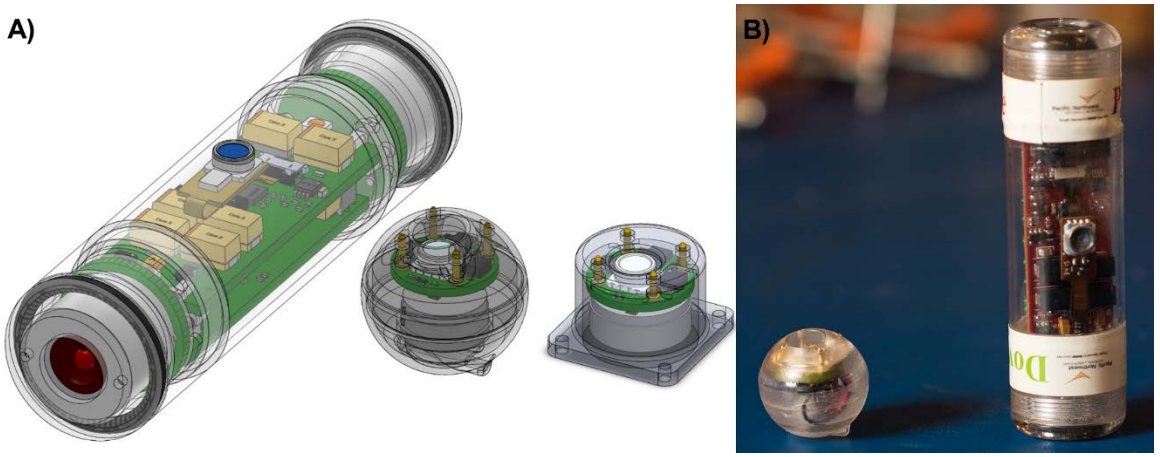


Commercialization of Sensor Fish Technology to Support Hydropower Development (TCF)

WBS: 2.5.0.604

Hydropower Program

October 10, 2019

Daniel Deng, Ph.D.

PNNL

Project Overview

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Project Summary

Under this project, we commercialized the Sensor Fish (SF) Technology to support hydropower development and evaluations and developed a prototype of a smaller version (SF Mini) to characterize the growing need for sustainable small hydro and testing scale-turbine models. This project provides information, data, and tools for dam operators and turbine designers to use to improve turbines and structures, and to understand and mitigate the environmental effects of hydropower operations on fish. It will also reduce regulatory review times and costs by reducing the need to conduct studies with live fish.

Project Objective & Impact

The project objectives were to 1) commercialize the SF Technology and 2) develop a prototype of a smaller version (SF Mini). A commercially available SF was transferred to industry and it is now available for use to evaluate existing, refurbished, or newly installed hydro-turbines; auxiliary dam structures that fish interact with; and other water pathways fish utilize. The SF Mini was patented as another product of this project. The SF Mini can be used to characterize the growing need for sustainable small hydro, and for testing scale-turbine models and other hydraulic structures with small clearance.

Project Information

Project Principal Investigator(s)

Daniel Deng

WPTO Lead

Tim Welch

Project Partners/Subs

Natel Energy, Inc (Natel), Farmers Irrigation District (FID), Farmers Conservation Alliance (FCA), and Advanced Telemetry Systems (ATS).

Project Duration

- Project Start Date: October 1, 2017
- Project End Date: September 30, 2018

Alignment with the Program

Hydropower Program Strategic Priorities

Environmental R&D and Hydrologic Systems Science

Big-Data Access and Analysis

- Technology R&D for Low-Impact Hydropower Growth
- R&D to Support Modernization, Upgrades and Security for Existing Hydropower Fleet
- Understand, Enable, and Improve Hydropower's Contributions to Grid Reliability, Resilience, and Integration

Alignment with the Hydro Program

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Environmental R&D and Hydrologic Systems Science

- **Develop better monitoring technologies to evaluate environmental impacts**
- Develop technologies and strategies that avoid, minimize, or mitigate ecological impacts
- Support development of metrics for better evaluating environmental sustainability for new hydropower developments
- Assess potential impacts of long-term hydrologic variations to hydropower generation and flexibility
- Improve abilities to assess potential methane emissions from reservoirs
- Better identify opportunities and weigh potential trade-offs across multiple objectives at basin-scales

Commercialization of Sensor Fish Technology and the development Sensor Fish Mini provides fisheries managers, dam owners, and researchers a commercially available tool that allows them to understand the hydraulic environment of a turbine and how the environment may affect fish. Using this technology hydropower developers can understand the environmental aspects of a new facility or upgraded turbine units.

