Progrès Nucléaire

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IRCE Energy Symposium
Paris – May 16, 2019

Our Mission and cardinal Values

Promote progress for Mankind and Nature through the **improvement of Nuclear Power Systems.**

1. Science
2. Pragmatism
3. Ecomodernism
4. Independence

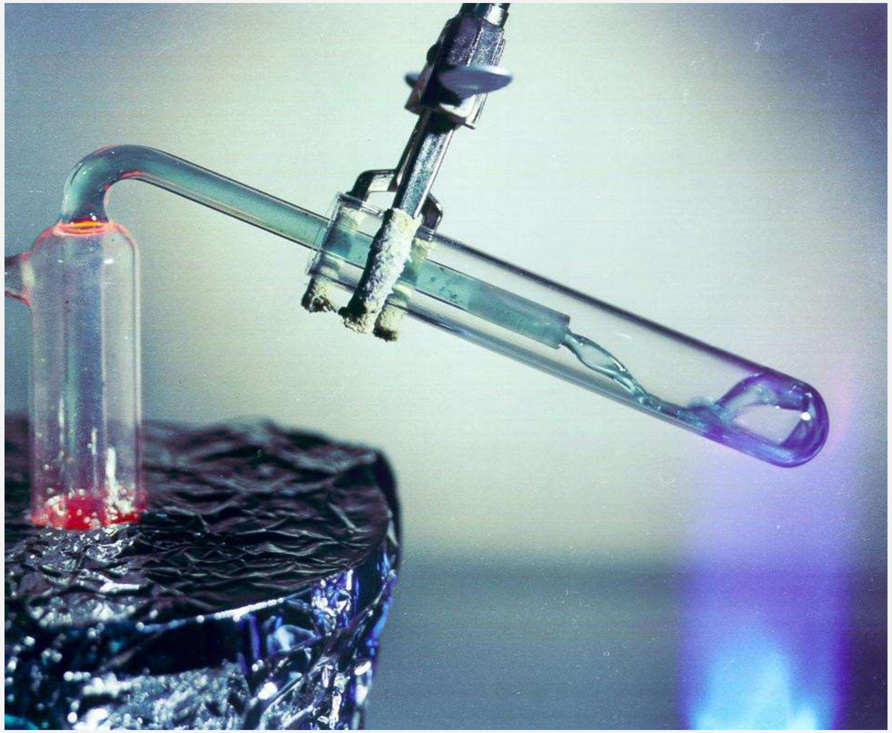
Our Goals

We believe **Molten Salt Reactors** (MSRs) represent the best current technology to answer the questions of **energetic prosperity** and **climate change**, offering an **efficient**, **safe** and **versatile solution.**

1. **Raise awareness** about Molten Salt Reactors
2. **Promote investments** in Molten Salt Reactors
3. **Create** a Molten Salt Reactor **community** and **facilitate exchanges between stakeholders**

What is a Molten Salt Reactor?

- Advanced Nuclear Reactor
- Use **Molten Salts** as **coolant/fuel**
- Most designs are **liquid-fueled**
- High-temperature heat
- Strong natural safety characteristics
- Closed fuel cycle potential
- Versatile

