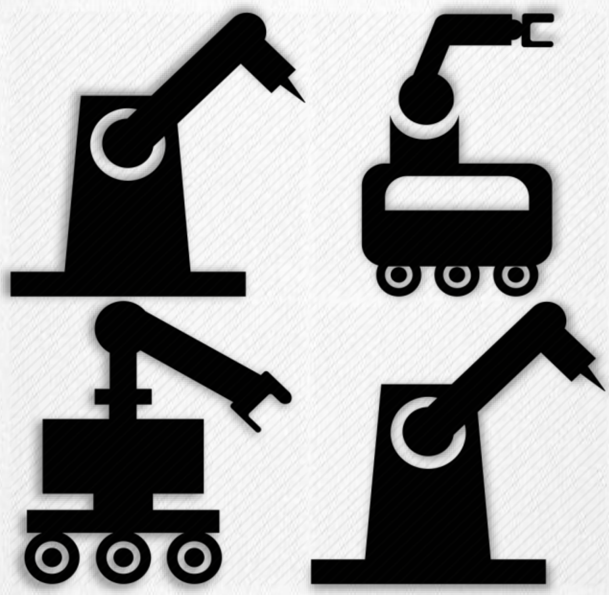
Nuclear Robotics Module



Section One	Lesson Plan
Section Two	Module PPT
Section Three	Hands-On Activity PPT
Section Four	Pre Assessment Test Pre Assessment Answer Key

RCNET

RCNET Nuclear Robotics Module

Topic

This module is an introduction to general robotics, robot operating systems, and the benefits and applications of robotics in nuclear technology.

Module Introduction / Brief Lesson Description

This module will cover the basic elements of robotics, discuss what a robot is and discuss the advantages robots can provide to the nuclear industry.

Learning Objectives / Outcomes

Upon completion of this module, students will be able to:

1. Identify what constitutes a robot
2. Identify Nuclear Applications of Robotics, both current and future
3. Enumerate and describe the basic methods of robot control
4. Identify and discuss functions and limitations of nuclear robotic systems
5. Describe the basics of the Robot Operating System
6. Define open/closed loop control and degrees of freedom

Procedure for Using the RCNET Module

This module was designed to be taught over a period of six lecture hours, as outlined below. However, the teacher may modify this curriculum, as needed, to fit into specific program allowances.

Prior to Starting:	Review module material included in this packet	
	Gather module materials, included and not included in this packet (see the **List of Materials** section)	
	If providing hard copies of the PPT, print class set to hand out after the pre-assessment.	
Day One, Hours 1-2:	1	Introduce topic. Ask questions to generate discussion. (See Lecture Notes, for specific questions.)
	2	Start student presentation. Introduce the topic, module introduction, learning objectives, and module agenda.
	3	STOP the PPT.
	4	Administer Pre-Assessment. Explain to students that this assessment is to gauge their pre-existing knowledge of nuclear robotics and will not count as a grade in the course.
	5	Collect pre-assessments for grading.
	6	Hand out pre-printed student slides (if using).
	7	If time permits, continue module, using PPT and lecture notes
	8	End day one of module.

	Day Two, Hours 3-4:	9	Briefly review topics discussed on previous day.
		10	Review results of pre-assessment. Tests can be handed back to students for discussion, but should be re-collected at the end of the discussion.
		11	Continue module, using PPT and lecture notes. Engage students in module by asking questions in lecture notes and allowing open discussion.
		12	End day two of module.
	Day Three, Hours 5-6:	13	Briefly review topics discussed on previous days.
		14	Continue module, using PPT and lecture notes. Engage students in module by asking questions in lecture notes and allowing open discussion.
		15	Demonstrate Hands-On Activity (see **Hands on Activity** section for specific details)
		16	Review material and takeaways and to prepare students for post assessment.
		17	Administer Post-Assessment. The post-assessment can be administered by any of the following methods: -- Same day with open books/notes -- Same day without books/notes -- Next day to allow students time to study on their own -- At a later day in the campus assessment center
		18	Collect post-assessment, grade with provided key and provide feedback to students.

List of Materials

	Required:	RCNET Nuclear Robotics PPT with Lecture Notes
		AV equipment with connection to a computer equipped with Microsoft PowerPoint
	Optional:	Printed class set of RCNET Nuclear Robotics PPT student handout (master included in this packet)
		Printed class set of Pre -Assessment (master included in this packet)
		Printed class set of Post -Assessment (master included in this packet)
		Ozobots for demonstration (link to purchase on Amazon.com: *http://amzn.to/1Nx01Yk*)
		Hands-On PPT with Lecture Notes for Ozobot demonstration (included in this packet)
		iRobot Brochure - Robots in Nuclear Power Plants

Lesson Plan & Lecture Notes

1. *Introduction, Learning Objectives, & Module Topics*

Slide 1

This presentation will cover the following topics:

What is a robot?
Why use robots? What are their benefits and where do they excel or fall short?
What are the global trends relating to robotics?
Why is robotics being discussed in the context of nuclear industry?
What are the components of a robot?
What courses and certificates would benefit nuclear technicians looking into robotics?

Slide 2

Suggested ACADs and sample Program Courses where this module may fit into your nuclear program.

ACADs

1.1.8.4.3 Exposure reduction methods
1.2.1.13 Post-accident sampling
2.1.1 Explain basic concepts related to accident analysis
3.1.1.14 radiation monitoring
3.3.3 Interactions of Radiation with Matter
3.3.5 Radiological Protection Standards
3.3.9.8 Describe techniques for controlling the spread of contamination to personnel and equipment

Program Courses

ETP 1230 Power Plant Systems
ETP 1220 Power Plant Fundamentals
ETI 1000 Industrial Plant Tools Equipment
ETI 1701 Industrial Safety

ETP 2941 Professional Internship for Maintenance Technicians

ETP 2211 Radiation Instrumentation
ETP 2213 Radiological Safety and Protection
ETP 2219 Radiation Protection/ Capstone Project

Slide 3

Upon completion of this module, students will be able to:

Identify what constitutes a robot
Identify Nuclear Applications of Robotics, both current and future
Enumerate and describe the basic methods of robot control
Identify and discuss functions and limitations of nuclear robotics systems
Describe the basics of the Robot Operating System
Define open/closed loop control and degrees of freedom

	Slide 4	This module is broken down into six sections: Introduction to Robotics Robot Applications Robot Components Robot Operating System (ROS) Concepts Relating to Robotics Taking it Further
2. Introduction to Robotics		
	Slide 5	Section two is an introduction to robotics and covers some of the benefits of using robots. What is a Robot? Why use robots? Benefits of robots
	Slide 6	What is the first image that comes to mind when you hear the word robot? “Robot” is a very broad and all-encompassing term. It stretches the gamut from reaction based industrial automation machinery, to complex decision-making humanoid automatons. For the purposes of this presentation, the strict definition of a robot is any device that automatically performs a set of actions while independent of human control. The word robot itself originates from the Czech words ”robotnik”, meaning slave, or “robota“, meaning forced labor. Tele manipulators, remotely operated devices and telepresence machines don’t strictly meet the definition of a robot, but are included due to their similarity and applicability.
	Slide 7	(Open Discussion) Where do robots excel? What are their benefits?
	Slide 8	Robots can be designed to operate with extreme precision, accuracy, and thus repeatability. [Video: 6-axis Dueling Katanas] *https://www.youtube.com/watch?v=cR-YlZ9NdIA* [Video: 6-Axis VS Katana Master] *https://www.youtube.com/watch?v=O3XyDLbaUmU* [Video: DaVinci Peeling a Grape] *https://www.youtube.com/watch?v=cpPofyZbv*
	Slide 9	Robots are robust and can operate in places inaccessible to people.

	Slide 10	Robots can calculate paths of least resistance or effort, and perform tasks with the utmost efficiency.
	Slide 11	Robots can perform tasks that are generally unpleasant or mundane. In cases of highly repetitive tasks, people may lose focus and attention to detail, whereas their robot counterparts operate with the same extreme scrutiny on the millionth iteration as they did on the first.
	Slide 12	Robots are expendable. They can be assigned tasks that are too dangerous for humans.
	Slide 13	Robots can be designed to operate in environments that are otherwise too extreme for humans. Such extremes include temperature or pressure, excess radiation, or lack of breathable atmosphere.
	Slide 14	The return on investments is large over the long-term. By limiting the need for on-site technicians, robots may reduce or eliminate downtime and associated costs. This diagram is based on a medium sized industrial robot (100-kg payload), estimating the average power consumption for this size robot of 7.35 kW and the average energy cost of 10 cents per kWh (based on 2013 rates for industrial usage, source: U.S. Department of Energy). The estimated average cost to operate this medium-sized robot is 75 cents an hour. Please see this excellent article from robotics.org on calculating an ROI for robotics automation, and cost vs cash flow. *http://www.robotics.org/content-detail.cfm/Industrial-Robotics-Industry-Insights/Calculating-Your-ROI-for-Robotic-Automation-Cost-vs-Cash-Flow/content_id/5285*
	Slide 15	There's a global trend towards robotics, and history shows us that generally, industries that embrace change fare better than those that are swept up by it. Additionally, due to the growth in the sector, the cost of entry is on the decline. [More Info] *https://www.bcgperspectives.com/content/articles/business_unit_strategy_innovation_rise_of_robotics/*
	Slide 16	Introduction to Robotics Takeaways A robot is an autonomous device that performs tasks while independent of human control. The benefits of robots include precision & accuracy, robustness & versatility, efficiency, ability to perform

3. Robot Applications	
Slide 17	Section three is about robot applications, specifically taking a look at how robots work in different sectors of the nuclear industry. General Applications Nuclear Robotics iRobot Nuclear Energy + Robots Nuclear Medicine + Robots Waste Management Fukushima + Robots Planning for Radiation
Slide 18	(Open Discussion) What are some of the applications of robotics?
Slide 19	Robots have applications in many fields across a multitude of fields, but have especially made their home in manufacturing. We'll look at some examples on the next slides.
Slide 20	Robotic welding is common in high production manufacturing, such as the automotive industry.
Slide 21	Pick & Place robots and various kinds of soldering machines are used to assemble most of the circuit boards destined for consumer electronics.
Slide 22	Robots are used in many industries for quality control, but are especially common in fields that demand high quality and high volume, such as the food industry. In this picture we see hamburger buns that don't meet a specific set of criteria being removed before packaging.
Slide 23	The Nuclear industry offers many benefits, but inherently demands a low tolerance for error. Robots can be specially designed to efficiently and reliably assist the industry while meeting these tolerances.
Slide 24	US-Based robotics company, iRobot has developed robots that are able to go into radiation control areas and perform operations, record critical data and protect personnel at safe standoff distances. (Print included in packet and available at the following link) http://www.irobot.com/~/media/Files/Robots/Defense/iRobot-Nuclear-Industry-Applications.pdf
Slide 25	This list, published by iRobot, outlines some of the applications of robots in the nuclear industry. (Print included in packet and available at the following link) http://www.irobot.com/~/media/Files/Robots/Defense/iRobot-Nuclear-Industry-Applications.pdf
Slide 26	Robots can be used to perform radiographic analysis on pipes and devices. In the image above, x-ray radiography is used to visualize cracks along a pipe weld. Gamma rays are also used in this manner.

