

# Robotics Utility Network

## 2023-Q1 Introductory Call

**Dexter Lewis**

Principal Technical Leader

**Sunny Bellary**

Engineer/Scientist III



# Safety Tip – Drones near Roads

- Safety/compliance tips from US Department of Transportation:
  - Appropriately colored or marked vehicles with high-intensity rotating, flashing, oscillating or strobe lights
  - Wear high-visibility safety apparel that meets the Performance Class 2 or 3 requirements of the ANSI/ISEA 107-2004



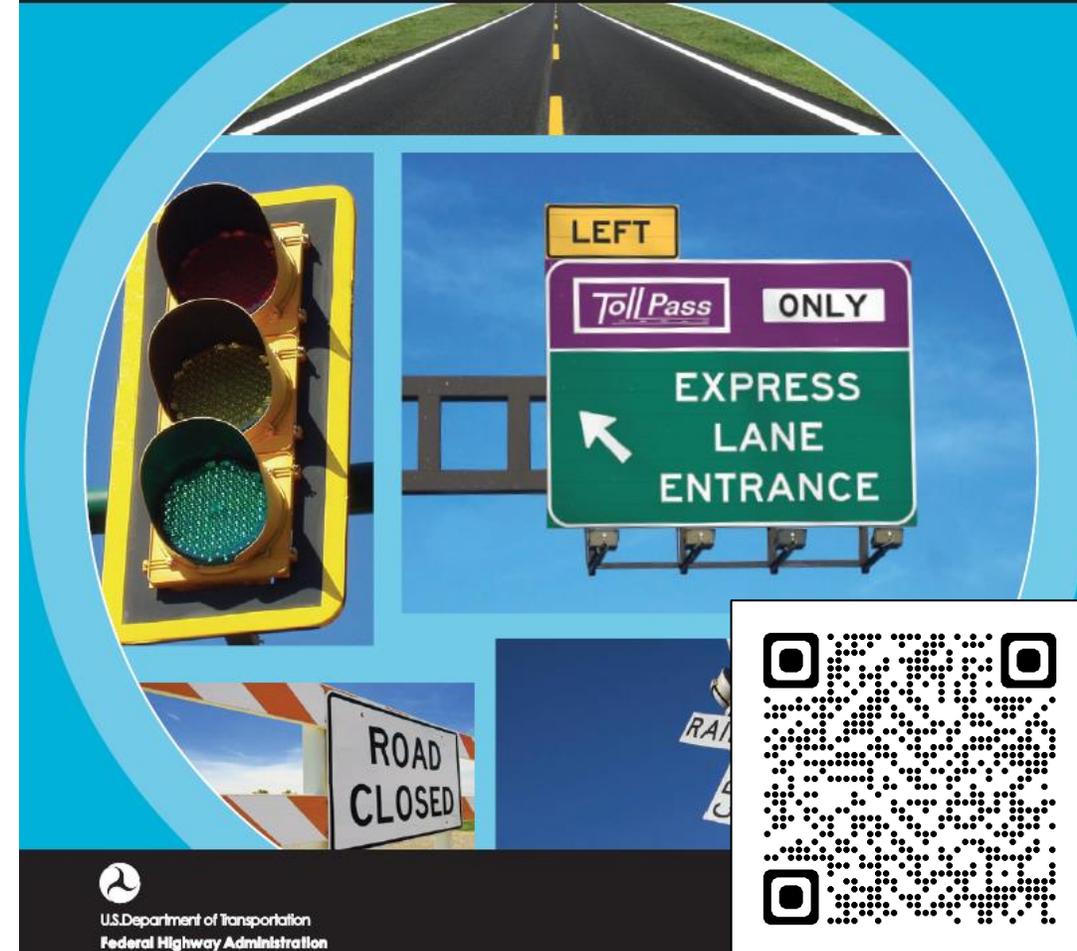
- 7 fundamental principals of Temporary Traffic Control (TTC)
  1. General plans or guidelines should be developed to provide safety for motorists, bicyclists, pedestrians, workers, enforcement/emergency officials, and equipment.
  2. Road user movement should be inhibited as little as practical
  3. Motorists, bicyclists, and pedestrians should be guided in a clear and positive manner while approaching and traversing TTC zones
  4. Routine day and night inspections of TTC elements should be performed
  5. Attention should be given to the maintenance of roadside safety during the life of the TTC zone
  6. Each person whose actions affect TTC zone safety, from upper-level management through the field workers, should receive training appropriate to the job decisions each individual is required to make.
  7. Good public relations should be maintained.

## Manual on Uniform Traffic Control Devices

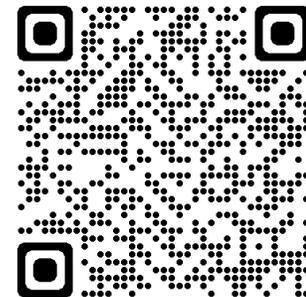
for Streets and Highways

2009 Edition

Including Revision 1 dated May 2012  
Revision 2 dated May 2012  
and Revision 3 dated July 2022



U.S. Department of Transportation  
Federal Highway Administration



# Agenda

- **Introduce of RUN and EPRI Strategy – 20 min**
  - Overview of RUN initiative, its objectives, and goals
  - EPRI’s strategy related to robotics in the utility industry
  - Collaborative Projects
- **Utility Presentation – 20 min (KEPCO)**
  - Presentation by a utility member on their experience with robotics  
Discussion on the challenges faced and lessons learned
- **Q&A – 20 min**
  - Member input via using Slido poll
  - Open forum for members to ask questions and share their thoughts on the presentations and discussions
- **Call to Action**
  - Next steps for members who are interested in participating in RUN
  - Solicit members to present their research
  - Identify a RUN leadership team



# Introduce of RUN and EPRI Strategy

# How it all started?



- This meeting was held with members during 2023 EPRI Transmission and Substations Spring Task Force in Charlotte.
- The action was for EPRI to produce a utility network that can meet regularly to share information and collaborate.

# What is Robotics Utility Network (RUN) Initiative

- Network of Electric Utility Professionals & EPRI researchers
  - SMEs, stakeholders, and operators
  - focused on innovating, implementing, and researching robotics & drone technology.



## Three Pillars of RUN

# Goals - Keeping up with the pace of innovation



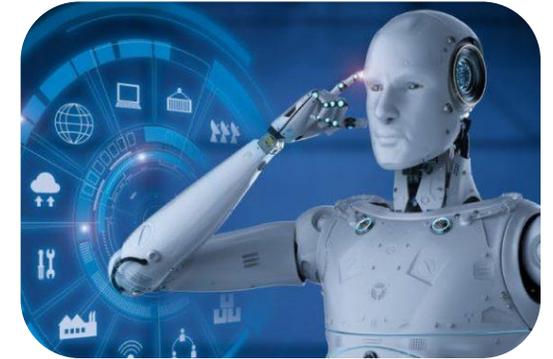
Organize recurrent meetings



Platform for peer-to-peer information exchange



Overcome challenges through collaboration



Advocate for adoption of robotic technologies



Identify collaborative project needs and opportunities



Highlight successes and failures



Consolidate information

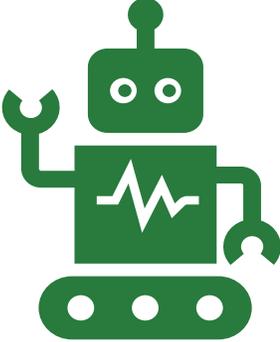


Foster Relationships

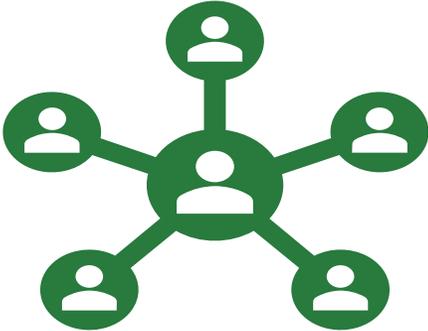
# How will this help?



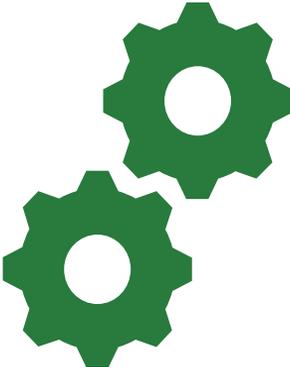
Vital hub



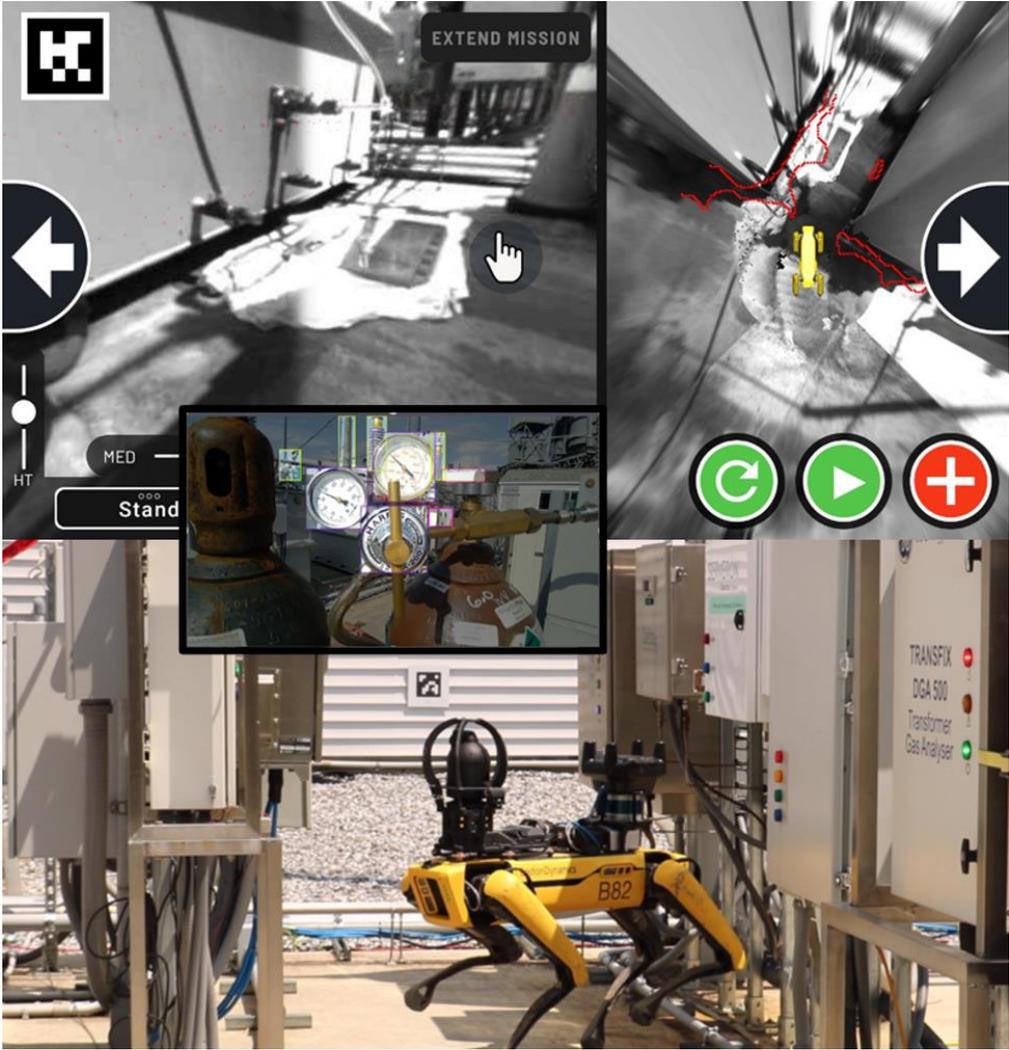
Help to collaborate, learn, and innovate



