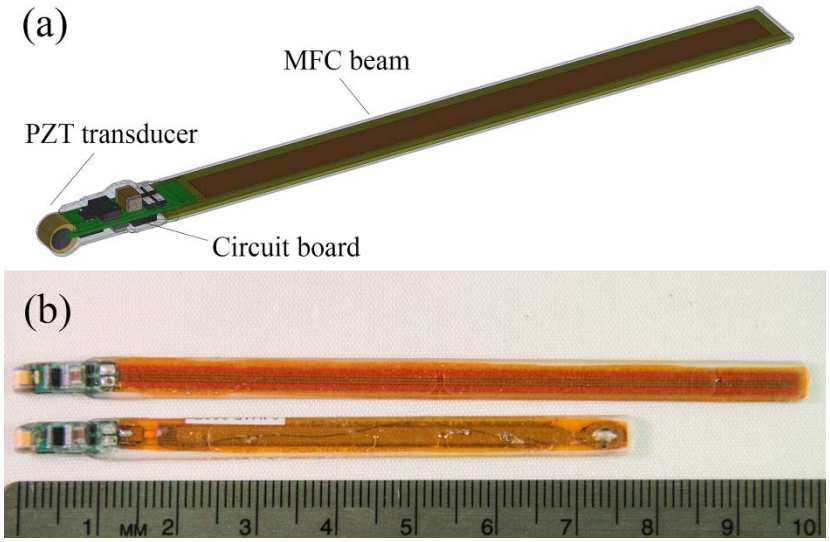


Self-Powered Acoustic Transmitter (TCF)

WBS: 2.5.0.602

Hydropower Program

October 10, 2019

Daniel Deng, Ph.D.

PNNL

Project Overview

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

Project Summary

The project's goal is to develop and prepare a self-powered transmitter for commercialization by demonstrating its viability and market impact in collaboration with private partners. The self-powered transmitter is a unique technology developed by PNNL and has generated interest from private sector for application and technology transfer. This project is part of Technology Commercialization Fund (TCF) Laboratory Call for Proposals in June 2016 and was extended without additional funds into 2019 to complete the field study component.

Project Objective & Impact

The objective is to increase the TRL to 8 for sturgeon research by developmental testing and evaluation of the system in the field. Advanced Telemetry Systems (ATS), a transmitter vendor, will assist in the design and manufacturability, while Idaho Power Company and Grant County PUD, potential end-user power companies, will assist in field deployments. Upon successful completion, ATS will bring the technology to the market. The ability to harvest energy from the fish movement has the potential to enable tracking fish throughout life stages. This capability would advance our understanding of migration timing and behaviors, habitat use, and survival rates; resulting in informed management decisions regarding new and existing hydroelectric facilities and inform designs of new hydropower systems to minimize or avoid impacts.

Project Information

Project Principal Investigator(s)

Daniel Deng

WPTO Lead

Tim Welch

Project Partners/Subs

Advanced Telemetry Systems (ATS); Idaho Power Company; Grant County; Smart Material Corp

Project Duration

- Project Start Date: October 1 , 2017
- Project End Date: September 30, 2019

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

This project provides a tool to conduct long-term, holistic life-cycle monitoring of long-lived species of concern. This technology provides the potential for a significant improvement over existing methods, since all other current technologies for species tracking utilize batteries with finite life spans, supporting goals to better evaluate environmental impacts of hydropower.

Information and data that this tool provides can inform adaptive management processes and other assessments.

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

This project is providing a tool that will enable long-term fish monitoring activities to inform the development of sustainable SMH technologies (e.g., component designs and facilities) for existing and new applications for low-impact growth. It can also provide information about species interactions with SMH facilities that can inform sustainable operations.

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
$124.6K	$0.2K	$0.4K	$125.2K	$150K

Management and Technical Approach

- **Formed a partnership between Advanced Telemetry Systems (ATS), Smart Material, Idaho Power Company and Grant County PUD:**
  - **ATS**: a commercial transmitter vendor, assisted in the design and manufacturability.
  - **Idaho Power Company and Grant County PUD**: potential end-users as power companies, will assist in conducting field deployments of the technology.
  - **Smart Material Corp.**: the vendor for piezoelectric-based energy-harvesting (EH) unit and has provided significant in-kind support for optimizing the design of the piezoelectric-based EH unit.
- **Required innovation in integrated circuits, piezoelectric beam design and implantation into fish.**
  - **This required close collaboration between fish biologists, chemists, battery engineers, electrical engineers, mechanical engineers, civil engineers, and materials scientists.**
- **Upon successful completion of the project, ATS will be able to bring the technology to the market for sturgeon research.**

Management and Technical Approach

This project involved the following four primary tasks:

Task 1: Optimized the transmitter design. Completed.