	Slide 27	(Open Discussion) What are some of the applications in nuclear energy?
	Slide 28	This is GE Hitachi's Stinger robot, developed to replace humans for cleaning and inspecting reactor vessels. Inspecting and maintaining a reactor's core is expensive, time consuming and labor intensive. Teams of workers need to go inside the containment vessel which means special bridges are installed over the pool so that workers can walk out with poles tipped with tools and instruments. This process exposes workers to radiation and interrupts the on-going operations to remove and replace spent fuel rods. The GE Hitachi Stinger is designed to simplify the whole inspection task by replacing the ream and the bridge with a free-swimming robot. The robot swims about using an advanced camera and remote positioning technology while being controlled by an operator in a tent away from the radiation area. This process even allows the refueling operations to continue, uninterrupted. [More Info] http://www.gizmag.com/ge-atomic-swimmer-robot-nuclear-reactor-inspector/38438/
	Slide 29	Robots have been or are in the process of being developed or tested to inspect, clean, repair, or otherwise work in or around reaction vessels, steam generators, fuel pools, and the like. [More Info] http://www.jsm.or.jp/ejam/Vol.5No.1/NT/NT54/NT54.html
	Slide 30	In maintaining a nuclear power plant, conditions are small, cramped, narrow, under water, and/or high radiation dose rates. To alleviate complications from these working conditions, robots have been developed to complete regular maintenance and inspection tasks. These robots include: RV Inspection Robot Maintenance & Inspection for RV Inlet & Outlet Nozzles Repair robot for SG Inlet and Outlet Nozzles Inspection Robot for SG Inlet and Outlet Nozzles
	Slide 31	The primary purpose of these robots is to reduce the radiation dose of field workers during inspection and maintenance work. According to estimates, by utilizing these robots and reactor design, reactor vessel inspection time can be reduced to 28% that of conventional systems. [More Info] *http://www.jsm.or.jp/ejam/Vol.5No.1/NT/NT54/NT54.html*

	Slide 32	Robots could transport and setup radiation barriers for the purpose of shielding technicians while they work.
	Slide 33	This robot is using visual, laser, and eddy-current sensors to inspect and measure the wall thickness of a rubber lined coolant pipe at a nuclear power station. [More Info] http://www.inspector-systems.com/Eddy_current_test_robot.html https://en.wikipedia.org/wiki/Eddy-current_testing
	Slide 34	This particular robot is able to detect reductions in wall thickness due to corrosion, erosion or pitting, and to distinguish between inner and external defect points. [More Info] http://www.inspector-systems.com/Eddy_current_test_robot.html https://en.wikipedia.org/wiki/Eddy-current_testing
	Slide 35	The precision and efficiency afforded by robots is especially valuable to the field of nuclear medicine (Open Discussion) What are some of the applications in nuclear medicine?
	Slide 36	Brachytherapy is the method of treating tumors by the insertion of sealed radioactive sources called “seeds” to the site. It provides high radiation dose to a specific area with minimal damage to surrounding tissues, provided the seed was placed accurately. Robots can deposit these seeds with more accuracy and precision than their human counterpart. (More Info) http://cdn.intechopen.com/pdfs-wm/27404.pdf
	Slide 37	Robots like the CyberKnife can be used to better track tumors and accurately deliver high dose beams of radiation to the site with minimal damage to surrounding tissue. Robots can more accurately track tumors and sites of interest as they move due to heartbeat and breathing. This eliminates the need to fix a metal frame to the patient’s bones to hold them steady. [More Info] http://www.accuray.com/sites/default/files/500929.A_CyberKnife_Patient_Brochure_FINAL.pdf
	Slide 38	(Open Discussion) What are some of the applications in nuclear waste management?

	Slide 39	Conventional waste management processes utilize well established techniques and processes. However, the complication of nuclear waste management is the hazard of radiation release. Workers, the general public, and the environment must be adequately protected. Automation and robotics introduced at nuclear waste management sites to reduce the does of exposure and speed the process without compromising safety. Robots can perform regular inspection of storage containers and alert on unusual variation from a baseline for various characteristics such as corrosion, heat, or radiation.
	Slide 40	The use of Unmanned Aerial Vehicles in the field of surveying is on the rise. They provide fast and accurate surveys regardless of the terrain, and can be built to provide thermal imaging as well. Robots such as these may have applications monitoring waste storage sites. UAV surveying robots from SenseFly provide x y z accuracy down to 3cm. [More Info] https://www.sensefly.com/applications/surveying.html
	Slide 41	“The great lesson of Fukushima, is that disasters are often fast moving and difficult to predict events, where the window of time for effective intervention is small.” Gill Pratt, head of Toyota’s artificial intelligence division, and an engineer who led DARPA‘s Robotics Challenge from 2012 to 2015. (Open Discussion) What are some of the lessons learned from the robots sent to Fukushima?
	Slide 42	Some estimate over 100 different robots have been sent to the Fukushima Daiichi plant to help further the efforts to map and contain the radiation. These are some of the robots that have been dispatched to the Fukushima plant. Quince, Rosemary & Sakura: Modified earthquake rescue robots Gathered data for radiation maps Sampled airborne radioactive particles Monitored radiation dose rates Packbot 510 & Kobra 710: Developed for battlefield task such as bomb disposal Withstood phenomenal radiation levels of more that 5 Sv per hour Early glimpse of the damage inflicted by the nuclear fuel meltdowns

	ASTACO-SoRa: 2.5-ton shovel-wielding robot with 2 swappable manipulator arms Removed debris such as sheet metal, fallen ducts, concrete, chunks, and nitrogen canisters from reactor Units 1 & 3 Surface Boat: 90-cm-long robot-boat with cameras above and below the water line Dosimeter radiation of about 2 Sv per hour in reactor Unit 1's suppression chamber Raccoon: A nuclear-hardened maid that has been scrubbing the floors of Unit 2 Decontamination work has helped tamp down radiation levels Quadruped inspection robot: 65-kilogram droid has a mobility advantage over crawling robots It can climb stairs and access hard-to-reach crannies http://www.sciencemag.org/news/2016/03/how-robots-are-becoming-critical-players-nuclear-disaster-cleanup
Slide 43	Many of the first Japanese robots sent into Fukushima were not designed to traverse the debris strewn landscape or the radiation. Nor were the buildings designed to accommodate robots. When it became obvious that existing robots weren't up to the task, they had to be retrofitted, costing valuable time. iRobot's PackBot was one of the first robots used because of its durability, weight, ability to climb stairs, and was designed to be fitted with an assortment of hazmat related sensors. In retrospect, had the robots initially sent to Fukushima been designed for the purpose ahead of time, or had the plant been designed to accommodate them, they would have been more able to act in that short window of opportunity. [More Info] http://www.popularmechanics.com/military/a6656/how-battle-tested-robots-are-helping-out-at-fukushima-5586925/ http://www.sciencealert.com/the-robots-sent-into-fukushima-have-died http://www.latimes.com/world/asia/la-fg-japan-fukushima-robots-20160310-story.html
Slide 44	Robots like the Raccoon are designed to scrub dust from surfaces to decrease radiation levels to the point that human workers can enter and assess the next course of action. Robots have been an essential tool to containment and decontamination at the Fukushima plant. http://spectrum.ieee.org/energy/nuclear/dismantling-fukushima-the-worlds-toughest-demolition-project http://spectrum.ieee.org/slideshow/robotics/industrial-robots/meet-the-robots-of-fukushima-daiichi

	Slide 45	Robots and electronics aren't impervious to radiation. Ionizing radiation can induce unintended electrical charges within integrated circuits causing unwanted "noise" in the circuit at best, and memory or state corruption at worst. High levels of radiation can also change the crystal structure of semiconductors used in integrated circuits causing permanent failure, or in the case of crystal oscillators, a drift in oscillation frequency. Circuits that may be exposed to high levels of radiation must be designed with radiation hardened components and must be properly shielded. Many hardened and shielded electronics are used and tested in space or at high altitudes where the atmosphere is thin or non-existent, and solar radiation is more prevalent. As technology advances, we hope to see more radiation resistance devices. Optical computing, for example, may pave the way to robots that are nearly completely resistant to radiation.
	Slide 46	Robot Applications Takeaways Applications for robots in nuclear industry include inspection, maintenance, and cleanup of steam generators, reactor vessels, waste storage sites and contaminated accident sites. Robots offer the potential for accurate and efficient operations in nuclear medicine. To fully utilize the potential of robotics in the nuclear industry, robots must be designed for a specific purpose and able to navigate the rough terrain of a possibly disabled plant. Robots are not impervious to radiation and must be designed with radiation hardened components and properly shielded to eliminate noise interference. Robots have been an essential tool to containment and decontamination at the Fukushima plant.
	4. Robot Components	
	Slide 47	Section four is about robot components. Form Input Output Logic
	Slide 48	(Open Discussion) What are some of the fundamental components of robots? What do they have in common? There are four basic components of a robot. Form, inputs, outputs, and logic.

Slide 49	The form is the basic structure and composition of the robot. The scale of the robot may vary from millimeters to multiple buildings in size. It may be a single consolidated unit, or it may be a large modular system. It may be constructed from a wide range of materials; from solid metal to lightweight composites. The form may not necessarily be rigid either. There has been a lot of research recently in soft-body robots.
Slide 50	There are an innumerable number of sensors available that could be used in robotics. This is a list of general sensors.
Slide 51	Quite often, it's the geo-spatial sensors that are utilized for the purpose of determining location and heading as well as pathfinding and navigation. Many of the geo-spatial sensors are incorporated into one unit, called an Inertial Management Unit, or IMU for short. In many instances, accurate time references are essential to robotics for scheduled actions, accurate delays, and for establishing reliable communications.
Slide 52	In many instances, accurate time references are essential to robotics for scheduled actions, accurate delays, and for establishing reliable communications. There are an innumerable number of sensors available that could be used in robotics. Quite often, it's the geo-spatial sensors that are utilized for the purpose of determining location and heading as well as pathfinding and navigation. Many of the geo-spatial sensors are incorporated into one unit, called an Inertial Management Unit, or IMU for short.
Slide 53	Output is comprised of all the devices used by the robot to perform work and transmit data.
Slide 54	Robots can move in varying degrees, depending on their tasks. The three modes of transportation are: Fixed Position – The robot is immobile Fixed Track – Robots such as automobile assembly arms may slide along tracks Free Range – The robot possesses the ability to move in an omnidirectional manner, rather than along a fixed track or grid
Slide 55	These are some of the peripheral output that robots may have. (This list is not inclusive).
Slide 56	Robot output devices aren't limited to being driven solely by electric motors. Many robots also use pneumatic and hydraulic actuators and devices. These are some of the pros and cons of each.

	Slide 57	The robot's logic defines how it processes inputs and directs outputs to perform a task. Essentially, the logic is a robot's instruction set. A remotely operated inspection robot may take remote joystick input, and translate it to corresponding wheel movements. An autonomous robot may use a combination of laser imaging sensors and gyroscopic sensors to navigate rooms in a building.
	Slide 58	A robot's logic may be implemented in: Hardware (i.e. in-circuit) Software (in virtual programs) Hybrid (combination of the two)
	Slide 59	This logic is hard wired on the circuit level, making it very fast. The hardware design complexity makes it uncommon in more complex decision capable systems. This kind of logic implementation may use custom integrated circuits, known as Application Specific Integrated Circuits, or ASICs. Custom hardware logic requires much forethought as the circuits must be custom made. As you might imagine, if the scope of the application changes, the hardware may likely require replacement as well. Strictly hardware based logic is rarely used in robotics due to its rigid single-purpose nature and relatively high production cost compared to off the shelf software based solutions.
	Slide 60	The software itself may be integrated into the operating system, or execute as a standalone program above the operating system. Software based logic uses programs stored in memory to dictate how the input data should be manipulated or interpreted, and how outputs should respond. Because many programs must share access to the processor, software implementations are inherently slower than their hardware counterparts. They are, however, far more flexible. Software based logic may be modified even while the robot is operating. They can also be written and updated according to a standard, making them easier to integrate with existing software and hardware.

	Slide 61	Hybrid controllers can provide the best of both worlds. Specifically, it combines the speed of the hardware solutions with the flexibility of software solutions. By putting lots of basic logic circuits on a chip all connected by software configurable interconnects, custom circuits can be defined and changed by software. These chips, known as Complex Programmable Logic Devices (CPLDs) and Field Programmable Gate Arrays (FPGAs), provide programmers with the ability to build custom circuits to handle high demand tasks that would otherwise overburden a typical processor. The use of CPLDs and FPGAs requires a strong understanding of Logic Design and hardware descriptive programming languages such as VHDL, Verilog, and the like. Hybrid logic such as this is especially used in high speed, high demand applications such as visual processing.
	Slide 62	The logic may be designed to simply translate a remote operator's input to the robot's output. The application may require that the robot be capable of making decisions based on any number of different inputs. A simple reaction control mechanism performs a standard set of actions after being triggered by an number of various inputs. A factory assembly line may use robots utilizing this scheme to assemble widgets on an assembly line. The most rudimentary form of this control mechanism would be The Most Useless Machine: https://www.youtube.com/watch?v=Z86V_ICUCD4 (The Most Useless Machine is also an example of strictly hardware based logic) Complex decision making may involve artificial intelligence, which extends far beyond the scope of this module. Briefly, complex decision making may fall into the categories of what I call "strict algorithms", neural networks, and deep learning. Strict algorithms simply refers to a static algorithm or set of algorithms used to evaluate conditions and make a decision; the algorithm doesn't change. Neural networks, on the other hand, are complex networks of virtual neurons that mimic rudimentary living organisms and attempt to modify it's own algorithm in the search of an ideal output state. The main drawback to neural networks is limitation of the hardware it runs on and the number of neurons it can simulate at one time. Deep learning is an entire branch of machine learning that may include both complex algorithms and neural networks. https://en.wikipedia.org/wiki/Artificial_neural_network#Neural_network_software https://en.wikipedia.org/wiki/Deep_learning

Slide 63	Robot Components Takeaways The four basic components that make up a robot are form, inputs, outputs, and logic. The form of a robot is its physical design, structure, and composition. Inputs is comprised of all the sensors and data available to the robot, such as sensors and communication receivers. Output is comprised of all the devices used by the robot to perform work and transmit data. The Robot's logic defines how it processes inputs and direct outputs to perform a task and may be implemented in hardware, software, or a hybrid of the two.