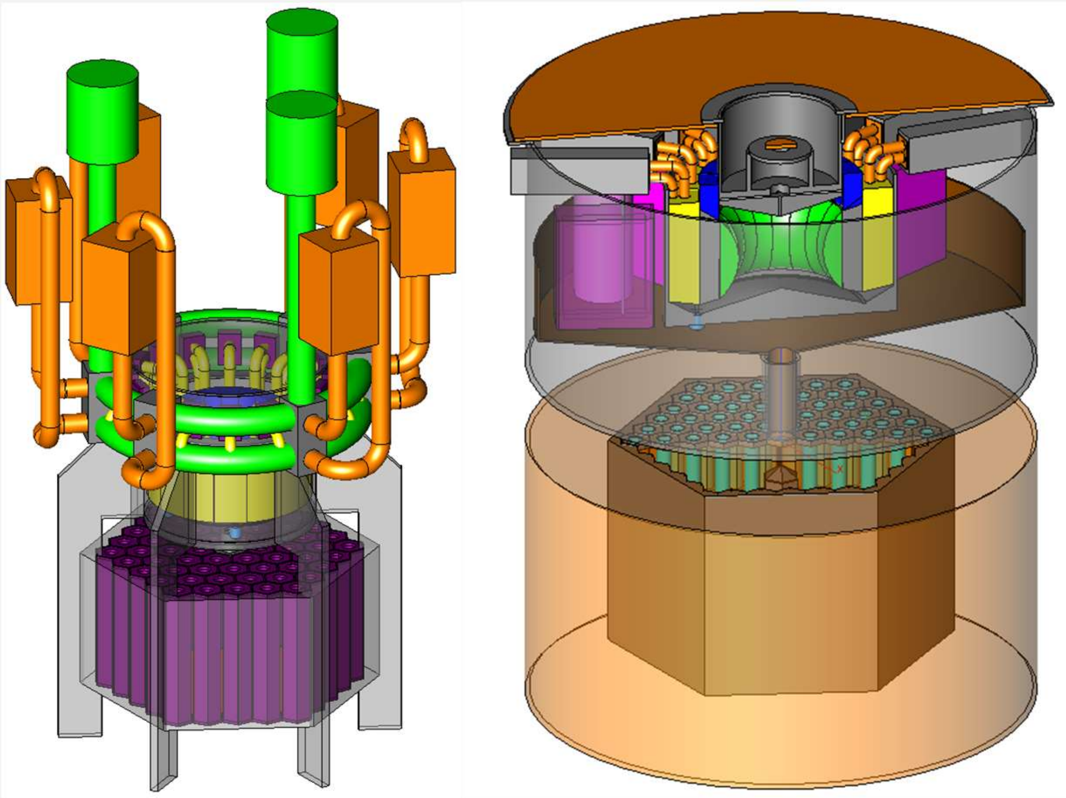


Molten fluoride with Uranium tetrafluoride

MSFR

2008: Selected by the Generation IV International Forum (GIF) as reference concept for MSRs
Developped since the 2000s in France (by the CNRS) and then in Europe

MSFR (Molten Salt Fast Reactor)



Slides with MSFR data taken from Dr. Elsa Merle’s presentation to OPECST (French parliamentary scientific choices evalution office) on the 24th May 2018

cnrs In2p3

LPSC Grenoble

NEEDS nucléaire énergie • environnement • déchets • société

SAMOFAR

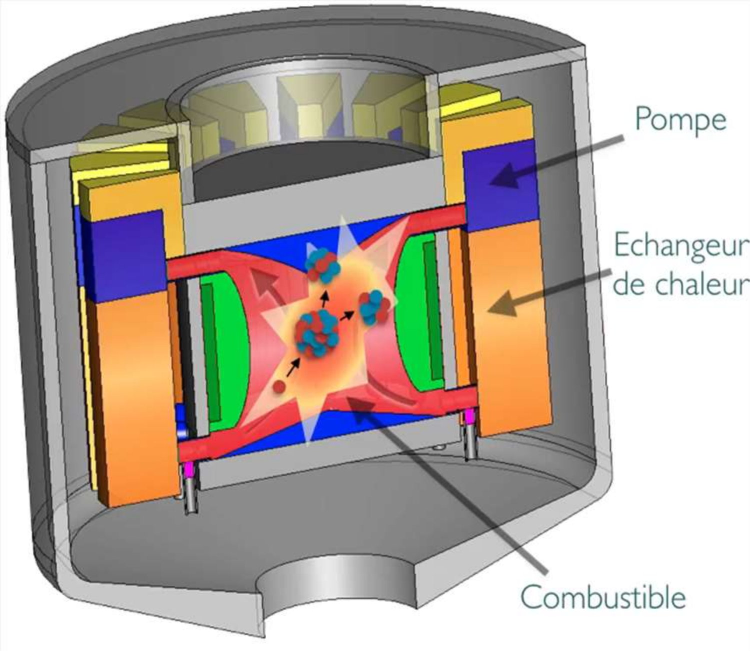
Grenoble INP

financé par IDEX Université Grenoble Alpes

MSFR - Concept

Technical characteristics:

- Cooled by circulating fuel
- Liquid fuel selected: molten fluoride salt
- High temperature = high thermal efficiency
- Compact reactor with simple core geometry
- Uses : Electricity generation, Waste burning, process heat…



Innovative characteristics compared to solid-fuel reactors :

- **Flexible reactor Design and Operation** at the level of **fuel composition**, **flexibility of operation** (load following), and of **power level**