Access to valuable resources, expertise, and networking opportunities



Help advance their projects and drive the adoption



# 2023 Calendar of Events – Save the date

Activity Name	Description	Date
Webcast	RUN group call	Dec. 7th, 2023, at 2 PM EST
Conference	Hybrid workshop	Oct. 12th, 2023, in Charlotte
Webcast	RUN group call	Aug. 3rd, 2023, at 2 PM EST
Webcast	RUN group call	May 4th, 2023, at 2 PM EST
Team Meeting	RUN ideation	Mar. 15th, 2023, at 6 PM EST

## Robotic Utility Workshop (hybrid)

*Audience: Inspectors, researchers,  
asset owners, data scientists, ...*

**Oct. 12th in Charlotte**



# Save the Date October 10-12

## EPRI Digital Worker Conference

### EPRI Office – Charlotte, NC



**Utility Digital Worker State-of-the-Industry**  
**Technology & Application Sessions**  
*& Demo's during breaks & receptions*

**Latest Trends & Emerging Research Across Utility Domains**  
*Nuclear, Generation, Transmission, Distribution & Cross-Cutting*

**Strategy**  
*Maturity Models, Roadmaps, Benchmarking*

**Learn from your Peers & EPRI SMEs**

**Tuesday Oct 10**

**Wednesday Oct 11**

**Thursday Oct 12**

AR, VR, Digital twins, LiDAR/3D Scanning,  
 AI/Analytics and Strategy

Drones and Robotics



**Invitations expected to come out in May**  
**We are looking for RUN Utility Speakers, if interested, let us know.**



# EPRI's Approach and Research

# EPRI's TDI Robotics & Drone Strategy

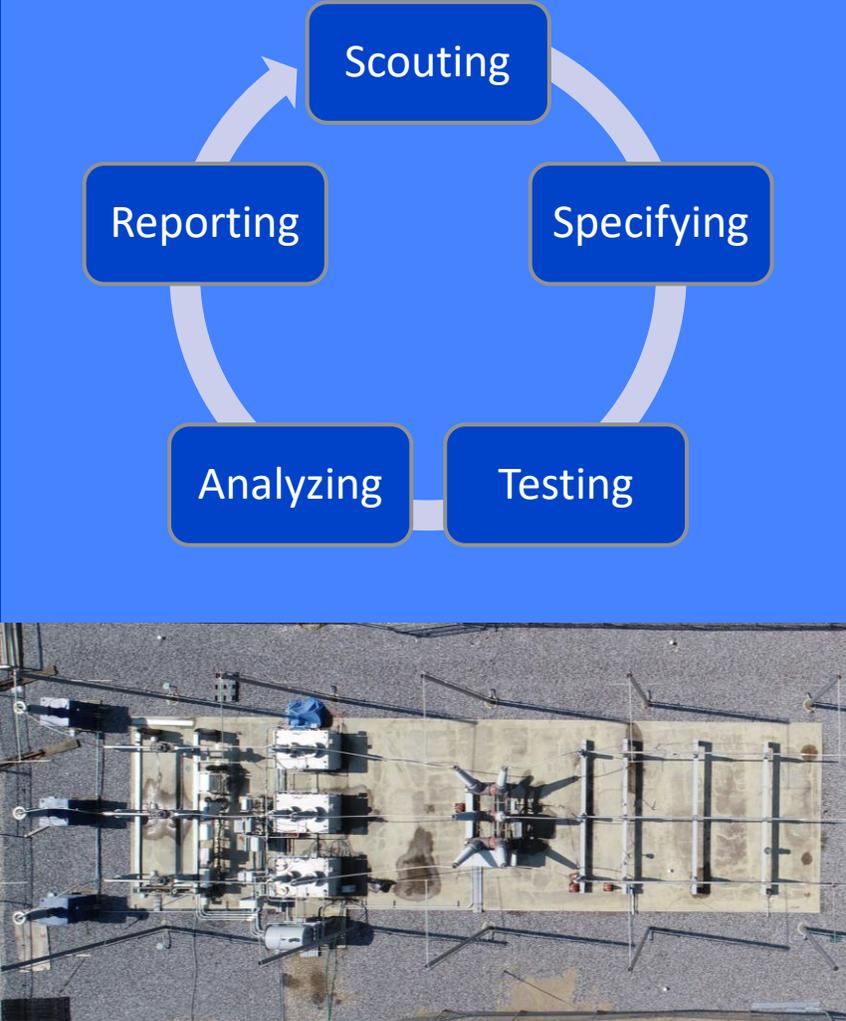
Technology innovation outpaces experience.



Collaboration is the most efficient method to keep up.



EPRI proposes repeatable projects that leverage labs.

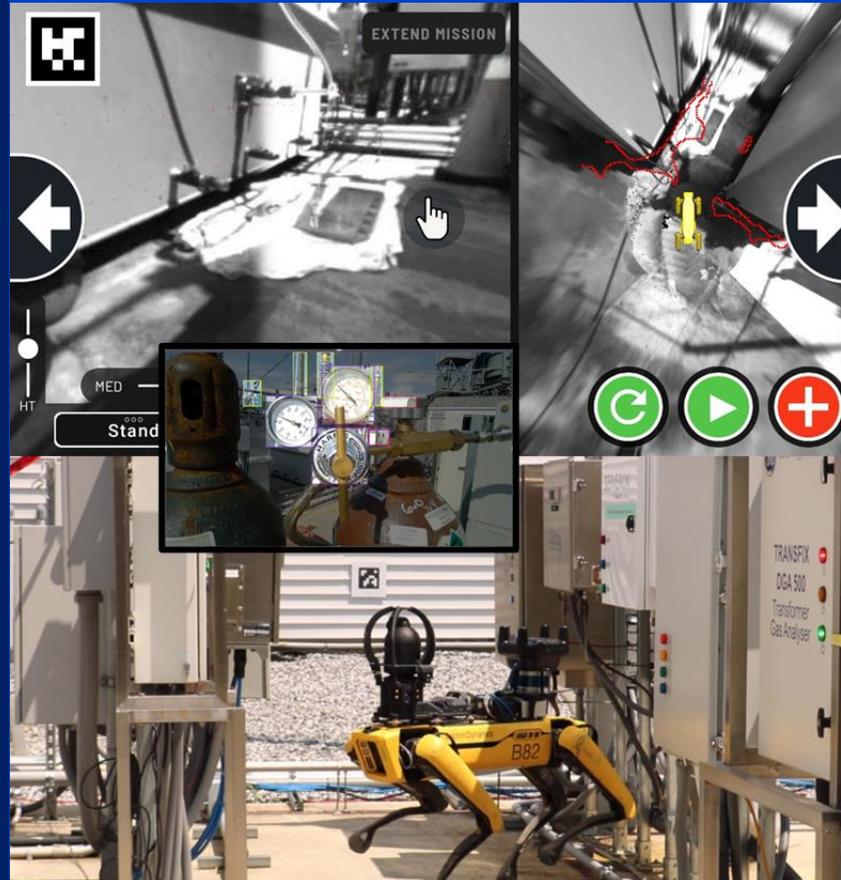


# 2023 Collaboration Opportunities

Evaluation of Substation Robotic Application (near completion)



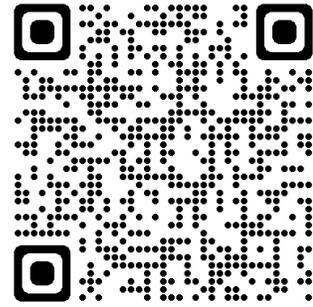
Evaluation of Substation Robotic Analytical Tools (ongoing)



Drone Dock Lab Testing and Utility Applications (ongoing)

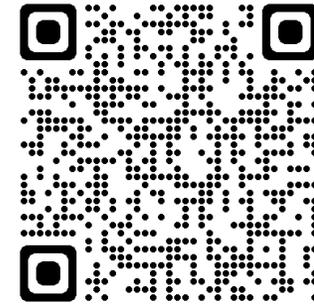


# Autonomous Robots in Substation



[Web Link](#)

# Autonomous Robots in Substation



Web Link

**Specification: The robot must avoid objects.**



EPRI Transmission and Substations Program

**Robotics and UAS Research**

Welcome to the EPRI Robotics and UAS Research website, where we showcase our innovative work in the fields of robotics and unmanned aerial systems (UAS). One of EPRI's focus areas is the development and deployment of robots and unmanned aerial systems (UAS) to improve the safety, reliability, and efficiency of electric power systems.

On this website, you will find information about EPRI's research and development efforts related to robotics and UAS technology, as well as the applications and benefits of this technology for the electricity industry. EPRI is working with various utility members and researchers to advance the state of the art in robotics and UAS, and this website is a hub for information about these efforts.

Whether you are an industry professional, a researcher, or simply curious about the cutting-edge technology being developed in the electricity sector, we hope you find this website informative and valuable. Please explore the resources available here and feel free to contact us with any questions or feedback. Thank you for your interest in EPRI's robotics and UAS research!

**Dexter Lewis**  
Principal Technical Leader  
lew@epri.com

**EPRi**

**Evaluation of Substation Inspection Robotics Platform in Lenox**  
Phase 1 and 2  
SAP Number

**Substation Robotics Application**  
Test plan - Autonomous Inspection - On-demand testing - Bin & EMF testing

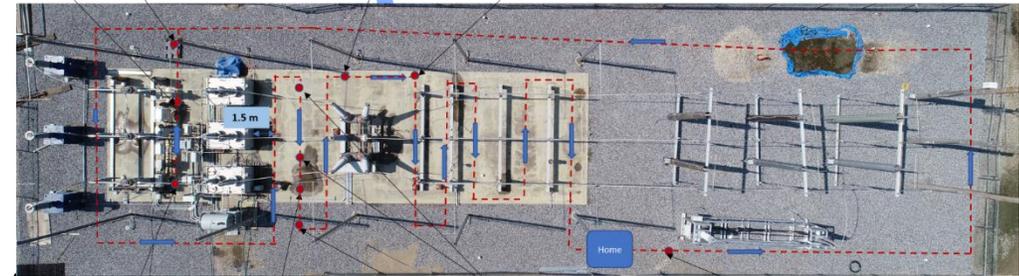
**Substation Robot Analytics**  
Command and Control - Fleet Management - Data Analytics - Deployment & Connectivity

**Drone in a Box solutions**  
System Integration - Drone Specifications - Capabilities testing

**EPRi**

**Evaluation of Substation Inspection Robotics Platform in Lenox**  
Phase 1 and 2  
SAP Number

**DRAFT**



**Evaluation of Substation Inspection Robotics Platform in Lenox - Test Plan**

**Introduction**  
The aim of this research is to evaluate the performance of three different robots (SPOT, ARIS, and Robot Dog) in a substation environment. The robots will be used to inspect the substation for defects and to collect data on the substation's performance. The robots will be used to inspect the substation for defects and to collect data on the substation's performance. The robots will be used to inspect the substation for defects and to collect data on the substation's performance.

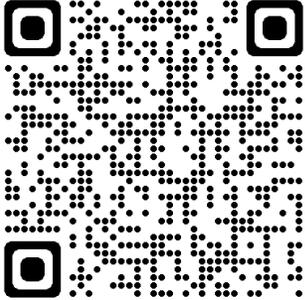
**Objectives of testing**  
The testing objectives for this research are to evaluate the performance of the robots in a substation environment. The testing objectives are to evaluate the performance of the robots in a substation environment. The testing objectives are to evaluate the performance of the robots in a substation environment.