5. Robot Operating System (ROS)

Slide 64	Section five is about the Robot Operating System, ROS. ROS ROS Nodes ROS Topics ROS Master ROS Security
Slide 65	The Robot Operating System, or ROS for short, is an ever-growing open source robotics framework that streamlines development and integration of robot software and controls. ROS falls under a software based logic system, though it could easily incorporate hybrid systems as well. ROS is a very flexible system, capable of handling anything from simple reaction, to complex decision making. ROS also has the added benefit of being able to test robots and their programming in a virtual environment. Though other robot software exists, we are going to look at ROS specifically because of its growing adoption in robotics. Additionally, it indirectly leads the developer to compartmentalize the robot’s software, leading to clear and well structured development objectives.
Slide 66	The name is a bit of a misnomer because it is not an operating system in the traditional sense. The handling of low-level operations is relegated to the Unix-based operating system on which ROS is installed. Most often, the underlying operating system used is Ubuntu Linux.
Slide 67	ROS is a set of programs that may be installed using a Linux package manager. The modular nature of the framework means you can install the modules applicable to your robot or application. It also provides a development environment for writing your own modules, with tutorials hosted on their website. It should be noted that ROS need not be on a single machine, and may communicate with ROS instances on other machines as though they were one.

Slide 68	Nodes are specific processes that are designed to handle a particular aspect of the robot. Nodes handle related data. Some communicate with sensor input, some with output devices, and some will handle interpreting data between other nodes. Nodes may push data in a process called “publishing”. Nodes may register interest in specific data in a process called “subscribing”. For Example: A node tasked with pathfinding and navigation may wish to receive data from the 2D laser mapping device to plot a course. Such a node would “subscribe” to a data topic named “map” and would “publish” the resulting path under the topic “course”. Another node tasked with directing the robot’s wheels might then subscribe to “course” and translate each directive to appropriate wheel speeds. The nodes need not be running on the same machine in order to communicate.
Slide 69	ROS utilizes named communication busses called “topics”. Nodes use these topics to share information. Topics are strongly typed, meaning they are well structured using predefined data types. The messages between nodes are verified to ensure the data is intact and the endpoints are up to date and expecting the same data structure. The communications are made using standard TCP/IP packets; the network communications protocols on which the internet is based. Some parts of ROS are capable of using UDP instead of TCP, though it’s a loose protocol best left for real-time control. IP – internet protocol, the primary protocol used to transmit data across computer networks TCP – Transmission Control Protocol; a protocol used over IP that ensures data arrives at the destination in the order it was sent UDP – User Datagram Protocol; a protocol used over IP that carries data quickly, but doesn’t care if it arrives out of order or didn’t arrive at all
Slide 70	The ROS Master is the central process for any ROS installation. The Master handles the registry of topics, publishers, and nodes. When a node publishes data under a specific topic, it’s the Master’s responsibility to add the topic to the registry if it doesn’t exist. The Master would then wait for nodes to subscribe to that topic. When the Master encounters a publisher and a subscriber under the same topic name, it introduces the nodes and they establish their own peer to peer communication channel and begin forwarding topic messages.

Slide 71	This graphic is an overview of a ROS system. The design of ROS helps compartmentalize the robot software, and the use of individual nodes creates clear development objectives. ROS is open source, and many community developed ROS packages are available for common robot devices such as laser scanners. Check for existing ROS packages before developing your own. Hardware may even be chosen in response to existing packages.
Slide 72	ROS relies on the security of the systems on which it is implemented. The usual operating system security hardening should be implemented in situations that require security. The networks used by ROS to communicate outside it's own system should be properly secured. Wireless networks should utilize WPA2-AES or WPA2-Enterprise encryption. As with most computer systems, security should be assumed non-existent if an individual has physical access to the machine.
Slide 73	Robot Operating Systems (ROS) Takeaways The basic components of ROS are nodes, topics, and the Master process. Technically, ROS is a framework installed within an operating system, not an operating system on itself. ROS Nodes are specific processes that are designed to handle a particular aspect of the robot. ROS utilized named communication bussed called "topics" to share information. ROS Master is the central process for any ROS installation and handles the registry of topics, publishers, and nodes. ROS relies on the security of the system on which it is installed.
6. Concepts Relating to Robotics	
Slide 74	Section six is about concepts relating to Robotics. Degrees of Freedom Open/Closed Loop Control

	Slide 75	(Open Discussion) Degrees of freedom is a common term in the field of robotics, but what does it mean? The number of joints in a mechanism, and the number of dimensions an affector can translate and rotate an object One Degree – Can move an object along one axis, whether the motion is translational or rotational is irrelevant Two Degrees – Can move an object along two axes; each axis may be translational or rotational Three Degrees – Can move an object along three axes Strictly translational: x, y, z Strictly rotational: pitch, yaw, roll Any combination in between: x, y, yaw More info about degrees of freedom can be found at: http://motioncontrolsrobotics.com/unraveling-degrees-of-freedom-and-robot-axis-what-does-it-mean-to-have-a-multiple-axis-pick-and-place-or-multiple-axis-robot/
	Slide 76	The concept of open and closed loop control is important to robotics. An open loop control is one that instructs the output device to perform an action, and then assumes that it completed successfully. Closed loop controls not only instruct the output to perform the action, they also use sensor data to track output performance and report the error. An example of open loop control might be a system that tells the driven wheels to proceed full speed long enough to reach a calculated position. A closed loop system would use rotary encoders or optical ground sensors to track actual travel per wheel. Such a system would be more accommodating to varying resistances of the terrain against the wheels.
	Slide 77	Concepts Relating to Robotics Takeaways Degrees of freedom refers to the number of joints in a mechanism, and by extension, the number of dimensions an affector, may translate and rotate an object. One Degree of Freedom = One Axis Two Degrees of Freedom = Two Axes Three Degrees of Freedom = Three Axes A closed loop control verifies the results of an output's action. An open loop control instructs the output to perform an action and assumes it is completed.

7. Taking it Further	
Slide 78	Section seven is about taking the module topic beyond this training and will wrap up with a module overview and takeaways. Education Certifications Nuclear Robotics Module Takeaways
Slide 79	These are some of the subjects that would be useful to individuals interested in robotics. This list is by no means comprehensive, but would form a basic foundation for understanding and working in robotics. The IEEE-RAS (IEEE Robotics and Automation Society) offers a number of workshops, conferences, and publications as well. NIST offers a workshop titled International Workshop on the Use of Robotic Technologies at Nuclear Facilities.
Slide 80	The National Robotics Training Center offers some certifications, such as the Certified Manufacturing Associate (CMA), Certified Robotics Engineering Associate I and II (CREA I/II), and the Certified Robotics Technician (CRT). These certificates are based on the Robotics Engineering Curriculum, by Intelitek. For more information on these certificates, please see the NRTC's website at www.nrtcenter.com. Some robotics companies offer their own certifications, but industry wide recognition is not guaranteed. [More Info] http://nrtcenter.com/Certification/programs.asp
Slide 81	Module Takeaways: Sections 2&3 2. Introduction to Robotics Takeaways A robot is an autonomous device that performs tasks while independent of human control. The benefits of robots include precision & accuracy, robustness & versatility, efficiency, ability to perform undesirable or tedious tasks, and a steady ROI.

	3. Robot Applications Takeaways Applications for robots in nuclear industry include inspection, maintenance, and cleanup of steam generators, reactor vessels, waste storage sites and contaminated accident sites. Robots offer the potential for accurate and efficient operations in nuclear medicine. To fully utilize the potential of robotics in the nuclear industry, robots must be designed for a specific purpose and able to navigate the rough terrain of a possibly disabled plant. Robots are not impervious to radiation and must be designed with radiation hardened components and properly shielded to eliminate noise interference. Robots have been an essential tool to containment and decontamination at the Fukushima plant.
Slide 82	Module Takeaways: Sections 4&5 4. Robot Components Takeaways The four basic components that make up a robot are form, inputs, outputs, and logic. The form of a robot is its physical design, structure, and composition. Inputs is comprised of all the sensors and data available to the robot, such as sensors and communication receivers. Output is comprised of all the devices used by the robot to perform work and transmit data. The Robot's logic defines how it processes inputs and direct outputs to perform a task and may be implemented in hardware, software, or a hybrid of the two.

5. Robot Operating Systems (ROS) Takeaways

The basic components of ROS are nodes, topics, and the Master process.

Technically, ROS is a framework installed within an operating system, not an operating system on itself.

ROS Nodes are specific processes that are designed to handle a particular aspect of the robot.

ROS utilized named communication bussed called "topics" to share information.

ROS Master is the central process for any ROS installation and handles the registry of topics, publishers, and nodes.

ROS relies on the security of the system on which it is installed.

Slide 83 Module Takeaways: Section 6

Concepts Relating to Robotics Takeaways

Degrees of freedom refers to the number of joints in a mechanism, and by extension, the number of dimensions an affector, may translate and rotate an object.

One Degree of Freedom = One Axis

Two Degrees of Freedom = Two Axes

Three Degrees of Freedom = Three Axes

A closed loop control verifies the results of an output's action.

An open loop control instructs the output to perform an action and assumes it is completed.

Hands-On Activity

The hands-on activity is designed to be presented at the end of the module to demonstrate the robotic concepts outlined in the lesson plan. Activity & Lecture notes are included in the PPT.

Step 1	Distribute Ozobots for demonstration. Each package contains materials for two students. Note that Ozobots may require charging before use.
Step 2	Start presentation for hands-on activity.
Step 3	Instruct the students to remove an Ozobot from the package and examine it.
Step 4	Follow presentation. See Lecture Notes in PPT for questions, instructions, and discussion topics.
Step 5	At the instructor's discretion, Ozobots may be collected for subsequent demonstrations, or left with students.

Lessons Learned & Takeaways

Introduction to Robotics

A robot is an autonomous device that performs tasks while independent of human control.

The benefits of robots include precision & accuracy, robustness & versatility, efficiency, ability to perform undesirable or tedious tasks, and a steady ROI.

Robot Applications

Applications for robots in nuclear industry include inspection, maintenance, and cleanup of steam generators, reactor vessels, waste storage sites and contaminated accident sites.

Robots offer the potential for accurate and efficient operations in nuclear medicine.

To fully utilize the potential of robotics in the nuclear industry, robots must be designed for a specific purpose and able to navigate the rough terrain of a possibly disabled plant.

Robots are not impervious to radiation and must be designed with radiation hardened components and properly shielded to eliminate noise interference.

Robots have been an essential tool to containment and decontamination at the Fukushima plant.

Robot Components

The four basic components that make up a robot are form, inputs, outputs, and logic.

The form of a robot is its physical design, structure, and composition.

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Robot Operating System (ROS)

The basic components of ROS are nodes, topics, and the Master process.

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	ROS Nodes are specific processes that are designed to handle a particular aspect of the robot.
	ROS utilized named communication bussed called "topics" to share information.
	ROS Master is the central process for any ROS installation and handles the registry of topics, publishers, and nodes.
	ROS relies on the security of the system on which it is installed.
	Concepts Relating to Robotics
	Degrees of freedom refers to the number of joints in a mechanism, and by extension, the number of dimensions an affector, may translate and rotate an object.
	One Degree of Freedom = One Axis
	Two Degrees of Freedom = Two Axes
	Three Degrees of Freedom = Three Axes
	A closed loop control verifies the results of an output's action.
	An open loop control instructs the output to perform an action and assumes it is completed.

