Robotics Utility Network

2023-Q1 Introductory Call

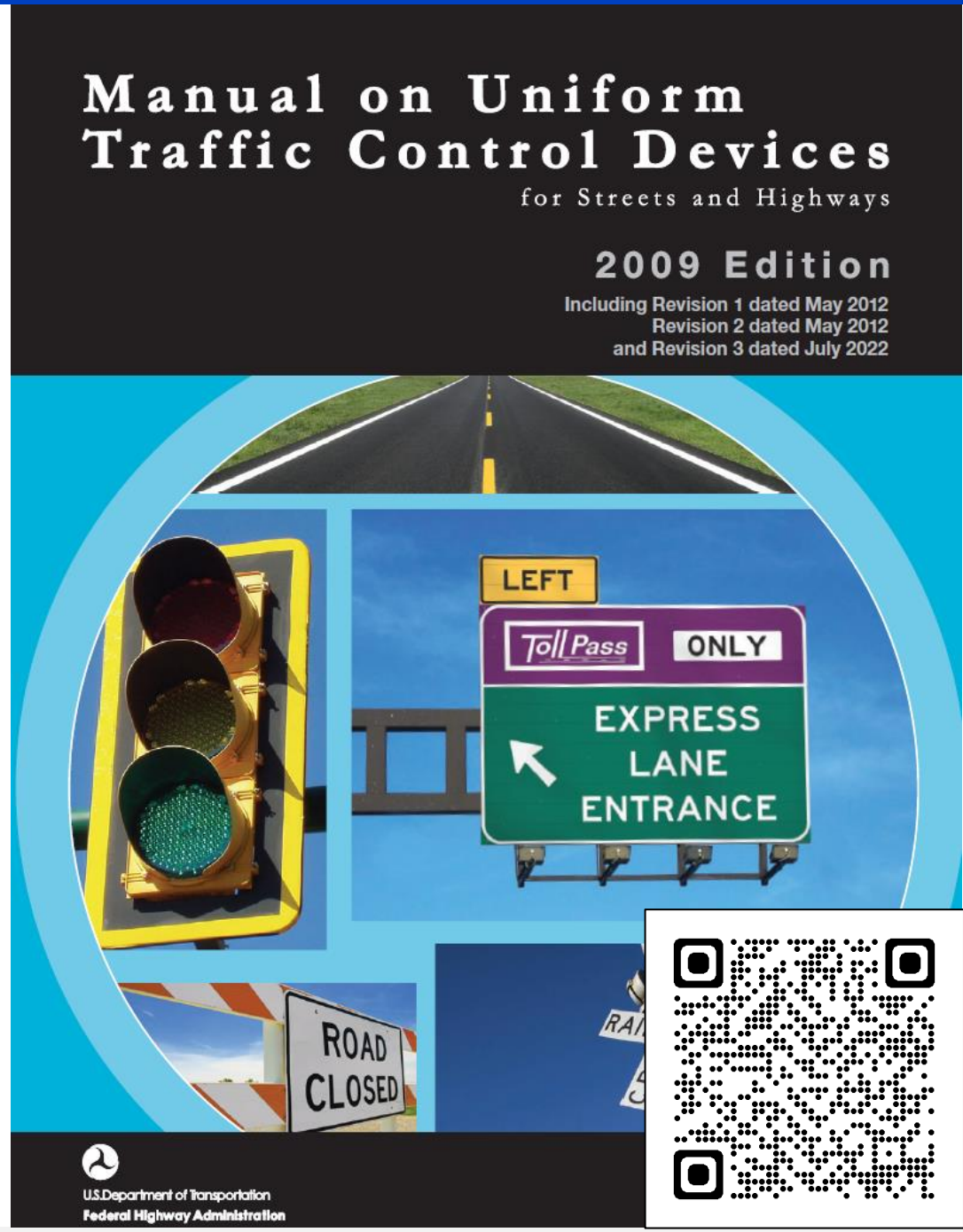
Dexter Lewis
Principal Technical Leader

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.



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?

Member Engagement on March 15th, 2023, at 6 PM EST.

- 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 met 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.

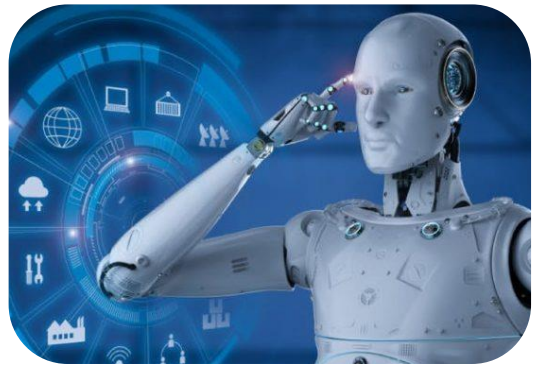
Three Pillars of RUN

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

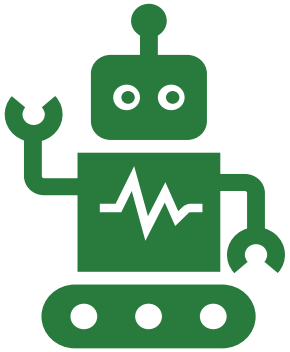
Highlight successes and failures

Consolidate information

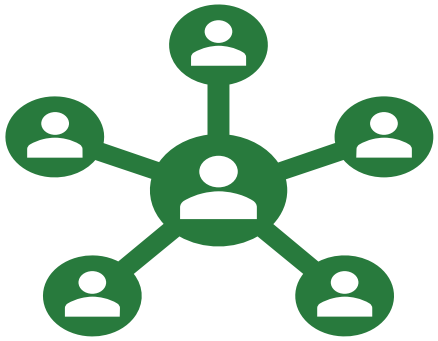
Foster Relationships

How will this help?

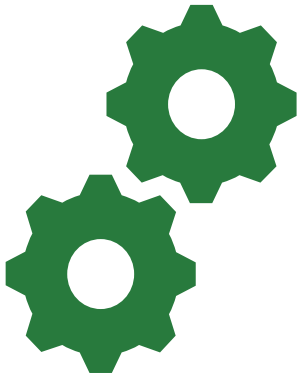
Vital hub



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

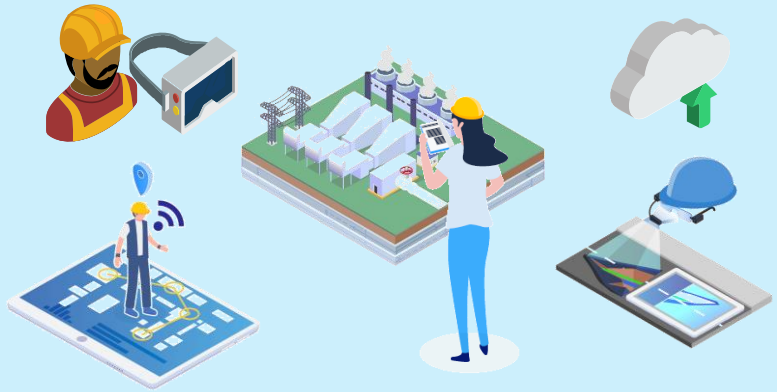
<u>Utility Digital Worker *State-of-the-Industry*</u>
Technology & Application Sessions
& Demo's during breaks & receptions

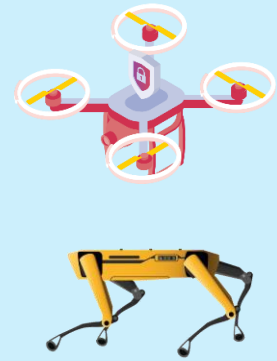
Latest Trends & Emerging Research Across Utility Domains
Nuclear, Generation, Transmission, Distribution & Cross-Cutting

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.

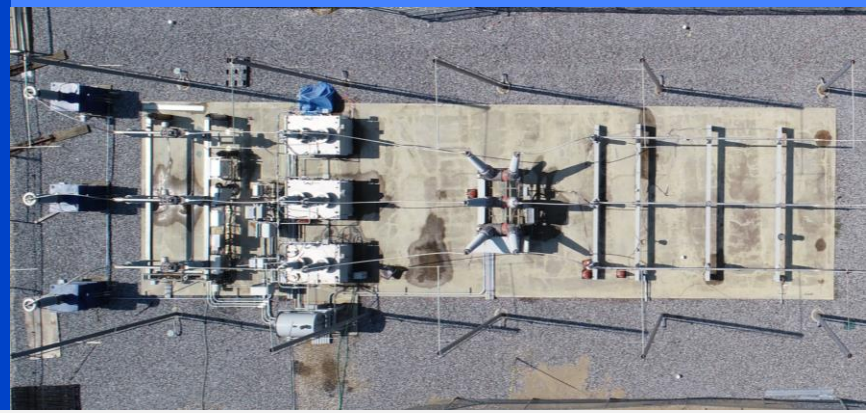
Safely

Quickly

Efficiently

Objectively

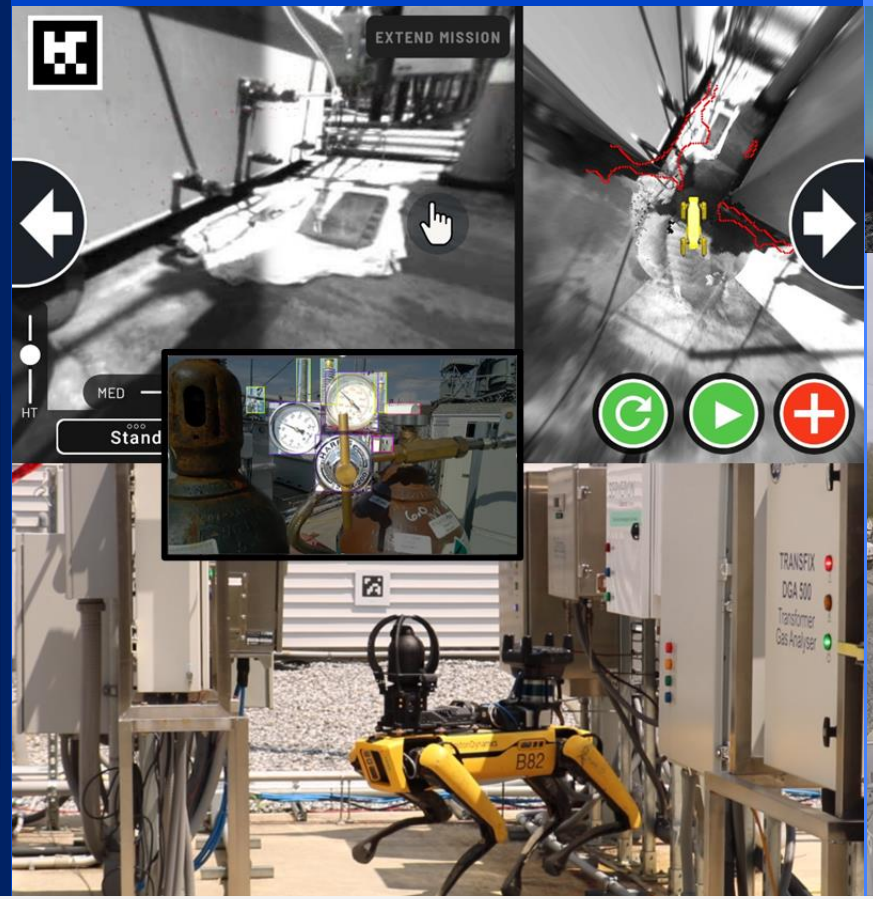
EPRI proposes repeatable projects that leverage labs.



