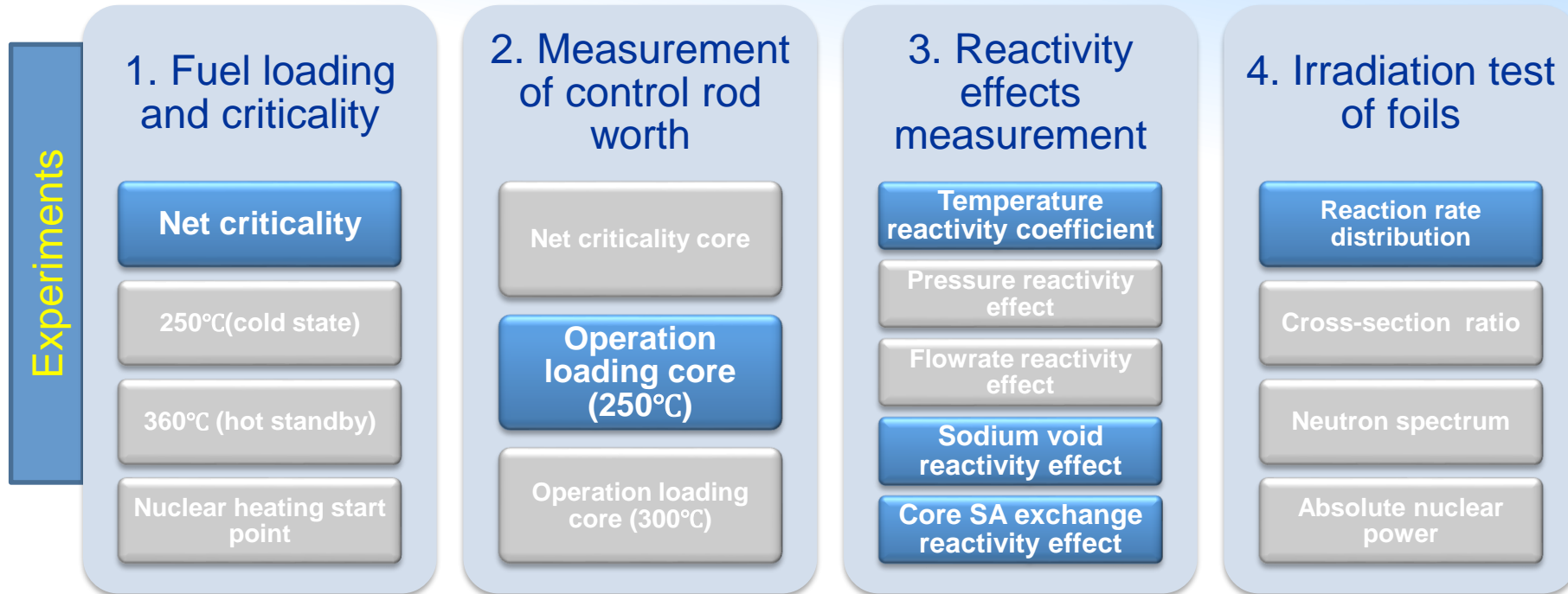
- China Experimental Fast Reactor
  - Sodium-cooled fast reactor with nominal power of 65MW(th), 20MW(e)
  - Reached the first criticality in 2010
  - Generated electricity at 40% full power and was connected firstly to the grid in July 2011
  - Generated electricity at 100% power in December 2015 and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



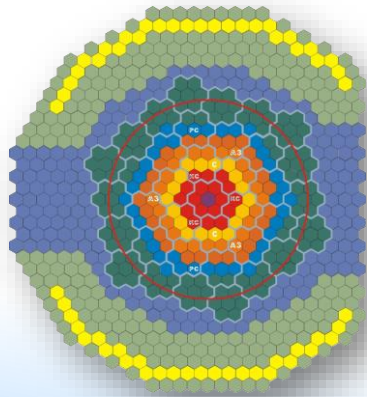
**1<sup>st</sup>, Kick-Off RCM: June 2018, Vienna**



