



*The Abdus Salam
International Centre for Theoretical Physics*



1858-5

**School on Physics, Technology and Applications of Accelerator Driven
Systems (ADS)**

19 - 30 November 2007

**Engineering Design of the MYRRHA.
Part V**

Didier DE BRUYN
*Myrrha Project Coordinator
Nuclear Research Division
SCK CEN
BE-2400 Mol (Belgium)*

MYRRHA – Draft 2 System Operation, Inspection & Maintenance

H. Aït Abderrahim, D. De Bruyn, P. Baeten,
W. Haeck & D. Maes

On behalf of MYRRHA team and MYRRHA support

<http://www.sckcen.be/myrrha>

Summary



- Introduction
- Working Regime of MYRRHA
- Reactivity monitoring approach in MYRRHA
- I&C approach in MYRRHA
- ISI&R approach in MYRRHA
- Conclusions



- MYRRHA is thought and designed as an experimental facility
- An experimental irradiation facility has a short operation cycle in order to allow loading and retrieval of irradiated devices on very regular and flexible manner
- an availability rate of 65% is targeted (3 MO + 1 MSShD) * 2 + 3 MO + 3 MLShD)
- Advantages of such short cycle:
 - Preventive maint. On Accel. => improve Reliab.
 - Δk_{eff} small => afford I_p ct. during cycle => ease licensing
 - ISI&R via RH & Robotics needed to achieve 65% avail.



- 3 MO + 1 MSShD)*2 + 3 MO + 3 MLShD:
 - 3 Months Operation:
 - ✓ Δk_{eff} small (~ -1700 pcm) : can be compensated by core reshuffling, burnable absorber or combination
 - ✓ Allow good irradiation results for material damage (7 to 15 dpa/cycle), MA transmutation (\gg than Chemical. Measurement), Fuel BU (10 GWd/t)
 - ✗ More challenging for short irradiations such as radioisotope production but feasible (need further design work)



- 3 MO + 1 MSShD)*2 + 3 MO + 3 MLShD:
 - 1 Month Short Shut Down :
 - ✓ Partial Core reload (few fresh FA) and reshuffling
 - ✓ Experimental devices handling
 - ✓ Routine inspection
 - 3 Months Long Shut Down :
 - ✓ larger Core reload and reshuffling
 - ✓ Fuel transfer from the in-vessel storage
 - ✓ Experimental devices handling
 - ✓ Heavy maintenance such as Spallation Target extraction and parts replacement

Reference Core



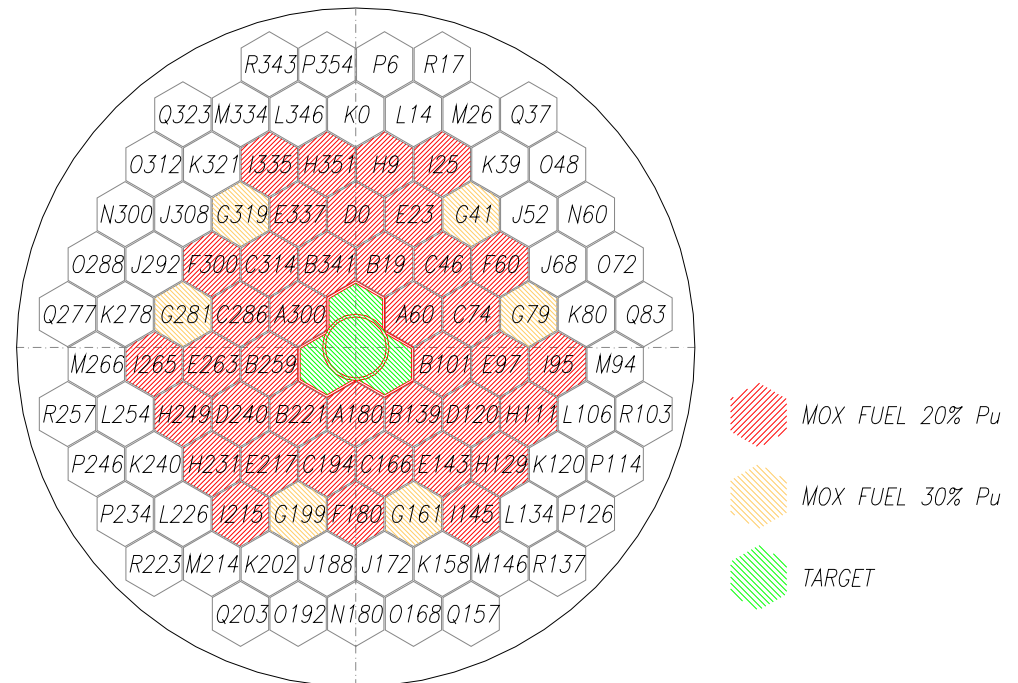
The reference core consists of 45 fuel assemblies:

