EPRI UAS Workshop

Post-processing and AI
12/7/2021

Dexter Lewis, PE
Pr. Technical Leader
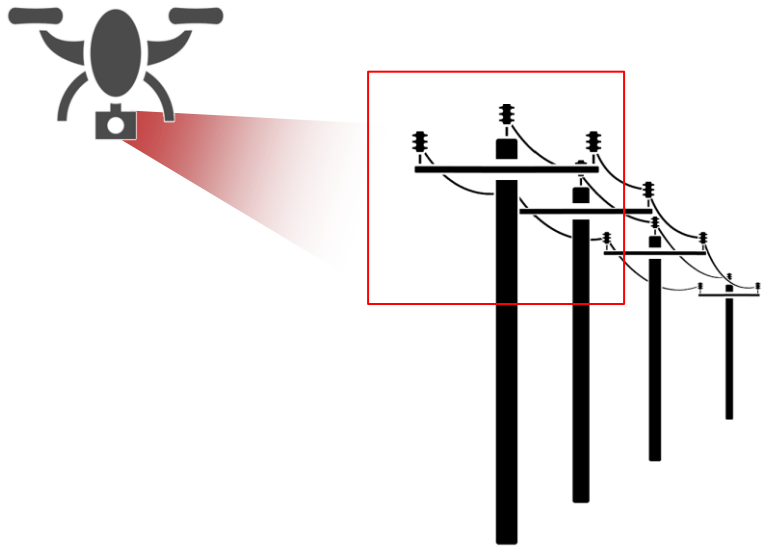EPRI T&D Systems
dlewis@epri.com

EPRI's research aim is to advance autonomous inspections.

The inspection process can consist of two steps:

Data Collection

Imagery, Video, LiDAR, etc

Data Analysis

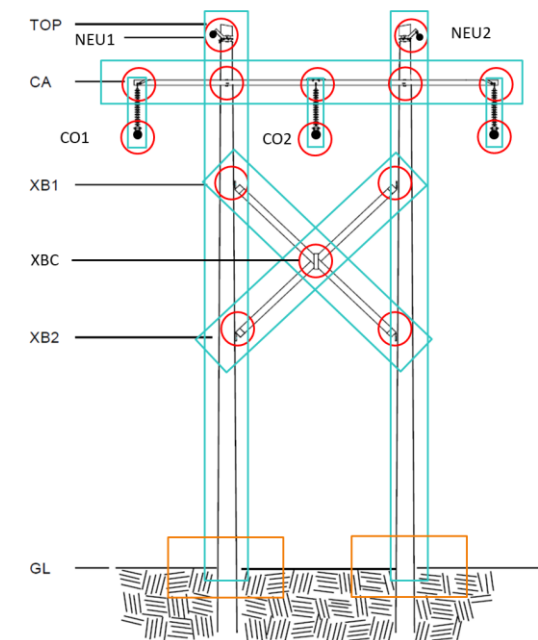Broken fiberglass arm and missing phase conductors

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Visual inspections are complex and subjective.

112 COMPONENTS

STRUCTURAL

Pole Structure Components | **Code**
- Bayonet — BAY
- Bracket — BR
  - *Bracket-Angle* — BRA
  - *Bracket-Crossarm* — BRC
  - *Bracket-X-Brace* — BRX
- Cable Brace — CB
- Crossarm — CA
  - *Alley Arm* — AA
  - *Crossarm-Distribution* — DCA
  - *Crossarm-Spar* — SCA
  - *Davit Arm* — DA
- Crossarm Brace — CAB
  - *Alley Arm Brace* — AAB
  - *Crossarm Brace-Distribution* — CBD
  - *Crossarm Brace-Compression* — CBC
  - *Crossarm Brace-Tension* — CBT
  - *Knee Brace* — KB
  - *Vee Brace* — VB
- Crosstie — CT
- Doubler Plate — DP
- End Plate — EP
- Ground Sleeve — GS
- Pole — PO
- Pole Cap — PC
- Slip Joint — SJ
- Vang — VA
- X-Brace — XB
- X-Brace Center Clamp — XCC