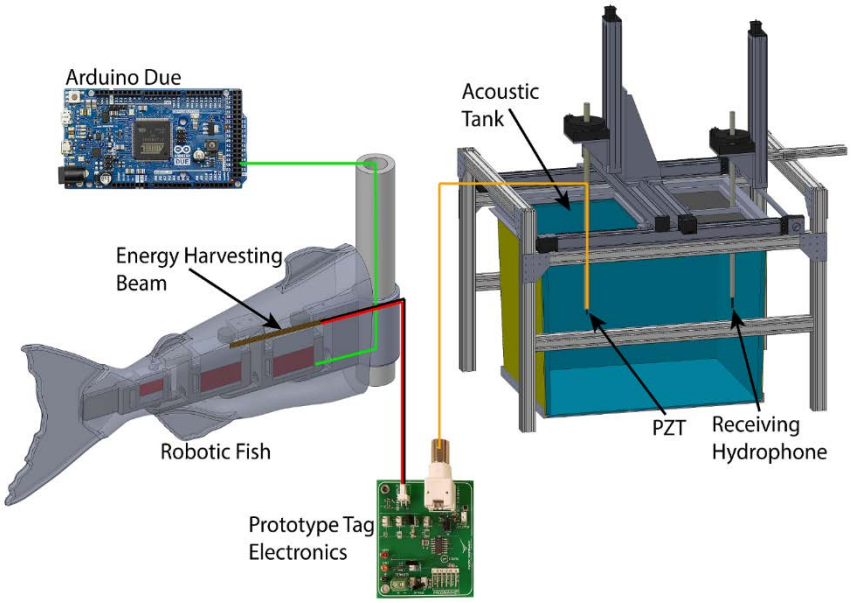
Task 2: Identified optimal implantation location and develop a tagging protocol. Completed.

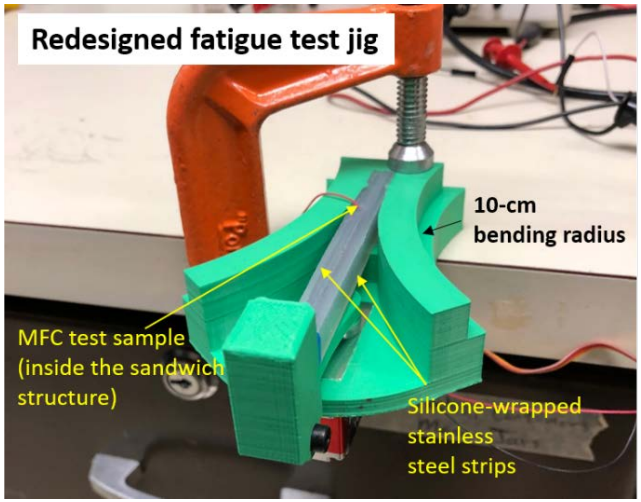
Task 3: Developed a manufacturing process at a scale that is needed for its targeted applications. Completed.

Task 4: Conduct evaluation in an actual field environment. Not completed.

