U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Office Of Nuclear Energy
Sensors and Instrumentation
Annual Review Meeting

Coolant Flow Sensor for Small Modular Reactors

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Phase II SBIR (August 2016 – July 2018)

October 18-19, 2017

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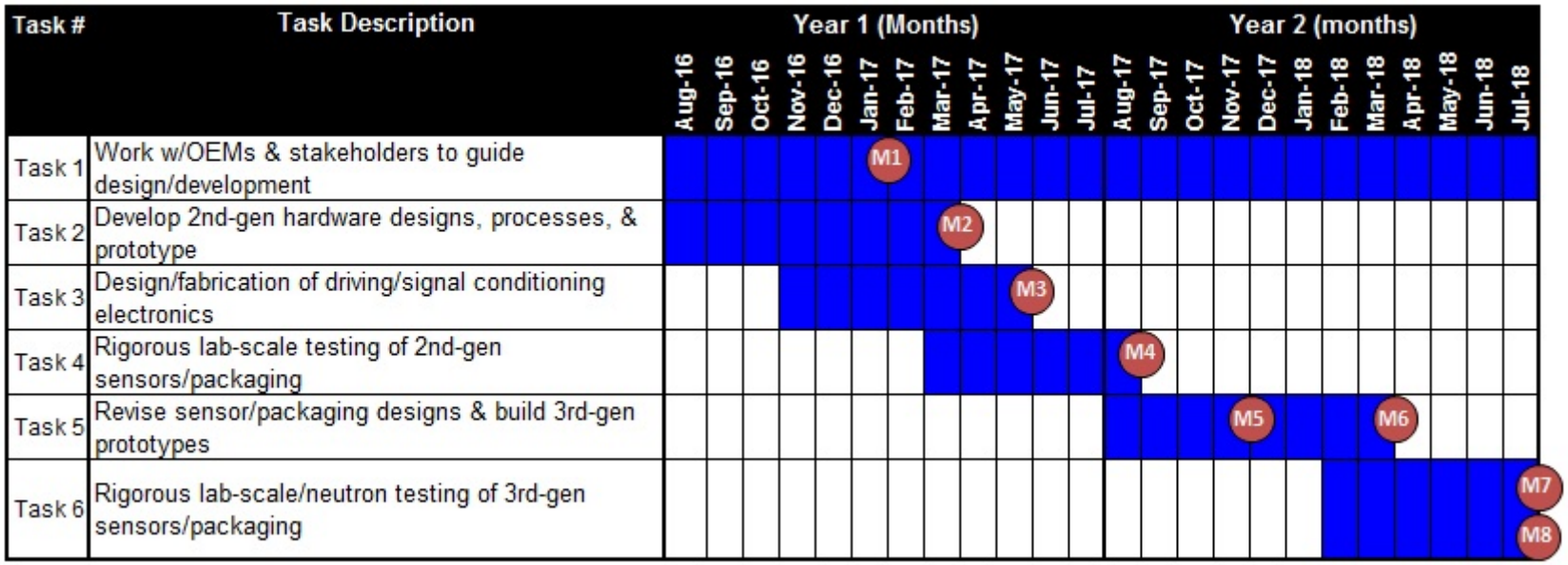
Project Overview

- **Motivation:** Nuclear Energy OEMS ID'd a high priority need for a liquid flow sensor to monitor reactor coolant flow
- **Objective:** Develop a coolant flow sensing system
  - Build upon prior Sporian-OEM collaboration for liquid and gas flow sensors
  - Harsh environment operation: 350°C; 2500 PSIG; 0.9 m/s liquid flow; borated water; irradiation (~8E+20 n/cm^2 fluence over the 60-year life of the reactor)
- **Task schedule in Phase II:**



