Digital Manufacturing and Analytics: R&D Perspectives for Aerospace MRO

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Aerospace MRO R&D Opportunities

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Technology development and insertion:

- Scalable, flexible machine sensor retrofit for legacy equipment
- Flexible digital architecture for manufacturing big data problems
- Digital asset tracking and health monitoring
- Machine learning methods for automated fault diagnosis
- Edge-based monitoring and control
- Human in the loop for part inspection and condition monitoring

Workforce development:

- Applications development for cloud-based analytics
- Hardware sensor deployment and reconfiguration
- Future of work in manufacturing – training automated systems

Reconfigurable machine sensing

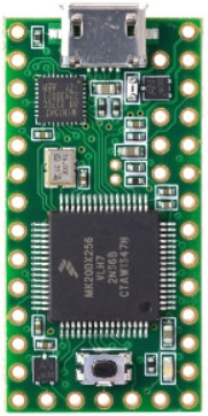
<u>Goal</u>: support diverse mix of legacy/modern equipment platforms

<u>Objective</u>: develop standardized IIOT sensor kit for non-intrusive sensing

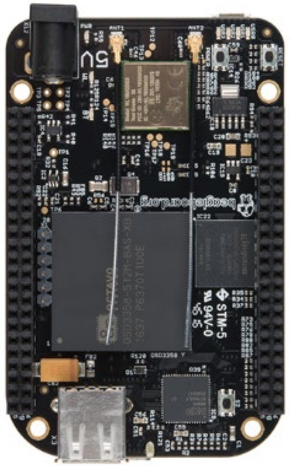
Current Sensor Reads Motor/Laser Current

Temperature Sensor Reads Motor Temperature

Accelerometer Reads Vibration from Motor Bearings/Spindle



Arduino Teensy samples sensor values



BeagleBone Black Wireless transmits data via Node-Red

Applications: Motor Health (Preventative Maintenance), Production Throughput, Machine Usage