Management and Technical Approach

Benchtop testing of the self-powered acoustic transmitter



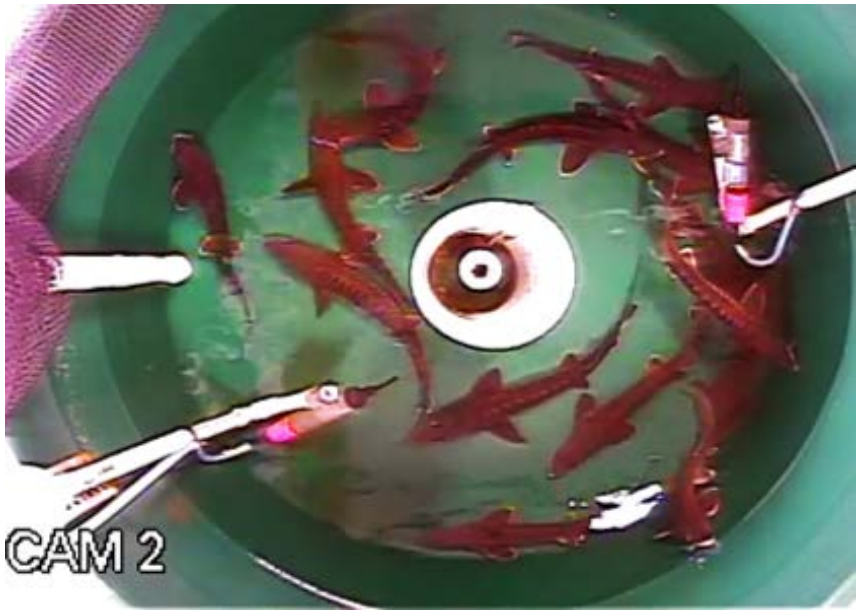


Transmitter fatigue testing setup

Management and Technical Approach

Live fish testing of the self-powered acoustic transmitter

Transmitter implantation



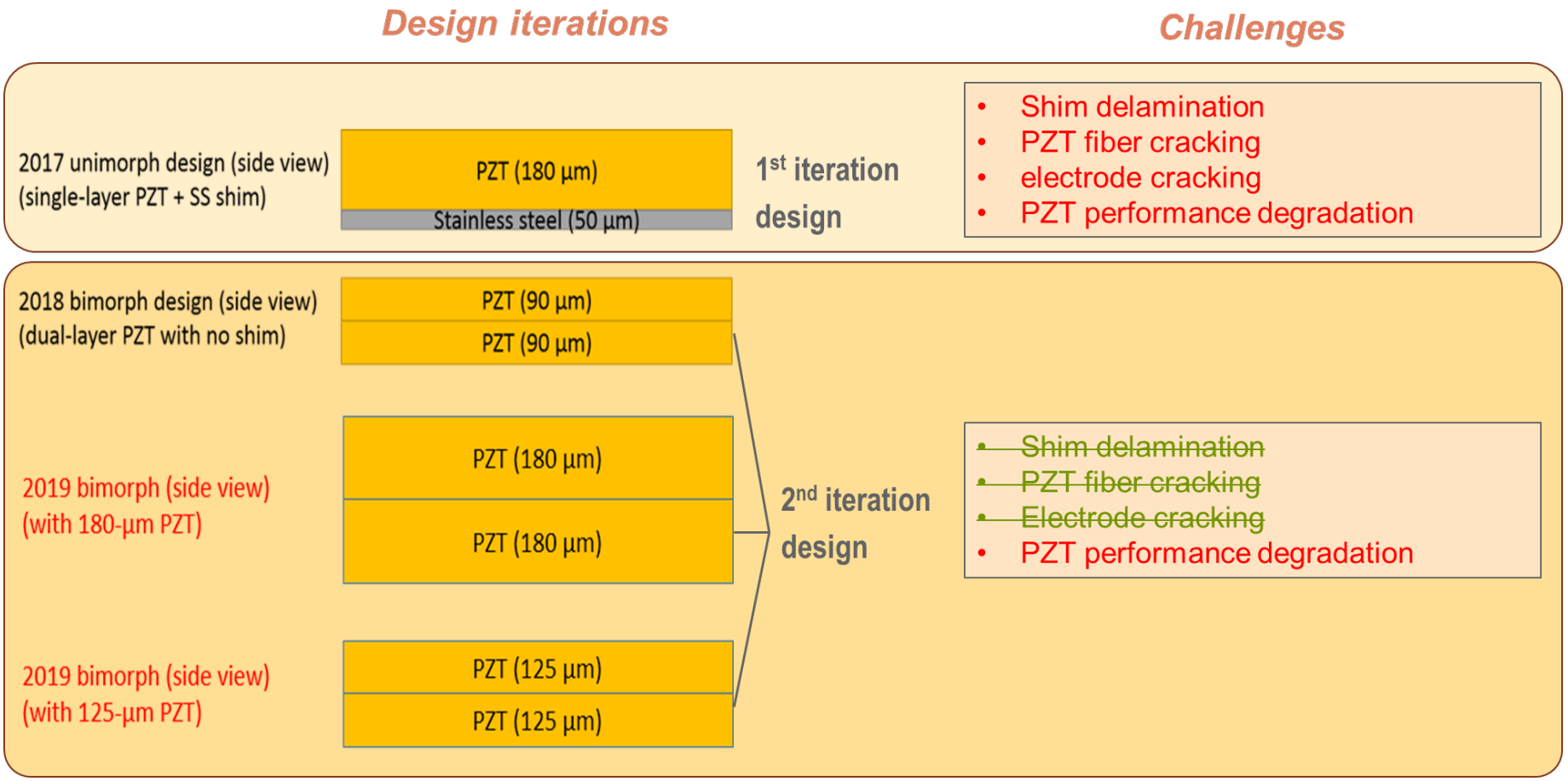
Fish behavior monitoring

End-User Engagement and Dissemination Strategy

- Worked directly with several partners including ATS, Idaho Power Company, Grant County PUD, Smart Material Corp.
- Presented our findings in multiple conferences including:
  - HydroVision International in 2018
  - Upper Colorado River Endangered Fish Recovery Program Annual Meeting in 2018