- 39 assemblies with 30% MOX (positions A-F, H-I)
- 6 assemblies with 20% MOX (position G)

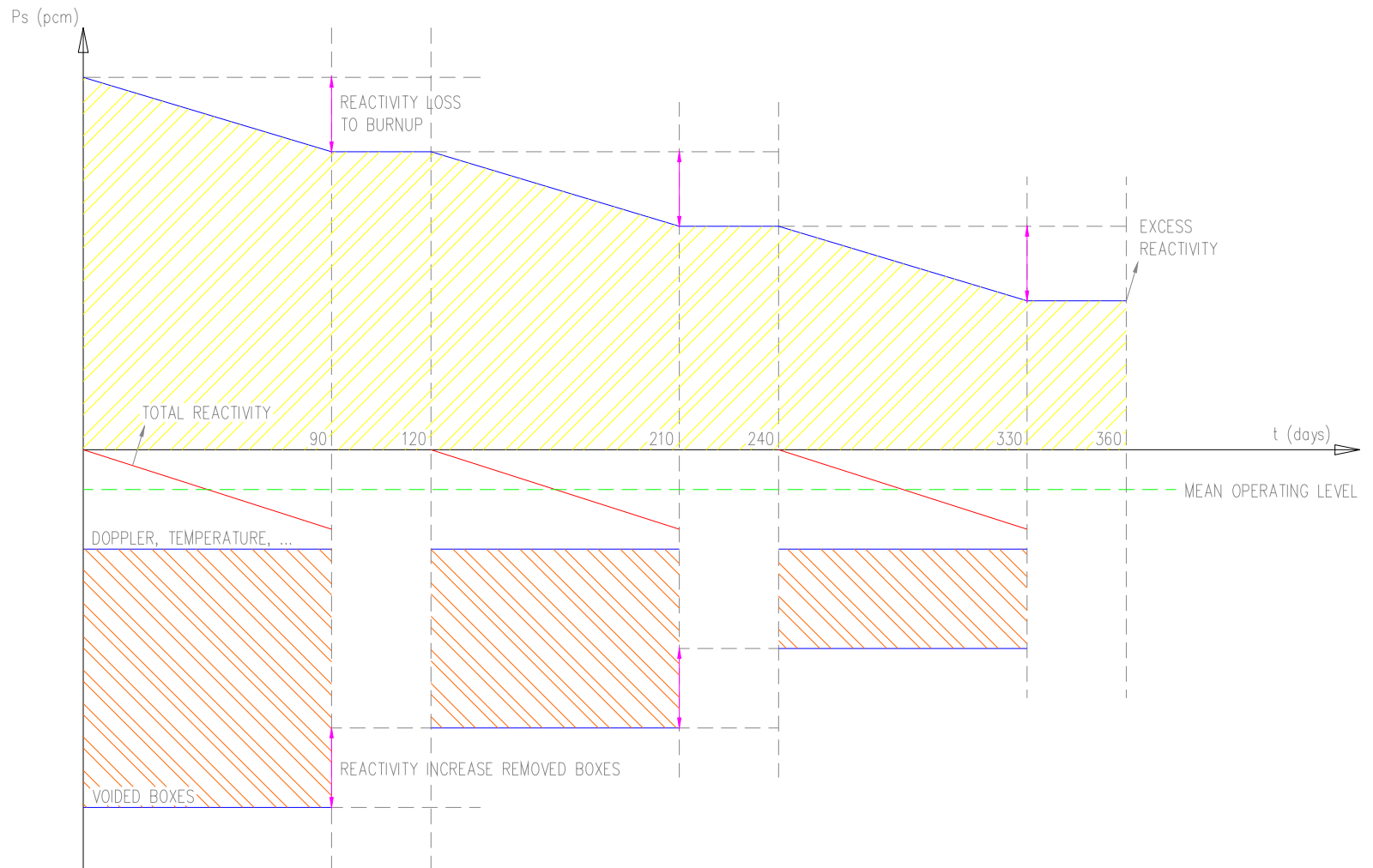
k_{eff}	0.94589
k_s	0.95236
ρ [pcm]	-5721
ρ_s [pcm]	-5002
P [MWth]	43