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Assessments

- Pre-Assessment (Answer Key Included)
- Post-Assessment (Answer Key Included)

Supplemental & Enrichment Material

Online Supplementary for Instructor

Calculating Robot ROI	http://www.robotics.org/content-detail.cfm/Industrial-Robotics-Industry-Insights/Calculating-Your-ROI-for-Robotic-Automation-Cost-vs-Cash-Flow/content_id/5285
The Robotics Megatrend	https://www.bcgperspectives.com/content/articles/business_unit_strategy_innovation_rise_of_robotics/

Online Enrichment for Instructor or Student

http://www.sciencemag.org/news/2016/03/how-robots-are-becoming-critical-players-nuclear-disaster-cleanup

http://www.gizmag.com/ge-atomic-swimmer-robot-nuclear-reactor-inspector/38438/

http://www.jsm.or.jp/ejam/Vol.5No.1/NT/NT54/NT54.html

http://spectrum.ieee.org/energy/nuclear/dismantling-fukushima-the-worlds-toughest-demolition-project

http://www.popularmechanics.com/military/a6656/how-battle-tested-robots-are-helping-out-at-fukushima-5586925/

http://www.sciencealert.com/the-robots-sent-into-fukushima-have-died

http://www.latimes.com/world/asia/la-fg-japan-fukushima-robots-20160310-story.html

RCNET

Nuclear Robotics Module

www.GoNuke.org

1

RCNET Nuclear Robotics Module

ACADs

1.1.8.4.3 Exposure reduction methods

1.2.1.13 Post-accident sampling

2.1.1 Explain basic concepts related to accident analysis

3.1.1.14 radiation monitoring

3.3.3 Interactions of Radiation with Matter

3.3.5 Radiological Protection Standards

3.3.9.8 Describe techniques for controlling the spread of contamination to personnel and equipment

Program Courses

ETP 1230 Power Plant Systems
ETP 1220 Power Plant Fundamentals
ETI 1000 Industrial Plant Tools Equipment
ETI 1701 Industrial Safety

ETP 2941 Professional Internship for Maintenance Technicians

ETP 2211 Radiation Instrumentation
ETP 2213 Radiological Safety and Protection
ETP 2219 Radiation Protection/ Capstone Project

2

LEARNING OBJECTIVES

- Identify what constitutes a robot
- Identify Nuclear Applications of Robotics, both current and future
- Enumerate and describe the basic methods of robot control
- Identify and discuss functions and limitations of nuclear robotic systems
- Describe the basics of the Robot Operating System
- Define open/closed loop control and degrees of freedom

3

Module Topics

- What is a robot?
- Why use robots?
- Benefits of Robots

Introduction to Robotics

- General
- Nuclear Robotics
  - iRobot
  - Nuclear Energy + Robots
  - Nuclear Medicine + Robots
  - Waste Management + Robots
  - Fukushima + Robots
- Planning for Radiation

Robot Applications

- Form
- Input
- Output
- Logic

Robot Components

- ROS
- ROS Nodes
- ROS Topics
- ROS Master
- ROS Security

Robot Operating System (ROS)

- Degrees of Freedom
- Open/Closed Loop Control

Concepts Relating to Robotics

- Education
- Certification
- Module Takeaways

Taking it Further

4

Introduction to Robotics

- What is a robot?
- Why use robots?
- Benefits of Robotics

5

WHAT IS A ROBOT?

- Industrial automation to complex decision-making automatons
- Strictly, a **device that performs actions without human control**
- We include remotely operated devices

6

WHY USE ROBOTS?

- Where do **robots excel**?
- What are the **benefits** of using robots?

7

Benefits of Robotics

PRECISION & ACCURACY

8

Benefits of Robotics

ROBUST & VERSATILE

9

Benefits of Robotics

EFFICIENCY

10

Benefits of Robotics

UNDESIRABLE TASKS

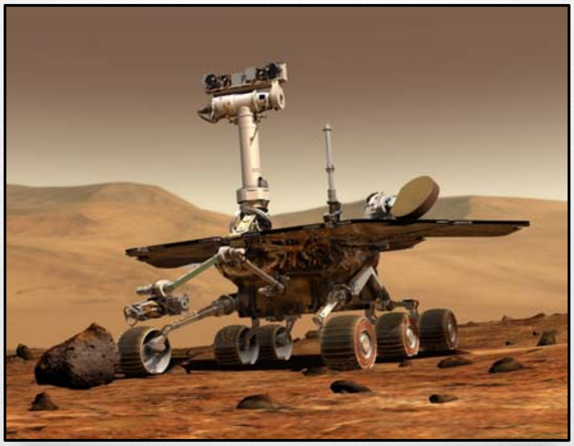
11

Benefits of Robotics

EXPENDABILITY

12

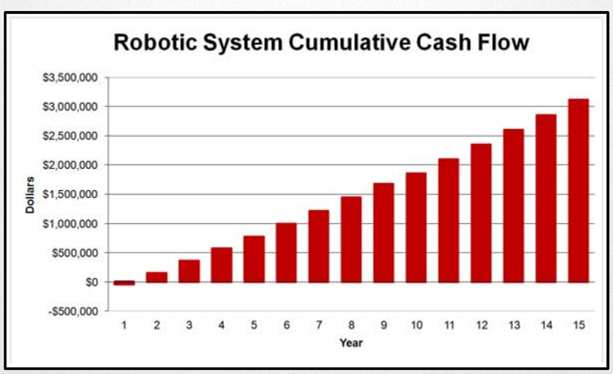
Benefits of Robotics



ENVIRONMENT AGNOSTIC

13

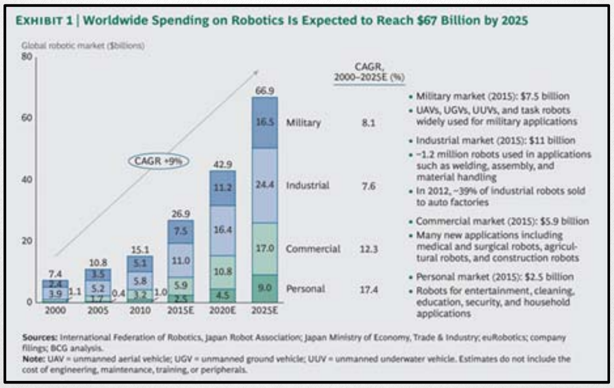
Benefits of Robotics



RETURN ON INVESTMENT

14

Benefits of Robotics



FOLLOWING THE TREND

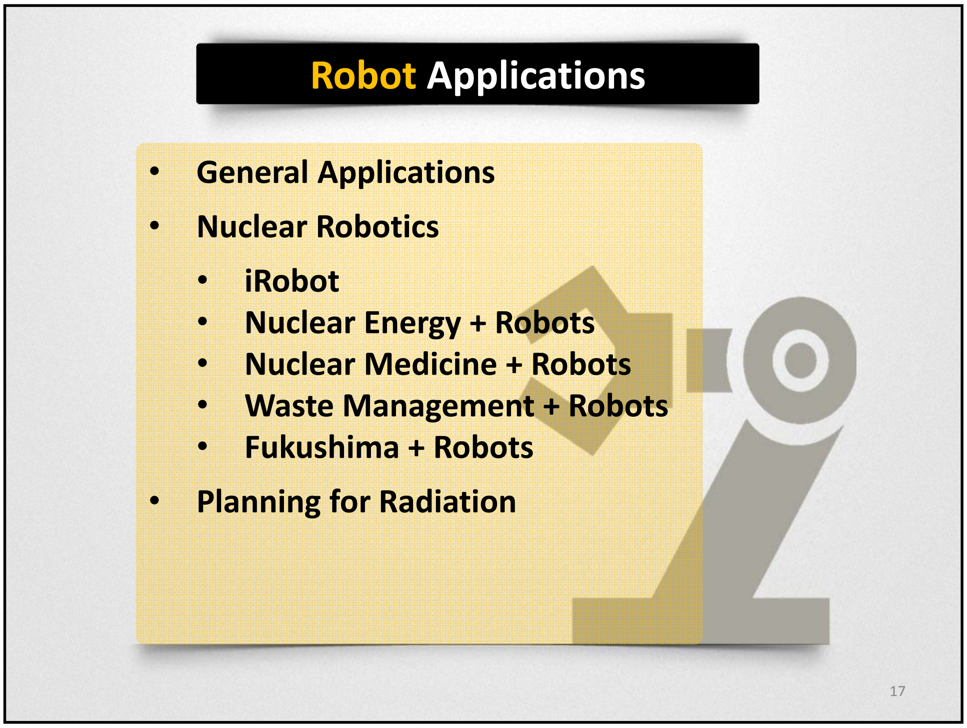
15

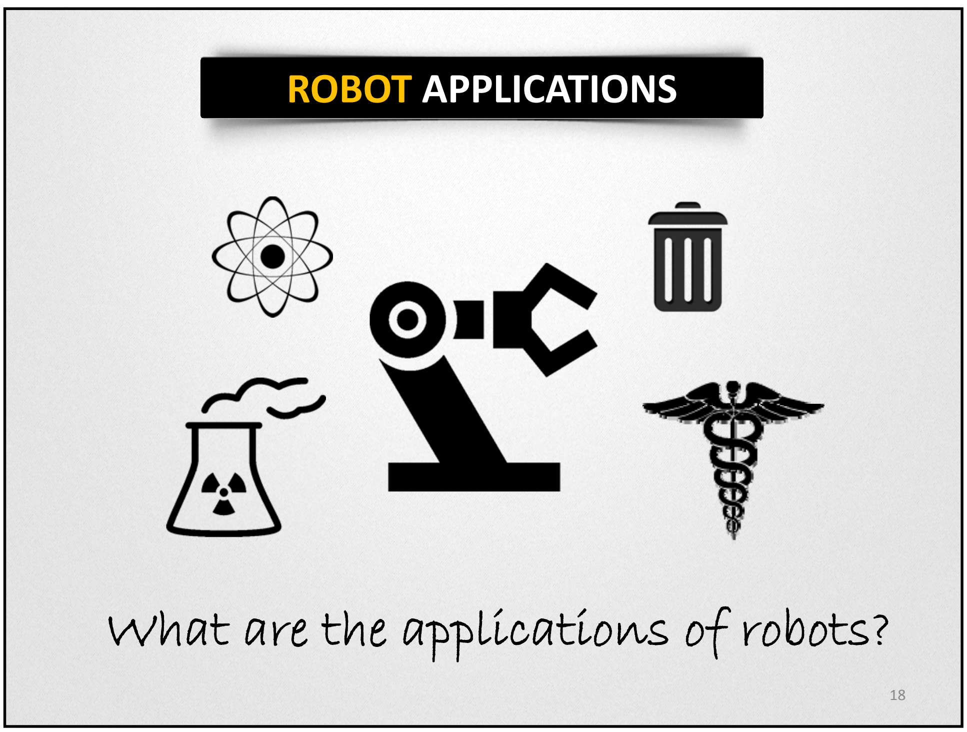
Introduction to Robotics

Takeaways

- A robot is an autonomous device that performs tasks while independent of human control.
- The benefits of robots include precision & accuracy, robustness & versatility, efficiency, ability to perform undesirable or tedious tasks, and a steady ROI.

16


Robot Applications
• General Applications
• Nuclear Robotics
• iRobot
• Nuclear Energy + Robots
• Nuclear Medicine + Robots
• Waste Management + Robots
• Fukushima + Robots
• Planning for Radiation
17


ROBOT APPLICATIONS
What are the applications of robots?
18

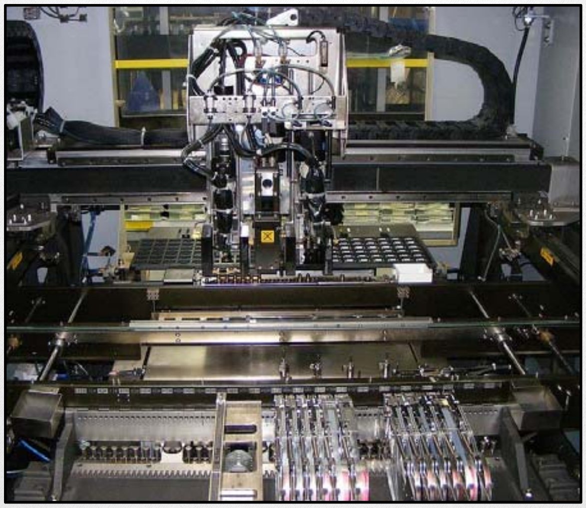
GENERAL APPLICATIONS

Robots have **applications** in many fields, but they have especially made their home in **manufacturing**.