**Testing Period:**  
09/15/22

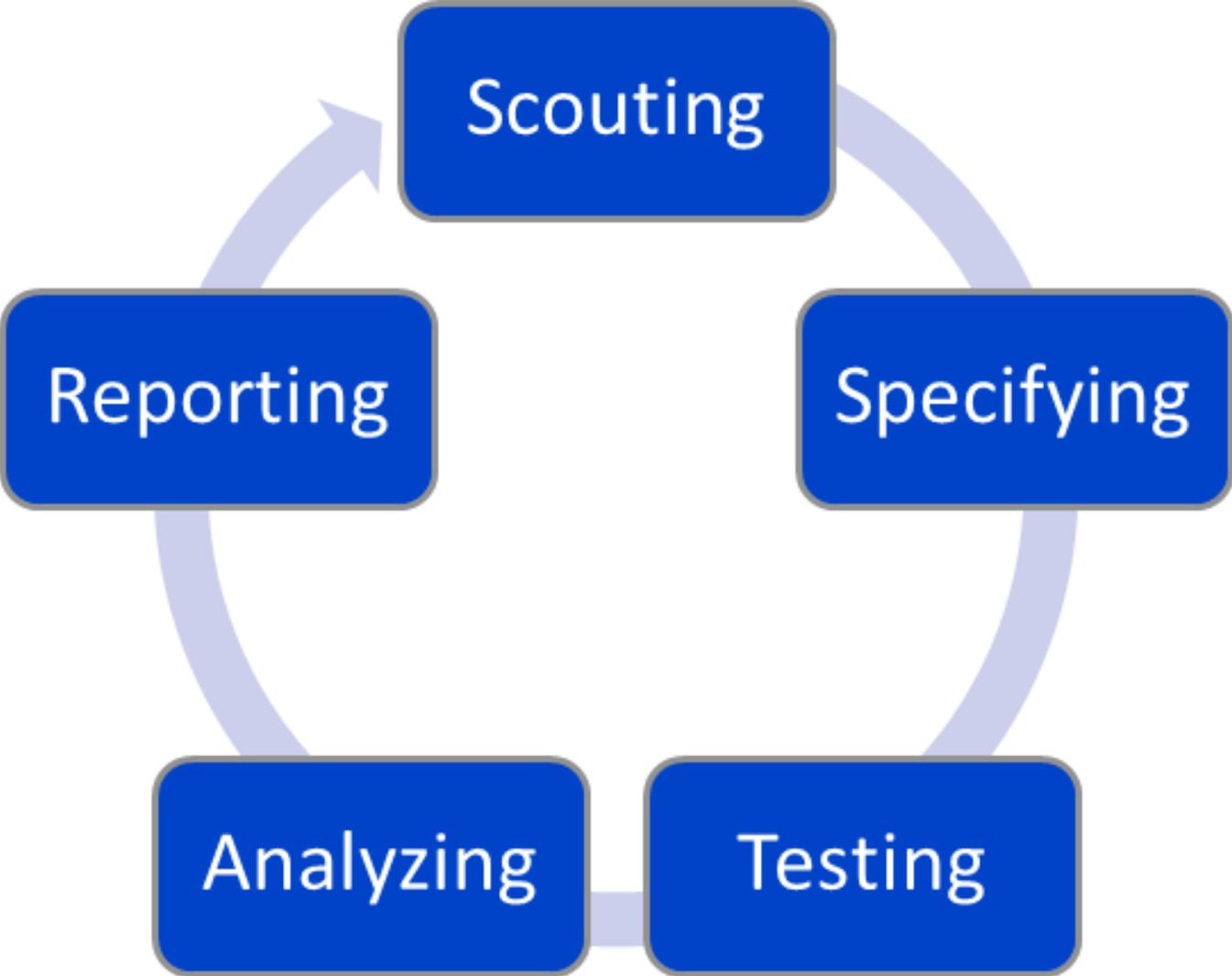
**Testing Location:**  
The testing location is the substation in Lenox, Virginia. The testing location is the substation in Lenox, Virginia. The testing location is the substation in Lenox, Virginia.



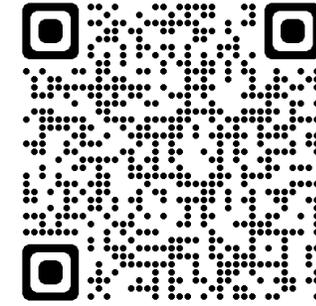
# Evaluation of Substation Robotic Analytical Tools



[Web Link](#)



# Evaluation of Substation Robotic Analytical Tools



Web Link

## Scouting

[Chironix](#); [Smart Inspection](#); [Plain Concepts](#); [Cognite](#); [Formant.io](#); [Boston Dynamics \(Scout Software\)](#); [IBM](#); [Dronedeploy/ROCOS](#); [Levatas](#)

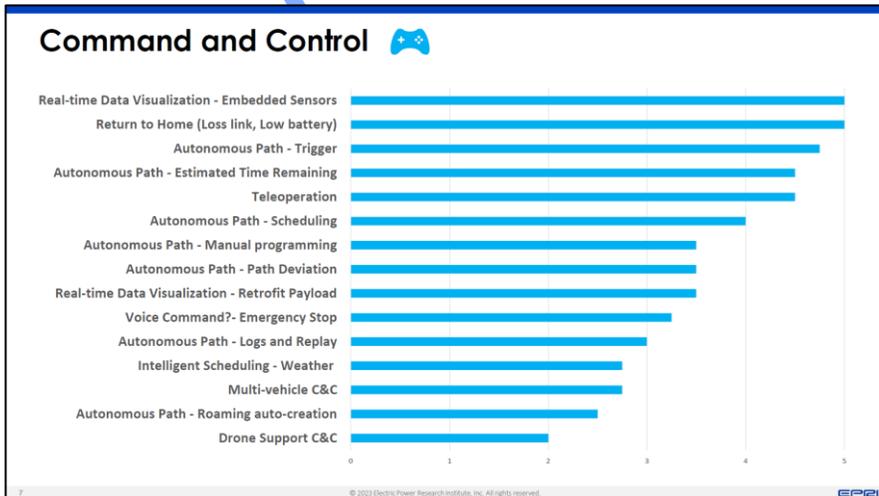
## Reporting

Quick update/learning- Levatas Site Visit – April 7<sup>th</sup> 2023

- Gauge angle correction – visual transformations is implemented
- Thermal images work with bounded box
- Integration with Scout Software
- Autonomous Inspections
- Other analytics models
  - Collision Avoidance at intersections
  - Door open/close
  - Person Detection model
  - Change detections – QR code
- Custom model deployment not supported as of now

Thermal Anomaly Gauge Reading

## Specifying



## Analyzing



## Testing



Research/Pilot phase	Rating System
I know I need that	5
I think I'm going to need this	4
I may want this.	3
I don't think I need this	1
I know I don't need it	0

# Drone Dock

## Lab Testing and Utility Applications



- 1 Determine specifications and technology requirements 
- 2 Scout, prioritize, and acquire hardware and software 
- 3 Perform crosscutting testing in an energized outdoor lab 
- 4 Perform use case specific testing  
Distribution, Substations, Transmission, (tbd) 
- 5 Document, communicate, and share the results 

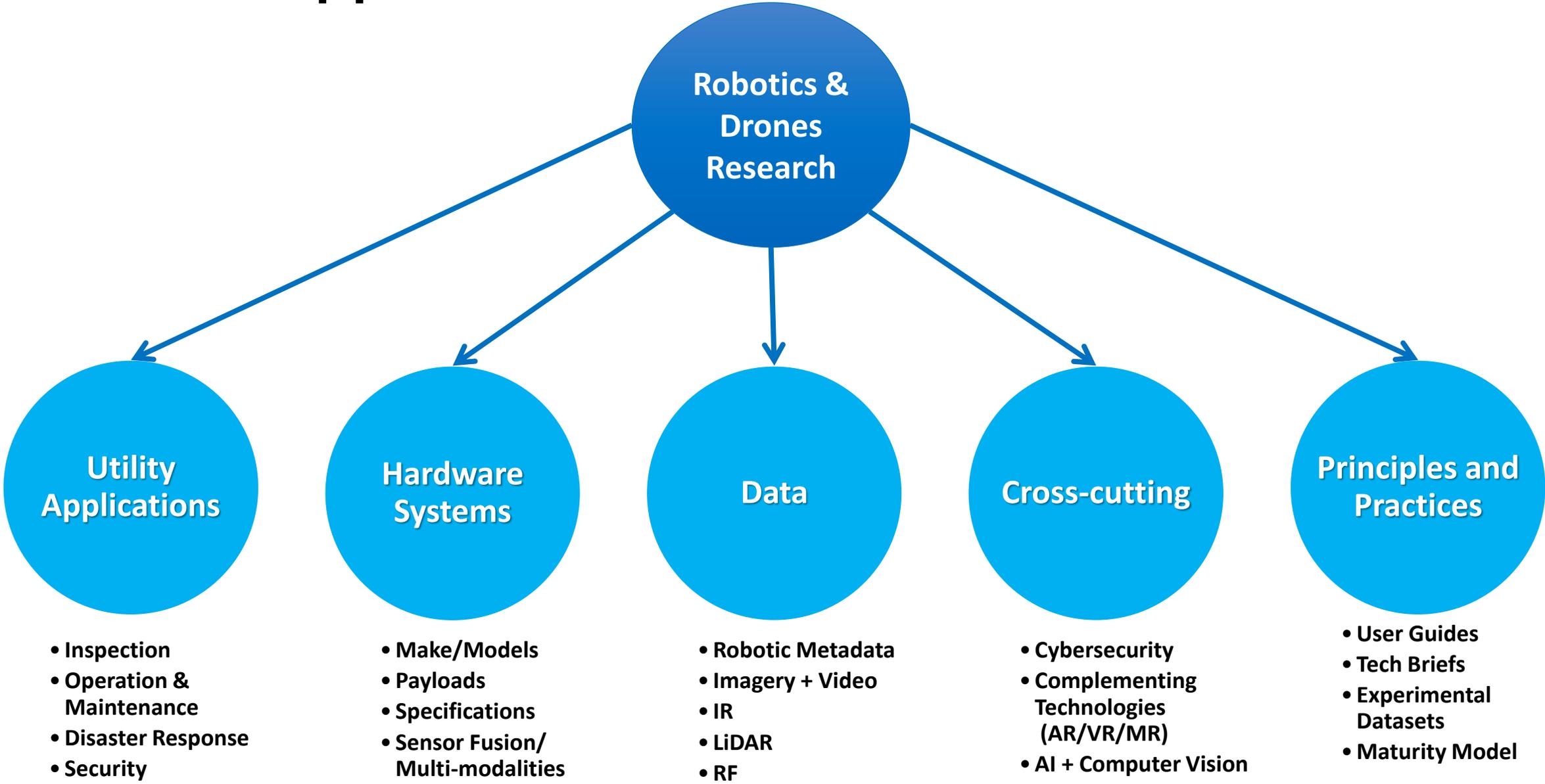


# Utility Presentation



# Potential Robotic Research Areas

# Research Opportunities



# Mobile Robotics for Substation Applications: Lab Testing and Experiments

The slide, titled "Autonomous Robots in Substation", features a grid layout. At the top left, it includes the EPRI logo and the text "Evaluation of Substation Inspection Robot Performance". Below this is a "Robotics and UAS Research" section with several small images. To the right, a 2x2 grid of images shows robots: SPOT, ARIS, Robot Dog, and Sentinel. A QR code in the top right corner is labeled "Web Link". A central text box contains the specification: "Specification: The robot must avoid objects." Below this is a wide panoramic photo of a laboratory setting. In the bottom left, there is a photo of a gravel-covered area with a robot. A large red "DRAFT" watermark is overlaid diagonally across the center, with "Round 2!" written in red below it. The slide number "15" is in the bottom left corner, and the EPRI logo is in the bottom right corner. The footer of the slide reads "© 2023 Electric Power Research Institute, Inc. All rights reserved."

This report and video compilation describes the related work, methods, results, and discussion from multiple robotic technology tests at EPRI's High Voltage Lenox facility. Repeatable lab testing allows for objective evaluation of these systems as they evolve over time.

# Substation Physical Work Assessment: Robotic Opportunities

This research describes the background investigation and assessment into physical work tasks performed within the substation environment. The intent is to identify near, mid, and long term opportunities for robotic systems to replicate physical tasks.



