ASNR Autorité de sûreté nucléaire et de radioprotection

Digital twins and Ontology for Robot Assisted Decommissioning Operations
DORADO

DORADO WEBINAR: ROBOTS AND DRONES IN NUCLEAR DECOMMISSIONING
WP4 – TEST CASE ON DECOMMISSIONING SAFETY
THE SAFE USE OF ROBOTICS SYSTEMS AND SOLUTIONS

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THE SAFE USE OF ROBOTIC SYSTEMS AND SOLUTIONS

- **When?**
  - Areas difficult to access:
    - ➢ High dose rate, reduced intervention time, limited access, no human intervention possible)
  - Specific work conditions:
    - ➢ Deteriorated / damaged structures (humidity, corrosion), no visibility Absence of appropriate containment zones in the intervention area)
- **Why?**
  - Improving Operator Protection (Remote work in the control room, Work limited to maintenance operations of robotic systems)
  - Optimizing Data Collection
  - Optimizing dismantling operations (speed, repeatability, precision, traceability)

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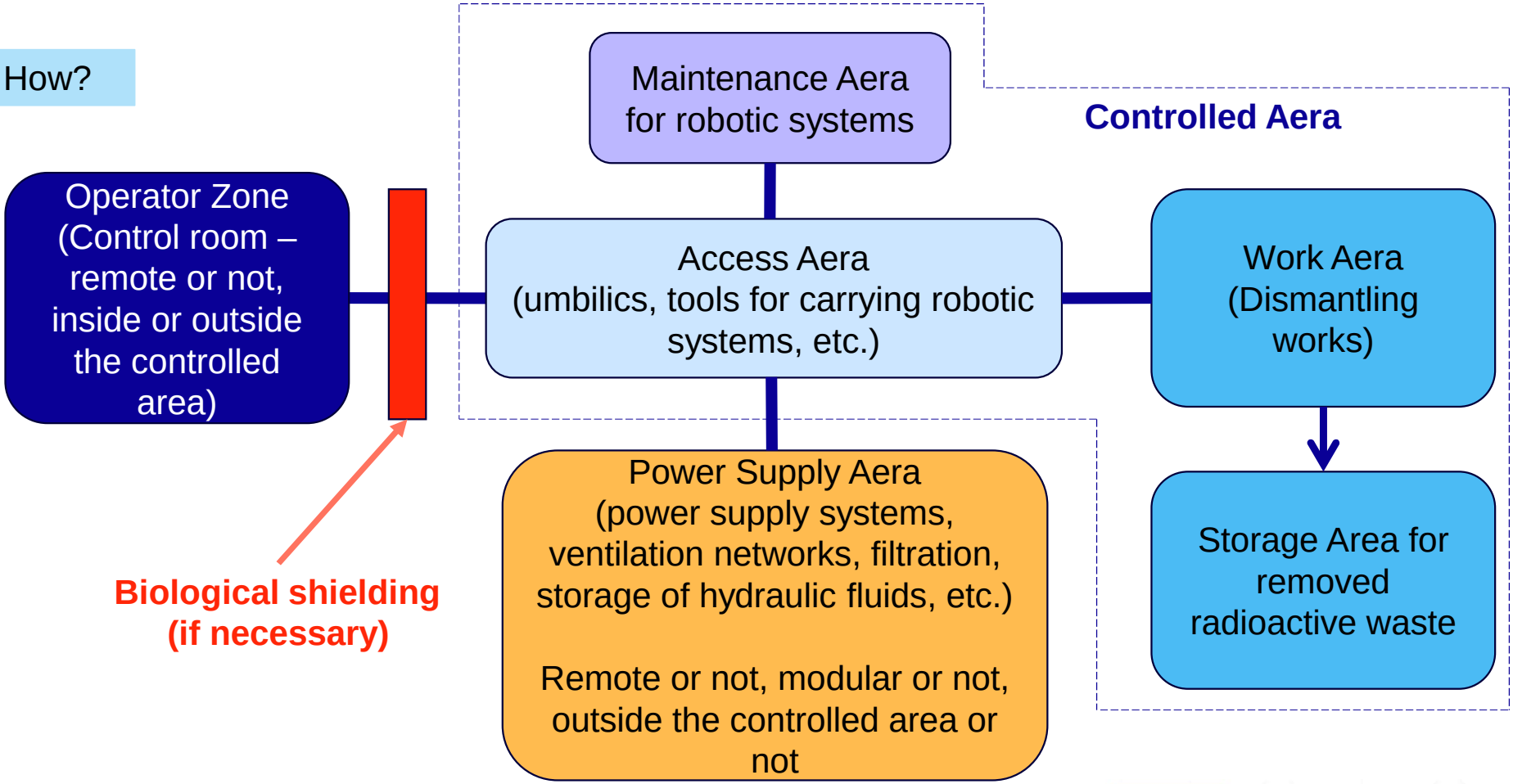
The safe use of Robotics Systems:

How?



