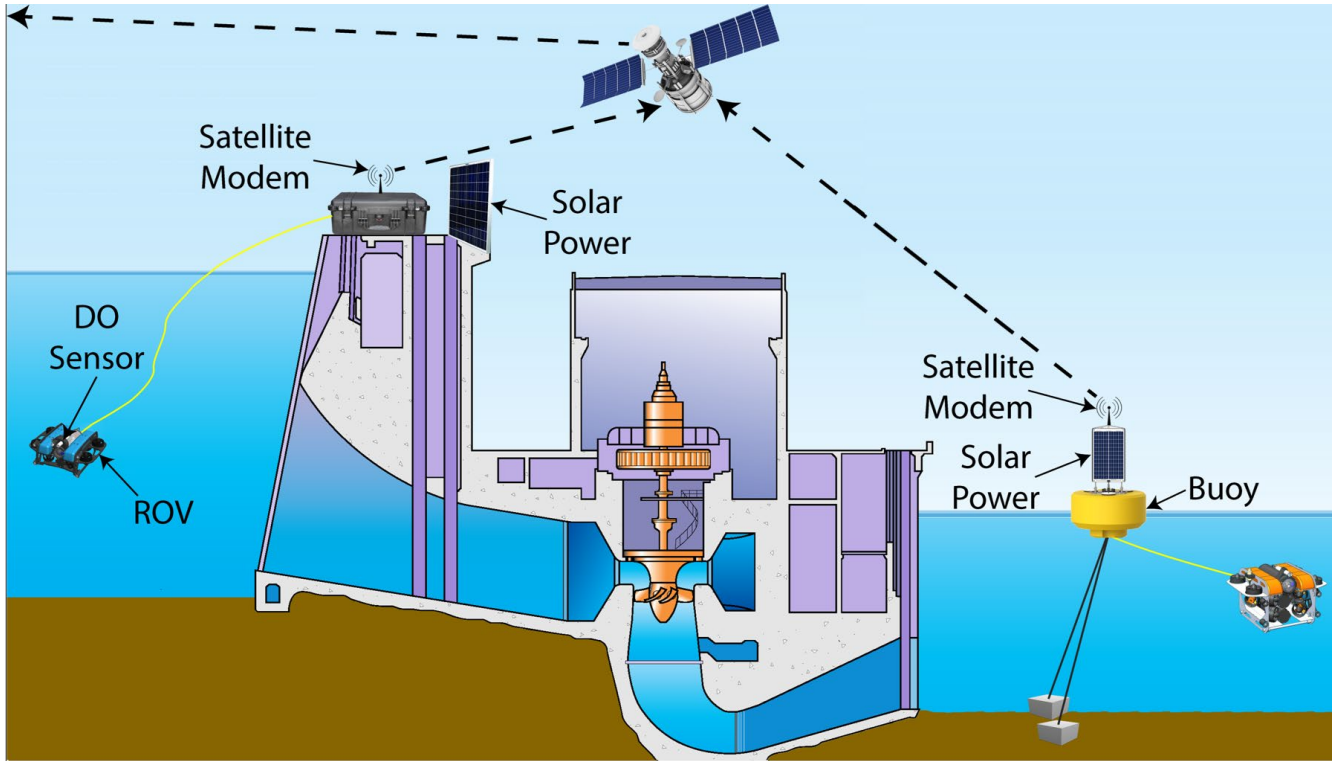
1.3.1.608 A Real-time and Autonomous Water Quality Monitoring System



Daniel Deng
Pacific Northwest National Laboratory

zhiqun.deng@pnnl.gov
July 26, 2022

Project Overview

Project Summary

Maintaining and improving water quality has been a longstanding challenge for many hydropower facilities. As new mitigation technologies are developed, we need to improve the monitoring technologies to validate that water quality targets are being met. PNNL developed a real-time, autonomous and modular water quality monitoring system to enable improved measurement in challenging locations, including dam tailraces. This system reduces risks to workers, provides greater spatial coverage of measurements, and improves communication between the sensor and dam operators. It can help identify and better understand complex issues such as when to implement mitigations, provide more accurate data for water quality models that inform compliance, and enable real-time operational changes to reduce impacts, and potentially increase generation or system flexibility.