# Mobile Robots and Physical Tasks

This research attempts to survey the state of the industry related to arm payloads. The brief likely will include lessons learned from prior EPRI experiments, public information, demonstrations, and literature review.



# 3D Scanning and Modeling Technologies for Substation Applications: Asset Health

This report documents the results from EPRI lab testing multiple scanning methods against known/simulated defects. The report outlines the technologies used, the methods applied, and a quality assessment of the data collected. The long-term research goal is to build confident relationships between 3D scanned data and asset health.

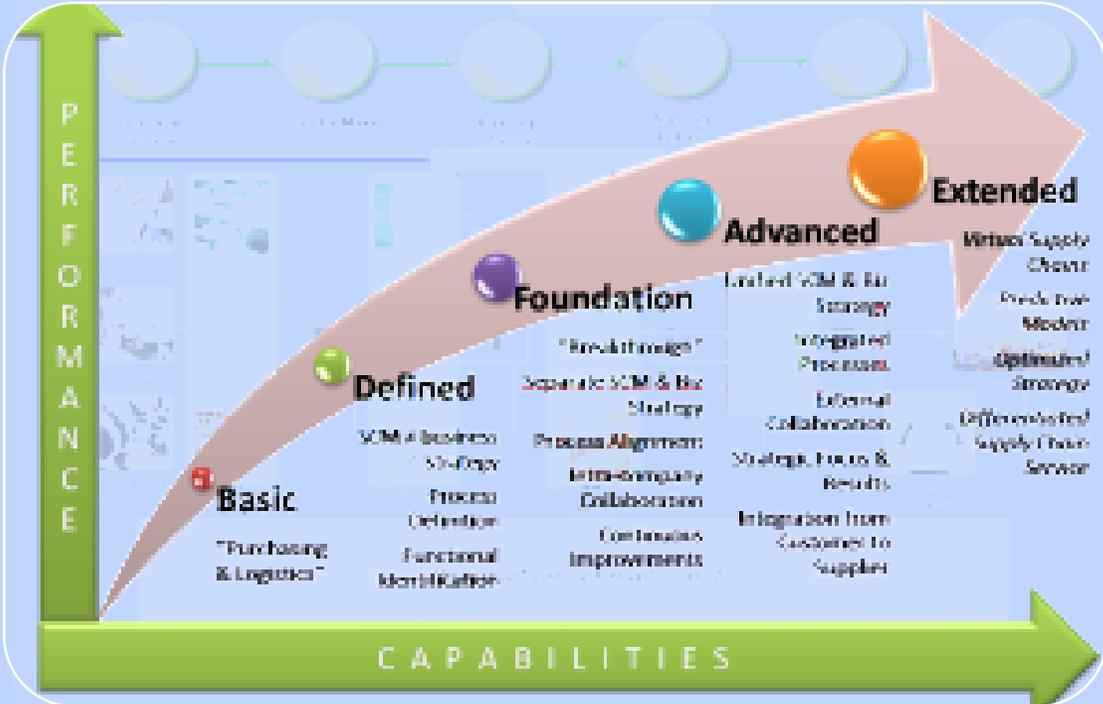


# 3D Data Applications: Electromagnetic Field Modeling, and Visualization

This technology brief attempts to model the energized lab test environments. Leveraging the 3D mapping data, the brief will experiment with modeling and field verification of 3D electromagnetic fields.

# Maturity Model for Substation Robotics:

This whitepaper defines the structure and criteria for strategic deployments of robotic systems within the substation environment.



# User Guide for Robotic Containers and Customization:

This whitepaper defines the structure and criteria for strategic deployments of robotic systems within the substation environment.

# Additional Project Ideas

- **BVLOS Operations for Disaster Response**
- **Rapid LiDAR and Edge Processing**
- **Study of Hybrid Systems: Drone + Ground Robots**
- **Multi-drone collaboration for inspection of utility assets**
- **AR/VR/MR with integration with robotics for utility applications**

Join at  
**slido.com**  
**#3808 270**

 Passcode: **epri-run**



<https://app.sli.do/event/9ZR1R9nhxNNFJAtt1TWSqw>

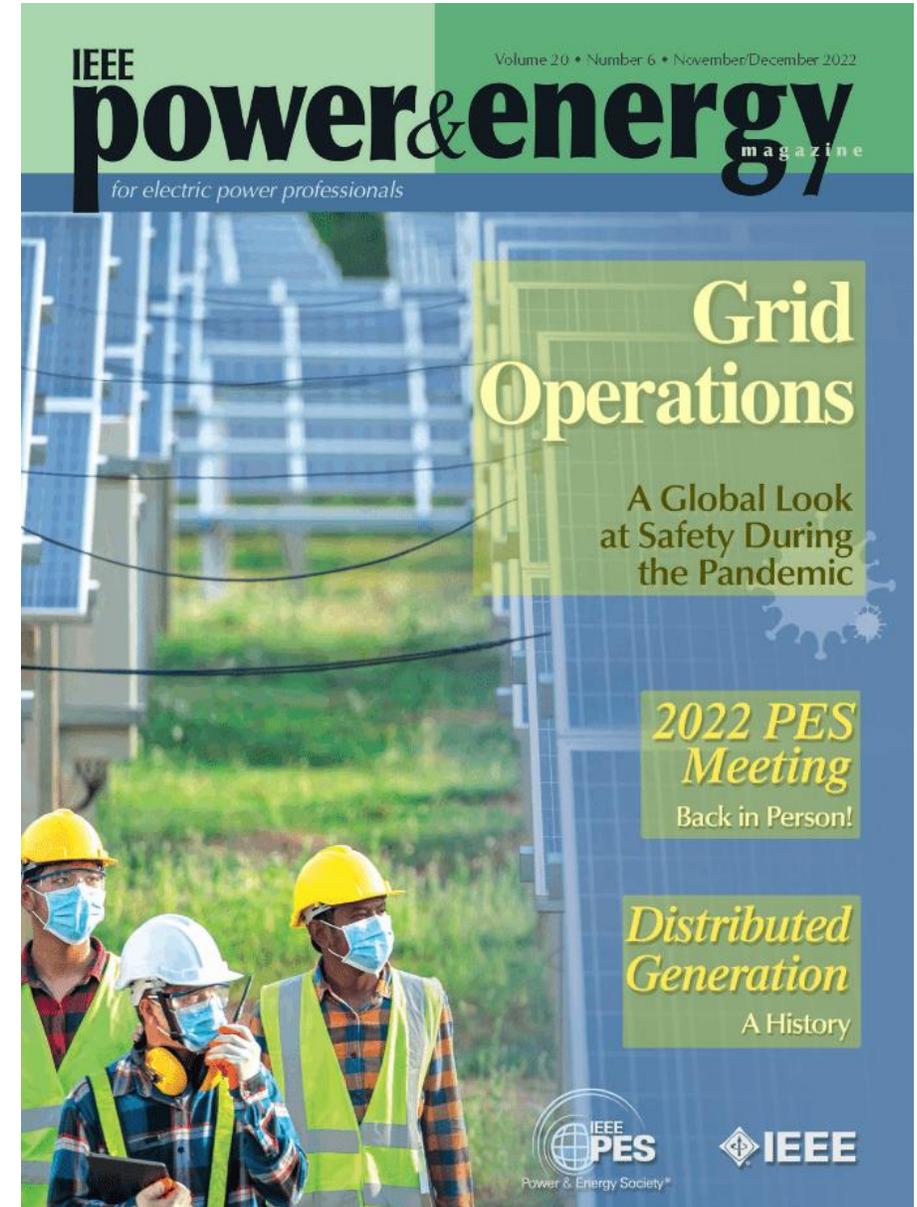
## Poll and Open Forum Discussion



**Next Meeting: Aug. 3rd, 2023, at 2 PM EST**

# IEEE P&E Magazine

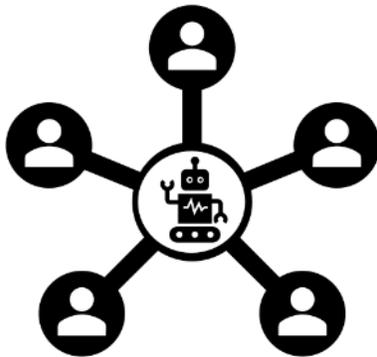
- Article on Robotics & Drones
- Guest Editors
- A total of 6 to 8 articles is required
  - number of co-authors to no more than five (5)
  - A first-year engineering student or a non-technical person familiar with the electric power industry (attorney, marketer, economist, regulator, etc.) should be able to understand at least 80% of every article
  - no equations/formulas or overly complex explanations
  - Articles are limited to approximately **5,000 to 6,000 words**
  - 6-8 figures including tables



# Member Website for RUN

## Robotics Utility Network (RUN)

Welcome to the EPRI's Robotics Utility Network (RUN)- Running to keep the pace with innovation. This network of contacts consists of electric utility professionals and EPRI researchers. Contacts are SMEs, researchers, stakeholders, and operators focused on developing, implementing, and advancing robotic technologies. EPRI's intent is to facilitate knowledge sharing, collaboration, and innovation.



### Overview & Events

Project Description • Research Value •  
Calendar of Events



### Research Status & Deliverables

Past Events • Meeting Notes

Dexter Lewis

Principal Technical Leader

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Sunny Arokia Swamy Bellary

Engineer/Scientist III

✉ sbellary@epri.com

- RUN objective & mission
- Research updates
- Meeting recordings and presentations
- Calendar of Events

[https://transandsubsdev.epri.com/p37\\_substations/public/robotics/run\\_group/](https://transandsubsdev.epri.com/p37_substations/public/robotics/run_group/)

A blue-tinted photograph of four people, two men and two women, standing together. They are dressed in professional attire, including lab coats and a hard hat. The image is overlaid with the text 'Together...Shaping the Future of Energy®'.

**Together...Shaping the Future of Energy®**

Drones and Robotic Transmission, Distribution, and Substation Applications/Research

# KEPCO Robot & Drone Projects

Jaekyung LEE

Robot & Drone Research team



KEPCO 전력연구원



### [T/L Inspection] [Canada Hydro-Quebec (LineScout)]

- Work : Line Inspection, Maintenance
- Function
  - Visual, Thermal Cam
  - Mounting Bolt
  - Single Line
- ❖ Transfer to UK, China



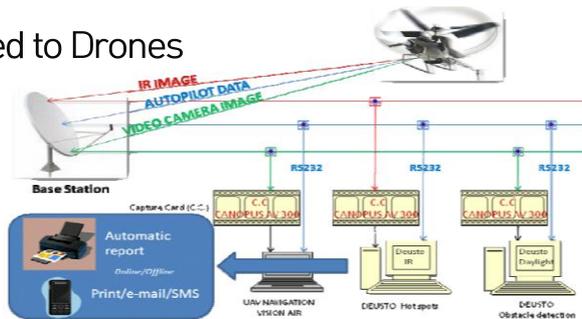
### [Substation Inspection] [SEPRI, China]

- Work : S/S Inspection, move along inspection route
- Function
  - H/D Image
  - (Gauge recognition)
  - Thermal cam, sound
- ❖ Applied to 388 S/S



### [T/L Inspection Helicopter] [Spain Deusto Uni]

- Function : AutoFlight, Optical/Thermal Camera
- Replaced to Drones



### [Transformer Inspection] [Swiss ABB]

- Work : Huge transformer inspection in oil tank
- Function
  - Camera, Light
  - First Person View
- ❖ Product Name: Txplore



Various robots are applied to **Dangerous, Repetitive, Difficult Tasks**

## [T/L Inspection]

[KAIST]

- Work : Moving on T/L, Inspection
- Function
  - Live-line operation
  - Optical Camera
- ❖ NOT used



## [Live D/L Robot]

[KEARI]

- Work : Live D/L work robot using dual manipulator
- Function
  - Live-line operation
  - using D/L working Tools
- ❖ NOT used



## [345kV Insulator Inspection]

[KEPCO]

- Work : 345kV Insulator Inspection
- Function
  - Live-line operation
  - Measure resistance&voltage
- Transfer to China
  - SEPRI 1,000kV HVDC Inspect



## [T/L Heaving Line Drone]

[KEPCO]

- Work : Deliver heaving line on T/L construction
- Function
  - Dispense heaving line
  - effective vs helicopter



Develop technology based on power industry and field experience.

