WBS 1.3.2.504 – Hydropower Fleet Intelligence (HFI)

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Hydropower Fleet Intelligence (HFI): Project Overview

Project Summary

- **Challenge:** Maintaining cost competitiveness and security of aging hydropower assets
- **Approach:** Develop tools to align, correlate, and analyze disparate national- and plant-scale data sets and provide actionable information to U.S. hydropower operators for optimizing operations and maintenance (O&M) decisions
  - Verify data availability and sufficiency
  - Benchmark and aggregate data from disparate sources
  - Develop methods for condition-based asset reliability assessment to support predictive and smart maintenance strategies.
  - Assess technologies and best practices for hydropower facility digitalization
- **Expected Impacts:**
  - Enable better understanding of the relationships between reliability, efficiency, and O&M performance
  - Empower hydropower asset managers to optimize facility management for cost and reliability

Intended Outcomes

- **Objective:** Develop and demonstrate standard processes to make data-driven decisions on operations and maintenance (O&M) for cost-effective hydropower generating unit asset management under evolving contexts
- **Expected products**
  - Data-driven method for assessing dispatch variability impact on hydropower O&M costs
  - Formal process for assessing hydropower data requirements for optimizing O&M
  - Software tools (algorithms) for hydropower data analysis to: (1) quantify asset condition and reliability; (2) enhance and integrate disparate cost, condition, operation, and reliability information to improve hydropower value and reliability

Project Information

Principal Investigator(s)

- P. Ramuhalli, G. Oladosu, S. Mukherjee, V. Rathod, Y. Chen, T. Ruggles

Project Partners/Subs

- L. J. Miller (Signal Hydropower LLC)

Collaborators:

- E. Hanson (PG&E)
- S. Signore (TVA)

Project Status

Ongoing

Project Duration

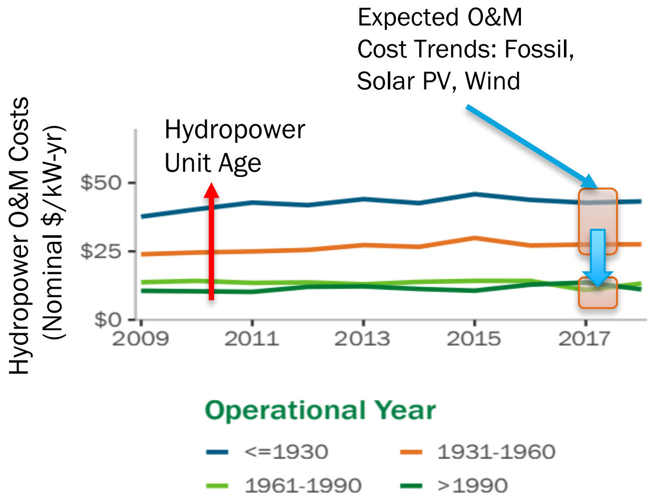
- FY2019 – FY2024

Total Costed (FY19–FY21)

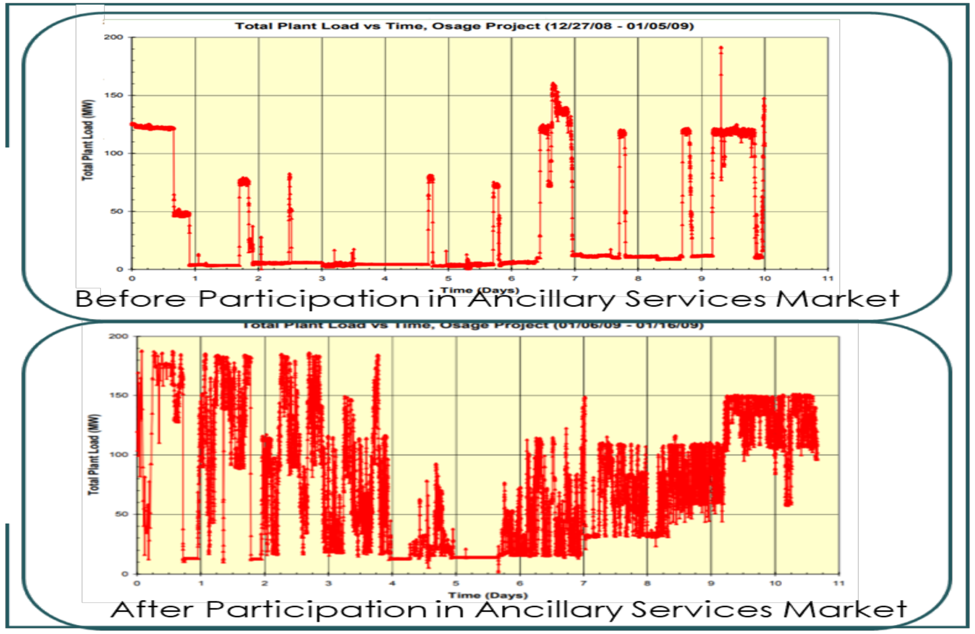
$1486K

Project Relevance

- *Challenge: Maintaining cost-competitiveness and security of existing hydropower assets through evolving power system contexts and aging of the fleet*
- **Goal: Develop and demonstrate standard processes for data-driven decisions on operations and maintenance (O&M) for cost-effective hydropower asset management under evolving contexts**



