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CHALLENGES TODAY.
RESPONSIBILITY FOR AGES

„Successful Completion of the RBMK-1500 Defueling Project at the Ignalina Nuclear Power Plant: Experience and Expertise Gained“

26 September 2022

ACCREDITED
MSCB-113

G-CERTi
SYSTEM SERVICE
ISO 9001:2015
GKLT-0199-QC

Ignalina NPP decommisioning activities are co-financed by the European Union

Ignalina NPP - general information

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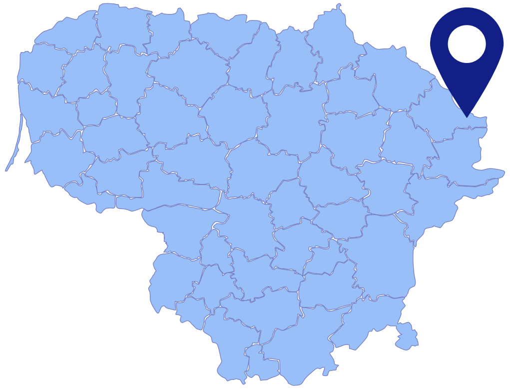

Location: Far north-east corner of Lithuania. Immediately bordering Latvia and Belarus

Design: 2 × RBMK-1500 water-cooled, graphite-moderated channel-type power reactors

Capacity: Intended to supply NW region of former USSR (not Lithuania). After independence, one unit could produce 80% of Lithuanian electricity demand

Operation:
Unit 1 commissioned Dec 1983 / closed Dec 2004
Unit 2 commissioned Aug 1987 / closed Dec 2009

Ignalina NPP - Strategy and Plan

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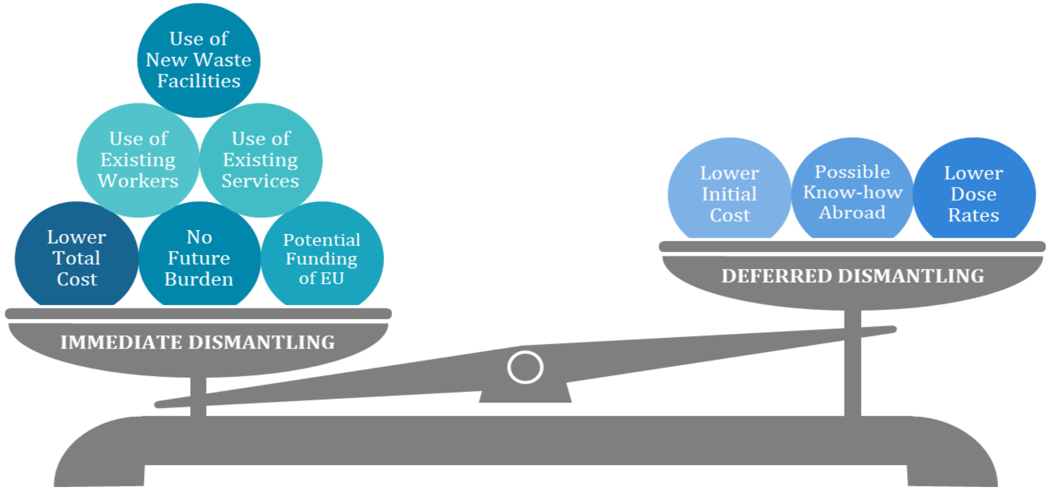
Strategy

- **Immediate Dismantling** selected by Government for technical, social and financial reasons



Final decommissioning plan

- **Technical measures** for dismantling, radioactive waste management and disposal with financial estimate.
- Approved 2005, revised 2014, next update plan 2019 verified and accepted by the EC

Ignalina NPP Decommissioning Plan

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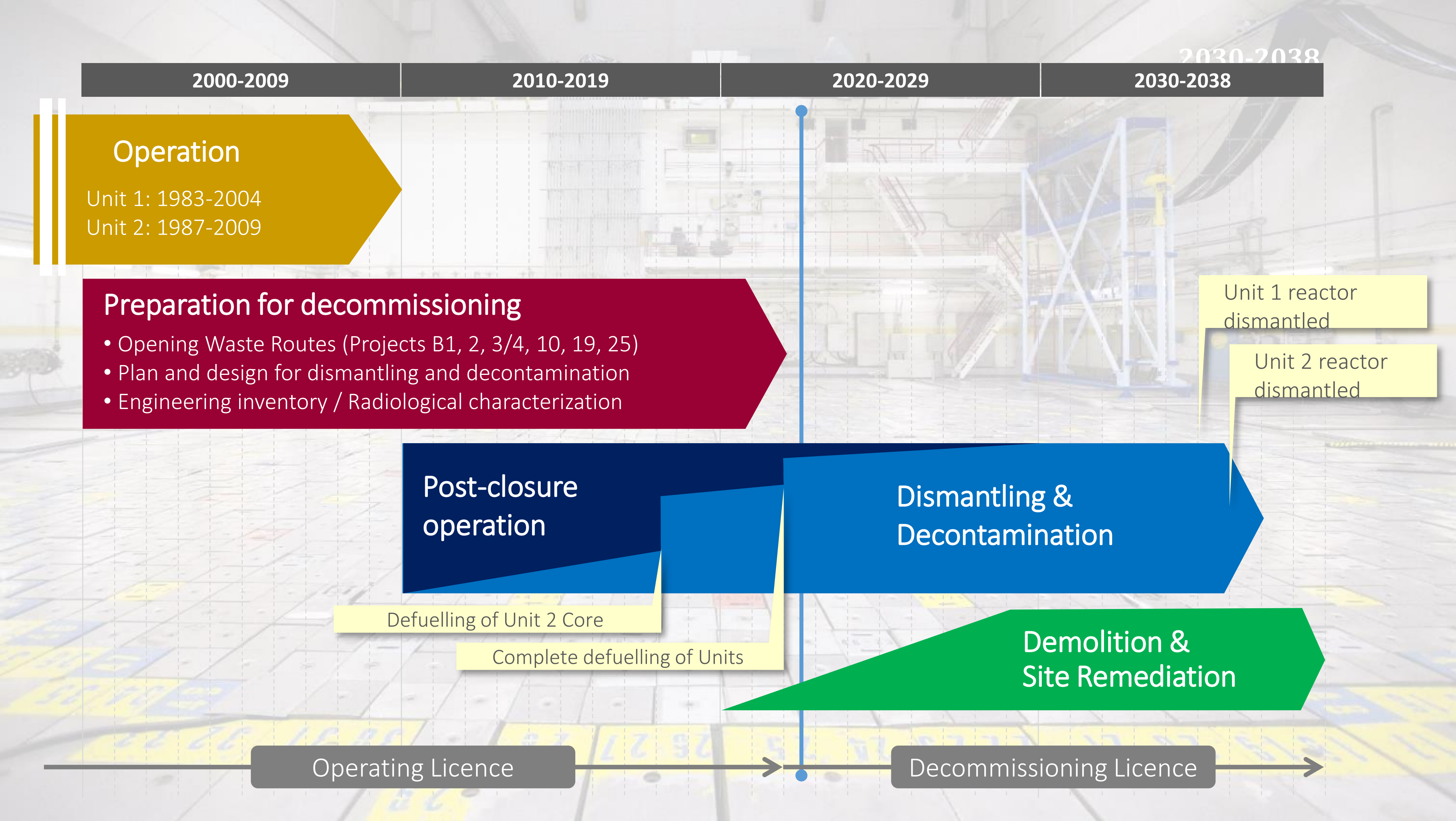

