CORE COMPETENCIES

CORE COMPETENCIES:	SINTEF	DTI	PIAP
Systems Development			
System Design	-Technical requirements definition. -Methodology for design, development and validation of mobile autonomous systems.	- Technical requirements definition - Methodology for design development and validation	- Robot specific design methodologies, - Simulation framework for mobile robotics,
System Architecture	- Control and safety system architectures		- Open frameworks: ROS, ROS2, MAVLink - Customized architecture solutions (JAUS, IOP)
System of Systems			- Distributed sensing systems with communication and cloud based computing - multi robotic platform solutions
Systems Engineering	- Optimization methods. - Risk management. - Safety lifecycle management.	- Safety management	- User requirements specification and analysis - Use case definition - Requirements traceability with architecture design - V&V
System Integration			- Integration of different platforms with one human-machine interface

	Modelling and Knowledge Engineering	-Functional flow block diagrams. -Physical modelling of dynamical systems.		Additive manufacturing (3D printing) modeling and design
Mechatronics	Power Management and Supply	- Fuel cell technology		- batteries (fuel cell integration)
	Sensors	- Vision technology - 3D sensor technology - Strain gauge technology - Positioning technology (IMS, GNSS, RTK-GNSS) - Fire & gas sensors	- Vision technology - 3D sensor technology - Strain gauge technology - Positioning technology (POZYX, GNSS, RTK-GNSS)	- Vision technology, - 3D sensor technology, - Sensor and measurement systems, bespoke camera systems - Positioning technology (IMS, GNSS, RTK-GNSS) - specialized CBRNe sensing for mobile platforms
	Actuators			-mobile robot manipulators, industrial fobot manipulators - variety of grippers - customized design - soft maniluplators and grippers (for fragile objects and environment)
	Mechanical Systems	- Mobile wheeled/tracked robots. - Mobile robot manipulators - Collaborative robots. - Snake robots. - Unmanned Vehicles (air, land, water)	- Mobile robots. - Unmanned Aerial Vechicles - Collaborative robots	- Mobile platforms, - Mobile robots, - Unmanned Vehicles, - Special vehicles, - Robot stations, automation and measuring equipment

	Control	-Classical control and modern control (particulary MPC and optimal control) theory and applications. - Nonlinear control - State estimation and output feedback control. - Tracking and syncronization of moving objects	-Classical control	- Teleoperation control, - Quality control systems using vision technology.
	Communications	- Communication buses such as CANBUs and PROFIBUS - Acoustic underwater communication - RF and Wireless communication - Safe Communication		-Customizable radio solutions for low energy multi-point data-link
	Materials			- Additive manufacturing using different materials
Cognition				
	Action Planning	- Traffic Management		
	Natural Interaction			
	Learning, Development & Adaptation		-Machine learning	Machine learning, image recognition
	Knowledge Representation & Reasoning			
	Cognitive Architectures			
Navigation				
	Mapping	- Simultanous Localisation and mapping (SLAM) - Semantic mapping	- Simultanous Localisation and mapping (SLAM)	- Simultanous Localisation and mapping (SLAM) - Semantic mapping
	Localization	-Terrain or map based localization. - Sensor fusion (Kalman filters, particle filters, etc) -	- Kalman filters, particle filters, etc - Sensor fusion	-Navigation camera with image analysis algorithms, - Recognition and remote observation.

	Motion Planning	-Collision detection and avoidance. -Motion planning of manipulator arms in dynamic environment -Viewpoint sampling and coverage based planning for infrastructure inspection - Rapidly exploring random tree	- Indoor/outdoor autonomous navigation in cluttered environment. - Collision detection and avoidance, optimal path planning. - Dynamic trajectory control -Motion planning of manipulator arms	- Indoor/outdoor autonomous navigation in cluttered environment. - Collision avoidance, optimal path planning. - Dynamic trajectory control
Perception				
	Sensing	-Sensor fusion	-Sensor fusion	- Sensor fusion
	Interpretation	- Fault monitoring - Condition monitoring - Biomechanical analysis - Detection and tracking of objects	-Fault monitoring -Condition monitoring -Detection and tracking of objects	-Detection and tracking of objects, - Environmental testing.
Human Robot Interaction				
	Safety	- Safe planning of robot manipulators in the presence of humans	-Safety planning of rbot manipulators in the presence of humans	- ATEX certified robots
	Human Machine Interface		-Force control	- Telepresence, - remote robot control (optic fiber, wireless) - 3D HMI interfaces - interfacing in VR/AR

Human Robot Collaboration -Force control

CORE COMPETENCIES :	USE	CEA	LMS
Systems Development			
System Design	-Technical requirements definition with and without actuators. -Design, development and validation of aerial and ground robot systems.	-Technical requirements definition. -Methodology for design, development and validation of mechatronic systems (e.g. collaborative robots, intervention robot arms, long reach inspection arms, exoskeletons, gripping tools).	-Technical requirements definition. -Design, development and validation of mechatronic systems (e.g. gripping tools).
System Architecture		- Control and safety system architectures	-Design of Synchronization and Control architecture
System of Systems	- Multi-Robot sytems.	-Road train, convoy management	
Systems Engineering	- Multi-Robot management systems	-System Design and simulation - Safety Management - Hazardous and extreme environment Management	-System design and simulation
System Integration	- Multirobot Integration Systems	- System integration - Interoperability	Sensors and resource integration under common control and synchronization architecture