- **No fuel fabrication as such** (cladding, assembly): cost reduction, ease of adding waste (actinides) produced currently to **burn it**

- **Removal of most accident initiators** + all **safety coefficients are excellent: Reactor with a high level of intrinsic safety**

MSFR – Safety

- **Goal** : exclude off-site consequences for the environment
- **Needs** : fulfill the **3 safety criteria** (control of *reactivity*, *cooling* of the fuel, *confinement* of radioactive elements), **remove accident initiators at the design stage**, avoid **accident degradation**

Control the chain reaction:

– All safety coefficients are excellent ⇒ intrinsic stability of the core
– Control rods not needed (removal of rod ejection risk)
– On-line fuel processing: continuous reloading, salt composition adjustment

Fuel cooling under all circumstances:

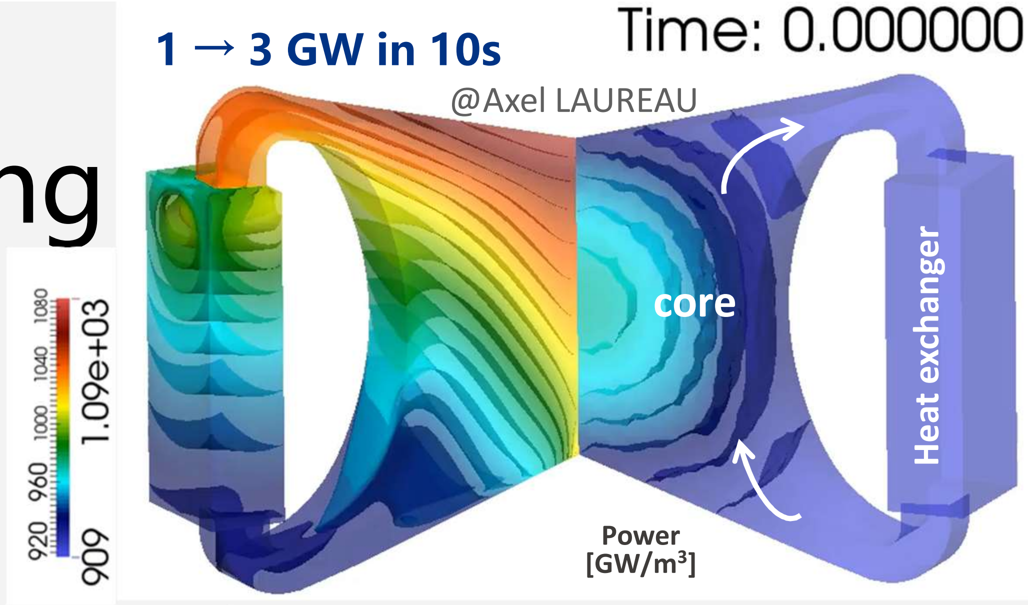
– Possibility of draining fuel to cooling tank with passive features

Confinement of radionuclides:

– System at near-atmospheric pressure
– Large margin to fuel/coolant boiling and no violent chemical reaction with the environment
– On-line fuel processing: removal of part of the radioactive inventory (fission products) from the core

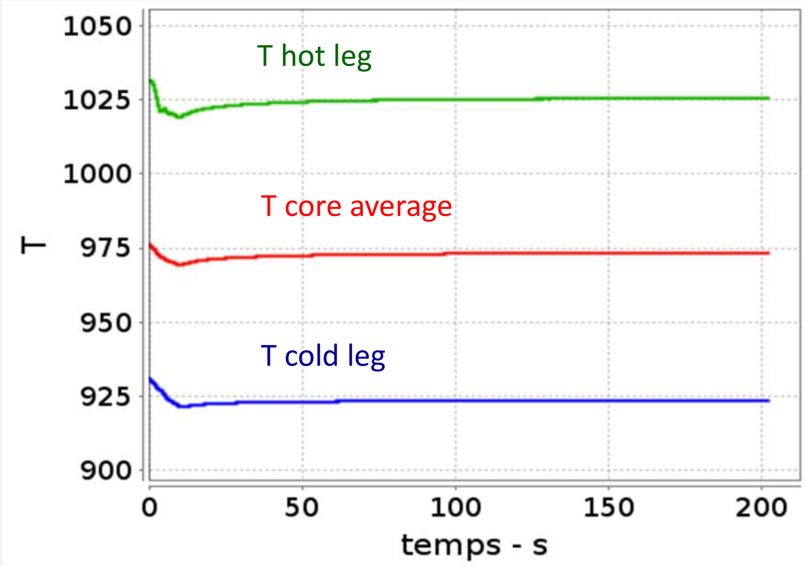
MSFR – Load Following

- **Goal** : grid balancing, essential to allow for an increase in variable renewable energy (VRE) generation
- **Needs** : Flexibility, Safety margins, low system fatigue, reduced investment cost to allow operation at reduced power



