Strategies and National Programs of Closed Fuel Cycles: Russian Expert Vision

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Actual Agenda:
New Technological Platform (NTP) of Nuclear Power

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NTP – Innovation Nuclear System (INS –definition by INPRO Project), which will includes:

- Full-scale reprocessing of Thermal Reactors SNF with production of Pu bearing fuel for Fast Reactors
- Fast Reactor Fleet with its Closed Fuel Cycle (FR CFC)
- This FR CFC includes full Recycle of Long-Lived MA and FP

So called Module of NTP =

TR SNF Reprocessing Plant + FR Fleet + FR CFC

GLOBAL STATUS OF SNF REPROCESSING

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COUNTRY	FACILITY	AMOUNT	OPERATION (Year)	CAPACITY (Fuel Type) tHM
France	Marcoule (UP1)	18, 000	1958 -1985	400 (GCR):decom
	La Hague (UP2/3)	25,000	1967/1990~	1600 (LWR)
Germany	WAK	180	1971 -1990	30 (LWR);decom
Japan	Tokai-Mura	1, 000	1977 ~	90 (LWR)
	Rokkasho-Mura	-	2006 ~	800 (LWR)
Russia	Chelyabinsk	3, 500	1971 ~	400 (VVER-440) real 100
	Krasnoyarsk	-	2020 ~	1500 (VVER-1000)
UK	B205	42, 000	1967~	1500 (GCR)
	THORP	4,390	1994 ~	900 (LWR)
USA	NFS West Valley	194	1966 -1972	194(LWR):decom
EURATOM	Mol	105	1966 -1975	105 (GCR+LWR):decom
India	Trombay/Tarapur/Kalpakam	?	1977~	~200 (LWR/PHWR)

Possible Reprocessing Plants

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Country	Reprocessing Plant (capacity, t/Year)	Start	Types of SNF	Possible Market/ NB
RUSSIA	RT-2/3 (up to 2000 t)	2025-2030	UO2 : VVER-1000, RBMK-1000 PWR	1000 t/Year – Russia 1000 t/Year - World
France	Gen-IV Plant (up to 2000 т)	2040-2050	UO2 , MOX: Any types of LWR and FR	1000 t/Year – France 1000 t/Year – World
China	Gen-III Plant (up to 2000 т)	2020-2025	UO2 , MOX: Only LWR	Only China
India	Gen-III Plant (up to 2000 т)	2020	UO2 : LWR и HWR MOX FR	Only India
Japan	Gen-IV Plant (up to 1000 т)	2050+	UO2 , MOX: Any types of LWR and FR	Only Japan
US	Gen-III Plant (up to 2000 т)	2040+	UO2 : LWR	Only US

Advanced Fuel Cycle

	Korea	USA	Japan	France	Russia	China	India
Policy	Wait and See	Direct → Reproces-sing	Reproces-sing	Reproces-sing	Reproces-sing	Reproces-sing	Reproces-sing
Introduc-tion Of AFC	-	~ 2050	~ 2025	2020 ~ 2040	~2025	~2025	~2020
Reproces-sing or Recycling Technolog y	Pyro	UREX+, Pyro	NEXT, Pyro	COEX /GANEX	Advanced Aqueous, Pyro, Vibro	Purex, Pyro	Purex, Pyro
Fast Reactor	SFR (Metal)	SFR (Metal, Oxide)	SFR (Oxide, Metal)	SFR (Oxide) GFR (Carbide, Nitride)	SFR /LFR (Oxide, Nitride)	SFR (Mixed oxide)	SFR (Mixed carbide, Oxide, Metal)

Examples of Transition Scenarios (1)

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Evolutionary Transition Scenario

Long-term horizon (2050)

1. Existing Large Reprocessing Plant for LWR SNF based on water technology
2. Adaptation the water reprocessing technology to FR SNF
3. Large centralized Reprocessing Plant for FR SNF based on water technology
4. Long-term horizon (after 2040-2050) development of AINFCT (Pyro) for CNFC

Countries – Japan (China?) – “French Influence Scenario”

Examples of Transition Scenarios (2-1)

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Combined Transition Scenario -1

Middle-term horizon (2025-2030)

1. New Large Reprocessing Plant for LWR SNF based on water technology (2020-2025)
2. Accelerated development the Pyro AINFCT for FR SNF reprocessing

3. Reprocessing Plant for FR SNF (2025)

Countries – (India?, Russia, US?)

