NextGen RP

For Normal Operations - Remote and Automated Technologies to Enhance and Optimize Nuclear Power Plant Radiation Protection Operations

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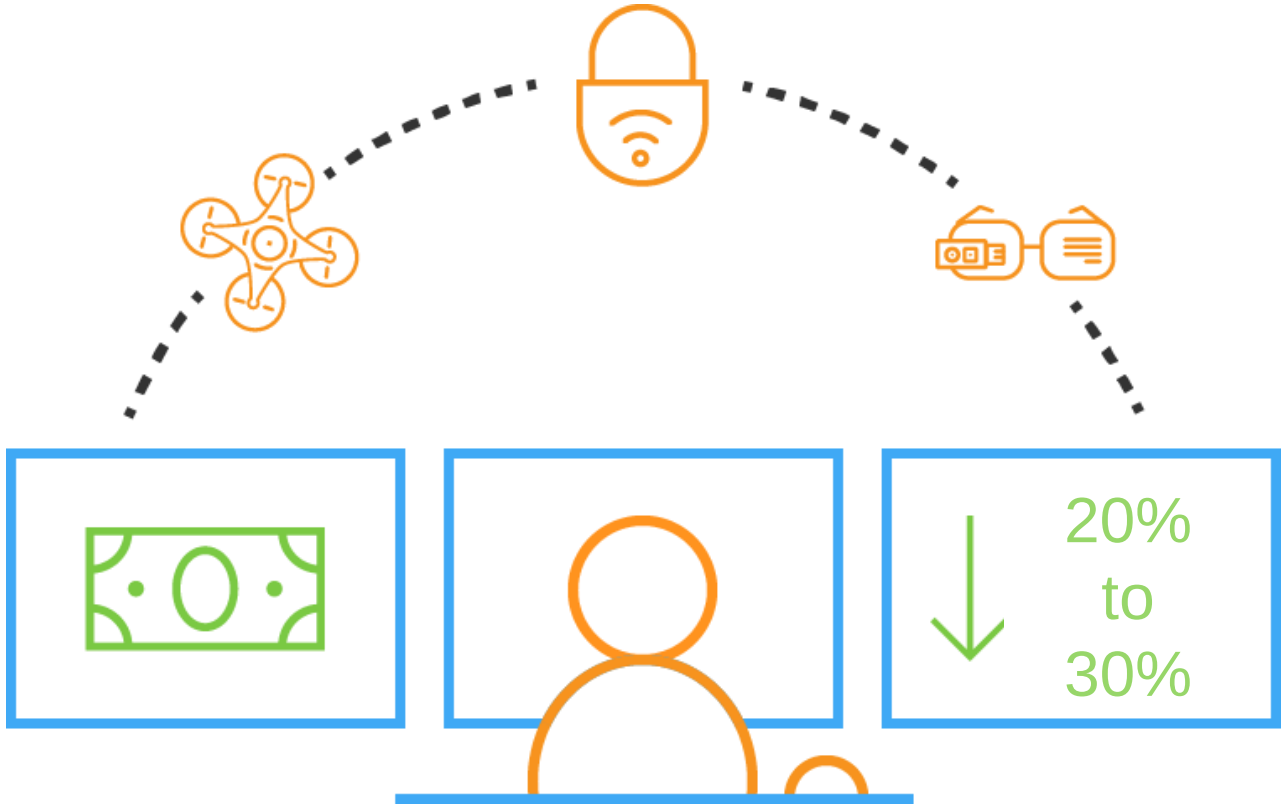
Goal