Modelling and Knowledge Engineering	- Modelado y simulación - Modelling of aerial robots - Modelling of ornithopters	- Robot systems modelling - Mechatronic systems modelling - Robot and Environnement simulation - Real time supervision using digital twins - Dynamic modelling of indoor or outdoor vehicle,	-Robot systems modelling -Mechatronic systems modelling -Simulation algorithms and environments -Task planning and schedulling algorithms
Mechatronics			
Power Management and Supply			
Sensors	- Vision technology - 3D sensor technology - Positioning technology (IMS, GNSS, RTK-GNSS) - Fire & gas sensors	- Interaction force sensors	-Vision -F/T -Voice recognition -Gesture recognition
Actuators	- Design of custom actuators - Low-weight actuators - Servo motors - Servo position and speed control	Actuators: - Multistage (belt+screw, gear+cabestan, friction+ cabestan) - reversible actuator - Gear reducer - flexible actuator structure	Low level motor control - Force / current control - Speed control - Position control
Mechanical Systems	- Aerial robot manipulators - Collaborative robots. - Snake robots. - Autonomous driving robots - Ground and aerial Unmanned Vehicles	Design, implementation, programming, integration and control of mechatronic devices : - Reversible mechanics for collaborative robots design - Mobile robot manipulators. - Exoskeletons - Master/Slave systems/arms (including long reach inspection arms) - Anthropomorphic mechatronics - Optimal design of monolithic compliant structures - Multifingered or multi-dof grippers	-Design, implementation, programming, integration and control of mechatronic devices (e.g. multi-finger grippers, assembly machines etc.)

Control	-Classical control theory and applications. - Nonlinear control - State estimation and output feedback control. - Visual tracking of moving objects. - Visual servoing	- Low level motor control (Force / current control, Speed control, Position control) - Robust predictive control - Optimal control - Homothetic strength and position control - Teleoperation arm control - Master / Slave hybrid force position control - Haptic control	-F/T control -Position control
Communications	- MEMS, NEMS, RF		-Fieldbus -CANbus -TCP/IP
Materials	-Fabricación aditiva (impresión 3D) - Soft Material for robotics		-3D-printed plastic -Metal parts
Cognition			
Action Planning	- Cooperative planning - Distributed planning	- Decisions making	-Task assignment and planning algorithms -Task scheduling algorithms
Natural Interaction		- Environment analysis (proprioceptive as well as exteroceptive sensing)	-HRI methods using AR, hands, voice, posture
Learning, Development & Adaptation	- Machine learning - Reinforcement Learning - Situation awarenses - Human coworker Robot Iteration	- Machine learning - Situation awareness - Human coworker intention detection	-Human intention recognition
Knowledge Representation & Reasoning			-Digital twin implementation
Cognitive Architectures			
Navigation			
Mapping	- Simultanous Localisation and mapping (SLAM) - Semantic mapping		-SLAM algorithms
Localization	-SLAM - Kalman filters, particle filters, etc - Sensor fusion	- Accurate localization from non-contact sensors.	-Terrain or map based localization -Sensor fusion

Motion Planning	- Collision detection and avoidance of cooperative UAVs. - Collision detection and avoidance of unknown obstacles	- Indoor/outdoor autonomous navigation in cluttered environment. - Collision avoidance, optimal path planning. - Dynamic trajectory control - Trajectory generation under geometric and kinematic constraints	-Motion planning -Path planning -Collision avoidance
Perception			
Sensing	-Sensor fusion - Visual perception - SLAM - Visual detection - Semantic perception	-Sensor fusion	-Sensor fusion -Vision systems -F/T sensing -Capacitive sensons -Hand tracking
Interpretation	- Object Detection and Tracking - Fault detection and Identification		-Object recognition and detection -Human detection
Human Robot Interaction			
Safety		- Safety implementation	-Human intention recognition -Human avoidance -Safety zones visualization using AR
Human Machine Interface	- Object Detection and Tracking - Fault detection and Identification	- Programming by demonstration. - Programming by observation. - Augmented Reality - Advanced HMI (3D) - Supervised learning / unsupervised -Multimodal Calibration - Force feedback - Advanced hand guiding - Force control - Tailored robotics architectures	-AR -Manual Guidance using force control

Human Robot Collaboration	- Aumented reality and virtual reality - Interaction technologies (e.g. human-machine interaction, motion recognition and language technologies)	- Human robot task sharing. - Human robot interaction - Human coworker intention detection - Virtual Guides - Augmented Reality - 3D and multi modal HMI - Collaborative robot control - Force control - Force amplification	-Human robot task assignment algorithms -AR and VR applications