19

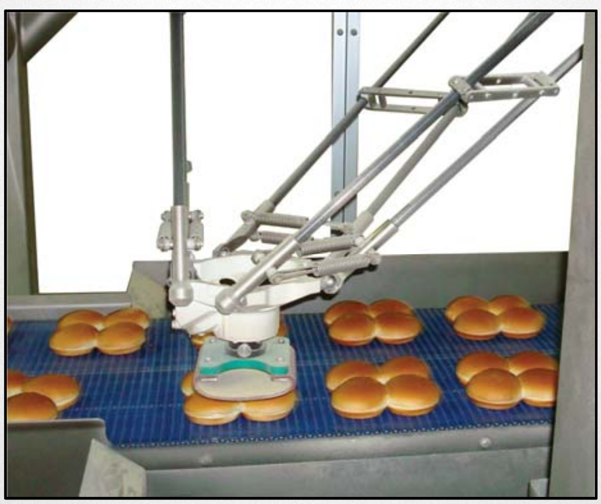
Robotic Welding In
the Automotive Industry

20



Robotic Pick & Place & **Soldering** In The Consumer Electronics Industry

21



Robotic Quality Control
in The Food Industry

22

NUCLEAR ROBOTIC APPLICATIONS

Robots are specially designed to complete tasks in the **Nuclear Industry**

23

iRobot

Equipped with a range of sensors and payloads, **iRobot's PackBot** & **Warrior** have been performing operations in areas of disabled power plants where **radiation levels** and **temperatures** are **too high** and **unsafe for people.**

iRobot

24

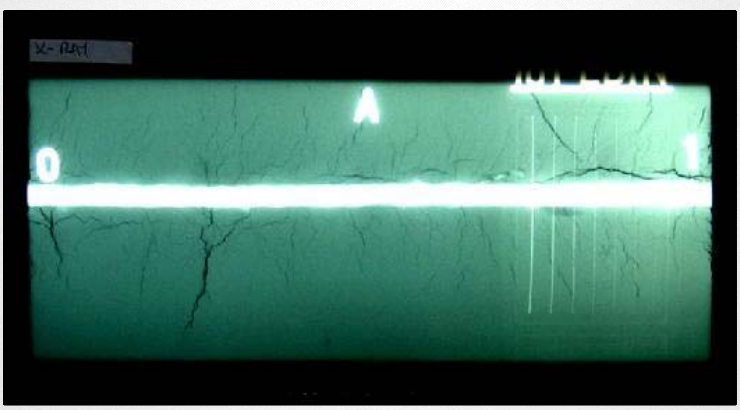
iRobot

Monitoring & Inspections
- Thermal & Visual Inspections
- Video Recordings of Inspections
- Two-Way Audio
- WRM-2 Network Compatible
- In-Service Inspections
- Leak Detection
- Meter & Gauge Verification
- Radiation Monitoring

Plant Applications
- Confined Spaces
- Emergency Response
- Environmental Cleanup
- Inspections and Investigations
- Materials Transport & Storage
- Remote Manipulation
- Security
- Waste Handling

iRobot

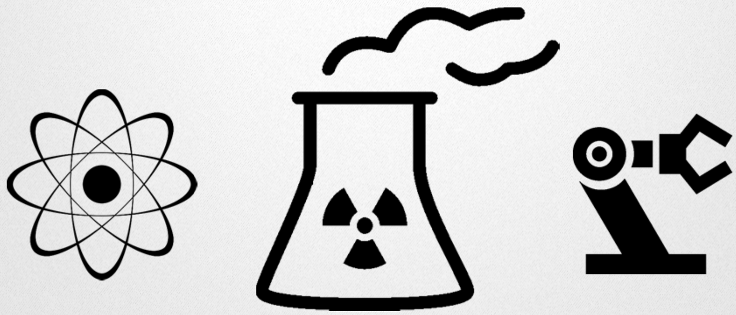
25



Industrial Radiography

26

NUCLEAR ENERGY + ROBOTS

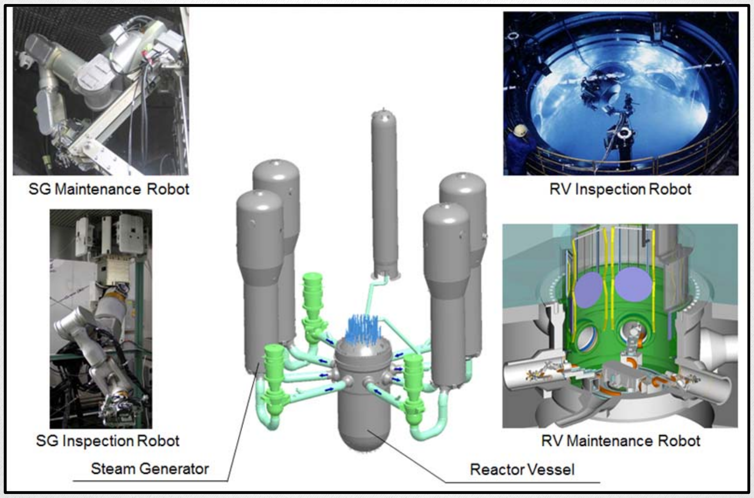


27

HITACHI

Underwater Cleaning, Inspection, & Repair

28



Power Plant Maintenance & Inspection

29

Maintenance & Inspection Robots

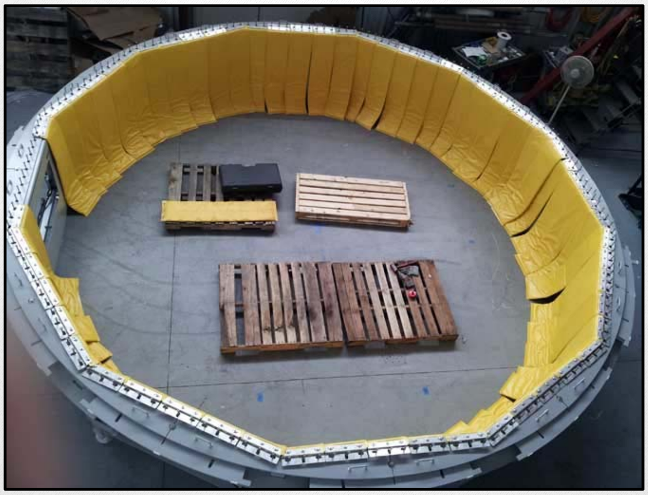
- RV **Inspection** Robot
- **Maintenance** & Inspection for RV Inlet & Outlet Nozzles
- **Repair** robot for SG Inlet & Outlet Nozzles
- Inspection Robot for SG Inlet & Outlet Nozzles

30

Reduce Exposure

- Primary purpose is to **reduce the radiation dose** of field workers
- **Robots**, together with reactor design, can **reduce reactor vessel inspection time to 28%** of conventional systems

31



Transporting Radiation Barriers for Technicians

32

Robotic Coolant Pipe Inspection

33

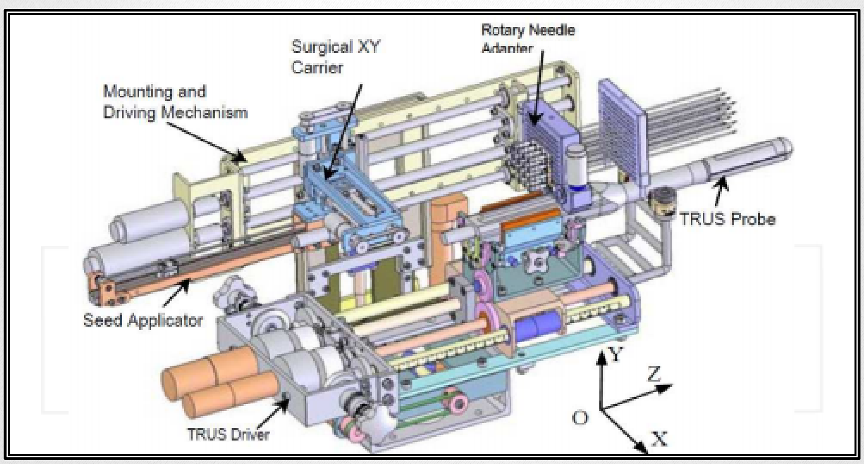
Robotic Pipe Inspection

- Uses **visual, laser, & eddy-current** sensors
- Detect reductions in wall thickness due to **corrosion, erosion, or pitting**
- Distinguish between **inner & external defect points**

34

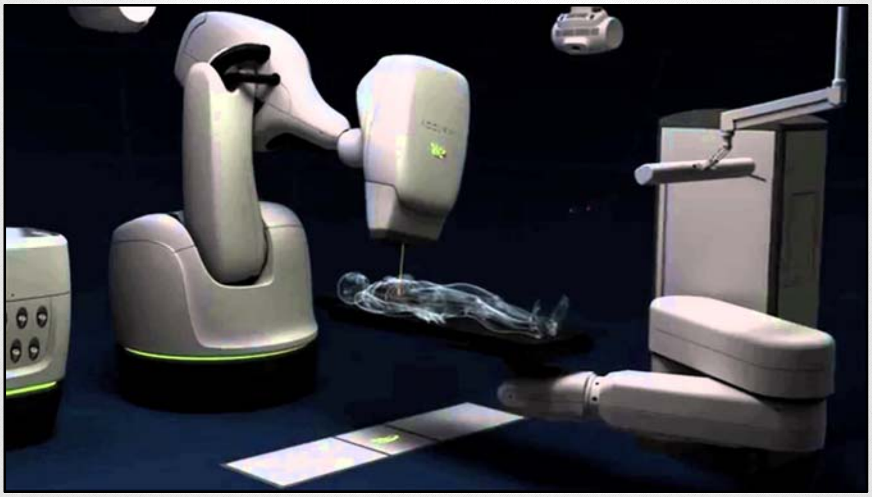
NUCLEAR MEDICINE + ROBOTS

35



Brachytherapy

36



Delivery Of Radiation Beams

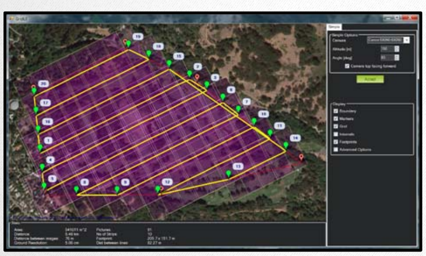
37

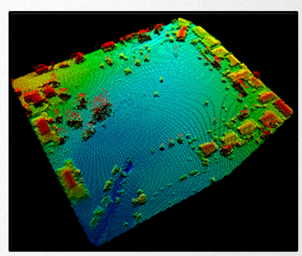
WASTE MANAGEMENT + ROBOTS

38

Routine Inspection & Monitoring at Waste Sites

39





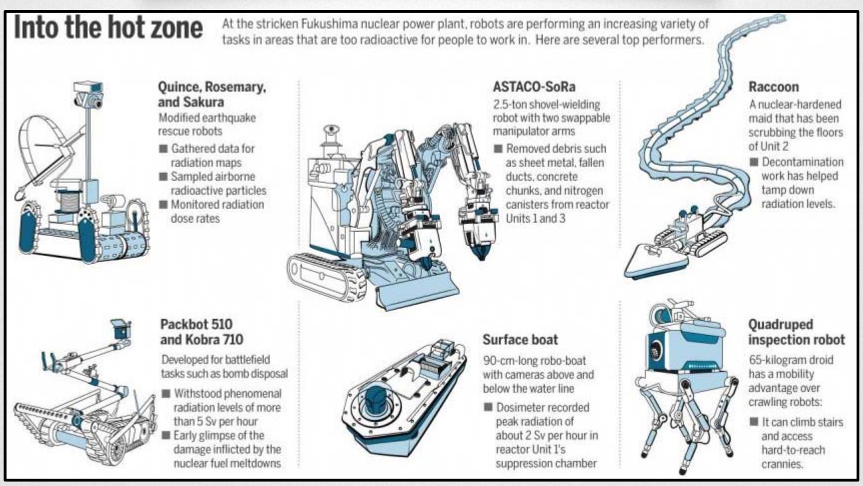
UAV Site Surveying

40

FUKUSHIMA + ROBOTS

41

FUKUSHIMA + ROBOTS



Top Performing Fukushima Robots

42

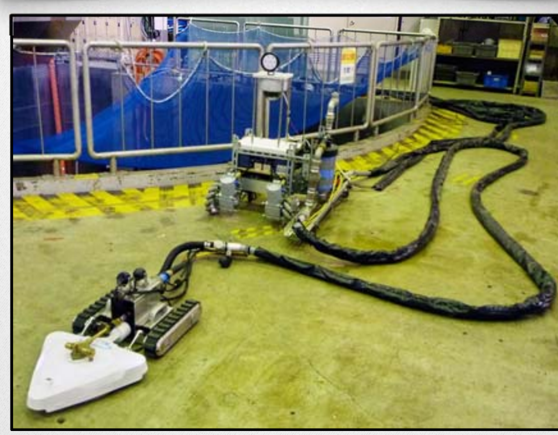
FUKUSHIMA + ROBOTS

- **Durable**
- Ability to **climb stairs**
- Fitted with an assortment of **hazmat** related **sensors**

Navigating Rough Terrain

43

FUKUSHIMA + ROBOTS



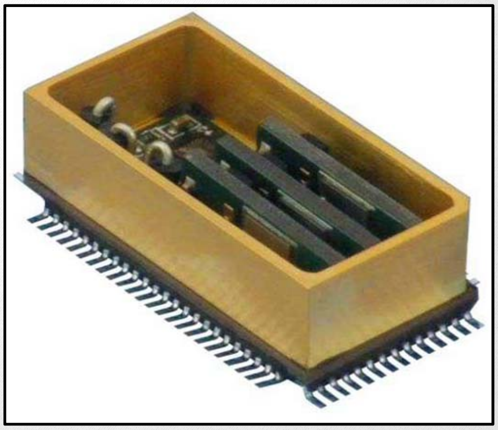
Dismantling & Cleaning Contaminated Sites

44

PLANNING FOR RADIATION

Designed with **radiation hardened components** & **properly shielded**

Tested in **space** or at **high altitudes** where the **atmosphere is thin** & **solar radiation** is more prevalent



Robots are not impervious to radiation

45

Robot Applications

Takeaways

- Applications for robots in nuclear industry include inspection, maintenance, and cleanup of steam generators, reactor vessels, waste storage sites and contaminated accident sites.
- Robots offer the potential for accurate and efficient operations in nuclear medicine.
- To fully utilize the potential of robotics in the nuclear industry, robots must be designed for a specific purpose and able to navigate the rough terrain of a possibly disabled plant.
- Robots are not impervious to radiation and must be designed with radiation hardened components and properly shielded to eliminate noise interference.
- Robots have been an essential tool to containment and decontamination at the Fukushima plant.