Ignalina NPP Opening Waste Routes and Dismantling

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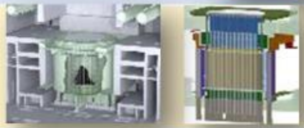
Stored Operational Waste (legacy)	Solid Waste	A B C	27,000 m^3
	Bituminized Waste	B	14,000 m^3
	Cemented Waste	C	4,000 m^3
Decommissioning Waste from Technological equipment D&D	Technological equipment (Steel)	A B C	180,000 t
Decommissioning Waste from Reactor D&D	Steel	A C D E	12,170 t.
	Graphite	D E	3,800 t.
	Fillers	A C	11,940 t.
Decommissioning Waste from Buildings demolishing	Concrete	0 A B	900,000 m^3
	Steel	0 A	200,000 t.
Spent nuclear fuel	Fuel Assemblies		21,571 item



Waste classification

- 0 Free Release Waste

Short-lived Low Level and Intermediate Level Waste:

- A Very Low Level Waste (<0,5 mSv/h)
- B Low Level Waste (0,5-2 mSv/h)
- C Intermediate Level Waste (>2 mSv/h)

Long-lived Low Level and Intermediate Level Waste:

- D Low Level Waste (<10 mSv/h)
- E Intermediate Level Waste (>10 mSv/h)

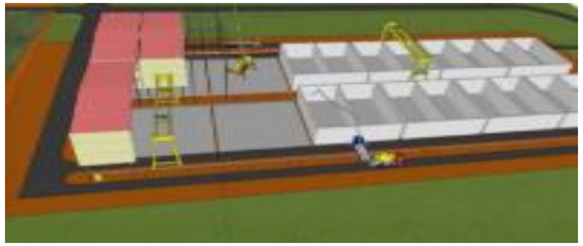
Implementation of ISFSF (B1 projects) and Units defueling program

Operational Waste Retrieval Units (B2) – in operation since 2018

Solid Waste Treatment and Storage Facilities (B3/4) - in operation since 2018

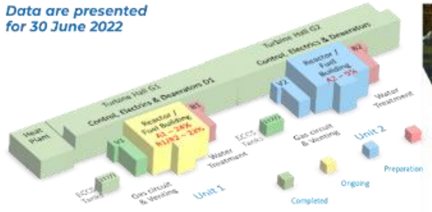
Very Low Waste Disposal (B19) – 1-st loading campaign is ongoing

Low and Intermediate Waste Disposal (B25) – construction procurement



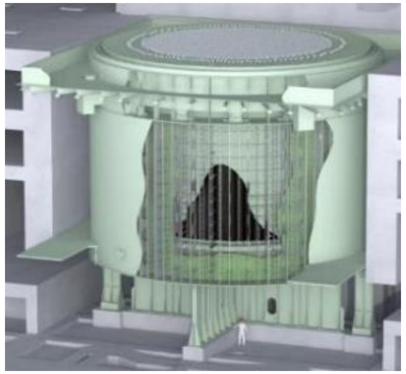
Series of Dismantling Projects – about 63000 t already dismantled

Data are presented for 30 June 2022



	x 1000 tons	2010-2021 (in all)	2010-2038 (in all)
Dismantled:	Equipment	62,4	180
	Concrete	9,2	1 920
Waste free-released:	Equipment	50,6	125
	Concrete	8,3	1 755

Reactors Dismantling Projects – tender for concept preparation



Spent Fuel at INPP after Units Final Shutdown in 2010

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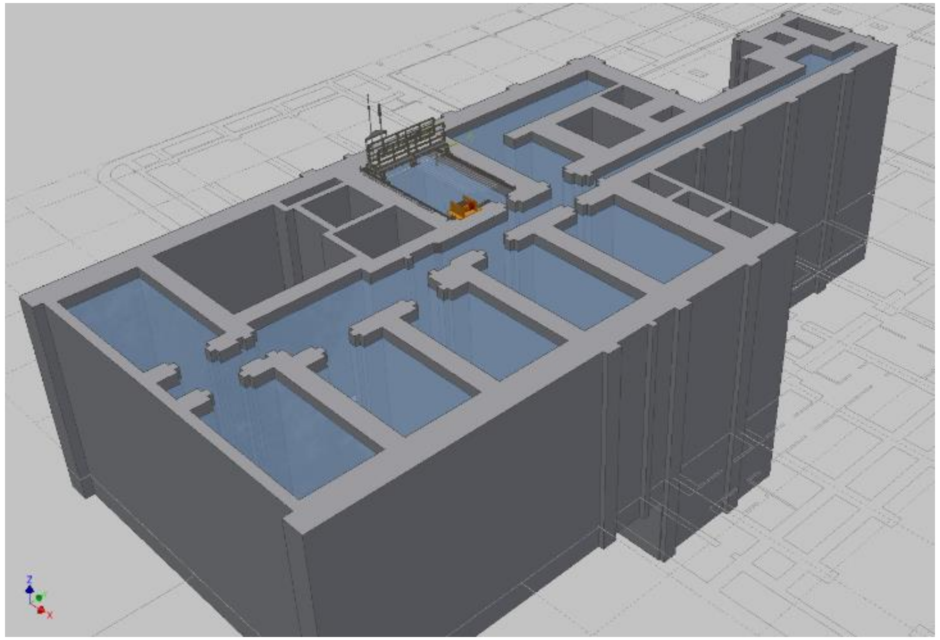
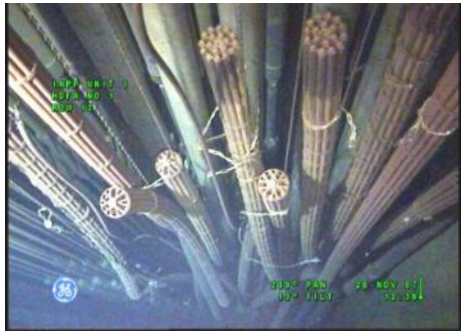
The specifics of INPP case are:

- The Spent Fuel Pools and Hot Cell for SFA cutting are built into the main Reactor Building
- Nuclear Spent Fuel has different U235 enrichment of 2.0, 2.4, 2.6, 2.8%
- In the 1990s a number of heavily damaged SFA occurred during operation in the SPH pools





Spent Fuel at INPP after Units Final Shutdown in 2010

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Unit 1:

- 0 fuel assemblies in the reactor core
- 7481 fuel assemblies in pools

Unit 2:

- 1653 fuel assemblies remain in the reactor core
- 6727 fuel assemblies in pools

Existing Dry Interim Storage Facility

- 5710 fuel assemblies in CASTOR and CONSTOR casks
  - → All storage capacity is used and no possibility to extend
  - → Designed and licensed for intact and 2.0% enriched fuel only

Dry Spent Fuel Storage Facility was put in operation in 2000

- CASTOR -20 casks, CONSTOR M1 - 98 casks.
- Heating -5,6 kW.
- Weight of the loaded cask ~ 90 tons.
- Loading -2% enrichment fuel, tight only.
- Load capacity – 51 SFA in cask.
- Design storage period – 50 years.

- Spent Fuel is the biggest hazard at the Units after final shutdown
- Necessity to operate the SF handling system and ensure corresponding safety limits and conditions
  - → Additional human and energy recourses
- Impossible to start dismantling activities in the Reactor Buildings
- Operational License is mandatory until the complete Units' defueling

INPP Units Defueling Program Objective and Scope

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The Objective:

- Safe defueling of INPP Units reactor cores and Spent Fuel Pools

The Scope:

- To build a new Interim SF Storage Facility with the capacity for at least 18000 SFAs
- To design, justify safety and manufacture casks for INPP RBMK-1500 type reactor spent fuel
  - → different enrichment (2.0-2.8%)/ burn up
  - → leaking / mechanically damaged
- To develop the technologies / modify existing ones for casks loading at Units and transportation from Units 1&2 to ISFSF
- To commission the new facilities, safe defueling and SPH pools cleaning

The Projects:

- B1 project (Contractor: Nukem – GNS, EBRD funding adm.)
  - Design and construction of ISFSF
  - Design and manufacture of the new casks
  - To develop the technologies for casks loading at Units and transportation from Units 1&2 to ISFSF
  - To develop the technologies for casks loading with heavily damaged SFA.
- External engineering infrastructure construction (utilities supply, technological road, CPMA funding adm.)
- B1-5 project (Contractor: Konecranes, EBRD funding adm.)
  - To enhance SPH Main Cranes 125 t reliability and safety
- FIHC modification project (Contractor: Nuvia, EBRD funding adm.)
  - To ensure a possibility to inspect SF for all types of the casks
- Fuel Debris Recovery Project (Contractor: Hofer&Bechtel, EBRD funding adm.)
  - To inspect SF pools, to remove the slug and scrap from the pools bottom and recover fuel debris if found

Technology – Casks and Storage

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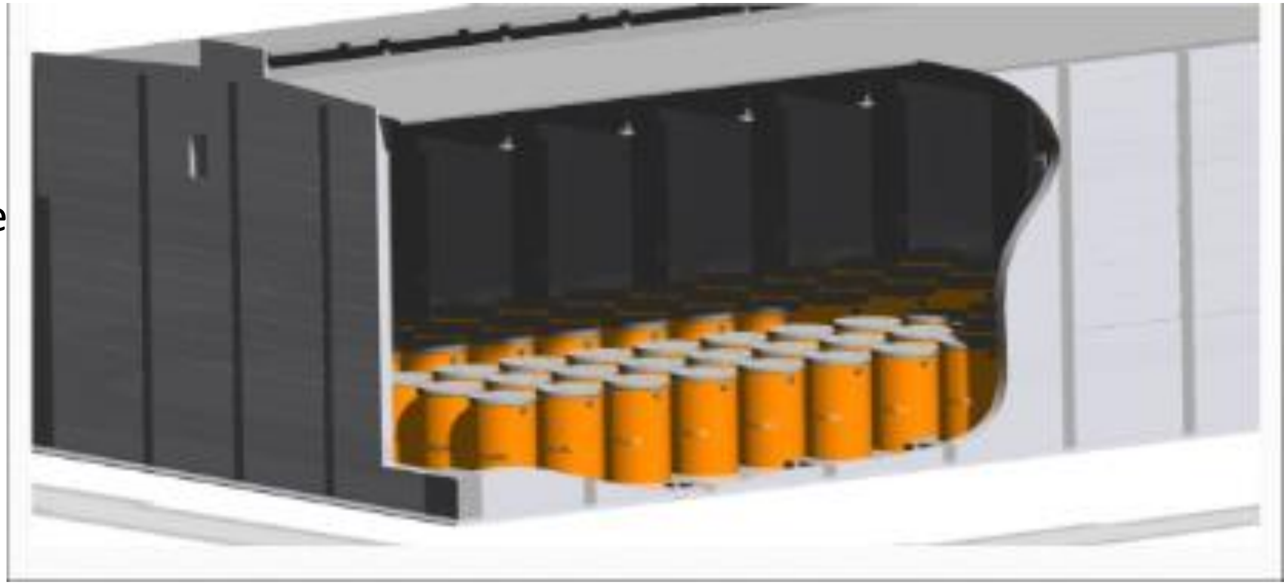
Cask CONSTOR® RBMK-1500/M2

To ensure safe loading & long-term storage for SF:	To withstand internal and external events:
• Capacity: 91 SFA • Height: 4520 m, diameter: 2628 mm • Empty cask: 90 t; fully loaded: 118 t • Heating capacity (max.): 12,55 kW • Sub-criticality: < 0.95 • Max. doze rate at surface: 1.0 mSv/h • Max surface temperature (calc.): 91°C	• Fire accident: 800 C for 30 min and 600 C for 1 h • Drop accident: 9 meter • Seismic event: 8 grades (MSK-64 scale) • Aeroplane impact

