CENTER OPERATIONS DIRECTORATE

Intern Exit Presentation

Maximo Hierarchy Graph Data Visualization & Machine Learning for Time Series Predictive Maintenance

ALBERT GALIMOV   12/08/2025

OSTEM INTERNSHIP PROGRAM

About Me

- Master's Student in Computer Science
  - University of Massachusetts (UMass), Amherst

- Automation and Control Engineer
  - Automated Traffic Control Systems, Russia

- Research Student Assistant
  - Fraunhofer, Germany

- AI Mentorship Program through UMass
  - Apple Team (Extern)

- NASA Langley Research Center Intern

Agenda

− Maximo Hierarchy Graph Data Visualization (Project 1)

− Machine Learning for Time Series Predictive Maintenance (Project 2)

− Potential Future Solutions for Predictive Maintenance (Project 3)
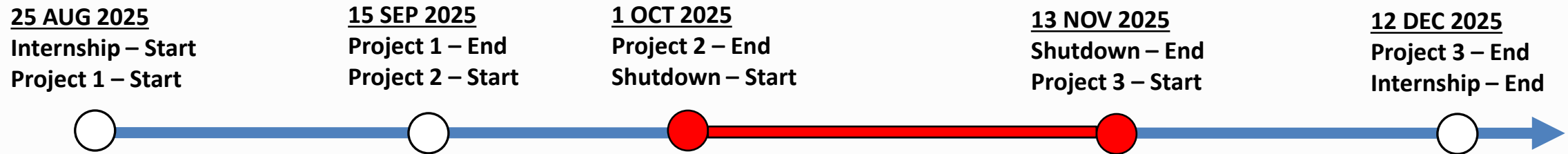
− Questions

About NASA Langley Research Center (LaRC)

- Founded: July 17, 1917

- Location: Hampton, VA

- People: 3,400+

- Facilities: 200+

- Focus: aviation, expand understanding of Earth's atmosphere, and develop technology for space exploration

Resource: https://www.nasa.gov/langley/

Internship Timeline

25 AUG 2025
Internship – Start
Project 1 – Start

15 SEP 2025
Project 1 – End
Project 2 – Start

1 OCT 2025
Project 2 – End
Shutdown – Start

13 NOV 2025
Shutdown – End
Project 3 – Start

12 DEC 2025
Project 3 – End
Internship – End

Maximo Hierarchy Graph Data Visualization

Maximo Hierarchy Graph Data Visualization

- **Current Challenge:** Data Management in Maximo Computerized Maintenance Management System (CMMS)

  Maximo: maintenance asset and work order tracking

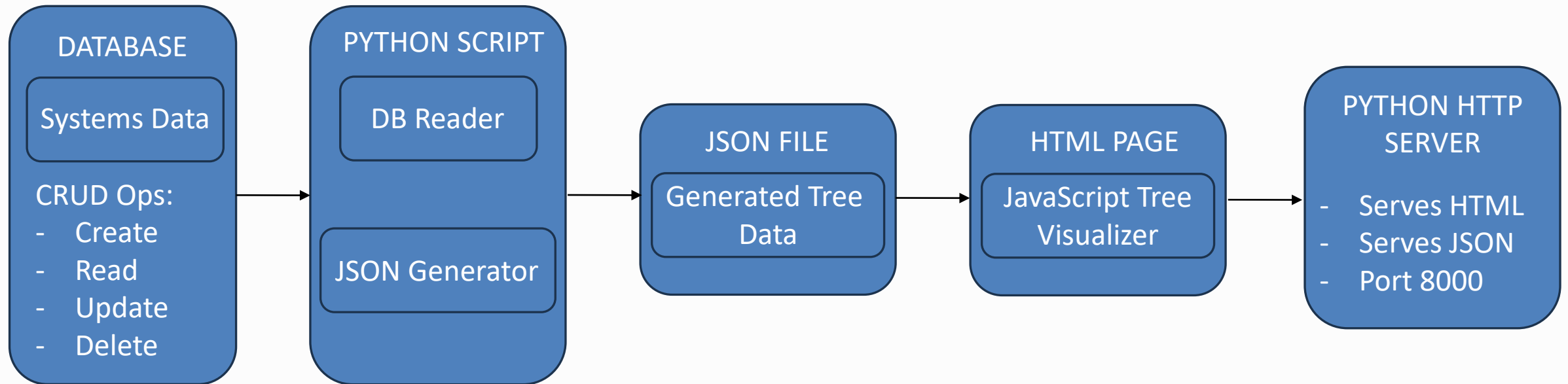- Assets taxonomic hierarchy lacking intuitive visualization
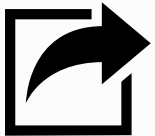
- NASA transition to *Enterprise CMMS (eCMMS)*