2023 Collaboration Opportunities

Evaluation of Substation Robotic Application (near completion)

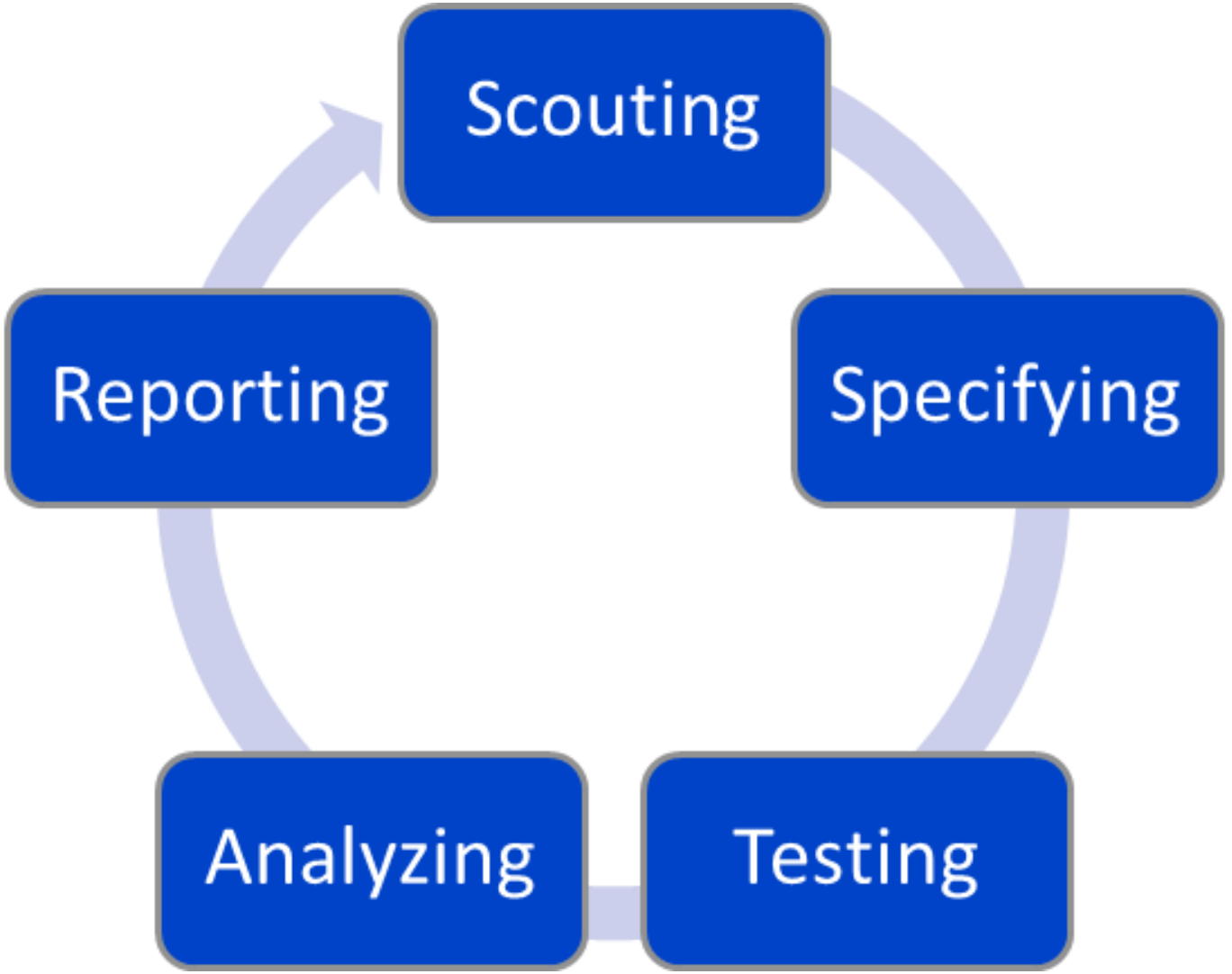
Evaluation of Substation Robotic Analytical Tools (ongoing)



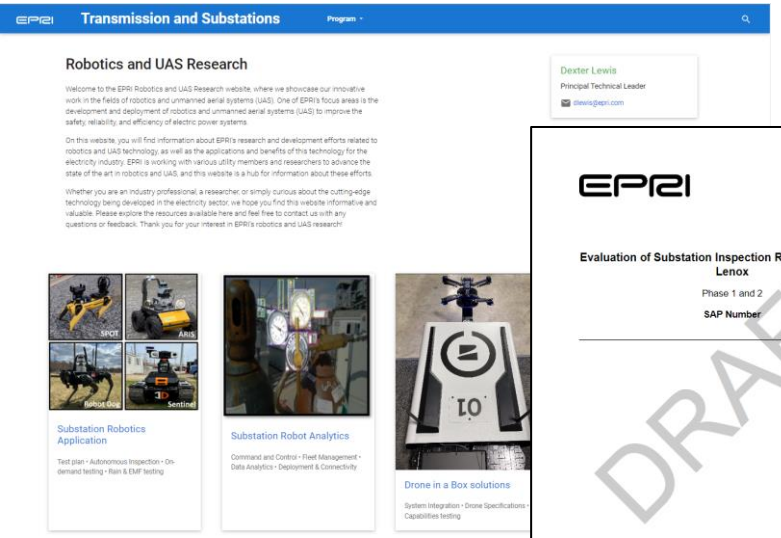
Drone Dock Lab Testing and Utility Applications (ongoing)

Autonomous Robots in Substation

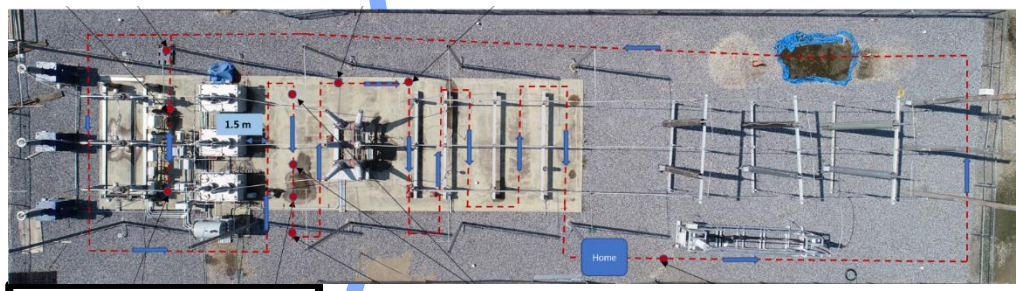
Web Link

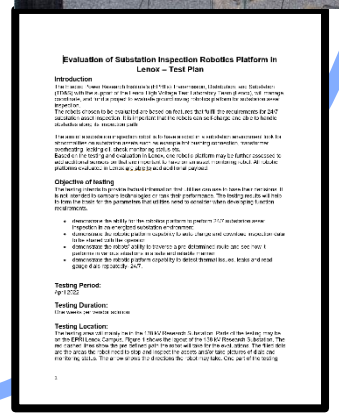


Autonomous Robots in Substation



Specification: The robot must avoid objects.