Intended Outcomes

The developed water quality monitoring system will greatly enhance the capability and flexibility of hydropower operators in timely and safely collecting water-quality data, which will consequently provide more comprehensive information to guide hydropower operations. This technology will maximize power generation revenue with the improved operation control and reduce Federal Energy Regulatory Commission and state water quality monitoring costs for compliance

Project Information

Principal Investigator(s)

- Daniel Deng
- Jayson Martinez

Project Partners/Subs

- Southern Company
- Eagle Creek Renewable Energy
- Sapere Consulting Inc.
- Blue Robotics Inc.

Project Status

Sunsetting

Project Duration

- Project Start Date: 2019
- Project End Date: 2022

Total Costed (FY19–FY21)

$1,050K

Project Objectives: Relevance

Relevance to Program Goals:

- Challenge: Addressing Environmental Impacts and Hydrologic Uncertainties
- Environmental and Hydrologic Systems Science
  - Develop better monitoring technologies to study river systems and evaluate environmental impacts
- The objective of this project is to advance the framework on state-of-the-art DO measurement and monitoring platforms to support the environmental performance of hydropower development and operations. This is well aligned with the WPTO goal of delivering low-cost hydropower power and resiliency to the nation's power grid. This project is also directly relevant to implementing the DOE Hydropower Vision Roadmap: "Technology Advancement Action 4.1.2, Enhance Environmental Performance of New and Existing Hydropower Technologies" and "Sustainable Development and Operation Action 4.2.4, Evaluate Environmental Sustainability of New Hydropower Facilities".

Project Objectives: Approach

Approach:

- PNNL is developing an enhanced real-time and autonomous water quality monitoring system. This system will allow for more informed management decisions regarding new and existing hydroelectric facilities that minimize or avoid environmental impacts and maximize operational efficiency.
- To provide appropriate and effective data inputs, we incorporate the following improvements into our technology:
  - Comprehensive water quality (DO and TDG) measurements throughout a 3D volume, as opposed to a fixed spatial location or manual sampling from a boat.
  - Enhanced worker safety since it doesn't require boat work to service a fixed station or perform manual sampling.
  - Real-time communication between the measurement platform and dam operators, as opposed to manual sampling on a monthly basis or retrieval of hourly logged data during equipment maintenance visits.
  - Real-time monitoring of the sensor equipment. Existing systems that can remotely transmit measurement data lack the ability to autonomously monitor the status of the measurement probe in real time.

Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

- The outputs of the project are a new system that implements one of two versions of a remote operated vehicle with custom integrated water quality sensors depending on target environment. The system includes the option for a variety of telemetry hardware (e.g., satellite, cellular, Wi-Fi, ethernet) to implement uploading measurements a cloud-based database. The database is connected to a web-based software interface for viewing the measurements in real-time.
- The details of the system and results from field evaluations are presented in a submitted peer-reviewed publication.

Outcomes:

- The developed water quality monitoring system will greatly enhance the capability and flexibility of hydropower operators in timely and safely collecting water-quality data, which will consequently provide more comprehensive information to guide hydropower operations.
- This technology will maximize power generation revenue with the improved operation control and reduce Federal Energy Regulatory Commission and state water quality monitoring costs for compliance.

Project Timeline

FY 2019

- Evaluated the performance and applicability of state-of-the-art DO sensors
- Evaluated and compared methods of existing real-time communication
- Developed the planned range of applications and established priority list of proposed functionalities

FY 2020

- Summarized the specific improvement needs and outlined the complete configuration of the proposed system
- Identified, communications, sensors and platform based on input from stakeholders
- Conducted a field trial of the dam-based version of the system at High Rock Dam in North Carolina

FY 2021

- Completed the system designs for both dam-based and buoy-based versions of the system by incorporating identified improvements.
- Developed the field test plan for a pilot field trial of the buoy-based version of the system at Logan Martin Dam in Alabama

Project Budget

Total Project Budget – Award Information		
DOE	Cost-share	Total
$1,050K	$K	$1,050K

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	Costed	Costed	Total Costed
$305K	$281K	$464K	$1,050K