Targeted operating regime:

- 90 days of operation
- 30 days for maintenance, ...
- 3 cycles a year



Reactivity Compensation Using Voided Boxes



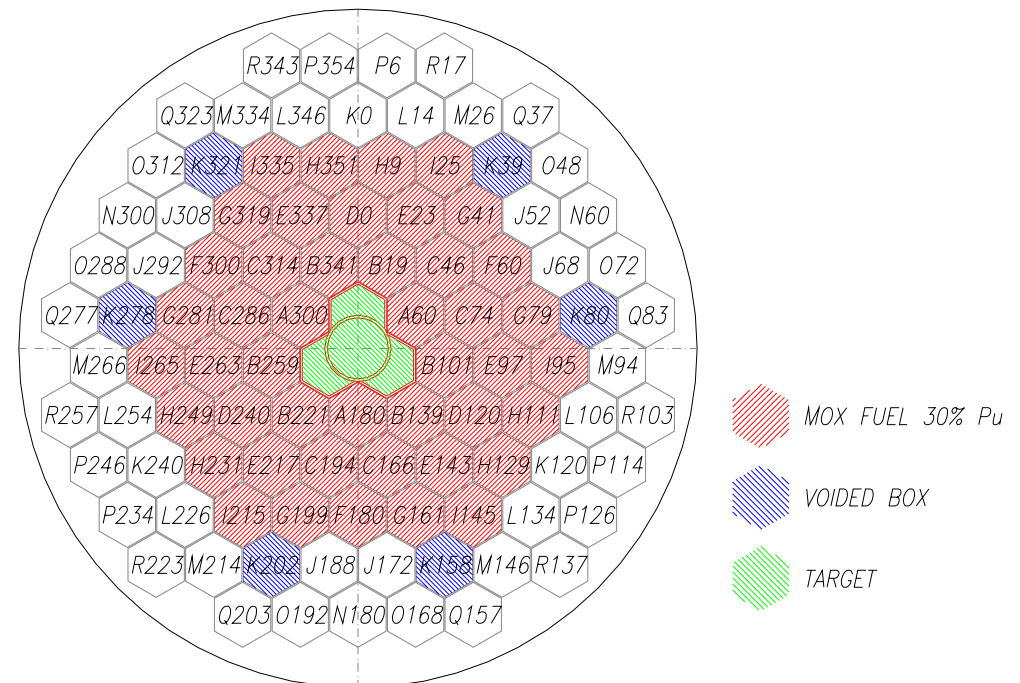
Modified Core



To demonstrate the previous concepts, we performed burn up calculations on a modified core:

- Replaced 20% MOX by 30 % MOX: $\Delta\rho_s = +1783$ pcm
- Added 6 voided box assemblies: $\Delta\rho_s = -1421$ pcm

	Reference core	Full 30% MOX core	Adding voided boxes
k_{eff}	0.94589	0.96614	0.94969
k_s	0.95236	0.96881	0.95565
ρ [pcm]	-5721	3505	-5298
ρ_s [pcm]	-5002	-3219	-4640
P [MWth]	43	69	46





- During a cycle of 90 days, the power and flux in MYRRHA drop by 20% on average
- The first burn up results demonstrate that:
 - the proposed operational cycles are realistic
 - in the case studied, no new fuel assemblies are needed in the second cycle to obtain the same operational level of the first cycle
- Further study:
 - introducing BA into the core – combined with voided box assemblies
 - burn up calculations of multiple cycles



- The I&C has not been worked out yet in MYRRHA and need to be addressed urgently
- A diagram principal scheme has been established based on FBR approach with instrumentation foreseen at the outcome of (each) FA to monitor:
 - Temperature
 - Neutron Flux
 - Coolant velocity
 - Pressure
- O₂ Control in the reactor pool is needed



- To achieve the 65% availability for MYRRHA, Remote Handling approach is mandatory due to:
 - High activation level in the MYRRHA Hall (neutron streaming through the Beam line)
 - Potential α -contamination in the MYRRHA Hall due to ^{210}Po
 - Inert gas environment in the MYRRHA Hall to avoid the Pb-Bi contamination by O₂ (PbO sludge formation)
- No real experience within the team => contracted a feasibility study by OTL Ltd (JET, UK)

1. PROJECT OVERVIEW

- Define the plant
- Define the working environment
- Define the task requirements
- Define the remote handling system requirements
- Decide a remote handling approach
- Derive a remote handling concept & plant layout
- Validate the remote handling concept
- Estimate costs of implementing and running the systems
- Establish any technological areas requiring further development
- Deliver written report and a VR model of the proposed concept

2. PLANT DEFINITION

- Spallation Loop
- Core Support Tube
- Heat Exchangers
- Main Pumps
- Internal Robots
- Lid
- Diaphragm with chemical insert module
- Emergency Heat Exchanger
- Beam Line in MYRRHA Hall
- Experimental devices
- Pb-Bi vessel (for decommissioning)

3. ENVIRONMENT DEFINITION

- 100% inert atmosphere
- 0% humidity
- Particulate and gaseous contamination
- Max normal dose rate exposure of 7 Gy/hr
- Worst case dose rate exposure of 21.5 Gy/hr
- Total dose of 46500 Gy

4. TASK REQUIREMENTS

- Removal and replacement of plant items
- Plant maintenance (e.g Spallation zone replacement)
- Decontamination of plant items
- Packaging of waste items
- Recovery from failure during plant handling (e.g jamming)
- Recovery of a failed Ex-vessel Fuel Transfer machine
- Recovery of debris from PbBi



- Fully remote
- System Availability >95%
- Fail-safe system
- Recoverable after failure
- Perform replacement of Spallation loop within a 3 month shutdown
- Reach and examine all parts of the MYRRHA Hall
- Be easy to operate
- Be easy to support and maintain
- Be able to deal with unexpected tasks
- Minimise the secondary wastes
- Operate in the specified radiation environment for 30 yrs.
- Manipulate loads up to 60 tonne
- Perform specialist operations (e.g cutting, welding, 3-D metrology)