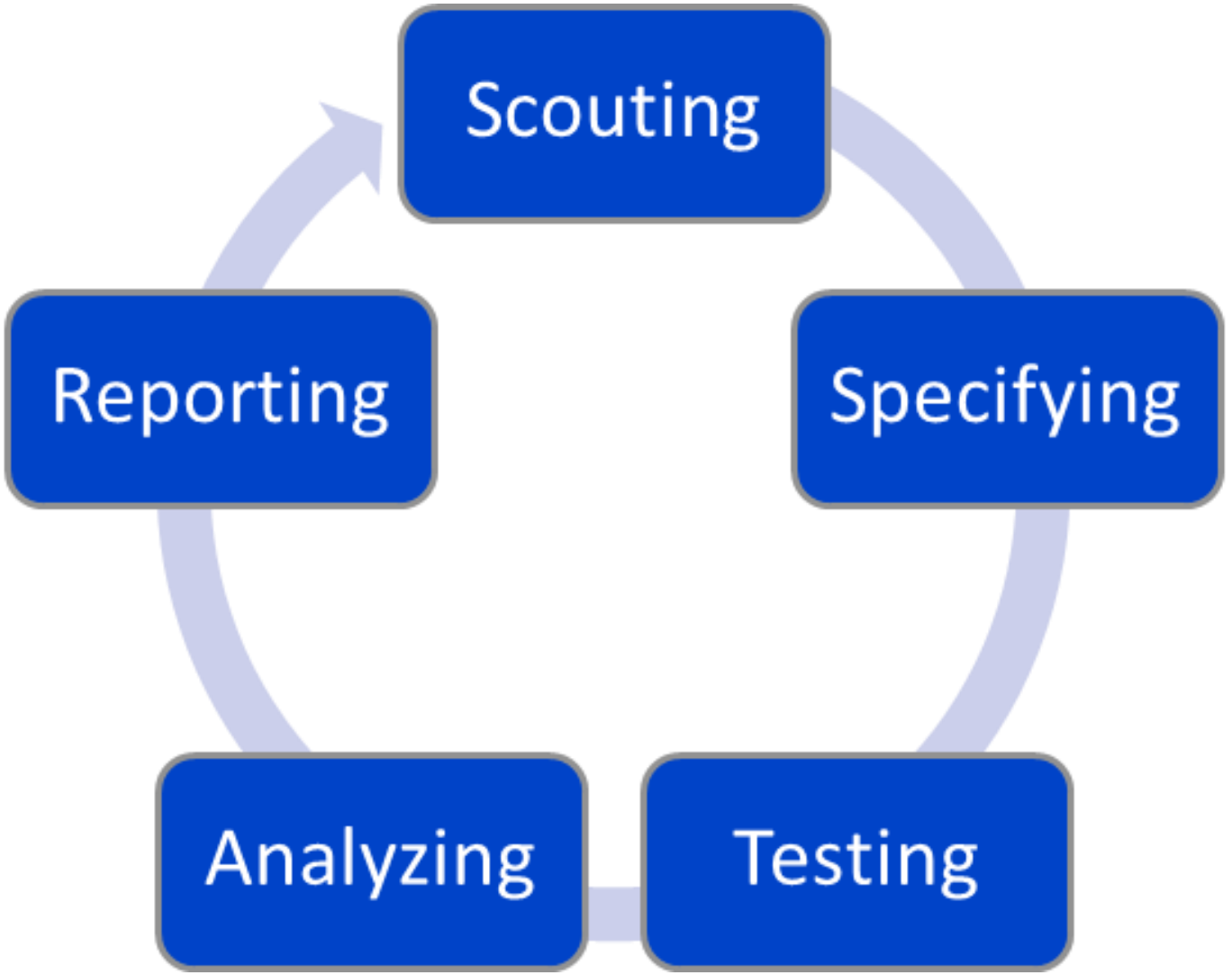




Web Link

Evaluation of Substation Robotic Analytical Tools

Web Link



Evaluation of Substation Robotic Analytical Tools

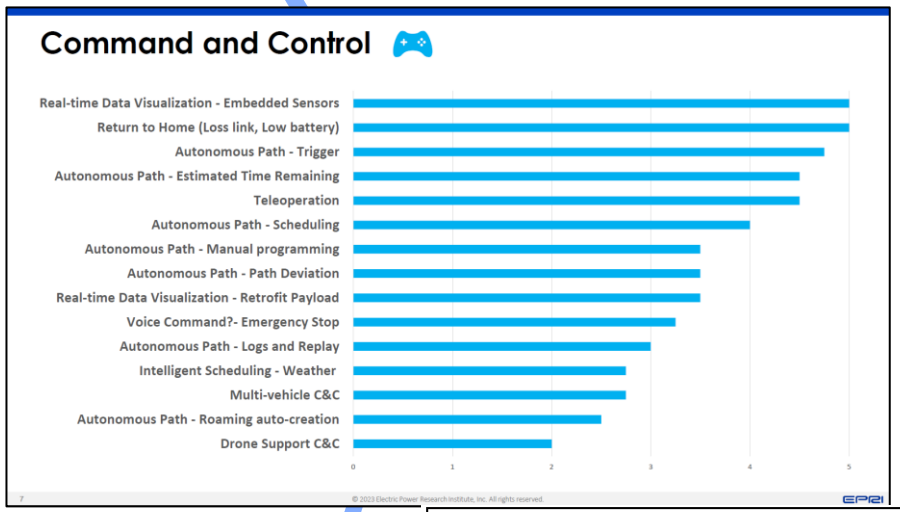
Scouting

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

Web Link

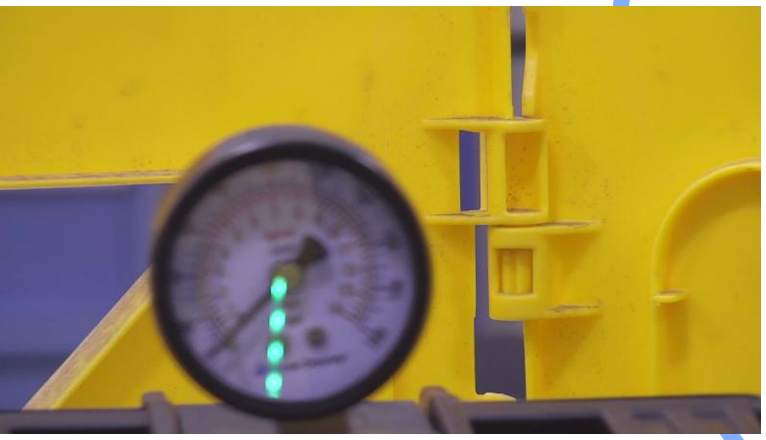
Reporting

Specifying



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

Analyzing



Testing

Drone Dock

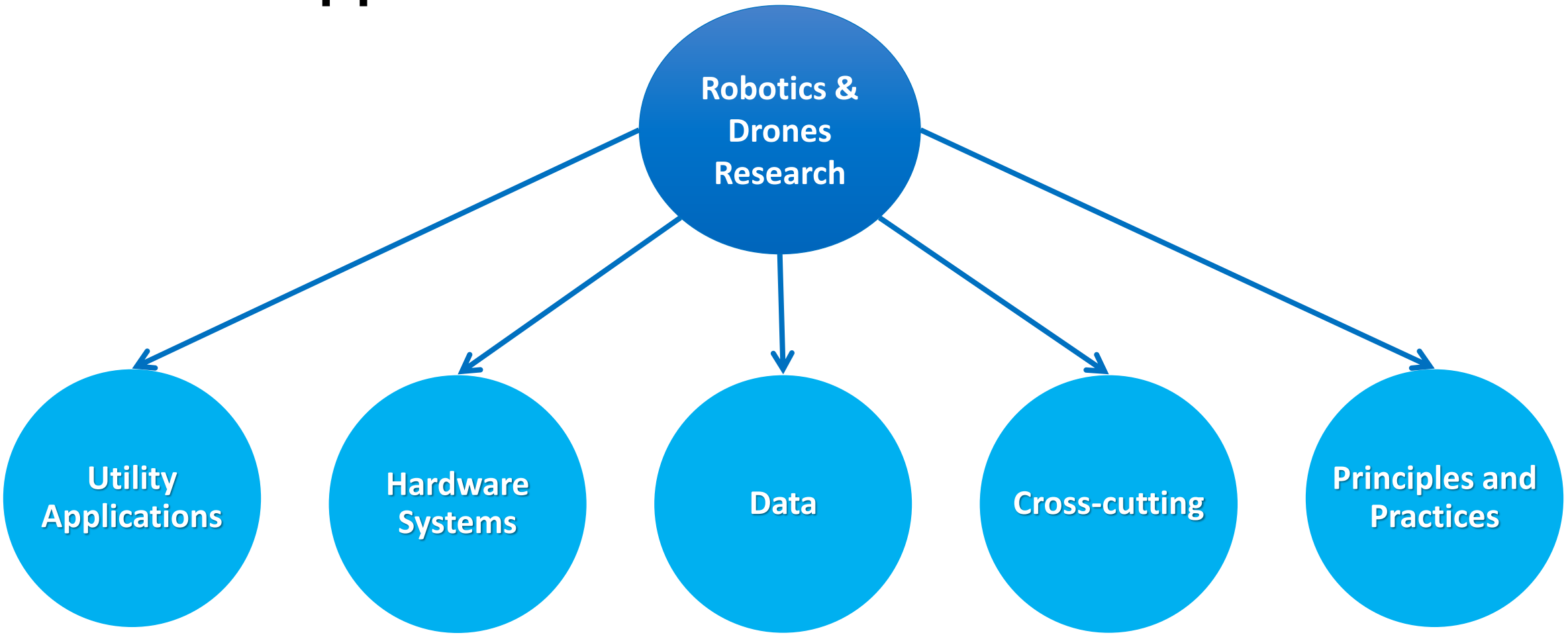
Lab Testing and Utility Applications

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

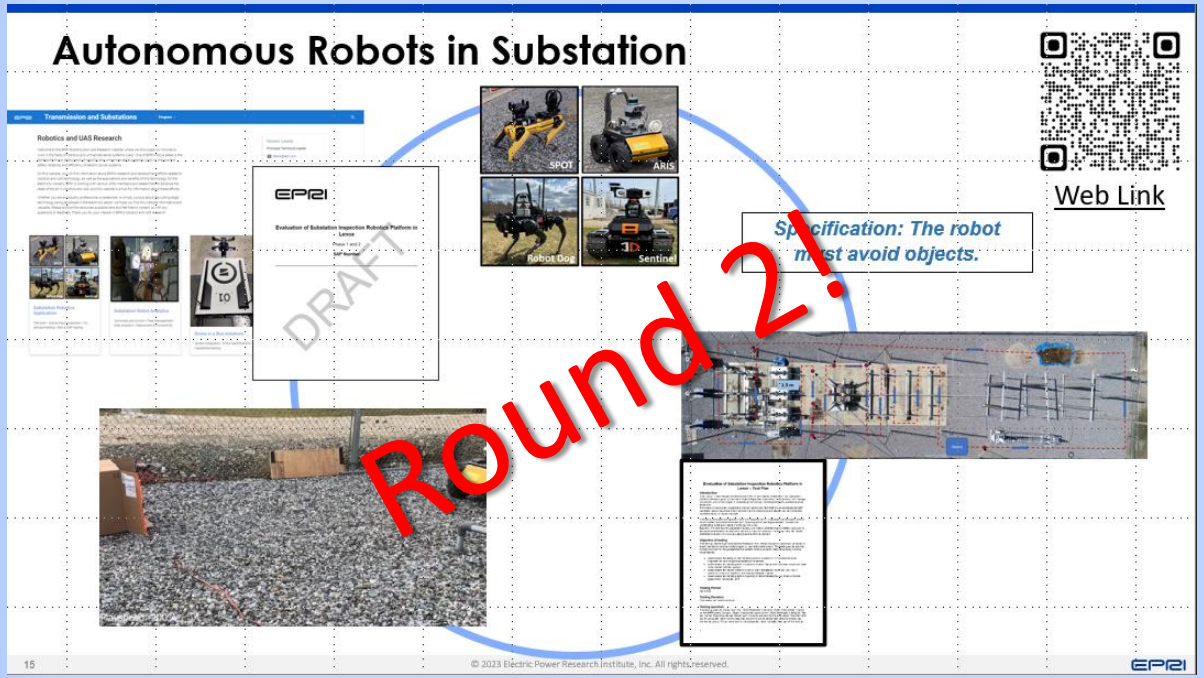
Utility Presentation

Potential Robotic Research Areas

Research Opportunities



Mobile Robotics for Substation Applications: Lab Testing and Experiments



This report and video complication 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

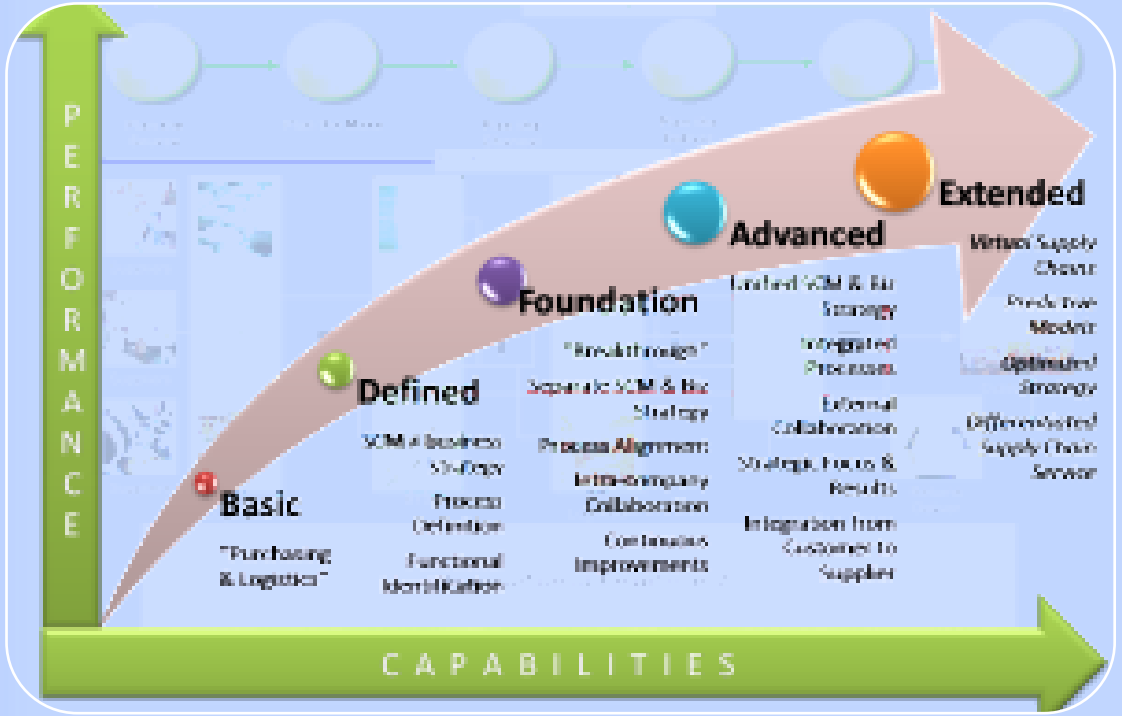
This research attempts to survey the state of the industry related to arm payloads. The brief likely will include lessons learned from prior EPRI experiments, public information, demonstrations, and literature review.