Interim Spent Fuel Storage Facility:

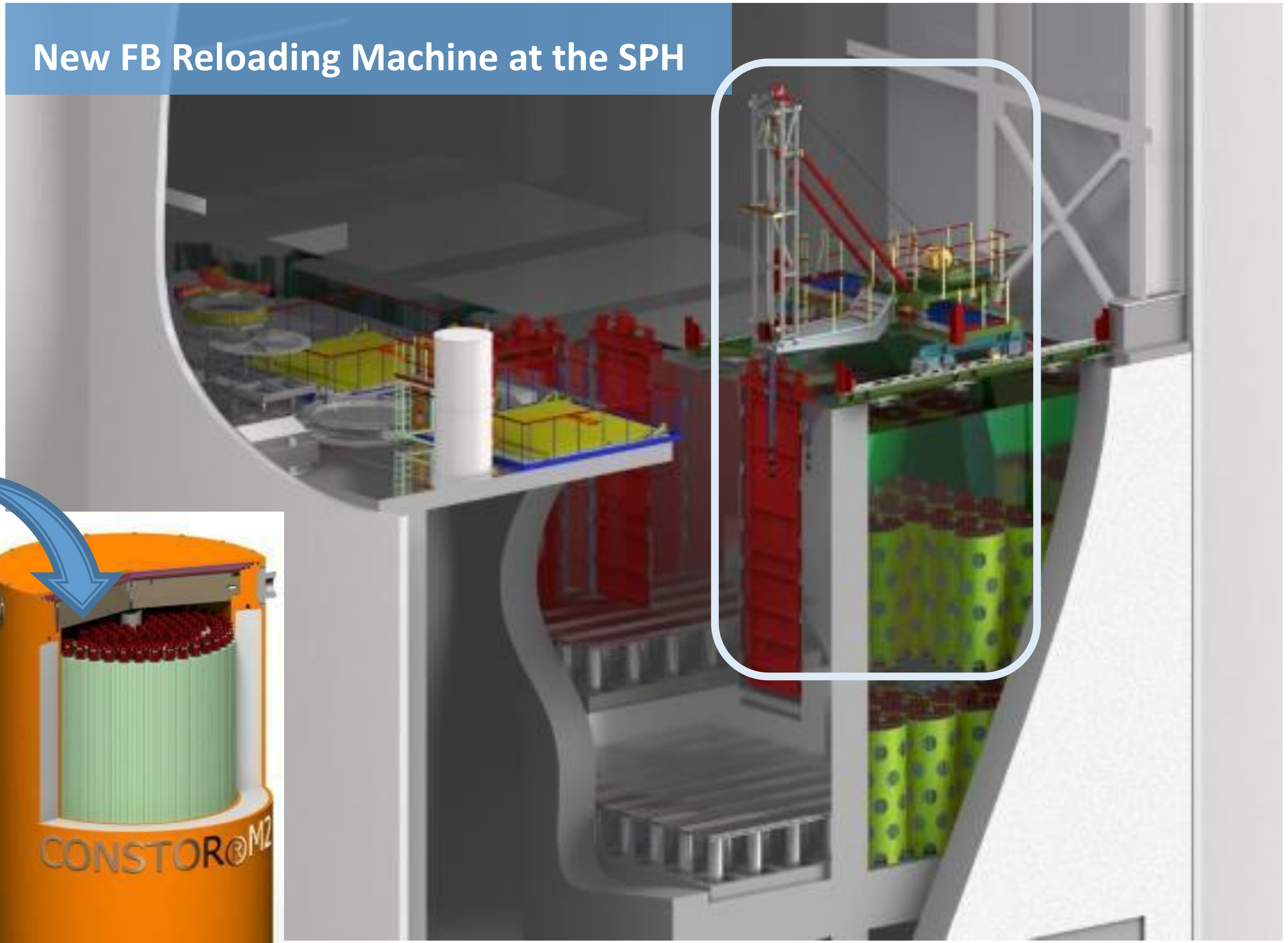
- Storage Hall capacity: 202 casks
- Cask Service Station: 2 welding platforms
- Fuel Inspection Hot Cell: for inspection and repackaging of the spent nuclear fuel
- Heat dissipation – natural convention
- Max. dose rate for population at security fence: 0,2 mSv/year
- Seismic event: 8 grades (MSK-64 scale)



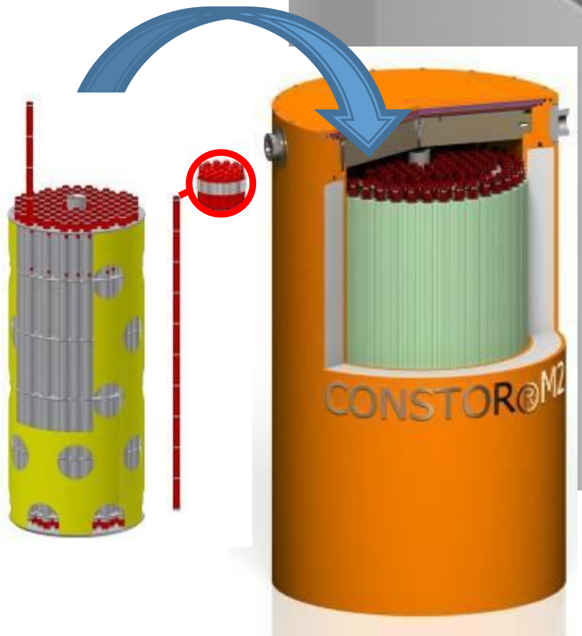
Technology – Spent Fuel Loading to the Cask

SF handling system modification at Units

- To modify all working platforms and axillary equipment for the new casks preparation and loading
- Implementation of the new FB reloading machine
  - To reload the Fuel Bundle from the central basket to the ring basket



New FB Reloading Machine at the SPH



Upper and Lower Fuel Bundles after treatment of SFA in Hot Cell

SPH Cranes 125 t Modification

Objectives:

- To enhance SPH Cranes 125 t reliability and safety
- To ensure the maintenance of the crane safety limits and conditions during cask loading operation

The scope:

- Protective measures for SF pools from drop accident
- Full replacement of the Crane trolley to meet requirements of KTA 3902 for single failure compliance
- Installation of high precision positioning system
- Installation of lifting height limiting system
- Installation of the crane remote control system
- Enforcement of the crane main beam

The result:

- All installations, testing and training works were successfully completed in September 2015 - February 2016

Main Crain 125 t modification works at Unit 2, 2015

Cold and Hot Trials

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Cold trials - objectives:

- Demonstration of safe functioning and interaction of all systems and equipment of the ISFSF and Units 1, 2
- Training of the operational staff
- Verification of the readiness of the systems and components of the complex for hot trials

Cold trials were conducted separately at the ISFSF and at the Units with the use of SF simulators

Result: The cold trials were successfully completed on June 30, 2016.