6. REMOTE HANDLING APPROACH

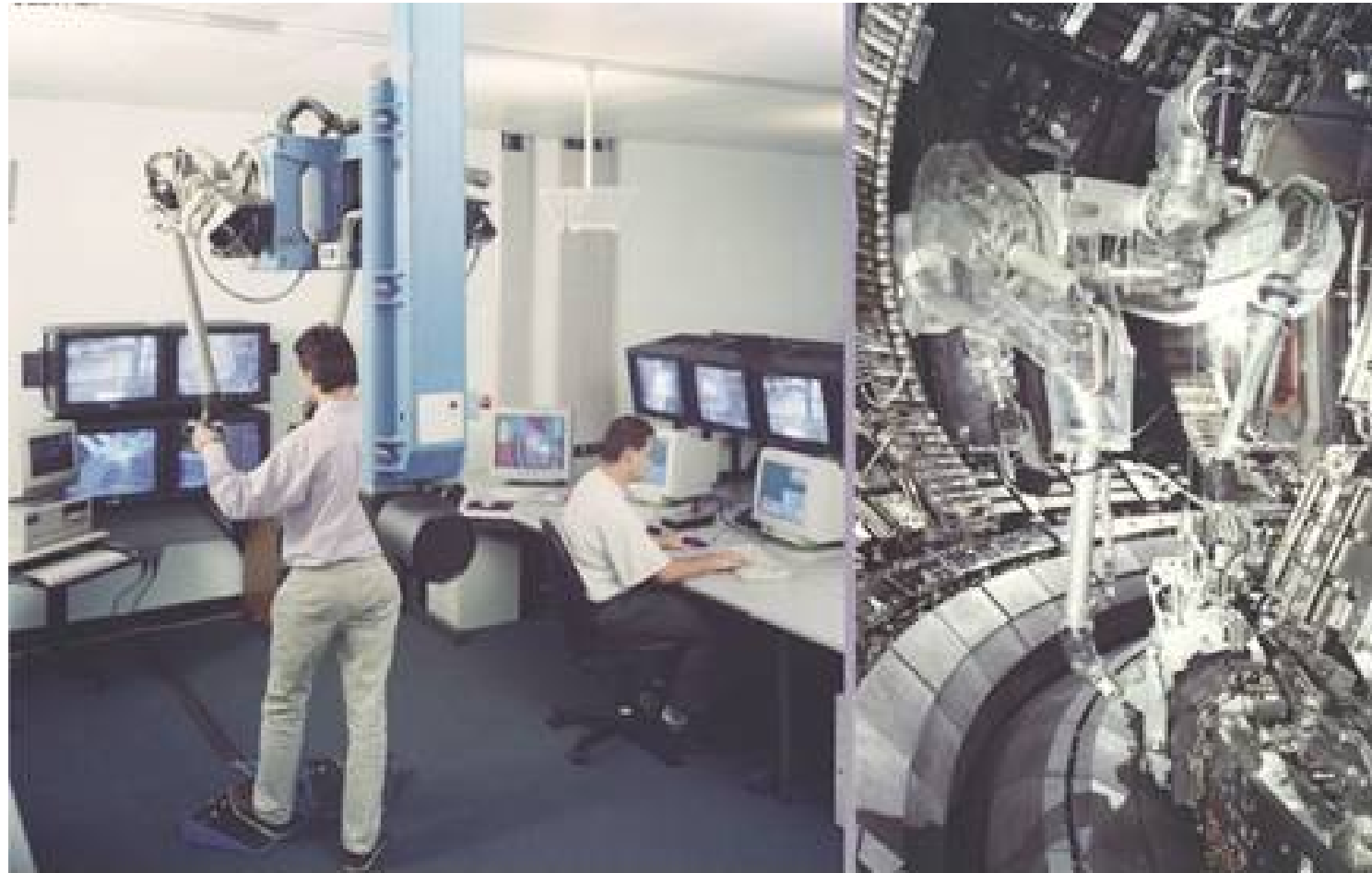
- Man-In-The-Loop using a Bi-lateral, force-reflecting, Master-Slave Servomanipulator.
- Robotic features to ease operation
- Cameras for visual feedback
- Independent craneage for lifting heavy loads
- Independent tool service system
- All remote handling work to be done within the same hall
- Remote equipment and tooling to be stored and maintained within the same hall
- Use of air-locks for transfers between areas