Guying Components | **Code**
- Anchor — AN
- Anchor Rod — ANR
- Guy Deadend — GD
- Guy Grip — GG
- Guy Marker — GM
- Guy Plate — GPL
  - *Guy Plate-Eye* — GPE
  - *Guy Plate-Hook* — GPH
- Guy Strain Insulator — GSI
- Guy Stub Pole — GPO
- Guy Wire — GUY
  - *Guy Wire-Distribution* — GUD
  - *Guy Wire-Foreign Attachment* — GUF
  - *Guy Wire-Conductor* — GUC
  - *Guy Wire-Shield Wire* — GUS
- Pole Band — PB
- Push Guy — PG
- Sidewalk Guy Brace — SGB

Foundation Components | **Code**
- Direct Embed Foundation — DEF

Climbing Components | **Code**
- Anti-Climbing Device — ACD
- Ladder — LAD
- Ladder Clip — LC
- Step Bolt — STB
- Step Nut — SN

Foreign Attachments | **Code**
- Cable Tv Attachment — CTV
- Light-Attachment — LGT
- Telecommunications Attachment — TEL

Reinforcement Components | **Code**
- Band (Splits) — BA
- Fre Wrap — FW
- Metal Encasement — ME
- Steel Truss — ST
- Wood Stub — WS

ELECTRICAL

Conductor, Shield Wire and Ground | **Code**
Wire Components
- Armor Rod — AR
- Conductor — CO
  - *Conductor-Distribution* — COD
- Counterweight — CW
  - *Counterweight-Conductor* — CWC
  - *Counterweight-Shield Wire* — CWS
- Ground Molding — GM
- Ground Pad — GP
- Ground Rod — GR
- Ground Wire — GW
- Jumper — JU
  - *Jumper-Conductor* — JUC
  - *Jumper-Shield Wire* — JUS
- Neutral — NEU
- Shield Wire — SW
  - *Fiber Optic Ground Wire* — FOG
- Shield Wire Connection — SWC
- Spacer — SPA
- Splice — SP
  - *Splice-Conductor* — SPC
  - *Splice-Ground Wire* — SPG
  - *Splice-Shield Wire* — SPS
- Vibration Damper — VD
  - *Vibration Damper-Conductor* — VDC
  - *Vibration Damper-Shield Wire* — VDS
- Yoke Plate — YP
- Wire Tie — WT

Insulator Components | **Code**
- Corona Ring — CR
- Insulator — IN
- *Insulator-Cold End Connection* — IC
- *Insulator-Hot End Connection* — IH
- *Insulator-Deadend Assembly* — IDE
- *Insulator-Horizontal Vee* — IHV
- *Insulator-Pin Type* — IPI
- *Insulator-Post Type* — IPO
- *Insulator-Shield Wire* — ISW
- *Insulator-Suspension Type* — ISU

Electrical Equipment Components | **Code**
- Arc Horn — AH
- Lightning Arrestor — LA
- Switch Assembly — SWI
  - *Switch-Handle* — SH
  - *Switch-Lock* — SL
  - *Switch-Shroud* — SS

GENERAL

Component | **Code**
- Light-Aerial — AL
- Marker Ball — MB
- Other (Specify) — OTH
- Pole Tag/Brand — PT
- Right-Of-Way — ROW
- Sign — SI
  - *Sign-Aerial Marker* — SIA
  - *Sign-Warning* — SIW
- Structure — STR

110 CONDITIONS

STRUCTURAL

General Structure Conditions | **Code**
- Bent — BE
- Burned — BN
- Damaged — DA
- Foreign Object — FO
- Hole in Member — HO
- Improper Installation — II
- Leaning Inline — LI
- Leaning Transverse — LT
- Lightning Damage — LD
- Missing — MI
- Non-standard Component — NS
- Plugged Holes — PL
- Unreadable — UR
- Worn — WO

Wood Component Conditions | **Code**
GENERAL
- Bow — BW
NATURAL
- Compression Wood — CW
- Cross Grain — CG
- Knot — KN
- Radial Check — RC
- Shake — SK
- Spiral Grain — SG
ENVIRONMENTAL
- Beetle Damage — ID
- Carpenter Ants — ID
- External Decay — ED
- Heart Rot — HR
- Marine Borer Tunnels — ID
- Pocket Rot — PR
- Shell Rot — SR
- Termites — ID
- Top Rot — TR
- Weathering — WT
- Woodpecker Damage — WD
MECHANICAL
- Compression Break — CB
- Delamination — DL
- Fire Damage — FD
- Fracture — FR
- Gaff Damage — GD
- Local Buckle — LB
- Split — SP
- Surface Abrasion — AB

