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Drone Uses for Rail Infrastructure Monitoring & Maintenance
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TABLE OF CONTENTS

3  Defining the Problem and Scoping a Solution
4  Demonstration Partners and Roles
5  Demonstration Objectives
6  Mission Plan
8  Data Outputs and Insights
12 Recommended Best Practices: Developing a Drone Program
18 Recommended Best Practices: Advanced Data Needs and Connectivity

Photo courtesy of Kate Calabra
DEFINING THE PROBLEM AND SCOPING A SOLUTION

This Demonstration Offered a Proof-of-Concept for a Solution to a Defined Problem within Public Transit and Infrastructure

**PROBLEM**

Physical infrastructure – including roads, rail, bridges, utility equipment, and more – provides the foundation for thriving communities and local economies. Infrastructure monitoring, maintenance, and incident response are among the most important and resource-intensive responsibilities of public sector agencies and private partners.

**OPPORTUNITY**

Drone technology can facilitate real-time infrastructure monitoring, data collection, and computer-assisted analysis of infrastructure conditions to inform necessary interventions or response. Drone technology can offer a safer, more efficient approach when combined with current rail inspection processes and other use cases for transit agencies.

**SOLUTION**

City Tech Collaborative organized a team of industry-leading technology companies and civic partners to develop a demonstration for a drone system operating on an urban, public transit railway. This demonstration served as a proof-of-concept and offered insights on opportunities for operationalization and scaling a drone program across inspection and other railway use cases.
DEMONSTRATION PARTNERS AND ROLES

City Tech Collaborative Gathered a Team of Experts Across Transit, Telecommunications, Drone Aviation, and Machine Learning to Conduct a Drone Demonstration over Urban, Public Transit

**Ecosystem Development**: Led partner coordination, demonstration scoping, and demonstration execution.

**Telecom Infrastructure & Connectivity**: Provided technology for data storage and transfer as well as insights for scaling connectivity.

**Facility Owner/ Operator**: Provided direction on rail infrastructure monitoring requirements; Provided access to railway.

**Mission Design / Drone Operations**: Ensured compliance with FAA requirements and safety regulations; provided insights for operationalizing and scaling a drone program.

**Software, Data Management & Analytics**: Provided drone equipment and pilot for the demonstration; processed datasets to produce a summary of infrastructure conditions.
DEMONSTRATION OBJECTIVES

The Team Scoped a Formal Statement of Work with Three Target Objectives Capturing the Problem, Opportunity, and Needs for Continued Solution Development Regarding Remote-Based Infrastructure Monitoring

Deploy a drone demonstration to evaluate the feasibility and applicability of drones and machine learning to capture and analyze visual data related to railway infrastructure integrity and maintenance.

Provide examples of data and analysis that can support improved operational decisions around inspection and maintenance of railway infrastructure.

Identify best practices for a scalable and repeatable system for drone deployment that complements existing inspection procedures and addresses advanced data needs across multiple use cases.

Photo courtesy of Kate Calabra
Objective #1

Deploy a drone demonstration to evaluate the feasibility and applicability of drones and machine learning to capture and analyze visual data related to railway infrastructure integrity and maintenance.
DEMONSTRATION: MISSION PLAN

The Demonstration Included Multiple Drone Flights at Two Locations to Evaluate Feasibility and Capture a Range of Datasets.

- The demonstration was deployed at two locations in Chicago:
  - **CTA Orange Line:** The drone was launched on a CTA right-of-way near Pershing and Western. The drone traveled south within line-of-sight and returned to the launch point.
  - **CTA Blue Line:** The drone was launched at the California Landmark Station and traveled within line-of-sight between S. California Avenue and S. Western Avenue.
  - CTA staff assisted with train coordination and communication.

- The demonstrations occurred in controlled airspace.

- A DJI Matrice 600 Drone was deployed at both sites:
  - Drone set-up, health-checks, and break down required 1-2 hours to ensure successful and accurate performance.

- Each flight was between 5-10 minutes.
  - The drone traveled the center of the track to capture nadir imagery.
  - The drone traveled the side of the track to capture oblique imagery.

