

# DOE15R2-20b: Integrated Sensors for Water Quality

**Contract #: DE-SC0013863**

**March 23, 2017**

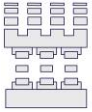
**Sporian Microsystems, Inc.**

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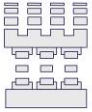
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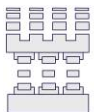
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# Overview

- Brief Intro to Sporian
- Project Motivation
- Related Prior Sporian Work
- Project Objectives
- Brief Review of Phase I and Phase II
- Phase II Plan



# About Sporian Microsystems

- Sporian develops advanced sensors and sensor systems for a range of applications.

## Core Technical Competencies

Novel Materials Science

Leading edge signal Conditioning & Smart Electronics

Advanced Electronics & Hardware Packaging

## Advanced Sensor Technologies

### Biological & Chemical

- Water Quality
- Gas Composition
- Biomedical
- Hyperspectral Imaging

### Energy & Aerospace

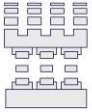
- Very High Temperature
- Harsh Environments
- Asset monitoring
- PHM





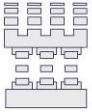
## Project Motivation

- **Motivation:** Present/growing emphasis on reducing or maintaining the water-use footprint in the energy sector (water-energy nexus).
  - Effective management water requires reliable, real-time, measurement-based data of water quality/composition.
  - Treatment systems & bodies of water associated with power generation facilities.
  - Existing water quality sensor technologies: large, difficult to install/deploy, and expensive.



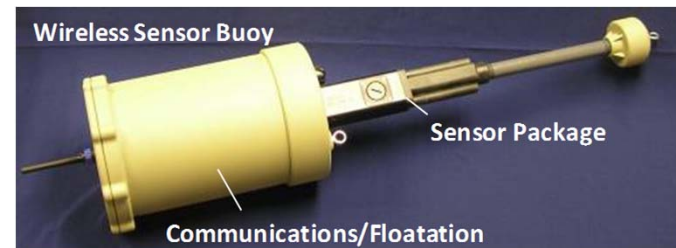
## Project Motivation – Cont.

- **Need:** The development of an integrated water sensor package
  - Low-cost, rapidly-deployable, wireless, self-powered, real-time, in-situ measurements.
  - Simultaneously monitor multiple factors/contaminants = reduced overall cost.
  - Hardware/packaging to function/survive environments.
  - Measurements of interest:
    - Temperature
    - Turbidity
    - pH
    - Total dissolved solids (TDS),
    - Scale forming minerals (ions) & salts,
    - Recovery Act (RCRA)-monitored heavy metals (RCRA 8s).

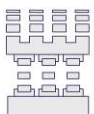


# Sporian's Related Prior Work/Technology

- Previously developed, field tested, and commercialized, low cost remote water quality monitoring systems for both the government and private industry
- Stemmed from US army SBIR - AQUAPATH
- Variety formats/sensor types:
  - Wireless buoys, inline process monitors, handhelds, downhole
  - Wireless comms (IEEE 802.15.4, ~1000 m range), GPS, data logging, expansion ports for additional sensors
    - Temperature, dissolved oxygen, pH, conductivity, salinity, turbidity, biological pathogens, TDS
    - Free chlorine and ion concentration (ongoing development)
  - "Smart" electronics for data processing
  - Low power consumption/battery operation
    - capability to add solar/PV
- Phase III Field Testing