- **Goal**: develop intuitive Maximo hierarchy visualization mechanism to facilitate updates from LaRC's Maximo data to the new eCMMS schema

Web Application flow


```
DATABASE
  [ Systems Data ]
  CRUD Ops:
  - Create
  - Read
  - Update
  - Delete
```
→
```
PYTHON SCRIPT
  [ DB Reader ]
  [ JSON Generator ]
```
→
```
JSON FILE
  [ Generated Tree Data ]
```
→
```
HTML PAGE
  [ JavaScript Tree Visualizer ]
```
→
```
PYTHON HTTP SERVER
  - Serves HTML
  - Serves JSON
  - Port 8000
```

Initial code for JavaScript Tree Visualizer provided by Braxton VanGundy

Web Application Back-end

Before update:

BUILDING 100

BUILDING 200

```
[
    {
        "file": "data\\BUILDING 100.json",
        "name": "BUILDING 100"
    },
    {
        "file": "data\\BUILDING 200.json",
        "name": "BUILDING 200"
    }
]
```

After update:

BUILDING 100

BUILDING 200

BUILDING 300

BUILDING 400

```
[
    {
        "file": "data\\BUILDING 100.json",
        "name": "BUILDING 100"
    },
    {
        "file": "data\\BUILDING 200.json",
        "name": "BUILDING 200"
    },
    {
        "file": "data\\BUILDING 300.json",
        "name": "BUILDING 300"
    },
    {
        "file": "data\\BUILDING 400.json",
        "name": "BUILDING 400"
    }
]
```

Web Application Interface
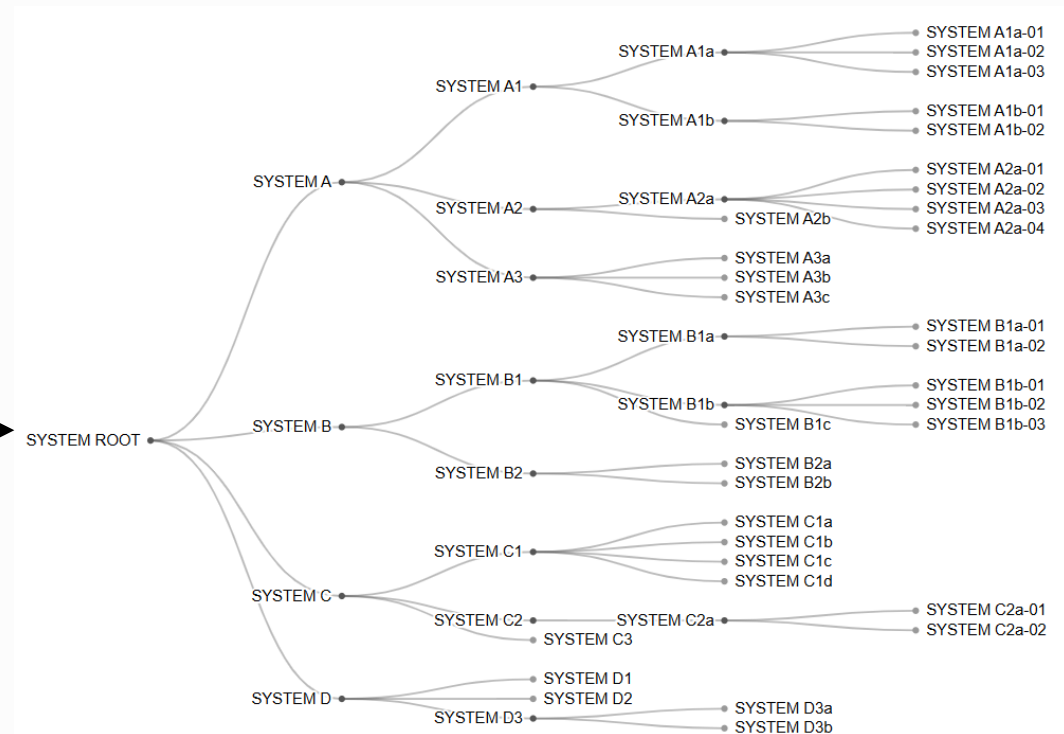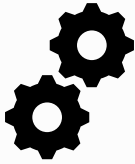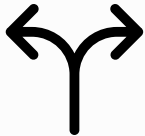
Results