Flexible machine data communication

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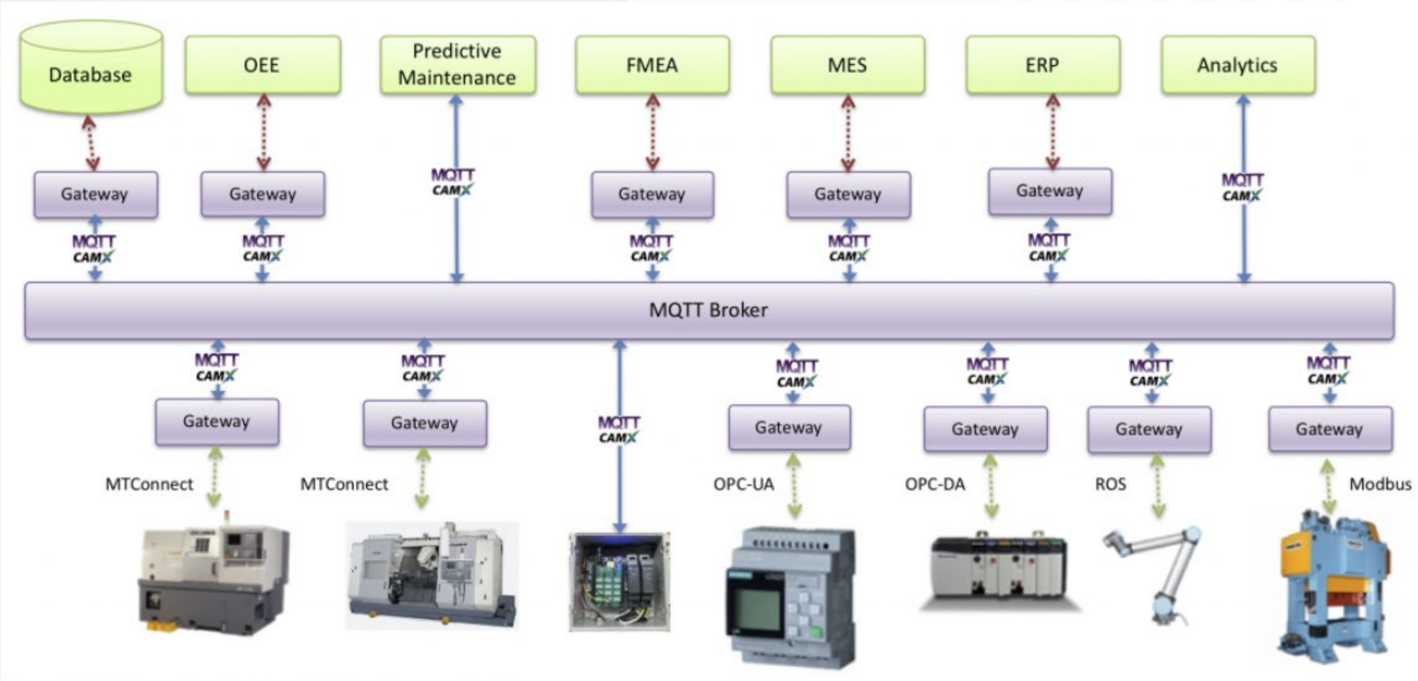
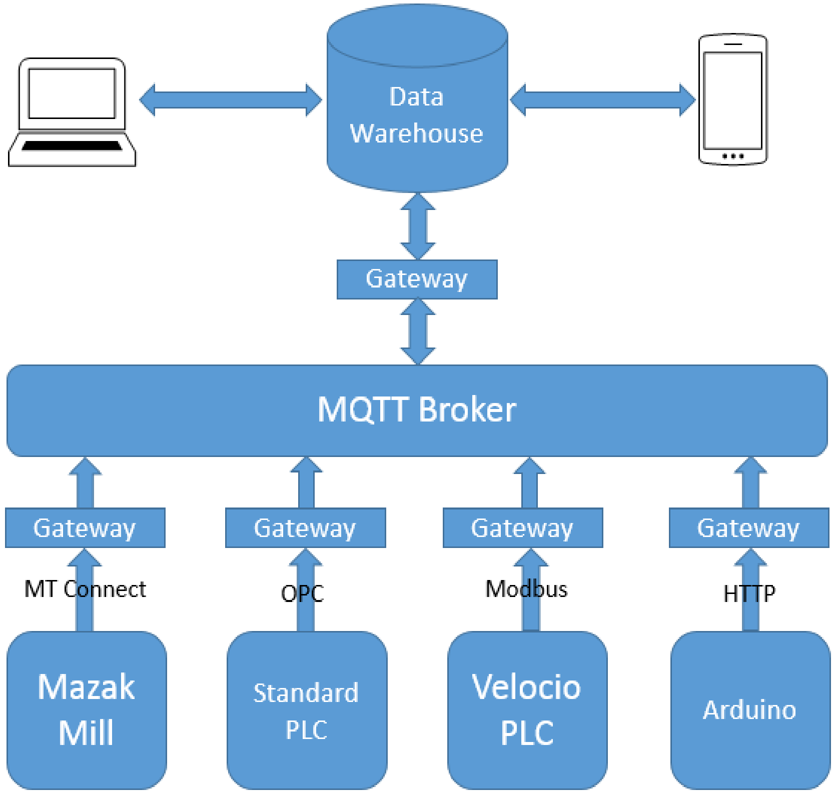
Goal: provide flexible data communication using common architecture