Aging Hydropower Infrastructure, Increasing Costs*



Plant Load Impact After Participation in Ancillary Services Market

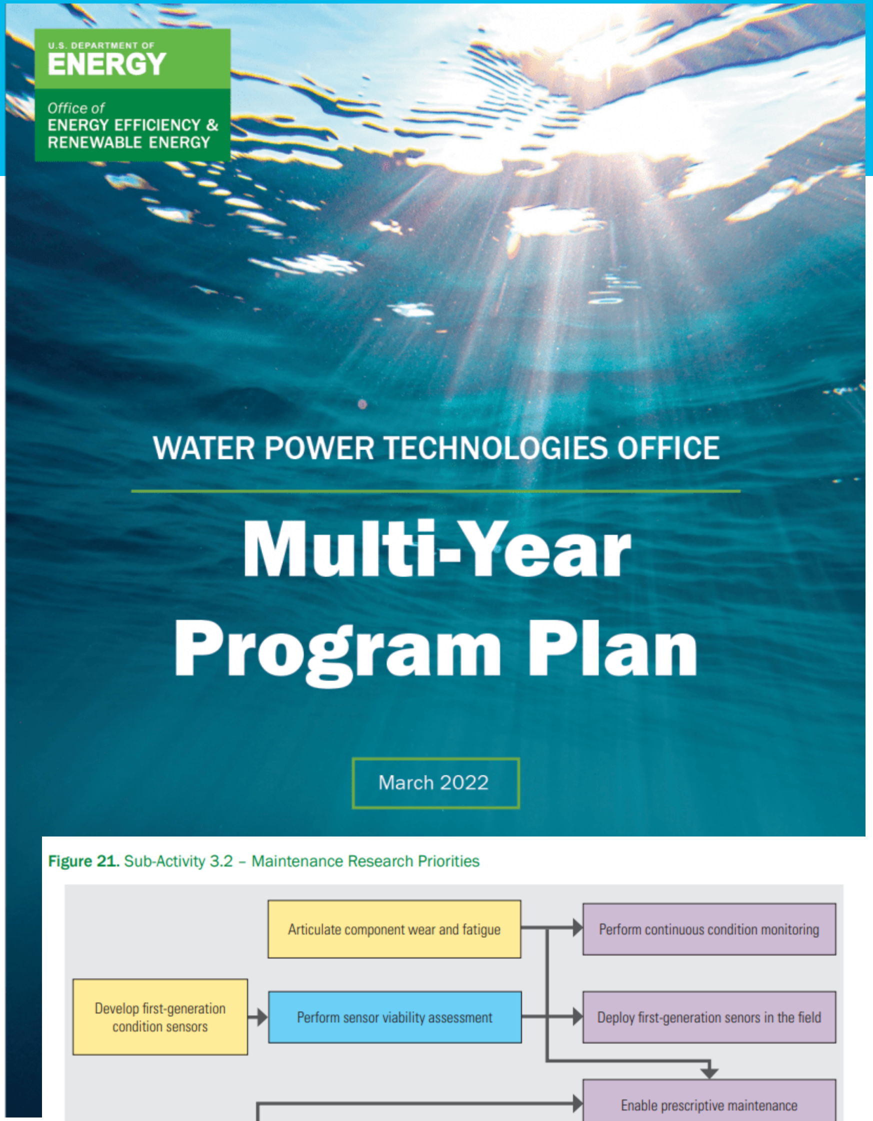
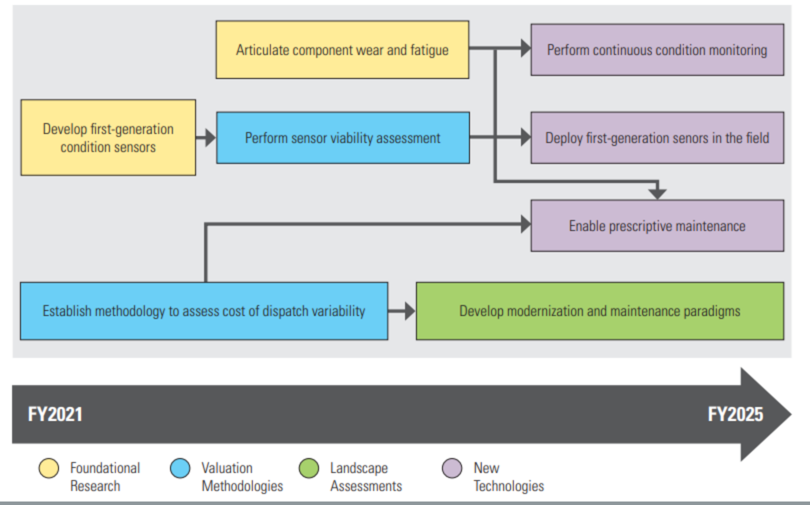
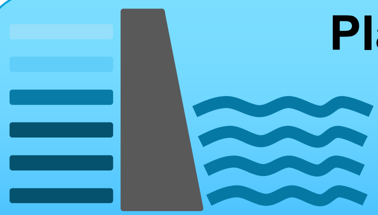