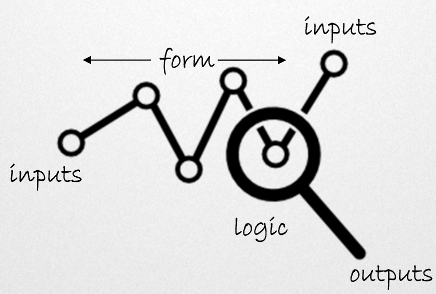
46

Robot Components

- Form
- Input
- Output
- Logic

47

ROBOT COMPONENTS



48

FORM

The basic structure &
composition of the robot body

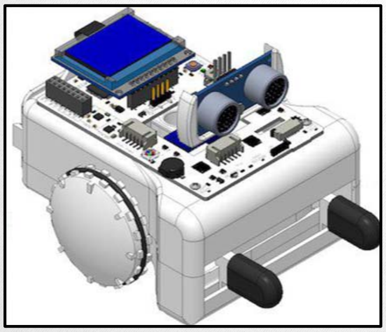
49

INPUT

The collection of all sensors
& data available to the robot

50

INPUT: Sensors



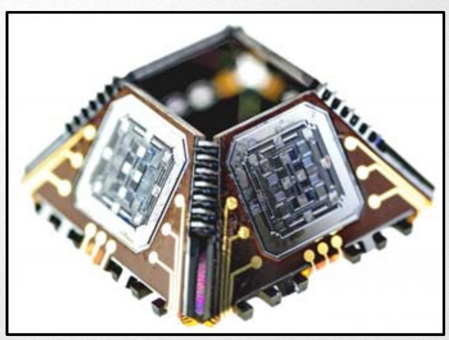
- Rotational
- Optical
- Thermal
- Radiological
- Chemical

51

INPUT: IMU Sensors

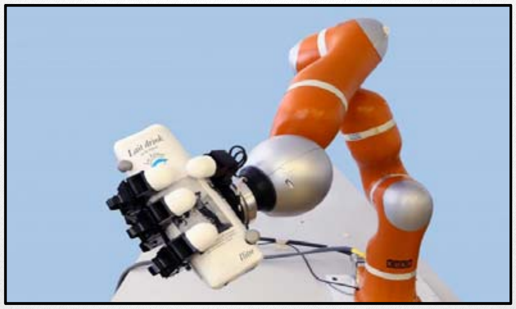
Inertial Management Unit (IMU)

- Geo-spatial
- GPS
- GPS-RTK
- Accelerometer
- Gyroscope
- Geomagnetic



52

OUTPUT

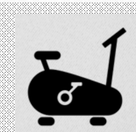


The devices used by the robot to perform work & transmit data

53

OUTPUT: Transportation

Fixed Position
Immobile



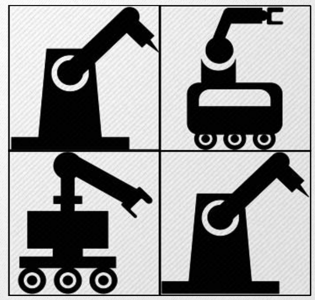
Fixed Track
Moves on a track

Free Range
Omnidirectional

54

OUTPUT: Peripherals

- Articulated Arms
- Work Devices
  - Grippers
  - Welders,
  - Cutoff Wheels, etc.
- Audible/Visual Alerts
- Electronic Alerts
  - Alert Roster
  - Email, etc.
- Signaling Other Robots



55

OUTPUT: Pros & Cons

Type	Pros	Cons
Electric	• Fluid free • Precisely controlled • Relatively quiet system • Powered from existing system supply	• Electric linear actuators do not perform as well as their hydraulic counterparts
Hydraulic	• Powerful	• Requires gas or electric pumps • Messy fluid under dangerously high pressure • Big, heavy and expensive
Pneumatic	• Freely available working fluid • Cheap to implement • Lightweight	• Requires gas or electric pumps or high pressure tanks • Less durable than hydraulics • Can be loud

56

LOGIC

The middle man **between inputs** and **outputs** that **defines** how the robot **performs** its intended **tasks**

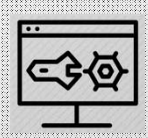
57

LOGIC

Hardware
In-circuit

Software
Virtual Programs

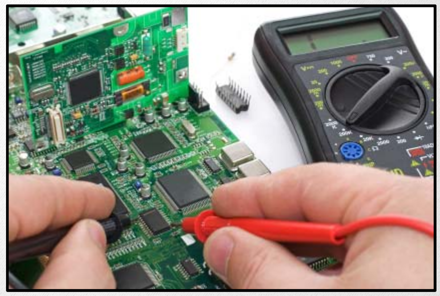
Hybrid
Combination of Hardware & Software



58

LOGIC: Hardware

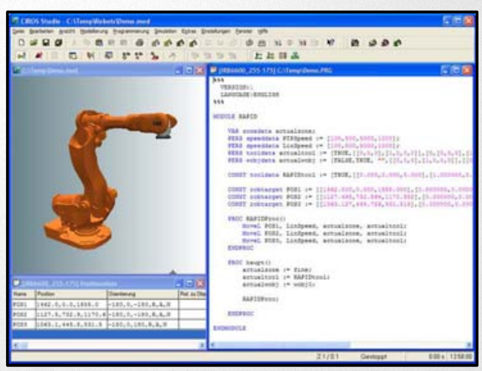
- Logic defined **in-circuit**
- **Uncommon** in **complex** decision capable **systems**
- May use application specific integrated circuits (**ASICs**)
- **Designed** with a **particular purpose** or action in mind
- More **expensive** to implement
- **Not easily modified**



59

LOGIC: Software

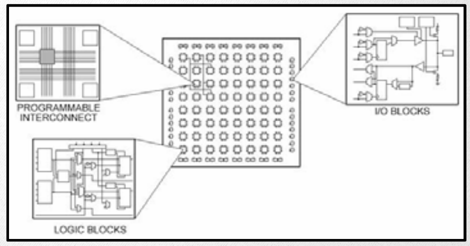
- May be **integrated** into an **operating system**, or a **software application** that executes within the operating system
- Logic & procedure **defined in instructions** and **saved in memory**
- More **easily modified & repurposed** than hardware based systems
- More easily **integrated with other systems**



60

LOGIC: Software

- Provides the **speed of the hardware solutions** with the **flexibility of the software solutions**
- **Requires experience programming** CPLDs, FPGAs, or others
- Often used in applications where an **input requires a prohibitive amount of overhead**, such as **visual processing**



CPLD: Complex Programmable Logic Devices

FPGA: Field Programmable Gate Arrays

61

LOGIC: Control Mechanisms

- Remote operation
- Simple reaction
- Complex decision making
- Any combination of the above

62

Robot Components

Takeaways

- The four basic components that make up a robot are form, inputs, outputs, and logic.
- The form of a robot is its physical design, structure, and composition.
- Inputs is comprised of all the sensors and data available to the robot, such as sensors and communication receivers.
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- The Robot's logic defines how it processes inputs and direct outputs to perform a task and may be implemented in hardware, software, or a hybrid of the two.

63

Robot Operating System (ROS)

- **ROS**
- **ROS Nodes**
- **ROS Topics**
- **ROS Master**
- **ROS Security**

64

Robot Operating System

ROS

65

ROS

Open Source Robotics Foundation

- A fast growing **open source project** & **community**
- Technically, it is a **framework installed within an operating system**, and not an operating system itself
- Designed to run on **Unix based operating systems**

66

ROS

- A **modular system** comprised of **specialized programs**
- Provides a **development environment** to write custom modules
- Helps **to abstract** low level **hardware functions**
- Helps **standardize software** for robots
- Provides a **standard framework** for robotics that may be developed in the following **programming languages**:
  - C++
  - Python
  - Lisp
  - Java (Experimental)
  - Lua (Experimental)

67

ROS "Nodes"

- **Computer process** that handles a specific aspect of the robot
- Handles **individual inputs, outputs, tasks, communications, states**, etc.
- Performs most of the **computation** and **abstraction** between **hardware** and **processes**, as well as between other **nodes**
- Nodes may **push data** in a process called "**publishing**"
- Nodes may **register interest** in specific data in a process called "**subscribing**"

68

ROS "Topics"

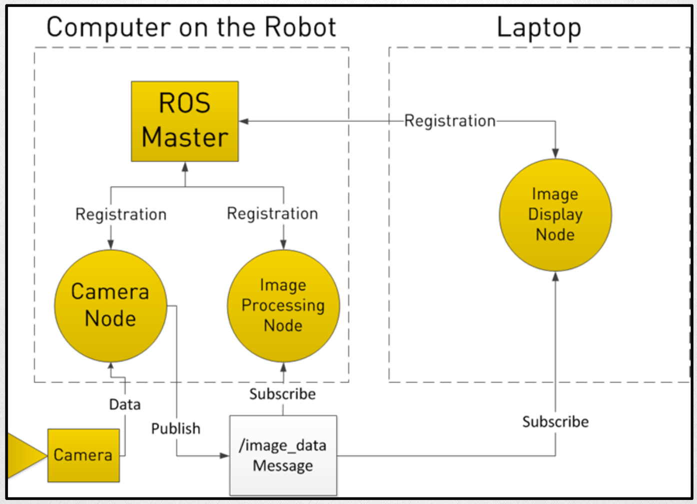
- Named **communication channels** for nodes
- Topics are **strongly typed**
- Topic messages are **verified**
- Topic messages are **transported locally** or **remotely** using standard **Transmission Control Protocol/Internet Protocol** packets.

69

ROS "Master"

- The **central process** for a **ROS installation**
- Responsible for the **registry of publishers, subscribers**, and **topics**
- **Introduces** nodes **publishing** and **subscribing** to the **same topic**

70



ROS System Overview

71

ROS Security

ROS relies on the security of the systems on which it is installed

- **Security** is provided by the underlying system
- **Typical** operating system **hardening**
- **Networks should be secured**
- **Security** should be considered **non-existent** if an individual has **physical access** to the machine

72

Robot Operating System (ROS)

Takeaways

- The basic components of ROS are nodes, topics, and the Master process.
- Technically, ROS is a framework installed within an operating system, not an operating system on itself.
- ROS Nodes are specific processes that are designed to handle a particular aspect of the robot.
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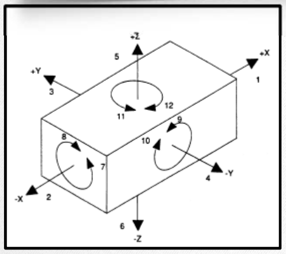
73

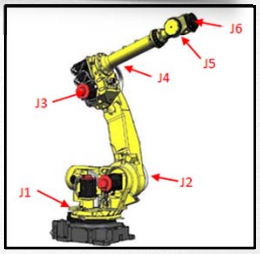
Concepts Relating to Robotics

- **Degrees of Freedom**
- **Open/Closed Loop Control**

74

Degrees of Freedom





The number of joints in a mechanism, and the number of dimensions an affector can translate and rotate an object

- **One Degree** – Can move an object along **one axis**, whether the motion is translational or rotational is irrelevant
- **Two Degrees** – Can move an object along **two axes**; each axis may be translational or rotational
- **Three Degrees** – Can move an object along **three axes**
  - Strictly translational: x, y, z
  - Strictly rotational: pitch, yaw, roll
  - Any combination in between: x, y, yaw

75

Degrees of Freedom

- **Open Loop** – instructs the output to perform an action and assumes it **completed without incident**
- **Closed Loop** – instructs the output to perform an action, and then **uses the inputs to verify that the action completed** or **returns the error between the expected result and the actual result**

76

Concepts Relating to Robotics

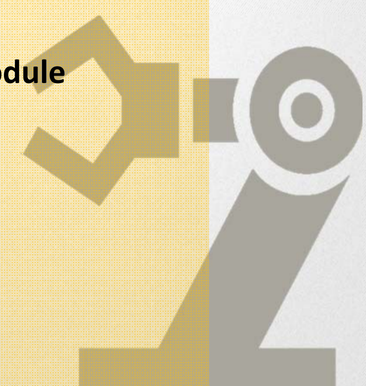
Takeaways

- Degrees of freedom refers to the number of joints in a mechanism, and by extension, the number of dimensions an affector, may translate and rotate an object.
  - One Degree of Freedom = One Axis
  - Two Degrees of Freedom = Two Axes
  - Three Degrees of Freedom = Three Axes
- A closed loop control verifies the results of an output's action.
- An open loop control instructs the output to perform an action and assumes it is completed.