Alignment with the Hydro Program

Technology R&D for Low-Impact Hydropower Growth

- Enable the design and development of new Standard Modular Hydropower (SMH) technologies for both existing water infrastructure and new stream-reach development. This new approach to systems design for hydropower projects incorporates ecological and social objectives for river systems earlier in design processes
- Leverage new advancements in manufacturing and materials to dramatically lower costs of SMH components and systems designs
- Support development of necessary testing infrastructure for new technologies

Commercialization of Sensor Fish Technology and the development Sensor Fish Mini provides fisheries managers, dam owners, and researchers a commercially available tool that allows them to understand the hydraulic environment of a turbine and how the environment may affect fish. Using this technology hydropower developers can understand the environmental aspects of a new facility or upgraded turbine units.

Project Budget

FY17	FY18	FY19 (Q1 & Q2 Only)	Total Project Budget FY17–FY19 Q1 & Q2 (October 2016 – March 2019)	
Costed	Costed	Costed	Total Costed	Total Authorized
0$K	$150K	$0K	$150K	$150K

Management and Technical Approach

- Multi-disciplinary collaboration between fisheries biologists, electrical engineers, mechanical engineers, civil engineers, software engineers
- Close collaboration between various organizations including:
  - Hydropower developer (Natel Energy)
  - Irrigation organizations (Farmers Irrigation District, Farmers Conservation Alliance)
  - Commercial vendor (Advanced Telemetry Systems)

Management and Technical Approach

This project involved three primary tasks:

- Optimize the Sensor Fish design and develop a prototype Sensor Fish Mini
  - The improvements focused on changes to increase the durability and manufacturability
  - Developed the Sensor Fish Mini to support small hydro deployment and physical model testing
    - Removed several functions unessential to these applications and reduced the size of the electronics to a minimum that still allowed for sensor measurements comparable to the regular Sensor Fish
- Conducted laboratory and field evaluations of Sensor Fish and Sensor Fish Mini
  - Used Sensor Fish and Mini to test the durability of their LP (linear Pelton) hydroEngine® at Natel's test facility
  - Used Sensor Fish and Mini to test fish and debris screens (Farmers Screen) in irrigation canals
- Developed a manufacturing process for Sensor Fish for commercialization

End-User Engagement and Dissemination Strategy

- The primary beneficiaries of this project are fisheries managers, dam owners, and researchers
  - Working with industry partners resulted in successful commercialize the Sensor Fish
  - Sensor Fish Mini can be utilized to emerging market of new small hydro facilities
- Disseminated the results of the project through:
  - Filing and licensing of intellectual property
  - Several presentations to fish passage conferences, hydropower workshops, working groups, and universities
  - Seven publications in peer-reviewed journals
  - several interviews by television, print, and digital media outlets