- **Real-Time Visualization:** web interface displaying Maximo hierarchy data with building selectability

- **Optimized Data Pipeline:** lightweight pipeline handling data retrieval, updates, and reload operations for large-scale maintenance data
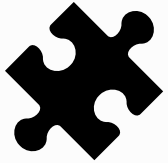
- **Scalable Architecture:** continuous improvement framework

- **Database Extensibility & Adaptability:** modular solution adaptable to any taxonomic hierarchy

Machine Learning for Time Series Predictive Maintenance

Machine Learning for Time Series Predictive Maintenance

- **Maintenance Timeline Opportunity**: develop ML models for expanded lead-time for predicting eminent maintenance system failures
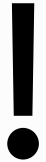
- **Operational Risk & Cost Impact:** Unexpected equipment failures compromise system reliability
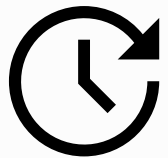
- **Predictive Opportunity:** AI and Machine Learning (ML) for time series predict maintenance

Predictive Maintenance Pipeline

DATA COLLECTION

- Aveva Pi Sensor Data
- Maximo Work Orders
- Langley AFB Weather Data

LABEL CREATION

- Days to failure
- Binary Labels

MODEL TRAINING

ML Algorithms

PREDICTION

- Days to Failure
- Maintenance Alerts
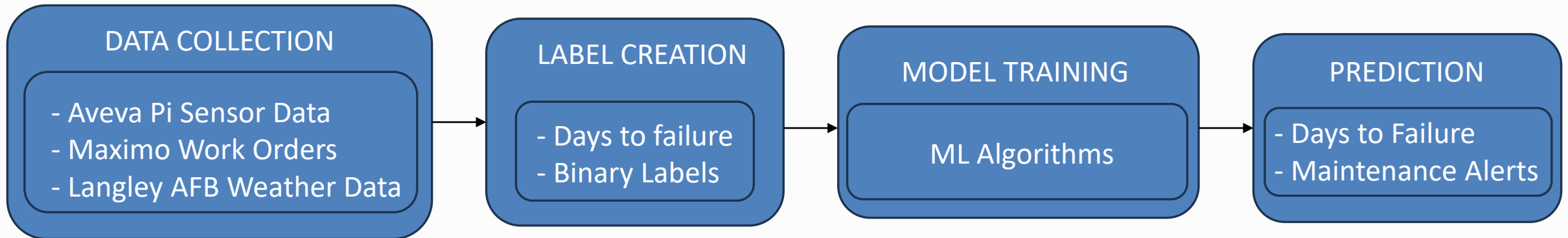
Data for Machine Learning Model