Characteristics of the liquid fuel reactor MSFR:

- Fission power directly deposited in coolant ⇒ **great flexibility of the core** which can follow grid load
- Power controlled by heat extraction **without necessitating control rods**
- Mass flow can be changed ⇒ **Average temperature of fuel and structures varies little** in power ramps thus low thermal fatigue
- Great intrinsic stability ⇒ **safety margins**

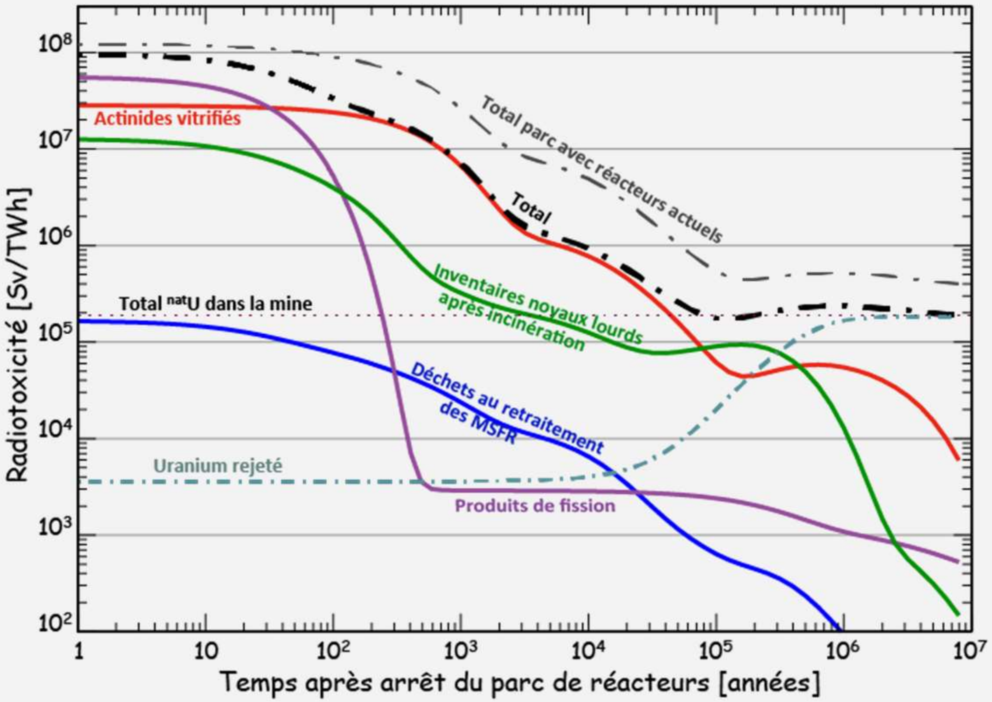


MSFR Transmutation

- **Goal** : reduce nuclear material amounts sent to the waste stream for current and future reactors, increase sustainability
- **Needs** : fuel management flexbility, safety margins, technical feasibility

Characteristics of a liquid fuel reactor:

- No fuel fabrication to speak of
- Actinides solubility
- Fast neutron spectrum possible depending on salt composition
- Several versions (energy production, waste burning) depending on fuel composition
- Excellent safety coefficients nearly independant on the fuel salt selection