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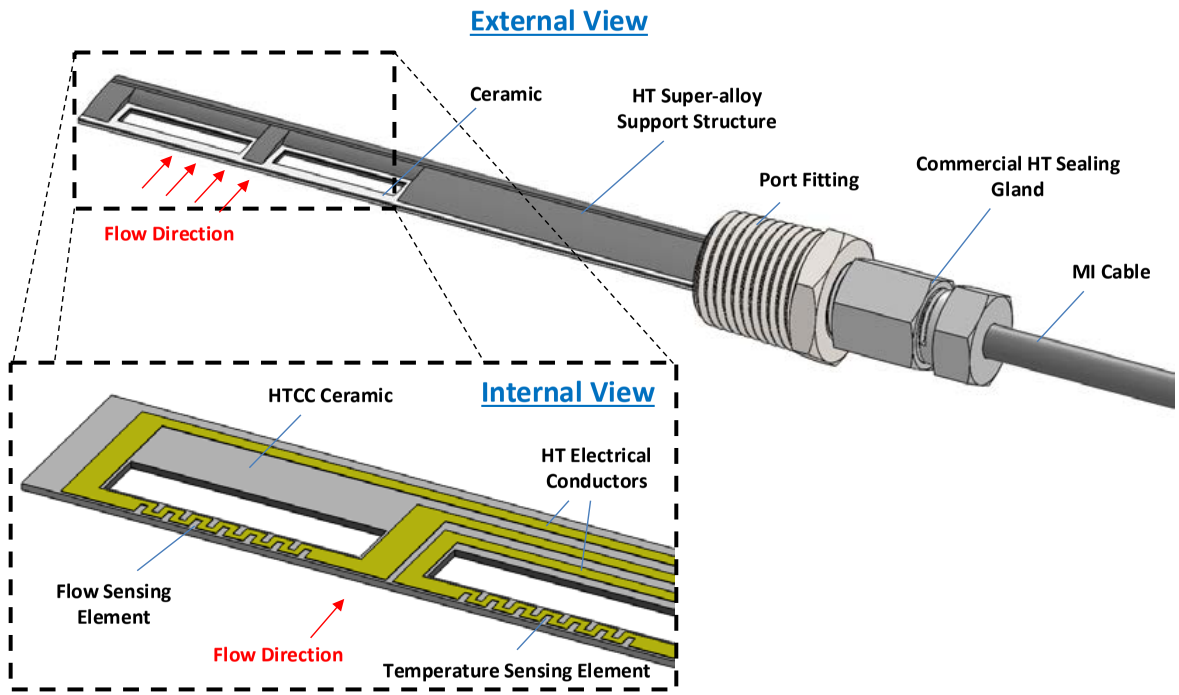
Technical Approach

- **Based on established anemometry methods**
- **Build upon prior Sporian development of liquid and gas flow sensors**
  - Leverage Sporian's previous experience in high temperature sensor materials, packaging, and design
- **Focus on materials, packaging, and testing**
  - Borated water
  - Irradiation effects
  - Media isolation (i.e., high-pressure sealing)
  - Demonstration and calibration



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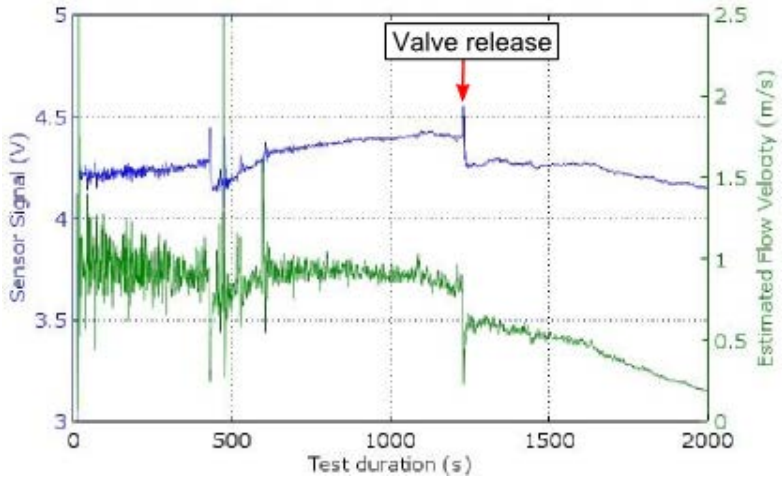
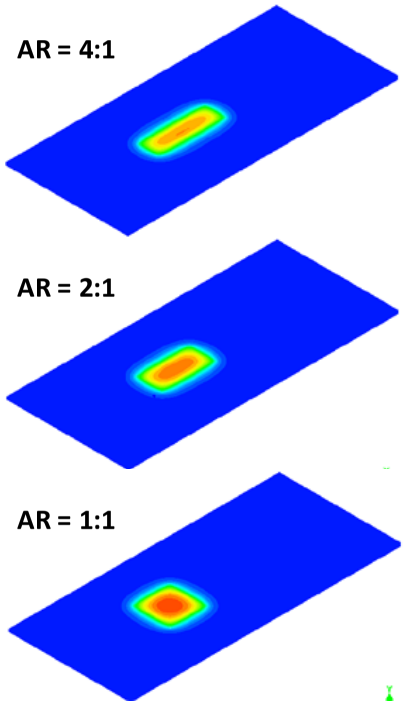
Phase I Results