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Situations to be avoided:

- Task becoming more difficult to perform than expected (lost of communication, short autonomy, cables and umbilical management)
- Loss of the robots in hazardous environment
- Hazards to personnel, equipment and enclosure systems (drop of items, break of items/objects, wrong task, collision, outbreak of fire, exposure during decontamination of robots, etc)
- Generating waste with no disposal routes (electronic components, batteries, wireless devices, etc)

Potential impact on safety:

- Workers, public and environment
- Structures, Systems and components important for safety

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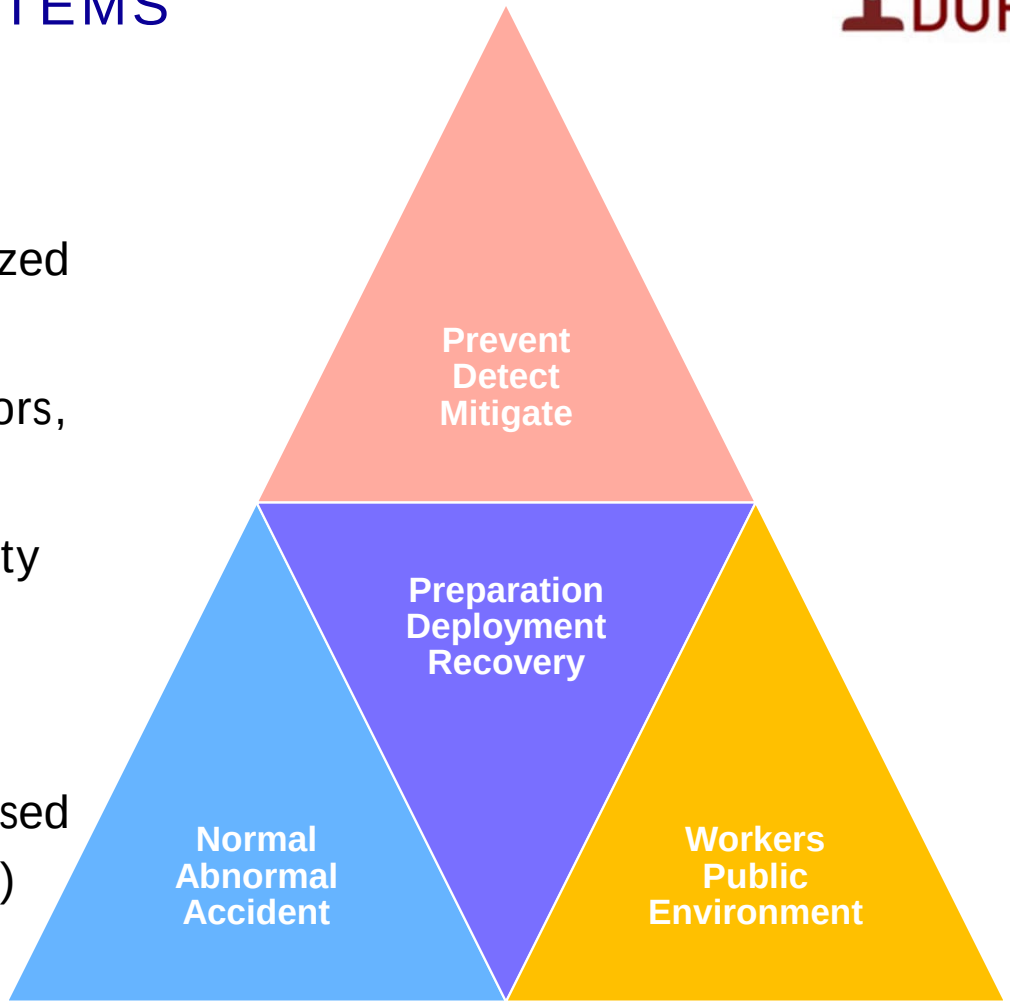
THE SAFE USE OF ROBOTIC SYSTEMS

DORADO WP4: Characterisation

- Campaigns of data collection are organized (BR3-BR1/Belgium and INPP/Lithuania)
- Several robotic solutions used (sensors, drones, robots)
- WP4 – Test case 4: decommissioning safety

DORADO Risk Matrix (DRM):

- Describe the robotic solutions used (Robots/sensors, Drones/Sensors, Sensors)