- The drone captured over 160 high-resolution images, LiDAR data, metadata, and PPK (geolocation) data.
  - Collectively, this data creates a comprehensive digital record of track condition with the exact location of the assets.
  - The ability to compare this record with manual inspections improves historical and real-time understanding of track integrity.

Photo courtesy of Kate Calabra
Objective #2

Provide examples of data and analysis that can support improved operational decisions around inspection and maintenance of railway infrastructure.
DEMONSTRATION: DATA OUTPUTS AND INSIGHTS

Data Collected During the Demonstration was Automatically Processed and Analyzed, Producing Results that Provide Insights on Track Health

- Data collected by the drone consisted of visual imagery, Lidar data, geospatial data, and other meta data.
  - The drone-collected data was stored on an SD card and then transferred to a secure Azure cloud platform for processing.
  - The data is owned and protected by the transit agency with limited permissions allowed to demonstration partners.
- AI-based software automatically processed the collected data to identify track components, make measurements, and perform analyses to assess track health.
  - The software accurately geolocates each track component or anomaly so that further inspection or repairs can be performed.
- Processed results from this demonstration include:
  - Tie spacing and tie skew measurements.
  - Cross-level heights of traveling rails and electrified rail.
  - Rail gap detection.
  - Joint bar and bolt/missing bolt detection.
  - Gage measurements.
DEMONSTRATION: DATA OUTPUTS AND INSIGHTS (CONTINUED)
Data Collected During the Demonstration was Automatically Processed and Analyzed, Producing Results that Provide Insights on Track Health

- The data collected and processed results are compiled into a comprehensive database.
  - The database serves as a detailed inventory of track assets geo-located within approximately 5 centimeters (2 inches).
  - The database also provides a digital record of track conditions in image and Lidar format.
  - Track / Asset Heath automatically determined.
- The database offers improved ability for short- and long-term decision making.
  - Results can be queried for consultation and/or integrated into existing railroad workflows.
  - Consistent, periodic data captures enables trend analysis to better understand and predict the health evolution of a track structure and identify operational inefficiencies.
  - Identifying inefficiencies early and often positions track operators to implement decisions that improve overall performance including opportunities for cost reduction, resource allocation, service reliability, and safety.

Photos courtesy of Ardenna
Data Collected During the Demonstration was Automatically Processed and Analyzed, Producing Results that Provide Insights on Track Health

- Limitations to flight performance and data collection throughout this demonstration were considered and will inform future flight plans.
  - This demonstration highlighted additional training tasks required for machine learning software such as:
    - Ability to identify and differentiate the electrified third-rail from other track components.
    - Ability to identify tie fastener types.
    - Ability to identify and differentiate rail tie material (composite, wood, concrete, etc.).
- During this demonstration, the drone experienced Electro-Magnetic Interference (EMI), which disrupted the ability to accurately establish GPS. Further investigations suggested to understand the cause and potential strategies to mitigate that limitation, especially in an urban setting.

Photos courtesy of Ardenna
Objective #3

Identify best practices for a scalable and repeatable system for drone deployment that complements existing inspection procedures and addresses advanced data needs across multiple use cases.
RECOMMENDED BEST PRACTICES: DEVELOPING A DRONE PROGRAM
A Successful Drone Program Will Follow a 5-Step Cycle to Ensure Efficiency and Allow for Continued Scaling

- Complete a Needs Assessment and Prioritize Use-Cases:
  - Determine prominent gaps in data or lapses in efficiencies and/or safety that can be supplemented by a drone.
  - Some use cases are less intensive than others, thus allowing for a smaller drone, more affordable payload, less skills required for piloting, and less demand on connectivity, storage, and compute for analysis.
  - Consider a trajectory for scaling a program upward based on priority use cases. Beyond track inspections, drones are applicable for additional use cases such as:
    - Security/surveillance along trainlines or in trainyards.
    - Public safety.
    - Facility and structure inspection.
**RECOMMENDED BEST PRACTICES: DEVELOPING A DRONE PROGRAM (CONTINUED)**