- Actively marketed to potential licensees, and put together a fact sheet on the self-powered acoustic transmitter and posted it on our website:

  https://waterpower.pnnl.gov/jsats/acoustictransmitters.asp

Technical Accomplishments



Technical Accomplishments (Cont.)

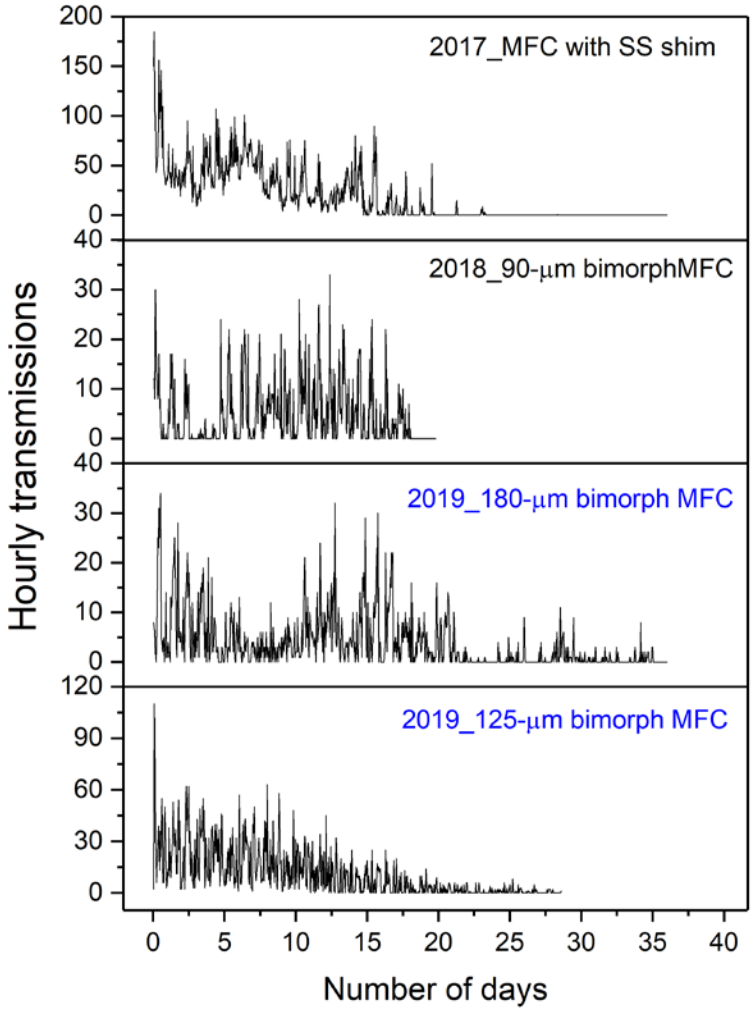
- **Sturgeon tagging protocol development:**
  - Pilot study with 12 fish tagged
  - An appropriate implantation location (flank, subdermal) on was identified
  - A tagging protocol was successfully developed
  - No significant differences were observed in fish fork length and weight between fish tagged with the transmitter and the control group after 14 days.