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

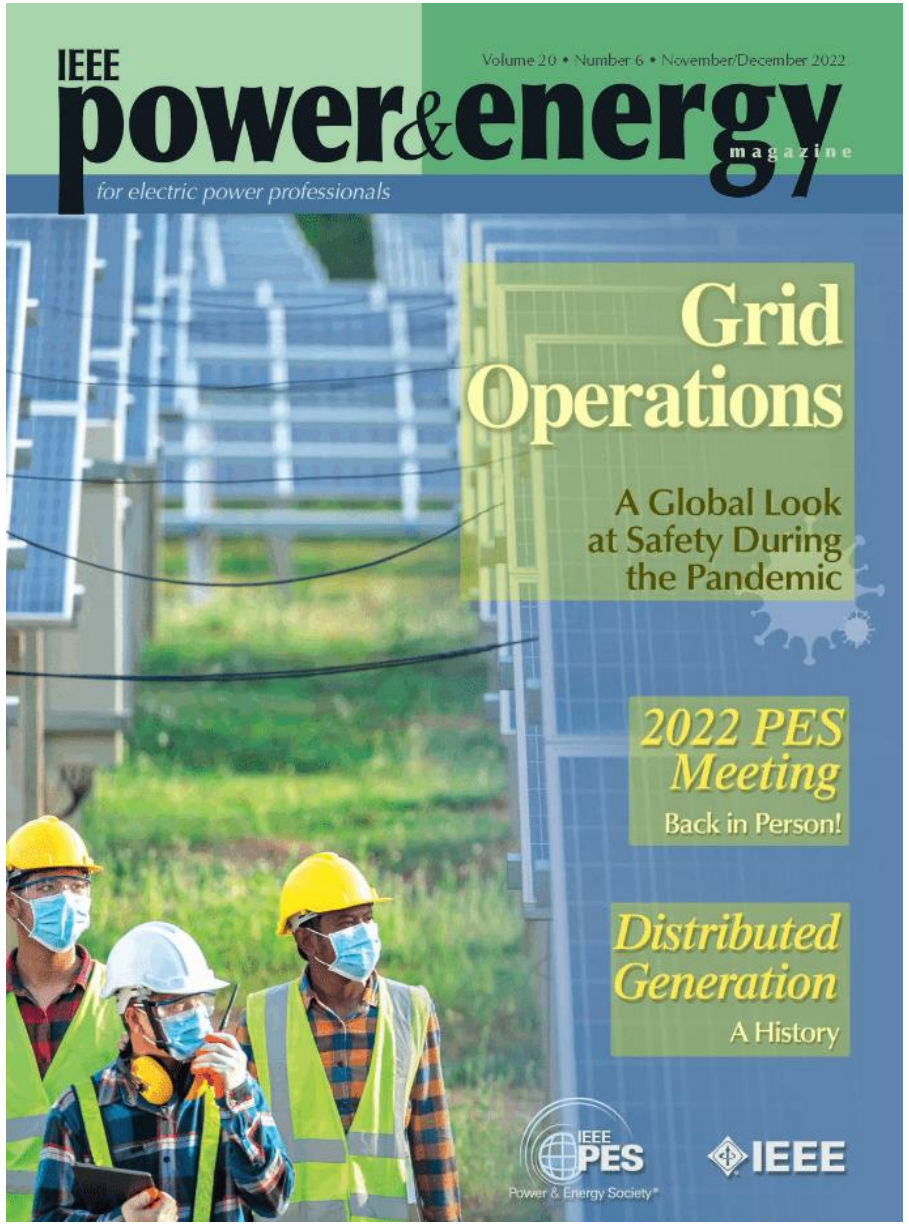
https://app.sli.do/event/9ZR1R9nhxNNFJAtt1TWSqw

Poll and Open Forum Discussion

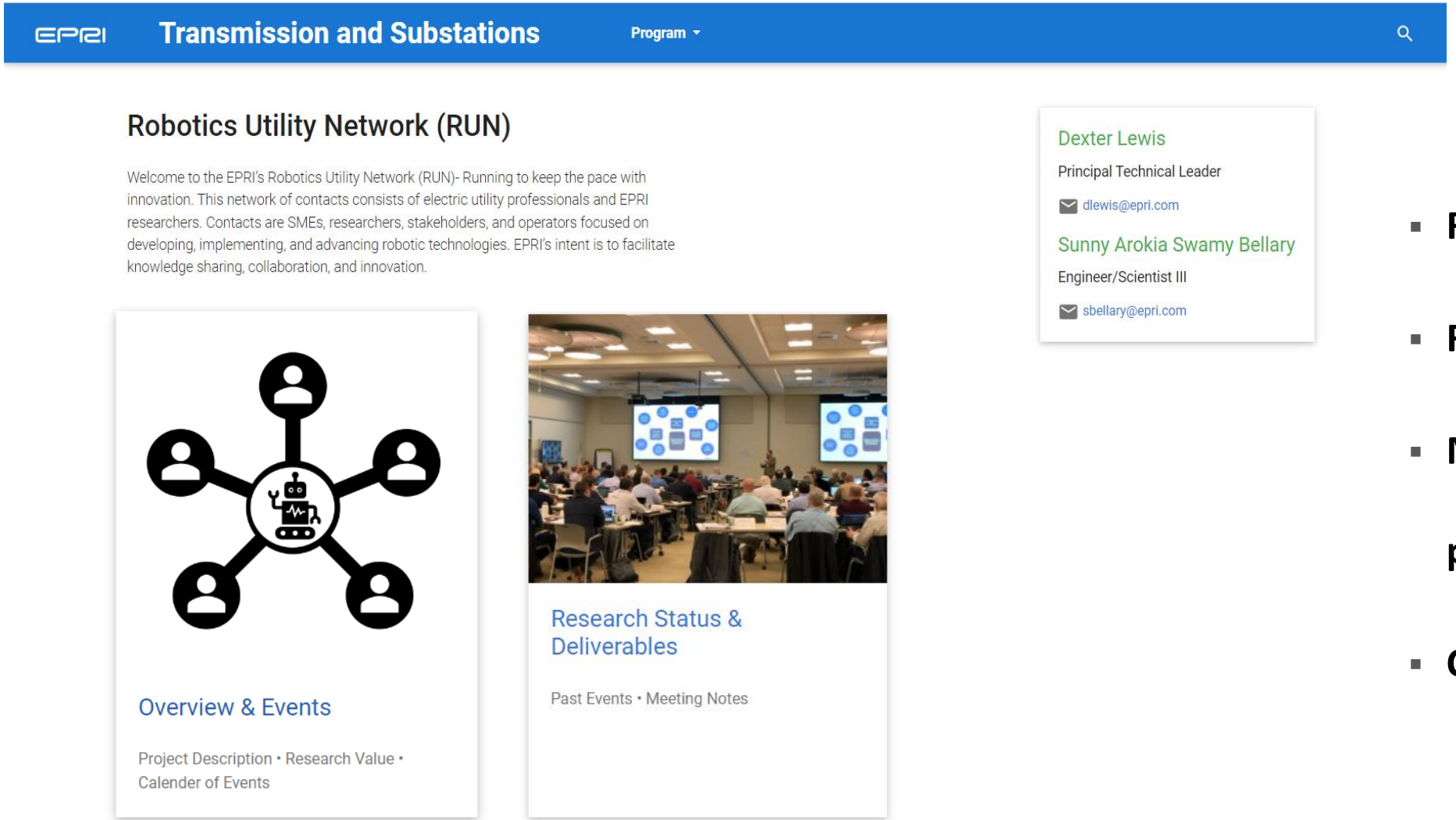
Next Meeting: Aug. 3rd, 2023, at 2 PM EST

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



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

https://transandsubsdev.epri.com/p37_substations/public/robotics/run_group/

KEPCO Robot & Drone Projects

JaeKyung LEE

Robot & Drone Research team

KEPCO 전력연구원

Global Trends

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

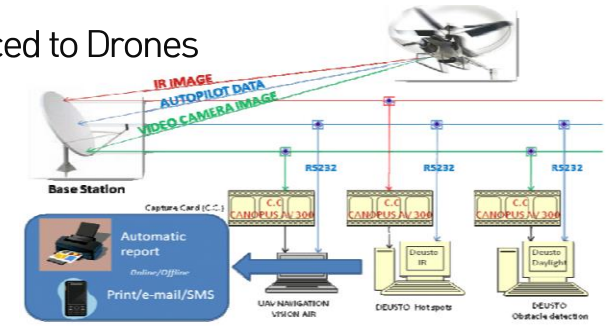
- Work : Line Inspection, Maintenance
- Function
  - Visual, Thermal Cam
  - Mounting Bolt
  - Single Line
- ❖ Transfer to UK, China

[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 : AutoFilght, 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

Robot trends in Korea

[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.

Research area

[Transmission]

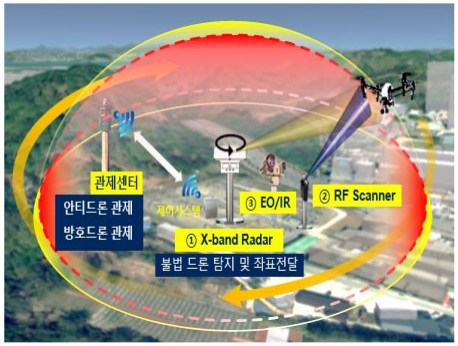
Insulator Inspection Robot

T/L Inspection Drone

Power Tunnel Patrol Robot

Insulator Inspection Drone

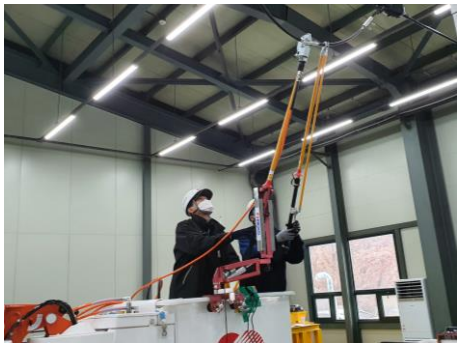
[Substation]



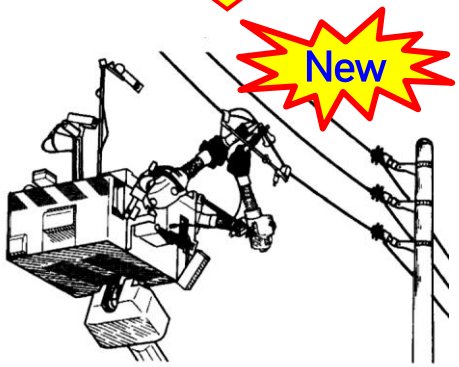
Count Drone System

Preliminary study of S/S inspection using SPOT

[Distribution]