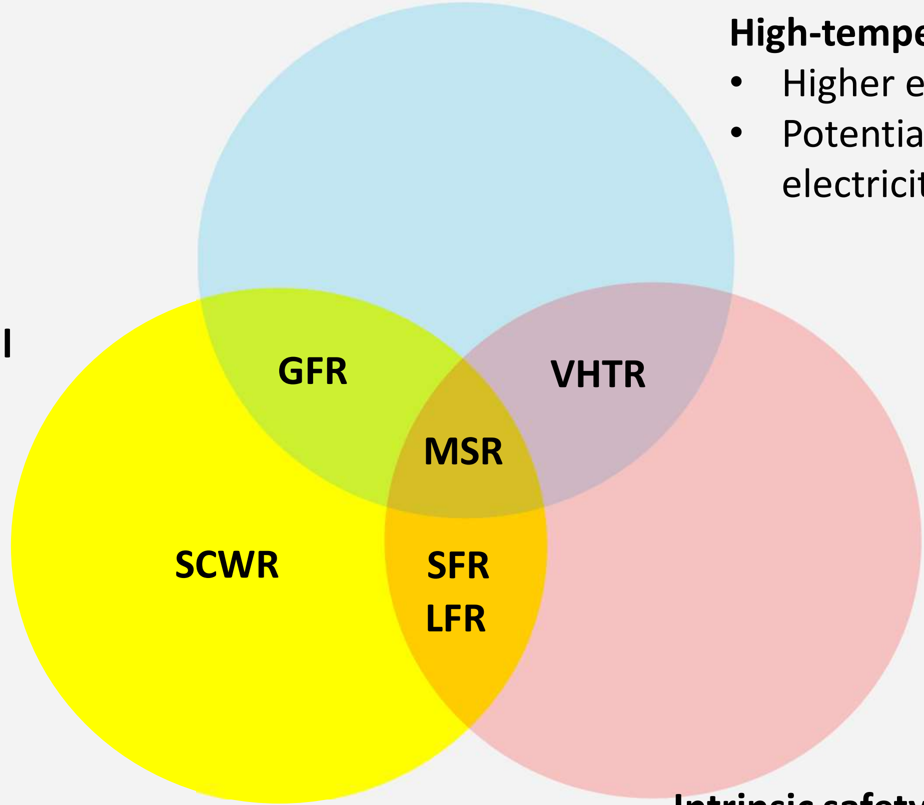


Radiotoxicity of the fleet reduced by a factor 3 to 10 and dominated by already vitrified waste, waste burning is efficient

