Use of Robotics for Dose Reduction and Efficiency Gains at US Commercial Nuclear Facilities

Daren Cato, Duke Energy
Joan Knight, Exelon Generation

Duke ALARA Robotics Program

The primary focus of the Duke program is to increase radiological safety by using the robots for standard operations.

- Advantages of Robots
  - Reduces exposure for personnel: Dose Savings
  - Removes personnel from radiation hazards
  - Cost savings
- Program Focus Areas
  - Inspections/Walkdowns - Units must be small, lightweight, and available for use on short notice by a wide range of personnel
  - Surveys/High Level Inspections – Must have cameras that provide image clarity meeting regulatory requirements and be able to manipulate objects
  - Remote Handling of Radioactive Materials - must have the power to lift heavy objects as well as responsive and fine controls to accurately position materials

H. B. Robinson's 510 PackBot®, "Jake" conducts visual inspections in the Regen heat exchanger

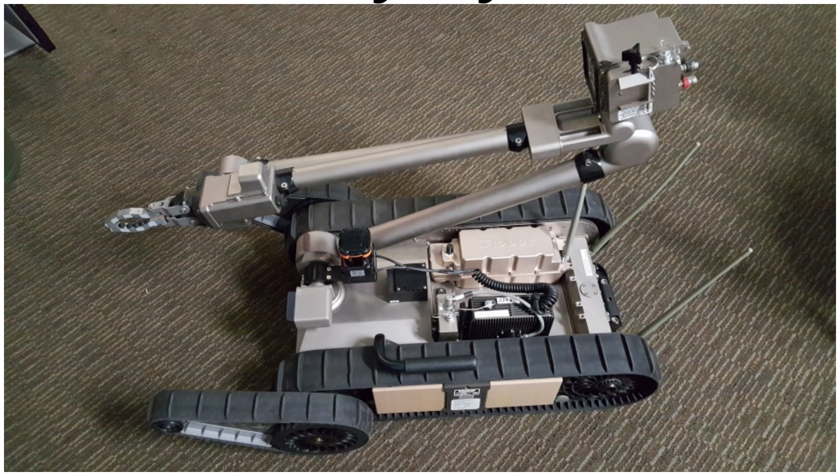
The Robots

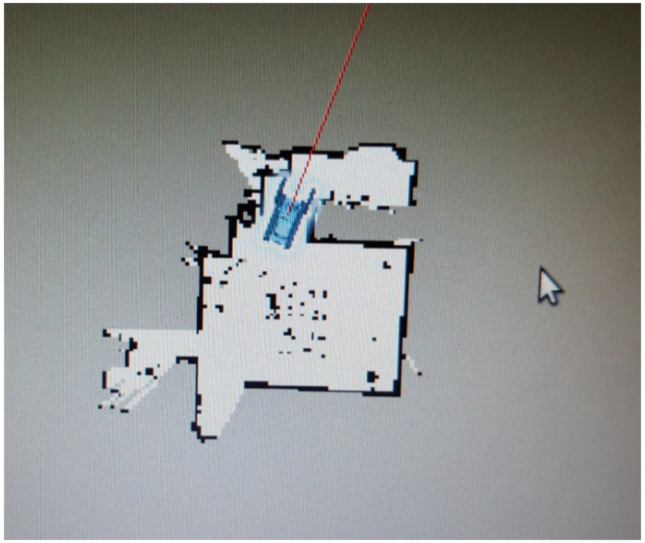
iRobot's
510 PackBot®

Used for: inspections, surveys, and manipulate items up to 30 pounds – operated via radio interface (2.4 or 4.9 Ghz)

- Dimensions: 27" long, 16"wide, and 7" tall; ~ 60lbs with a manipulator arm and separate laptop radio controller
- The operator accurately manipulates objects as small as a watch battery with the user-friendly, 3-D active modeling on the controller
- Equipped with 3 cameras and a gripper, the 3-jointed, multi-speed manipulator arm has a 7' reach.
  - This 3 camera configuration provides the operator a safe, full field of vision of the robot's environment
  - The main camera has a zoom of 300 times and provides an overhead view in a level of detail that cannot be observed by a person standing on the floor
  - The thermal camera accessory monitors for heat signatures and is used to accurately determine location and condition of piping for locating leaks – without personnel needing to enter the space