# CEFR Start-Up: Tests and Simulations



Planned duration: 2018 – 2022

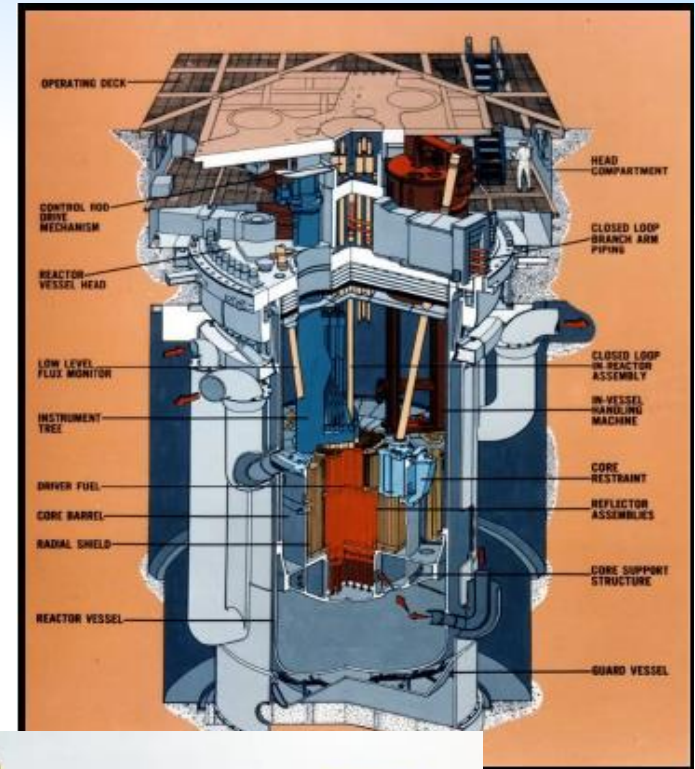


**Kick-off RCM:** 11-14 June 2018 (27 Participants from 17 MSs)

**2<sup>nd</sup> RCM:** 28 October – 1 November, Beijing

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

- FFTF Reactor:
  - 400 MWth sodium cooled fast test reactor
  - Mixed UO<sub>2</sub>-PuO<sub>2</sub> (MOX) fuel
  - Loop type plant, axial and radial reflectors
  - Prototypic size
    - ~1m<sup>3</sup> 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 devices (GEMs)

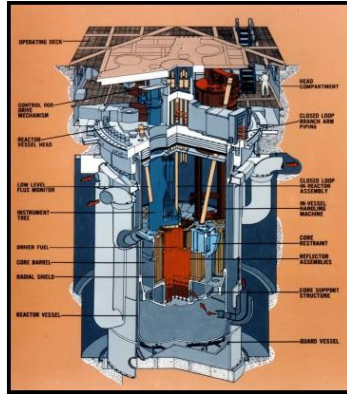


**PNNL/ANL at Consultants' Meeting**  
November 2017, Vienna

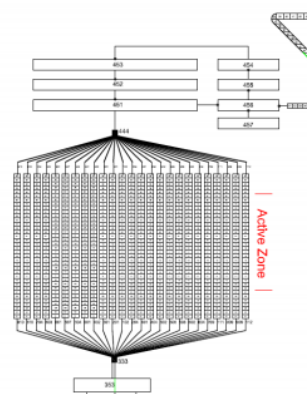


# CRP Benchmark: FFTF ULOF Test

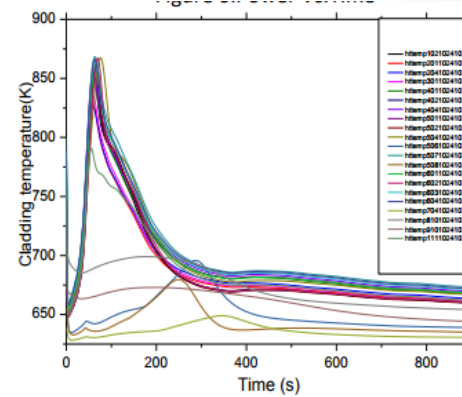
Coupled Neutronic, Thermalhydraulic and System Codes