7. PLANT LAYOUT AND INFRASTRUCTURE

- MYRRHA Hall
- Contamination control
- Commissioning, Assembly, Test and Mock-up facilities
- Decontamination
- Waste Packaging
- Active workshop
- Remote handling control rooms
- Health Physics Laboratory

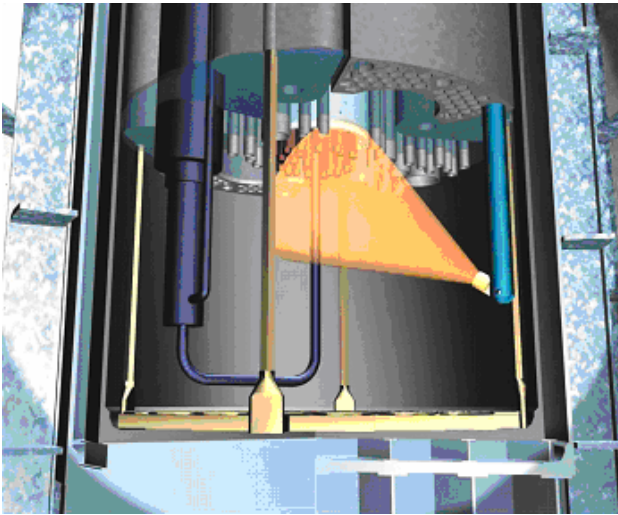
Science Fiction or Reality?



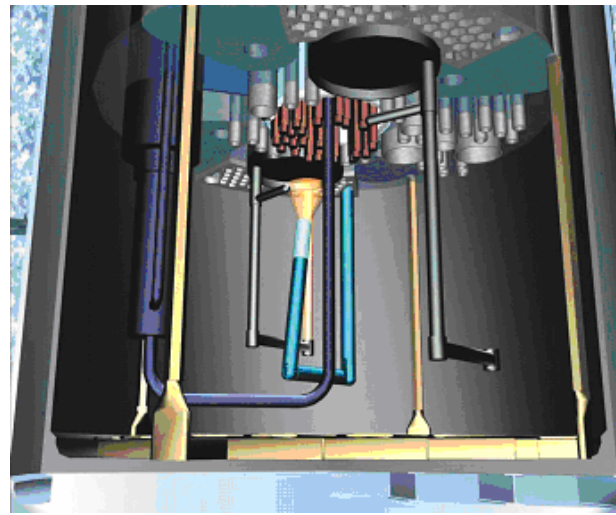




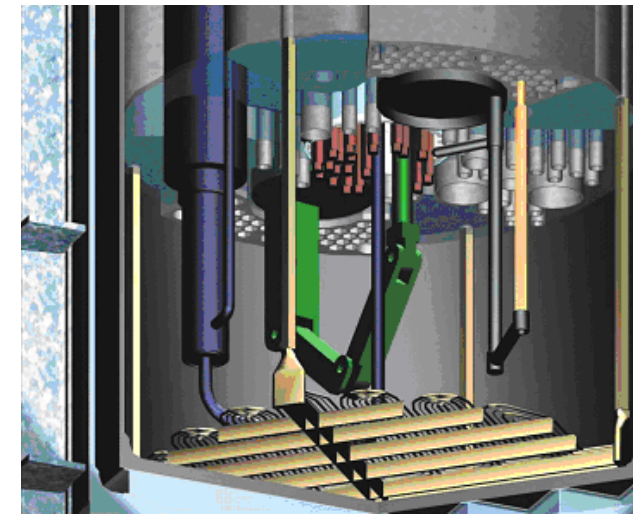
Design of MYRRHA In-service inspection and repair



Two permanently installed *inspection* manipulators with US camera to provide a general *overview*. (periscope type device with three degrees of freedom)



The second *inspection* manipulator positions the camera close to critical components for *detailed* inspection. (anthropomorphic type device with five degrees of freedom)