Semi-Autonomous Robotic Survey System



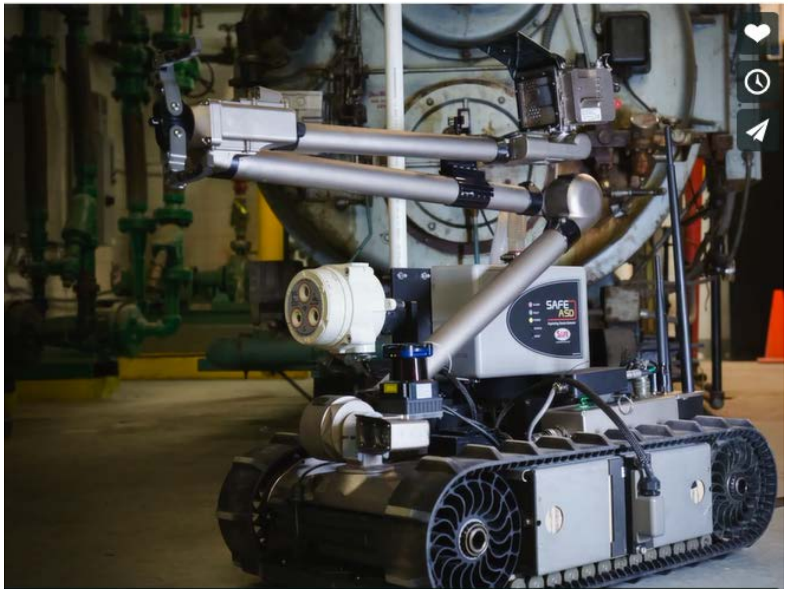


- Using Lidar the software renders a 2D map of the area.
- The robot can autonomously drive to a location chosen by the robot operator.
- The robot collects dose rates at varying heights at each location.
- The software produces a spreadsheet of the correlating data.
- Currently integrating dose rate instrumentation.

PackBot Continued

Autonomous Fire Watch Robot

- Robot follows a set path through the area of interest and continuously monitors for smoke and flame.
- Reports status to a central control console.
- Uses magnetic strip following and Lidar for object detection.
- Currently in testing at the iRobot facility.



The Robots

DUKE ENERGY. PROGRESS

iRobot's 710 Warrior®

The 710 Warrior is primarily used to handle heavy and radioactive material such as filters

- A large robot capable of handling material weighing up to 200 lbs
- Dimensions: 21" wide, 30"long, and 18" tall with a manipulator arm and separate laptop radio controller
- With a 12' reach, its scale and heavy lifting arm give it the ability of manipulate large items over a large barrier and areas

iRobot's 110 FirstLook®

This is the newest and smallest of the 3 robots – used for investigation and inspection

- Dimensions: 9" wide, 10" long and 4" tall
- 4 built-in cameras – front/back and one on each side
- Weighs 5.4 pounds with a separate hand held controller
- An exceedingly rugged platform that is throw- able / droppable and capable of handling the physical stresses of a 16 foot fall

Exelon Generation.

Under Development
In Cooperation With V6 Automation

- Purpose built filter manipulation robot in cooperation with V6 Automation.
- Universal Robot UR10 manipulator with vertical lift column.
- Multiple mount configuration.