Figure 21. Sub-Activity 3.2 – Maintenance Research Priorities



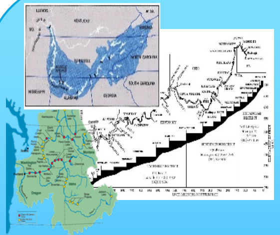
*Trends in O&M Costs for Hydropower Projects by Age Class (Source: U.S. Hydropower Market Report, January 2021)

Approach



Plant Managers

- *How to justify selection of a maintenance strategy?*
- *If I take action X, what will be the response of component Y in my facility?*

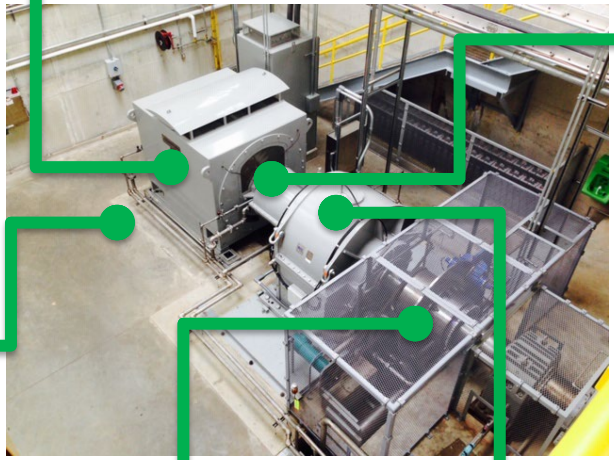


Fleet and Utility Managers

- *How should (flexibility, investment, risk, …) be allocated?*
- *How to balance reliability, profit, risk in allocating across fleet?*
- *How to expand/sustain hydropower assets for evolving objectives?*

Policy-makers

- *Rate cases*
- *Public research investments*
- *Power market design*
- *Cost-benefit of regulations*



