Advanced Machinery Technology Symposium

April 30-May 2, 2024 | Philadelphia, PA

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Collection and Analysis of LUSV Test Data

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Project Setup

Primary Goals:

Demonstrations of each engine configuration took place over 720 continuous hours. No human intervention or preventative/corrective maintenance on the equipment was permitted during this time. Successfully completing the demonstration meant that an engine system could not exhibit any failures or issues that would require maintenance of any kind during operations on an unmanned ship for 30 days.

Huntington Ingalls Incorporated (HII), in partnership with the U.S. Coast Guard, conducted a successful 720-hour demonstration on behalf of MTU of the MTU 20V 4000 M93L, a Main Propulsion Diesel Engine configuration.

Secondary Goals:

1. Experiment with computational infrastructure needed for data collection and analysis
2. Evaluate strengths and weaknesses of cloud and edge infrastructure
3. Explore opportunities for data-driven analysis
4. Exercise secondary sensing technology

TL;DR

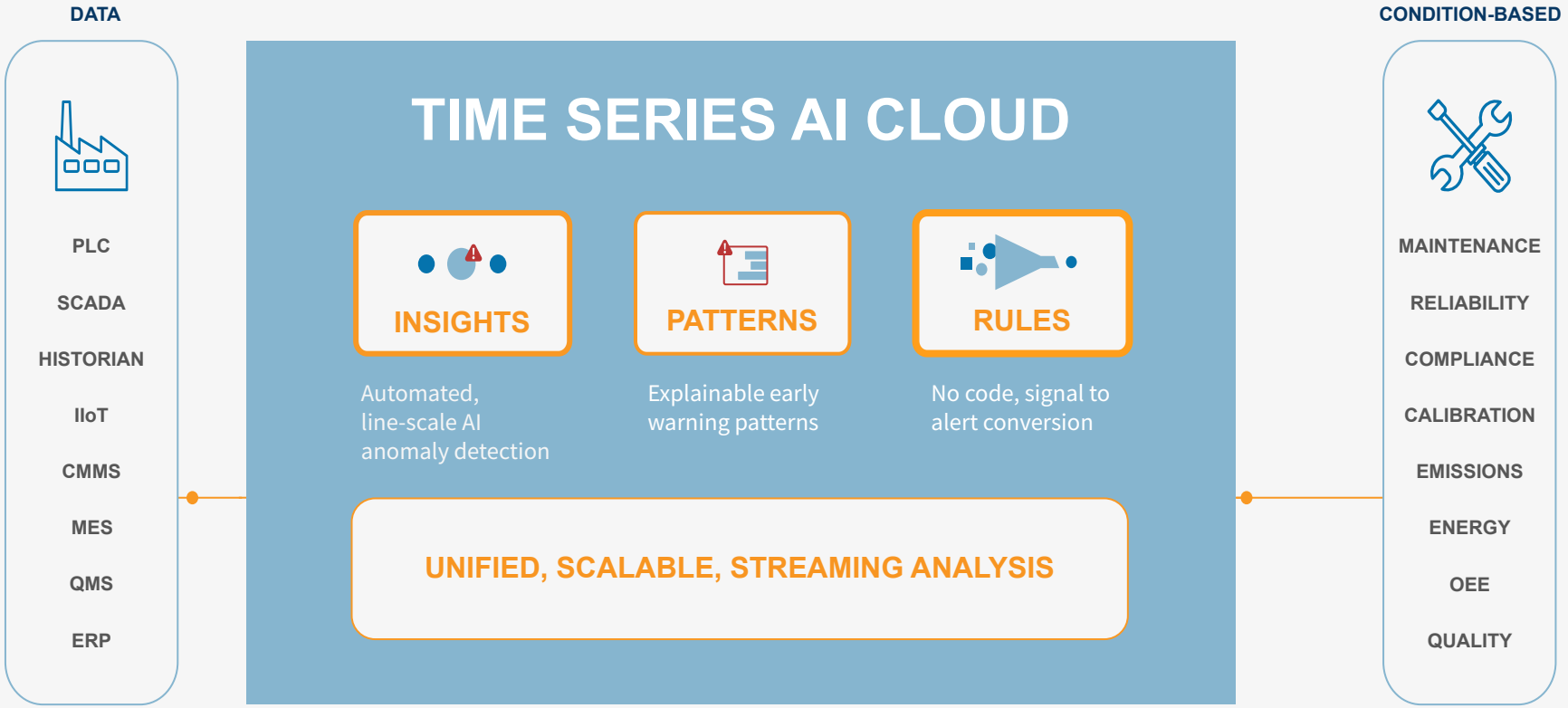
1. The equipment is more reliable than the test infrastructure