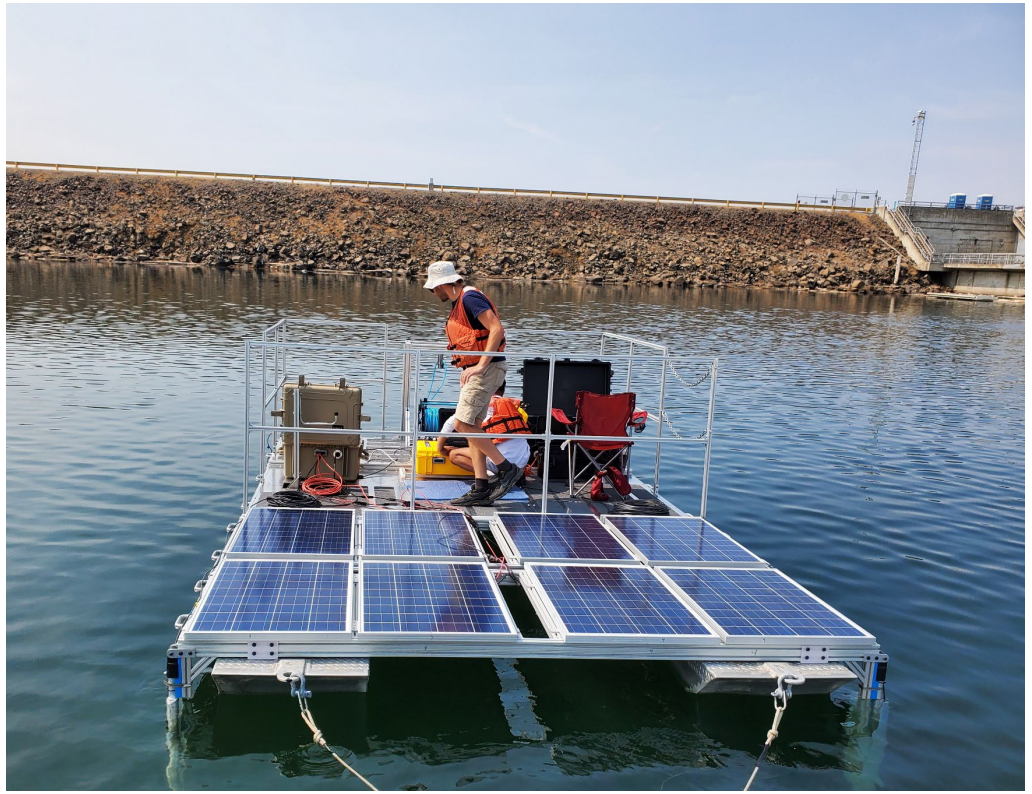
- Due to the Covid-19 pandemic the field deployment of the buoy-based system originally planned for FY21 was pushed back to FY22 and appropriate funding was carried over.
- No cash cost-share, only in-kind cost-share.

End-User Engagement and Dissemination

- This project helps provide information, data, and tools for the hydropower community to use to improve turbines and dam structures, and to understand and mitigate the environmental effects of hydropower operations on fish – all while improving operational efficiency. We worked directly with a hydropower owner/operator and a consulting company to conduct evaluations of our design and solicited feedback through project interactions.
- Communications and outreach related to this project were shared with the hydropower community through a combination of a submitted peer-reviewed publication, regular email correspondences, and conference presentations. The peer-review publication targets researchers, engineers, regulators, consultants, while the conference presentations target a general industry audience.
- We worked with DOE WPTO communication teams to disseminate project results through publishing on a DOE website to highlight the public-private partnership between PNNL, DOE, Eagle Creek (formerly Cube Hydro), and General Electric.
  - https://www.energy.gov/eere/water/articles/public-private-partnership-new-autonomous-dissolved-oxygen-sensor-enables-hydro