		SPECIALIZED EQUIPMENT			
EQUIPMENT	LIST OF KEY PROPERTIES TO INCLUDE	SINTEF	DTI	TUKE	PIAP
Multi-rotor Unmanned Aerial Vehicles (UAVs)	**- Max payload?** **- What onboard equipment?** **- Specialized technology/ setups (e.g. UAV with two-arm setup)** **- Associated test infrastructure (if any)**	1. DJI Flame Wheel - Payload: ?? Kg - Equipment: Pixhawk autopilot, camera gimbal 2. DJI Mavic - Payload: ?? - Equipment: camera gimbal - Specialized technology: Collision avoidance Outdoor industrial test facility in Trondheim	1. DJI M210 RTK - Payload: 1.6Kg - Equipment: Pixhawk autopilot 2. DJI M100 - Payload: 1.2Kg - Equipment: camera zenmuse x4, dji guidance 3. DJI S1000 - A3 controller - Payload: 6Kg - Equipment: Ronin gimbal		1. DJI 1000+ - Payload 4 kg - Autopilot, camera gimbal - on board custom computer 2. DJI S1000 - Payload 11 kg - Pixhawk autopilot - on board custom computer
Fixed-wing UAVs	**- Max payload?** **- Max range?** **- What onboard equipment?** **- Specialized technology/setups (e.g. Fixed-wing UAV with vertical takeoff)?** **- Associated test infrastructure (if any)**				

Mobile robots	**- Max payload?** **- What onboard equipment?** **- Type of locomotion (e.g. wheeled, tracked, crawler etc.)** **- Key functionality** **- Specialized technology/setups (e.g. ATEX certified, fully autonomous, teleoperated, can be fitted with xyz robot manipulator)** **- Associated test infrastructure (if any)**	1. Summit XL - Type: Battery powered, wheeled AGV - Max payload: ?? - Onboard equipment: RTK GNSS with heading, Double IMU, 2x Camera gimbal, Front and rear Sick laser scanner, Axis pan tilt zoom camera, Microsoft Kinect 2, PC, wireless communication - Key functionality: Odometry, visual navigation - Specialized technology: Running ROS, teleoperated 2. Seekur jr. - Type: Battery powered, wheeled AGV - Onboard equipment: RTK GNSS with heading, Camera gimbal, IR camera, 2x PC, wireless communication - Specialized technology: Bracket for UR5 manipulator arm, running ROS, teleoperated 3. INACHUS S&R Snake Robot - Type: Wired communication and power, tracked locomotion for each of three links. 2 DOF between each link - Onboard Equipment: Infrared camera, "sniffer", RGB camera, flash light - Specialized technology: 2 DOF between each link. Outdoor test facility in Trondheim with RTK GNSS base station and wireless communication.	1. MIR 100 - Payload: 100kg 2. Custom build platforms - Payload: ? - specialized technology: two platforms, that can move individually or as one mobile robot - http://www.safecop.eu/wp-content/uploads/2019/04/FlyerUC1-March2019.pdf	1. GEARS SMP Mobile Platform (6 pieces): Weight: 8,16 kg; Payload: 8,16 kg; Length: 600 mm; Width: 600 mm; Height: 330 mm; Wheel Base: 420 mm; Tire Diameter: 177 mm; Average Ground Clearance: 114 mm or 30% of overall height 2. Dr. Robot Jaguar Lite Tracked Mobile Platform (4 pieces): Slope: > 45°; Maximum vertical step: 180mm; Stair climbing: Max stair step height 180mm; Traverse: > 200mm; Speed: 0 - 8.5Km/hr; Ground clearance: 38mm 3. Sensors: Sick - S32B-3011EA (2 pieces); Sick - DL50-P1123 (2 pieces) Mobile robot lab	1. Robrex robot - Type: wheeled battery powered mobile robot, 40 kg - Use: indoor exploration/services - ROS, teleoperated - Autonomy kit (2D and 3D lidars, Kinect) - Microtik communication setup 2. MBGPIAP robot - Type: wheeled/tracked battery powered robot, 60 kg - Use: outdoor exploration/services - ROS, teleoperated - Autonomy kit (2D and 3D lidars, Kinect) - Microtik communication setup 3. MBIPIAP robot - Type: 6 wheel battery powered robot 300 kg - Integrated high power manipulator (up to 50 kg lift) - Use: outdoor exploration/services - ROS, teleoperated - Offroad capabilities - Autonomy kit (2D and 3D lidars, Kinect) - Microtik communication setup
Mobile robot manipulators	**- Max payload for manipulator?** **- Capability/functionality for manipulator?** **- Compatibility with mobile robot platforms?** **- Specialized technology/setups (e.g. can be fitted with grippers X and Y, can be teleoperated etc.)**				1. 2x mobile manipulator setup - 5 DOF, 5-15 kg lift - Compatibile with Robrex robot and MBGPIAP robot - One type of gripper (parallel gripper jaws). - Can be teleoperated and driven by inverse-kinematics
Unmanned Surface Vehicle (USV)	**- Max payload?** **- Max range?** **- What onboard equipment?** **- Specialized technology/setups (e.g. can be fitted with xyz robot manipulator etc.)?** **- Associated test infrastructure (if any)**				