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Description of robotic solutions implemented for radiological characterization:
10 solutions implemented

Robotic System (RB) = sensors and robot assistance			Supervision		
RB	**Device**	**Assistance**	**Control**	**Number of operators**	**Power Supply**
RB1	Sensors	Drone	Joystick	2	On-board battery, fully autonomous drone
RB2	Sensors	Drone	Joystick	2	Outdoor power supply with ombilic connection, the drone moves connected to an ombilic
RB3	Sensors	Drone	Joystick	2	Indoor autonomous Battery with ombilic connection to the drone
RB4	Sensors	Drone & Robot	Joystick	4 (2 + 2)	Indoor autonomous Battery with ombilic connection moved by a robot with on-board battery
RB5	Sensors	Robot -bluetooth	Joystick	2	On-board autonomous battery, operator following the robots while using the joystic, bluetooth
RB6	Sensors	Robot -Wifi	Joystick	2	On-board autonomous battery, Full control of the robot over Wi-Fi, operator located outside the area during measurements
RB7	TLS (Terrestrial Laser Scanner)	human	operator	1	Tripod with the Terrestrial Laser Scanner (TLS), On-board battery, operator access several times in the area to change the location of the sensor
RB8	Camera	human	human	1	On-board autonomous battery, operator walking down in the area, photos
RB9	Headphones	human	operator	1	SPIX voice recognition system (headphones and Mobile phone)
RB10	Thermal camera	human	human	1	VTT Thermal camera

Main activities: Preparation, deployment (measurement campaigns) and recovery

Robotic System (RB) = sensors and robot assistance					Preparation		Deployment (measurements)		Recovery	
RB	**Device**	**Assistance**	**Project**	**Place of test**	**Operator in the area**		**Operator in the area**		**Operator in the area**	
RB1	Sensors	Drone	XS-Ability	BR1, BR3	**P1**	yes	**D1**	no	**R1**	yes
RB2	Sensors	Drone	XS-Ability	BR1, BR3	**P2**	yes	**D2**	no	**R2**	yes
RB3	Sensors	Drone	XS-Ability	BR1, BR3	**P3**	yes	**D3**	no	**R3**	yes
RB4	Sensors	Drone & Robot	XS-Ability / Dorado	BR1, BR3	**P4**	yes	**D4**	yes	**R4**	yes
RB5	Sensors	Robot -bluetooth	Dorado	BR1, BR3	**P5**	yes	**D5**	yes	**R5**	yes
RB6	Sensors	Robot -Wifi	Dorado	INPP	**P6**	yes	**D6**	no	**R6**	yes
RB7	TLS (Terrestrial Laser Scanner)	human	Dorado	BR1, BR3	**P7**	yes	**D7**	yes (part-time)	**R7**	yes
RB8	Camera	human	Dorado	BR1, BR3	**P8**	no	**D8**	yes	**R8**	yes
RB9	Headphones	human	Dorado	BR3	**P9**	no	**D9**	yes	**R9**	yes
RB10	Thermal camera	human	Dorado	BR3	**P10**	no	**D10**	yes (part-time)	**R10**	yes

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Building the Risk Matrix: Identify all situations and activities