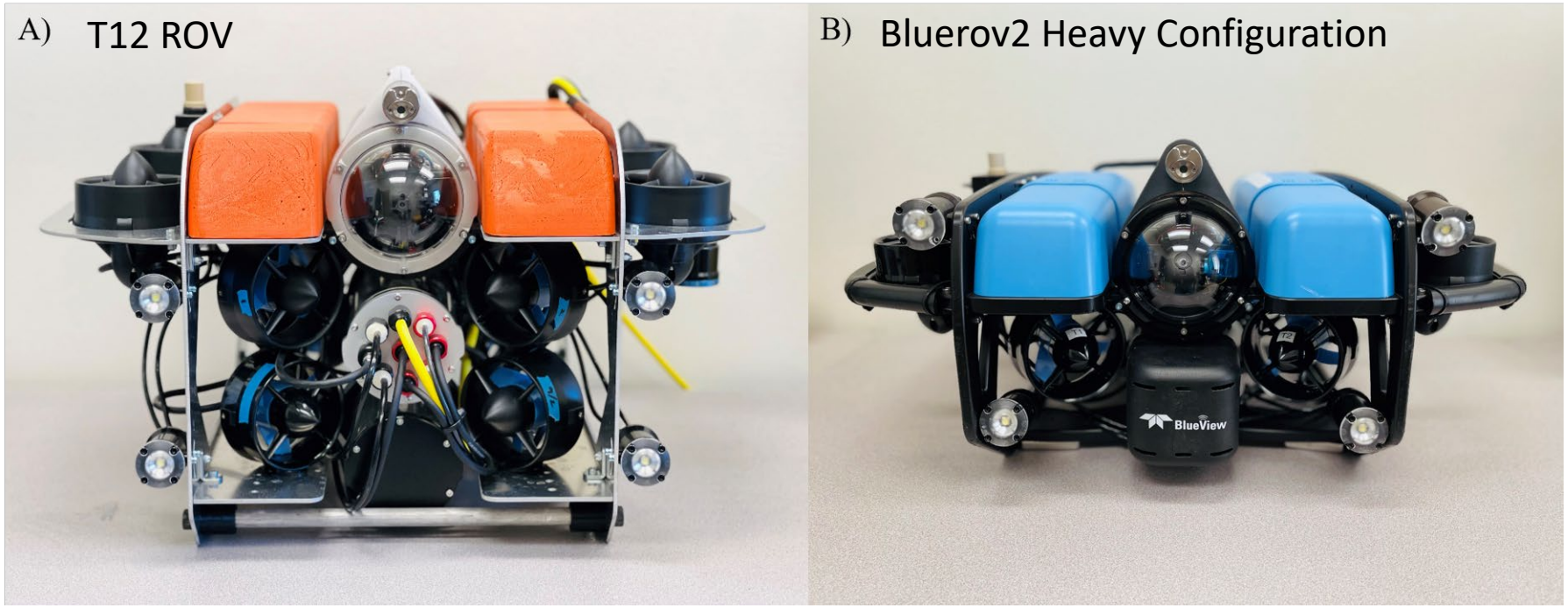
Performance: Accomplishments and Progress

- Developed two versions of the autonomous water quality system, a dam-based and a buoy-based system. Both versions can be powered by solar energy.
  - This allows the system to be deployed upstream of the dam, either in the immediate forebay or further upstream, to gather upstream data for modelling the effect of the hydropower operations, **or** downstream in the tailrace measure the downstream conditions to understand the impact of the dam.



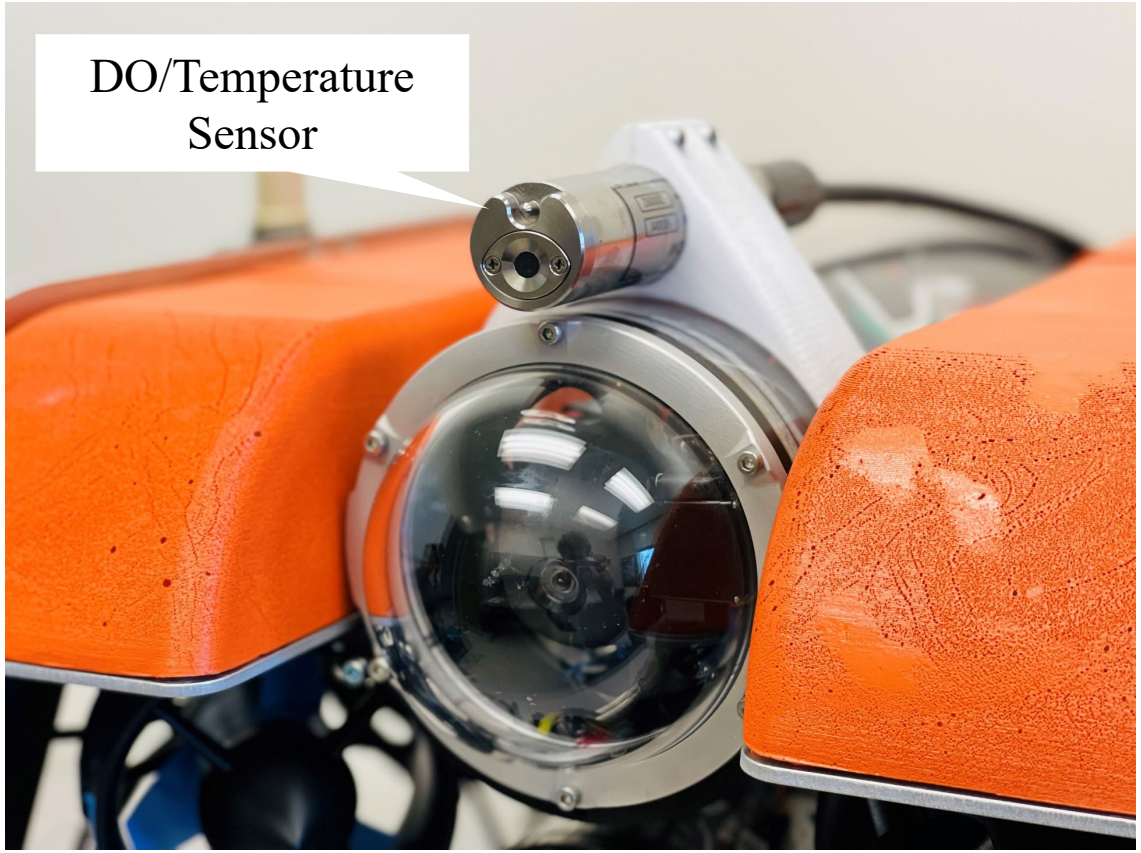
Performance: Accomplishments and Progress (cont.)