Unmanned Underwater Vehicle (UUV)	**- Max payload? - Max range? - What onboard equipment? - Specialized technology/setups (e.g. can be fitted with xyz robot manipulator etc.)? - Associated test infrastructure (if any)**				
Cobots (manipulator robots working in cooperation with humans with no barriers)	**- Max payload? - Capability/functionality for Cobot? - Associated test infrastructure (if any)**	1. Universal Robots UR5 - Max payload: 5 kg - Capability: Stops when hitting something 2. Universal Robots UR10 - Max payload: 10 kg - Capability: Stops when hitting something, integrated F/T sensor at end effector	1. Universal Robots UR5 - Max payload: 5 kg - Capability: Stops when hitting something 2. Universal Robots UR10 - Max payload: 10 kg - Capability: integrated F/T sensor at end effector 3. Universal Robots UR3 - Max payload: 5kg - Capability: Stops when hitting something	- Cobots	
Collaborative Robots					
Industrial robot manipulators	**-Max payload? - Capability/functionality for robot? (e.g. can be fitted with grippers X and Y, can be teleoperated etc.) - Associated test infrastructure (if any)**		1. Kuka ??? 2. Fanuc	- Double hand Motoman Industrial robotics lab	**Industrial robot with linear unit:** Model KR 500 R 2830 MT - Max payload - 500 kg, - Weight - 2440 kg. - A milling Robot i.e. a combination of a heavy-duty robot with a cnc machine with linear unit. **Industrial robot manipulator:** KUKA Model KR 16 -2F, Range 1611 mm, - Max payload - 16 kg, - Weight - 235 kg. - for welding **Training robot** - KUKA - Model KR 5, Range 1402 mm, - Max payload - 5 kg, - Weight - 127 kg. , (training robot)

Master-slave manipulators (typically used for remote handling tools for the nuclear industry)	**-Max payload? - Capability/functionality for robot? (e.g. can be fitted with grippers X and Y, can be teleoperated etc.) - Associated test infrastructure (if any)**				
Exoskeletons	**-What type of equipment? - Capability/Functionality for exoskeleton? - Associated test infrastructure (if any)**				
Sensors	**- What type of sensors? (e.g. ultrasound, hyperspectral camera, etc.) - Key properties/capabilities**	- IR-camera - RealSense 3D-camera - Kinect 3D-camera - F/T-sensor	- F/T sensor - RealSense 3D-camera - Kinect 3D-camera - IR-camera - hyperspectral camera		- IR-camera - RealSense 3D-camera - Kinect 3D-camera - Set of Velodyne Lidars
End-effectors, Grippers	**- What type of end-effectors? - What type of actuation style (e.g. pneumatic, electromechanical etc.) - Capability/functionality for end-effector? - Compatibility with robot manipulators?**	- Vacuum grippers - Schunk SDH multi-jointed 3-finger gripping hand (https://schunk.com/us_en/gripping-systems/series/sdh/)	- OnRobot RG6 gripper -		- Soft flexible grippers for fragile objects **Welder for robots:** -MIG / MAG welding, TIG DC welding and using a hot melt electrode (part of the welding station) - FRONIUS - trans puls synergic 3200 - FRONIUS - trans puls synergic 3200
Haptic devices	**- What type of device/technology? - Brief description of use and possibilities?**				

Specialized software	**- What software? (E.g. Simulation software such as VR, Solidworks etc.)** **- Brief description of use and possibilities?** **- Licencing/leasing possibilities**			Noise analysis software: - CADNA A, R, APL; Noise Image, Noise at work	
Machining tools	**- What equipment?** **- What are the capability/range of the tools?**	- 3D printer, max size 30x30x30 cm3	- 3D printer x 2 - Carbon 3D printer	- Several CNC machining tools etc. see link: http://www.sjf.tuke.sk/paic/en/	**3D printers:** **1.FORTUS:**http://rpl.mechse.illinois.edu/img/printers/fdm.pdf; **2.OBJET:**http://usglobalimages.stratasys.com/Main/Files/Machine_Spec_Sheets/PSS_PJ_Objet30.pdf **Welding Table for trials:** - company STALCHEMIA
Measurement and Quality Assurance tools	**- What equipment? (e.g. X-ray, scanning etc.)** **- What are the capability/range of the tools?**			- Zeiss Metroton 1500 tomograph (X-ray) - CMM CONTURA G2 (Carl Zeiss) (Scanning) - 3D optical shape dynamic (non contact) measurement Q-400 / Q-450 Dantec Dynamics	**3D Scanners:** **1.ATOS II Triple SCAN:** http://spectromas.ro/wp-content/uploads/2018/07/GOM_Brochure_ATOS_TripleScan_EN.pdf; **2.ATOS CORE 80:** http://www.henindo.co.id/home/ATOS_Core_Flyer_EN_RevB.pdf