Connection Conditions | **Code**
- Broken Connectors — BH
- Corroded Connectors — CH
- Disconnected — DC
- Distorted Connectors — DH
- Gaps Between Mating Parts — GA
- Hole Elongation — EL
- Loose Connectors — LH
- Loose Staples — LS
- Missing Connectors — MH
- Pin Backing Out — BO
- Slipped Connection — SH
- Worn Connectors — WH

Guying Conditions | **Code**
GENERAL
- Corrosion — CO
- Damaged Hardware — DA
- Worn — WO
GUY WIRE
- Broken Strands/Wire — BS
- Buried — BU
- Out-of-Lay — OL
- Slack Wire — SW
GUY ANCHOR
- Anchor Movement — MV
- Scour — ER

Foundation Conditions | **Code**
GENERAL
- Improper Embedment — EM
- Movement — MV
- Scour — ER
- Soil Deposits — SD

ELECTRICAL

General Electrical Conditions
- Bird Droppings — BD
- Burned — BN
- Corrosion — CO
- Damaged — DA
- Foreign Object — FO
- Improper Installation — II
- Inadequate Bonding — IB
- Lightning Damage — LD
- Loose Connections — LH
- Missing — MI
- Worn — WO
- Non-standard Component — NS

Conductor, Shield Wire, and Ground Wire Conditions
- Bad Splice — SB
- Birdcages — BC
- Broken Strands — BS
- Clearance, Phase to Ground — CG,
- Clearance, Phase to Phase — CP,
- Clearance, Phase to Structure — CS
- Corona — CN
- Interference — RF

Insulator Conditions
- Broken Bells — BB
- Contaminated — CN
- Flashed — FL
- Hole — HO
- Out-of-plumb — OP
- Tracking — TR

Line Hardware Conditions
- Disconnected — DI
- Slipped — SL
- Misaligned — MA
- Galvanizing Loss — GL
- Out-of-Lay — OL

Electrical Equipment Conditions
SWITCHES
- Burned — BN
- Insulation Damage — ID
- Misaligned — MA
- Worn — WO
LIGHTNING ARRESTORS
- Lightning Damage — LD

RIGHT-OF-WAY

Defect
- Danger Tree — DT
- Debris — DB
- Encroachment — EN
- Erosion — ER
- Foreign Objects — FO
- Locked Access — LA
- Standing Water — SW
- Vegetation — VE

Connection Points

Objects of Interest

Areas of Interest

EPRI's Taxonomies and Ontologies
- Distribution Taxonomy V0.9
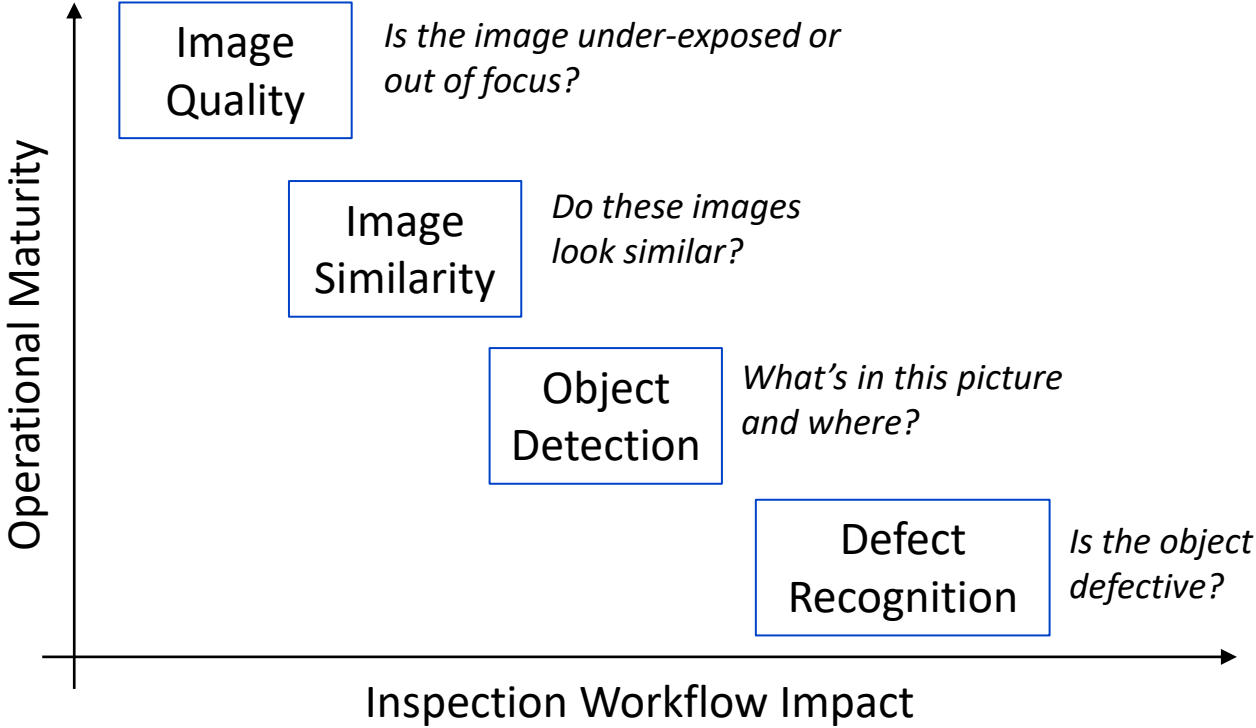- Transmission Taxonomy V0.6