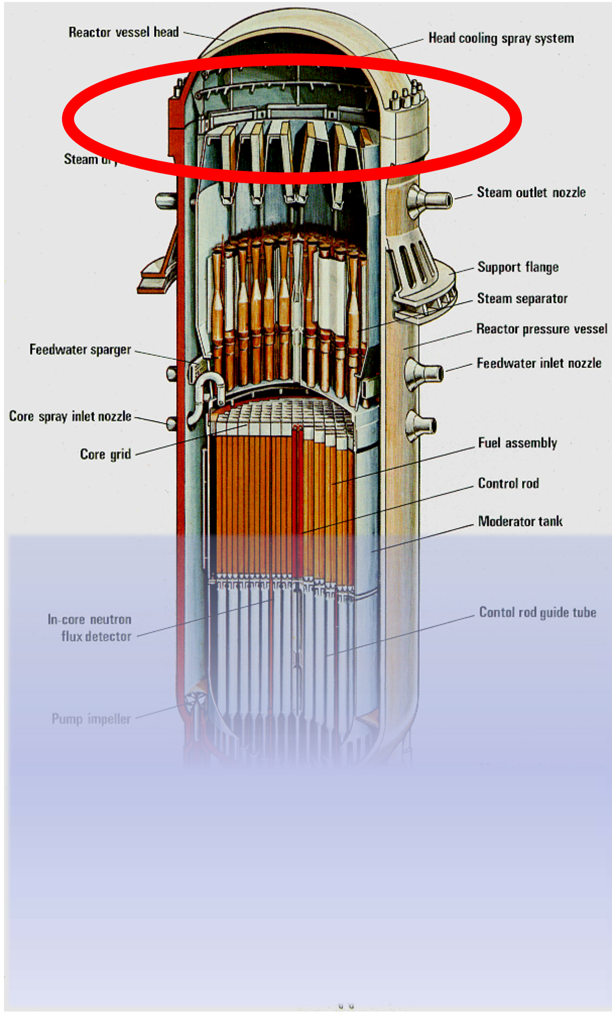
Reactor Pressure Vessel Flange Inspection

TVA Browns Ferry 1

Used with permission

Background / Overview

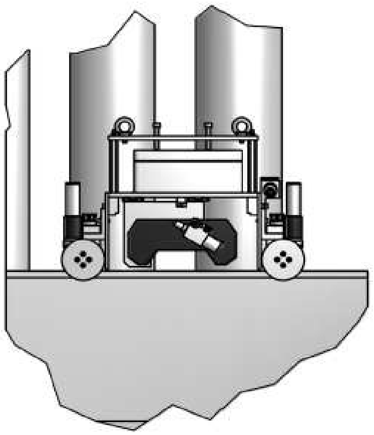
- Minor leakage issues following 2007 unit re-start
  - Repairs performed with limited success
  - Following 2012 outage, different approach needed
- ~4 month pre-planning period
  - First in US; Similar robotic inspections performed numerous times world wide
- Process
  - De-tension / Remove reactor head
  - Perform vessel flange and head flange Inspection
    - Visual inspections / profilometer inspections
    - Laser and enhanced video inspections
  - Continue with refueling activities
  - Evaluate inspection data
    - Determine appropriate repair activities
  - Execute repair