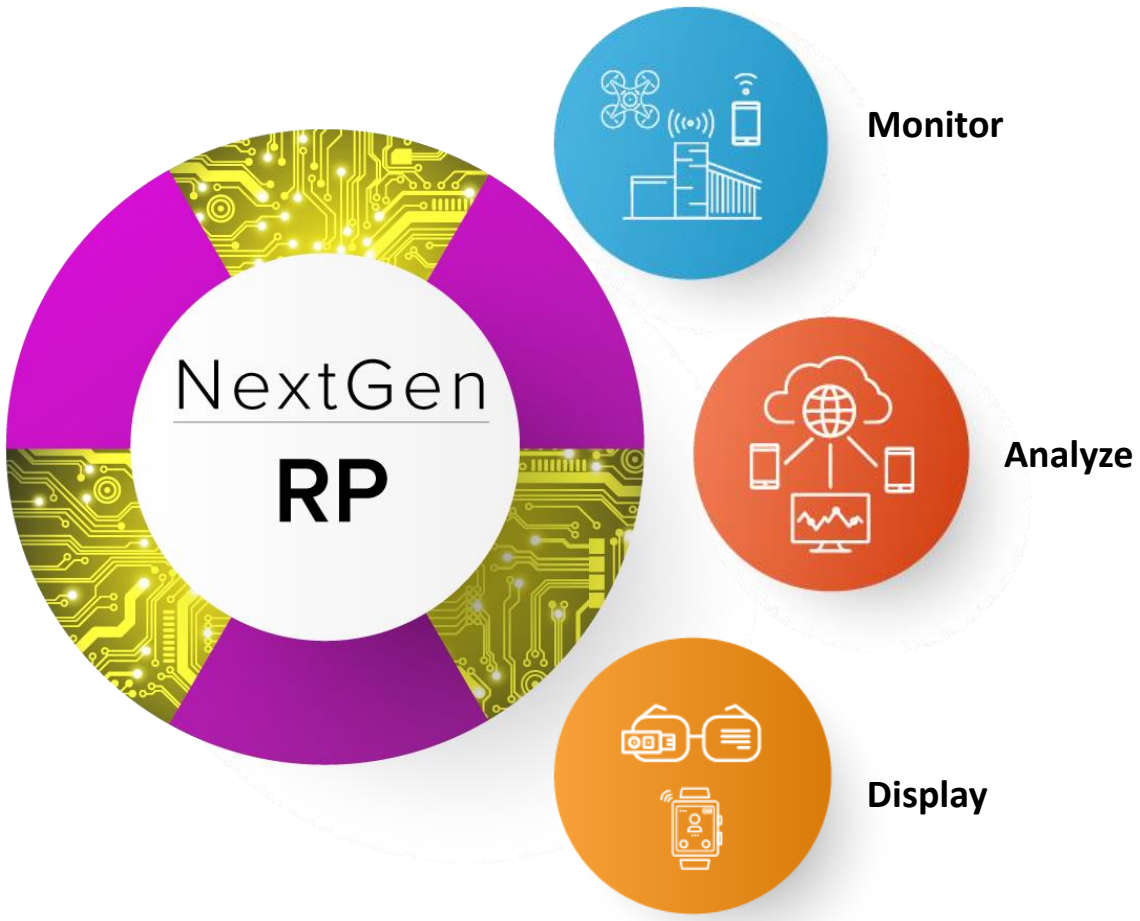
NextGen RP

Apply advanced technologies to
- enhance worker and public radiological safety
- enable risk and condition based planning and practices
- optimize RP operations

Anticipated outcomes:
- 20% - 30% cost reduction
- Reduced dose
- Timely, comprehensive, and integrated understanding of radiological conditions



Current NextGen RP Focus



MONITOR: Apply real-time, remote monitoring and control technologies (2020-2022)

- Develop and Demonstrate Contamination Survey Unmanned Ground Vehicle (UGV)
- Evaluate Technologies for the Remote Control of Access to High Radiation Areas
- Emergency Response Field Monitoring Team (FMT) Technology Enhancement

ANALYZE: Apply smart analytical tools for data trending, modeling, planning, and reporting (2021-2024)

- Geospatial Remote Live Streaming Radiation Monitoring Network a.k.a. Digital Twin

Goal: Support optimization of RP operations remote tools and with risk-based planning

Demonstration of Autonomous Indoor Drone for Radiation Surveys and Visual Inspections

EPRI Demonstration of Aerial Drone

- Need identified by US utility to save dose and cost by using aerial drones to perform tasks such as:
  - Dose rate surveys
  - Inspections required by Engineering Department
  - Heat-mapping of components
- Limitations of many drone systems:
  - Require operator to maintain “line of sight” of drone during flight – reduces dose reduction benefit
  - Manual control required for some designs has proven difficult in limited space, GPS denied indoor applications
- Guidance systems for GPS denied applications have improved greatly including the ability to:
  - Autonomously create a 3D map of building interior
  - Autonomously fly to chosen waypoints to perform tasks such as those identified by Exelon above