Examples of Transition Scenarios (2-2)

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Combined Transition Scenario - 2

Long-term horizon (2040)

1. Existing Large Reprocessing Plant for LWR SNF based on water technology - till 2040
2. Development the AINFCT for FR SNF reprocessing
3. Large Reprocessing Plant for Gen-IV Reactors SNF - 2040

Countries – France (Itself French Scenario)

Examples of Transition Scenarios (3)

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Accelerated Innovative Transition Scenario

Middle-term horizon (2025)

1. New Large Reprocessing Plant for LWR SNF based AINFCT (Fluoride volatility + Pyro) – 2025
2. Accelerated development the Pyro AINFCT for FR SNF reprocessing
3. On-Site Reprocessing Plants for FR SNF - 2025

Countries – Russia?, India?

Russian National Program

ГК "РОСАТОМ"

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Stages of Russian nuclear energy innovative development

The Initial stage till 2020:

Creation of experienced-industrial infrastructure of CNFC and technologies development, providing its evolution.

Transitional stage 2020-2030:

Development of CNFC technology on industrial scale.

Main stage after 2030:

NE development based on a new technological platform.

Large-scale NE as a basis of the energy provision for national and world development is possible when based on the following key technological and system decisions:

- NE system based on CFC with FR and TR;
- NE system with high temperature reactors;
- Optimum recycle for MA and LLFP;
- International Fuel Cycle Services Centres

FTP "Nuclear energy technologies of the new generation" in 2010-2020

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Concept of the program is:

consolidation of efforts and resources to create the basis of new technological platform in 2020-2030 and till 2050, including :

1. key technologies of new generation:

- *high safety reactor technologies (SFR, PFR, PBFR);*
- *the new types of fuel;*
- *dry reprocessing of spent fuel;*
- *final disposition of radioactive waste.*

2. the experimental research base, providing achievement of these tasks, as well as groundworks for new technologies.

Russian Federal Tasks-oriented Program "New Generation Nuclear Power Technologies" (2010-2020)

- *New Reactor Systems:*
  - *Commercial SFR*
  - *Unique Test SFR – MFTR (MBIR)*
  - *Pb FR – BREST-300*
  - *Pb-Bi FR – SVBR-100*
- *Advanced NFCT*
  - *Pyro-reprocessing (Molten Salt + Fluoride Vol.)*
  - *High-density Fuels for FR*
  - *HLW management*
- *Advanced experimental base*
- *Others*

Characteristics of new Russian fast test reactor – Multi-functional Fast Test Reactor (MFTR/MBIR)

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FTP "New Generation Nuclear Power Technologies

Characteristic	Value
Maximum flux Φmax, n/cm^2·s	~ 6.0·10^{15}
Thermal power, MWth	~ 150
Electric power, MWe	~ 40
Number of independent experimental loops (~1 MWth each, sodium, heavy metal and gas coolant + water coolants)	3 (+1 behind reactor vessel)
Fuel	Reprocessed Vi-pack MOX, (PuN+UN)
Core height, mm	400-500
Maximum heat rate, kW/l	1100
Number of vertical experimental channels 100-200 mm in diameter	up to 7
Maximum fluence in one year, n/cm2	~ 1,2·10E23 (~55 dpa)
Design lifetime	50 year
RR creation time	2009 – 2018

Federal Tasks Program
"New Generation Nuclear Power Technologies"