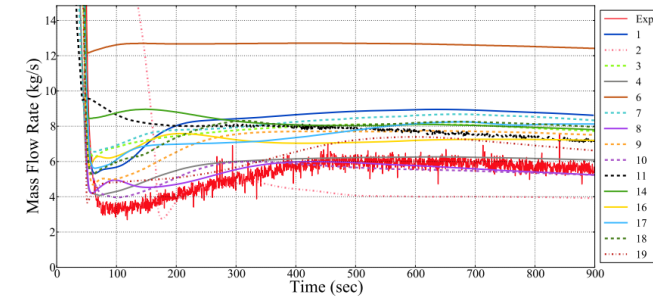
Plant Data



Modelling



Simulations



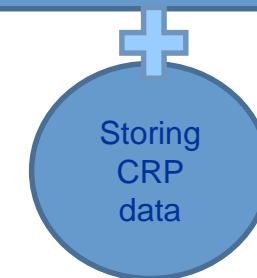
Comparison

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



Planned duration: 2018 – 2022

**Kick-off RCM: 22-25 October 2018**





# TM on Benefits and Challenges of Fast SMRs



*24-27 September 2019, Milan, Hosted by CIRTEN:  
Consortium of Italian Nuclear Universities*



Country	Participants /Papers
Belgium	4/1
China	2/2
France	1/1
Germany	2/0
India	1/1
Italy	13/5
Japan	3/2
Korea, Rep. of	2/3
Luxembourg	1/1
Netherlands	1/1
Russia	3/2
Slovakia	1/0
Switzerland	1/1
Sweden	1/1
USA	1/1
EC/JRC	3/1
<b>Total: 16</b>	<b>40/23</b>

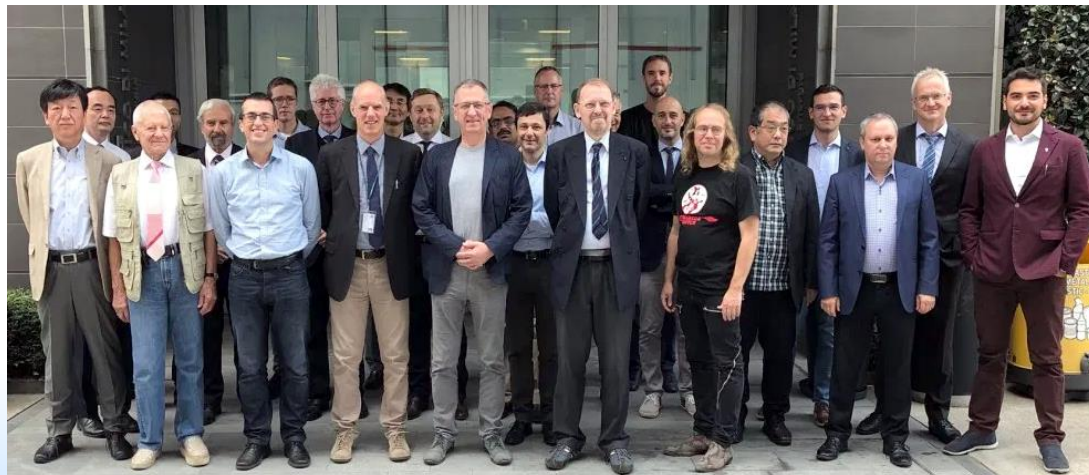
## Six Technical Sessions:

- Sodium Cooled Fast SMRs
- Heavy Liquid Metal Cooled Fast SMRs
- Safety Investigations
- Technology and Research in Support of Fast SMRs

## Three Group Discussions:

- In-factory construction
- Benefits of Fast SMRs including market needs
- Technological Challenges

TECDOC Proceedings to be published in 2020



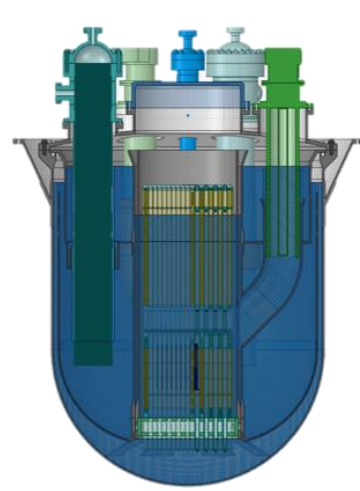
Thanks to advanced coolants, Fast SMRs can be safer and of simplified design