EPRI Demonstration of Aerial Drone

- Drone System Components
  - Commercially Available Drone – Battery Powered
  - Navigation System
    - Lidar* based hardware
    - Proprietary software by Exyn Technologies of Philadelphia, Pennsylvania USA
  - Attachments:
    - Mirion Technologies RDS-31 Radiation Detector for dose rate measurements
    - Video camera for inspections
      - Controlled independently from drone navigation using separate tablet
    - Thermal Imaging Camera

Lidar Based Hardware for Mapping and Navigation

Camera Package is Connected by Bluetooth to Tablet

*Lidar = Light Detection and Ranging

EPRI Demonstration of Aerial Drone

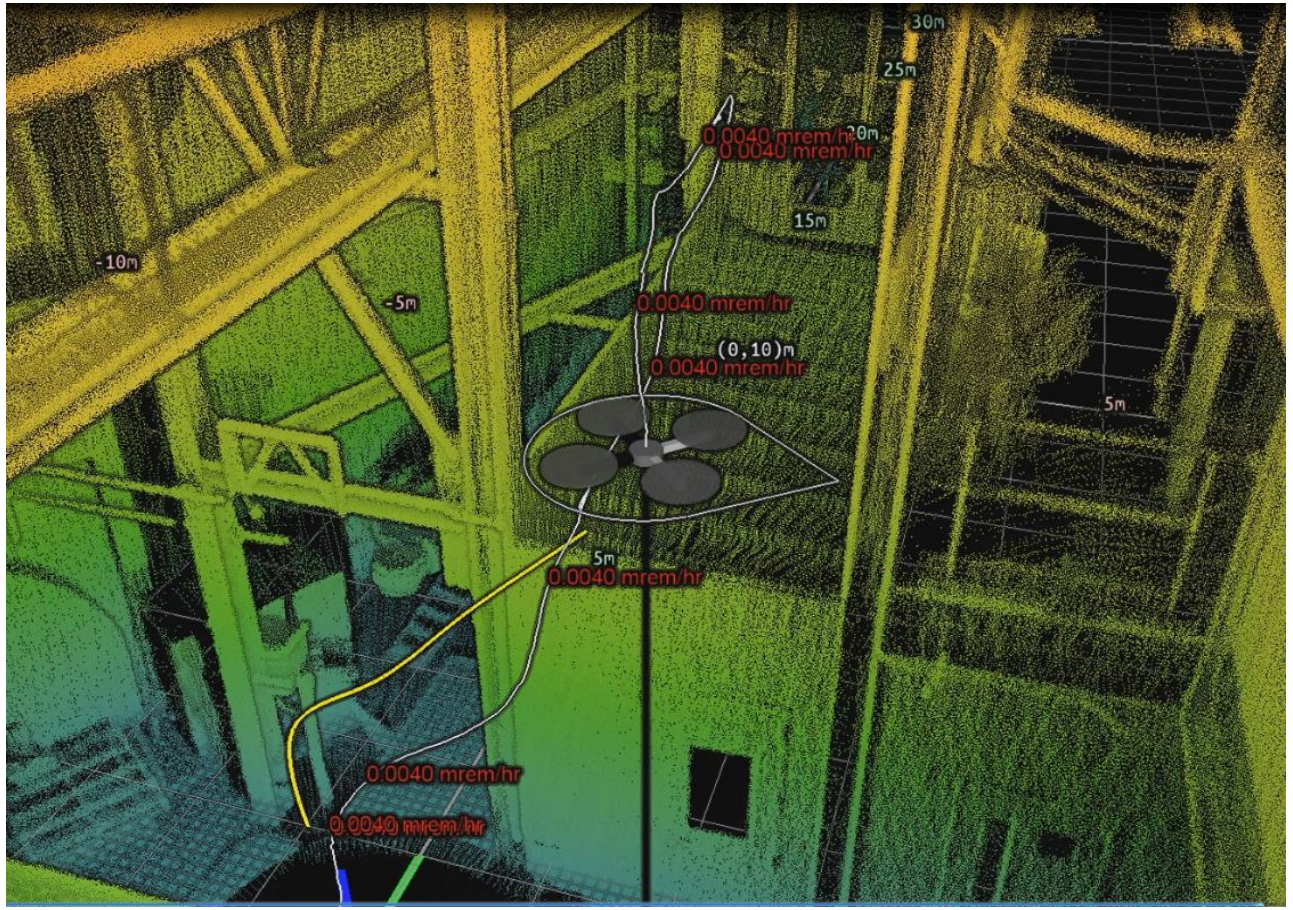
- Demonstration conducted in December 2019:
  - Demonstrations in permanently shutdown
    - Autonomous mapping of Primary Auxiliary Building
    - Autonomous transit to pre-programmed waypoint locations
    - Recording of dose rate measurements
    - Performed thermal imaging test
  - Demonstrations in Low Level Radwaste Building (common to all units)
    - Autonomous flight into high radiation area
    - Demonstration of avoiding an unexpected obstacle