### [Transmission]

### [Substation]

### [Distribution]



Insulator Inspection Robot



T/L Inspection Drone



Count Drone System



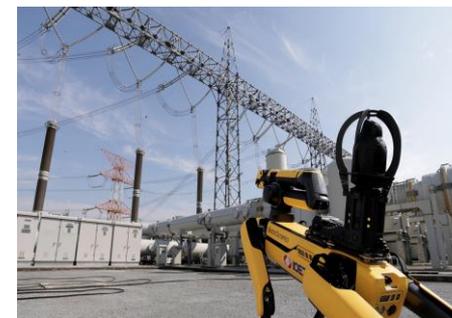
Multi-function pre-tooling unit for indirect live-line work



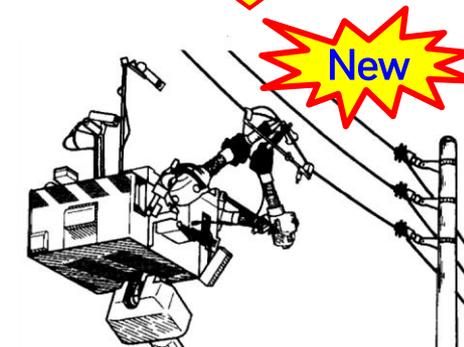
Power Tunnel Patrol Robot



Insulator Inspection Drone



Preliminary study of S/S inspection using SPOT

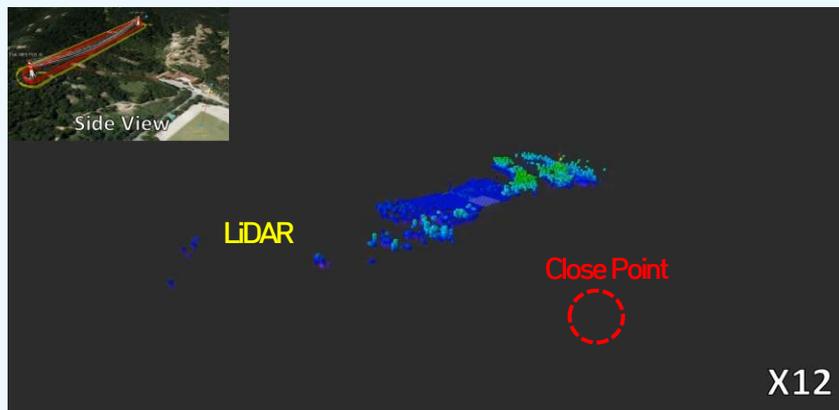


Live-line Maintenance robot for D/L

## Autonomous Drone for Transmission Line Inspection : More than 240 pylons



## Sag estimation & Vegetation encroachments



## Corona Inspection



- Faulty more than 5,000
- Close Inspection

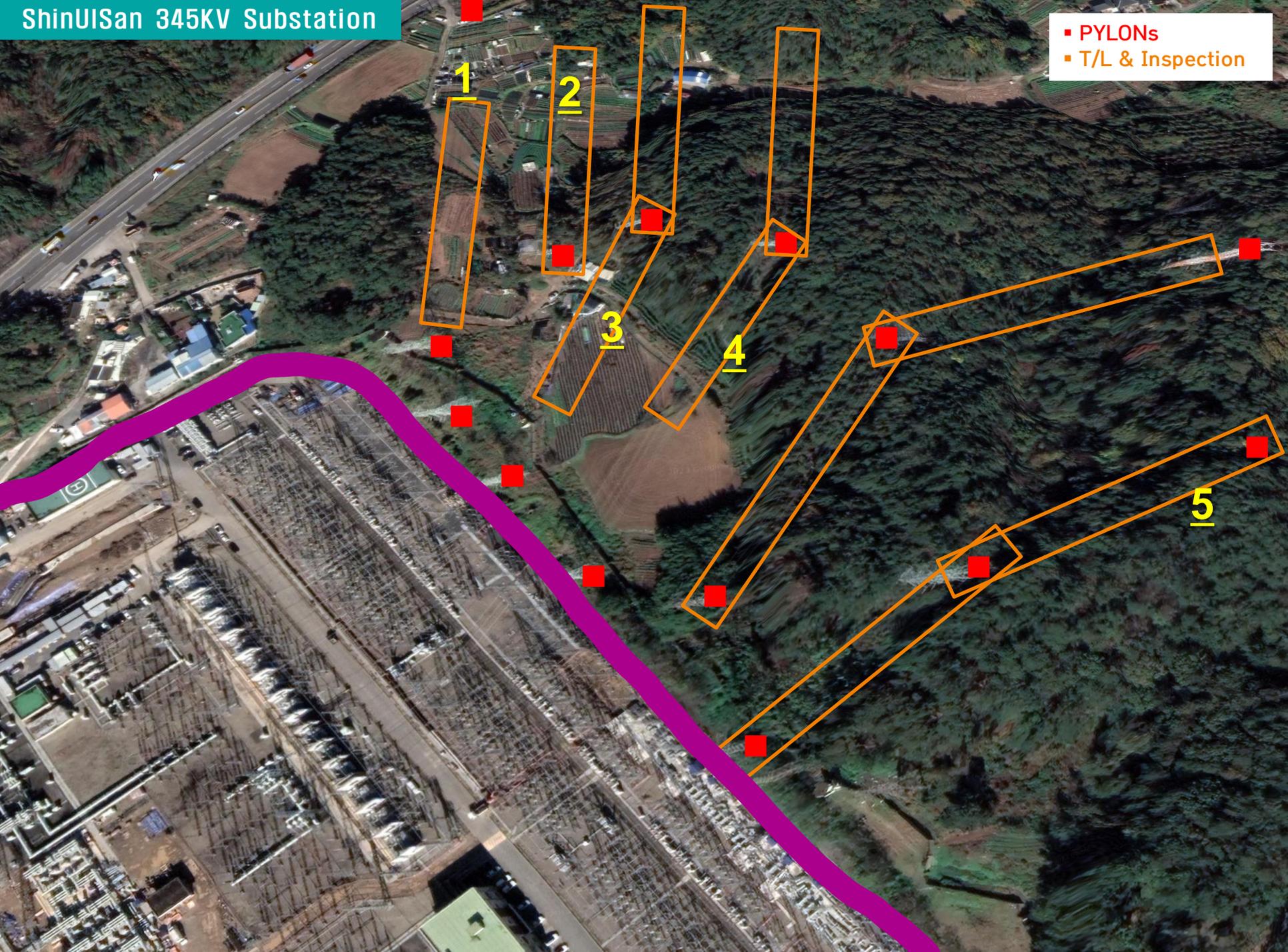


Developing various application to make Drone technology valuable



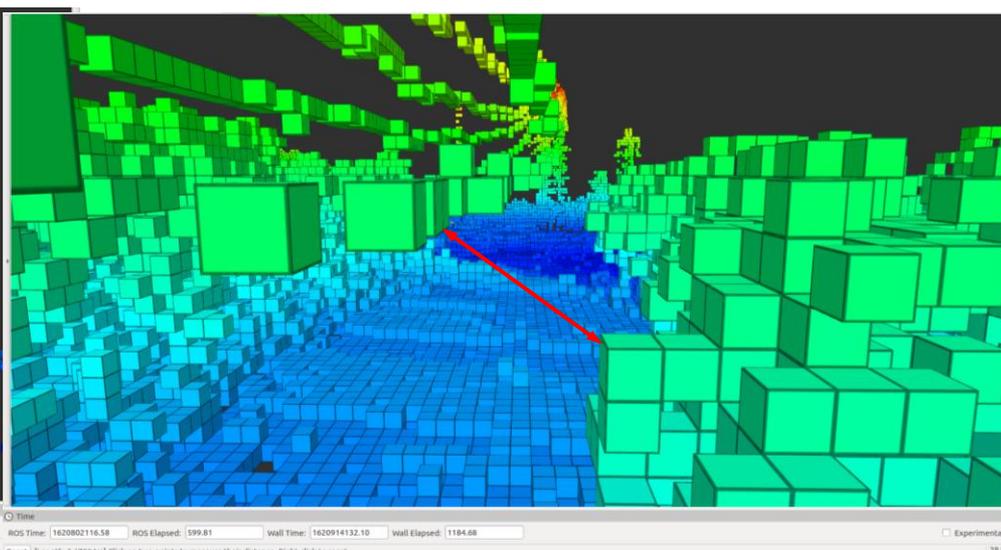
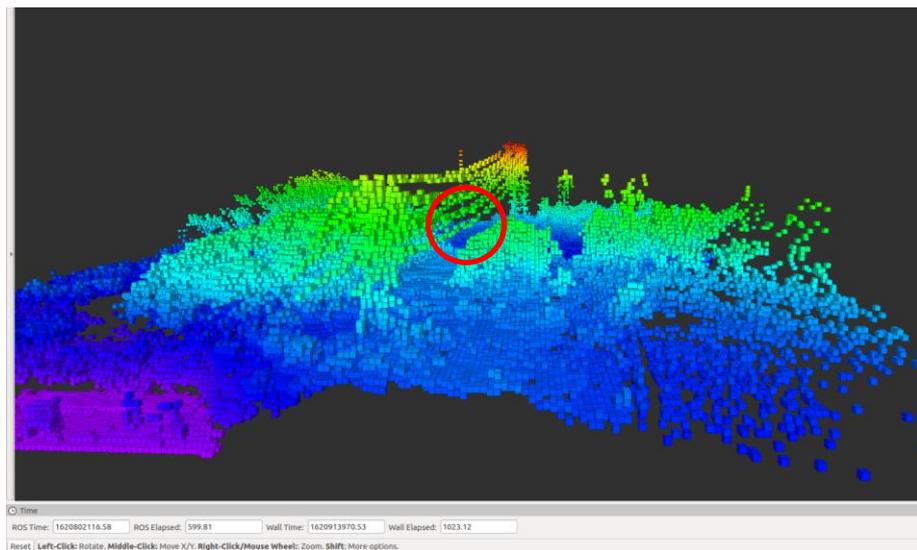
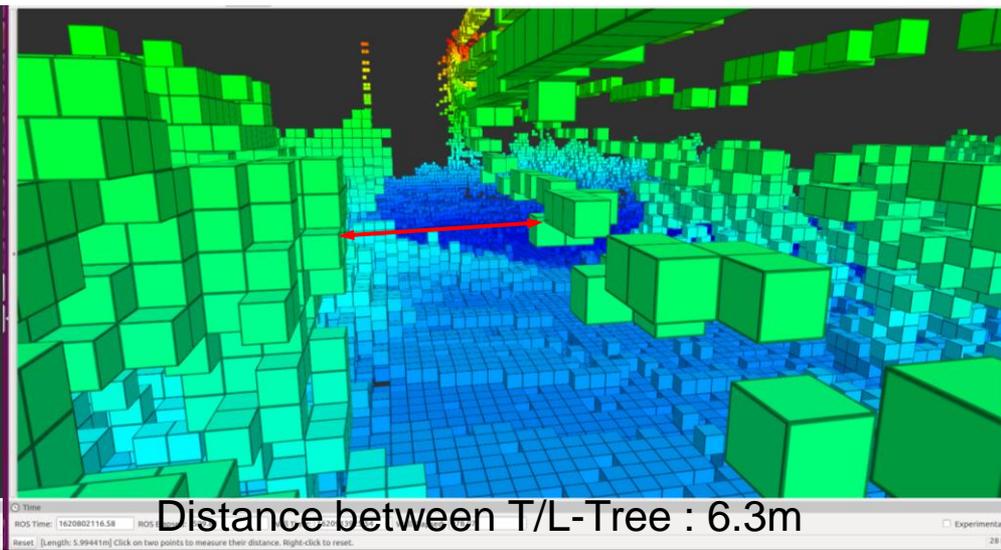
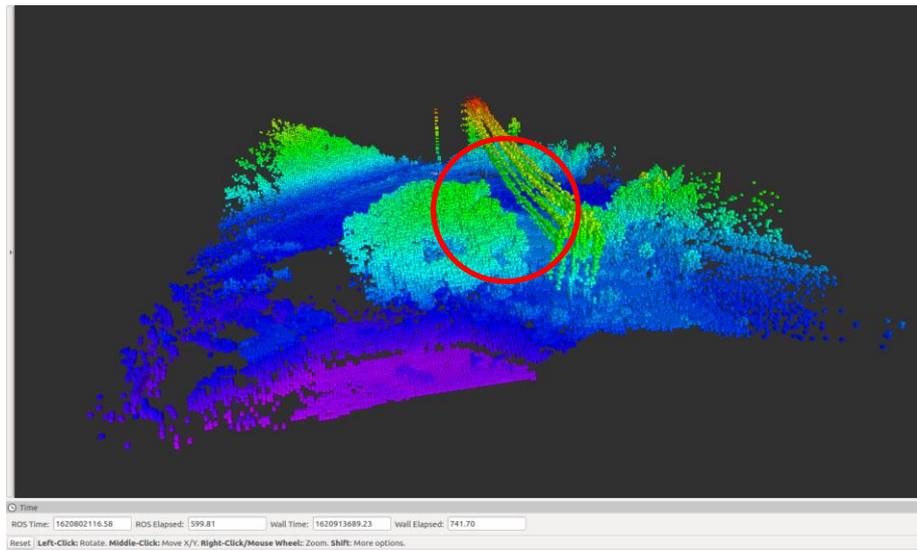
# ShinUISan 345KV Substation