Unit/Plant/Fleet Data

- Quality
- Management
- Benchmarking
- Recommendations

Analytics

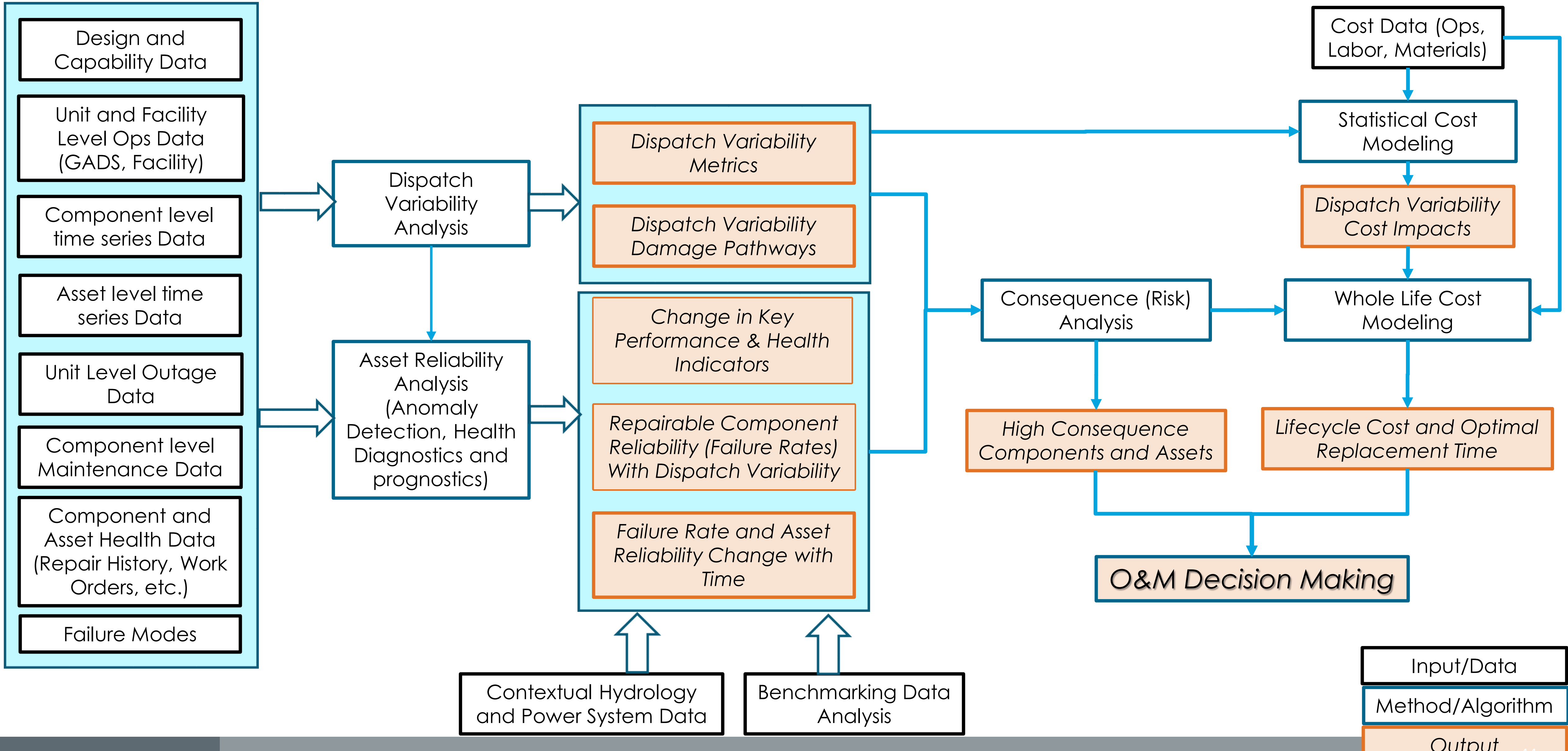
- Ops Signatures
- Asset condition & health
- Cost
- Digitalization
- Recommendations

- Condition monitoring
- Predictive and smart maintenance
- Unit/plant benchmarking

- Cost & reliability correlation
- Optimization of ……
- Fleet benchmarking

- National scale correlations
- Aggregated impacts
- Economic models

Approach: HFI Dataflow Overview



Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

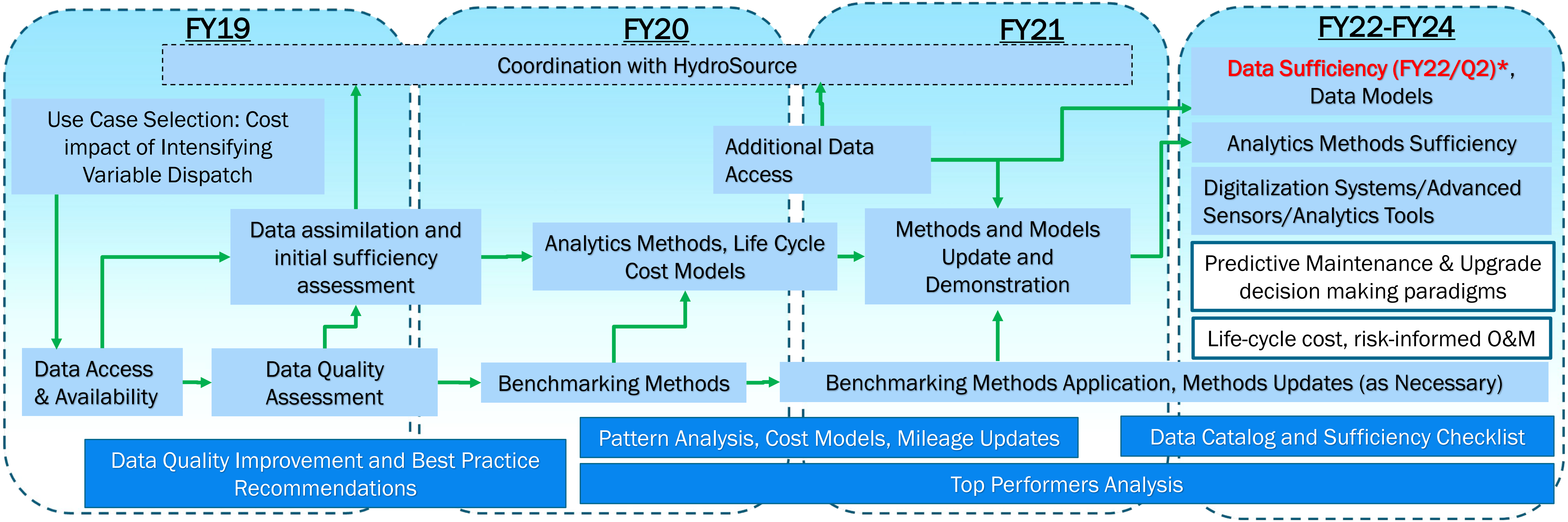
- Tools
  - Algorithms for machine and facility-level analysis, operational mode change detection, patterns in data
  - Correlations between cost, operations, performance, asset health, asset availability and reliability, asset end-of-life
- Methods
  - Assessing data sufficiency, benchmarking data, correlating information across scales (time, facility)
  - Quantifying cost & reliability impacts of variable dispatch
- Models
  - Data models relating disparate types of facility information Whole life cost models for optimal asset replacement
- Publications
  - Presentations: Clean Currents, CEATI Asset Management Conference, CEATI HPEIG Conference
  - Technical reports and papers (“Cost Impact of Increasing Variable Dispatch”, “Hydro asset reliability with flexible dispatch”, “Present state of hydro digitalization”, “Digitalization best practices”)

