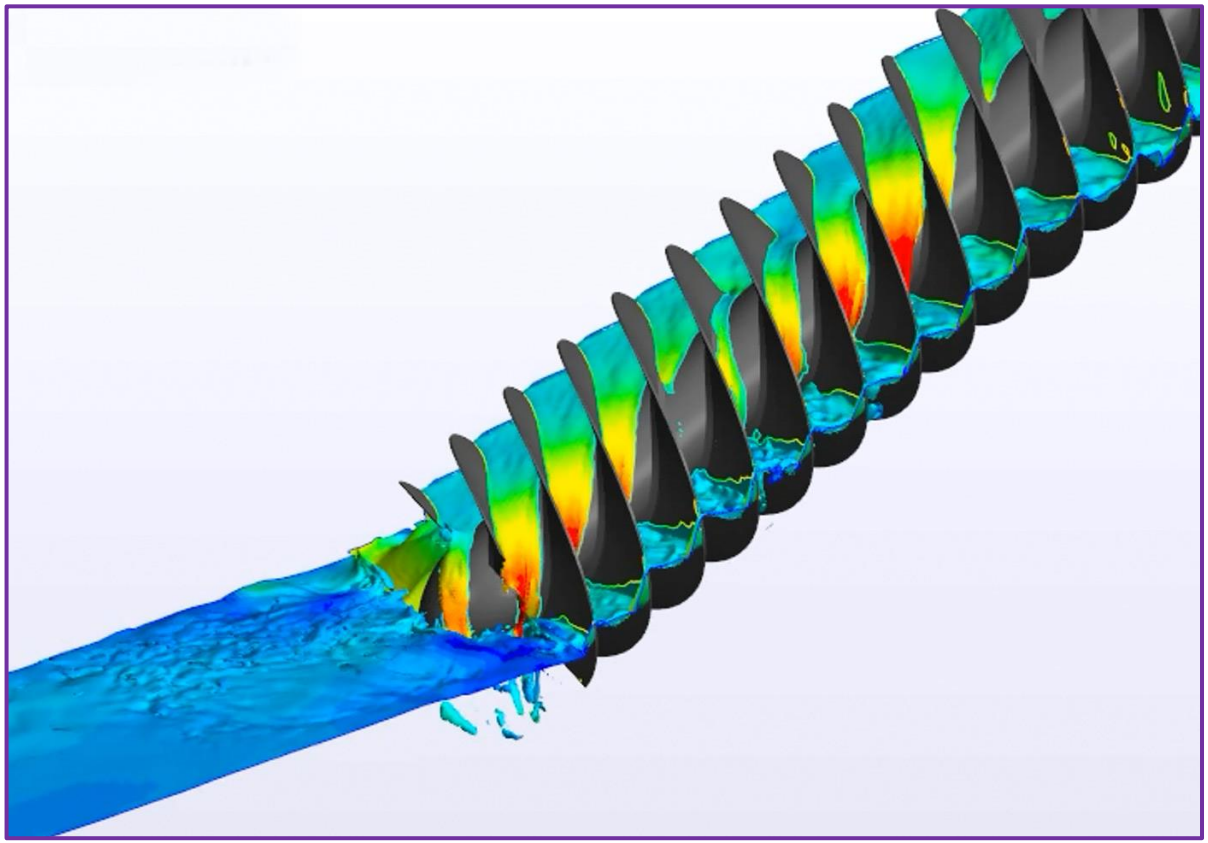

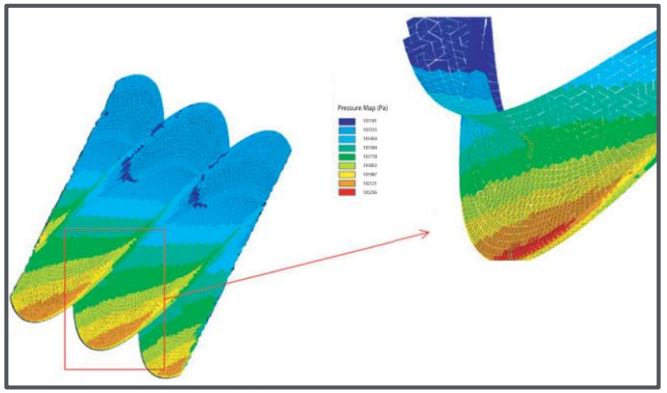

Optimized Composite Prototype for Archimedes Turbine Manufacture

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Optimized Composite Prototype for Archimedes Turbine Manufacture:

The Objective: Develop "next gen" Archimedes Hydrodynamic Screw (AHS) turbines using advanced components/composite materials and establish U.S. manufacturing capability with new protected IP

The Challenge: To decrease the levelized cost of energy/installed capital costs of this proven technology significantly enough to make many more low-head hydro plants viable in the United States

Partners:

- Pacific Northwest National Lab – Computational fluid dynamics (CFD), finite element analysis (FEA), materials consultation
- Hertelendy Research Associates, Inc. (HRA) – Blade/mold design and fab
- Mid Columbia Engineering, Inc. (MCE) – Bench scale test/turbine assembly
- Utah Water Research Lab/Utah State University (UWRL/USU) – Prototype testing
- Dr. Chris Rorres and Dr. Dirk Nuernbergk – Modeling and analyses
- Ershigs, Inc. – Central tube

Next Generation Hydropower (HydroNEXT)

Optimization

- Optimize technical, environmental, and water-use efficiency of existing fleet
- Collect and disseminate data on new and existing assets
- Facilitate interagency collaboration to increase regulatory process efficiency
- Identify revenue streams for ancillary services

Growth

- **Lower costs of hydropower components and civil works**
- **Increase power train efficiency for low-head, variable flow applications**
- Facilitate mechanisms for testing and advancing new hydropower systems and components
- Reduce costs and deployment timelines of new PSH plants
- Prepare the incoming hydropower workforce

Sustainability

- **Design new hydropower systems that minimize or avoid environmental impacts**
- Support development of new fish passage technologies and approaches
- Develop technologies, tools, and strategies to evaluate and address environmental impacts
- Increase resilience to climate change

Next Generation Hydropower (HydroNEXT)

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The Impact

- Optimum AHS turbine designs are developed, modeled and performance tested
  - **More efficient, lighter weight, environmentally friendly, and economically viable.**
- **Desired Result:** Lower cost, optimum efficiency turbines are manufactured in the United States instead of being imported, and are rapidly deployed at hundreds of existing low- head sites.
- **Final Project Deliverable:** Fabricate, Test and Deliver a fully-validated prototype CAHS turbine system for permanent field demonstration.

Next Generation Hydropower (HydroNEXT)

Sustainability

- **Design new hydropower systems that minimize or avoid environmental impacts**
- Support development of new fish passage technologies and approaches
- Develop technologies, tools, and strategies of evaluate and address environmental impacts
- Increase resilience to climate change

The Impact

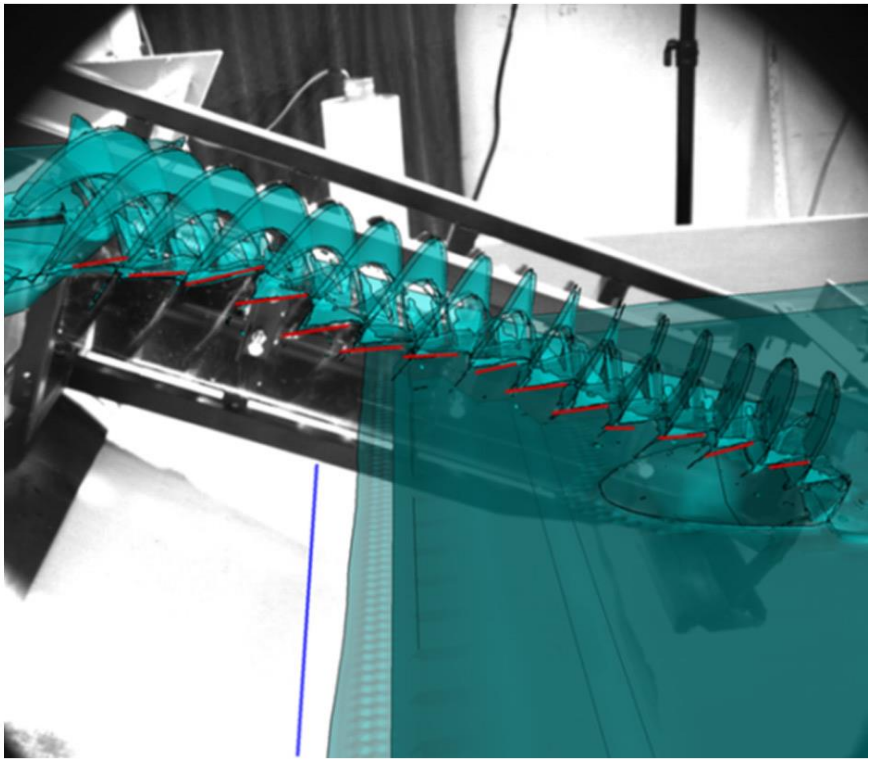
- The extremely fish-friendly Archimedes turbine is further improved and optimized for viable deployment in the United States.
- **Desired Result:**
  - Lighter weight turbine assemblies and new modular on-site installation methods are developed for fish-friendly AHS turbines
    - **Smaller plant footprints, reduced construction times, costs and environmental impacts.**
  - New distributed capacity is added to the U.S. hydropower fleet with ultra-low environmental impact utilizing existing man-made drops and infrastructure.