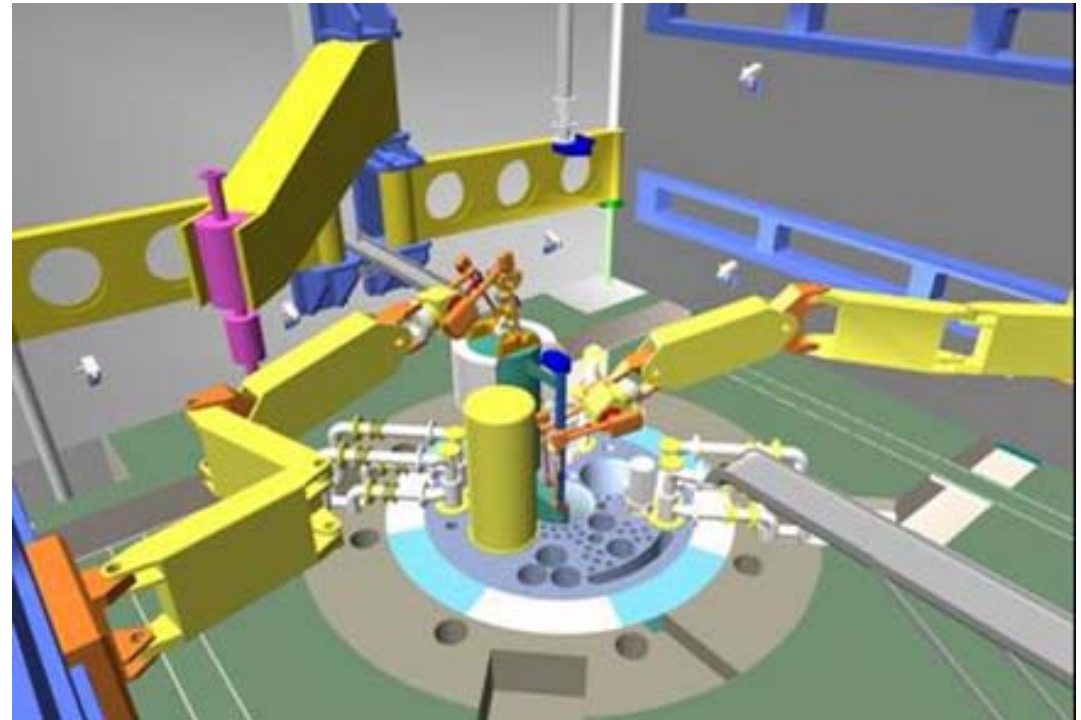


The *repair* manipulator recovers debris or deploys specialised tooling for repair. (anthropomorphic type device with eight degrees of freedom)

O.T.L. concludes positive on the feasibility of the proposed RH approach.

All MYRRHA maintenance operations on the machine primary systems and associated equipment is performed by remote handling, which is based on the *Man-In-The-Loop principle*:

- force reflecting servomanipulators
- Master-Slave mode: the slave servo-manipulators are commanded by remote operators using kinematically identical master manipulators
- supported with closed-cycle TV (CCTV) feedback



O.T.L. concludes positive on the feasibility of the proposed RH approach.

Conclusions



- MYRRHA being an irradiation facility has dictated the choices of the remote handling as a first choice for achieving an availability factor of 65% which compatible with operational cost that would be affordable.
- The fact of being a first-of-a-kind has also conditioned some design option in terms of operation cycle and the allowable beam trip mitigation via a preventive maintenance made repetitively during the shut down periods between cycles.
- The k_{eff} drop being limited per three months cycle make it manageable by a policy of fuel reshuffling supplemented by the use of burnable poisons or void boxes.
- The instrumentation and control is sketched and is not very different from the classical one of a classical reactor but need urgently further development.
- The sub-criticality monitoring is addressed and a promising route for the on-line monitoring is proposed.