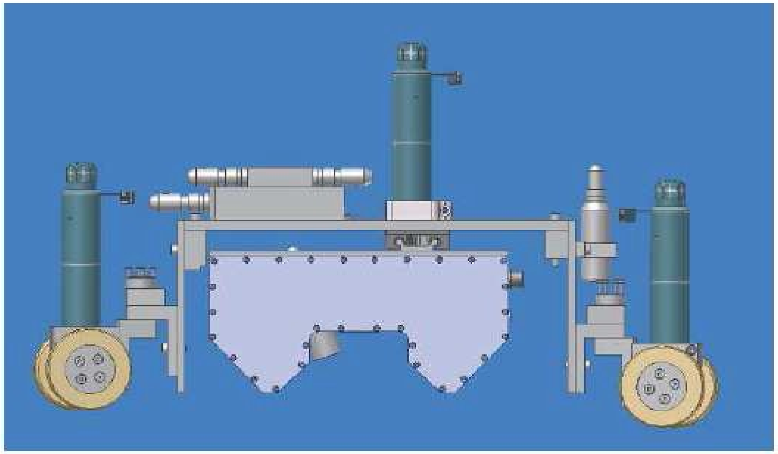


AREVA Laser Flange Inspection

Inspection and Laser scanning of RPV Flange Sealing Surface

Laser line scanner



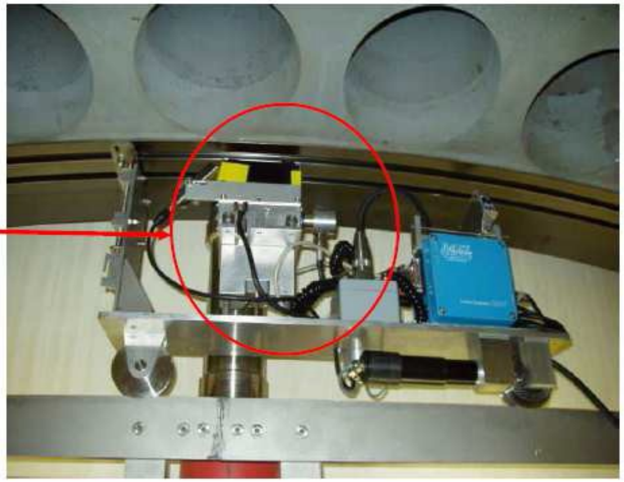


Inspection and Laserscan of the RPV-Flange Sealing Surface

- Challenges:
  - Vessel studs remain in place
  - Visual inspections had not yielded adequate results

AREVA Proprietary

AREVA RV Head Flange Laser Inspection



Single Device for Inspection ans Laserscan of seal groove surfaces at the RPV closure head

- Both vessel and head flanges were examined in detail
- Comparative analysis of flange contact areas

Controlled Document

AREVA	Inspection Inspection-Report	Specification: attachment 1 Page: 9
	Outage: 2014 STONE	Inspection-Report-No: D02-ARV-01-059-569 Date: 10/05/2014

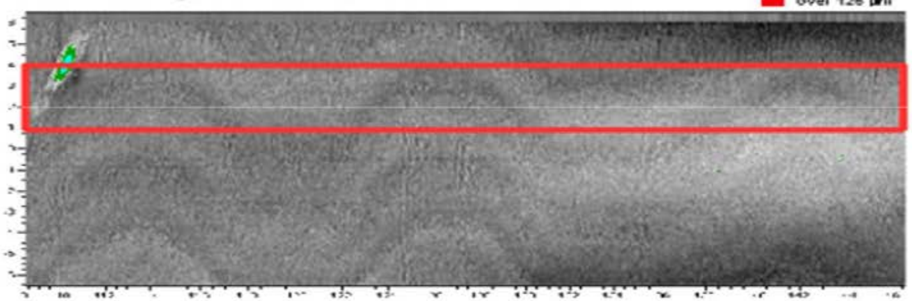
Pic. 15 : Outer seal-surface stud 57 – 58 at 110mm, size: 1.8mm, depth: max.80µm

LASER-Profilometry of the RPV-seal surface 330

Project: Browns Ferry 10/2014 File: BF2014F0057.bin

Position: RPV-flange, outer seal surface, stud hole 57 - 58 Date: 05.10.2014

25..50 µm
50..75 µm
75..100 µm
100..125 µm
over 125 µm



Pic. 16 : Outer seal-surface stud 57 – 58 at 110mm, size: 1.8mm, depth: max.80µm

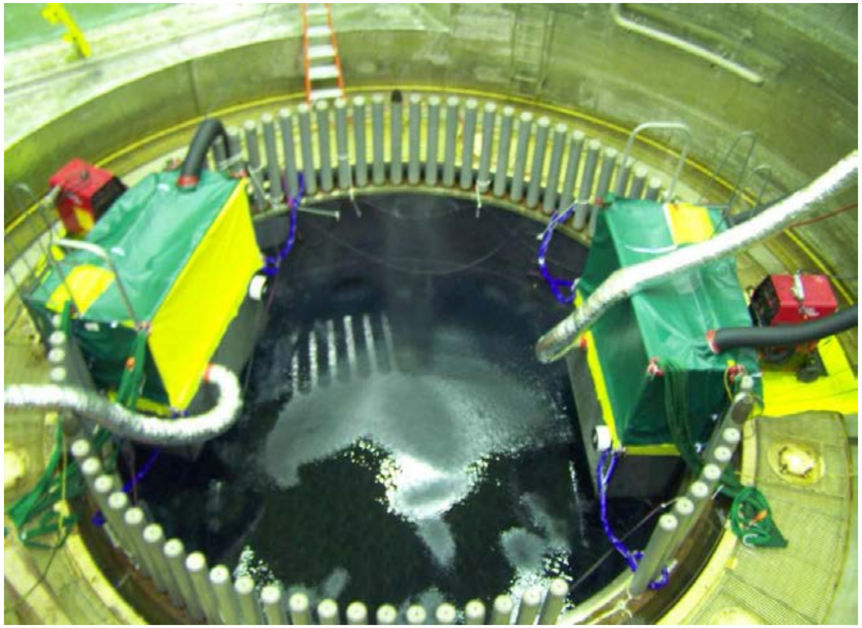
Date	Areva GmbH		
October 9, 2014	Henglein IBOOG		