Available here:
https://epri.box.com/s/ikx0xubpiihu698zqlooxgl9jwbd3cc2

Source: Assessment and Inspection Methods (AIM)-Methodology: Inspection Methodologies for Overhead Transmission Lines, EPRI, Palo Alto, CA, 2000. TR-108212-CD.

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AI/ML-based inspection models need to improve.

Inspection Requirement/ Taxonomy			Does an AI model exist?
Object	Attributes	Description	Class
Arresters	Conditions	Broken	Yes
Arresters	Conditions	Cracked/Chipped	No
Arresters	Conditions	Animal Guard Missing	No
Arresters	Conditions	Isolator Blown	No
Arresters	Conditions	Misaligned	No
Arresters	Conditions	Flashed/Burnt	Yes
Arresters	Conditions	Missing	No
Arresters	Type	Distribution	No
Arresters	Type	Riser Pole	No
Arresters	Material	Porcelain Housing	Yes
Arresters	Material	Polymer Housing	Yes

The previous slide noted the 100+ objects and the 100+ conditions…now consider the variability between equipment (type, material, manufacturer), image perspective, lighting, camera parameters…

AI/ML for Utility Inspection Imagery

Operational Maturity (vertical axis)

Image Quality — *Is the image under-exposed or out of focus?*

Image Similarity — *Do these images look similar?*

Object Detection — *What's in this picture and where?*

Defect Recognition — *Is the object defective?*

Inspection Workflow Impact (horizontal axis)

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Collaboration can accelerate dataset creation and benefit everyone.

There's not a lot of publicly available imagery of T&D infrastructure.

Risks and mitigations with industry collaboration:

- PII or sensitive information
  - Image scrubbing
  - Time/date can be removed.
  - Exif removal or translation code
    - https://github.com/pkulkarni-epri/DistributionTaxonomy
- Competitive advantage
  - Model vs. software development
- Asset health reputation and exposure
  - Industry data pooling

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EPRI is sharing data to address industry gaps.

- Taxonomies and License Forms
  - https://epri.box.com/s/ikx0xubpiihu698zqlooxgl9jwbd3cc2

- **Step 1:** Complete License Form
  - Creative Commons Attribution
  - Creative Commons Attribution + ShareAlike
- **Step 2:** Email ai@epri.com Completed License form(s)
- **Step 3:** EPRI to Send .zip file Download Links

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Labeled Insulator Defect Image Dataset (IDID)