Objective: implement hybrid publish/subscribe architecture based on MQTT





HITL augmented part inspection

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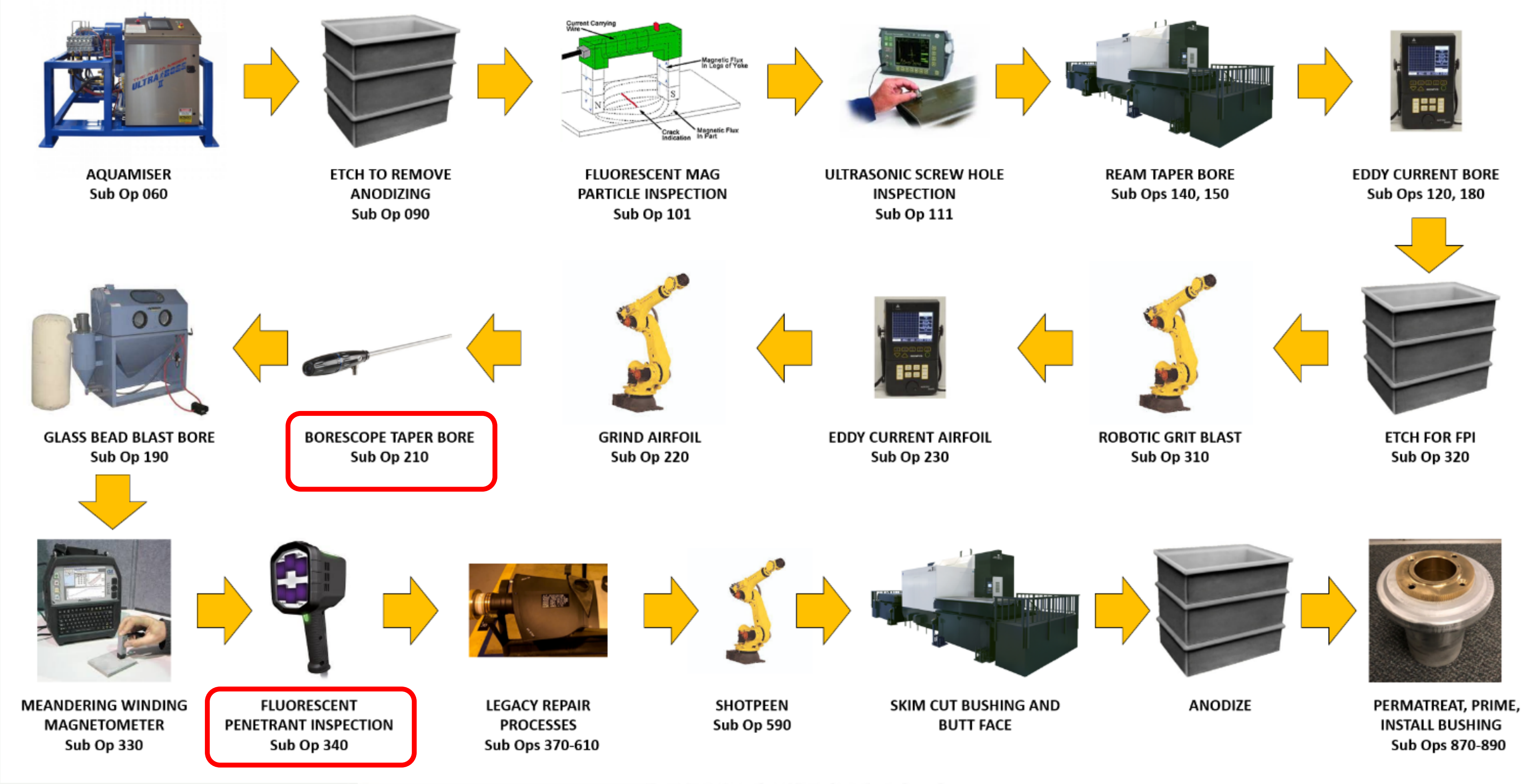
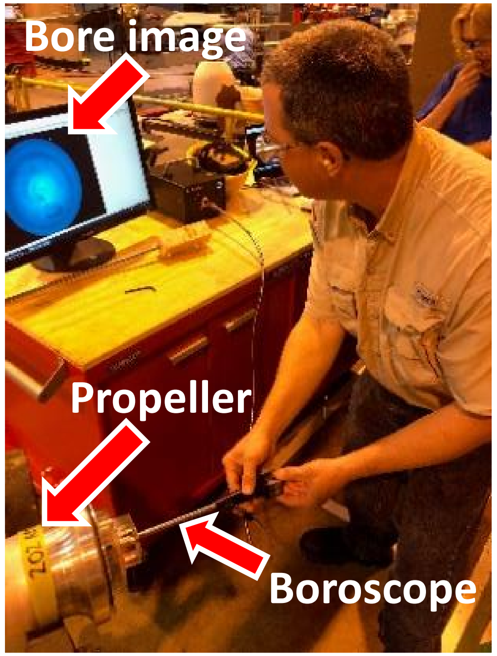
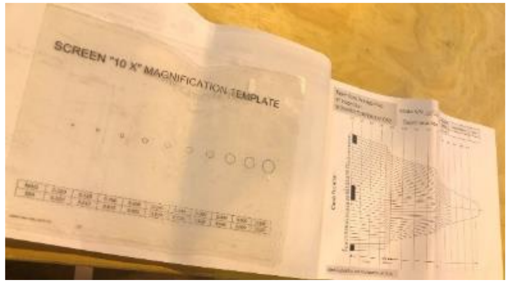
Product Repair and Inspection Sequence