AREVA GmbH

Redlines indicate
O-ring point of contact

Browns Ferry Work Platforms

Work Platforms Installed for Weld Repair



Nuclear Storage Tank Automated and Robotic Inspections

APS Palo Verde

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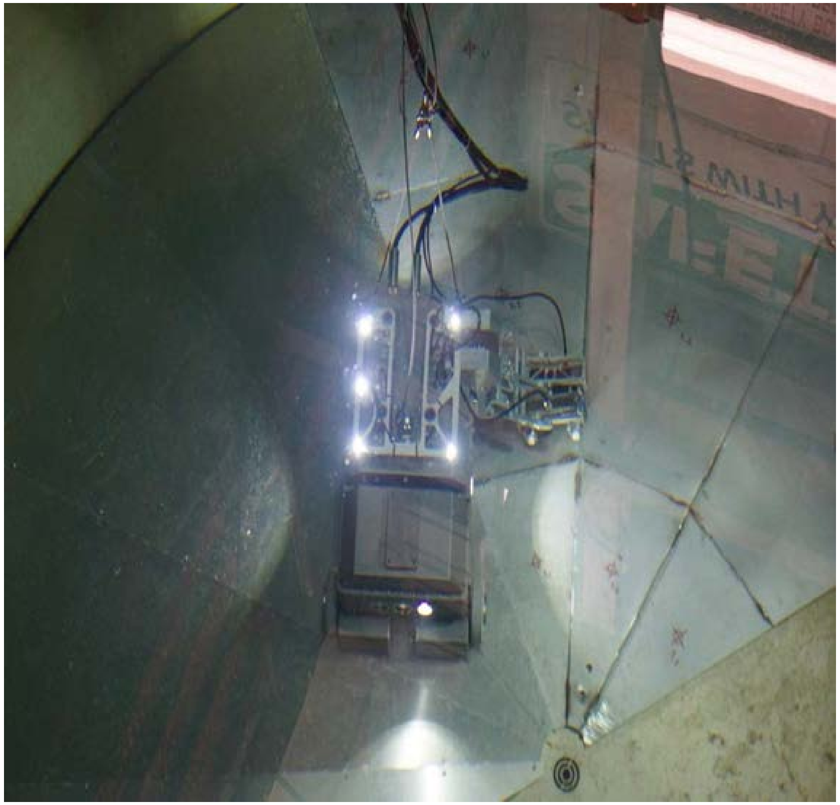
Exelon Generation

History – Problem Statement

- Nuclear power station water storage tanks are constructed of aluminum, stainless steel, or carbon steel
- Defects that develop on the underside of tank floors are particularly difficult to detect and measure
- Nuclear industry is committed to periodic inspections in support of plant and environmental safety
- Historically, tanks have been drained and manual surveys and non-destructive examination (NDE) inspections conducted
    - costly, time consuming, and can restrict certain operations

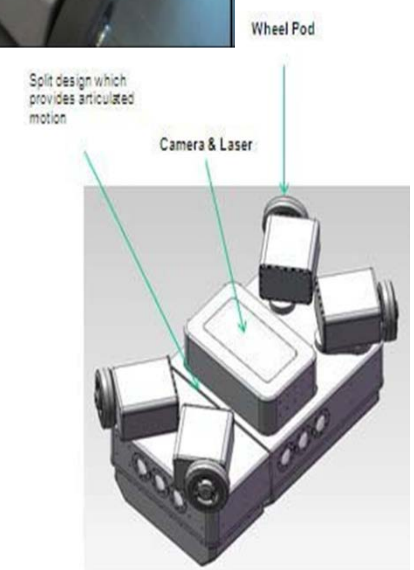


Development work for remote inspection

- EPRI & industry development work on remote inspection ongoing for a few years prior
  - Comparative testing conducted
- Considerations:
  - Two different NDE methods
  - Exact locations relative to map needed
  - Submerged operation
- Initial full use fall 2014 at Arizona Public Service Palo Verde Station