Specialized test equipment				MATERIAL ANALYSIS/TESTING - Hydraulic bulging BUGLE Hydrotest - Chemical analyzer BELEC - Metallographic microscope Olympus - Sheet metal testing Erichsen 145-60 - Tenzometric apparatus Quantum MX 440 - Digital microscope Keyence VH-5000 - Differential scanning calorimeter Perkin Elmer Q600 STRESS/VIBRATION TESTING - Determination of residual Vishay RS-200, SINT MTS-3000 POLLUTION AND NOISE ANALYSIS - SHIMADZU ICPE-9000 - Olympus BX51 - HACH LANGE DR 2800 & LT 200	
Other	**-Any other potentially relevant equipment not included already?**		- Swift Navigation Piksi Multi x 2		

EQUIPMENT	LIST OF KEY PROPERTIES TO INCLUDE	USE	CEA	CUT RCDS	LMS
Multi-rotor Unmanned Aerial Vehicles (UAVs)	**- Max payload? - What onboard equipment? - Specialized technology/ setups (e.g. UAV with two-arm setup) - Associated test infrastructure (if any)**	1. Darius - Diameter: 1.7m - 12 minutes endurance (fully loaded) - Weight: 7kg +8kg extra payload 2. DJI F550 - Diameter: 550mm - Endurance: 20 minutes - Weight: 478g - Takeoff max weight: 2400g 3. AMUSE - Equipped with 3D Lidar, Zed Camera, IMU, RTK GPS, Jetson Compute - MTOW: 14kg - Endurance: 10 minutes - Weight: 12kg		1. 2x DJI M210 - 2 Thermal cameras (1 radiometric) - 2 UHD Optical cameras - 2.3kg max payload - 38 min max flight time	
Fixed-wing UAVs	**- Max payload? - Max range? - What onboard equipment? - Specialized technology/setups (e.g. Fixed-wing UAV with vertical takeoff)? - Associated test infrastructure (if any)**	3. Ranger - Payload: Up to 2 kg - Wingspan: 1980mm - Endurance: 2 hours - Weight: 1500g 2. Skysurfer - Length: 925mm - Autonomy: 20 minutes - Wingspan: 1400mm - Range: 1000m			

Mobile robots	**- Max payload?** **- What onboard equipment?** **- Type of locomotion (e.g. wheeled, tracked, crawler etc.)** **- Key functionality** **- Specialized technology/setups (e.g. ATEX certified, fully autonomous, teleoperated, can be fitted with xyz robot manipulator)** **- Associated test infrastructure (if any)**	1.Bobcat - Autopilot: Pixhawk - Payload: 363kg - Speed: 40km/h - Length: 317cm - Weight: 639.6kg 2.8×8 AGV - Payload: +6kg - Speed: 30km/h - Endurance: 30 minutes - Weight: 10kg - Autopilot: Pixhawk 3. Pioneer 3-AT - Payload: Up to 12kg - Speed: 0.7m/s - Endurance: 2-4 hours - Weight: 12kg - Control: Laptop with Ubuntu/ROS	MIR ASTI: EasyBot	1. Robotnik RB-1 Base - 50 Kg payload - 10 hrs autonomy - Depth sensor - Scanning laser rangefinder - Logistics related test infrastructure 2. 4x Custom Turtlebots - 15 kg payload - 4 hrs autonomy - Scanning laser rangefinder - Image based localization	1. FESTO Robotino -Battery powered -Equipped with Kinect and distance sensors -Running ROS -Equipped with 3D cameras and gripping tools
Mobile robot manipulators	**- Max payload for manipulator?** **- Capability/functionality for manipulator?** **- Compatibility with mobile robot platforms?** **- Specialized technology/setups (e.g. can be fitted with grippers X and Y, can be teleoperated etc.)**	1. Lightweigth aerial manipulators (USE) - Max payload manipulators 300 g - Embed in Darius Aerial platform - Suitable for maintenance tasks in high altitudes - 600g each 2. 3D printable Manipulators for aerial robots (https://github.com/Bardo91/hecatonquiros) - Switchable end-effectors - 4, 5, or 6 Dof - Max payload 300g - 750g each			1. Mobile platform equipped with two UR-10 robots on a torso -Battery powered -Equipped with two SICK laser scanners -The torso can rotate and make vertical movements -Running ROS, teleoperated
Unmanned Surface Vehicle (USV)	**- Max payload?** **- Max range?** **- What onboard equipment?** **- Specialized technology/setups (e.g. can be fitted with xyz robot manipulator etc.)?** **- Associated test infrastructure (if any)**				