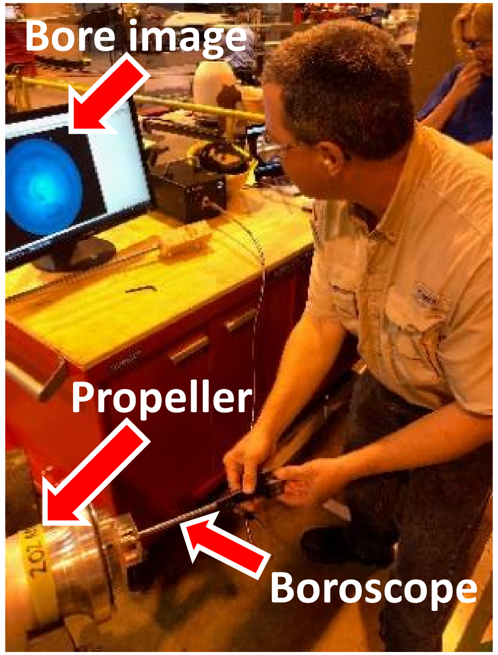
HITL augmented part inspection

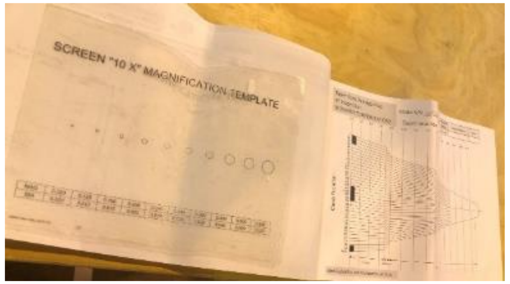
Current inspection process:

- FP dye inspection used to highlight defects on bore surface
- Robotic boroscope system automatically takes 455 images/blade
- Boroscope traces helical path, images at axial/angular positions
- CMXG personnel must visually confirm each image
- Approximate time for image collection: 5 minutes/blade
- Time for manual defect identification: 2 hours/blade

Future inspection process:

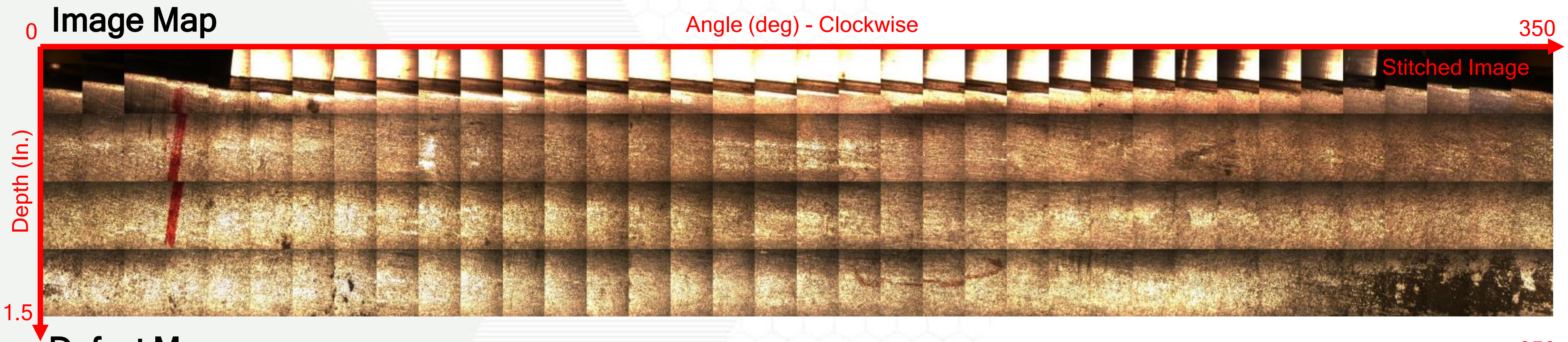
- Utilize automated image analysis methods to flag suspect images, highlight defects for operators to verify, and reduce cognitive workload within a human in loop framework
- Balance type I (false positive) and type II (missed detection) errors
- Display computer-generated map of errors across bore surface