Aveva PI: Data Management Platform that collects and stores historical data

GB	Gearbox
InBrg	Inboard Bearing
OutBrg	Outboard Bearing
OB	Outboard
IB	Inboard
PeakVue	Method of measuring vibration
Overall	Another method of measuring vibration
PMPA	Pump A
PMPB	Pump B
CBM	Condition Based Maintenance
IOC	Integrated Operations Center
AlertFlag	Low setpoint for vibration measurements
AlarmFlag	Higher industry standard setpoint for vibration measurements
CLTA	Cooling tower A

Maximo Data: Computerized Maintenance Management System (CMMS). Asset and work order tracking

Worktype	Description
CBMF	Condition-Based Maintenance Find
REPR	Repair
PM	Preventative Maintenance
PTIF	Predictive Testing & Inspection Find
SSR	Service Support Request
PMF	Preventative Maintenance Find
REPR	Repair
TC	Trouble Call
MREA	Maintenance & Reliability Engineering (or Effects) Analysis

Previous Intern Work

◦ Previous intern work was implemented combining XGBoost Algorithm which uses gradient boosting for ensemble learning, along with cross validation and hyperparameter tuning

Results of previous work:

Naïve Benchmark: **39.43 days remaining useful life (RUL)**

Model Overall Average: **~41 days RUL**

A Naïve baseline is the simplest possible model that serves as a performance benchmark (represents predicting the underlying probability distribution of the predicted value)

Model is similar to the Naïve estimation, indicating poor current performance

New approach

- Recurrent Neural Network (RNN) for capturing temporal patterns
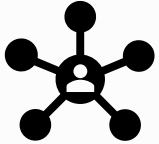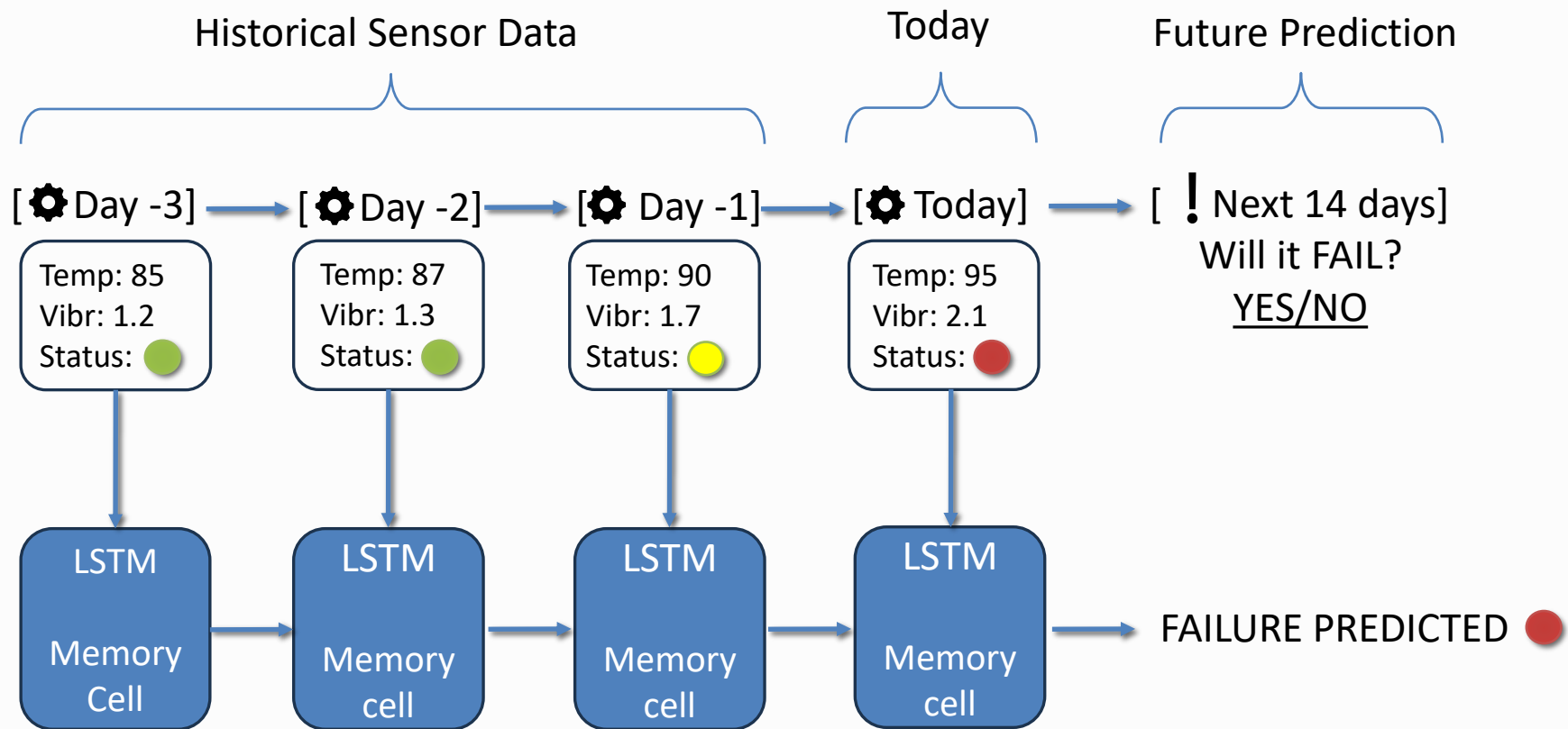
- Long Short-Term Memory as RNN approach - long-term patterns for early failure detection