Outcomes:

- Inform asset owners about
  - What they can learn from disparate operational data and highlight what data would provide additional value
  - Hydro asset reliability margins and O&M cost change from increased flexible operations
  - Extent to which hydropower asset condition can be measured using direct and indirect data
- Increased adoption of digitalization to empower data-driven decisions on hydropower O&M
- Improved decision making by plant owners about when to perform predictive maintenance
- Reduced costs and improved reliability from the reduction of unplanned outages
- Co-optimization of hydropower capabilities for grid services and reliability

Project Timeline

Challenge: Maintaining cost-competitiveness, reliability, and security of existing hydropower assets given fleet age



Expected Impact: Increased hydropower reliability; Reduced hydropower operations and maintenance (O&M) costs

Color key:

Major Research Tasks (current and Past) | Major products/outcomes | Future Work | *Go/No Go

Project Budget

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	**Costed**	**Costed**	**Total Costed**
$507K	$495K	$484K	$1486K

- Variance in planned budgets due to challenges from:
    - PI change (FY20) and staff changes (FY20, FY21)
    - Uncertainties in travel due to the pandemic
- Plans for FY21 and beyond adjusted to account for travel restrictions, staffing delays

End-User Engagement and Dissemination

- End-user engagement with multiple stakeholder groups to gather input and disseminate research findings
- Hydropower owner/operators – *Data and demonstration*
  - Ongoing collaboration with PG&E and TVA for data access and interpretation
  - Initiated discussions with US hydropower owners/operators on data sufficiency and data analysis capability assessment
  - Initiated discussions with multiple US hydropower owners/operators on digitalization status and practices
  - Validating analyses with industry compiled data sets
- Industry consortia – *Industry challenges*
  - CEATI: Data quality assessment of existing data sets; discussions on industry needs
  - Electric Utility Cost Group (EUCG): Annual Top Performers report
- Researchers – *Technology advances*
  - Ongoing support of WPTO MOU with Norway (hydropower digitalization, smart maintenance)
- Presentations at industry conferences and workshops
  - CEATI Asset Management (AM) conference (2020, 2021)
  - CEATI Hydropower Plant Equipment Interest Group (HPEIG) meetings (2022)
  - EPRI Hydropower Materials Workshop 2022
- Software modules developed in python and R being vetted for release in FY2022/FY2023

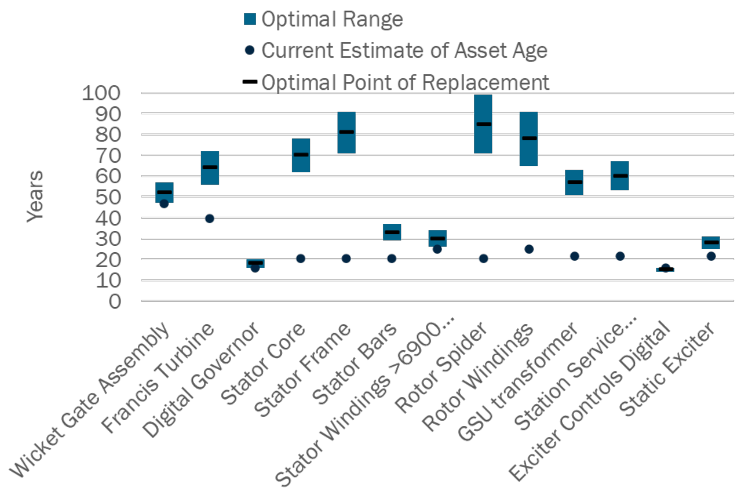
Performance: Accomplishments and Progress

