SAND2016-4687R

Future Technology Estimation Survey form for the Robotics Technology Alternatives in the Electric Power Industry: Submersible Mini-Robot

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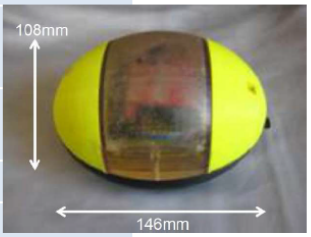
Submersible Mini-Robot

Related Institutes	MIT
Main Function	Visual inspection of submerged components in nuclear reactor vessels and spent fuel pools
Working Environment	Underwater
Motion Pattern	Underwater navigating
Propulsion	Water Jet
Requirement	- Appendage-free Appearance - Ability to navigate through intricate and tight geometries - Ability to conduct inspection-type passes over surfaces - Enough payload for two camera - Wireless optical communication



Perspectives	Criterion	Description	Measurement Unit	Time Period				Note
				2015-2016	2017-2018	2019-2020	2021-2022	
Functionality	Multi-Functions	A robotic system consists of multiple functions enabling the system to conduct diverse tasks given. In order to complete the tasks successfully, the reasonable number of functions need to be combined.	ea	**2**	**2**	**2**	**2**	
	Multi-Environments	A robotic system for the electric power industry needs to conduct diverse tasks given under one or environments (e.g. high temperature, high radiation	ea	**1**	**1**	**1**	**1**	**Water filled environments**

		, over high-voltage transmission lines or underwater). The capability of working under multiple environments increases the versatility of the system. However, because of design constraints, the number of applicable environments needs to be identified.						
	Multi-Applications	A robotic system is designed for one or multiple applications or tasks such as inspection, monitoring, maintenance and cleaning. The	ea	**1**	**1**	**2**	**2**	**Visual Inspection, NDE**

		number of applications the system should carry out needs to be identified.						
Design	Heavy-duty	A robotic system should carry out tasks given without any failure during its operation. In particular, a trouble-free design is desirable for the robotic systems in the electric power industry because of its severe environments. The reliability in operation for a robotic system is quantified as mean time before failure (MTBF).	MTBF (yr)	**Unknown**	**N/A**	**N/A**	**N/A**	**Has not been evaluated**

		It is defined as total operation time over the number of failure.						
	Motion flexibility	A robotic system carry out its tasks through multiple motions such as moving and handling. Therefore, the motion flexibility of the system is quantified as the degree of freedom (dof).	dof	**5dof**	**5**	**5**	**5**	
	Size	The size of a robotic system should be within acceptable dimensions or appropriate volume to be used, carried, applied, and operated effectively. This is quantified by 5-	5-point Scale	**3**	**3**	**3**	**4**	

		point scale (1: Gigantic, 2: Large, 3: Small, 4: Miniature, 5: Microscopic)						
	Contamination Proof	A robotic system for the electric power industry should be highly protected from the negative impacts of hazard materials or environmental causes during its operation. Therefore, the long-hour operation without any failures under the severe environments is desirable for the robotic system.	hr	**<0.5 hr**	**2**	**4**	**10**	
	Nondestructive	In carrying out inspection or monitori	mm	**0**	**0**	**10**	**10**	

		ng tasks given, a robotic system may do the jobs without negative impact/damages or residues to the surroundings or working objects. Therefore, the capability of carrying out tasks without any negative impacts on working objects is desirable for the system. The capability is quantified as the depth from the surface of working objects to the position where the system can measure under the surface of a						

		concrete structure						
Technological	Positioning	A robotic system should be capable of identify its location and position while performing its job, or to be allocated easily at certain location. Therefore, the high accuracy of positioning is desirable. The measure of positioning accuracy is quantified as the maximum radius of errors in positioning.	m	**N/A**	**1**	**0.5**	**0.25**	**Depends on sensor suite, existence of pre-existing maps/data.**
	Precision	A robotic system should be capable of identify	%	**N/A**	**90**	**90**	**90**	**Current design does not include end effector. If vehicle position is known, end effector location should be straightforward. Estimating vehicle position is far more challenging.**

		the location of its end-effector in order to assure high performance and accurate results. Therefore, the precise operation is desirable. The measure of precision is quantified as the percent accuracy in operating its end-effector.						
	Assessment Time	In inspecting or monitoring the status of working objects, the speed of issue evaluation lead to reduction of time or efforts.	hr	**Unknown**	**Unknown**	**Unknown**	**Unknown**	
User Experience	Easy to Use	Simple, effortless, trouble-free, straightforward,	6-point Scale	**4**	**4**	**5**	**5**	

		and direct use are desirable for operating a robotic system. The level of easy to use is quantified by 6-point scale related to training. For example, while 1 point means that longer training period is required for operation, 6 point means no training required.						
	Upgradability	The potential for more improvement to accommodate future needs is sometimes required. The level of upgradability is quantified as the percent	%	**50**	**50**	**100**	**100**	**As mechanical hardware is finalized, upgradability will depend on improving software and electronics, two fields that are rapidly improving.**

		improvement. For example, more than 100% of upgradability means that the system is capable of improving its performance over twice by upgrade.						
	Maintainability	Mean Time To Repair (MTTR) is defined as the time needed to repair a failed hardware module. A short MTTR of a module means that the maintainability of it is better than one that needs a longer MTTR.	MTTR (hr)	**<6hr**	**<4hr**	**<3hr**	**<3hr**	
	Working Speed	In carrying out tasks given, the working	hr	**3**	**6**	**8**	**10**	

		speed of a robotic system enable to reduce time or efforts. It is quantified by the average hours of total working time on the system						
Electronics	Remote Operation	A robotic system need to be operated and controlled remotely from a acceptable distance of operation.	Miles	**<0.02**	**<0.02**	**<0.02**	**<0.02**	**Depends on Line of Sight. Note, if a tether is used this metric and the ones below should substantially improve. Communication and imaging resolution would improve dramatically.**
	Visual Capability	In order to achieve visual information around a robotic system, the visual capability of imaging system (e.g. still cameras or video cameras) is required. The	Resolution	**NTSC**	**NTSC or 752 x 480**	**NTSC or 752 x 480**	**NTSC or 752 x 480**	**Depends on communication bandwidth, http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6631308 . If a tether is used, HD video is possible.**

		capability is quantified by the resolution of the image achievable from the imaging system.						
	Dual Communication	Two-way and high-rate of data transmission for easy operation and real-time control or assessment is desirable between a robot and operator/ controller. The communication capability is quantified by the sampling rate of its communication system (Mega sample per second, MSPS).	MSPS	**<1M SPS**	**<1M SPS**	**<1M SPS**	**<1M SPS**	**Restricted by presence of water. If optical communication can be achieved, data rate will be limited by the optical components. If a tether is used, communication bandwidth would be that of optical fibers or wires. Optical fibers are capable of data rates up to 10Gbps.**
	Data Processing	The data processing speed of a robotic system	Mb/sec	**16 MHz**	**120 MHz**	**700 MHz**	**700 MHz**	**Anticipating move towards higher performance microcontrollers and perhaps single board computers.**

		is critical for reducing working time in carrying out tasks given. This capability depends on the performance of the data processing system such as processors and communication bus.						
	Interface Proof	Some robotic systems need to carry out tasks given under high radiation environment. Therefore, the systems are capable of operating without any failure under a certain amount of radiation does. The capability of	Sv/hr	**N/A**	**Unknown**	**Unknown**	**Unknown**	**Requires rigorous testing to determine. Numbers are currently unavailable.**

		interface proof against radiation is quantified by the level of radiation which the robotic system can conduct tasks normally under over 3 hours.						