2. Real progress on USV will require improved testing capabilities

Outline

1. What Falkonry does
    a. data acquisition, contextualization, visualization
    b. AI patterns and anomaly detection
    c. historical data annotation & augmentation
2. LUSV project details
    a. primary project goals, instrumentation exercise goals
    b. autonomous vs cloud, mobile compute asset options
    c. data sources and integration
    d. data results
3. Lessons learned
    a. data acquisition and storage strategy
    b. live and remote monitoring & supervision
    c. test protocol compliance evaluation
    d. event annotation & archival strategy
    e. use of support staff

Making Smart easy with next generation analytics technology

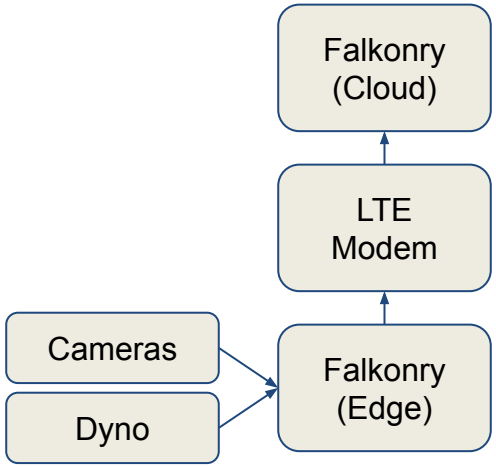


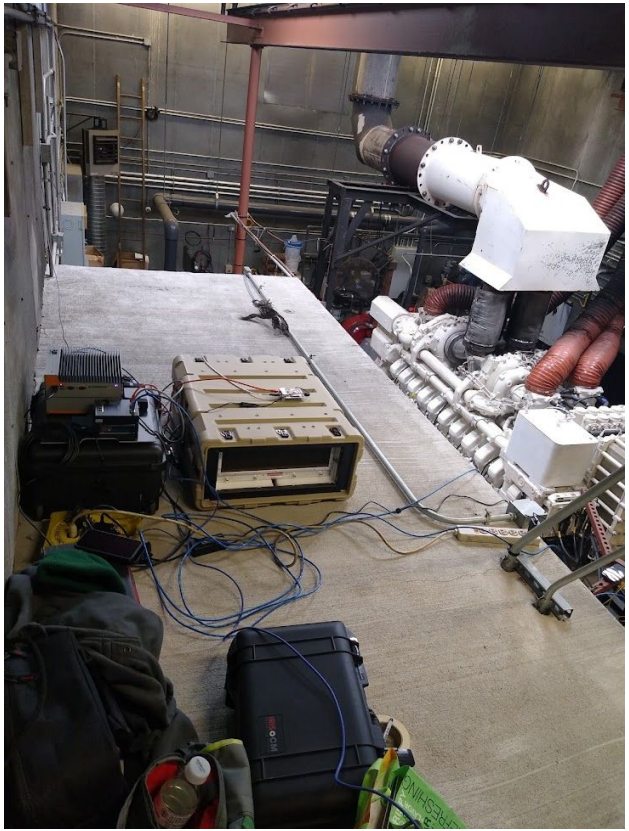
Key Features

- Cloud or edge, enclave or connected
- Any time series data, sensor agnostic
- Stream, store, manage, view, analyze
- Combine historical and live, multiple sources
- Contextualize and annotate data
- Two flavors of AI, plus thresholds and alerting