## BUT:

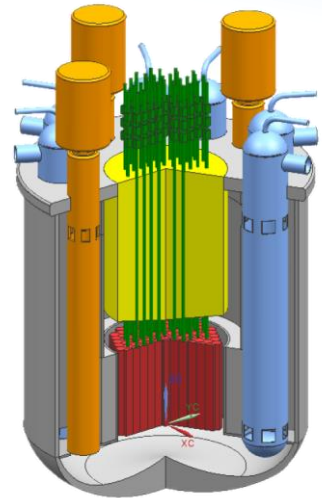
- Fast construction (in- factory) is required to win economic competition;
- Extended R&D are needed to fit technological gaps
- LFRs require more R&D to prove material compatibility and develop new materials
- Licensing challenges

# Liquid Metal cooled Fast SMRs

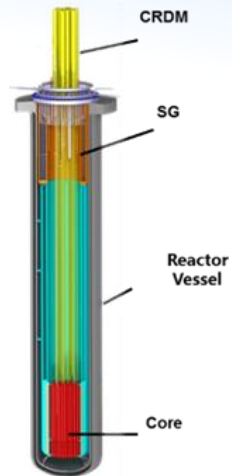
Latest reactor designs presented at TM on Fast SMRs in Milan



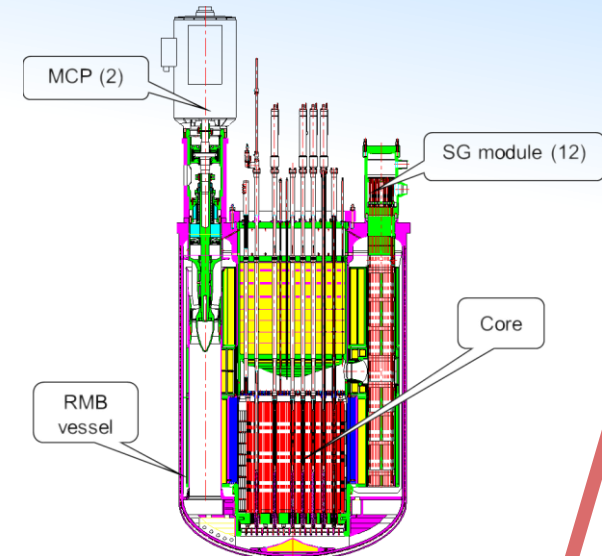
**ALFRED**  
125-250 MW(e)  
EU



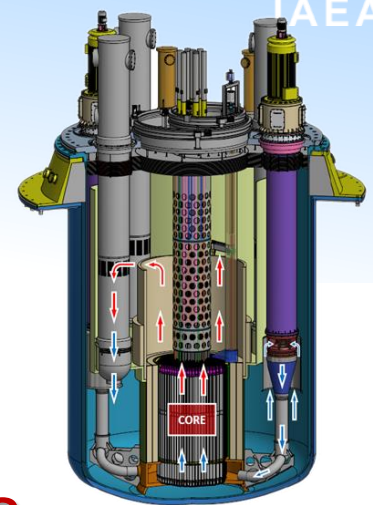
**CLFR-300**  
China



**14 MW(e) CLEAR-M10d**  
China



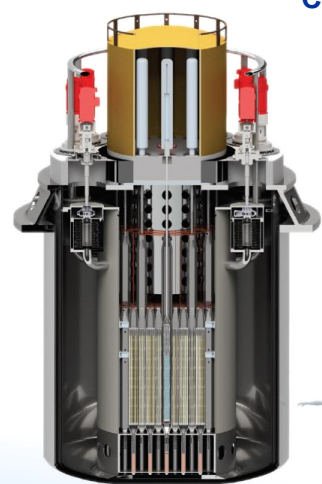
**CB5P-100 (LBE)**  
Russia



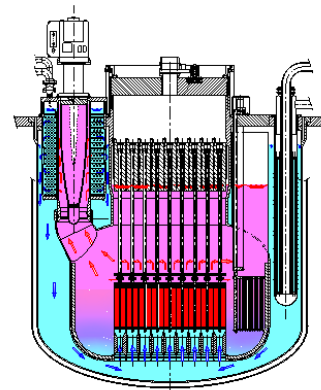
**150 MW(e) PGSFR**  
Rep. of Korea



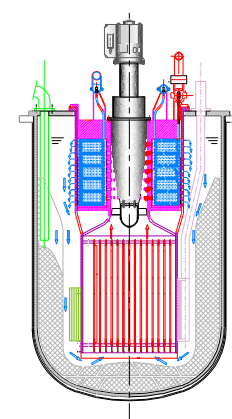
**3-10 MW(e) SEALER**  
Sweden



**55 MW(e) SEALER-UK**  
Sweden



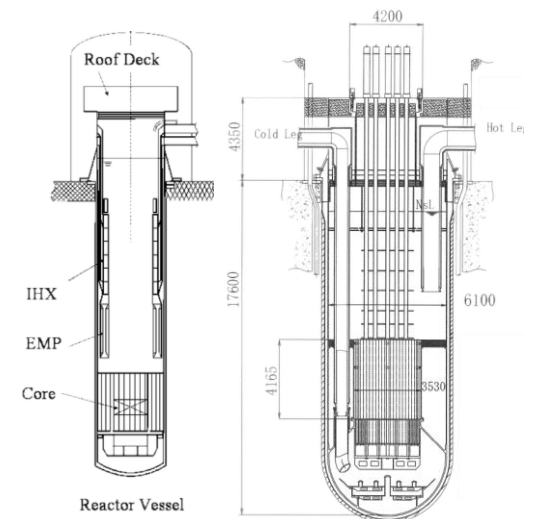
**LFR-AS-200 MW(e)**  
Luxembourg



**Transportable LFR-TL-5 MW(e)**  
Luxembourg

**SFRs**

**LFRs**



**50 MW(e) SMFR**  
Japan

**300 MW(e) SFR**  
Japan





# TM on Structural Materials for Heavy Liquid Metal Cooled Fast Reactors



Country	Participants /Papers
Belgium	2/1
China	7/4
Czech Rep.	3/1
Germany	1/1
Italy	5/3
Korea, Rep. of	4/1
Luxembourg	1/0
Netherlands	1/0
Romania	2/2
Russia	3/3
Slovakia	1/1
Sweden	2/1
UK	1/0
Ukraine	1/1
EC/JRC	1/1
<b>Total: 14</b>	<b>34/20</b>

## Three Technical Sessions:

- HLM Compatibility with Structural Materials
- Corrosion Mitigation Measures
- Qualification Programmes of Structural Materials

## Three Group Discussions:

- Outstanding Research Challenges
- New Materials and Coating Techniques
- Technology Readiness

*15-17 October 2019, Vienna*



TECDOC Proceedings to be published in 2020