- PYLONS
- T/L & Inspection



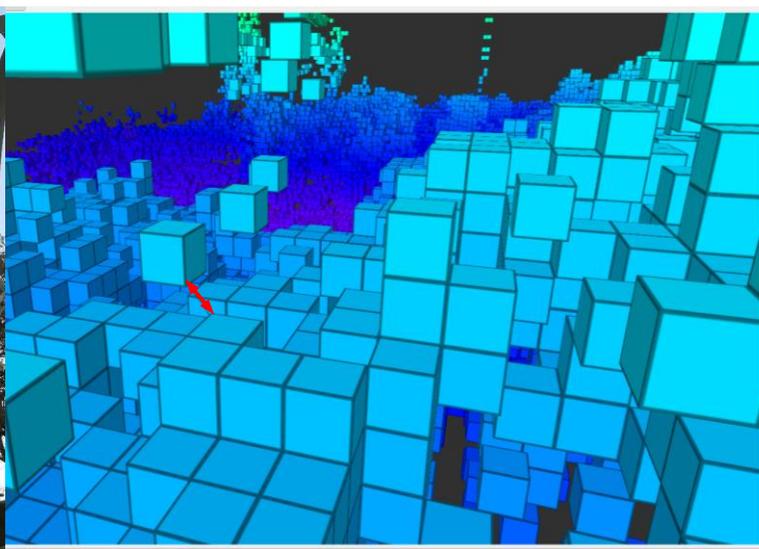
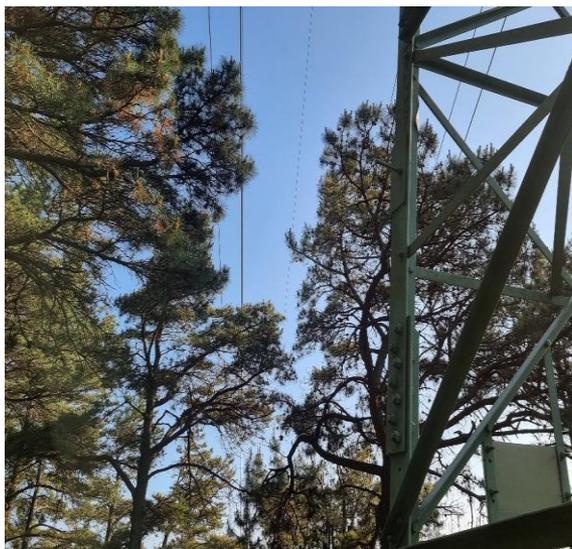
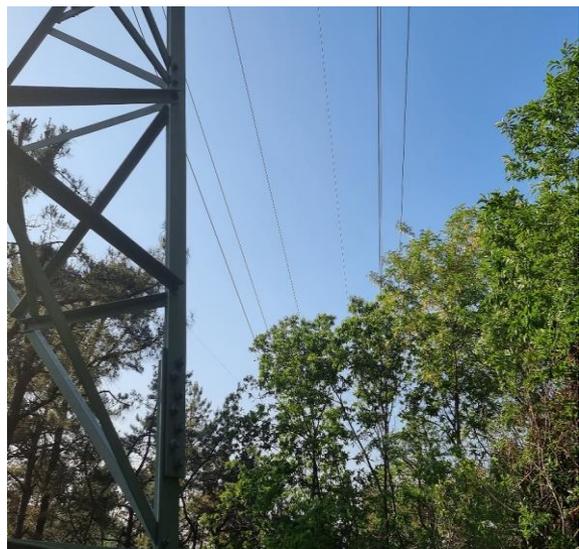
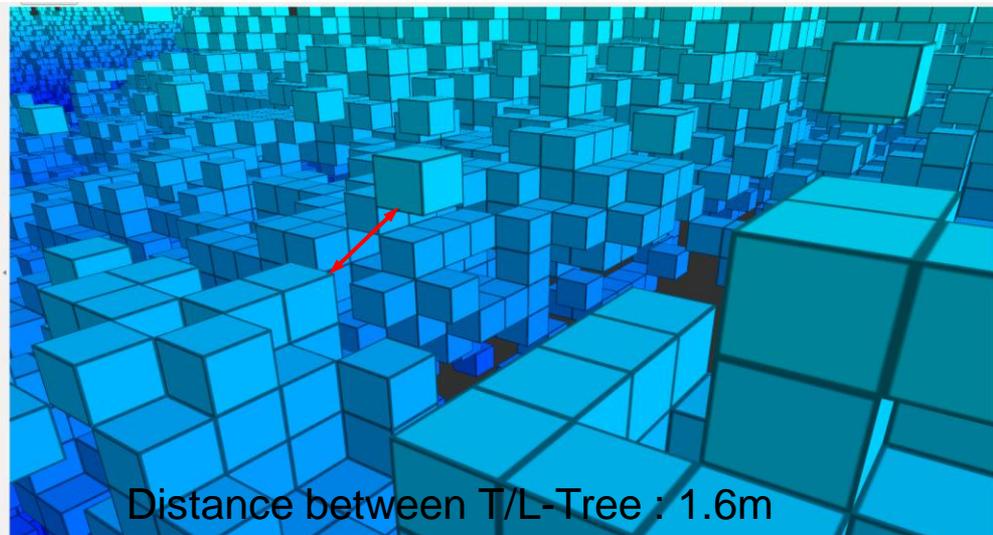
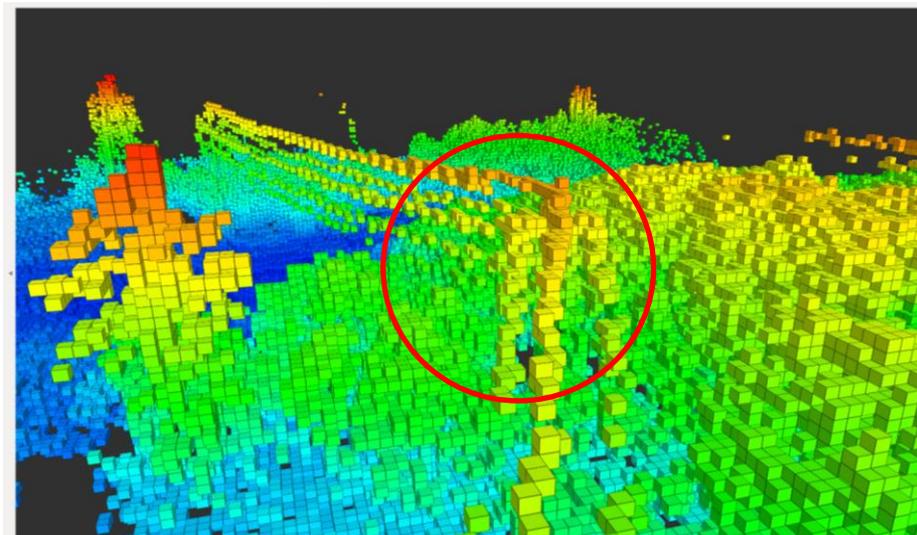
# Transmission Line Inspection Drone – 1<sup>st</sup> Sector