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

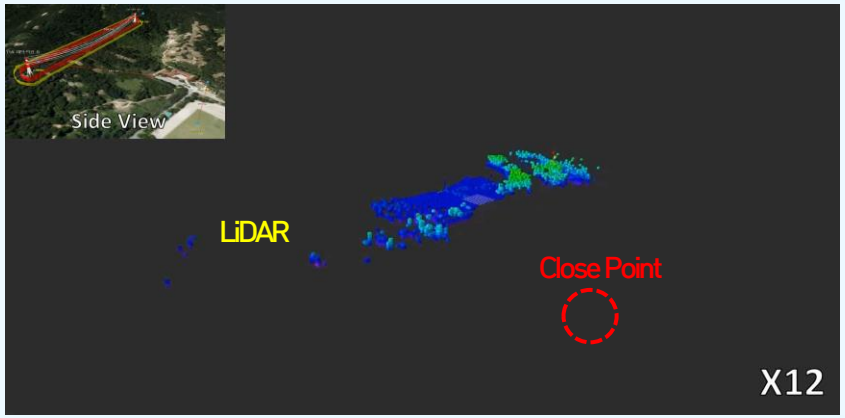


Live-line Maintenance robot for D/L

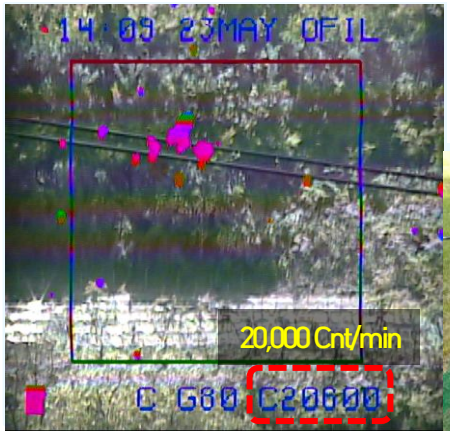
Transmission Line Inspection Drone

Autonomous Drone for Transmission Line Inspection : More than 240 pylons

Sag estimation & Vegetation encroachments



Corona Inspection

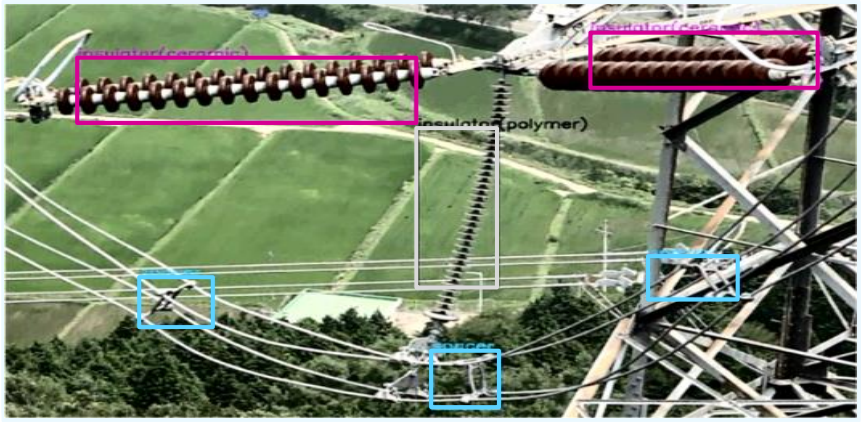


- Faulty more than 5,000
- Close Inspection

Developing various application to make Drone technology valuable

Transmission Line Inspection Drone

Auto tracking Camera gimbal



Hydrogen-Fuelcell Drone

- Fly more than 2 hours
- BVLOS using LTE

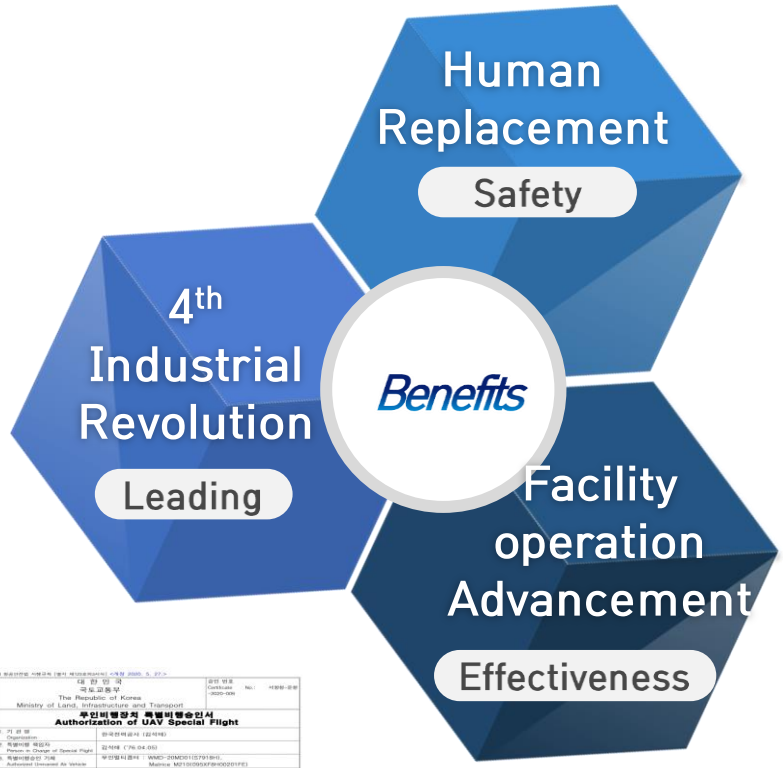
대 한 민 국
국토교통부
The Republic of Korea
Ministry of Land, Infrastructure and Transport

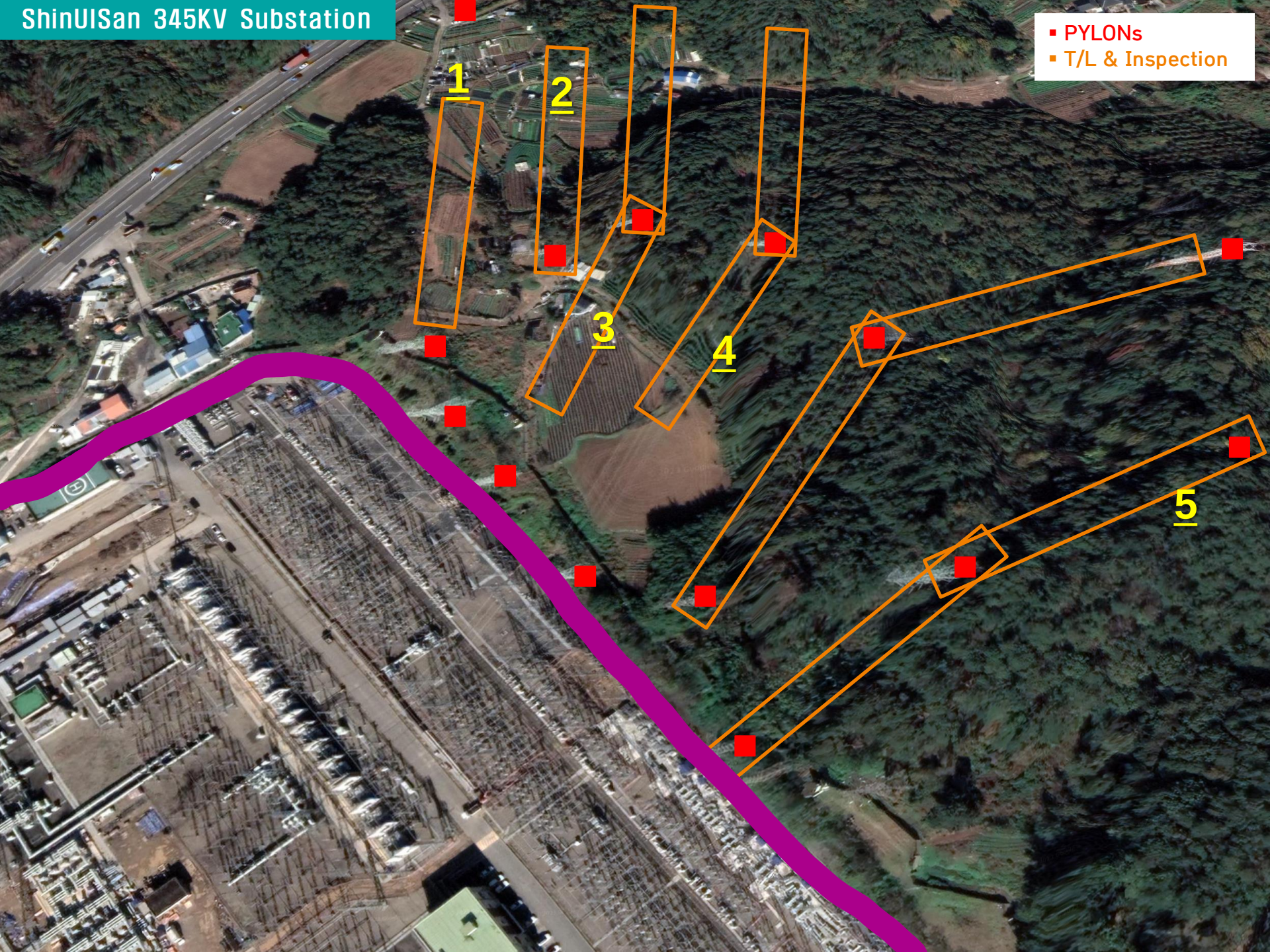
무인비행장치 특별비행승인서
Authorization of UAV Special Flight

서울지방항공청장

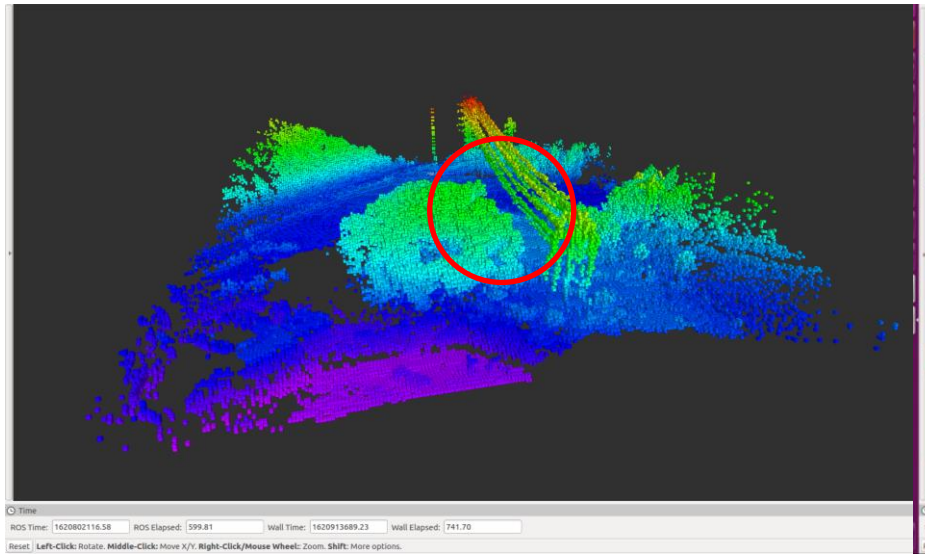
Minister of Ministry of Land, Infrastructure and Transport