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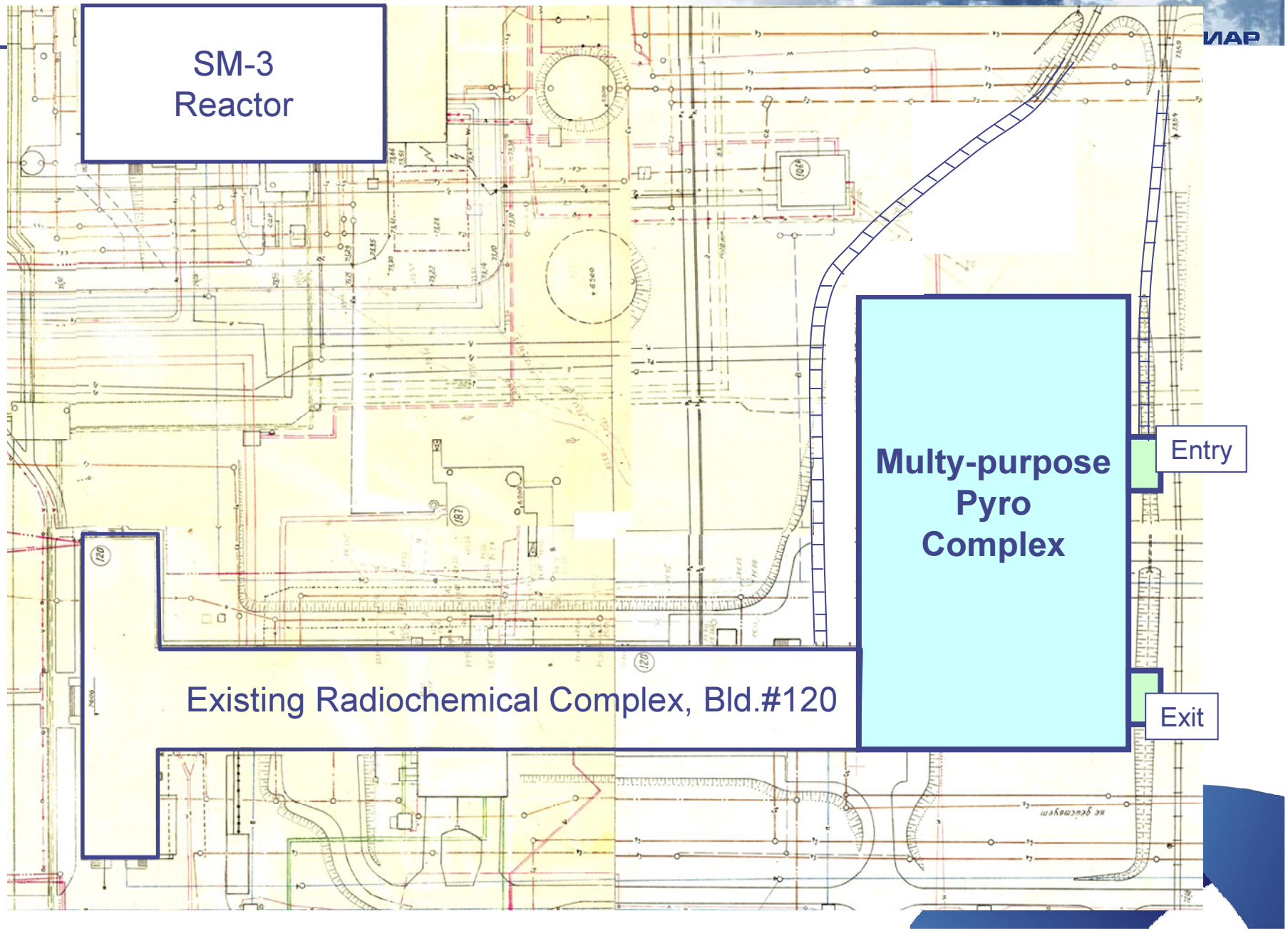
RIAR planned participation in the field of AFC