- **Materials Testing**
  - Material screening by gamma spectroscopy
  - Soak in 300°C, 1600psig borated water
- **Prototype Device Design and Testing**
  - FEA to maximize sensitivity
  - Active device irradiation test (1E+18 n/cm^2 fast)
  - Flow testing - 1600psig, 315°C water





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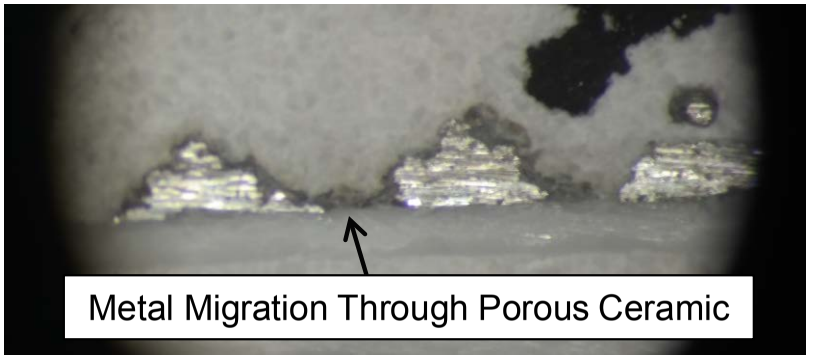
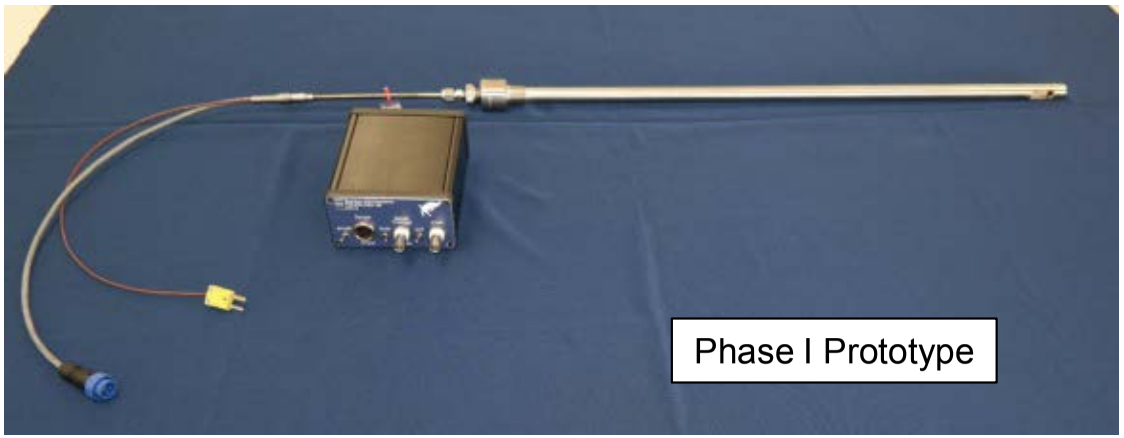
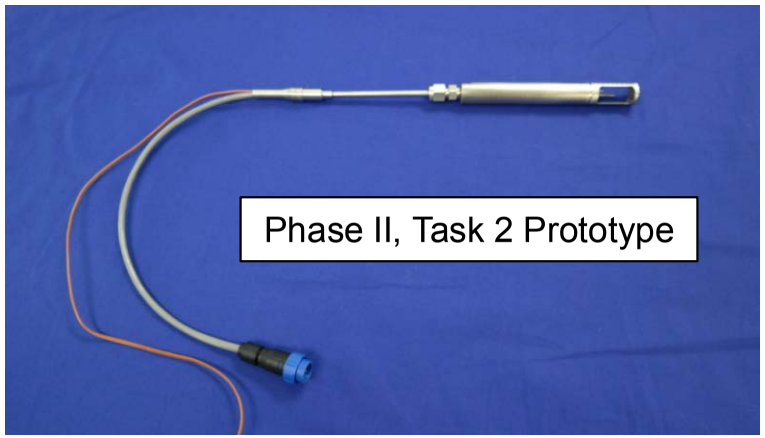
Phase II Results