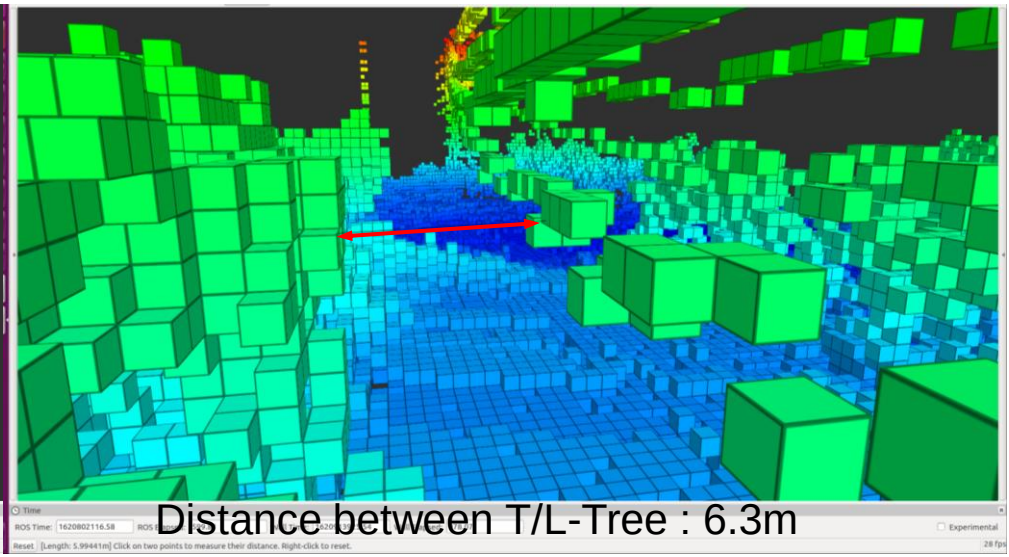
Admission for BVLOS



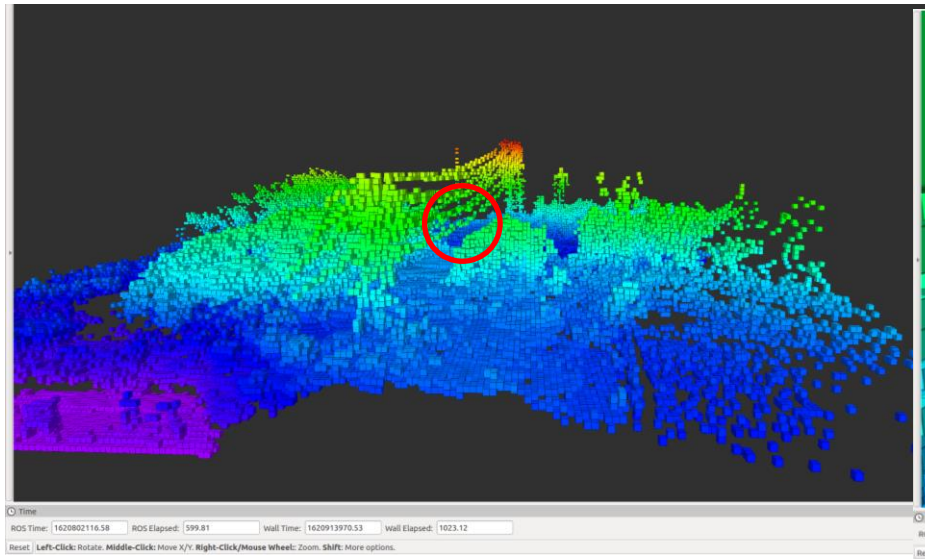

ShinUlSan 345KV Substation
PYLONs
T/L & Inspection
1
2
3
4
5

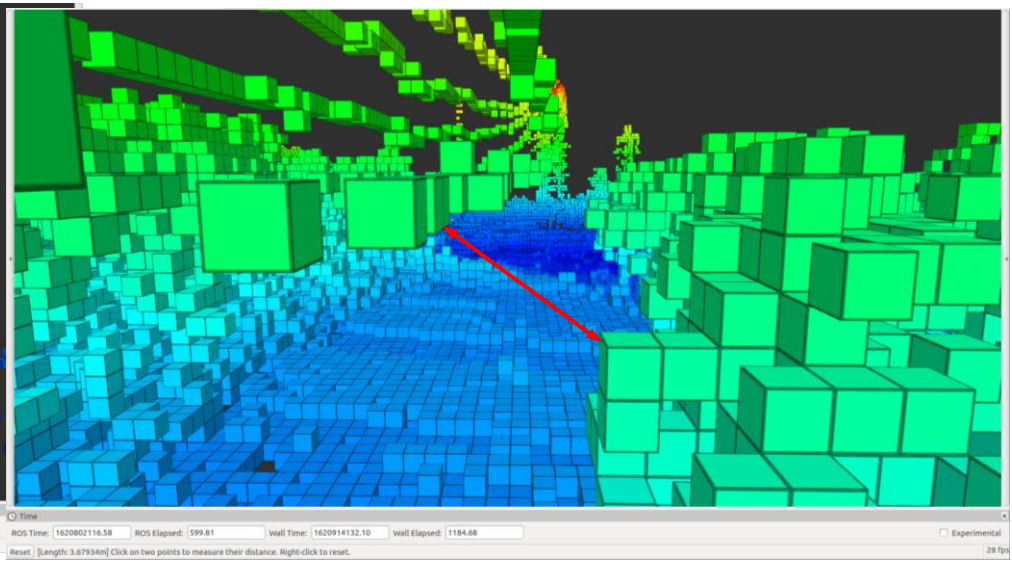
Transmission Line Inspection Drone – 1st Sector





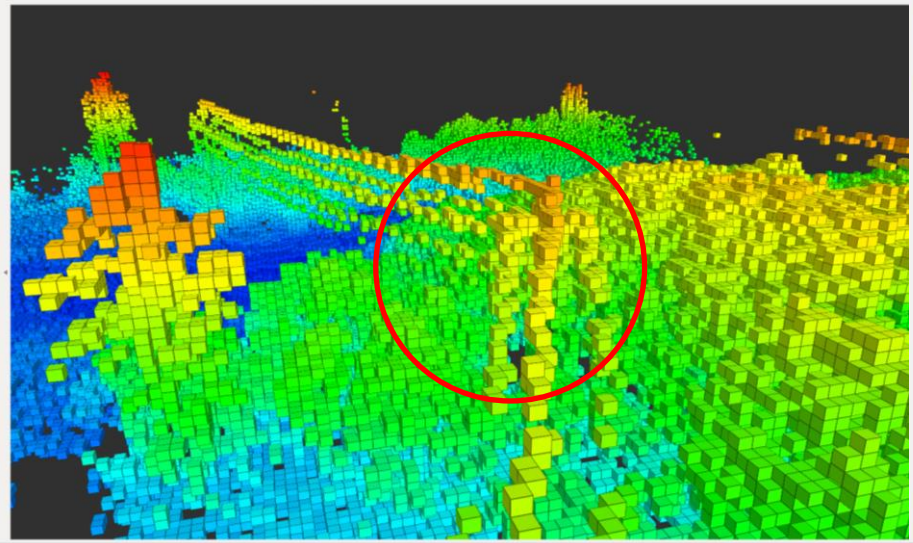
Distance between T/L-Tree : 6.3m

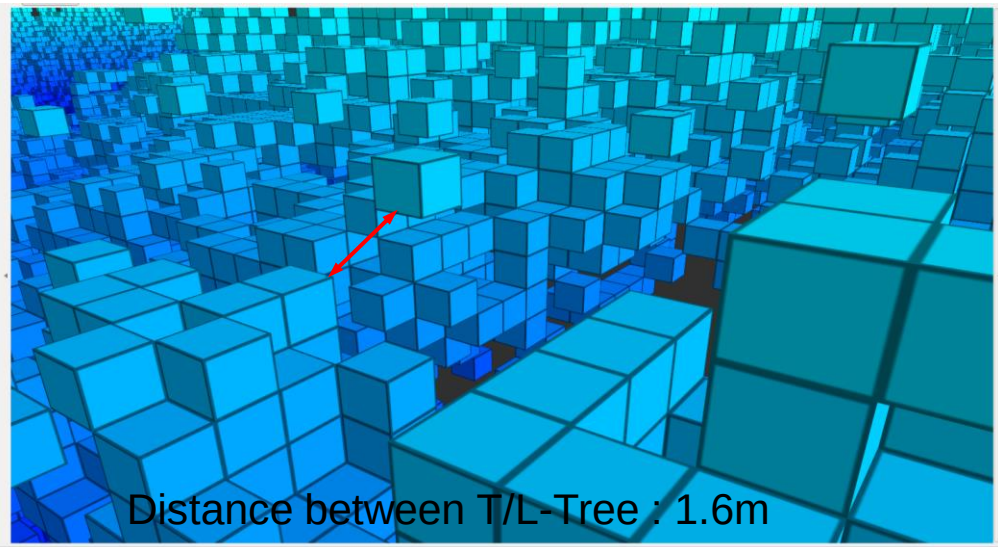


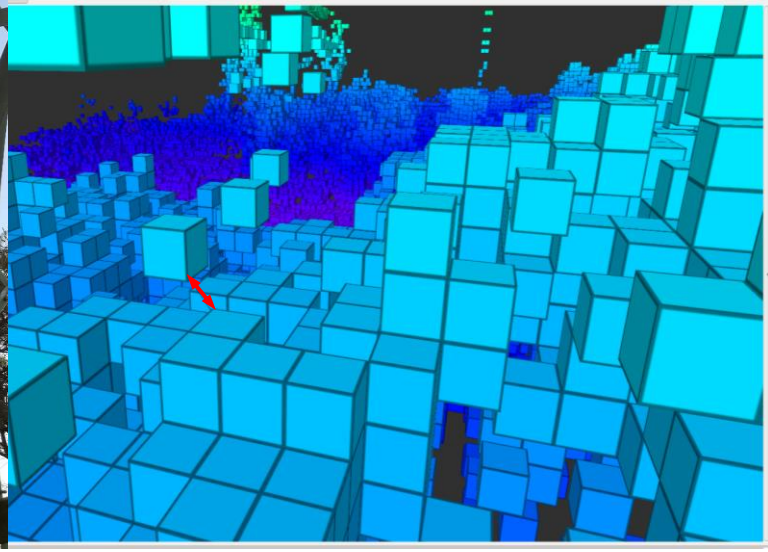


Distance between T/L-Tree : 4.9m

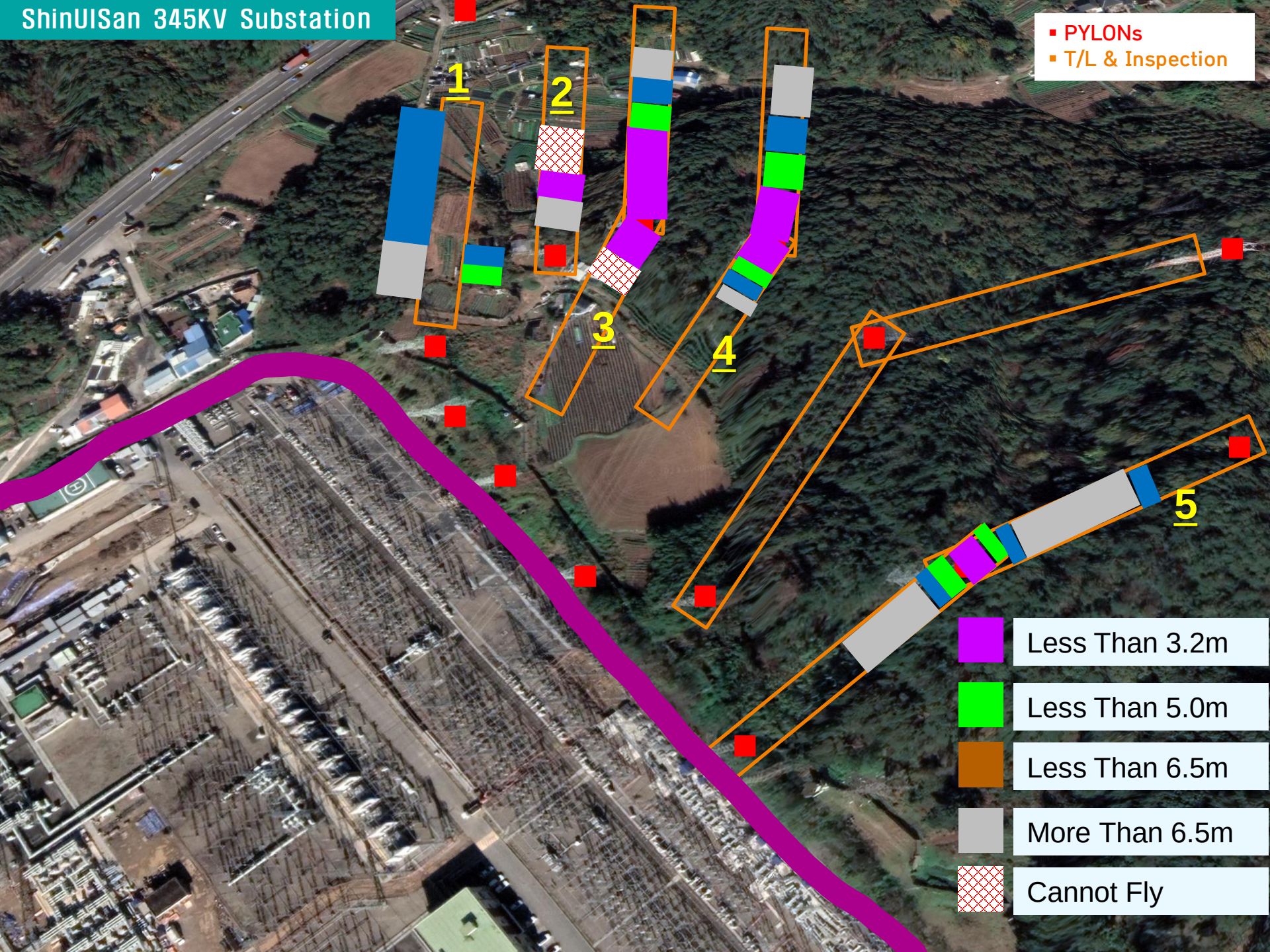
Transmission Line Inspection Drone – 3rd Sector