Robot & Drone Team

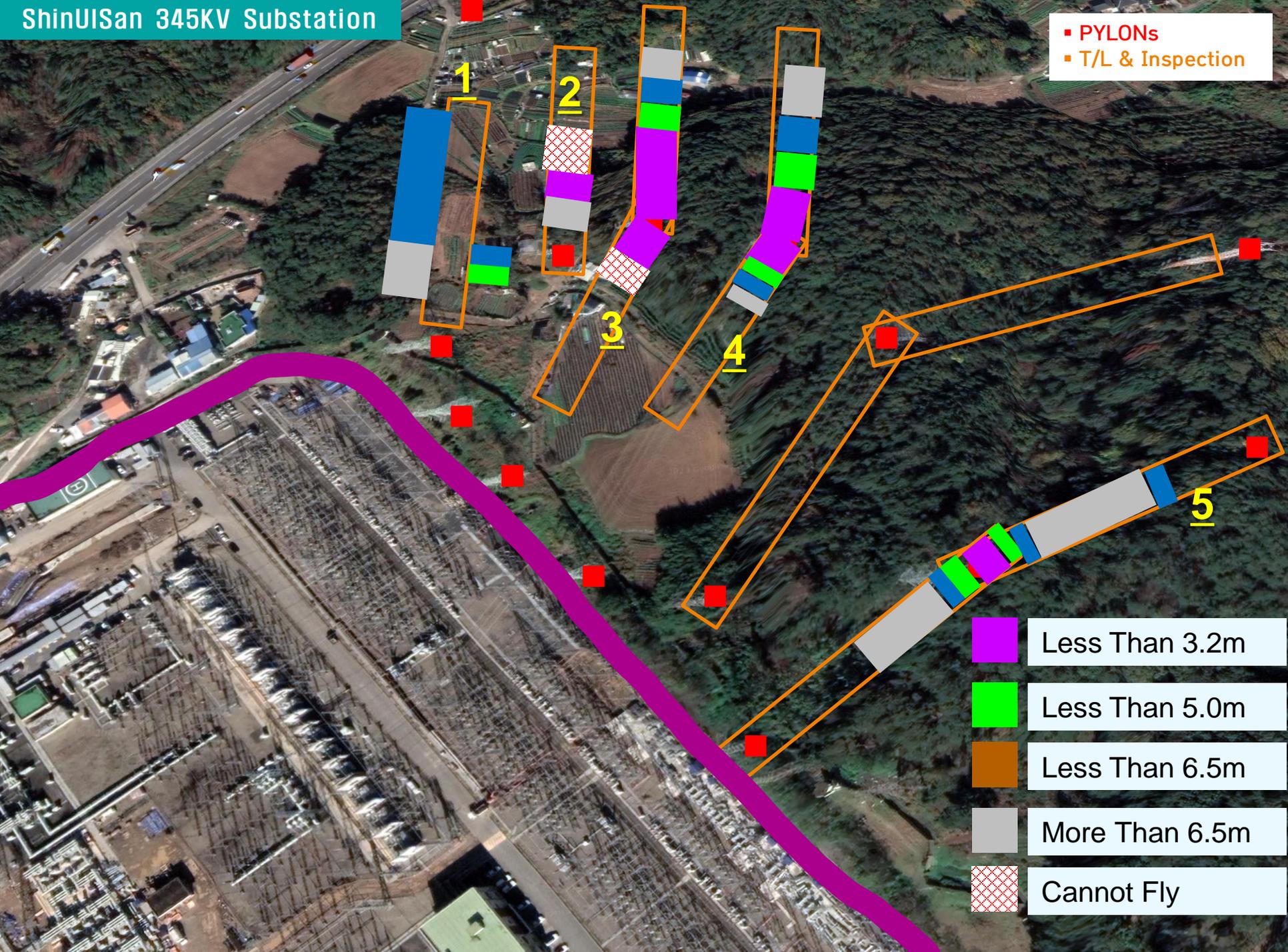


# Transmission Line Inspection Drone – 3<sup>rd</sup> Sector

Robot & Drone Team



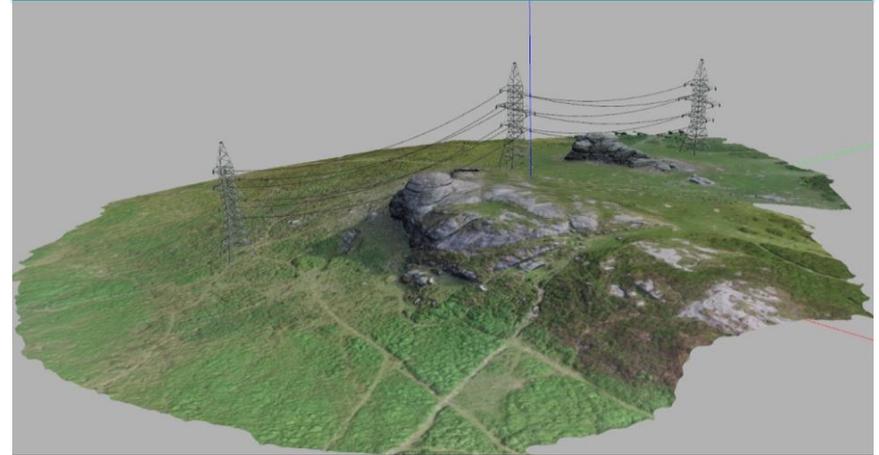
# ShinUISan 345KV Substation



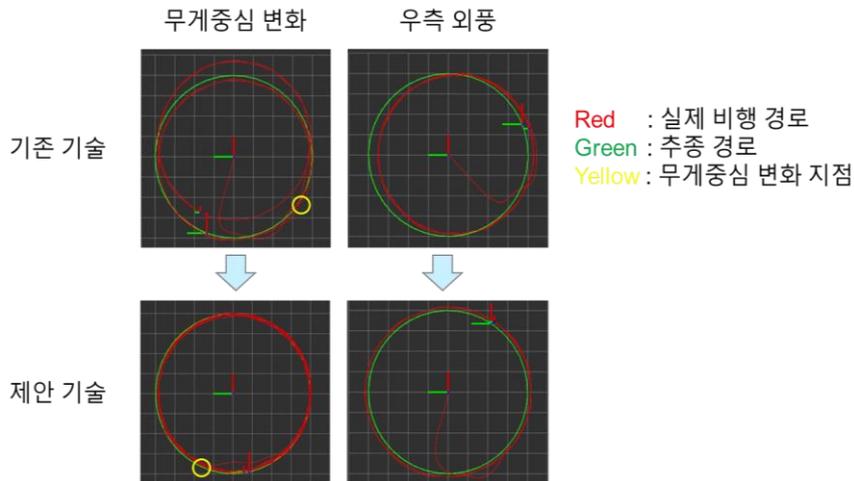
## Design of Inspection Drone



## Simulation Environments



## Drone Control with Disturbance & COG



- Establishment of simulation environment for autonomous flight algorithm development
- Developing control algorithm to overcome draft wind and change in center of gravity
- SLAM & path planning to avoid irregular obstacles using LiDAR
- Developing insulator inspection algorithm.
- Object detection using heterogeneity

## Development of inspection robot for underground Tunnel facilities and structures

Tunnel

Driving, Docking

Optical/Thermal 360° Images

Recharging/Waterproof/ Data Transmission

Office

Robot remote control/ operation  
AI based inspection/ Reporting

Robot

3D LiDAR(VLP-16)

Thermal cam (TE/EV1)

360 cam(Theta V)

Localization/ Mapping

Structure Inspection

Cable Contacts Inspection

360° Inspection

Robot Station

Wireless recharging

Fire Extinguisher

De-humidifier

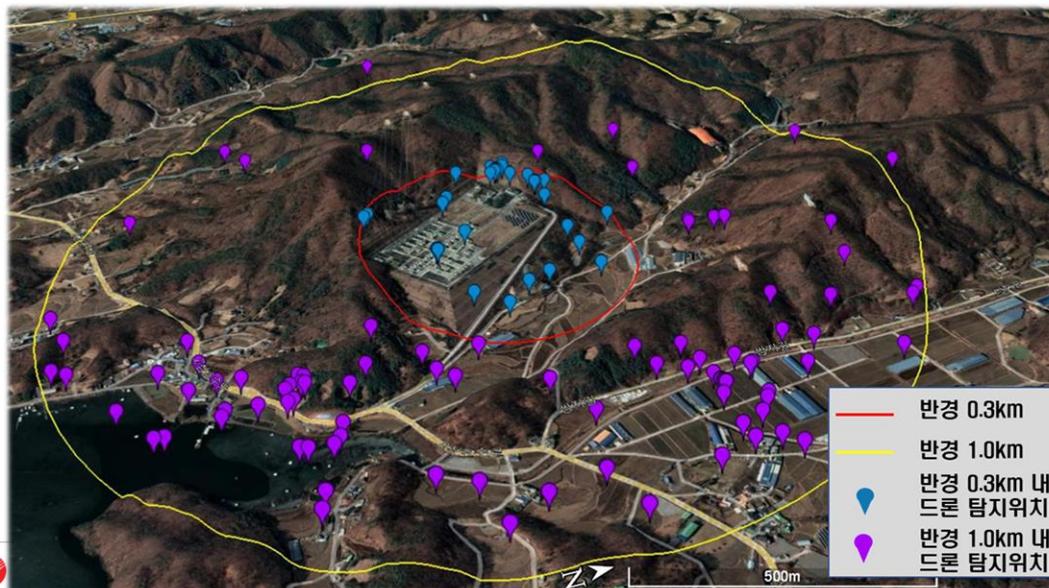
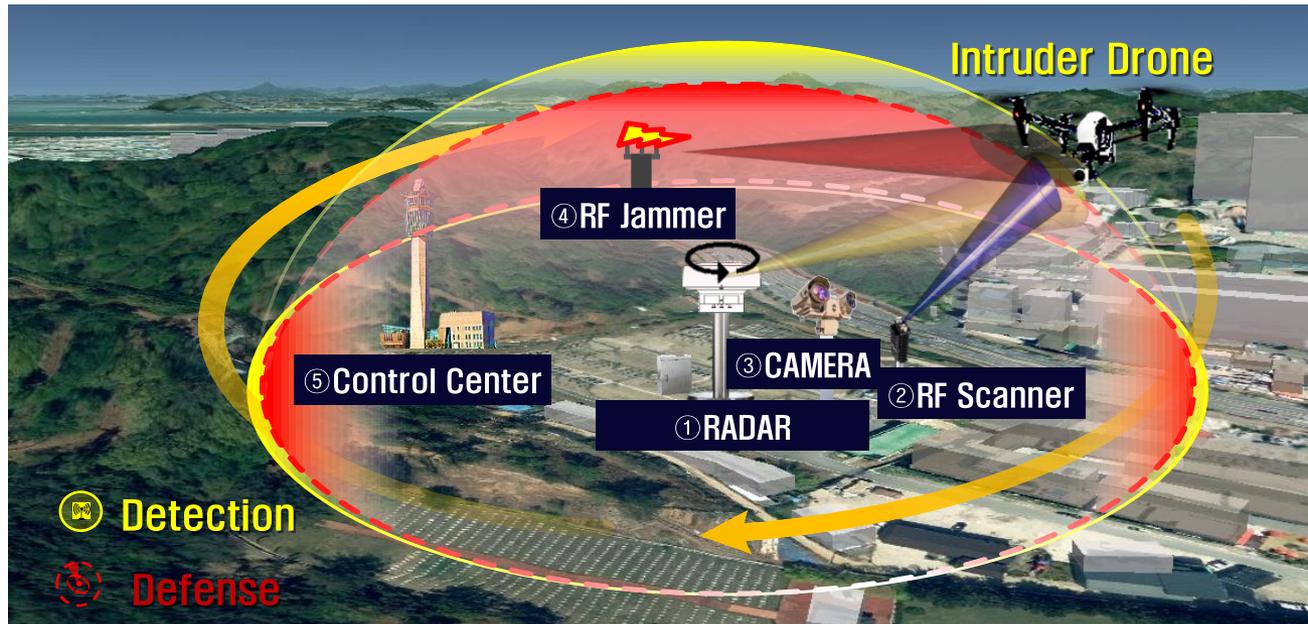
Immersion Sensor

# Underground Tunnel Inspection Robot

Robot & Drone Team

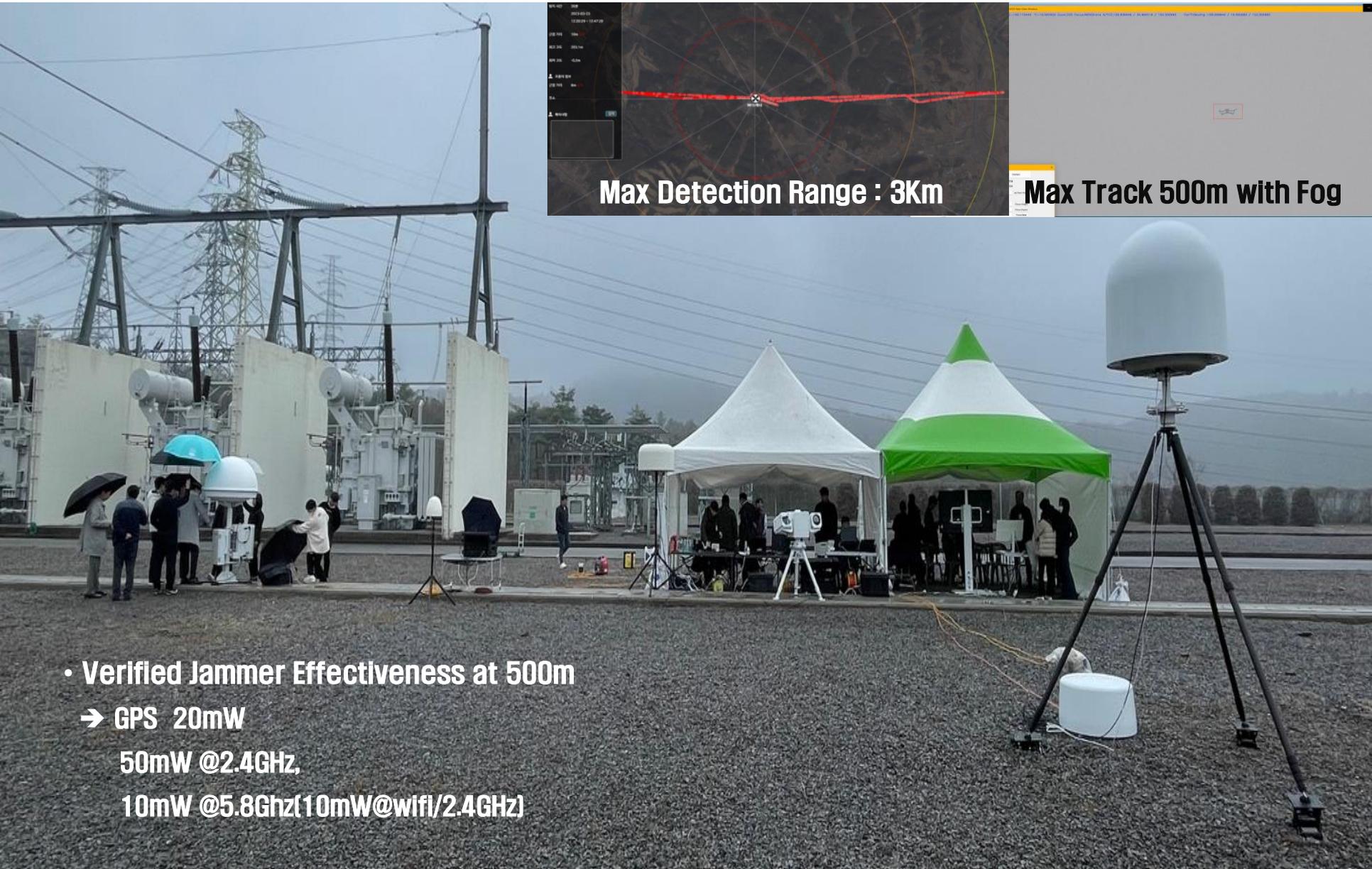
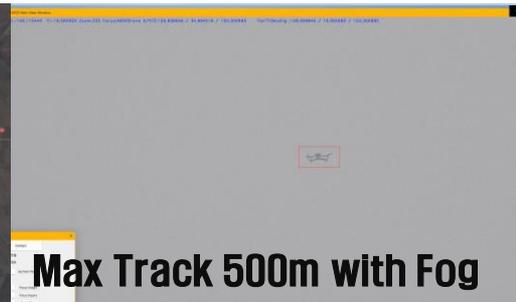