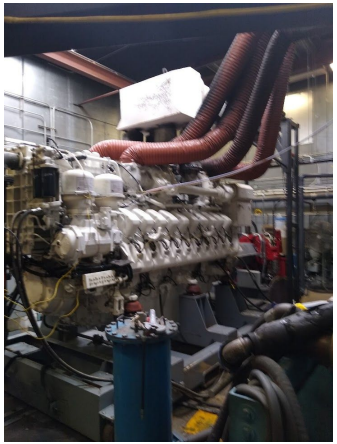
Collection Infrastructure

- Oracle roving edge device
  - 40 core, 400GB, 40TB, GPU
  - Charged per day
  - Integrates with Oracle Cloud
- RDI IPC and cameras for vibration
- Raspberry Pi as glue





Equipment in exposed space



View from vibration camera

Sample Data Findings

Human annotation is present, but does not mention any issue

Left: normal test power profile
Right: abnormal test

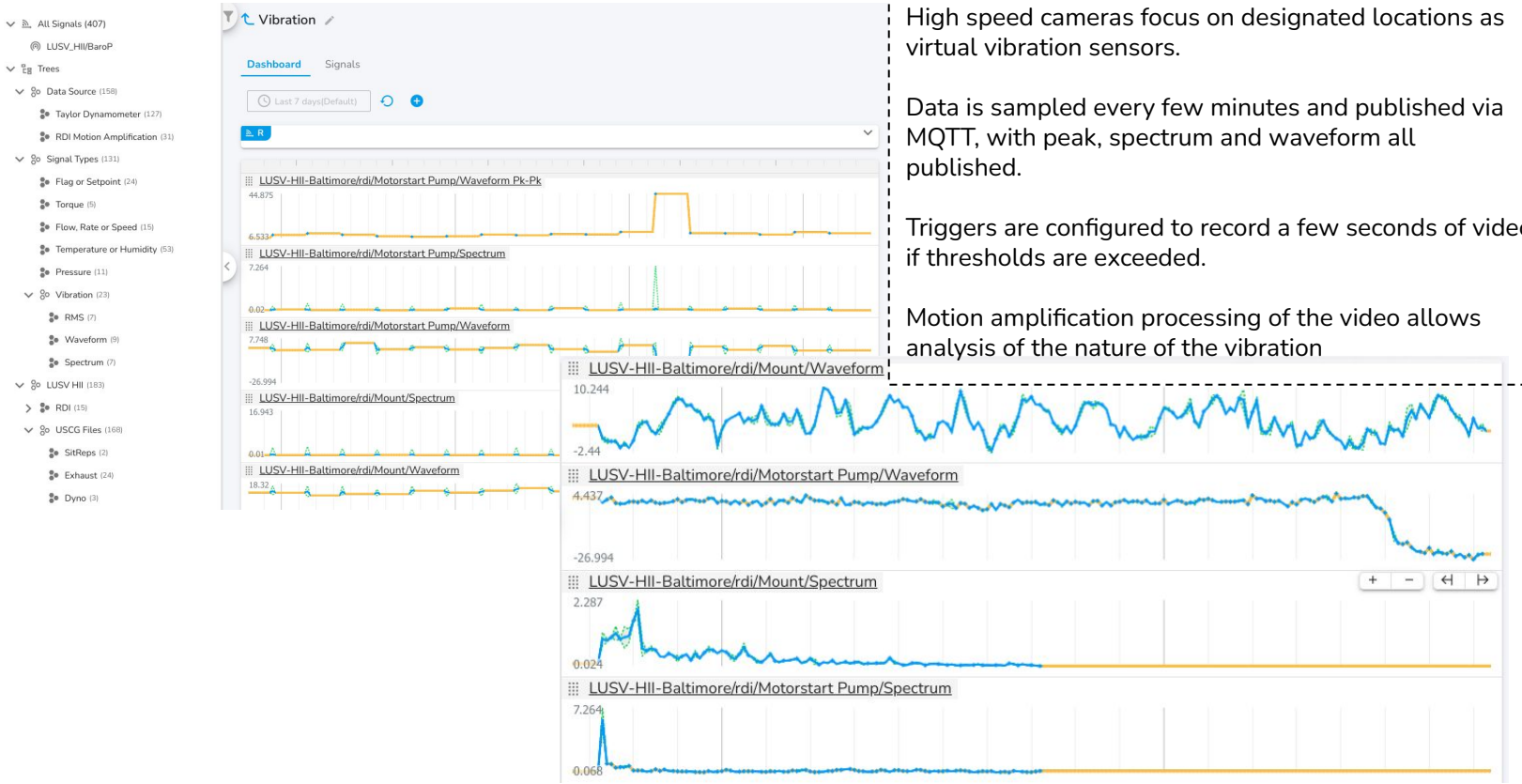
Automated anomaly detection learns normal profile. Almost all sensors are flagged with deviations.