Cold trial performance 2015

Hot trials: 2 phases

- <u>**1st phase**</u>
  - to confirm the safety criteria established by the Design
  - 4 casks with different loading schemes were loaded at Units
- <u>**2nd phase**</u>
  - to prove functional requirements of the Contract and the rate of the SFA removal
  - 6 casks were loaded on both power Units

Result: Hot trials were successfully completed on April 28, 2017, **4 months ahead of schedule**


First loaded cask transferred to ISFSF on 14 October 2016

Technology - Heavily Damaged Fuel Handling

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Objective: To ensure the safe loading & storage of damaged SFA

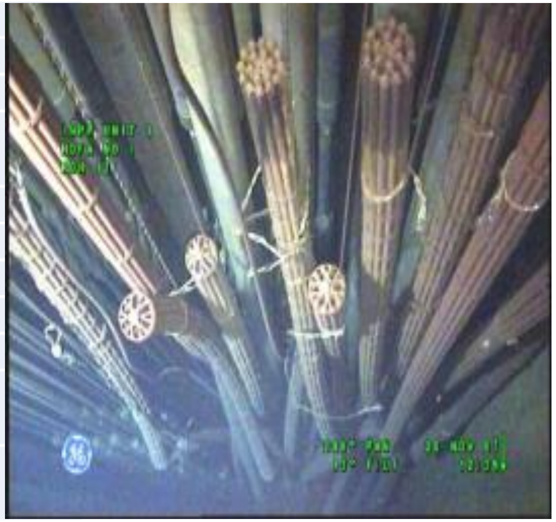
Handling:

- Heavily damaged fuel assemblies
- Experimental fuel assemblies
- Damaged fuel assemblies with different SFA defects
- Fuel debris

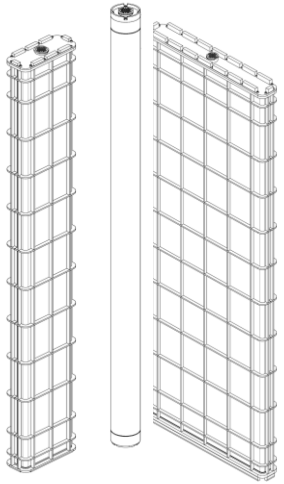
The scope:

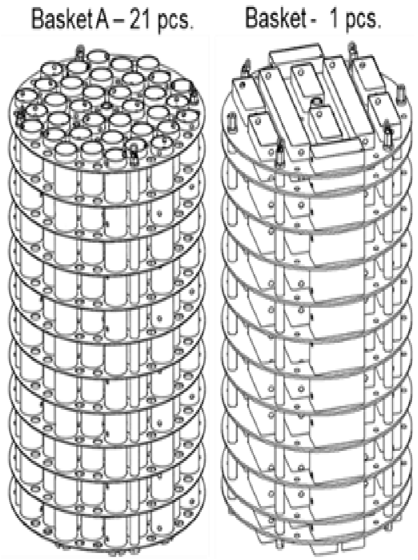
- Video survey of HD SFA
    → creation of 3D model of all HD SFA
- Leaking fuel classification system
- Overpack cartridges CAN160, CAN500 and CAN1200
- Underwater table, service platform and axillary equipment
- Underwater wire, debris recovery system

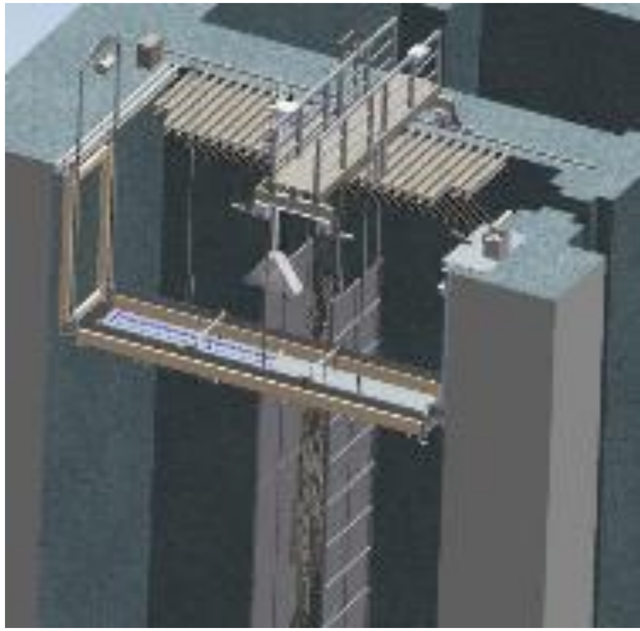
Damage Fuel Defect Description	Code
Grid damaged	E
Foreign objects in the space between fuel rods	F
Fuel assembly central rod bent between upper & lower bundles	G
Bundle skeleton bent	H
Fuel assembly with missing upper or lower bundles	I
Fuel assembly with missing or damaged extension tube	J
Fuel rod cladding damage (cracks)	K
Impossible to remove fuel assembly from case	L
Broken fuel rod or fuel rod with missing or damaged end plug	M
Gap between bundles very small - less then 3 mm. (The thickness of cutting saw is 3.5 mm)	N



Overpack cartridges CAN160, CAN500 and CAN1200







Technology - Heavily Damaged Fuel Handling System

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Technological process:

- Transfer of DSFA to underwater working table in pool
- Cutting DSFA in two fuel bundles
- Loading FB into the overpack cartridges
- Loading the overpack cartridges into cask basket
- CONSTOR/RBMK-1500 M2 cask drying and transfer to ISFSF for welding/final storage