77

Taking it Further

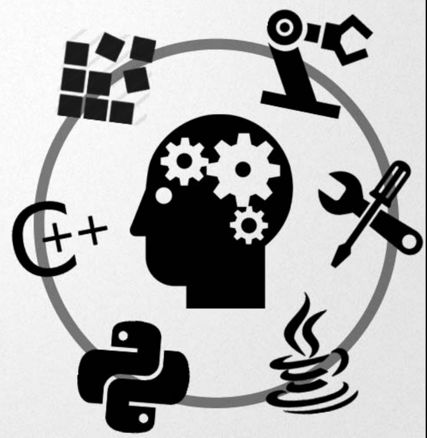
- **Education**
- **Certifications**
- **Nuclear Robotics Module Takeaways**



78

Education

- General Robotics
- Mechanical and Electrical Engineering
- Microcontrollers/Embedded Systems
- Unix Based Operating Systems
- ROS
- Computer Programing
  - Assembly
  - C/C++
  - Python
  - Java



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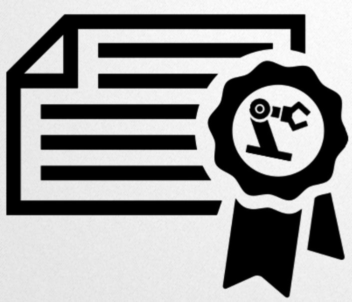
Certifications



- National Robotics Training Center
- Certified Manufacturing Associate (CMA)
- Certified Robotics Engineering Associate I (CREA I) & 2 (CREA II)
- Certified Robotics Technician (CRT)

80

Module Takeaways

- A robot is an autonomous device that performs tasks while independent of human control.
- The benefits of robots include precision & accuracy, robustness & versatility, efficiency, ability to perform undesirable or tedious tasks, and a steady ROI.

Introduction to Robotics

- Applications for robots in nuclear industry include inspection, maintenance, and cleanup of steam generators, reactor vessels, waste storage sites and contaminated accident sites.
- Robots offer the potential for accurate and efficient operations in nuclear medicine.
- To fully utilize the potential of robotics in the nuclear industry, robots must be designed for a specific purpose and able to navigate the rough terrain of a possibly disabled plant.
- Robots are not impervious to radiation and must be designed with radiation hardened components and properly shielded to eliminate noise interference.
- Robots have been an essential tool to containment and decontamination at the Fukushima plant.

Robot Applications

81

Module Takeaways

- The four basic components that make up a robot are form, inputs, outputs, and logic.
- The form of a robot is its physical design, structure, and composition.
- Inputs is comprised of all the sensors and data available to the robot, such as sensors and communication receivers.
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Robot Components

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- ROS utilized named communication bussed called "topics" to share information.
- ROS Master is the central process for any ROS installation and handles the registry of topics, publishers, and nodes.
- ROS relies on the security of the system on which it is installed.

Robot Operating System (ROS)

82

Module Takeaways

- Degrees of freedom refers to the number of joints in a mechanism, and by extension, the number of dimensions an affector, may translate and rotate an object.
  - One Degree of Freedom = One Axis
    - Two Degrees of Freedom = Two Axes
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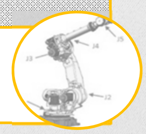
Concepts Relating to Robotics



83

THANK YOU

84

Ozobot Activity

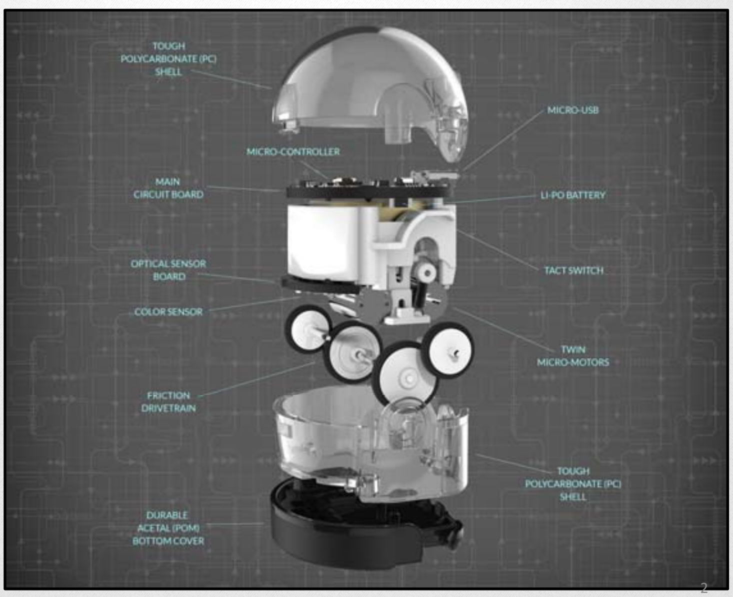
RCNET Nuclear Robotics Module
Hands-On Activity

RCNET

www.GoNuke.org 1

Form

ozobot



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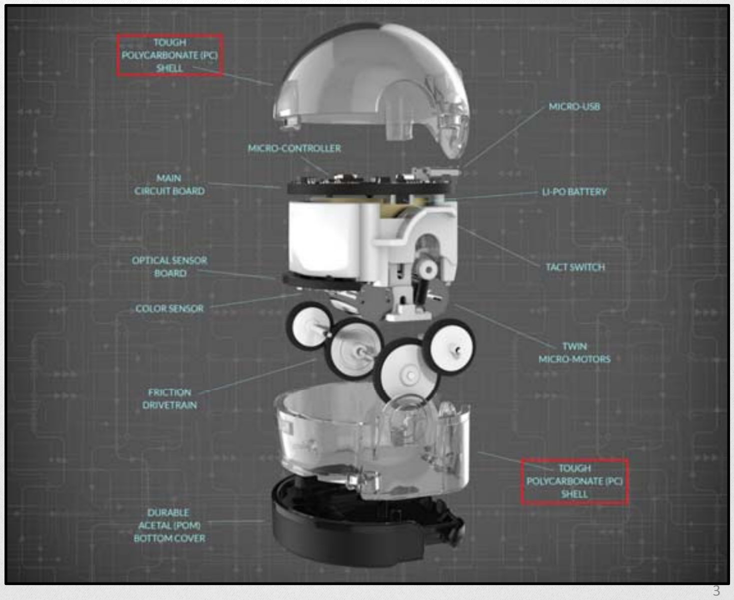
Form



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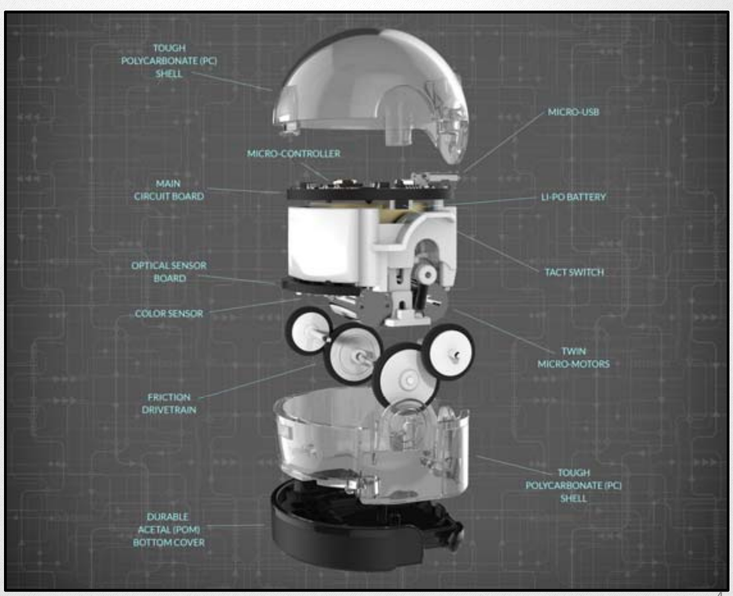
Inputs



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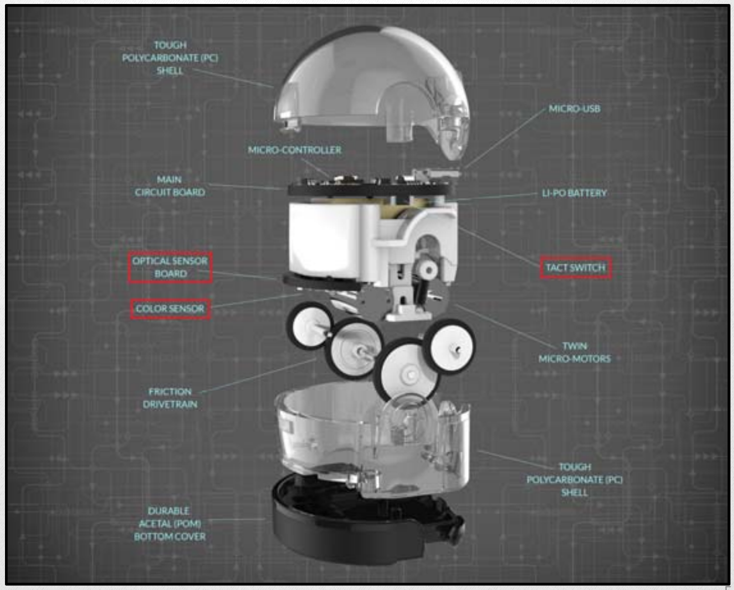
Inputs

ozobot



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Outputs

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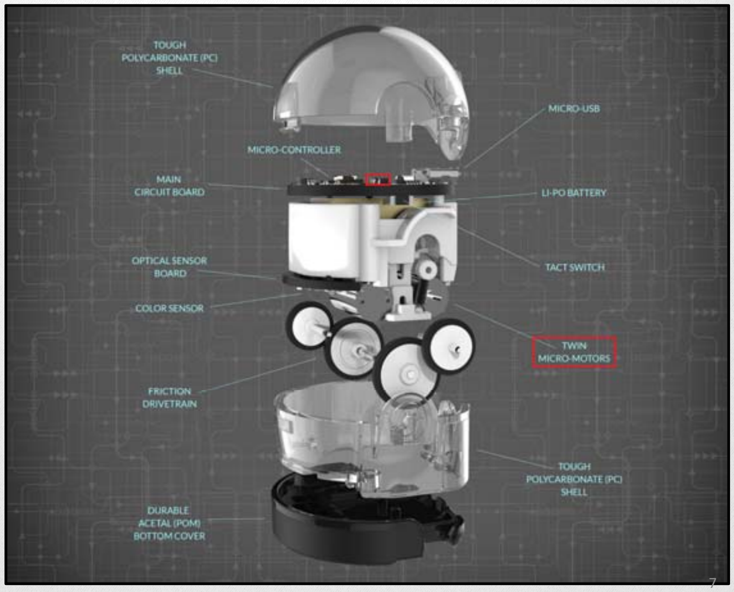
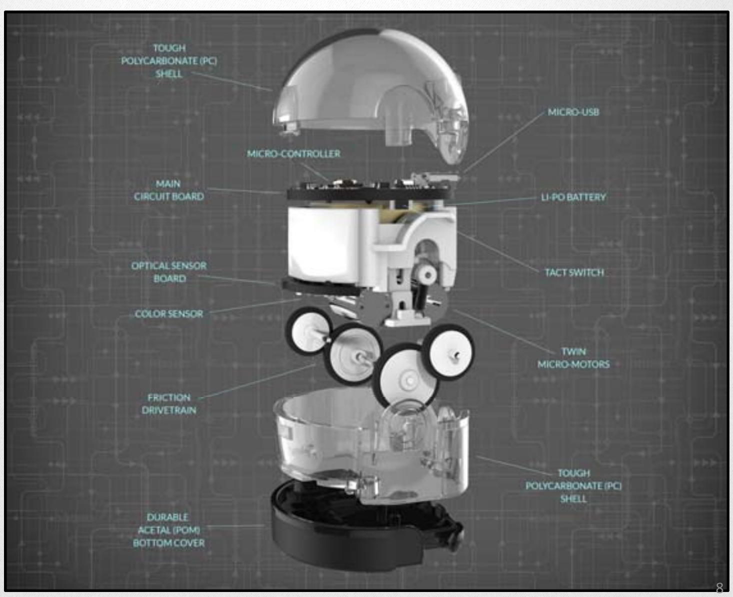
6