- **Task 2 Milestone:** 2nd-generation device designs and processes developed, and prototype sensor & packaging hardware constructed
  - Borated water corrosion/compatibility
  - Irradiation insensitivity
  - Media isolation
  - Electrical interconnect reliability







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Phase II Results

- **Task 3 Milestone:** Operational, 1st-generation, integrated electronics platform that can be used to support parallel and subsequent testing and prototyping efforts
  - Analog and digital versions

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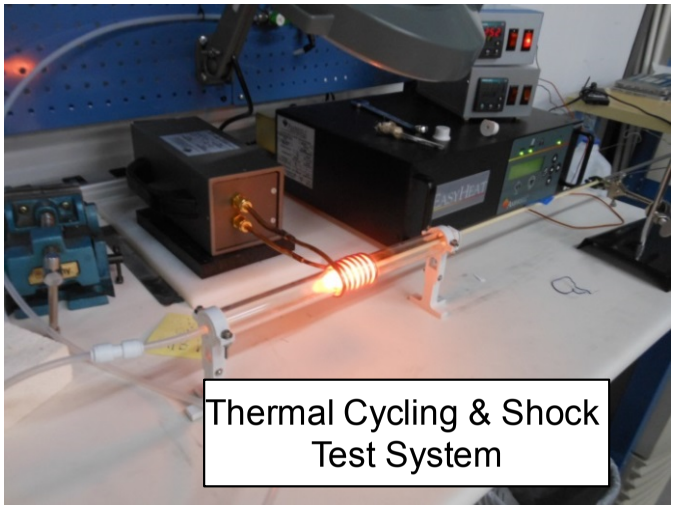
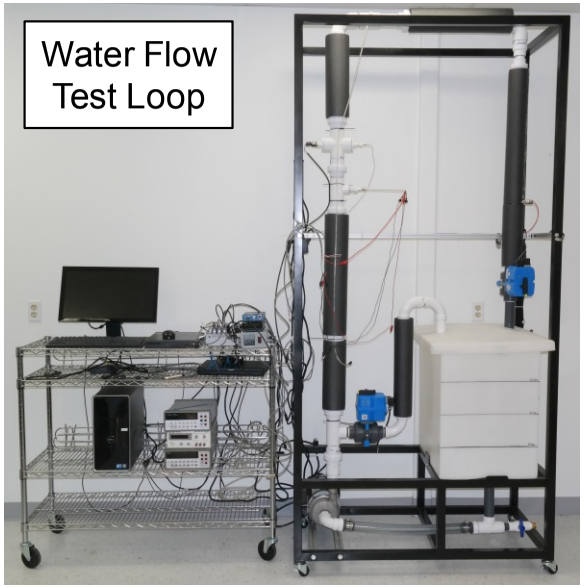
Phase II Results

- **Task 4 Milestone:** Experimental results from testing of 2nd-generation designs and prototypes
  - 100's of hours in Sporian flow loop (50°C, 1 atm, 3 ft/s max)
  - Thermal soak, shock, cycling
  - 100 hours in 300°C pressurized water
  - Electronics verification