Unmanned Underwater Vehicle (UUV)	**- Max payload?** **- Max range?** **- What onboard equipment?** **- Specialized technology/setups (e.g. can be fitted with xyz robot manipulator etc.)?** **- Associated test infrastructure (if any)**			1. Hybrid Gantry-Delta robot - Custom in-house design - Semisubmersible (delta part) - 15 kg payload - 5 DOF 2. 2x Videoray Pro-4 ROVs - 300m depth rating - 9 Knots - Custom laser vision system for relative 3D positioning - Custom 2DOF gripper - 110m tether - Custom control and stabilization software	
Cobots **(manipulator robots working in cooperation with humans with no barriers)**	**- Max payload?** **- Capability/functionality for Cobot?** **- Associated test infrastructure (if any)**		UR10 IIWA7, IIWA14 YUMII DOOSAN iSYBOT: SYB4, SYB6, SYBXL FANUC: CR35I (35 kg payload)		1. Two Universal Robots UR10 - Max payload: 10 kg - Capability: Stops when hitting something, integrated F/T sensor at end effector
Collaborative Robots			ALTIFOR: COBOMANIP RB3D: A615 CEA: LDC		
Industrial robot manipulators	**-Max payload?** **- Capability/functionality for robot? (e.g. can be fitted with grippers X and Y, can be teleoperated etc.)** **- Associated test infrastructure (if any)**	1. Pair of RX-90 in a shared work-space - Max speed: 11m/s - Load capacity: 6kg - Repeatability: 0.02mm - Weight: 111kg - Control: Laptop with Ubuntu/ROS	STAUBLI: TX90, RX90, RX130, TX2-90, ABB: IRB4600	1. Fanuc 100i - Mig Arc welding - 6DOF	1. Two COMAU NJ 130 robots -Max Payload: 130Kg 2. COMAU NJ 370 robot -Max Payload: 370Kg 3. COMAU Smart Dual Arm robot -Max Payload: 7Kg per arm 4. Two COMAU Racer robots -Max Payload: 7Kg per arm

Master-slave manipulators (typically used for remote handling tools for the nuclear industry)	**-Max payload?** **- Capability/functionality for robot? (e.g. can be fitted with grippers X and Y, can be teleoperated etc.)** **- Associated test infrastructure (if any)**		Master Arms MA23 HAPTION: VIRTUOSE 3D, VIRTUOSE 6D GEOMAGIC: TOUCHX Slave arm Staubli: RX90, TX90, RX130 iSYBOT: SYB3, SYB4, SYB6 Long reach arms, snake robots (up to 9m/ 10kg payload) Inflatable robot		
Exoskeletons	**-What type of equipment?** **- Capability/Functionality for exoskeleton?** **- Associated test infrastructure (if any)**		HAPTION: ABLE CEA: BALANCE, HV-SLIM		
Sensors	**- What type of sensors? (e.g. ultrasound, hyperspectral camera, etc.)** **- Key properties/capabilities**	- Laser sensors - Realsense RGBD Camera - Kinect Camera - Thermal camera small 240x180 embedded - LIDAR	Force sensors Force sensor based on vibration analysis Vision sensor Capacitive sensors Inductive sensors	- F/T- sensor - Magnetic tracker (3x 6DOF) - RGBD Cameras - Scanning laser rangefinders - Custom laser vision system for underwater relative posture estimation - 120fps cameras - Thermal (incl. radiometric) cameras - Optical cameras - High performance IMU/AHRS	1. Two Kinect sensors -3D vision sensor 2. Two F/T sensors -Sensor Typ 6-DOF 2KN/400Nm -Sensor Type: 6-DOF 600N/60Nm 3. RFID part tracking system 4. Two 3D Safety cameras from PILZ 5. Basler Industrial Cameras 6. Two industrial voice cancelling headsets 7. Leap motion sensor -Hand tracking sensor
End-effectors, Grippers	**- What type of end-effectors?** **- What type of actuation style (e.g. pneumatic, electromechanical etc.)** **- Capability/functionality for end-effector?** **- Compatibitity with robot manipulators?**		SCHUNK ROBOT-IQ DESUTTER: Automatic screw driver CEA: - HANDLE 5 finger grippers, - ROMANS 4 finger gripper	- Custom 2DOF underwater manipulator with interchangengeable end-effector	1. Two Schunk grippers (PG70 & EGN160) -Two-finger grippers -Electromechanical actuated
Haptic devices	**- What type of device/technology?** **- Brief description of use and possibilities?**		HAPTION: VIRTUOSE 3D, VIRTUOSE 6D GEOMAGIC: TOUCHX CEA: Three finger glove with haptic feedback		

Specialized software	**- What software? (E.g. Simulation software such as VR, Solidworks etc.)** **- Brief description of use and possibilities?** **- Licencing/leasing possibilities**		SolidWorks Mathematica Matlab COMSOL multi physics simulation XDE SEEROB: cobotics scene simulation TAO: SCORE: 3D graphics programming ROS: Robotics Operating System TANGO: SCADA for data collection and workflow control	- ROS: Robotic Operating System - SolidWorks - Visual Components - Mathematica - Matlab - UCCNC	1. Product development (Pro/Engineer, CATIA) 2. Process planning and simulation (DELMIA, Process Simulate, IMPACT, WITNESS, ROBCAD, Invision, WinMod) 3. Integration/communication 4. Visualization Virtools and a Virtual and Augmented Reality Room
Machining tools	**- What equipment?** **- What are the capability/range of the tools?**	- Sigmax BCN 3D 60x30x30 cm	Lathe, Drillling machine, Sanding machine LEICA for metrology	- Machine shop - 3D printers - CNC router	1. Printer BFB 3D touch 2. Lathe machine 3. 3-axis CNC milling machine
Measurement and Quality Assurance tools	**- What equipment? (e.g. X-ray, scanning etc.)** **- What are the capability/range of the tools?**			- SPM/AFM - Nanoindentation	