HITL augmented part inspection

Convolutional Neural Network Approach



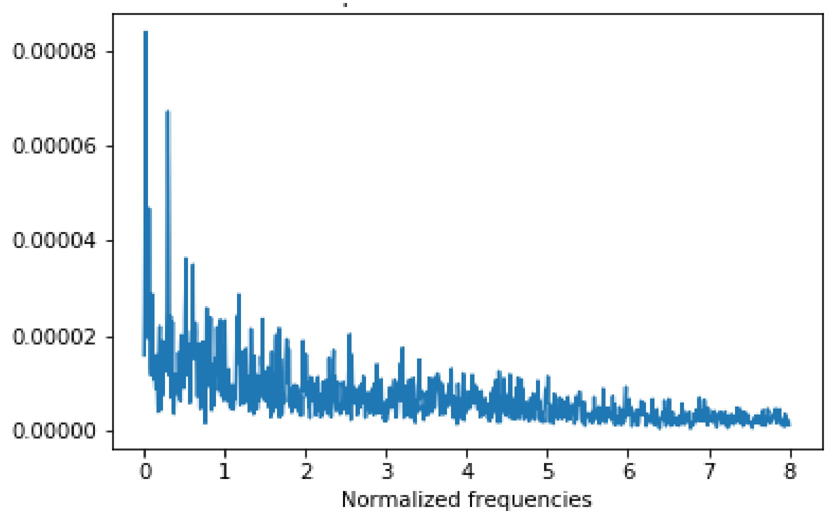
HITL augmented condition monitoring

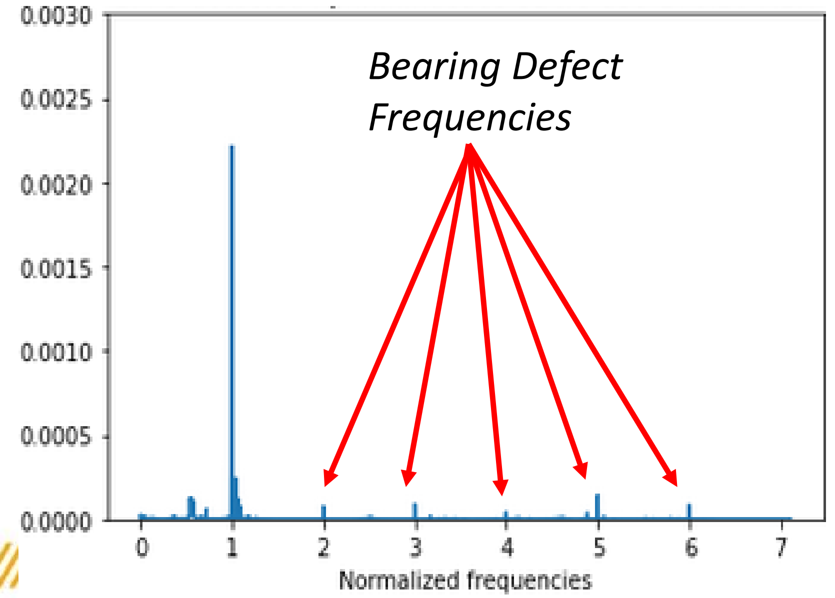
Goal: Identify BPFO/BPFI defects automatically on large roll bearings

- Manufacturer monitoring hundreds of bearings
- Currently bearing defects are caught very late at the stage of failure with RMS detection
- Experienced engineers visually determine presence of BPFO/BPFI faults

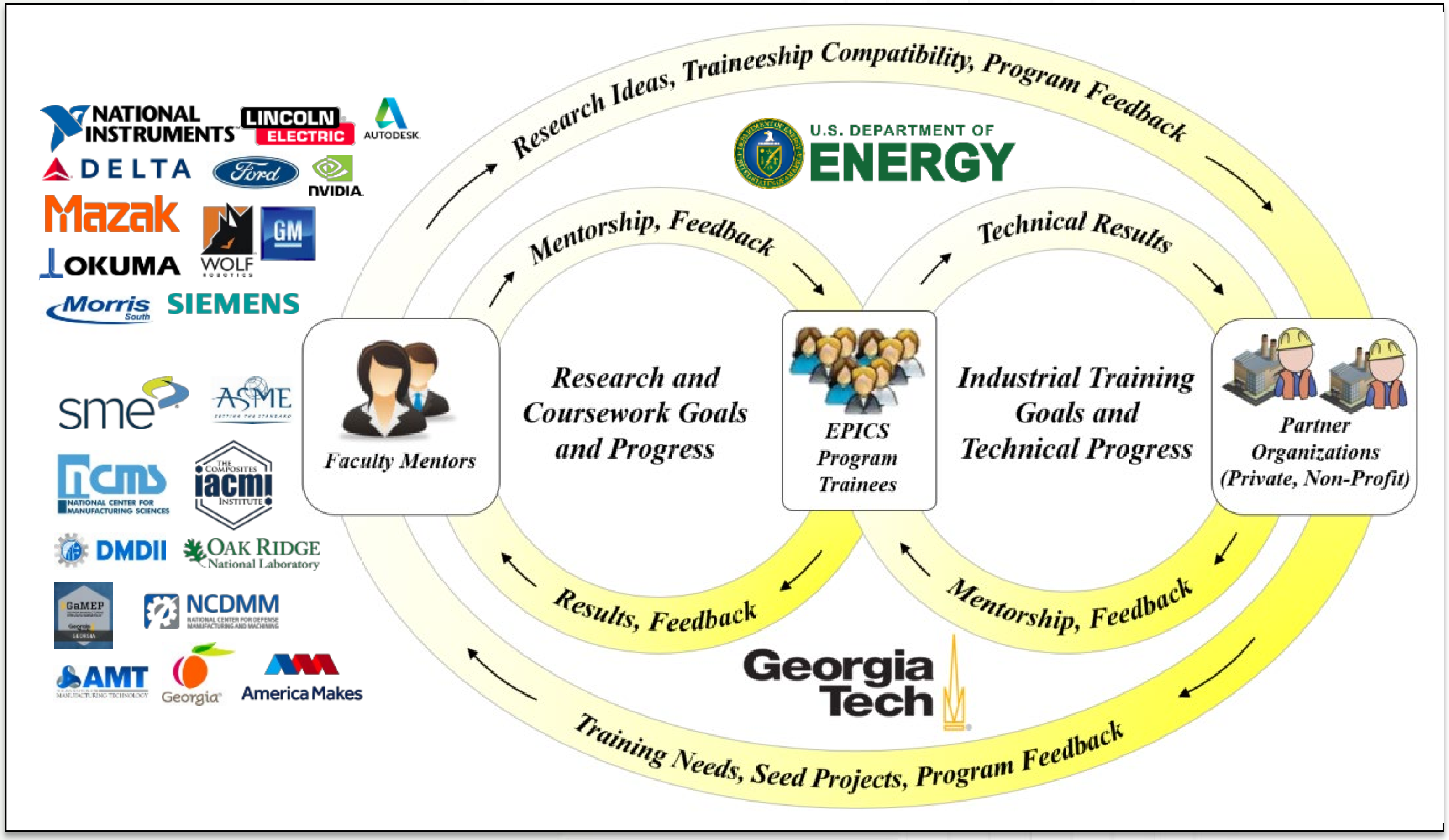
Approach: automated fault detection using pattern recognition algorithms