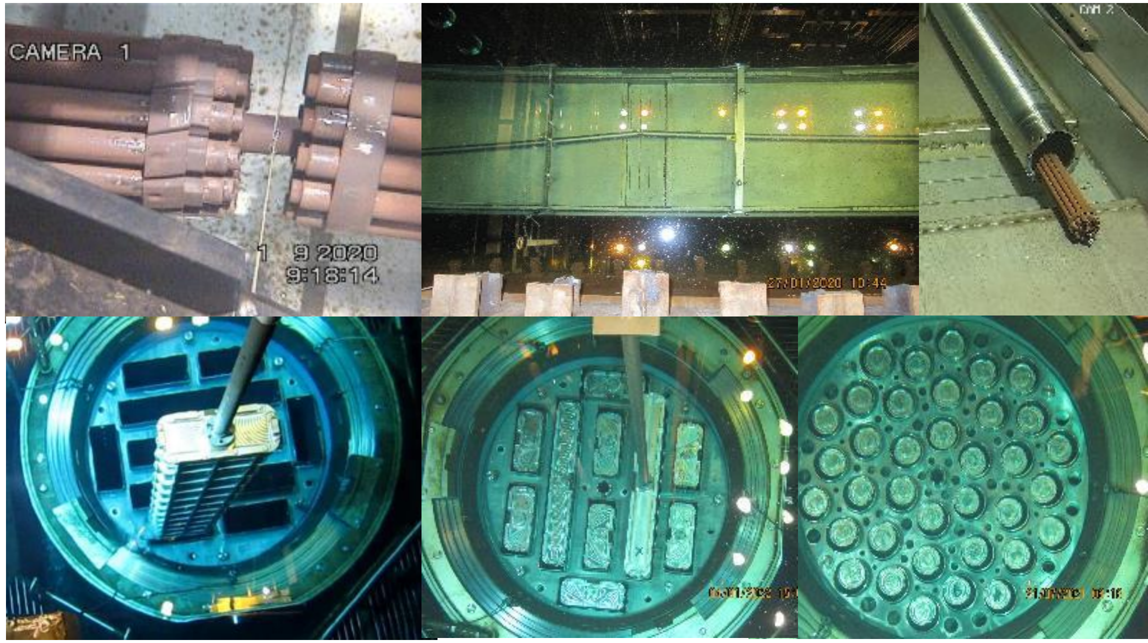
Key milestones:

- DFHS equipment installation completed in September 2019
- Cold Trials started in January and completed on 29 February 2020
- Hot Trials started in July and completed on 11 September 2020
- 6 December 2020, VATESI issued permit for the DFHS industrial operation

Result:

- 22 casks have been loaded with damaged SF (21 casks with basket A and 1 cask with basket B)

Operations with damaged fuel



Examples of fuel debris on working table

Fuel Debris Recovery Project

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Objectives:

- Recovery and safe storage of RBMK fuel element debris enabling final CONSTOR M2 cask loading and draining of SF pools

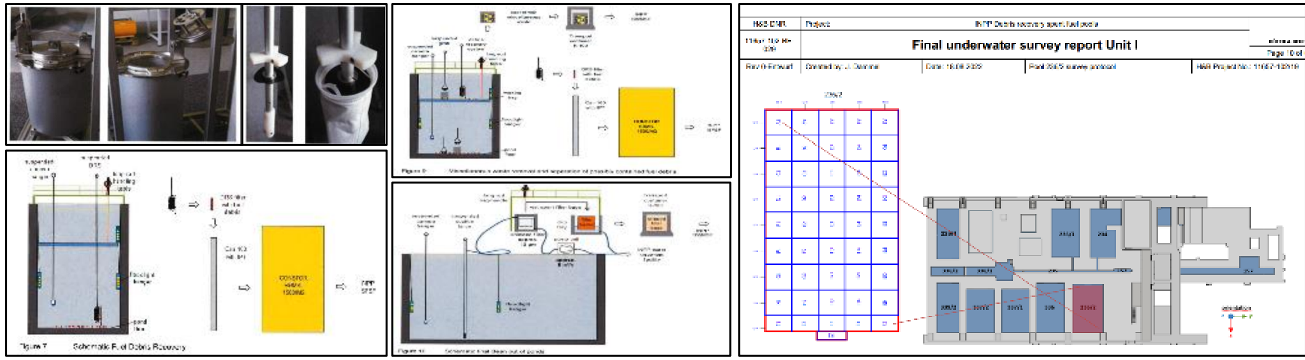
Main steps:

- Retrieval of large sized scrap materials
- Elimination of sludge/corrosion products
- Video inspection #1 for fuel rods/pellets searching on the bottom of the pools
- Fuel rods/pellets (if found) removal to the cartridge CAN 160s
- Video inspection #2 to confirm that the bottom of the pool is free from the fuel debris
- The last CONSTOR®RBMK-1500/M2 cask will be finally welded when the absence of fuel debris is confirmed.

Result:

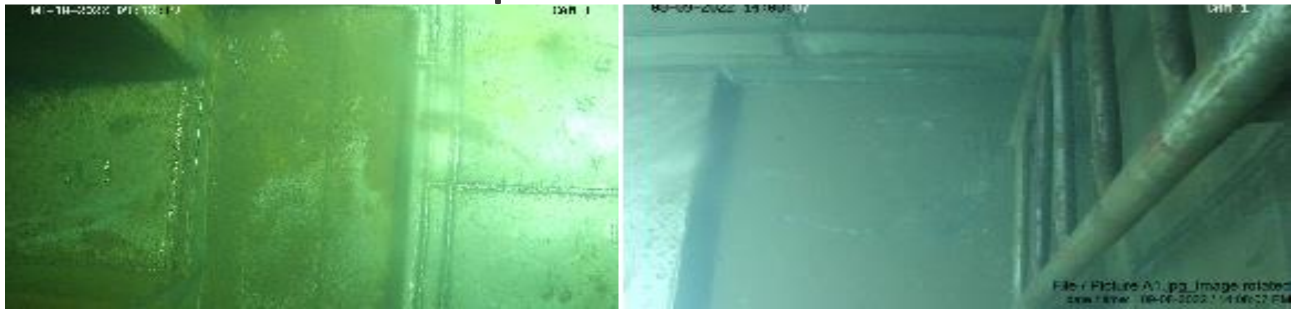
- Cleaning of SPH pool at the Unit 1 is nearly completed
- Cleaning of SPH pool at the Unit 2 is ongoing and to be completed in November 2022