Thermal Cycling & Shock Test System


Water Flow Test Loop


High-temp, High-pressure Water Test System

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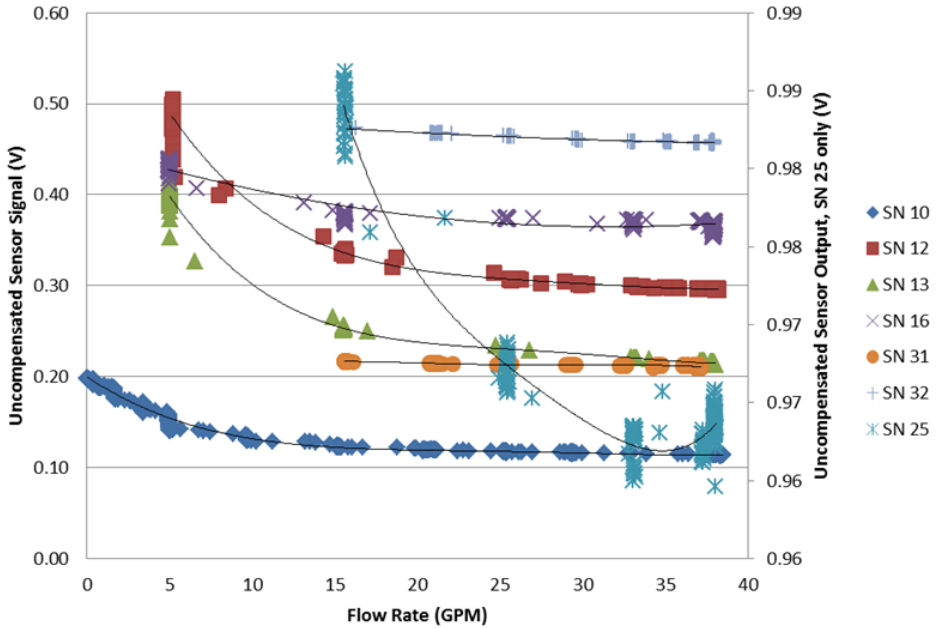
Phase II Future Work

- **Task 5 (Aug 2017 – March 2018):** Redesign based on test results
  - Reliability
  - Optimize signal:noise
  - Design for manufacture
  - Application-specific packaging



- **Month 16 Milestone:** 3rd-generation device designs
- **Month 20 Milestone:** 3rd-generation device prototypes

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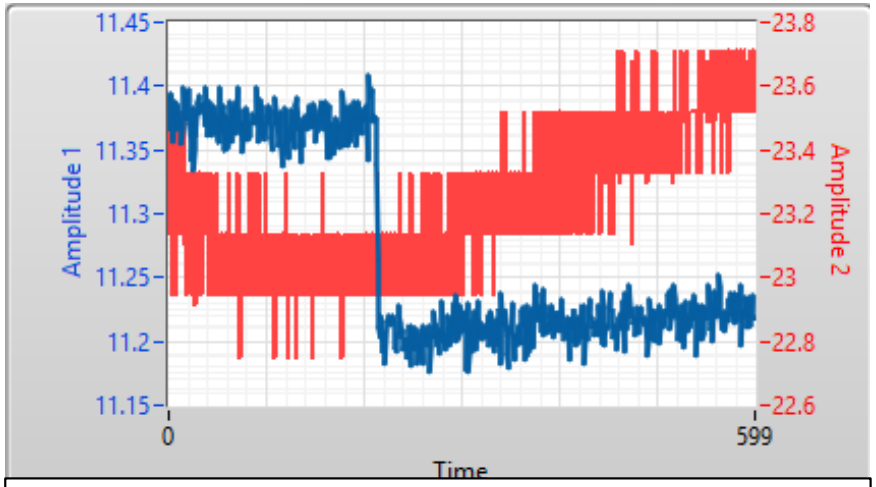
Phase II Future Work

- **Task 6:** Rigorous lab-scale testing of 3rd-generation prototypes.
  - Sensors, packaging, and fully integrated electronics
  - Partially coupled temperature, pressure, and flow testing (in-house)
  - Fully coupled temperature, pressure, and flow testing (external test facilities)
  - Active device irradiation
  - Steps toward nuclear qualification



AMS flow loop – transition from 1.7 to 2.6 fps

- **Month 24 Milestone:**
  Rigorous experimental results showing the application suitability of 3rd-gen designs and prototypes.

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Technology Impact

- **Contribute to understanding of coolant dynamics**
- **Improved reactor efficiency and safety**
- **Benefits of Sporian's design**
  - Single vessel penetration
  - Minimal flow restriction
  - Suitable for large non-pipe flow channels
  - High accuracy
  - Diversity

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Conclusion

- **New need for flow sensor in passively safe reactors**
- **Sporian developing novel coolant flow sensor**
- **Status: 3rd generation product design**
- **Phase II ends July 2018**

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