Heat Blanket for Thermal Imaging Test

Thermal Camera on Drone Detects Heat Blanket Remotely

EPRI Demonstration of Aerial Drone– Data Display and Recording

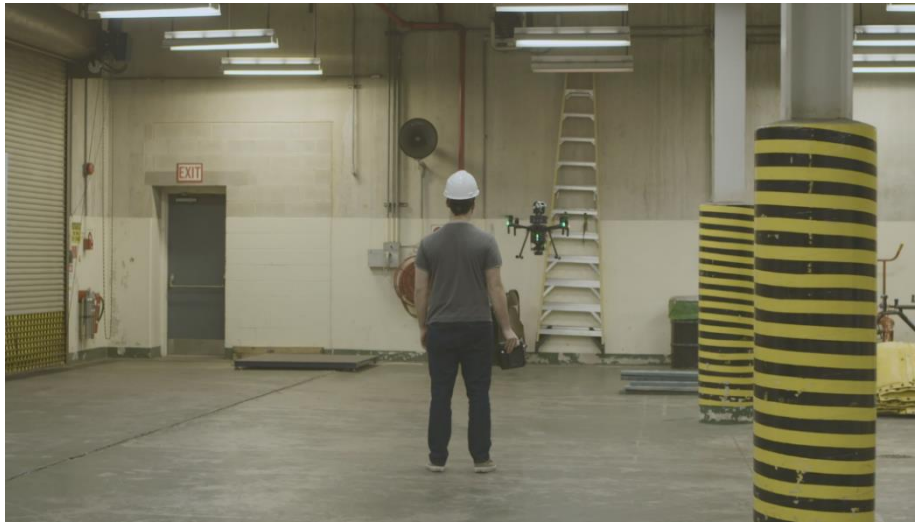
- Data was collected onboard and via wireless link:
  - Flight path shown on 3D map of building:
    - White line is path flown
    - Yellow line is remaining planned path
  - Dose rate information recorded
  - Video files saved for later viewing:
    - Component Inspections
    - Infrared camera images
- Display of Dose Rate Data (in red on image):
  - Navigation system software overlays dose rates onto the 3D transit map every three seconds
  - Image to the right illustrates how this information was displayed and recorded during the actual drone demonstration



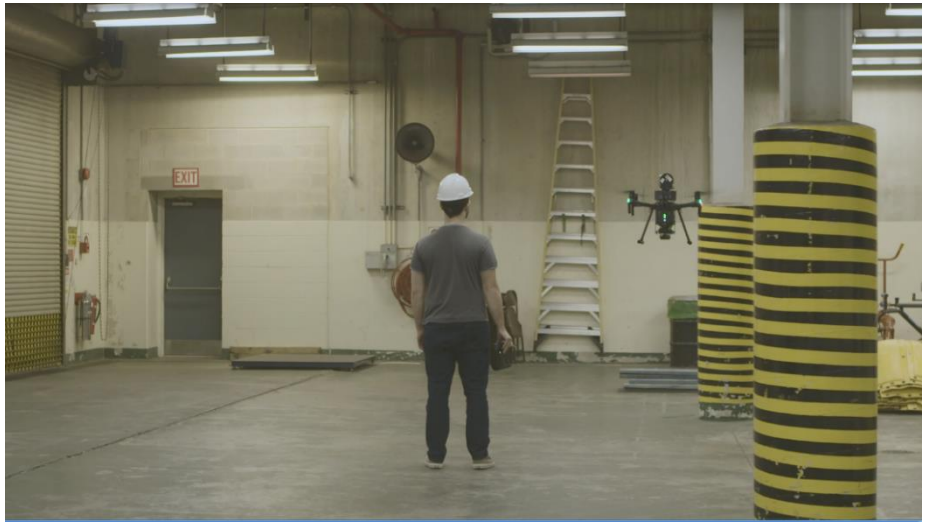
Autonomous Flight Path in the unit with Overlay of Dose Rates