# TM on LFR Materials: Sessions and Topical Discussions

IAEA

- General Chair: *Daniela Gugiu*
- IAEA Secretariat: *Vladimir Kriventsev, Chirayu Batra*

	Session Title	Chair(s)	Papers/ Presentations
I	HLM Compatibility with Structural Materials: Phenomena, Modelling and Operational Experience	Kamil Tucek (EC/JRC)	6/6
II	Corrosion Mitigation Measures: Coating, New Structural Materials, Environmental Conditioning	Peter Szakalos (KTH), Alfons Weisenburger (KIT)	6/8
III	Qualification Programmes of Structural Materials for HLM Fast Reactors	Bin Long (CIAE)	3/5

Group Discussion	Title	Moderator
I	Outstanding Research Challenges	Kamil Tucek
II	New Materials and Coating Techniques	Alfons Weisenburger
III	Industrialization	Erich Stergar



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



1<sup>st</sup> : June 2010

2<sup>nd</sup> : Dec 2011

3<sup>rd</sup> : Feb. 2013

4<sup>th</sup> : June 2014

5<sup>th</sup> : June 2015

## 6<sup>th</sup> GIF-IAEA Workshop on Safety of SFR

November 2016

## 7<sup>th</sup> 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

## 8<sup>th</sup> 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”

## 9<sup>th</sup> GIF-IAEA Workshop on LMFR Safety

18-20 March 2020



Advanced Non-Light Water Reactors –  
Materials and Component Integrity Workshop  
Vladimir Kriventsev, 9 Dec 2019, U.S.NRC, USA





# Online Catalogue on LMFNS Experimental Facilities

Experimental Facilities in support of Development and Deployment of Liquid Metal cooled Fast Neutron Systems



Includes an overview as well as detailed information on **150** experimental facilities under design, construction or operation

19 institutions from 14 IAEA Member States contributed

Freely Available at [iaea.org](http://iaea.org):  
Search for **"IAEA LMFNS"**

Updated August 2019!