Summary

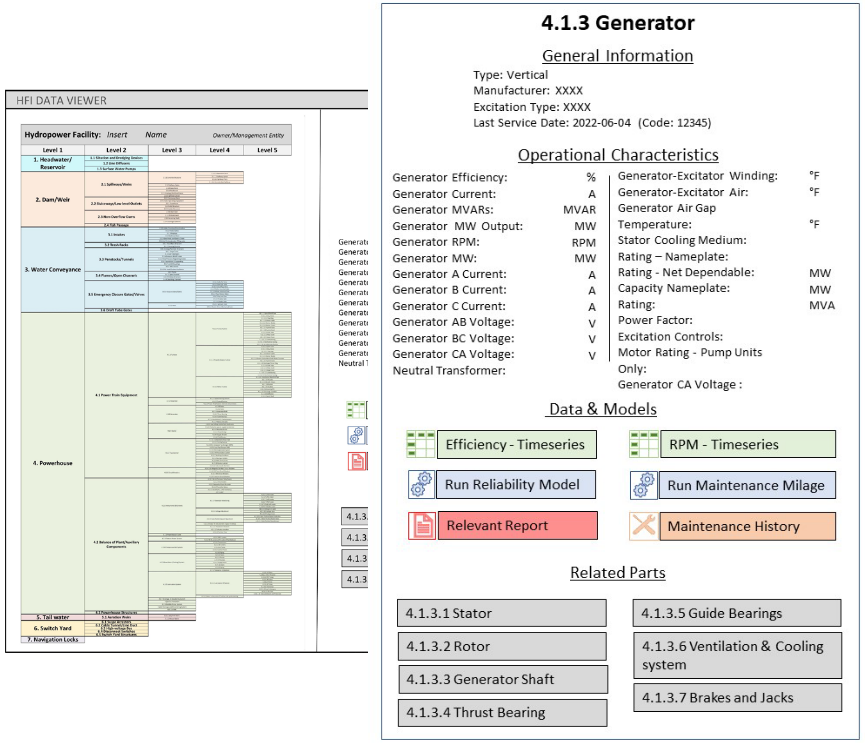
- **Annual Cost Data** - Annual Electric Utility Cost Group (EUCG) Report
  - Redesigned top performers analysis
- **Equipment Condition Data** - hydroAMP data quality report completed
  - Implementing 22-point improvement plan
- **Reliability, Availability, & Outage Data** - NERC GADS data quality report
  - Leading to changes in design data compilation
- **Case Study:** Cost Impacts of Intensifying Dispatch Variability
  - Developed methods for hydropower data integration and analysis, models correlating intensity of dispatch variability with cost, and whole life cost models
- **Digitalization** – state of hydropower digitalization and lessons (ongoing)
  - Will lead to best practice guidance for implementing digitalization technologies
- **Asset Reliability Monitoring** – development of tools and methods (ongoing)
  - Methodology for assessing data sufficiency (what data is available and what can be done with it)
  - Data model for simplifying hydropower data management and integration
  - Data integration and analysis tool kits for asset reliability and condition monitoring

Performance: Accomplishments and Progress

- Software modules
  - Signatures of various operational modes/variable operations & quantification of start-stops from *operational time-series data*
  - Asset reliability assessment from *maintenance data*
  - Mileage calculation for hydropower assets using *GADS* + *maintenance data (+ operational data, if available)*
  - Cost models (cost correlations with operations; whole life cost models) using *cost data* + *mileage (condition)* + *asset reliability models*
- Data catalog and sufficiency checklist template
  - Mechanism for compiling data documentation and identifying gaps relative to use case needs
- Data model for simplifying hydropower data management and integration (under development)
- Technical Paper on present status of hydropower digitalization in the US fleet



Whole Life Cost Model Results

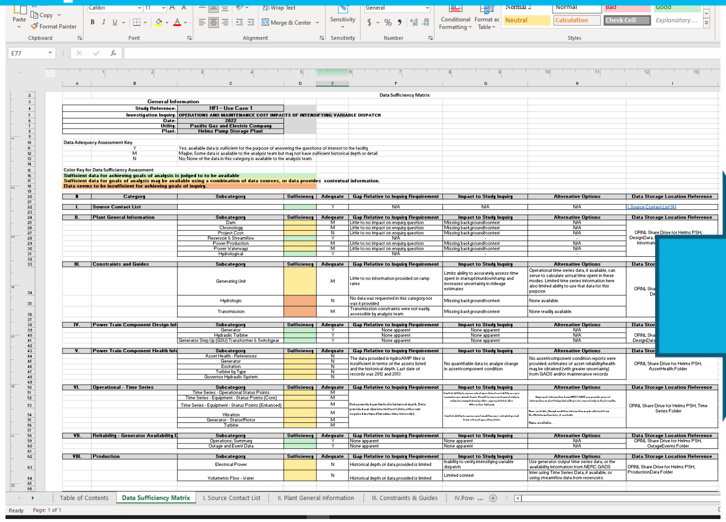


Data Model and Visualization Tool

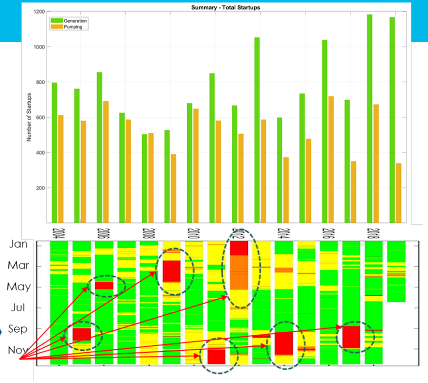
Performance: Accomplishments and Progress