Operational steps and video survey



SPH pools bottom in 2019

SPH pools bottom in 2022



Main Milestones - ISFSF and Defueling Program

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- Tendering, Concept preparation **2005-2006**
- Siting, Environmental Impact Assessment Procedure including ESPOO procedure **2008.**
- Technical Design and Preliminary SAR development and agreements with Lithuanian institutions **2007-2009**
- License for Construction - **September 2009.**
- Construction of ISFSF, external infrastructure and SF handling system modification at Units: **2009 – 2015.**
- SPH Main Crain modification at Units: **2015-2016.**
- Cold trials (2 casks loaded with dummy SFA): **October 2014 - June 2016.**
- Hot trials (10 casks loaded SFA): **September 2016 – May 2017.**
- Permission for ISFSF Industrial Operation was granted on **5th May 2017.**
- Casks loading and transportation at ISFSF: Unit 1 **May 2017-July 2020**, Unit 2 **May 2017-December 2020.**
- Heavily Damaged SF loading at ISFSF: Unit 1 **September 2020-April 2021**, Unit 2 **May 2021-April 2022.**
- Last cask transportation to the ISFSF: **21 April 2022**
- SPH pools cleaning and confirmation of fuel debris absence – to be completed in **November 2022**


Site view in 2005


Site view in 2017


Last cask ceremony, 21 April 2022
INPP, Min. of Energy, EC, EBRD, VATESI


Fully loaded ISFSF Storage Hall

Results of the Projects and Defueling Program

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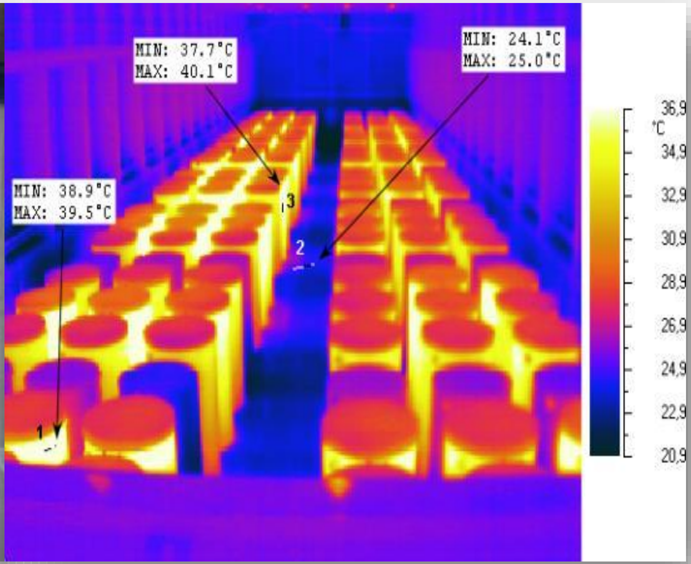
- All SFA were loaded into 190 casks and transported to the ISFSF for the interim storage
- All safety limits and conditions established in Design and Safety Analysis Report were ensured:
  - the adequate performance of the radiological shielding
  - the accuracy of heat transfer and fuel storage temperature calculations,
  - the effectiveness of the process controls and monitoring,
  - compliance with the functional performance requirements.
- No accidents during defueling program occurred



Safety limits – design value	Maximum value
Dose to the population per year on security fence – no more than 0,2 mSv/year	0,17 mSv/year
Total gamma and neutron radiation dose rate on the surface of the fully assembled cask loaded with SNF < 1 mSv/h	0,173 mSv/h
Exposure dose for the personnel 20 mSv/year	3,6 mSv/year
Residual decay heat, 12.25 kW/cask	10,6 kW
Maximum temperature of the cask surface <90°C	45°C

Results and Good Practices of the Program

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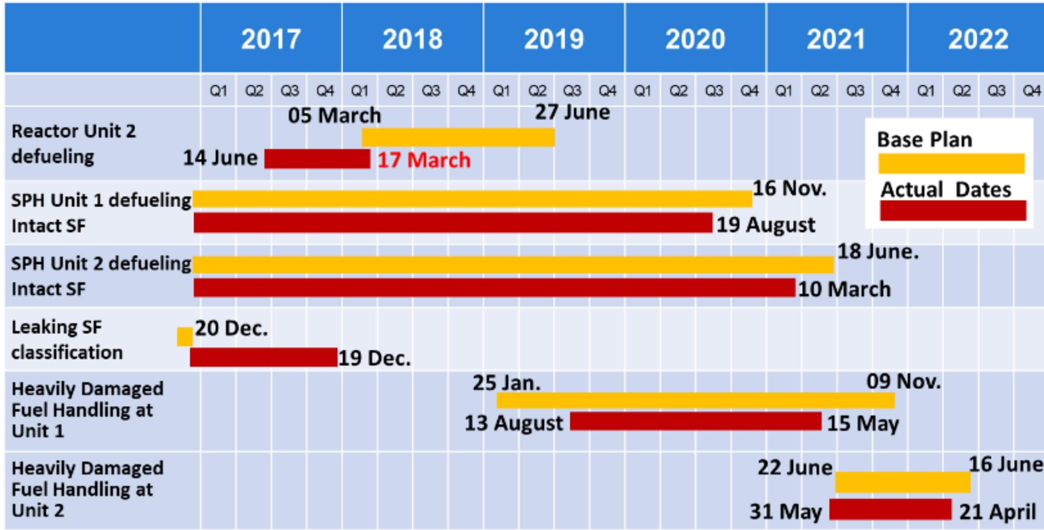
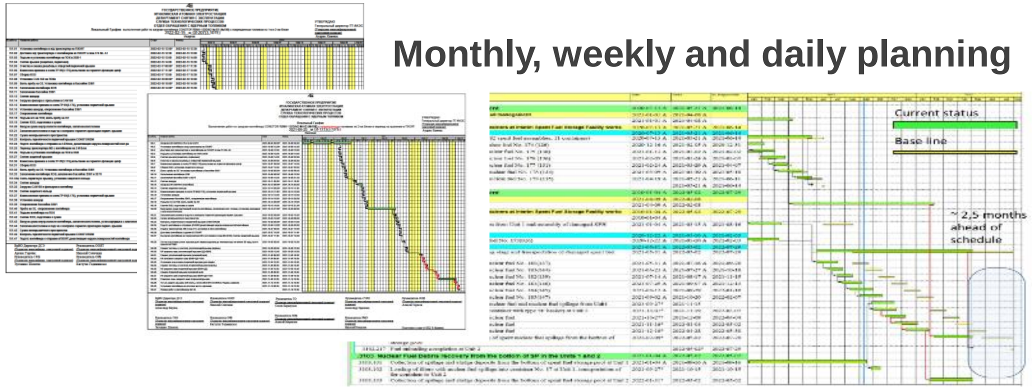
- The overall INPP Units defueling program was completed 3 months ahead of the schedule:
  - The priority to all defueling activities was given by Top Management of INPP
  - Maintenance and defect repairs, including weekends, if necessary
  - The operational staff was well trained and prepared during commissioning phase
  - INPP long term experience in leaking SFA investigation was combined with the contractor’s proposed measurement equipment resulting in the robust leaking fuel classification system
  - The defueling program was carefully planned and monitored:
    - → The daily and weekly planning & control of activities were ensured
  - Motivation system for the staff was introduced based on milestones achievement combined with safety criteria