Equipment - The Inspector

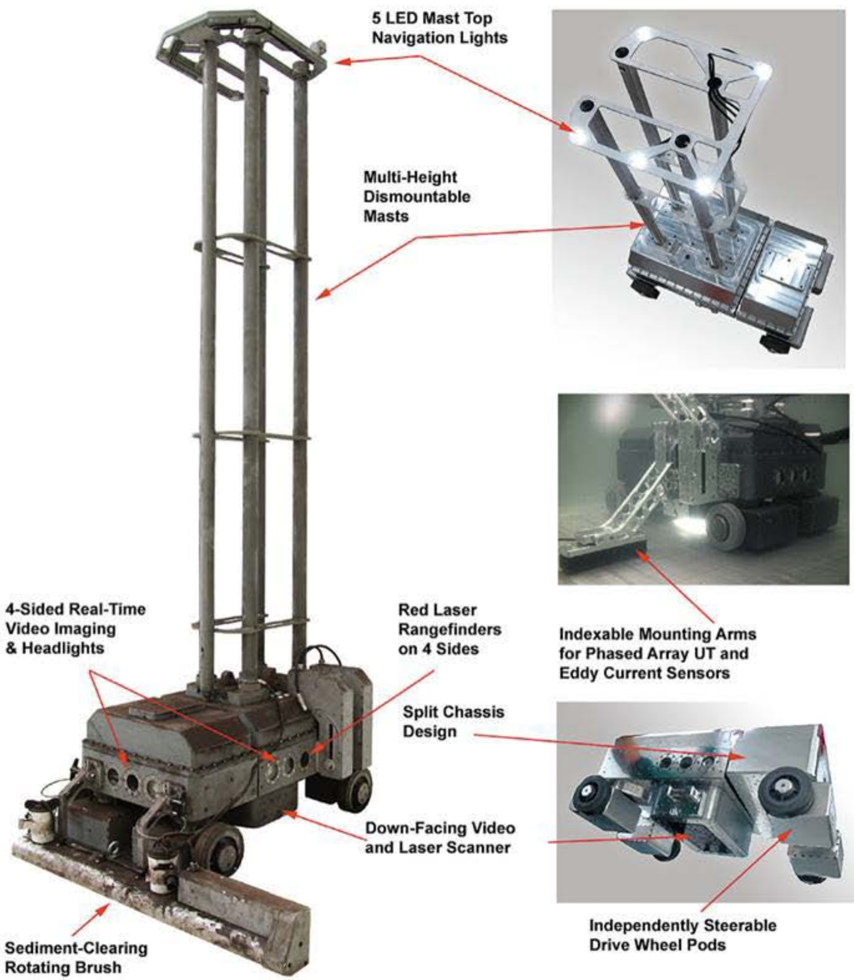
- semi-autonomous underwater robotic delivery platform with
  - Cleaning capability
  - Sensors
  - measuring instruments
- Performs NDE tank floor surveys and inspections without the need for draining
  - >90% coverage of the tank floor
- Is designed to fit through 19” opening
- Can sense obstacles and stop
- Top speed is in excess of six inches per second
- on-board 360-degree video imaging system



Inspector System Overall Features and Benefits

- Precision navigation locates damaged areas and returns to that location within 3.25 mm (1/8")
- The overhead navigation system (The Navigation System's camera allows a high degree of accuracy)
- Highly maneuverable four-wheel steering
- Accurately identifies and maps weld locations using machine vision
- Eliminates the need of human divers to perform inspections of liquid storage tanks
- Cost effective in regards to monetary spending and yearly dosage allowance

Graphic 1: Inspector Gadget



Summary

Process

- Inspector performs a high-speed "weld mapping" pass
- Accurately identifies and maps weld locations using machine vision
- Performs a detailed inspection on a per-plate basis
- Provides XYZ cooridinate locations of all flaws in tank using Phased Array UT scans

Benefits

- Eliminates the need of human divers to perform inspections of liquid storage tanks
- Cost effective
- The "Gods Eye" camera allows a high degree of accuracy
- Software allows virtual tank viewing and precise maneuvering