Outputs



7

Logic



8

Logic

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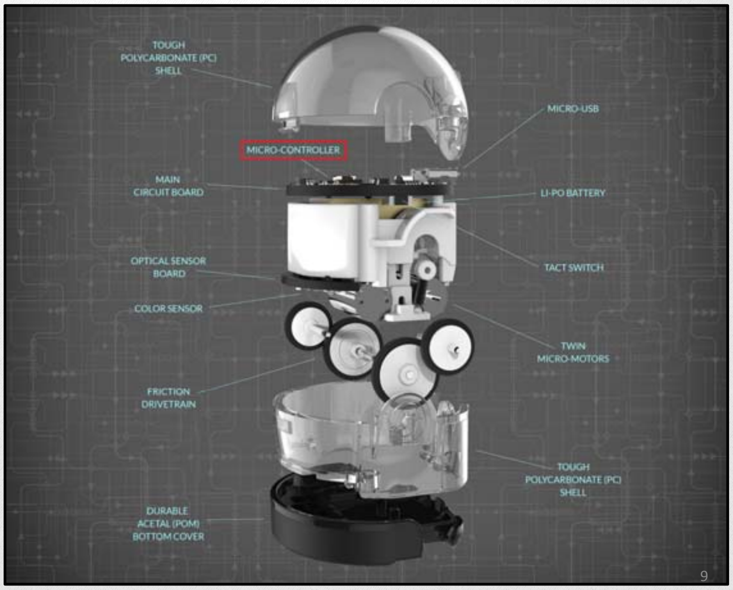
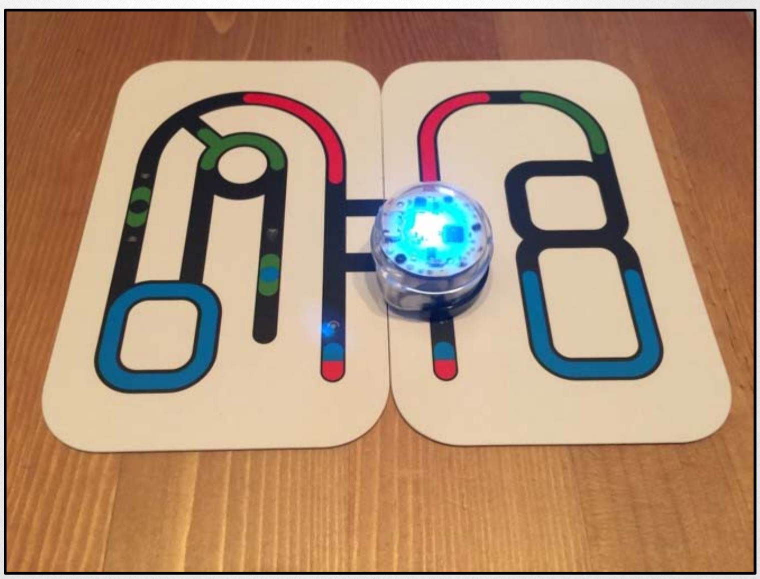


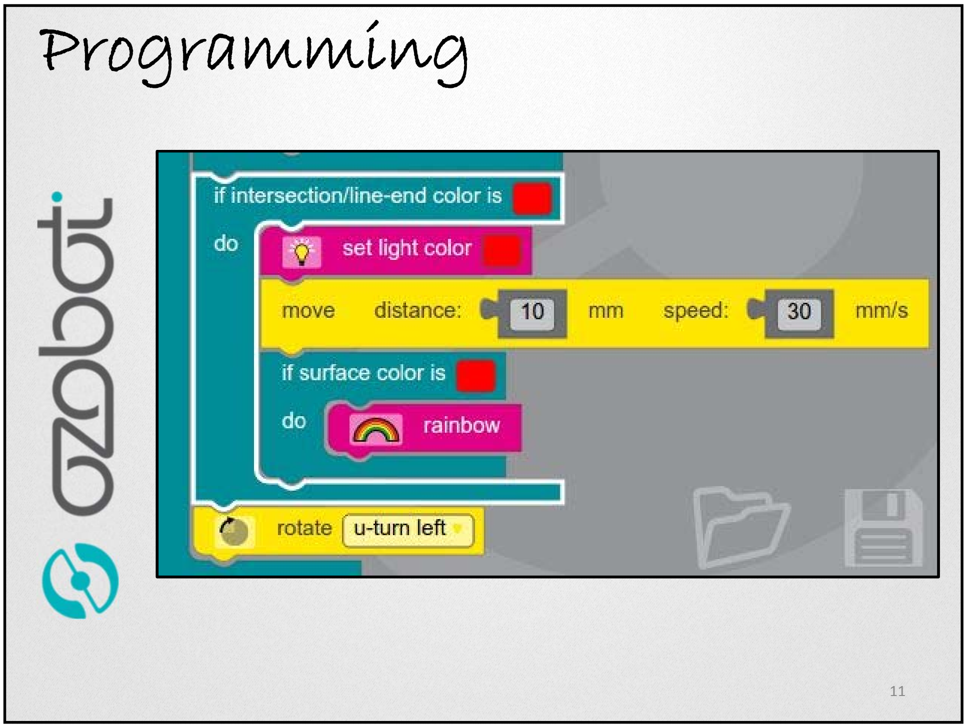
9

Navigation

ozobot



10


Programming
ozobot
if intersection/line-end color is
do
set light color
move distance: 10 mm speed: 30 mm/s
if surface color is
do
rainbow
rotate u-turn left
11

RCNET Nuclear Robotics Module Name:_________________

*PRE Assessment **TEST*** Date:_________________

*This assessment is designed to determine your pre-existing knowledge about robotics and their nuclear applications. This assessment should be taken prior to starting the **RCNET Nuclear Robotics Module** and will not count as a grade.*

Please write the correct answer directly on this test. Some questions may have more than one answer, please circle ALL the correct answers for each question.

1. What is the definition of a robot?
   a) A mechanical device that sometimes resembles a human and is capable of performing a variety of complex human tasks.
   b) A robot is a device that performs a set of actions automatically, without human interaction.
   c) A real or imaginary machine that is controlled by a computer and is often made to look like a human or animal.
   d) All of the above
   e) None of the above

2. What are the advantages to using robots in the nuclear industry (for the purposes of this module)?
   a) Robots are precise, robust, efficient, expendable, and environment agnostic. They perform unpleasant or mundane tasks without growing weary.
   b) Robots have the capacity to dramatically affect processes.
   c) Robot make industrial environments more fun and exciting to work in.
   d) All of the above
   e) None of the above

3. Why is robotics important to the nuclear industry (according to this presentation)?
   a) Robots can be specially designed to efficiently and reliably assist the nuclear industry why meeting stringent industry guidelines.
   b) Robots can go into radiation control areas and perform operations while personnel remain at a safe standoff distances.
   c) Robots can perform maintenance and repair tasks without disrupting the ongoing operations of the nuclear power plant.
   d) All of the above
   e) None of the above

4. Circle all of the facts that are TRUE about Robots in the field of Nuclear Medicine (according to this presentation).
   a) Precision and efficiency are the robot characteristics most sought after in nuclear medicine, where accurate exposure is critical.
   b) Robots offer the potential for accurate and efficient operations in nuclear medicine.

c) Robots can perform more accurately and with more precision that human counterparts.
d) All of the above
e) None of the above

5. Of the 3 statement below, which are true about robots sent to Fukushima?

Statement 1*:* *Robots have been essential in containment and decontamination at Fukushima.*

Statement 2*:* *Robots do not need to be fitted with an assortment of hazmat related sensors.*

Statement 3*:* *Robots must be designed for a specific purpose and able to navigate the rough terrain of a possibly disabled plant.*

a) Statements 1 & 2 are True
b) Statements 1 & 3 are True
c) Statements 2 & 3 are True
d) All are True
e) All are False

6. Which is TRUE about the limitation of robots in the Nuclear Industry?
   a) Robots must use radiation hardened electronic components.
   b) Robots must utilize proper shielding.
   c) Robots are not impervious to radiation.
   d) All of the above
   e) None of the above

7. Circle the four basic components that make up a robot.
   a) Form
   b) Language
   c) Output
   d) Input
   e) Logic

8. Circle the three basic components of a robot's form.
   a) Physical Design
   b) Structure
   c) Strength
   d) Speed
   e) Composition

9. **True / False:** Inputs are comprised of all the sensors and data available to the robot.
   a) True
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10. **True / False:** Output is comprised of all the devices used by the robot to perform work and transmit data.
    a) True
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    a) A robot's logic defines how it processes inputs and directs outputs to perform a task.
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12. **True / False:** Technically, ROS is a framework installed within an operating system, not an operating system itself.
    c) True
    d) False

13. Circle the three basic components of a ROS.
    a) IMU
    b) Topic
    c) Nodes
    d) Master
    e) GPS-RTK

14. **True / False:** ROS TOPICS are specific processes that are designed to handle a particular aspect of the robot.
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18. How does a closed loop control perform?
    a) It instructs the output to perform an action and assumes it is completed.
    b) It identifies the input's action as complete or incomplete.
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19. How does an open loop control perform?
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20. What does the term DEGREES OF FREEDOM refer to? (Circle all that Apply)
    a) The number of tracks by which a static system can move.
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POST Assessment ***TEST*** Date:__________________

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   b) Robots can go into radiation control areas and perform operations while personnel remain at a safe standoff distances.
   c) Robots can perform maintenance and repair tasks without disrupting the ongoing operations of the nuclear power plant.
   d) All of the above
   e) None of the above

4. Circle all of the facts that are TRUE about Robots in the field of Nuclear Medicine (according to this presentation).
   a) Precision and efficiency are the robot characteristics most sought after in nuclear medicine, where accurate exposure is critical.
   b) Robots offer the potential for accurate and efficient operations in nuclear medicine.

c) Robots can perform more accurately and with more precision that human counterparts.
d) All of the above
e) None of the above

5. Of the 3 statement below, which are true about robots sent to Fukushima?

   Statement 1*:* *Robots have been essential in containment and decontamination at Fukushima.*

   Statement 2*:* *Robots do not need to be fitted with an assortment of hazmat related sensors.*

   Statement 3*:* *Robots must be designed for a specific purpose and able to navigate the rough terrain of a possibly disabled plant.*

   a) Statements 1 & 2 are True
   b) Statements 1 & 3 are True
   c) Statements 2 & 3 are True
   d) All are True
   e) All are False

6. Which is TRUE about the limitation of robots in the Nuclear Industry?
   a) Robots must use radiation hardened electronic components.
   b) Robots must utilize proper shielding.
   c) Robots are not impervious to radiation.
   d) All of the above
   e) None of the above

7. Circle the four basic components that make up a robot.
   a) Form
   b) Language
   c) Output
   d) Input
   e) Logic

8. Circle the three basic components of a robot's form.
   a) Physical Design
   b) Structure
   c) Strength
   d) Speed
   e) Composition

9. **True / False:** Inputs are comprised of all the sensors and data available to the robot.
   a) True
   b) False

10. **True / False:** Output is comprised of all the devices used by the robot to perform work and transmit data.
    a) True
    b) False

11. Circle ALL the facts that are TRUE about a robot's Logic.
    a) A robot's logic defines how it processes inputs and directs outputs to perform a task.
    b) Logic may be implemented in hardware, software or a hybrid of the two.
    c) Logic is part of the ROS security of a robot.
    d) All of the above
    e) None of the above

12. **True / False:** Technically, ROS is a framework installed within an operating system, not an operating system itself.
    c) True
    d) False

13. Circle the three basic components of a ROS.
    a) IMU
    b) Topic
    c) Nodes
    d) Master
    e) GPS-RTK

14. **True / False:** ROS TOPICS are specific processes that are designed to handle a particular aspect of the robot.
    a) True
    b) False

15. **True / False:** ROS Master is the central process for any ROS installation and handles the registry of topics, publishers, and nodes.
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16. **True / False:** ROS utilizes named communication busses called NODES to share information.
    a) True
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17. **True / False:** ROS has its own security protocol built into the framework of the operating system.
    a) True
    b) False

18. How does a closed loop control perform?
    a) It instructs the output to perform an action and assumes it is completed.
    b) It identifies the input's action as complete or incomplete.
    c) It verifies the results of an output's action.
    d) All of the above
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19. How does an open loop control perform?
    a) It instructs the output to perform an action and assumes it is completed.
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    d) All of the above
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20. What does the term DEGREES OF FREEDOM refer to? (Circle all that Apply)
    a) The number of tracks by which a static system can move.
    b) The number of dimensions an affector may translate and rotate an object.
    c) The number of joints in a mechanism.
    d) All of the above
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RCNET Nuclear Robotics Module Name:_________________

POST Assessment ***ANSWER KEY*** Date:__________________

This assessment is designed to determine what you have learned about robotics and their nuclear applications. This assessment should be taken after completing the ***RCNET Nuclear Robotics Module*** *and will count as a grade.*

Please write the correct answer directly on this test. Some questions may have more than one answer, please circle ALL the correct answers for each question.

1. What is the definition of a robot?
   a) A mechanical device that sometimes resembles a human and is capable of performing a variety of complex human tasks.
   b) A robot is a device that performs a set of actions automatically, without human interaction.
   c) A real or imaginary machine that is controlled by a computer and is often made to look like a human or animal.
   d) All of the above
   e) None of the above

2. What are the advantages to using robots in the nuclear industry (for the purposes of this module)?
   a) Robots are precise, robust, efficient, expendable, and environment agnostic. They perform unpleasant or mundane tasks without growing weary.
   b) Robots have the capacity to dramatically affect processes.
   c) Robot make industrial environments more fun and exciting to work in.
   d) All of the above
   e) None of the above

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