A Successful Drone Program Will Follow a 5-Step Cycle to Ensure Efficiency and Allow for Continued Scaling

- **Acquire Appropriate Drone Hardware and Software** based on:
  - Desired outputs determined in the needs assessment to select software and required payload features (e.g. video and photo resolution, GPS, LiDAR, photogrammetry, etc.).
  - Prioritization of general capabilities such as overall performance, ease-of-use, portability and storage, durability, etc.
  - Budget and preference to own or lease.
  - Required insurance policies and providers.
  - Ancillary capabilities required such as connectivity, data storage, processing, and analysis requirements (including at various scales).
RECOMMENDED BEST PRACTICES: DEVELOPING A DRONE PROGRAM (CONTINUED)
A Successful Drone Program Will Follow a 5-Step Cycle to Ensure Efficiency and Allow for Continued Scaling

- Develop Standard Operating Procedures by working with aviation specialists and across agency departments to develop and implement protocols including, but not limited to:
  - **Personnel training** such as pilots, visual observers, and other support.
  - **Compliance procedures** across FAA, local, and agency policies for airspace access, data sharing and usage, privacy, etc.
  - **Application and skills requirements for specialized waivers** such as beyond-visual-line-of-sight.
  - **Pre-Flight Operations** such as a confirming/programming a mission plan, site inspection, FAA approvals and temporary flight restrictions, required weather conditions, hardware/software “health check”, and any accompanying documentation.
  - **During-Flight Operations** such as requirements for flights in and beyond visual line of sight and flight team communications.
  - **Post-Flight Operations** such as confirming completed objectives, transferring data, and properly powering down equipment.
  - **Emergency Procedures and Accident Reporting** for incidents such as loss of datalink communications, loss of GPS, loss of power, etc.
  - **Site Management and Security** for ensuring safety.
RECOMMENDED BEST PRACTICES: DEVELOPING A DRONE PROGRAM (CONTINUED)

A Successful Drone Program Will Follow a 5-Step Cycle to Ensure Efficiency and Allow for Continued Scaling

- **Develop Staff Training and Skills Development Protocol** to train pilots, visual observers, other staff engaged in flight communications, and staff designated to train peers. This protocol may include:
  - FAA Pilot Certification(s) and any local permits required.
  - Minimum completed flight hours.
  - Minimum proficiency requirements in UAS operations, aircrafts, and associated equipment.
  - Advanced training for special waivers and other high-skill use cases.
  - Recurrent training schedule to maintain proficiency and develop new skills as needed.
RECOMMENDED BEST PRACTICES: DEVELOPING A DRONE PROGRAM (CONTINUED)
A Successful Drone Program Will Follow a 5-Step Cycle to Ensure Efficiency and Allow for Continued Scaling

- **Schedule Routine Evaluations** to inform any necessary decisions that need to be made within the drone program.
- This evaluation positions an agency to restart the cycle and consider any changes such as:
  - Adjustments to improve program efficiencies or safety.
  - Identifying new priority use cases.
  - Incorporating opportunities for scaling up or down.
  - Implementing required advancements or upgrades to the hardware or software to match new efficiencies or scaling.
  - Ensuring all changes align with or are reflected within Standard Operation Procedures.
RECOMMENDED BEST PRACTICES: ADVANCED DATA NEEDS AND CONNECTIVITY

As Data Needs Advance and a Drone Program Grows, Connectivity will become Increasingly Important and Must Scale with Demand

Cellular-connected drones equipped with high-resolution mobile cameras can be used to quickly inspect a large expanse of the railway and closely monitor, facilitate, and revolutionize railway inspection processes and procedures.

The captured high-resolution footage can be reviewed using cloud-based video analytics to identify anomalies and proactively create railway infrastructure repairs.

Provide Private 5G network to offload all the imagery files with immediate response to high data bandwidth requirements.

Multi-access 5G Edge computing (MEC) to process and store data at the network’s edge, allowing for faster processing of extensive imagery data. This allows for machine learning and improves future outcomes with the analyzed data.
THANK YOU

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