MSR vs. other Gen IV systems

High-temperature
- Higher efficiency
- Potential for non-electricity generation

Closed fuel cycle potential
- Better resource utilization
- Less waste

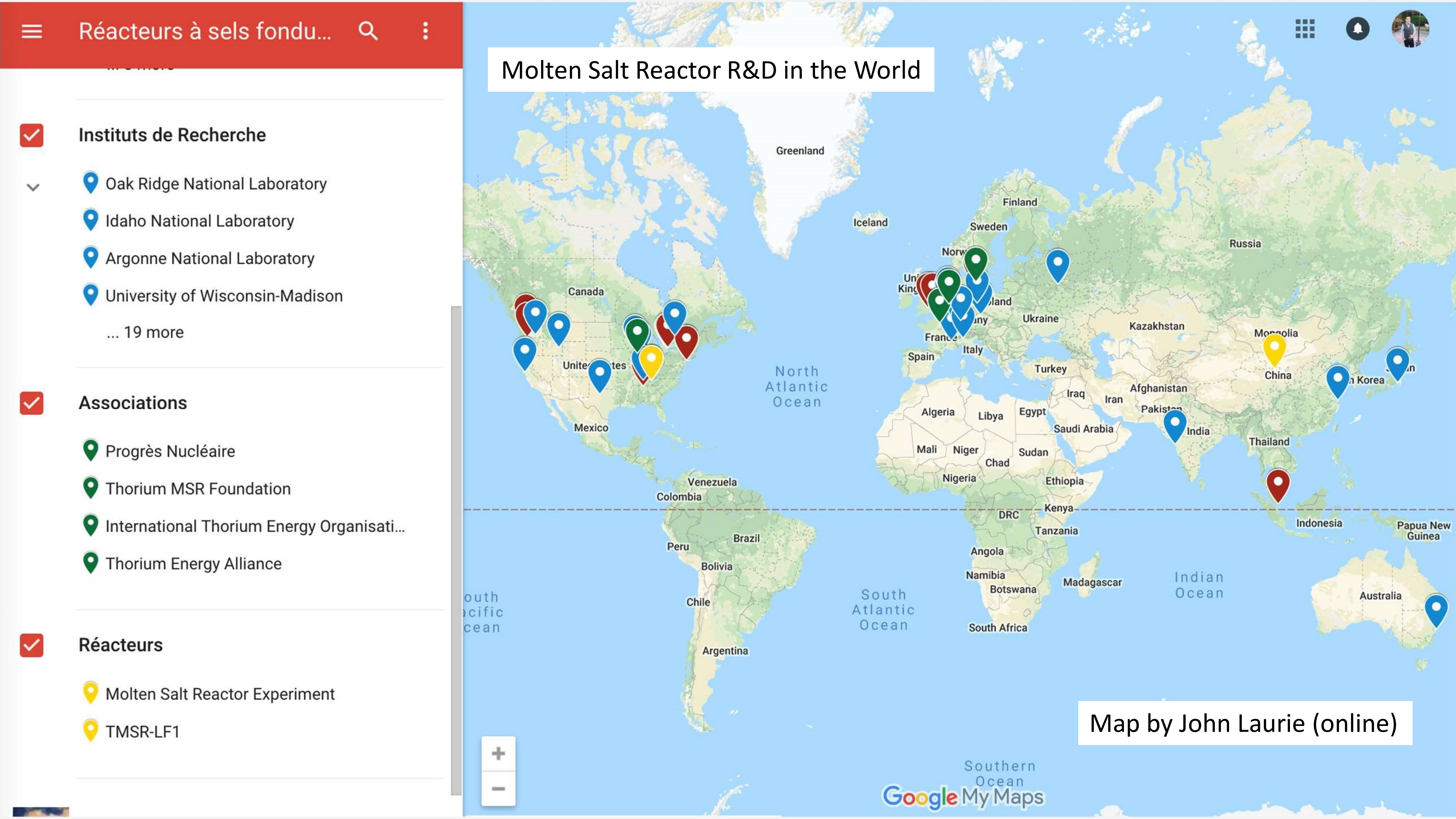


Intrinsic safety

Timeline of renewed interest in MSRs

- **2001**: Generation IV International Forum (GIF) founded
- **2002**: MSRs selected as part of the 6 GIF systems
- **2004**: France starts national R&D program (CNRS)
- **2010**: France & EURATOM join GIF MSR MoU
- **2011**: China starts national R&D program (CAS/SINAP)
- **2013**: Russia joins GIF MSR MoU
- **2015**: USA start national R&D program (DOE/ORNL), Switzerland joins GIF MSR MoU
- **2017**: Australia & USA join GIF MSR MoU
- **2019**: Terrestrial Energy (CAN, private) joins GIF MSR MoU

Molten Salt Reactor R&D in the World



Map by John Laurie (online)

R&D projects in Europe

Funding in France and Europe, 2000 →

Project	Financed by	€m	Dates	Goals / results
MOST	EURATOM FIKI-CT-2001-20183	0,6	2001 - 2004	Review of molten salt reactor technology
PCR ANSF	CNRS	1,8	2004 - 2011	Concerted research program – Molten Salt application to Nuclear
ALISIA	EURATOM 44809	0,25	2007 - 2008	Assessment of LIquid Salts for innovative applications
TSF	Institut Carnot Energie du Futur	0,3	2009 - 2011	Molten Salt Technology (FFFER molten salt loop in Grenoble)
EVOL	EURATOM 249696	1	2010 - 2013	Evaluation and Viability of Liquid Fuel Fast Reactor System
CLEF	Grenoble-INP (projet structurant)	0,2	2013 - 2015	Liquid nuclear fuel for future energy
SAMOFAR	EURATOM 661891	3,5	2015 - 2019	A Paradigm Shift in Reactor Safety with the Molten Salt Fast Reactor
SAMOSAFER	EURATOM	3,5	2020 -?	Follow up on SAMOFAR, safety-oriented

Current status in France

- CNRS/CEA MSR Days in Massy in March 2018
  - Publication of a Report on the status of MSR research
- Inauguration of Progrès Nucléaire in June 2018
- Open letter to the French Government in October 2018
  - Several reactions from major nuclear French actors
- 2 internal CEA Seminars on MSRs in November 2018

- We endeavor to start more discussions of this nature!

Conclusions & Outlook

- Molten Salt Reactors are a very promising kind of advanced nuclear technology
- Europe and particularly France lead the renewed research starting in the 2000s
- The rest of the World has since caught up with both strong public and private R&D funding
- We advocate for increased investment in Europe, both privately and publicly, in MSR research

Questions?

If in hindsight:

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Changeons d’ère, changeons le nucléaire !