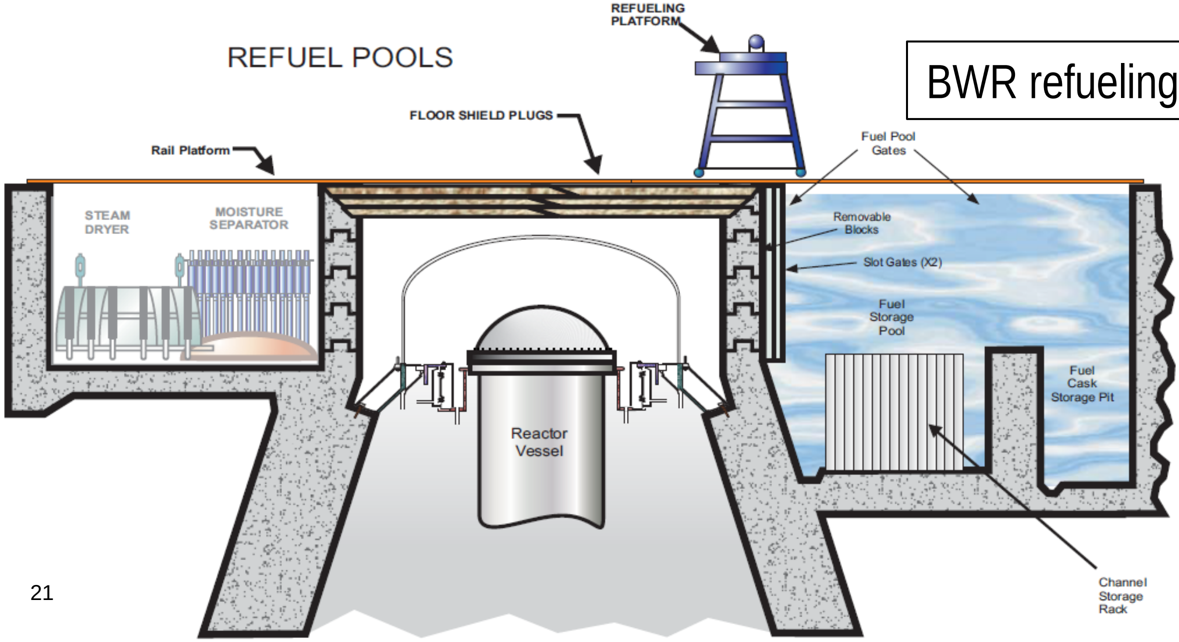
Refuel Cavity Cleaning System

Exelon LaSalle Station and

ROV Technologies

Cavity Cleaning System Development

- Refueling cavities become contaminated when in use, elevating area dose rates
- Decontamination is necessary to allow workers to reassemble the reactor head after water is drained
- Decontamination efforts can be labor intensive and extend outage lengths
- A robotic system that could be deployed in parallel with other activities became attractive



BWR refueling areas

Cavity Cleaning System Components

- The components shown in this picture are the buoyancy compensation chamber at the top
- The mid section contains the thrusters, lights and cameras
- The bottom section houses the deployable mini crawler and additional lights and cameras

Cavity Cleaning System Components

- The control station is placed in a remote, low dose area and provides the operators multiple views of the operation of the vehicle
- There are two general area cameras placed in the cavity to monitor the overall positioning of the system

Results of the Initial Deployment

- Underwater survey results taken prior to and post cleaning show a 40 – 60% reduction in the contact dose rates
- The system is capable of movement under the refueling inspection platform which can minimize or eliminate the need for cavity vacuuming on critical path
- Future enhancements to the system will allow it to be used for all cavity configurations and perform more efficient dose reduction efforts across the Exelon fleet

ALARA

An acronym that represents the concept of reducing exposure to ionizing radiation.

* As
* Low
* As
* Reasonably
* Achievable

Results of the First Deployment – Lessons Learned

- During the deployment of the tool at LaSalle Unit #1, several lessons were learned:
  - Additional testing needed for hoist and delivery
  - Re-design of the cleaning brush arm for additional robustness of attachments
  - Re-design of the buoyancy motor control system

Generic refueling

Thank you!