- Two versions of the mobile platform (ROV) were implemented to handle differences in flow. This allows the platform that is best suited for the specific flow conditions to be selected and demonstrates the flexibility of the system.



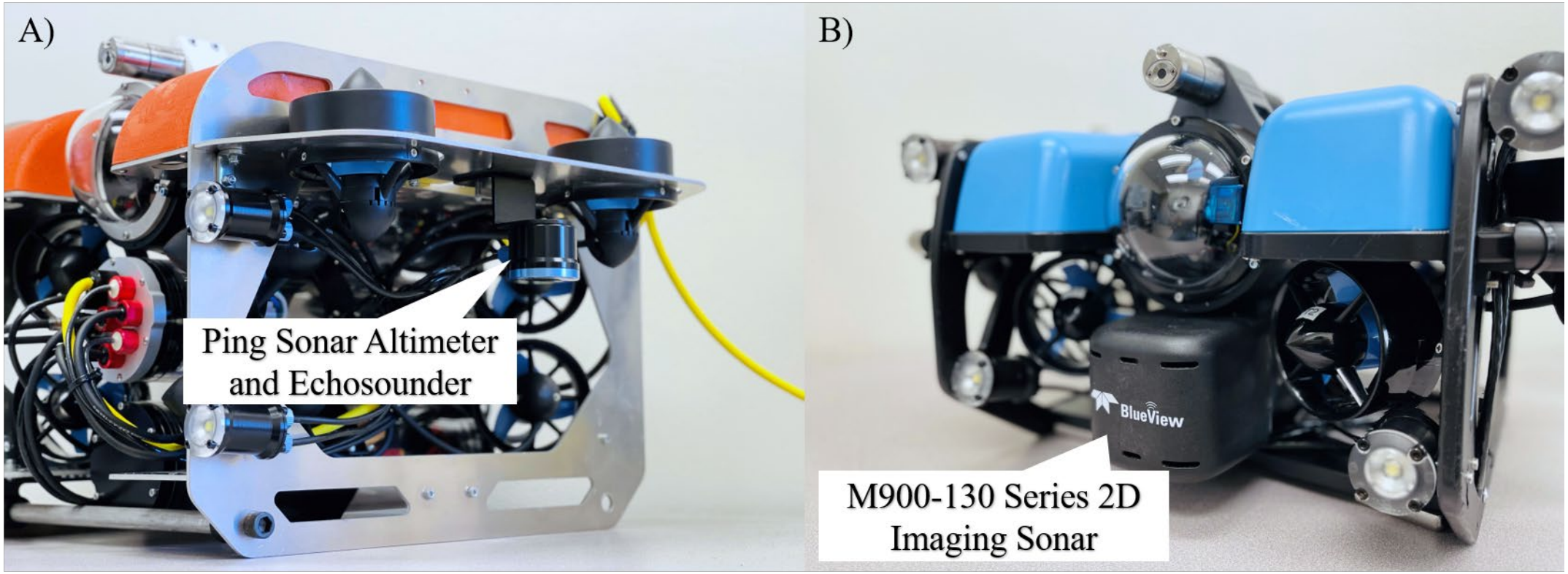
Performance: Accomplishments and Progress (cont.)