# Counter Drone for Substations



# Counter Drone for Substation

Robot & Drone Team



- Verified Jammer Effectiveness at 500m
  - GPS 20mW
  - 50mW @2.4GHz,
  - 10mW @5.8Ghz(10mW@wifi/2.4GHz)

## Feasibility study using SPOT

점검상비	점검개소	점검항목	점검내역	기존대비 변화	
점검상비	본체 및 부속상비	외부현반	누유누기, 이음 이취, 변색, 손상 유무	유지	
			[과열개소 측정] 본체 외함 (상법 측정)	신설	
	본체	계기	권선온도(1,2,3차) 측정 여부	유지	
			유연 측정 여부	유지	
			유연 측정 여부	유지	
			유압 이상 유무(Hv, Xv)	유지	
		본상	유연 측정 여부(Hv)	유지	
			[과열개소 측정] 본상 접속부(1/2/3차, N상, Wall 등)	신설	
			[최음파 측정] 본상 접속부(1/2/3차, N상, Wall 등)	신설	
			[과열개소 측정] BCT 외함 (1/2/3차, N상 등)	신설	
			KP	[과열개소 측정] 접속부	신설
			공간단자함	[과열개소 측정] 내부 단자대	신설
	주변장기	Cooler (본체&한류리액터)	현재 가동 냉각기 Group 이상유무	유지	
			권선온도와 연동상태 이상유무	유지	
		피뢰기 (1,2차)	접지선, 카운터, 누설전류계 이상 등	신설	
			누설전류 측정 여부	유지	
			동작계수기 동작 유무	변경	
			[과열개소 측정] 외관(에폭시) 및 접속부(1/2/3차)	신설	
			[최음파 측정] 접속부(1/2/3차)	신설	
			[피뢰기 진단] 누설전류 측정	신설	
한류리액터		계기	유연 측정 여부	유지	
		본상	유연 측정 여부	유지	
OLTC 및 부속장치	계기	[과열개소 측정] 본체 및 접속부	신설		
		OLTC TAP			
		OLTC 카운터			
		OFU 압력			
		유연			



Path walk & Door Open



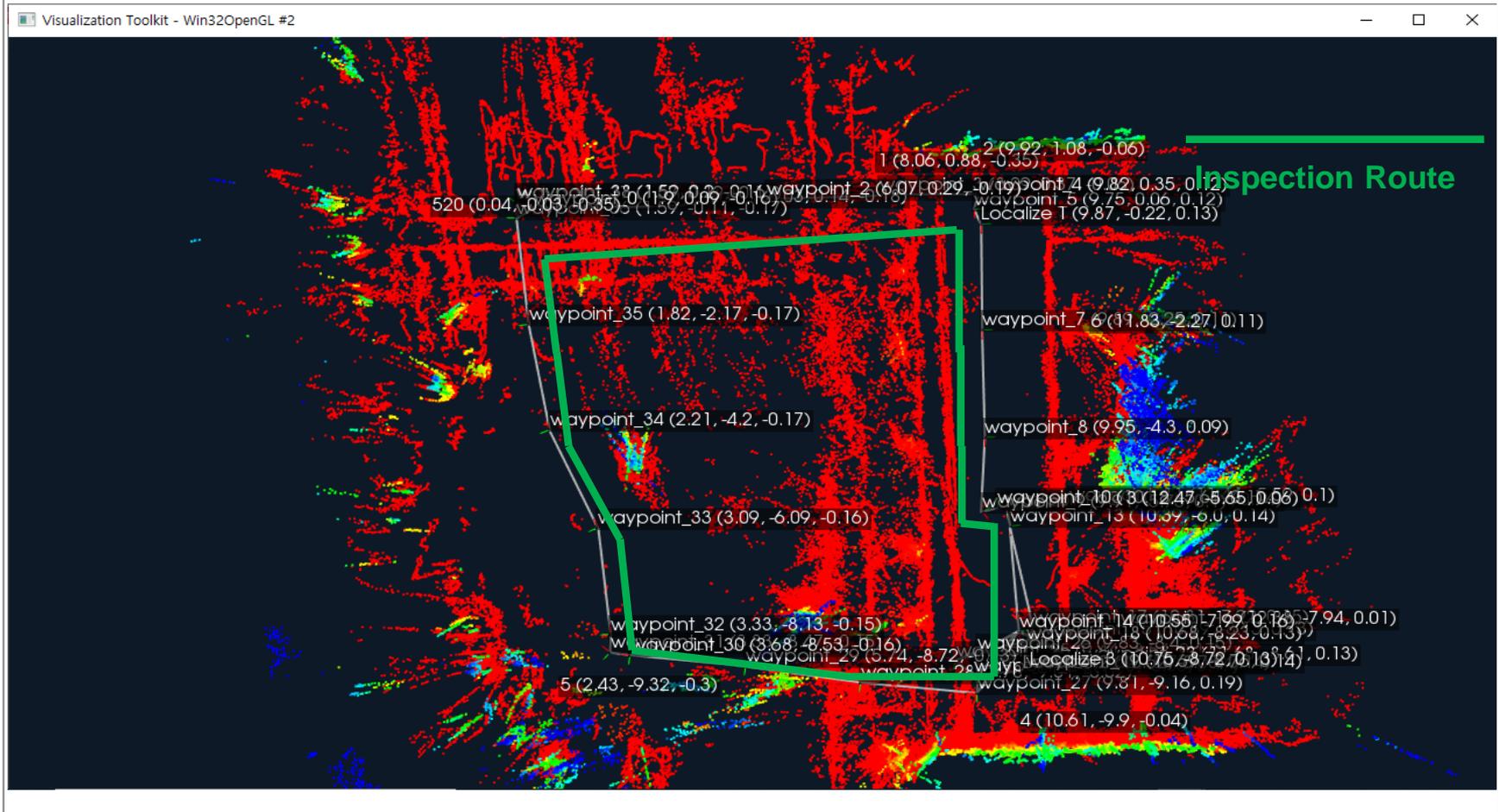
Climb steps & Rough terrain

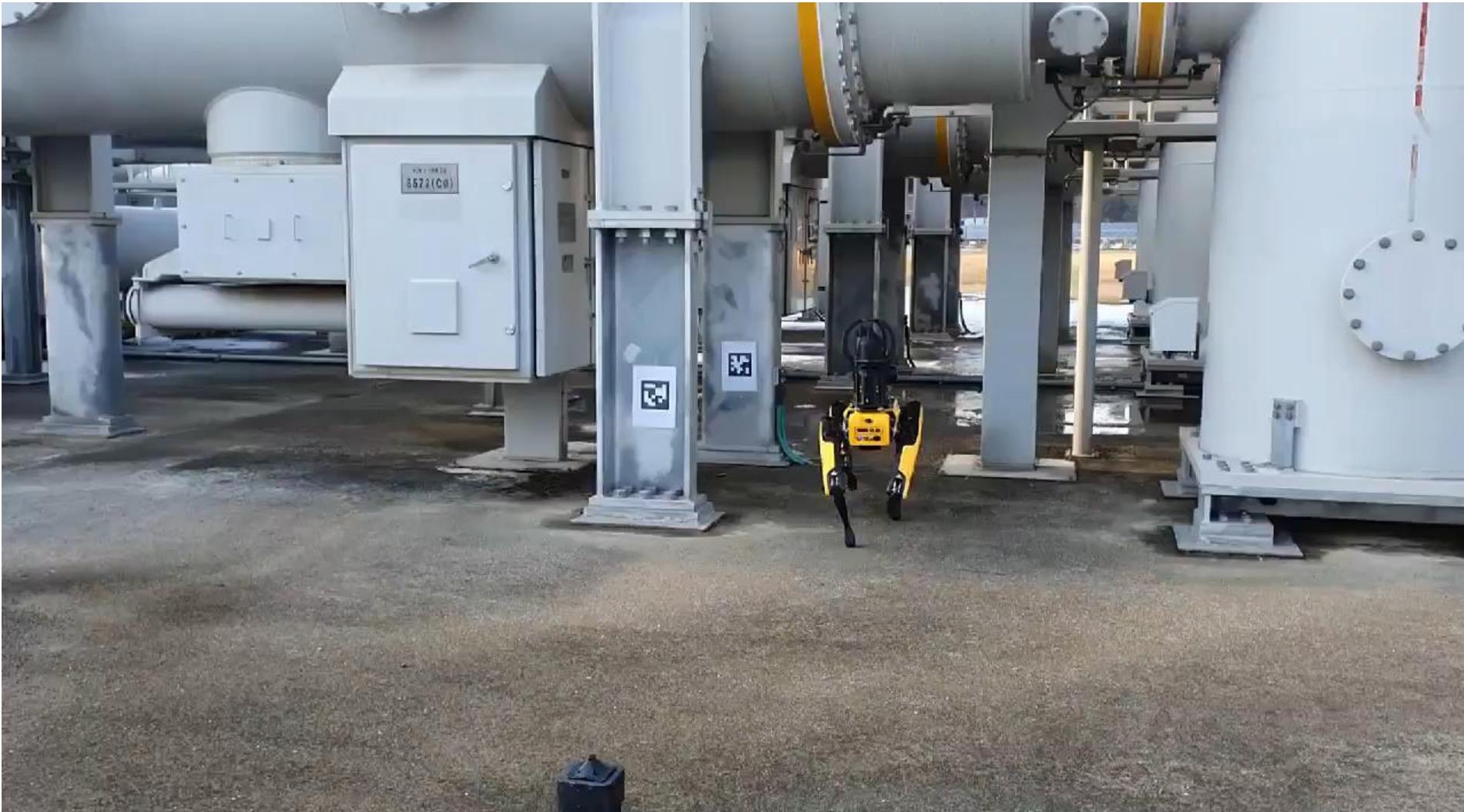


External & Internal Transformer Inspection

- Substation inspection points : 1200
- Categorize inspection point
- Mapping with robot motions

## Setup Inspection route







# Robot arm for indirect live line work assistance

Robot & Drone Team



'92~'17 Direct Live-line work (Rubber Gloves)



'18~ Indirect Live-line work with smart stick



Indirect Live-line work with compressor stick

## Design of non-powered robot arm using gravity compensation mechanism





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FUTURE

INNOVATION

RESPECT

SOCIAL RESPONSIBILITY

TOGETHER

**Thank You**