Initial Planning versus Actual Dates





Monthly, weekly and daily planning

Main Challenges During Implementation

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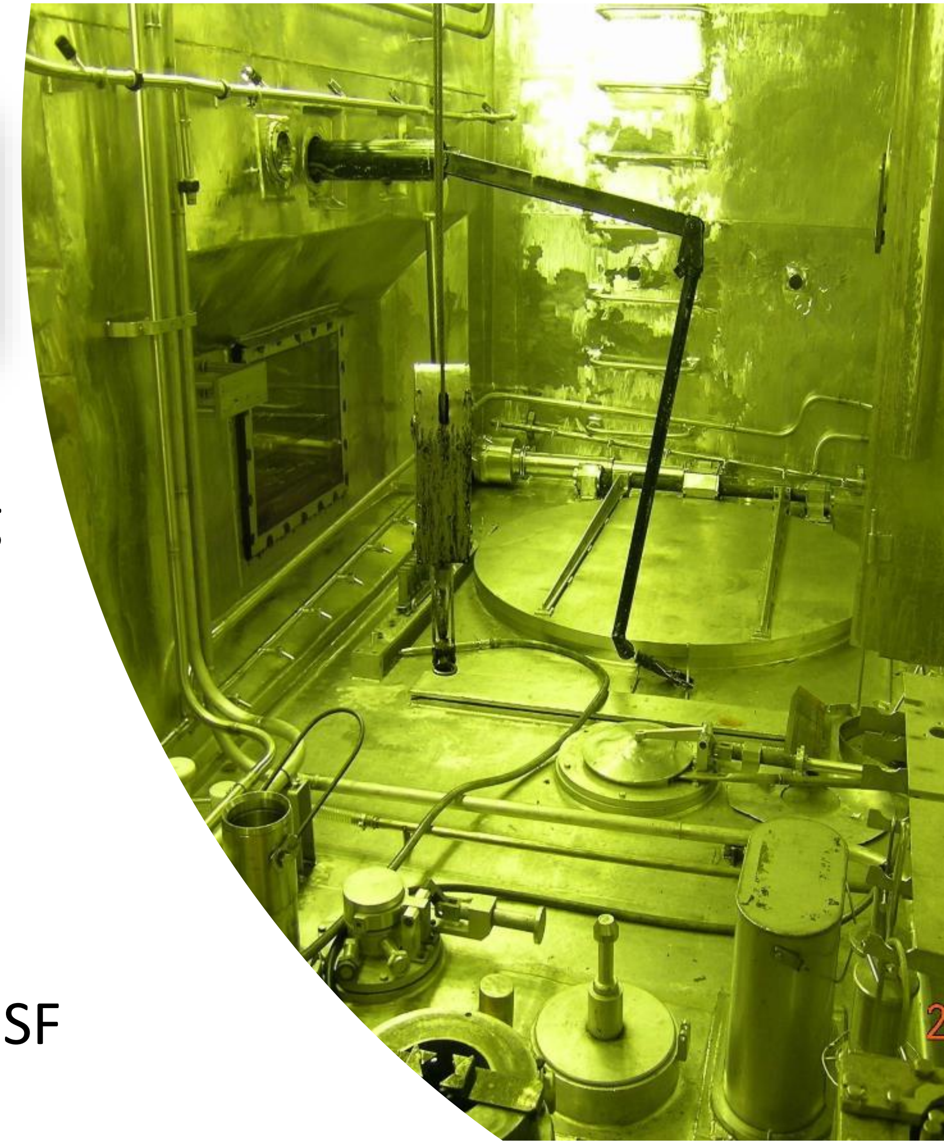
- Units "Old" Hot Cells' failures due to equipment aging

Hot Cell	Start of operation	Defects statistic	
		2018	2019
Unit 1	1990	30	47
Unit 2	1991	18	20

Hot Cells at Units are used to cut SFA into two "upper and lower bundles"



- Human factors:
  - ➢ Personnel aging - average 58-60 at the end of defueling
  - ➢ Operators' mistakes in the initial stage of the defueling
- Delayed materials delivery for in-house manufacturing
- COVID-19 impact:
  - ➢ All activities shutdown for two weeks
  - ➢ Interruptions in IAEA and Euratom inspectors' visits for SF movement inspection due to quarantine

Lessons Learnt

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- The EPC contract (“turnkey”) does not mean that the Employer should wait until the ready facility is handed over as fully operational:

  → The close involvement of the future operator/owner in the project management team is mandatory and to be ensured by the top management from the very beginning:

    - Involvement in the technical documentation review
    - Early formation and preparedness of operational staff
    - Involvement in the FATs and SATs, installation and commissioning works

Lessons Learnt

IGNALINA NUCLEAR POWER PLANT

- It is essential to ensure that the input data in technical specifications are as precise as possible:
  - → Especially Spent Fuel data and inventory, existing conditions at the Site/Units
  - → Additional surveys to be included into the TS clearly and clear responsibilities identified where related data are not available
  - → It should be considered that accurate as-built documentation is not available for “old” designed and constructed facilities
- The technical support / spare parts for initial operation time should be clearly identified in TC
- The most of delays in the complex nuclear projects are caused by initial optimistic planning:
  - → any complex nuclear designs and safety justifications requires more than 2 iterations for the discussion with institutions and Regulator/TSO
- The commercial disputes with the contractors should be oriented at finding compromises but should not lead to deadlocks, the support of external lawyers is essential

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Elektrinės str. 4, K 47
Drūkšinių vil.
31152 Visagino mun.
Lithuania

State Enterprise
Ignalina Nuclear Power Plant
https://www.iae.lt/en

Phone +370 386 28985
Fax +370 386 24396
E-mail iae@iae.lt

Thank you for attention!

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Ignalinos AE eksploatacijos nutraukimo veikla yra bendrai finansuojama Europos Sąjungos