Dorsal implantation.
Wound still open after 14 days

Flank implantation.
Wound closed or nearly closed after 14 days

Technical Accomplishments (Cont.)

- Tag life improvements (project goal is one year)



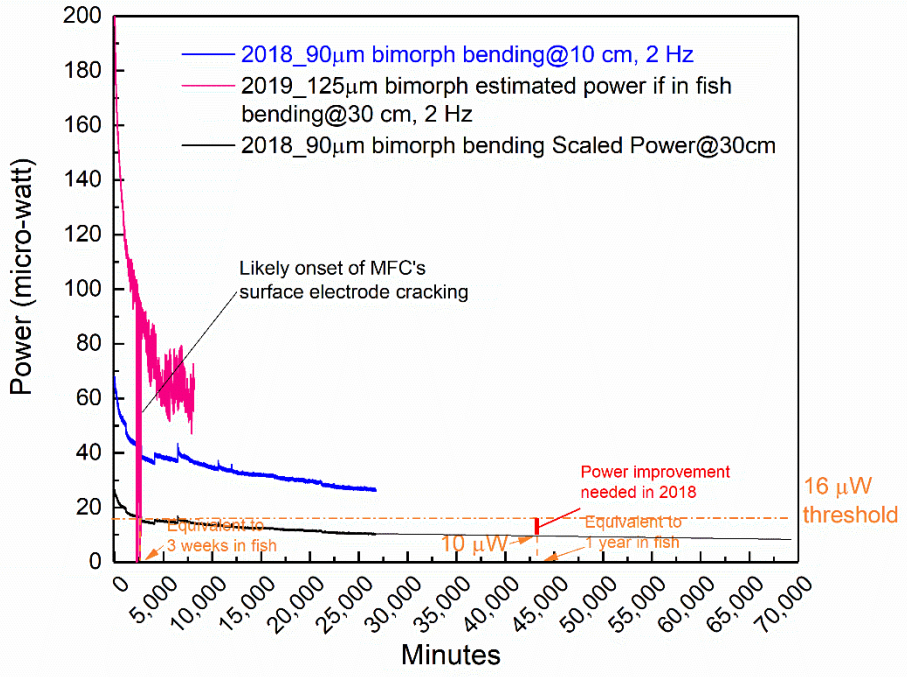
2017 tag life: 2-3 weeks

2018 tag life: 2-3 weeks

2019 tag life: 4-5 weeks

Technical Accomplishments (Cont.)

- **Attempt to overcome macro-fiber composite (MFC) fatigue under cyclic bending**
  - Identified energy-harvesting performance degradation under cyclic bending at juvenile sturgeon's extreme bending condition (when fish is making 180-deg. turns)
  - **Doubled** the initial power output of MFC by increasing piezoelectric layer thickn



Technical Accomplishments (Cont.)

Accomplishment summary

- Identified main failure modes of the transmitter in fish:
  A. Shim delamination (for 1st -iteration design)
  B. Cracking of piezoelectric fibers in the transmitter due to mechanical fatigue under fish's repetitive extreme bending
  C. Cracking of copper electrodes of the piezoelectric fibers due to mechanical fatigue under fish's repetitive extreme bending
  D. Piezoelectric performance degradation of the piezoelectric fibers in the transmitter due to mechanical fatigue
- Failure modes A, B and C have been resolved with the bimorph design of the MFC
- Improved service life of the transmitter prototypes from 2-3 weeks to 4-5 weeks
- Developed an implantation protocol which allows the fish to successfully heal and retain the transmitter
- Confirmed failure mode D to be the primary cause of tag failure and identified potential material option to resolve this issue.

Progress Since Project Summary Submittal

- Due to the delay in manufacturing of the MFC beams and their preliminary performance test results, the field demonstration won't be conducted in FY19.
  - Industry partners are aware of the delay and continue to supportive this effort.
- Smart Material informed PNNL of an exciting development regarding the MFC beam. A group at Penn State University (PSU) has recently developed a "textured" piezoelectric ceramics which may achieve good piezoelectric properties while retaining slow-degradation characteristic.

Future Work

- PNNL and Smart Material will contact the researchers at PSU who developed this technology regarding potentially using the textured piezoelectric ceramics in the bimorph MFC for the Self-powered tag.
- Identify a path forward for evaluating the new MFC design
- Explore the feasibility of design to study other species