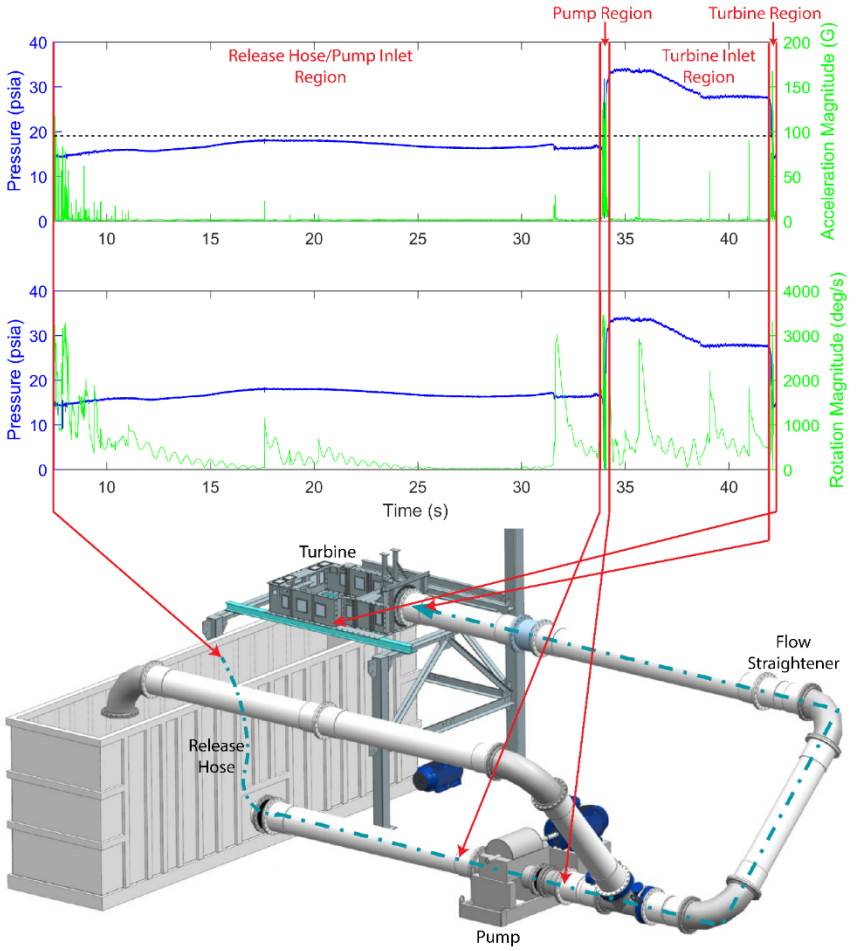
Technical Accomplishments

- The patent for Sensor Fish (10,067,112) was granted
- The IP for the Sensor Fish was licensed to ATS –who has subsequently produced a commercially available that has already being delivered to customers in several countries
- Developed a prototype for the Sensor Fish Mini with measurement capabilities comparable to the regular Sensor Fish, but in a much smaller spherical shape (diameter of 23.2 mm)
- Several Sensor Fish Mini prototypes were produced and used to conduct small field studies at Natel Energy's turbine test facility and at irrigation screens operated by Framer's Irrigation District and Farmer's Conservation Alliance

Technical Accomplishments (Cont.)

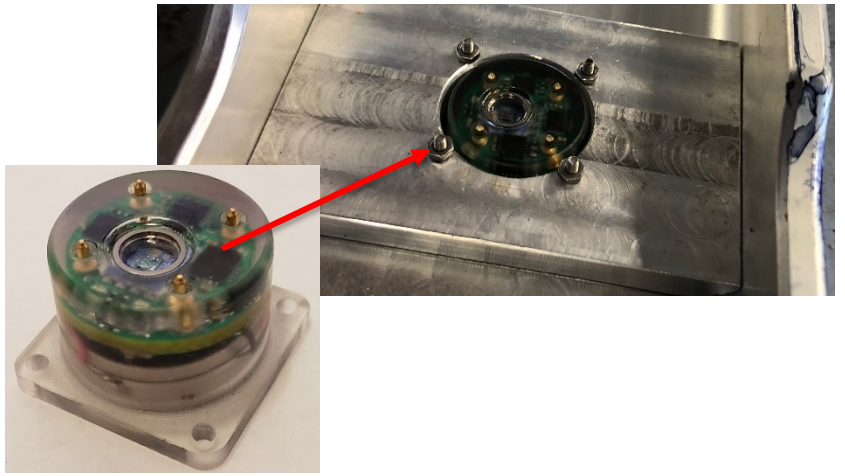
Sensor Fish Mini Testing at Natel Energy's Turbine Test Facility

- Used to test durability of Natel's LP (linear Pelton) hydroEngine®
- Sensor Fish Mini were introduced into a flexible hose running into the pipe inlet
- Sensor Fish Mini were released thirteen times through the turbine at the operating condition of 10 m of head and eight times at 6 m of head
- Data from Sensor Fish Mini were divided into different passage regions



Sensor Fish Mini Testing at Natel Energy's Turbine Test Facility (Cont.)