		RISK Matrix	Activites			
		Situations	Préparation	Deployment	Recovery	Potential causes
S1	Normal conditions	External exposure	P1-P6	D4-D5 / D7-D10	R1-R7	Operators close to SSCs
S2	Normal conditions	Internal exposure	P1-P6	D4-D5 / D7-D10	R1-R7	Operators close to SSCs, change of aerodynamic conditions during the use of drones
S3	Normal conditions	Effluents	*NA*	*NA*	*NA*	no use of liquids or oil during operation
S4	Normal conditions	Secondary waste	*NA*	*NA*	R1-R7	contamination of technological materials, waste generated by the decontamination of items
S5	Normal conditions	Waste	P1-P6	*NA*	R1-R7	Contamination of sensors, batteries, ombilics, wheels, electronic components, wireless devices, drone, robot
S6	Normal conditions	Hazardous materials exposure (Asbestos, dust)	P1-P6	D4-D5 / D7-D10	D4-D7	Exposure of operators to asbestos, dust, etc
S7	Normal conditions	Maintenance operation (change of battery, etc)	*NA*	*NA*	R1-R7	Contamination of operators during installation, change or removal of sensors, batteries, cameras, ligthning, laptop
S8	Normal conditions	Handling	D1-D7/D10	D4-D5	R1-R7	Operators carrying drone or robot in stairs or not easy access areas, worker carrying a drone or robot in his arms
S9	Abnormal conditions	External exposure - non-planned	*NA*	D4-D5 / D7-D10	R1-R7	Recovery of drone or robot or ombilic stucked in the area, loss of wifi connection
S10	Abnormal conditions	Internal exposure - non-planned	*NA*	D4-D5 / D7-D10	R1-R7	Recovery of drone or robot or ombilic stucked in the area, loss of wifi connection
S11	Abnormal conditions	Spread of dust	*NA*	D4-D5 / D7-D10	R1-R7	Spread of dust by the drone or robots movements
S12	Abnormal conditions	Spread of contamination (cross contamination)	*NA*	D4-D5 / D7-D10	R1-R7	Spread of contamination by openings made for ombilics
S13	Abnormal conditions	Electrical hazards	P1-P4	D4-D7	R1-R4	Degradation of the 400 V cable of the drone ombilics
S14	Abnormal conditions	Drop of items	*NA*	D4-D5 / D7-D10	R1-R7	Drop of drone, fall of the robot, potential loss of the robot/drone in hazardous environment
S15	Abnormal conditions	Damaged to the robotic systems	*NA*	D1-D6	*NA*	Drone collision, robot collision: damaged to the robotic systems
S16	Abnormal conditions	Human factors - co-activities	P1-P6	D4-D5 / D7-D10	R1-R7	Poor visibility, noisy environment, repetitive tasks, operators working at the same time in the area operated by drone, robot
S17	Abnormal conditions	Working at height	*NA*	D4-D5 / D7-D10	R1-R7	Use of scaffolding
S18	Accidental conditions	Fire / explosion	*NA*	D1,D3-D10	R1-R7	Fire of on-board battery (risks of gas release, spontaneous ignition of gases, combustion and projection of particules around)
S19	Accidental conditions	Collisions witn SSCs	*NA*	D1-D6	*NA*	Drone collision, robot collision: damaged to equipment and/or systems located in the area of investigation

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Building the Risk Matrix: Safety provisions

		RISK Matrix	Safety measures		
		Situations	Prevention	Detection	Mitigation of consequences
S1	Normal conditions	External exposure	Train drone/robot operators to radiation exposure Arrange a shielded zone for intervention in the area Suspension of dismantling activities during the intervention	Individual operational dosimeters, RP monitioning system in the area with alarms	Evacuation of the area in case of alarm
S2	Normal conditions	Internal exposure	Train drone/robot operators to radiation exposure, Individual protective equipment (IPE) Suspension of dismantling activities during the intervention	RP monitoring system in the area with alarms	Evacuation of the area in case of alarm
S3	Normal conditions	Effluents	NA	NA	NA
S4	Normal conditions	Secondary waste	Protection of the sensors and robotic systems against contaminati	Check contamination when leaving the area	Decontamination of items if possible
S5	Normal conditions	Waste	Protection of the sensors and robotic systems against contaminati	Check contamination when leaving the area	Decontamination of items if possible
S6	Normal conditions	Hazardous materials exposure	Train drone/robot operators to conventional risks (asbestos, dust), Individual protective equipment (IPE)	Visual inspection (dust)	Avoid zones of the area with dust when using drones
S7	Normal conditions	Maintenance operation	Train drone/robot operators to radiation exposure, Arrange a shielded zone intervention in the area	Individual operational dosimeters, RP monitioning system in the area with alarms	Evacuation of the area in case of alarm
S8	Normal conditions	Handling	Limit the weight of the robot/drone for manual handling (30-35 kg) Check access conditions to the area (doors, openings, stairs)	Direct or remote supervision by additional operator Check contamination when leaving the area	
S9	Abnormal conditions	External exposure	Identify areas with no easy access for robots/drones (corridors, stairs) Avoid the use of ombilics in complex areas	Individual operational dosimeters, RP monitioning system in the area with alarms	Removal of stucked items
S10	Abnormal conditions	Internal exposure	Identify areas with complex environment and access for robots/drones (corridors, stairs) Avoid the use of ombilics in complex areas	Individual operational dosimeters, RP monitioning system in the area with alarms	Intervention of workers in the area

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DORADO Risk Matrix (DRM):

- Structured process to assess relevant situations which may occur during the use of robotic systems
- Determine the design safety provisions to be implemented
- Follow the defence in depth principle: Detect, Prevent, Mitigate
- First draft of the DORADO Risk Matrix with BR3/BR1 campaigns

Consolidation of the DRM

- Radiological campaigns to be implemented at INPP/Lithuania September 2026
- Improvement of the DRM reflecting the solutions that will be implemented
- Cover additional situations: Robotics solutions AI assisted

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