IAEA.org NUCLEUS

IAEA Catalogue of Facilities in Support of LMFNS

Home LMFNS Facilities Database Overview of SFR Overview of LFR LMFNS Compendium

Catalogue of Facilities in Support of Liquid Metal-cooled Fast Neutron Systems (LMFNS Catalogue)

MYRRHABELLE facility - Belgium

This LMFNS catalogue is a [living database](#), which is, in its current form, presents an electronic version of section 4 of the IAEA Nuclear Energy Series publication (*in progress*) "Experimental Facilities in Support of Liquid Metal Cooled Fast Neutron Systems. A Compendium".

LMFNS Compendium. Summary of the IAEA publication

To overview the potential capabilities of 150 experimental facilities in 14 IAEA Member States to support the development and deployment of the innovative Liquid Metal cooled Fast Neutron Systems (LMFNS) and navigate yourself through the [LMFNS Facilities Database](#) click on the below buttons:

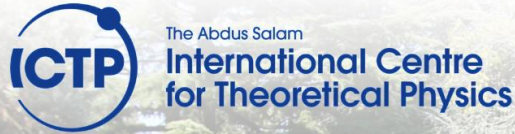
Overview of SFR Overview of LFR

For detailed information on these facilities 1) click on the below button "LMFNS Facilities Database" (also on top of this page), 2) select the Coolant technology - SFR, LFR or both in the search box, 3) use other search and filtering tools as appropriate, 4) click on the Facility Profile you are interested in.

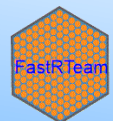
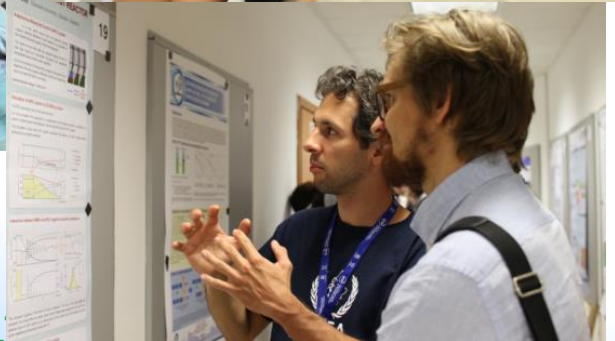
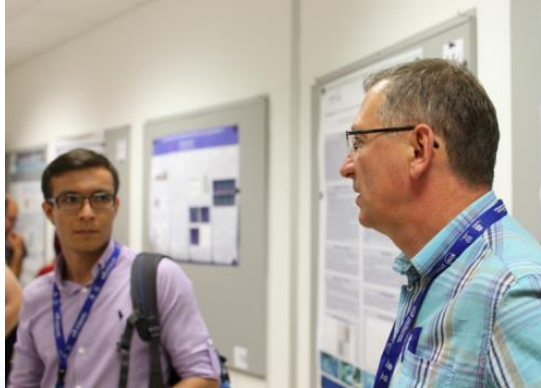
LMFNS Facilities Database



# 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
- **Next Workshop: 13-17 July 2020**



Advanced Non-Light Water Reactors  
Materials and Component Integrity Workshop  
Vladimir Kriventsev, 9 Dec 2019, U.S.NRC, USA