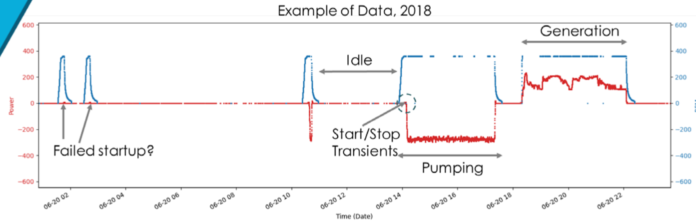
Cost Impacts of Intensifying Variable Dispatch

- Assessment of methods using data from pumped storage hydro facility
- Data catalog and sufficiency matrix
  - Used to identify gaps in data availability and alternate sources of information
- Availability and unit outage information used for quantifying trends in variable operation and mileage estimates
  - Limited operational data used to validate signature analysis methods by comparing to startup numbers in GADS
- Cost models leverage historical cost data to quantify O&M cost changes due to increased flexible operations
- Whole life cost model developed for optimal hydropower asset replacement times

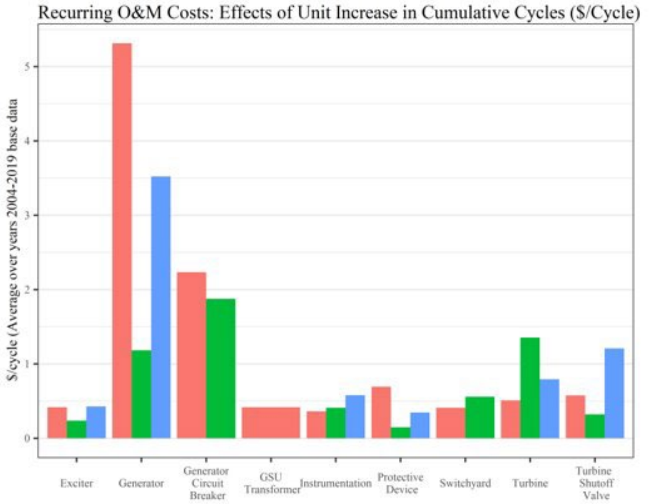


Data Catalog and Sufficiency

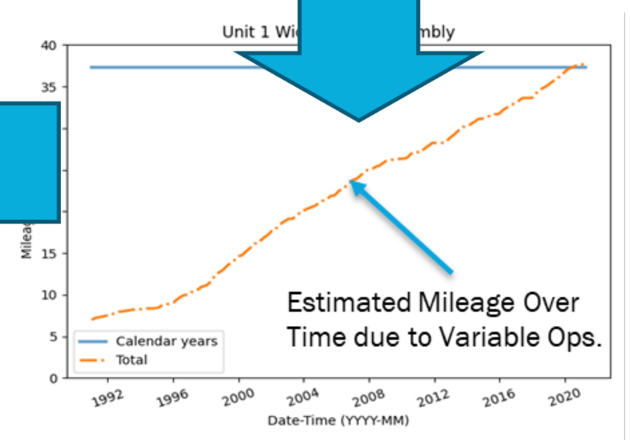




Change in Variable Operations (Startups, Outages)