Project Scope:

Design, Fabricate and Test an Optimized AHS Turbine Prototype using advanced materials and methods

- Utilize iterative approach
  - Theoretical mathematical models
  - Experimental results on water tests of bench-scale turbines
  - Computational Fluid Dynamics (CFD) modeling
  - Finite Element Analyses (FEA) using pressure maps from CFD
  - Water testing of larger Prototype assembly
- Focus on delivering the most power output per unit cost of the turbine assembly
- Pay closer attention to entrance/exit effects
- Utilize bench-scale tests to cost-effectively validate selected optimized designs before scaling up.

Technical Approach



- Bench Scale Testing provides hands-on insight
- Enables validation of CFD modeling
- Will provide cost-efficient testing of design optimizations

Accomplishments and Progress

Project underway since March 2016

- Completed bench-scale water testing on 3 turbines (over 800 data sets)
  - Including first ever testing of “strake” design by Rorres (patent pending)
- Completed mathematical modeling and selected parameter sets for 4 optimized prototypes (to move onto CFD/FEA modeling by PNNL)
  - Currently analyzing initial CFD/FEA results by PNNL
- Developed and approved first mold/blade design for prototype manufacture.

Project is on schedule

- Additional bench-scale tests to be performed on optimized designs for cost effective validation/refinement prior to fabricating larger prototype.

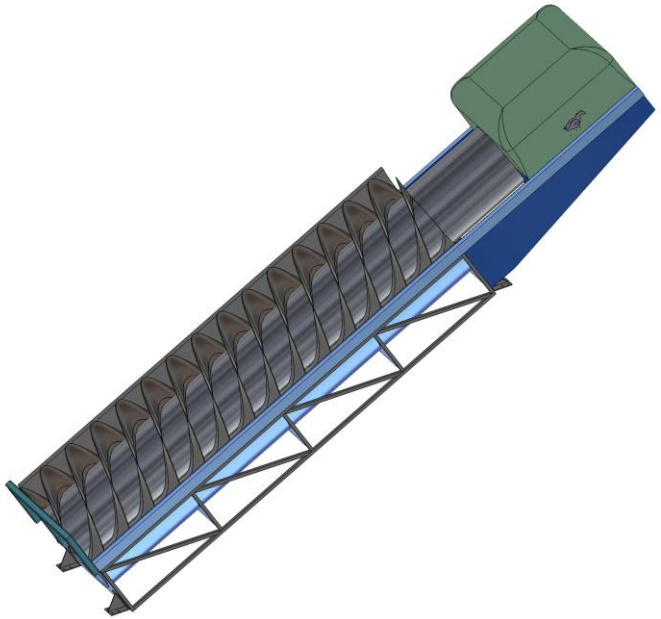
Recognition

- Entrepreneurial Award to Percheron by Richland Rotary/Chamber of Commerce (sponsored by Pacific Northwest National Laboratory)
- Several news articles featuring project in local/regional press and television
- High-profile municipality in Colorado plans to run permanent demonstration of prototype following successful lab testing.

Project Plan & Schedule

Project on Schedule

- Started March 1, 2016 and planned completion February 28, 2018
- All milestones to date achieved as scheduled
- One Go/No-Go Decision Point for Project in Month 15 (June 2017)
  - Readiness to Proceed with Testing of Prototypes at Utah Water Research Laboratory



Project Budget

Budget History					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
n/a	n/a	n/a	n/a	$306 K	$104 K

- Total Budget: $1,111 K DOE; $278 K Cost-share
- 30% of the project budget expended to date
  - Project is on schedule and within budget
- Matching funds being contributed by all team members (Percheron, MCE, HRA, UWRL/USU, consultants)
- Additional funding through DOE Small Business Voucher and PNNL Technology Assistance Program for PNNL support.

Research Integration & Collaboration

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

Partners, Subcontractors, and Collaborators:

- Pacific Northwest National Lab – CFD, FEA, materials consultation
- Hertelendy Research Associates, Inc. – Blade/mold design and fab
- Mid Columbia Engineering, Inc. – Bench scale test/turbine assembly
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Communications and Technology Transfer:

- Technical Paper drafted for submittal to Journal of Hydraulic Engineering
  - Present bench-scale test set-up and results
- Optimum turbine design details to be protected data/IP, as per contract terms
  - Goal is competitive manufacture of advanced AHS turbine in United States.

Next Steps and Future Research

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

FY17/Current research:

- Compare model predictions and test results to select optimized designs
- Fabricate prototype turbine blade assemblies
- Develop/procure remaining turbine system components
- Receive Go/No-Go approval from DOE for testing (6/2017)
- Perform in-water performance testing at UWRL/USU.

Proposed future research:

- Develop systems model for optimum turbine design
- Develop and test improved efficiency powertrain
- Continue development of entrance/exit optimizations
- Develop flexible test facility for permanent in-water testing of optimized low head turbines.