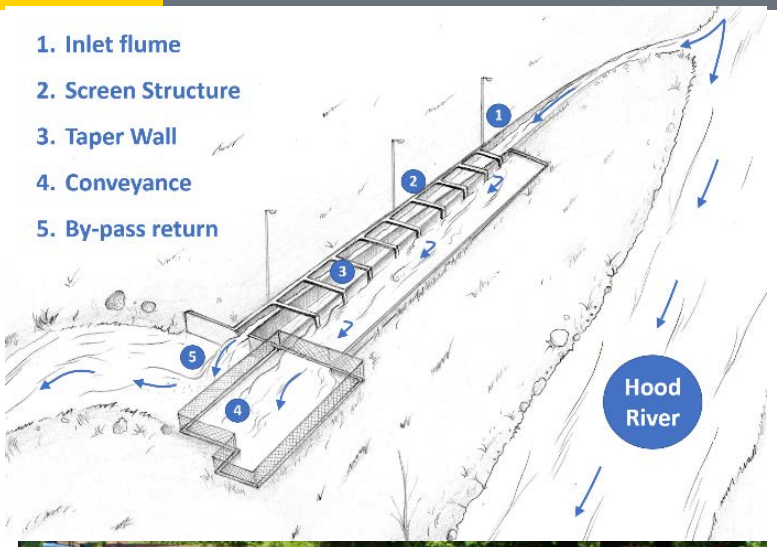
- Natel Energy had been trying to identify an inertial measurement unit (IMU) that could be mounted directly on the arms of their turbine to investigate machine dynamics
- Performed a test using the original Sensor Fish Mini by setting 15 minute delay to allow time to mount and close up machine and was able to capture data with machine running
- Designed an alternative form factor that allows Sensor Fish Mini to be hard mounted to a flat surface



Technical Accomplishments (Cont.)

Sensor Fish Mini Testing at Irrigation Screens:

- Released both Sensor Fish and Sensor Fish Mini into horizontal, flat-plate fish and debris screens, known as Farmers Screen, at three irrigation sites in Oregon
- Investigated occurrences of severe acceleration (>95 G) events
- Compared results to previous Sensor Fish studies conducted alongside live fish tests
- Results indicate that Farmers Screens can provide safe downstream passage for fish, which is consistent with a live fish test conducted on a smaller scale version
- Published a paper on the findings

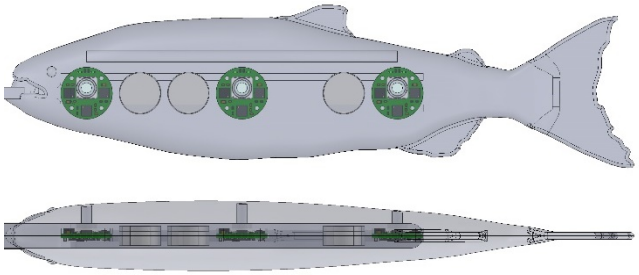


*Salalila A.L., et al. 2019. "Evaluation of a Fish-friendly Self-cleaning Horizontal Irrigation Screen Using Autonomous Sensors." *Marine and Freshwater Research*.

Progress Since Project Summary Submittal

Conducted a Strike Test at Alden Labs Using Sensor Fish Mini

- Investigated strike from different turbine blade designs at different speeds using SF Mini
- Prototyped a fish-shaped device consisting of three Sensor Fish Mini circuit boards encapsulated in a silicone



Summary

- Commercialized the Sensor Fish.
  - Positive media coverage including hydroworld, popular mechanics.
  - has been purchased across the country as well as internationally in Austria, Australia, Canada, France, Germany, and the United Kingdom.
- Developed the Sensor Fish Mini to support small hydro deployment and physical model testing
  - Two form factors
  - Can be molded into fish shape with multiple Sensor Fish Mini inside.
- Conducted small field studies at Natel Energy's turbine test facility and at irrigation screens operated by Framer's Irrigation District and Farmer's Conservation Alliance
- As a follow-up, conducted a Strike Test at Alden Labs Using Sensor Fish Mini