Specialized test equipment					
Other	**-Any other potentially relevant equipment not included already?**				1. PLC Siemens Simatic S7 2. PILZ PSS 4000 safe PLC 3. PILZ PSS 3000 I/O controller 4. Wall CAVE system BARCO RLM-W12 projectors and 4x VICON Bonita 3 tracking cameras -For Virtual Reality applications 5. EON ICrystal holographic display -For holographic projection 6. Vuzix STAR 1200XL AR glasses 7. EPSON Moverio AR glasses 8. Microsoft HoloLens headset

SPECIALIZED TEST FACILITIES

TEST FACILITY	DESCRIPTION OF TEST FACILITY	DIH PARTNER
SINTEF outdoor robotics lab	- Located at SINTEF's premises in Trondheim, Norway - Purpose: to provide a realistic industrial test environment for outdoor robotic platforms - 12.5 x 30 flat concrete floor surrounded by 2 m high fences, and with a wide gate to bring large equipment into the lab. - Heated work-men's hut for personnel to work in and with automatic garage door which allows robots to drive directly out onto the concrete floor via a ramp. - Artificial lighting and high-speed internet (cabled and wireless) - RTK-GPS high precision (millimeter precision) satellite-based localization system. - Access to single-phase and three-phase high-current power outlets on designated spots around on the concrete floor. - 6 mock-up process equipment modules with pumps, electrical motors, piping, manometers, valves. - Pant-tilt high-resolution zoom surveillance camera for monitoring operations.	SINTEF
JRC Labs (FORATOM can support for Nuclear orientated lad ie rad materials testing etc) (not technically part of this project but we should be able to access if planned correctly)	https://ec.europa.eu/jrc/en/research-facility/open-access JRC Research Infrastructures now opening access through the relevance-driven mode: Nuclear calls: Actinide User Laboratory (ActUsLab) Nuclear calls: European research infrastructure for nuclear reaction, radioactivity, radiation and technology studies in science and applications (EUFRAT) Non-nuclear calls	FORATOM > JRC

GRVC Robotics Laboratory (counts with Excellent Robotic Laboratories)	Located at the school of engineering in the University of Seville. Seville, SPAIN (https://grvc.us.es).
	- Researchers and Engineers with strong experience in robotics and particularly in aerial robotics
	- Fleet of multi-rotor systems, fixed wing, and ground robots
	- Multiple sensors for robotics (cameras, lasers, IMUs...)
	- Indoor test bed facilities:
	    - Dimensions 20x15x16 (m)
	    - Equiped with 26 OptiTrack Motion Capture Cameras for multiple robots including passive and active tags
	    - Pipe mock-ups modules to simulate industrial environments
	- Outdoor testbed facilities:
	    - Dimensions 30x30x10 (m)
	    - RTK-GPS for aerial robots
	    - Protected by a net to make possible the flights in an urban area
		USE

Assembly & Testing Halls for Prototyping	- located at TUKE / - 300 m2 / - heavy overhead cranes	TUKE
Lab for testing & diagnostics of pneumatic systems	all functional testings & analysis possible	TUKE
PIAP indoor mobile robots test area	- Located at ŁUKASIEWICZ-PIAP in Warsaw, Poland - Purpose: test and compare mobile robots in same conditions - Container size space, filled with wooden elements that allow for creation of repetable tests of drivinf and manipulation tasks - follow US NIST analogue	ŁUKASIEWICZ PIAP Institute
PIAP robotics and automation test area	Located at ŁUKASIEWICZ PIAP Institute premises in Warsaw Poland Purpose: to provide an area to test and do research in the robotics and automation area in industry flat concrete floor in the robotics laboratory - size about 12 x 40 meters, with the gate 4 x 4 meters Artificial lighting and high-speed internet (cabled and wireless) Access to single-phase and three-phase high-current power outlets on designated spots around on the concrete floor. Three industrial KUKA robots, KR 5 (5 kg payload, with KRC 2), KR16 Foundry (16 kg payloads for working in high temperature), KR 500 MT (500 kg payload, with bigger momentum on the axis) on the linear unit with range about 5 m. Those robots can be applied to many tests and research, in the areas of welding (also ŁUKASIEWICZ PIAP Institute is equimpment with fronius TPS 4000 CMT, and TPS 3200), palletizing (direct access to Schmalz distributor - on the same land), painting, polishing and milling (milling unit form KUKA - 13 kW with a huge set of tools).	ŁUKASIEWICZ PIAP Institute