- Binary classification approach - predict failure within 14 days vs. continuous time-to-failure estimation

Long Short-Term Memory (LSTM)

Historical Sensor Data

Today

Future Prediction

Temperature: Temp
Vibration: Vibr

[⚙ Day -3] → [⚙ Day -2] → [⚙ Day -1] → [⚙ Today] → [! Next 14 days]
Will it FAIL?
YES/NO

Temp: 85
Vibr: 1.2
Status: 🟢

Temp: 87
Vibr: 1.3
Status: 🟢

Temp: 90
Vibr: 1.7
Status: 🟡

Temp: 95
Vibr: 2.1
Status: 🔴

LSTM Memory Cell → LSTM Memory cell → LSTM Memory cell → LSTM Memory cell → FAILURE PREDICTED 🔴

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Labels generation

- **Approach 1**: Predict days until failure

- **Approach 2**: Create binary labels if failure happens within specific window days

Equipment ID	Days until failure	Failure within 14 days?
Pump-001	45 days	No
Pump-002	12 days	Yes
Pump-003	78 days	No
Pump-004	3 days	Yes
Pump-005	32 days	No

Result

Note: experiments with various dataset configurations, labeling approaches, and ML models presenting results from three representative models.

Failure Prediction: Model Comparison by F1-Score
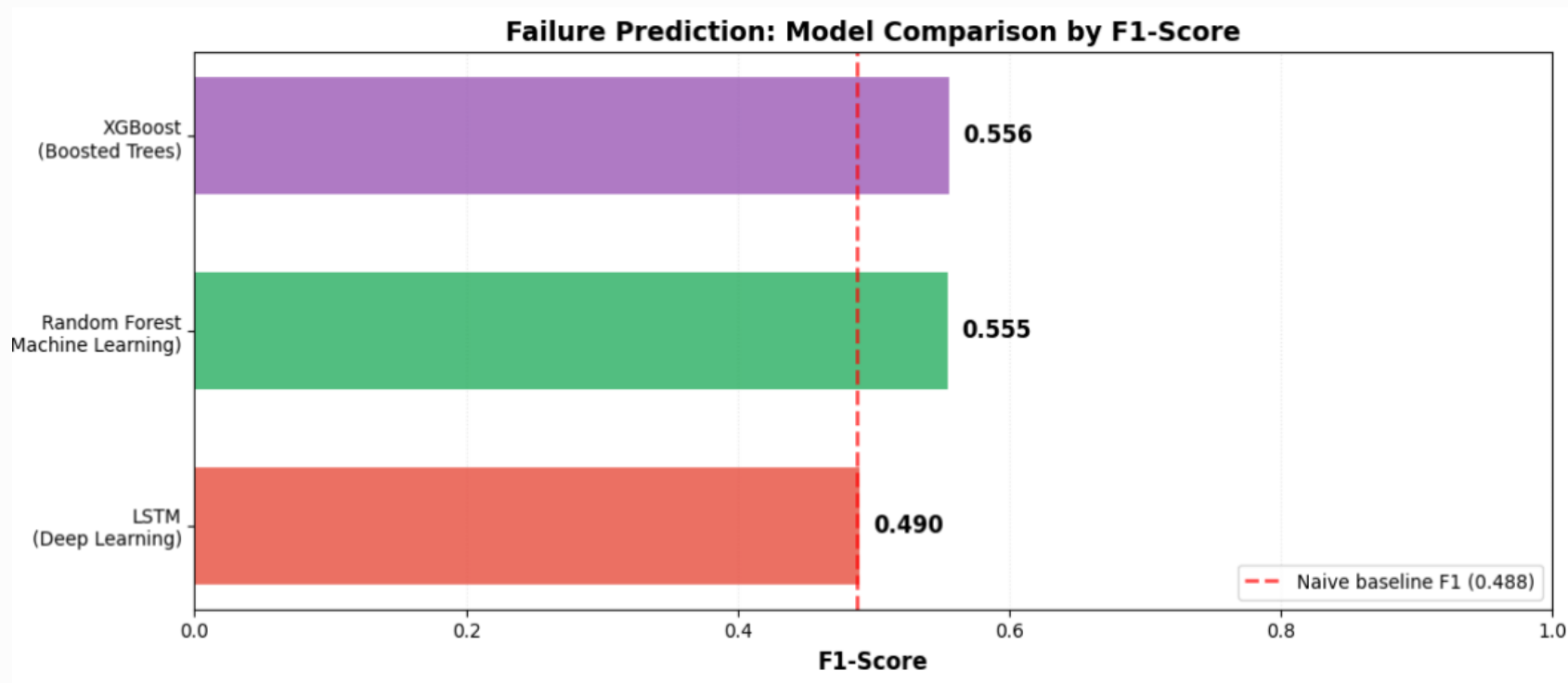
The F1 score is a measurement of accuracy that balances two factors and ranges from 0 to 1:

- How many correct positive results your model found (recall)

- How many of your model's positive predictions were actually correct (precision)
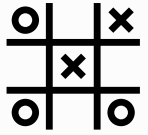
Conclusion

- Insufficient predictive signal with ML models performing only marginally better than naive baselines

- Future work: explore additional sensor modalities and data collection strategies, guided by subject matter expertise