Detailed data is available for further inspection

Data Analysis Notes

- Available data Sept 23 2023 through Jan 13 2024 (~2,700 hours)
  - Daily logs cover ~568 hours
  - Sensor data cover ~600 hours
  - Best guess, total engine hours ~733 hours
  - Best guess, test protocol success rate ~80%
- Notable meta-analysis:
  - Human error: test protocols, execution of procedures
  - Environmental problems: compressed air, dyno
  - Often cited monitoring candidates:
    - Exhaust temperatures
    - Fuel supply
    - Force sensor calibration
  - Transition stress (turbo stages on/off, etc.)

Secondary Sensing - Vibration



High speed cameras focus on designated locations as virtual vibration sensors.

Data is sampled every few minutes and published via MQTT, with peak, spectrum and waveform all published.

Triggers are configured to record a few seconds of video if thresholds are exceeded.

Motion amplification processing of the video allows analysis of the nature of the vibration

Human Factors

Entry	Time	Description	Event Flag "f"
1	6:20	Begin cycle #44. Start step 1. Engine running idle @500rpm. Engine hrs 4957 at start.	
2	6:30	Start step 2. Dyno reads 8350Nm/800rpm/700kW.	
3	7:00	Start step 3. Dyno reads 7782Nm/1100rpm/895kW. Turbo I engaged	
4	9:00	Start step 4. Dyno reads 11900Nm/1301rpm/1625kW. Turbo II engaged	
5	10:10	Start step 5. Dyno reads 12986Nm/1601rpm/2175kW.	
6	12:30	Start step 6. Dyno reads 13801Nm/1748rpm/2517kW. Turbo III engaged.	
7	12:40	Start step 7. Dyno reads 13500Nm/2050rpm/2901kW. Turbo IV engaged. Received a High Exh Temp Alarm at B10 (1127 Deg) apprx 1241, @1257, (1154 Deg) Power Reduction Mode (PRM) on MTU Panel.(Red) Received another alarm (PRM) @1321 B10 was reading (1160 Deg). USCG Test Lead reduced load to Idle 500 rpm at 1322, 1327 Engine	
8	14:10	**********See Step 7 Notes Above**********	
9	14:20	**********See Step 7 Notes Above**********	
10	1515 HRS	START TESTING CYCLE #44 - 4965 ENGINE HOURS	
11	1515 HRS	START LOAD STEP 1 : ENGINE IDLE	
12	1525 HRS	START LOAD STEP 2 : 20% RATED LOAD	
13	1555 HRS	START LOAD STEP 3 : 25% RATED LOAD	
14	1755 HRS	START LOAD STEP 4 : 45% RATED LOAD	

Time formatting is inconsistent even within one file, lacks date and timezone

Copy-Paste errors are common

Nobody knows what this column is for?

Seems like a serious doc, I'm going for all-caps!

Uses for Test Data

1. Real-time remote supervision and SME availability
2. Prepare for LUSV telemetry capture and analysis
3. Validate and document test protocol compliance
4. Root cause analysis
5. Retrospective testing in the future
    a. Is this behavior normal?
    b. Has this ever happened before?

Lessons Learned

- Limit exposure to human error:
  - Automate boilerplate field values like dates or cycle counts
  - Use forms instead of spreadsheets
  - Eliminate data movement: Use an application or cloud instead of local files
- Prepare for data collection:
  - Start early!
  - Establish data ownership, classification, IP issues, archival strategy
  - Enforce minimal information standards and data dictionary
  - Ascertain ephemeral infrastructure needs:
    - cloud/remote surveillance needs: mobile data coverage, antennas
    - environmental factors: space, power, temperature, vibration, dust, cabling, line-of-sight
    - human factors: space, accessibility, setup time, physical safety, noise, inventory
- Validate data after collection:
  - Expected fields from data dictionary
  - Expected data quantities, value ranges, time-zones, and total time coverage
  - Manual annotations co-located with data
  - Archival expectations and obsolescence