- Modular design: Adaptable for various water quality sensors (e.g., TDG, temperature, DO, methane etc.)



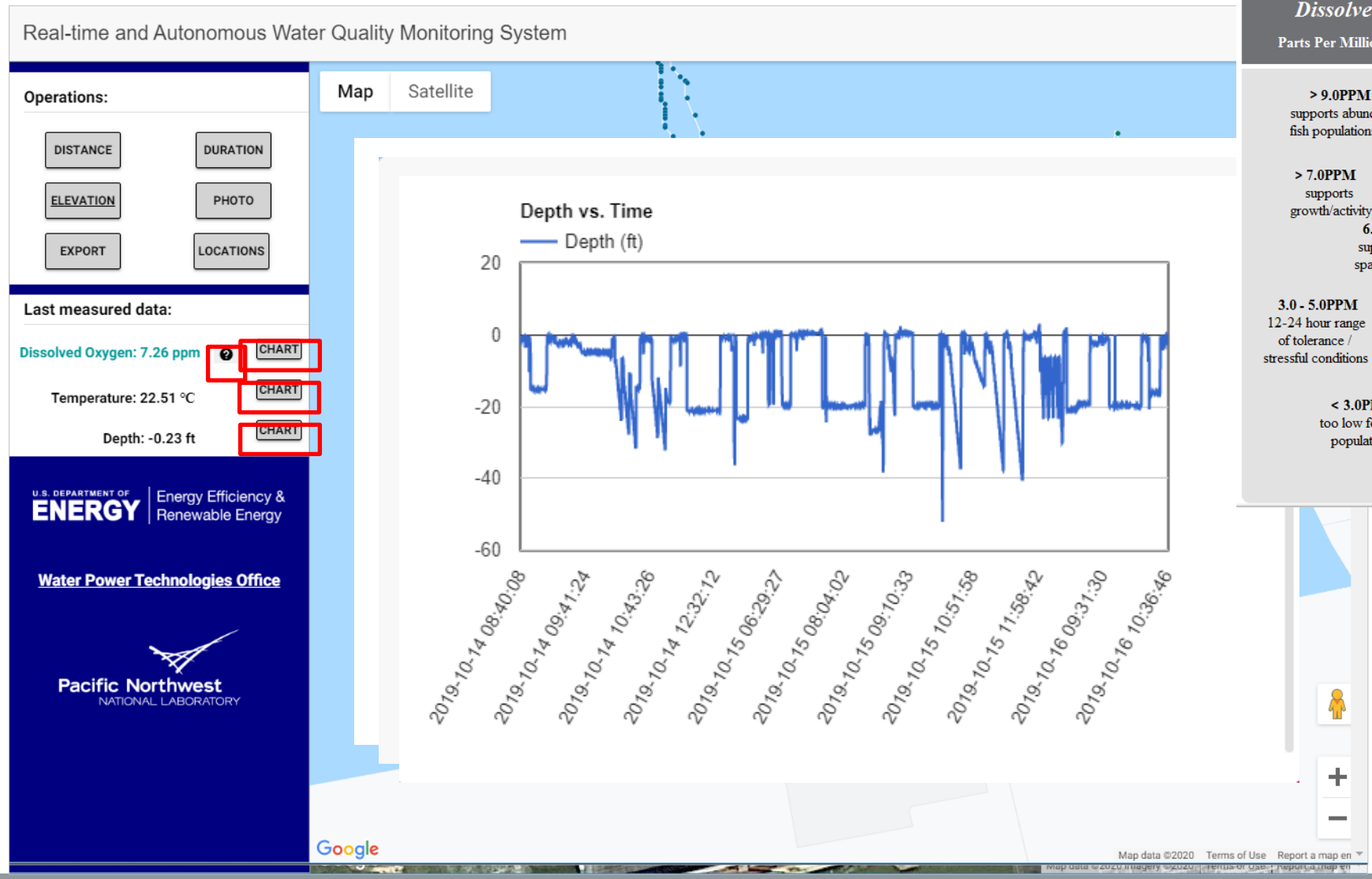
Performance: Accomplishments and Progress (cont.)

- Active Acoustic Sensing Devices: Sonar was implemented to allow the system to also be utilized for O&M applications at hydropower facilities. This allows the system to be used for a variety of activities at a dam that extend beyond measuring the water quality.



Performance: Accomplishments and Progress (cont.)