Aerial Drone Autonomous Avoidance of Unexpected Obstacles

- Two exercises demonstrated this capability in Radwaste Building:
  - High Radiation Area:
    - Drone programmed to fly near stanchions and barrier rope located at the entry into area
    - Drone detected obstacles in flight replotted a course safely above the obstacles and then resumed the plotted course
  - Testing of dynamic obstacle – Unexpected obstacle in path
    - Straight line out and back travel path plotted on the 3D map of a room
    - Drone flew autonomously to the most distant point
    - Exyn flight controller, holding a kill switch for safety, moved directly into the return path of the drone
    - Drone detected new obstacle while returning to base
    - Plotted and flew a safe path around the person *then*
    - Resumed the original flight path
    - Demonstrated a good safety feature to address an unexpected obstacle into the drone travel path



Simulated Obstacle Moves in to Travel Path



Drone Detects and Autonomously Rerouted Around Obstacle

EPRI Demonstration of Ground Vehicle- Operating Units

- Unmanned Ground Vehicle (UGV) was used to test capabilities in locked high-rad area in the operating unit
- Mapping and rad data collection conducted in both operating units
- UGV fitted with similar equipment to the drone:
  - Lidar based mapping software
  - Mirion Technologies, RDS-31 Radiation Detector for dose rate measurements
  - Video camera for inspections
  - UVG used remote manual control due to short project schedule

Summary of EPRI Aerial Drone at Demonstration

- Drone performed a number simulated tasks without operator control (i.e., autonomously):
  - Surveys for area dose rates
  - Inspection of plant systems, structures and components (SSCs)
  - Performed thermal imaging test
- Created a 3D map of a large portion of the unit Auxiliary Building in 5 secs without leaving the staging point
- Dose rates were successfully recorded every 3 seconds and instantaneously displayed on the 3D map
- Video and infrared cameras were able to simulate inspecting components during drone flights
- Drone's navigation system detected and safety flew around a new obstacle in its autonomous travel path
- EPRI Deliverables:
  - EPRI Quick Guide 3002018409
  - Narrated video of demonstration: https://youtu.be/97lyDoAOif4

Remote Control of Locked High Radiation Areas

Remote Control of Access to High Radiation Areas

- Positive control of the entry points to high radiation areas at nuclear power plants is a regulatory requirement.
- The current typical practice is for Radiation Protection (RP) to control dedicated keys and unlock the gates at entrances to Locked High Radiation Areas (LHRA) in person.
- This practice is highly manpower intensive, especially during outage periods when many more worker entries are required, and extra temporary RP technicians are hired to cover these and other activities.
- Goal of this EPRI project is to identify remote, state of the art access monitoring and control technologies that can be applied to nuclear power plants.

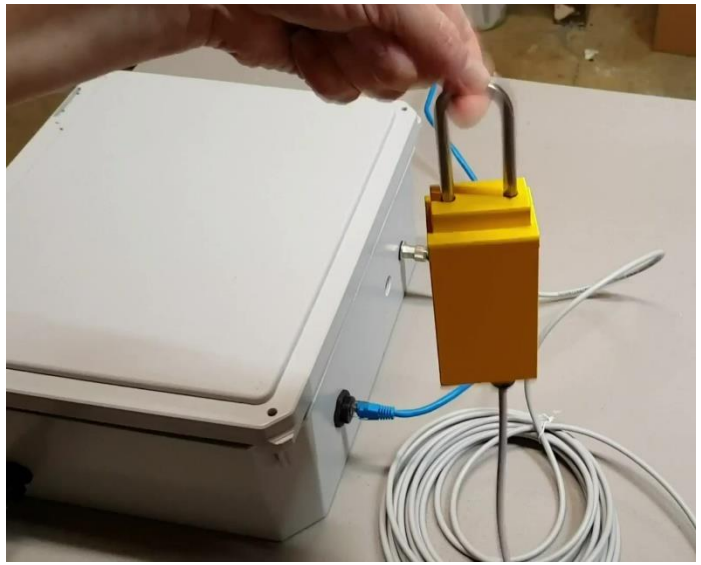
Example of Lock at High Radiation Area Entrance