DFKI Maritime Exploration Hall	The 1,300 m² Maritime Exploration Hall (Located at DFKI's premises in Bremen, Germany) serves to test new robotic technologies on and under water. Everyday missions of the offshore industry are simulated, maneuvers are carried out and skills of future systems are demonstrated. The infrastructure comprises a large basin, two separate test basins, a pressure chamber as well as complete technical equipment from cranes up to laboratories. DFKI UNDERWATER TEST BED: - Purpose: to provide a realistic test environment for subsea robotic platforms - a 23 m x 19 m x 8 m test basin, including mechanical infrastructure - 3.4 million liters of saltwater (18 g of salt per liter) - crane systems (12.5 t and 250 kgs) to immerse systems and test objects in the basin - a window close to ground level that allows observers to look into the large basin - space for two 20’ containers near the basin and a spacious logistics area in front of the building DFKI SEPARATE TEST BASIN A: - A 5 m x 4 m x 2.2 m glass tank containing 40,000 liters of water with three glass walls for optimum observation of test runs DFKI SEPARATE TEST BASIN B: - A 3.4 m x 2.6 m x 2.2 m black tank that can be covered to shield it against external light and permitting control of the water turbidity DFKI PRESSURE CHAMBER: - Water pressure corresponding to a depth of 6,000 m (600 bar)	DFKI

DFKI Space Exploration Hall	The 288 square meter space exploration hall allows to test space robots under realistic conditions. Systems can demonstrate their skills in the 9 meters wide crater test area within the test hall. The surface was modeled based on a crater at the south pole on the moon. The surface can be altered, rock segments can be exchanged for certain tests on different undergrounds. An additional 18 square meter ramp on a four meter high plateau at the head of the crater area is adjustable in its gradient degree. In this way it is possible to test the mobility of the robot on a horizontal ground and on varying slopes. For similar light conditions to the moon, the inner walls are furnished with a black non-reflective coating. With a height of ten meters, the space hall provides enough space for testing flight systems as well as interactions between satellites and robots. VICON TRACKING SYSTEM (ASSOCIATED TEST INFRASTRUCTURE) The VICON tracking system uses six cameras mounted in a height of 6.5 m each and cover a volume of about 770 cubic meters. Three cameras are distributed on each of the two long sides of the hall. A seventh camera can be positioned flexibly to reach higher accuracy in varying volumes of the hall. The tracking system can be controlled with variable speeds between about 4 ms and 12 ms. The cameras operate in the infrared wavelength range and actively transmit the light in this band. Markers are attached to the cable-robot to determine the position which in this wavelength region has a high reflection coefficient and hence can be detected particularly well by the tracking system. number of cameras: 6, covered volume: ca. 770 m^3, cycle time: ca. 4 ms – 12 ms, wavelength range, (received and sent): Infrared HEADLIGHT SYSTEM (ASSOCIATED TEST INFRASTRUCTURE) Headlights in the Exploration Hall, number of cable control: 5, max. number of headlight per cable: 3, number of headlights in hall: 6, headlight type: ADB Warp motorisch The headlights have a color temperature of 6000 K and produce daylight conditions. With the ability to influence the light cone in its form, defined areas of light and shadow can be created. In addition, there are no overlapping light fields which would result in unwanted areas with deepest shadow and partial shade in the crater area. The control panel for lighting control provides the ability to store up to eight different lighting themes. In this way, experimental conditions can be stored and recalled at any time. Depending on the orientation of the headlamps, the sun's position for satellite missions or the position of the sun in exploration missions to the lunar south pole can be simulated.	DFKI
DFKI Outdoor Testing Facility for Robot Benchmarking	The robot test track is an outdoor testing facility with 15 challenging obstacles and an area of more than 500 m^2. The obstacles can be used for performance evaluation of walking, driving and climbing robots. On the 70 m x 6 m -area our robots can be tested on slopes with different inclinations and surface characteristics. The substrates consist of sand, rocks, grass, gravel, metal and wood. The pond in front of the building serves as an outdoor basin for swimming and diving robots. The obstacles of the robot test track can be combined to several challenging testing courses. The obstacles are the following: Wooden Staircase; Concrete Tube; Rock Hill; Cattle Bridge; Rock Canyon; Grass Dunes; Small Rock Field; Large Rock Field; Random Stepping Field; Gap Tester; Log Pile; Gravel Field; Railroad Tracks; Climbing Fence; Pond	DFKI

RIF@Paris-Saclay	Technological infrastructures for unit test in realistic conditions: - FFLOR (France East, Trémery), - TROPIC(France South West, Bordeaux), - AXESS (France Ouest, Nantes), - SMART (Paris region, Saclay) IT support with protection of data Mechanical workshop	CEA
CUT RCDS	1. Underwater Robotics infrastructure - 3mx5mx1.2m water tank with custom overhead x-y-delta robot - Seaports and aquacutlure facilities access option for real world testing 2. Mobile and Aerial cooperative robotics test facilities - 10mx10mx2.3m test facility 3. Anechoic chamber - 5mx5mx23m anechoic chamber	CUT
LMS Machine Shop	-Located at the Mechanical department of University of Patras -All the robots and heavy machines are installed in this area -Artificial lighting and high-speed internet (cabled and wireless)	LMS
LMS Cave	-Located at the Mechanical department of University of Patras -All the VR-related equipment is installed in this area -Artificial lighting and high-speed internet (cabled and wireless)	LMS
DTI Robot Safety Lab	Robot Safety Lab - for collaborative robots	DTI