400x4 Defect Images

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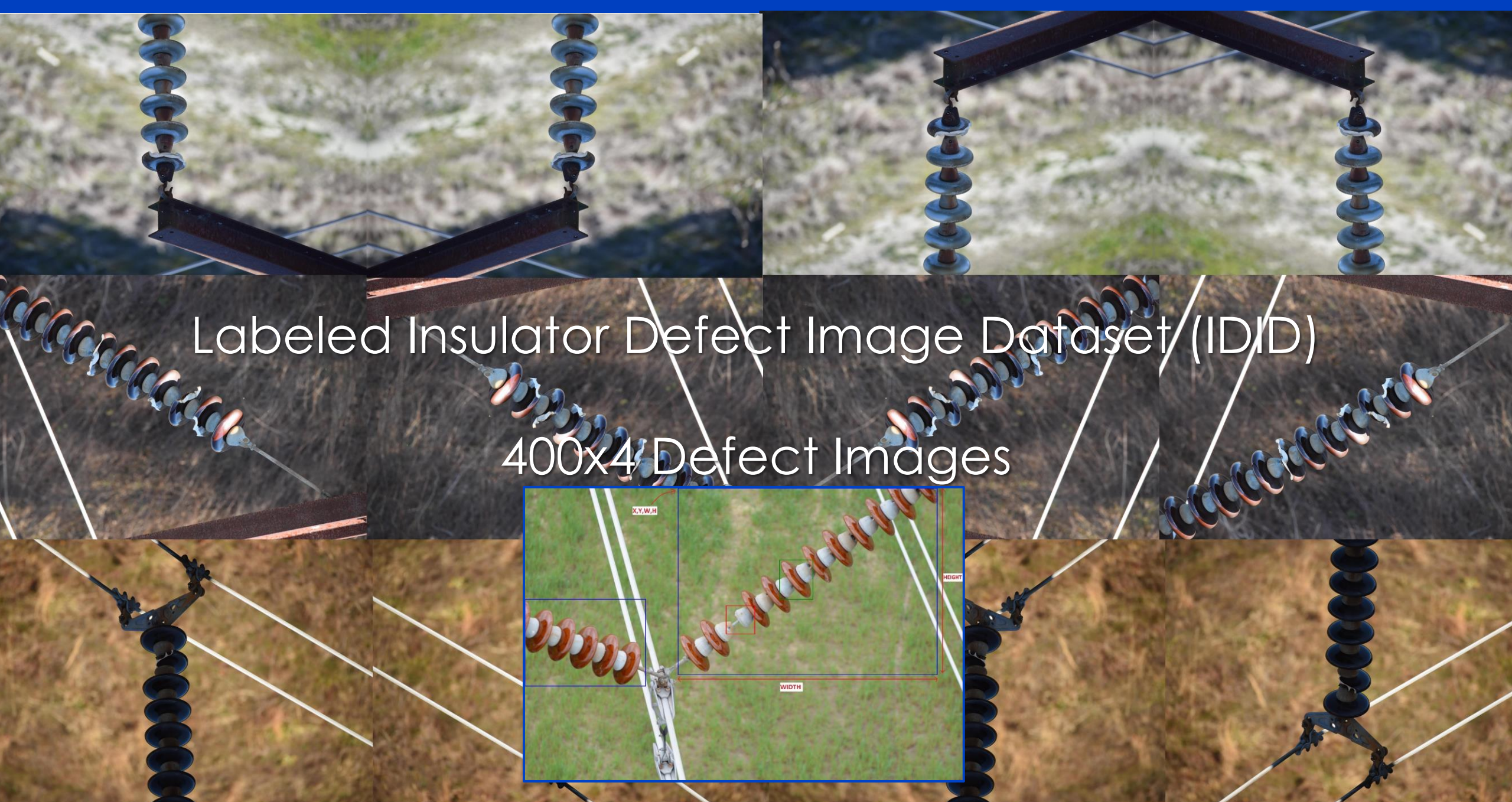
Labeled Synthetic Insulator Defect Image Dataset (S-IDID)