Remote Control of Access to High Radiation Areas

Project Objective and Potential Benefits

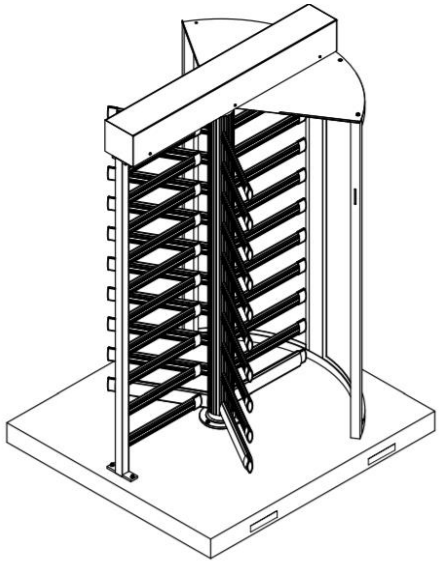
- Documented in EPRI Technical Report 3002020979
- Types of technologies/functionality to be evaluated:
  - Ability to unlock the gates from a central control station
  - Remote monitoring of status of the gates using video coverage and/or limit switches
  - Verification that workers are on the correct RWP prior to allowing access
- Potential benefits of advanced technologies:
  - Reducing the need to send RP technicians to open high radiation area gates:
    - Reduce radiation exposure and reduce cost
  - Improvement in the control of entries to LHRA through:
    - Continuous monitoring and allow personnel accountability in case of an emergency

South Texas Project Remote Control of S/G Manway Locks



Remote Control of Access to High Radiation Areas

Example: Drywell Remote Access Control



- Locked High Radiation Area (LHRA) Gate controlled by RP Tech at Remote Monitoring Center (RMC)
  - RP Tech uses issued LHRA key to grant access
  - Coverages at Drywell Entrance available at RMC
    - Video
    - Telemetry of individuals tele-dosimetry
    - Audio communication with worker
- Steps of Drywell Access Control:
  - Worker request access from RMC using audio communication device
  - Worker scans dosimetry using reader located at turnstile
  - RMC control console verifies that worker is allowed into LHRA
  - RP Tech verifies that worker has LHRA permission and that tele-dosimetry is functioning
  - RP Tech rotates LHRA key on console to grant access to one worker

Ongoing Projects

Smearbot: An Automated Contamination Survey Robot

Research Objective – ***Develop specifications for a cost-effective robot that can:***

- Perform contamination surveys following autonomous routes or user defined routes.
- Determine and map the total area surveyed and calculate the removeable contamination levels in that area.

Project Progress:

- Specifications for Basic Floor Model, Middle End Model, High End Model developed.
  - Discussed with NextGen RP Working Group Utility Members.
- Next step: Work with a technology developer to build and demonstrate a prototype.

Reduce Frequency of Manual, Routine Contamination Surveys.

Smearbot: An Automated Contamination Survey Robot

Basic Floor Model

Takes removeable surface contamination smears on floor surfaces and returns to a home base to count the samples and determine the level of removeable contamination.

<$20,000

Build in 2021-2022, Demonstrate in 2022.

Seeking volunteers for demonstration plant.

Medium End Model

Performs the tasks of the basic model plus additional tasks such as contamination survey at height, dose rate surveys and has ability for basic communications.

<$40,000

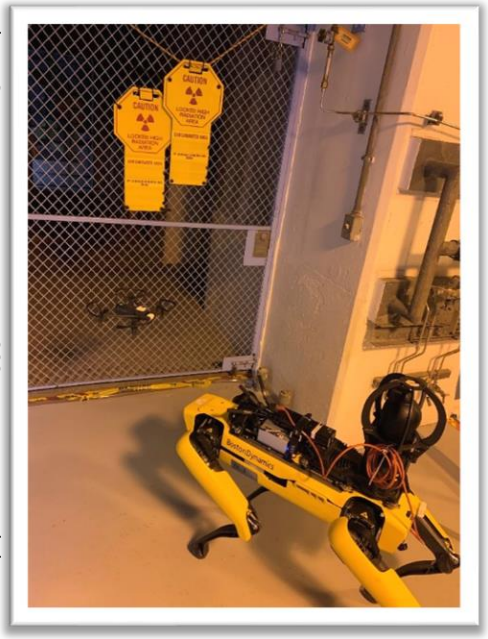


Photo Source: NextEra Energy at 2021 EPRI RMT Workshop

High End Model

Perform disc smear of specific components, area dose rate measurements, contact dose rate measurements, obtain air samples.

<$120,000