- Large Multi-purpose Pyro Complex (MPC) - 2017
  - Molten salt Reprocessing Facility
    - ✓ capacity – up to 2 500 kg of FR SNF per Year (fuel type: oxide, nitride, metallic, IMF)
  - Fluoride volatility Reprocessing Facility,
    - ✓ capacity – up to 1000 kg of SNF per Year (mainly – LWR SNF)
- New Lab for Experimental and Innovative Fuel Production – 2010-1014
  (incl. Fuel and Targets with MA)
- New facility for HLW treatment
- Demonstration of Closing Fuel Cycle based on Pyrochemical technologies -2017-2020-... on a levels:
  - Up to 120-130 spent FAs of BN-600/800
  - Full scale CFC for MBIR from initial fuel loading
  - Other experimental implementations

Main goals of RIAR MPC for 2020

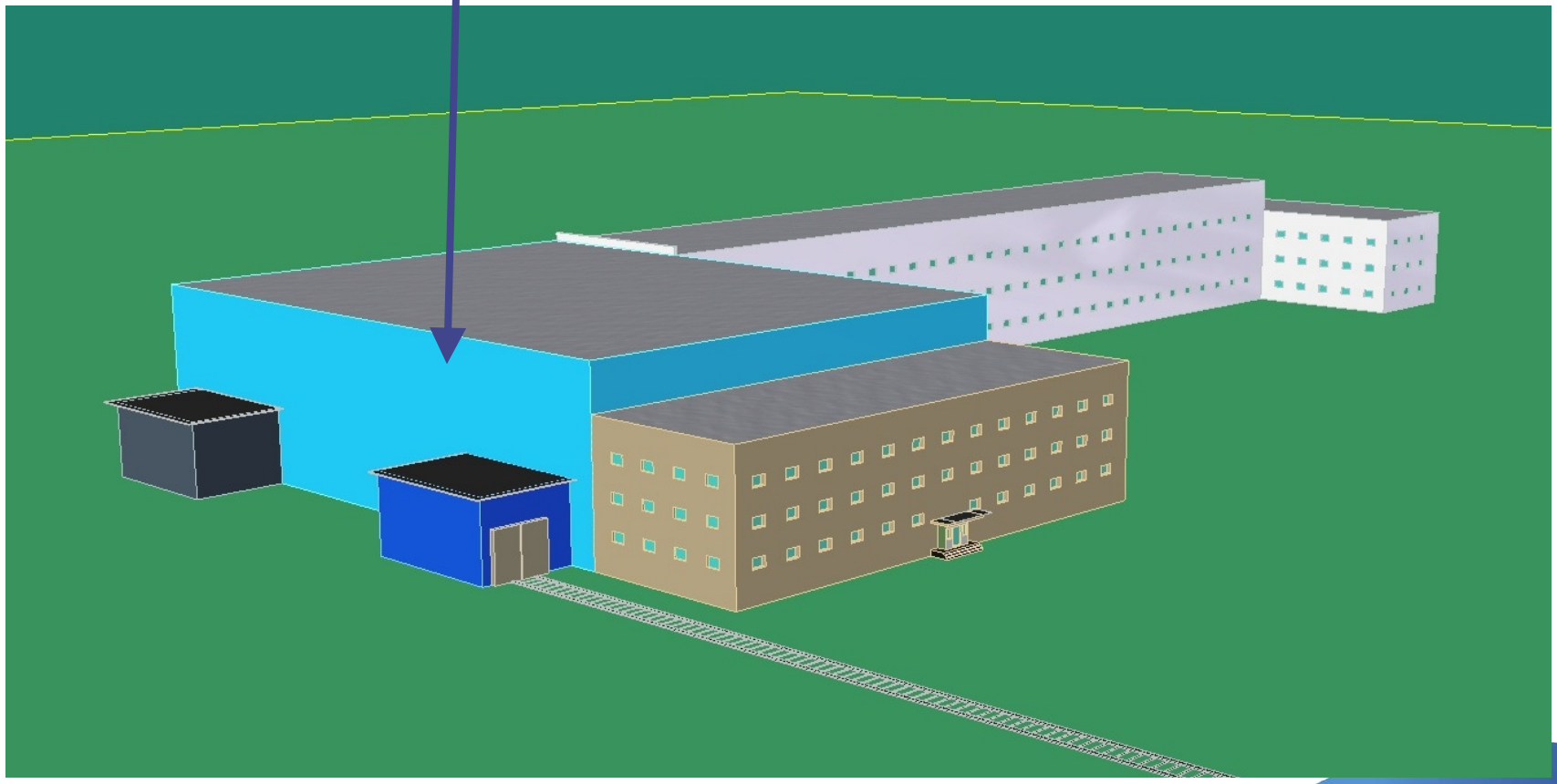
- Development of Pyro reprocessing technologies on a semi-industrial level:
  - FR SNF – molten salt technologies
    - MOX
    - Mixed Nitrides
    - Metallic
  - LWR SNF – combination of fluoride volatility and molten salt technologies
    - UOX
    - MOX
  - Others
    - So called hard-to-reprocessing SNF (test and transportation reactors)
    - Innovation types of fuel (IMF, MSR +++)
- Demonstration of Closing of BN-800 Fuel Cycle - on a semi-industrial level
    - up to 30 % annual loading, i.e. up to 3,5 – 4 t of MOX SNF per Year
- Testing and Demonstration of Closing FR Fuel Cycle for MA
- Develop the Initial Data for full scale Design of Industrial Pyro Module for FR SNF Reprocessing