Potential Future Solutions for Predictive Maintenance

Potential Future Solutions for Predictive Maintenance
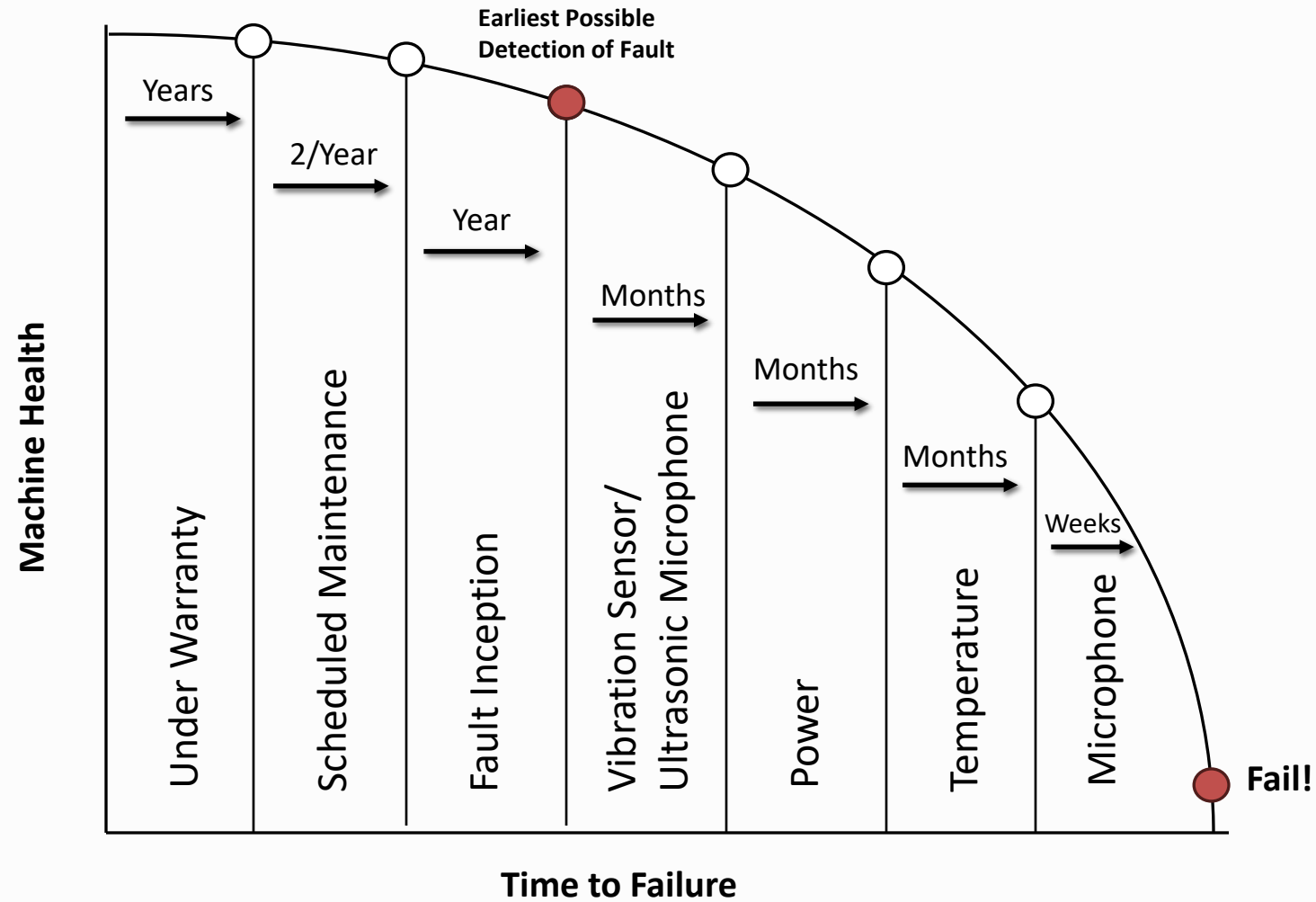
Current approach: amplitude-based accelerometer measurements

Limitation: early-stage bearing/gear defects: subtle vibrations typically undetectable via amplitude measurements

Solution: potential frequency-based accelerometers + acoustic sensors

Machine Health

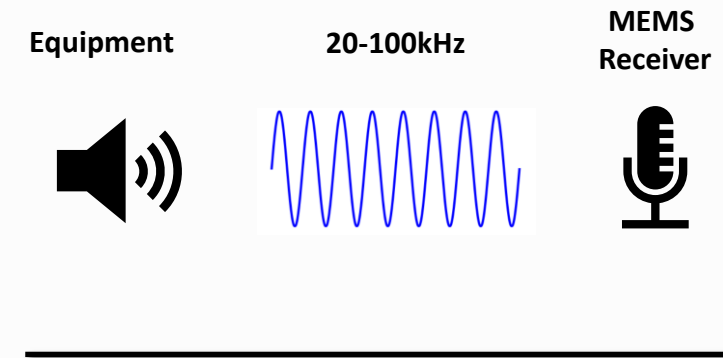# MEMS (Micro-Electro-Mechanical Systems) Ultrasonic Microphones