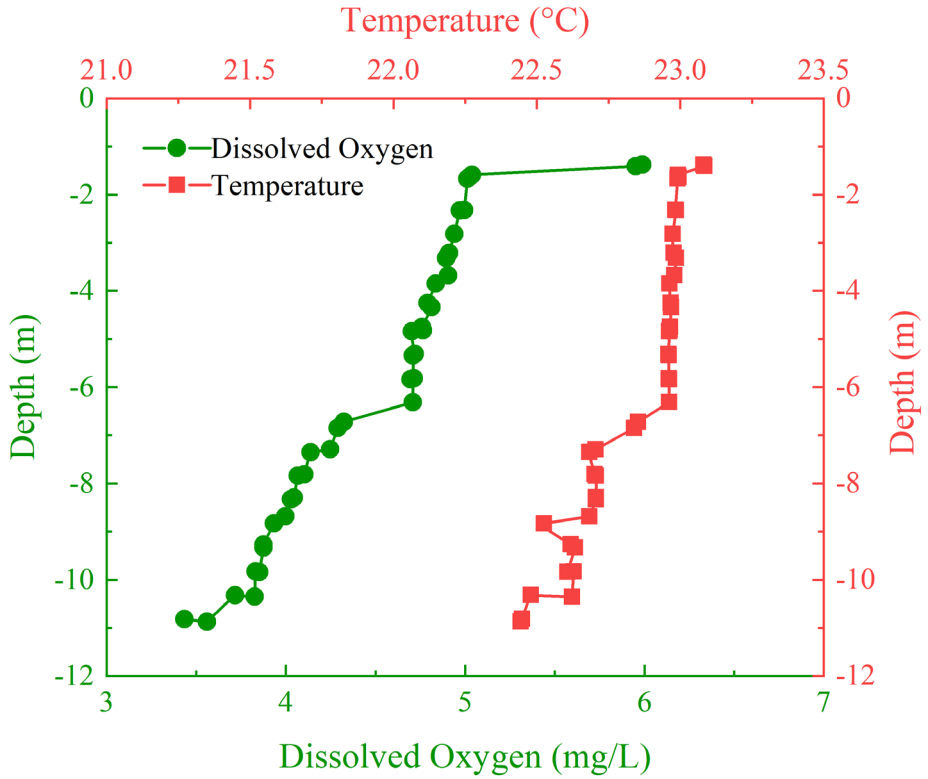
- Cloud-based User interface



https://awsuswebazurewebsites.net/home/

Performance: Accomplishments and Progress (cont.)

- Pilot Study Site: High Rock Dam, North Carolina in collaboration with Eagle Creek Renewable Energy



Performance: Accomplishments and Progress (cont.)

- The autonomous water quality system was presented at numerous domestic and international conferences to disseminate the information and engage with stakeholders and potential end-users:
  - Anadromous Fish Evaluation Program (AFEP) Conference 2021
  - Clean Currents 2021
  - CEATI International Hydropower Conference 2020
  - Oceans 2020
  - American Society of Mechanical Engineers Tri-cities Chapter
  - American Society of Mechanical Engineers Yale University Study Chapter
- Published a peer-reviewed conference paper based on the presentation from the Oceans 2020 conference. https://ieeexplore.ieee.org/document/9389374
- Submitted a peer-reviewed publication for the IEEE Internet-of-Things Journal.
- Part of the project was used as a Master's thesis in Mechanical Engineering for a student from an underrepresented minority group.
- DOE published a Success Story on their website to highlight the public-private partnership between PNNL, DOE, Eagle Creek (formerly Cube Hydro), and General Electric from the field test at High Rock Dam in North Carolina. https://www.energy.gov/eere/water/articles/public-private-partnership-new-autonomous-dissolved-oxygen-sensor-enables-hydro

Performance: Accomplishments and Progress (cont.)

Summary of System Features

Autonomous	Takes pre-programed or real-time measurements at multiple locations
Self-powered	Harvests solar energy to support autonomous operation
Wireless real-time communication	Transmits measurement and maintenance data to an on-or-offsite computer
Modular and expandable	Carries various combinations of sensors (TDG, temperature, DO, methane, etc.) via a modular mount configuration
Remote monitoring of sensor	Monitors onboard sensors through real-time video images to detect biofouling or other potential issues
Ease of servicing	Travels to shore for maintenance, away from the challenging environment where it is deployed

Q&A