MPC location at RIAR site

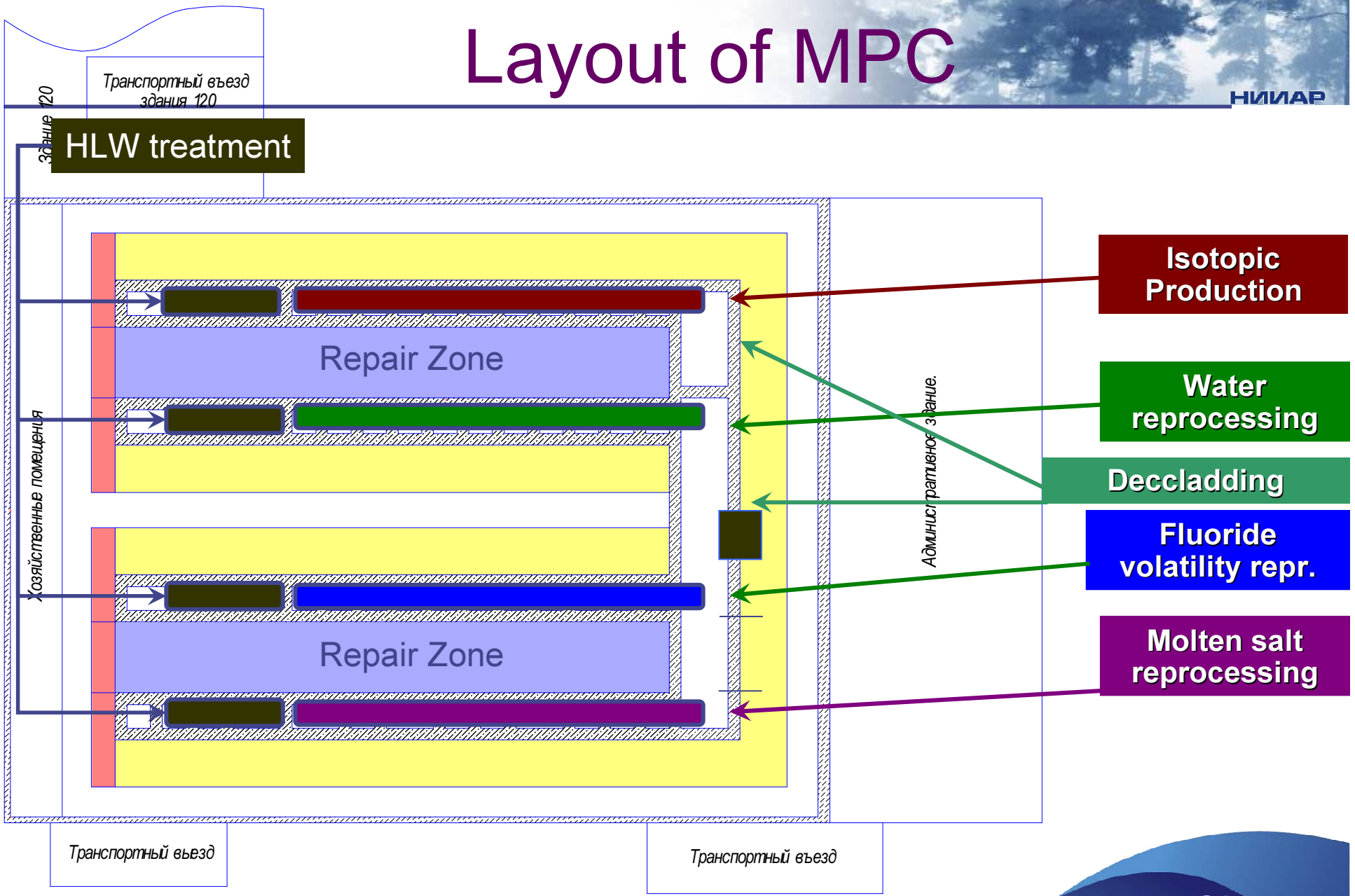



SM-3
Existing
Rad-Chem
Complex
MPC

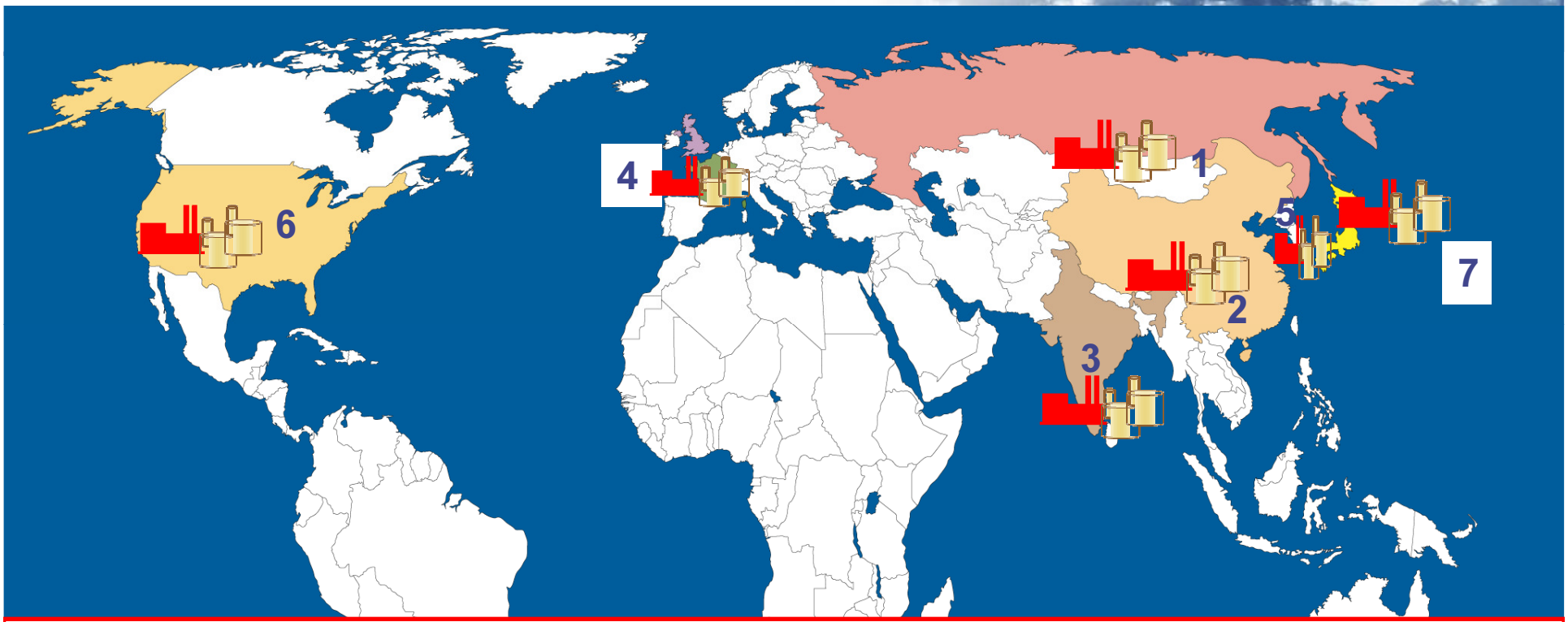
3D View on MPC



Layout of MPC



NTP modules in a world



1. Russia – (2025+): BN-800 + RIAR Pyro Module (2017) + Repr. Plant RT-2/3 (2025+)
2. China – CDFR (2018+)
3. India – 6 Units of PFBR/CFBR + Water reprocessing
4. France – ASTRID (2020+) + La-Hauge reprocessing Plant
5. Rep. of Korea – KALIMER (2025+)

6. US - Probably INL site (2050+): AFCI
7. Japan - Pilot JSFR (2025+)

Reactor base of national NTP

Country	Reactor	Fuel	Coolant	Capacity (MWe) /+NB	Repro-cessing	Start
Russia	BN-800	MOX (nitrid)	Na	880 MWe / Pu weapon grade	Pyro	2014
	BREST	Nitride	Pb	1200 MWe	Pyro	2020+
China	2 units CDFR	MOX	Na	800/900 MWe	?	2018+
India	6 units PFBR/ CFBR	MOX	Na	500 MWe	Water	2011-2023