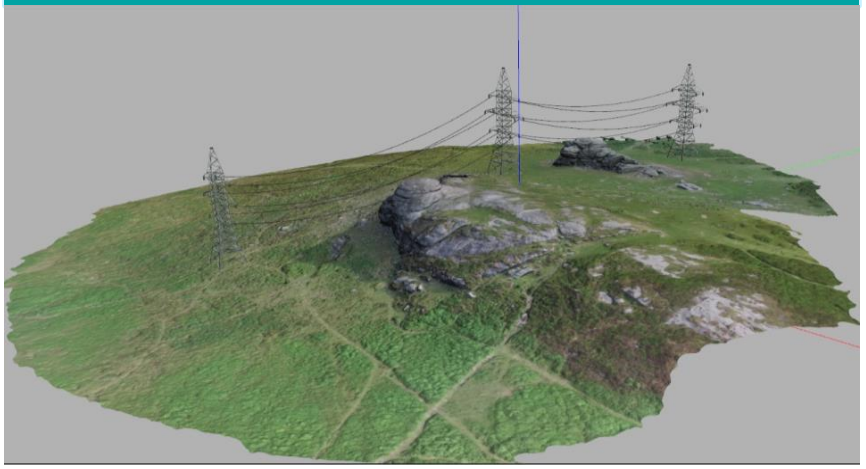
Distance between T/L-Tree : 1.5m


ShinUISan 345KV Substation
PYLONs
T/L & Inspection
1
2
3
4
5
Less Than 3.2m
Less Than 5.0m
Less Than 6.5m
More Than 6.5m
Cannot Fly

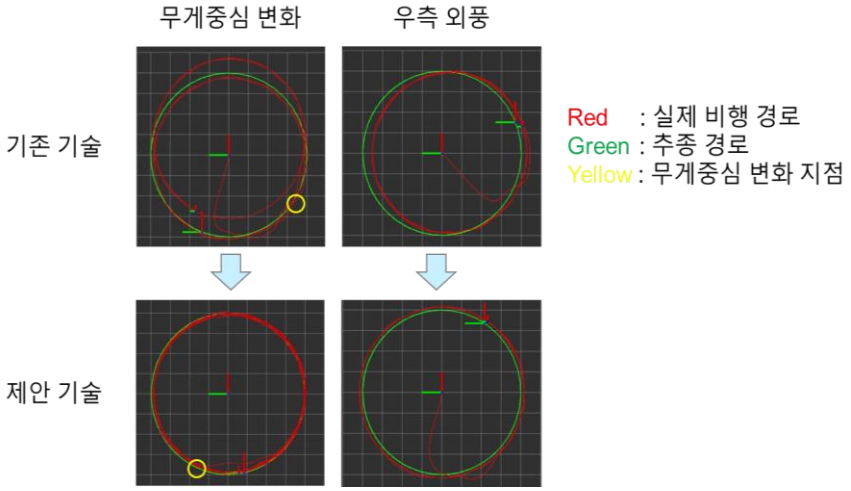
Insulator Inspection Drone

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

Underground Tunnel Inspection Robot

Development of inspection robot for underground Tunnel facilities and structures

Tunnel

Driving, Docking

Optical/Thermal 360˚ Images

Recharging/Waterproof/ Data Transmission

Office

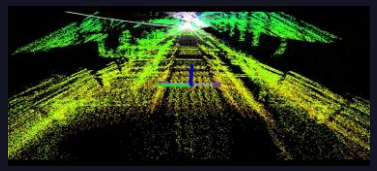
Robot remote control/ operation
AI based inspection/ Reporting

Robot

3D LiDAR(VLP-16)

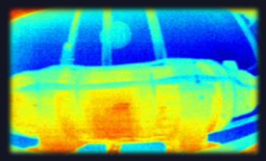
Thermal cam (TE/EV1)

360 cam(Theta V)