- Low type II error, controllable type I error
- Time required per bearing: 0.5 seconds





Workforce development for IIOT (EPICS)



Case Examples: supporting operators

Bearing fault detection

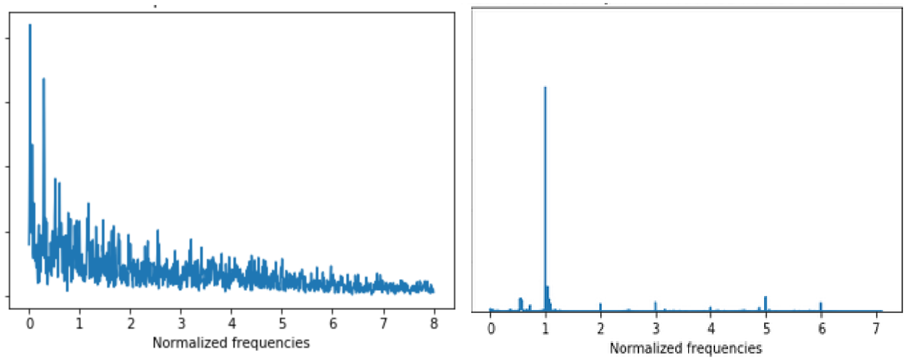
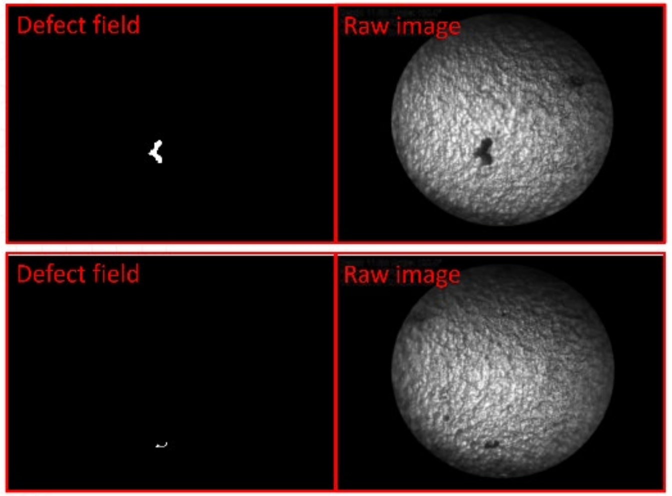


Image defect classification



Cross-level teams: pairing operators with embedded technology developers

Target projects: sensor retrofit, process monitoring, root cause analysis, sensor fusion

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