	Series FBR	Met. U+Pu	Na	500 MWe / BR=1,6	Pyro	20223+
France	ASTRID	MOX	Na	350-500 МВт / MA fuel	Water	2020+
Korea	KALIMER	Met. U+Pu+Zr	Na	300-500	Pyro	2025-2030
Япония	JSFR	MOX	Na	?	Water	2025+
US						

Schedule of NTP development

- France
  - 2006-2008 – start of NTP
    - Conceptual Design of ASTRID Reactor
    - Design of new fuel facility for ASTRID (MOX and fuel with MA)
  - 2012 -2014
    - Start of ASTRID construction
  - 2020
    - ASTRID putting into operation
- India
  - 2011
    - Putting into operation of PFBR -500 with pellets MOX fuel
  - 2013 - 2023
    - Putting into operation of 5 units of CFBR (totally – 3,0 GWe of SER!)
  - 2015 - 2025
    - Industrial FR CFC (water reprocessing of FR MOX fuel)
  - 2023+
    - New generation of SFR with metallic fuel and pyro reprocessing
- Rep. of Korea
  - 2025 -2030
    - Pilot SFR with metallic fuel and pyro reprocessing
- China
  - 2020
    - CDFR-800/900
- Japan
  - 2025
    - Pilot JSFR

Final key notes

New International Policy of Russian State Corporation "Rosatom"

- Russian Federal Tasks-oriented Program (FTP) "New Generation Nuclear Power Technologies" (2010-2020) **now is open for international cooperation**
- **Not only for R&D collaboration**
- **But also for large-scale commercial type cooperation based on main Projects of Russian FTP**
- **For example:**
  - International fast reactor MBIR
  - International R&D Center based on RIAR Pyro Reprocessing Complex
  - International commercial fast reactor Project
  - Possible International Consortium for mutual development and future selling of Commercial FR and CFC service on a World Market
- **Nowadays we are ready to initiate the widely international discussions**
- **We are open for any ideas!**