Localization/ Mapping

Structure Inspection



Cable Contacts Inspection

360˚ Inspection

Robot Station

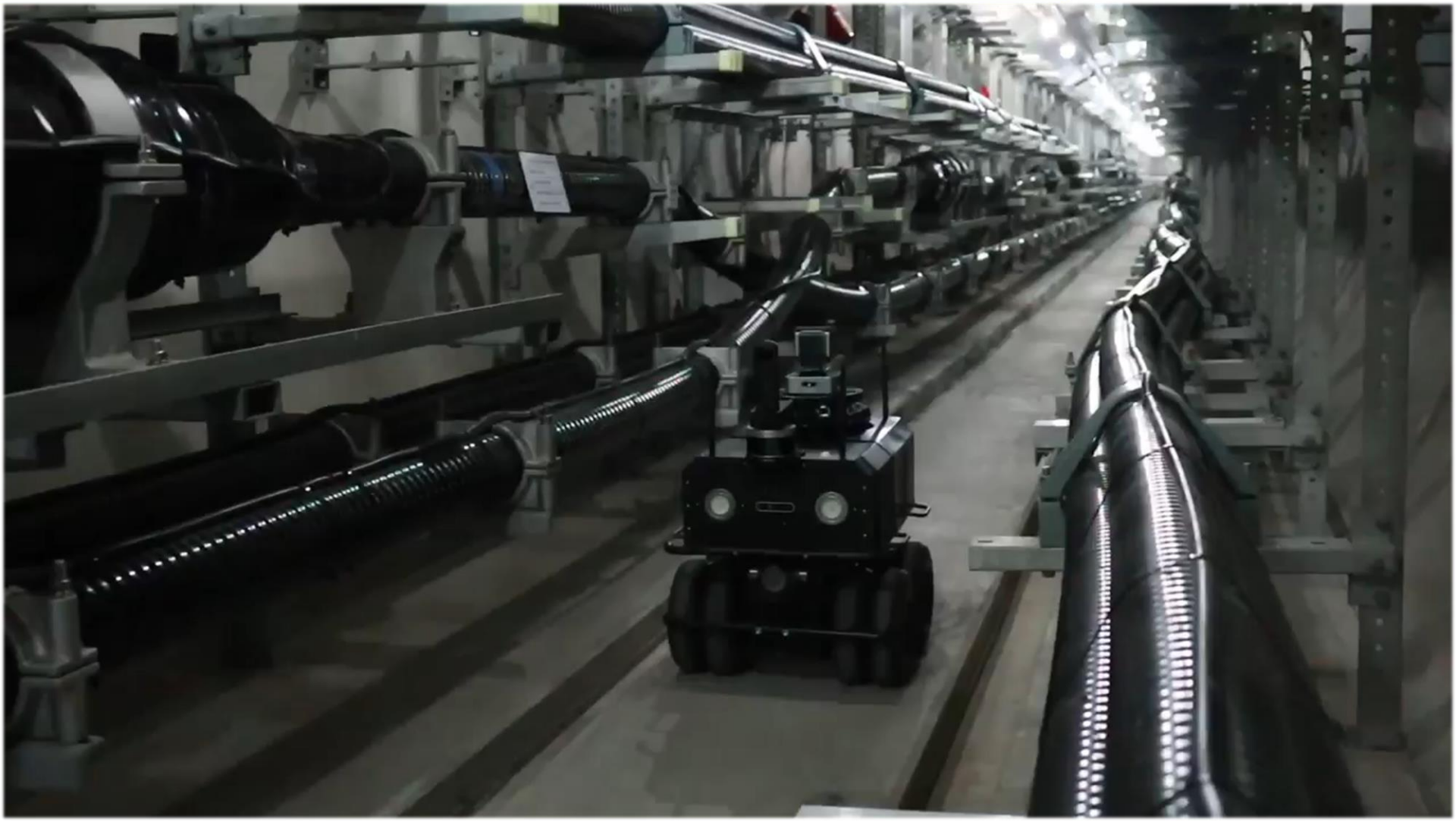
Wireless recharging

Fire Extinguisher

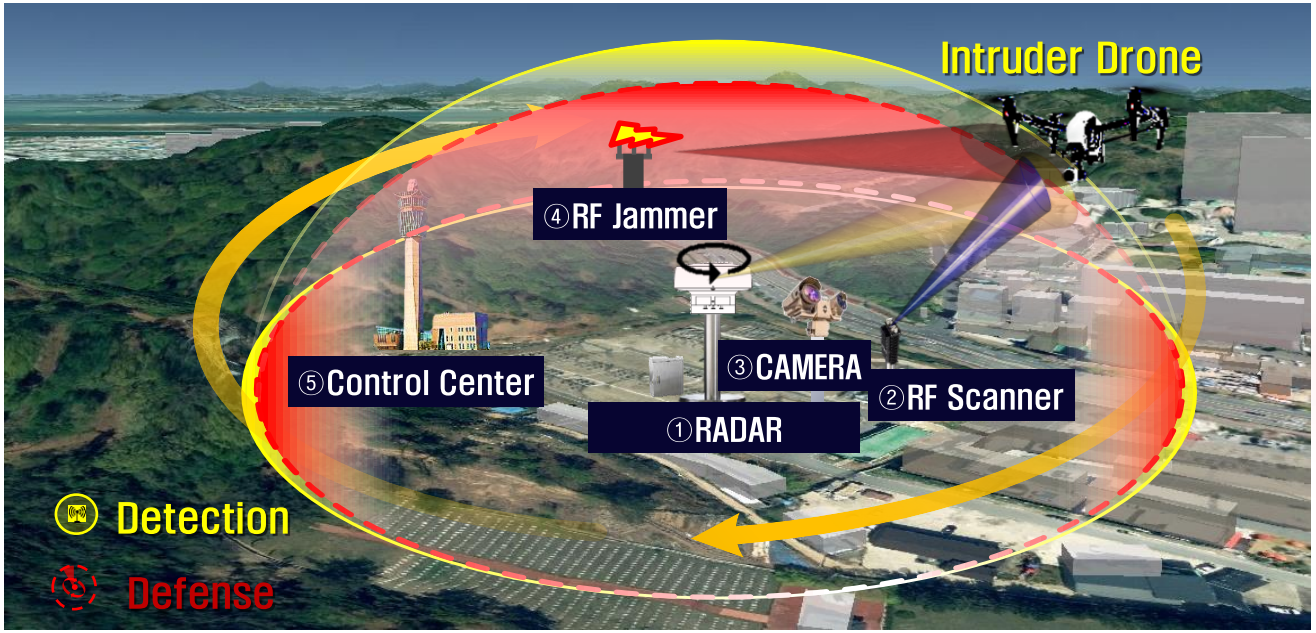
De-humidifier

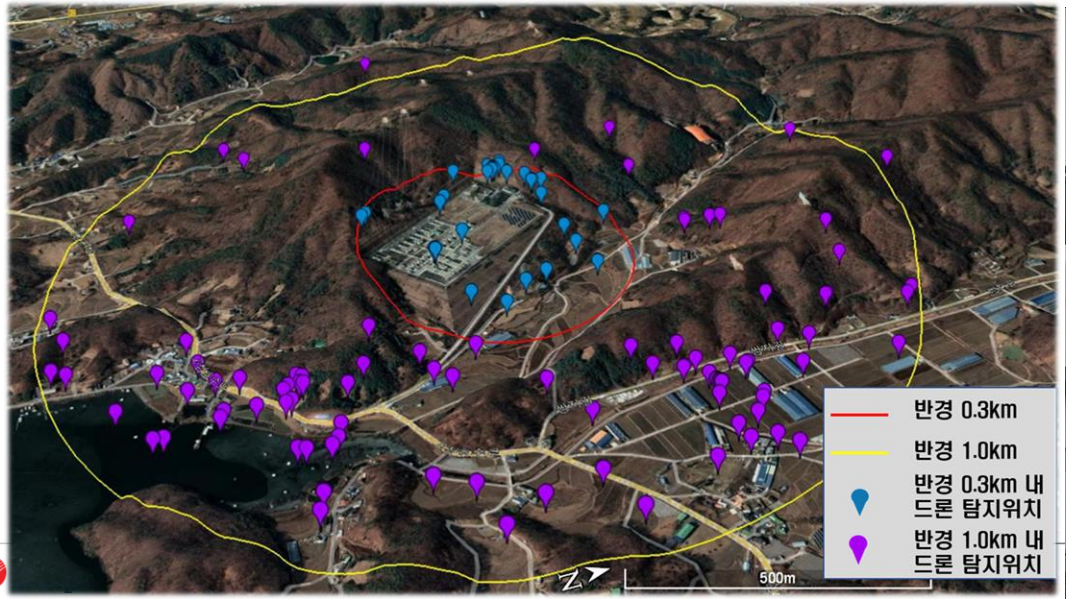
Immersion Sensor

Underground Tunnel Inspection Robot



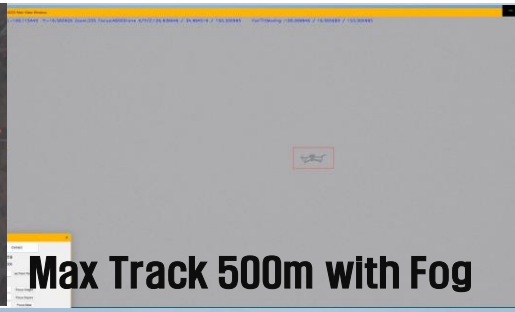
Counter Drone for Substations





Counter Drone for Substation

Robot & Drone Team



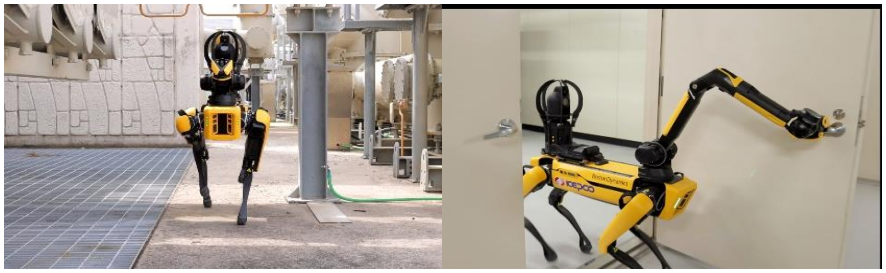
- Verified Jammer Effectiveness at 500m
  - ➔ GPS 20mW
    50mW @2.4GHz,
    10mW @5.8Ghz(10mW@wifi/2.4GHz)

Substation Inspection using SPOT

Feasibility study using SPOT

점검설비	점검개소	점검항목	점검내역	기존대비 변화
주변압기	본체 및 부속설비	외부전반	누유,누기,이음,이취,변색,손상 유무	통합
			[과열개소 측정] 본체 외함 (상별 측정)	신설
	본 체	계 기	권선온도(1,2,3차) 적정 여부	유지
			유온 적정 여부	유지
			유면 적정 여부	유지
		붓 싱	유압 이상 유무(Hv, Xv)	유지
			유면 적정 여부(Hv)	유지
			[과열개소 측정] 붓싱 접속부(1/2/3차, N상, Wall 등)	신설
			[초음파 측정] 붓싱 접속부(1/2/3차, N상, Wall 등)	신설
		BCT	[과열개소 측정] BCT 외함 (1/2/3차, N상 등)	신설
		KP	[과열개소 측정] 접속부	신설
		중간단자함	[과열개소 측정] 내부 단자대	신설
	Cooler (본체&한류리액터)		현재 가동 냉각기 Group 이상유무	유지
			권선온도와 연동상태 이상유무	유지
	피뢰기 (1,2차)		접지선, 카운터, 누설전류계 이상 등	신설
			누설전류 증감 여부	유지
			동작계수기 동작 유무	변경
			[과열개소 측정] 외관(에폭시) 및 접속부(1/2/3차)	신설
			[초음파 측정] 접속부(1/2/3차)	신설
			[피뢰기 진단] 누설전류 측정	신설
	한류리액터	계기	유온 적정 여부	유지
		붓싱	유면 적정 여부	유지
		한류리액터	[과열개소 측정] 본체 및 접속부	신설
	OLTC 및 부속장치	계기	OLTC TAP	
			OLTC 카운터	
			OFU 압력	
			유면	

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



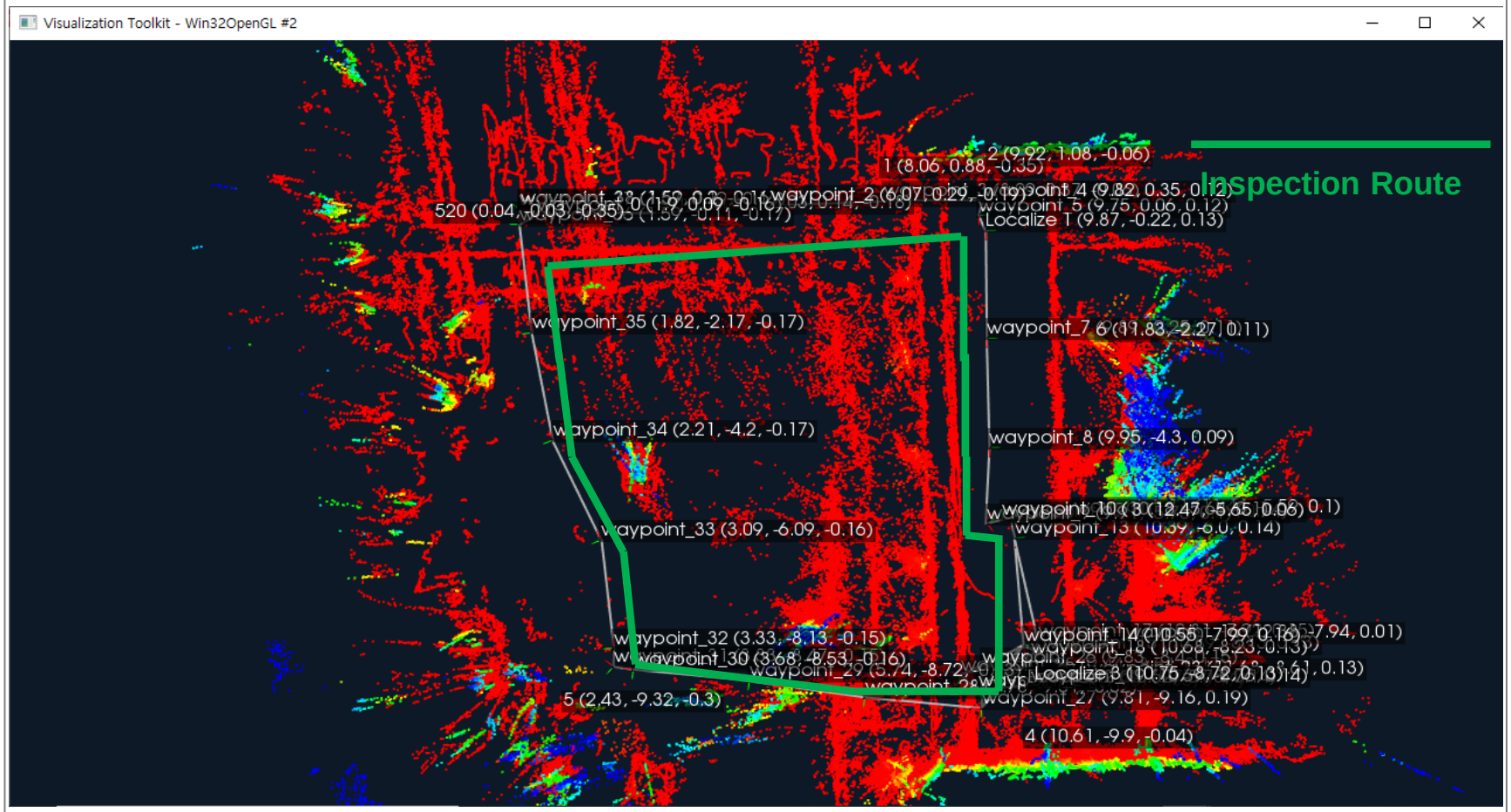
Path walk & Door Open

Climb steps & Rough terrain

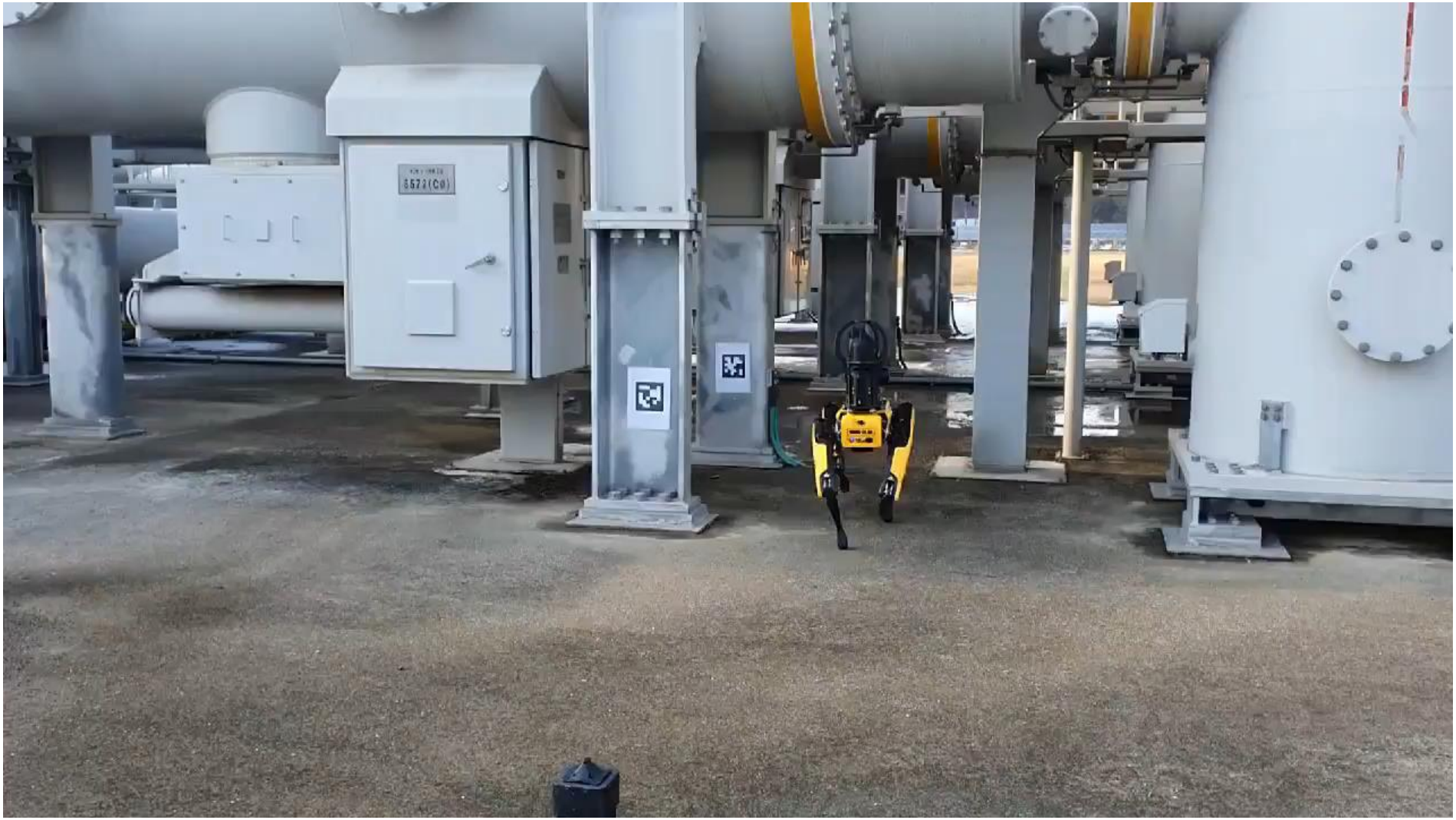
External & Internal Transformer Inspection

Substation Inspection using SPOT

Setup Inspection route



Substation Inspection using SPOT



Substation Inspection using SPOT

Robot arm for indirect live line work assistance

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

’18~ Indirect Live-line work with smart stick

Indirect Live-line work with compressor stick

Robot arm for indirect live line work assistance

Design of non-powered robot arm using gravity compensation mechanism

Thank You

KEPCO