Capability: monitors non-audible frequencies

Benefits: directive ultrasonic signals with precise fault localization in bearings and housings
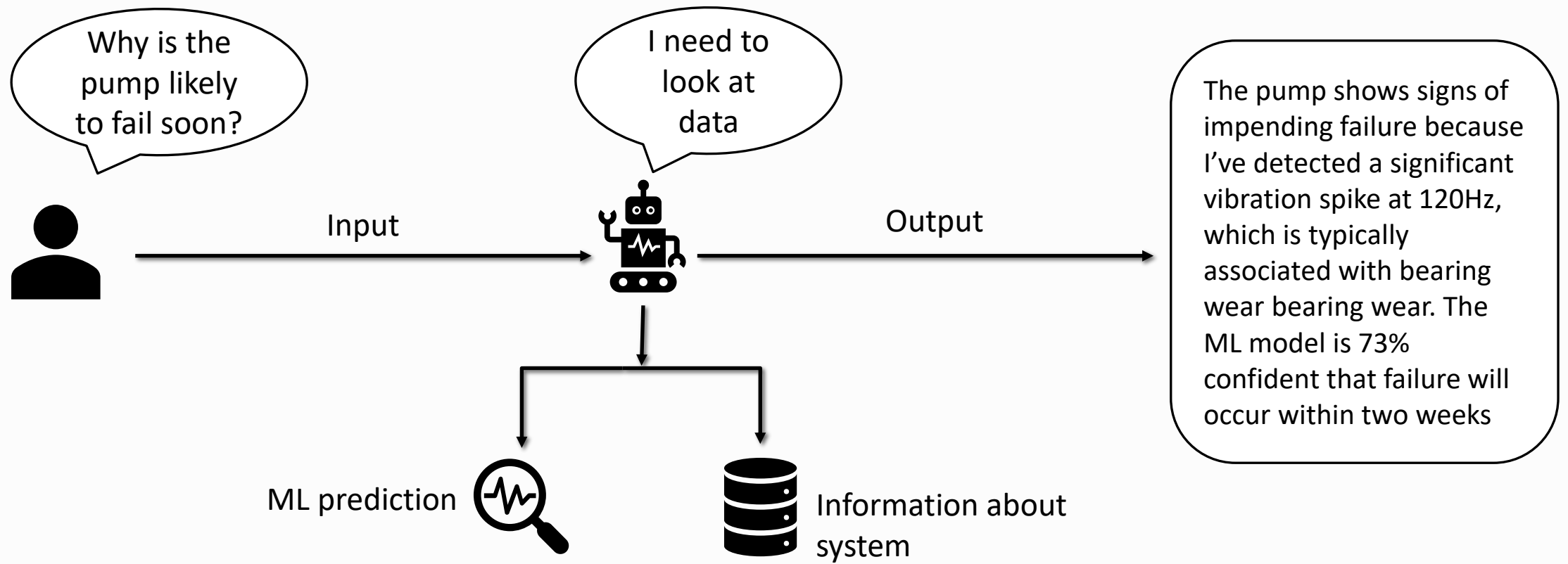
Alternative sensor: acoustic emission sensor

MEMS: Micro-Electro-Mechanic Systems

| Equipment | 20-100kHz | MEMS Receiver |

Explainable AI for future

- Example of interaction with the GenAI

Acknowledgements

- Langley Transformation Initiative
- Office of STEM Internships
- LaRC Center Operations Directorate
- Mentor: Charles Liles
- Braxton VanGundy
- Amentum Center Maintenance, Operations, and Engineering
  - Sarah Ritchey

? Questions