The Abdus Salam  
International Centre  
for Theoretical Physics

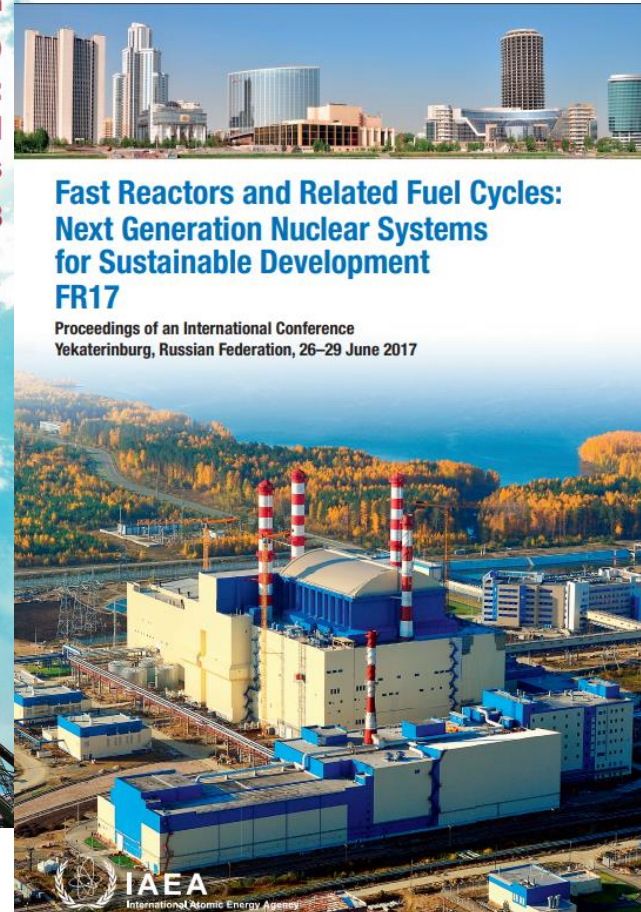


29 August - 2 September 2016  
Miramare, Trieste



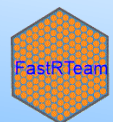
# FR09 >> FR13 >> FR17 >> FR21 Conferences

## IAEA International Conferences on *Fast Reactors and Related Fuel Cycles*



**FR21**  
**June 2021**  
**Vienna?**

**Yekaterinburg 2017**  
~600 Participants from  
27 IAEA Member States  
6 International Organizations  
460 Technical Papers  
10 Invited Plenary Speeches



**Advanced Non-Light Water Reactors –  
Materials and Component Integrity Workshop**  
Vladimir Kriventsev, 9 Dec 2019, U.S.NRC, USA

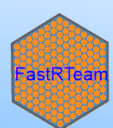
# Main IAEA Activities on Fast Reactor Technology in 2018 - 2019



## 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 Benefits and Challenges of Fast SMRs** (2019)
- **TM on Structural Materials for HLM Reactors** (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**
  - 51<sup>st</sup> TWG-FR Meeting in Hefei, China, 21-25 May 2018
  - **52<sup>nd</sup> TWG-FR Meeting in Romania, 10-14 June 2019**
- **Joint IAEA-GIF Workshops on LMFR Safety**
  - 7th GIF-IAEA Workshop on LMFR Safety: 27-29 March 2018
  - **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, 2020 in Trieste, Italy)
    - 3<sup>rd</sup> Workshop: 13 -17 July 2020
  - Regional Workshop on Advances in Modelling & Simulation of Thermal Hydraulics in LMFRs
    - 6-10 April 2020, India





# FRs: Planned Events and Activities in 2020-2021



Year	Title	Location
2020-2021	53 <sup>rd</sup> and 54 <sup>th</sup> Meetings of the Technical Working Group on Fast Reactors (TWG-FR)	
2020	4th RCM of CRP on Radioactive Release from PSFR under Severe Accident Conditions	Vienna
2020-2021	3 <sup>rd</sup> and 4 <sup>th</sup> RCMs of CRP on Neutronics Benchmark of CEFR Start-Up Tests	
2020-2021	2 <sup>nd</sup> and 3 <sup>rd</sup> RCMs of CRP on Benchmark Analysis of FFTF ULOF Test	
2021	New CRP on Benchmark Analysis of Loss-Of-Flow Test at CLEAR-S Pool Facility	China
2021	New CRP on Benchmark Analysis of STELLA-2 LOHS (or LOF) Test	Rep. of Korea
2021	New CRP on Computational Modelling of Total Instantaneous Blockage of SFR S/A	India
2020	Joint ICTP–IAEA Workshops on Physics and Technology of Innovative NESs	Trieste, Italy
2020	Regional WS on Advances in Modelling & Simulation of Thermal-Hydraulics in LMFRs	GNCEP, India
2020-2021	Training Course with PC-based SFR Simulators for Educational Purposes	
2020-2021	TM on Economic and Industrial Optimization of LMFR Designs	
2020-2021	TM on Proliferation Resistant Features of Fast Reactors and Related Fuel Cycles	
2020-2021	TM on Status of the IAEA Fast Reactor Knowledge Preservation Initiative	
2020-2021	Joint IAEA–GIF Workshops on LMFR Safety	Vienna
2021	<b>IAEA International Conference on Fast Reactors and Related Fuel Cycles (FR21)</b>	



*Thank you!*

email: [FR@IAEA.ORG](mailto:FR@IAEA.ORG)