1000 Images

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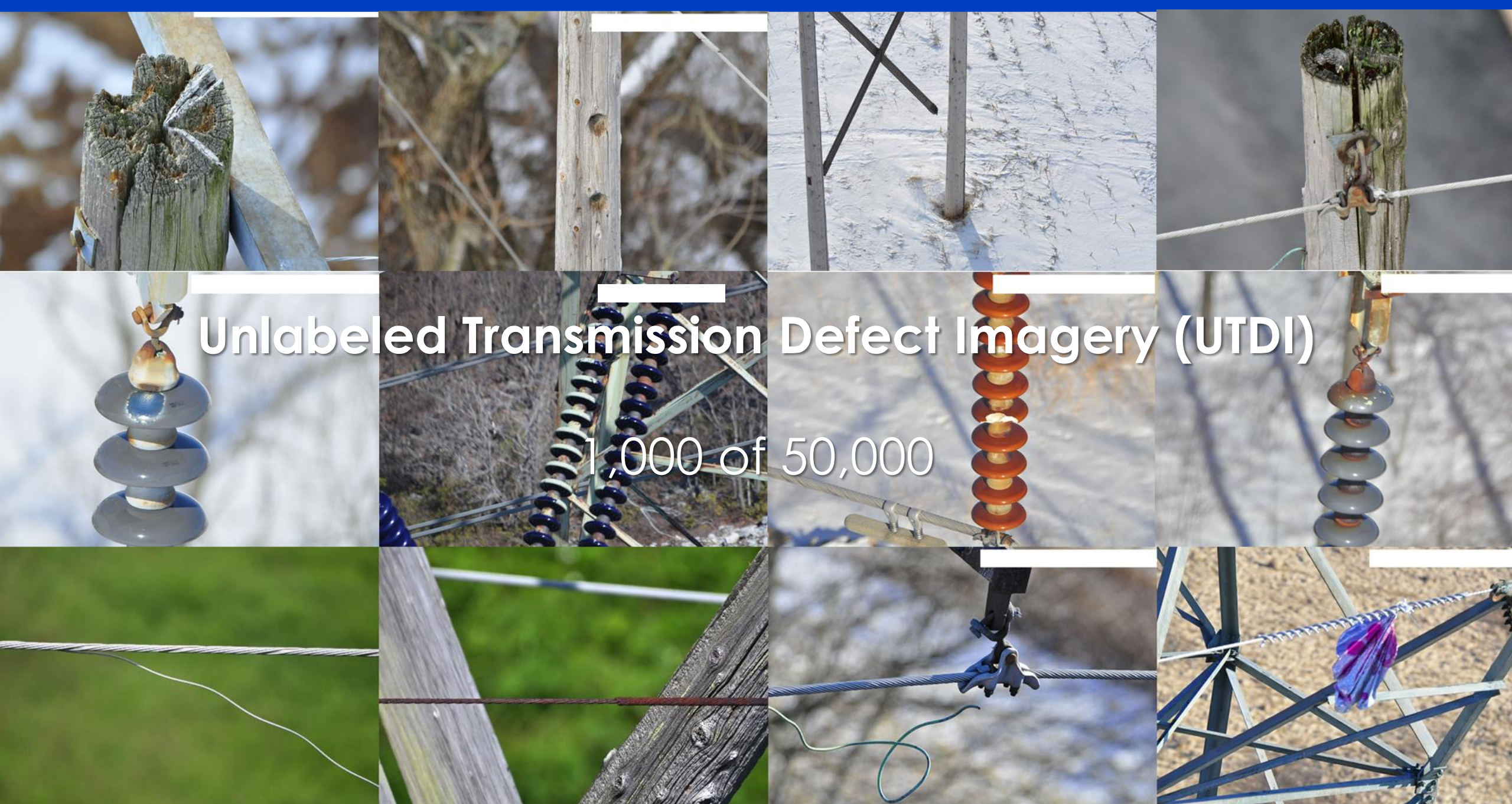
Unlabeled Transmission Defect Imagery (UTDI)

1,000 of 50,000

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Unlabeled Distribution Drone Dataset(DDD)

30,000 Images

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Coming Soon

Ground-based Imagery

Coming Soon

Imagery with Geospatial Data

Coming Soon

Distribution Equipment Assemblies
Imagery and Low-res Video

EPRI is hosting more data science competitions in 2022.

Submission-

"INSULATOR DEFECT DETECTION ALGORITHM OF TRANSMISSION LINE BASED ON YOLOV5", Nikheel Jain, Dr Jatin Bedi, *Thapar Institute of Engineering & Technology*

IoU threshold	Corresponding Mean Average Precision score
0.5	0.674
0.6	0.670
0.7	0.654
0.8	0.589
0.9	0.159

https://ieee-dataport.org/competitions/insulator-defect-detection

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3 Takeaways

Consider contributing to publicly available AI datasets

Consider contributing to labeling taxonomies and Share-a-Like datasets

Engage in industry data science competitions

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