Cost Impact of Cycling



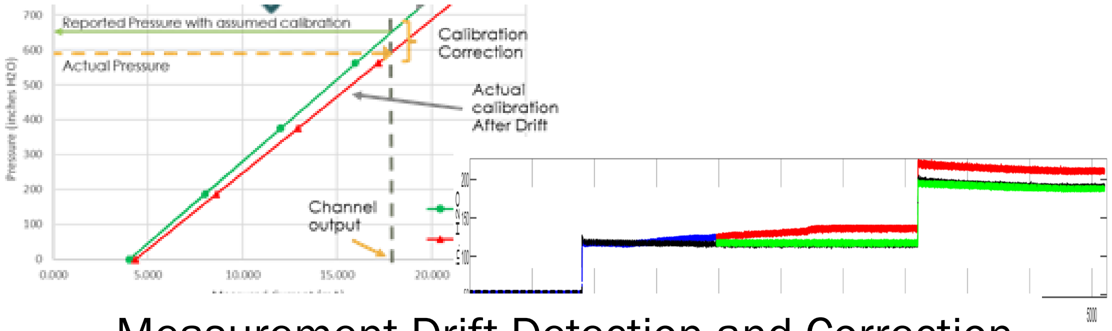
Generator Mileage Estimate

Future Work

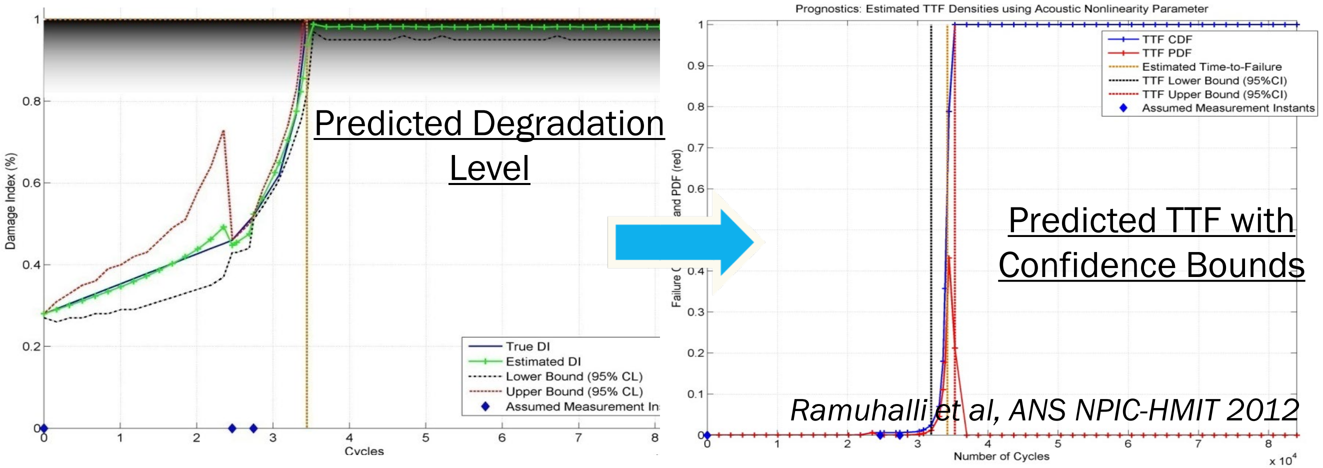
Duration	Type	CauseCode	RevisedCode	CauseDescript	Description
8.033333	U1	7123	✓	SHUTOFF VALVE BYPASS LINE AND VALVE	REPLACED TSV OPEN LIMIT SWITCH 33VO/LS1 DUE TO CORRODED AND
1.666666	MO	7050	✓	TURBINE GOVERNOR (CODE IS PREFERRED,GOVERNOR TYPE)	GOV SYSTEM TEST.
1.116666	SF	4630	✓	LIQUID COOLING SYSTEM	
0.016666	U1	3829	✓	OTHER CLOSED COOLING WATER SYSTEM PROBLEMS	
12.51667	U1	7121	✓	SHUTOFF VALVES (USE OF CODE PREFERRED,VALVE TYPE)	TSV WOULD NOT OPEN.
90.35	U1	3644	✓	PROTECTION DEVICES	UNIT FORCED OUT OF SERVICE DUE TO BAD FOXBORO CARD
0.1	SF	4740	4630	~~EMERGENCY GENERATOR TRIP DEVICES~~	GEN TRIPPED ON STARTUP BY STATOR COOLING LOW FLOW TRIP
0.4	U1	3644	4630	~~PROTECTION DEVICES~~	UNIT TRIPPED WITH 350MW'S BY STATOR COOLING WATER DIFF BAD P
0.5	U1	3644	4630	~~PROTECTION DEVICES~~	UNIT TRIPPED BY STATOR C/W DIFF
0.166666	MO	7170	✓	DRAFT TUBE	
22.56667	SF	7121	✓	SHUTOFF VALVES (USE OF CODE PREFERRED,VALVE TYPE)	TSV FAILED TO OPEN, STARTED UNIT 1 INSTEAD

Text Analytics

- FY22/FY23
  - Facility- and fleet- scale data models for enabling efficient data management
  - Data-driven methods for asset condition and reliability estimation
    - Text analytics for automating work order analysis
    - Machine learning tools for data quality assessment and data cleanup
    - Analysis tools for integrating operational data and outage event data to improve confidence in asset condition assessment, asset reliability, and predicting remaining useful life (RUL)
    - Continued refinement of cost models
  - Compiling hydropower digitalization best practices
- Planned
  - Integrate digital twins and wear models as technologies mature



Measurement Drift Detection and Correction



Asset Health Assessment and RUL Estimation

Questions?

Q&A