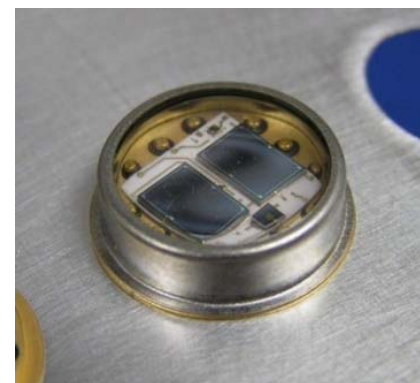
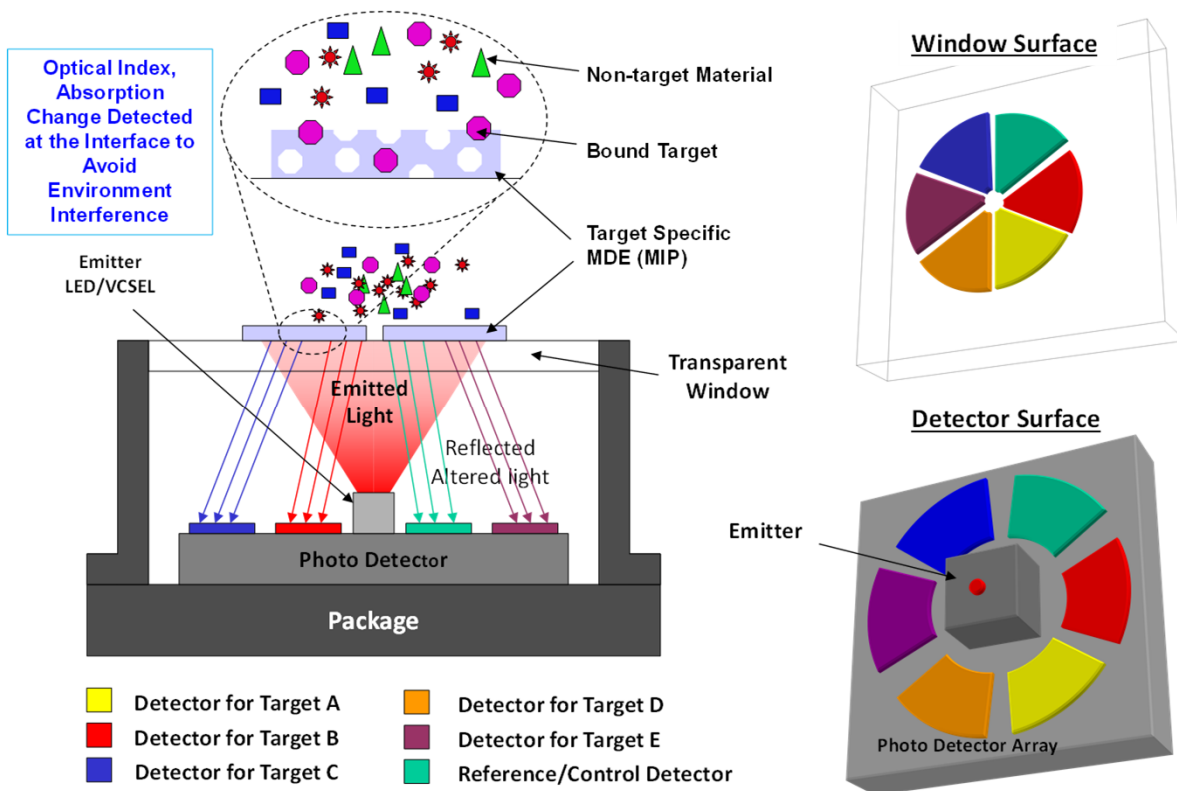






# Core Sensor Technology

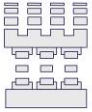
- Core of these detection systems is Sporian's patented small, low cost, multi-sensor optical detection element:
  - Tailored molecular detection element (MDE).
  - Leverages traditional optoelectronics packaging/manufacturing.
  - Small, low power, reliable, inexpensive.
  - Not previously applied to heavy metal monitoring, **requires a new MDE.**



## Background: MIPS/IIPS

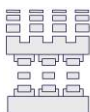
- Molecularly imprinted polymer (MIPs)/Ion Imprinted Polymers (IIPs)
  - Highly crosslinking polymers w/recognition properties based on the formation of a complex between an analyte (template) and a functional monomer during synthesis and cross linking.
  - Complexes preserved after cross linking, leaving binding selective molecular cavities physically and chemically complimentary to the target.
  - Polymer => tailored to desired properties: durability, permeability, optical characteristics, inexpensive, etc.
  - Commercially sold for highly specific chemical separation/filtration.
- Prior MIP/IIP Work:
  - Reported for a range of heavy metal targets including all of the RCRA 8 metals.
  - Reported in optical sensing applications (but not heavy metal MIP/IIPs).





# Primary Phase II Objectives

- **Approach:**
  - Update and extend the sensing capability of the existing systems to include heavy metal contamination
  - Use of Molecularly Imprinted Polymer (MIP) based materials/schemes in place of existing MDEs
  - Work with water/energy industry stakeholders to guide development
- **Phase I Focus:**
  - MIP development and preliminary hardware concept development
- **Phase II Focus:**
  - Developing, building, and testing (lab and field) two basic implementations
    - **Buoy** based water monitoring multi-sensor package
      - Remote/autonomous surface monitoring of bodies of water
    - **In-line** water monitoring multi-sensor package
      - Remote/autonomous monitoring of water treatment systems



# Target Hardware Implementations for Phase II

Feature/Capability	Buoy	In-line
Temperature sensor	Yes	Yes
Turbidity Sensor (EPA/ISO standard)	Yes	Yes
Flow	No	Yes
pH	Yes	Yes
Total dissolved solids (TDS)	Yes	Yes
Scale/Hardness Ions	Modular option	Modular option
RCRA heavy metals	Yes	Yes
3rd party sensor expansion ports (digital & analog) – TDO, chlorine, etc.	Yes	Yes
Rapidly Deployable Format	Yes	Yes
Wireless communications (~1000m range, transition to Ethernet/network)	Yes	Optional
Wired communications (digital/Ethernet)	No	Yes
Remotely configurable over network	Yes	Yes
Onboard data processing (time stamp, engineering units, alarm flags, etc.)	Yes	Yes
Data logging (persistent operation if comms temporarily lost)	Yes	Yes
Self-identification, self-test capabilities	Yes	Yes
Battery power	Yes	Optional
Energy harvesting/self-powered (solar, etc.)	Yes	Optional
Wired/line power	No	Yes
External visual power/alarm indicators.	No	Yes
Internal system temperature/power sensors	Yes	Yes
Inertial impact detection/log	Yes	No
Rugged packaging for field use applications	Yes	Yes



# Brief Review of Recent Efforts

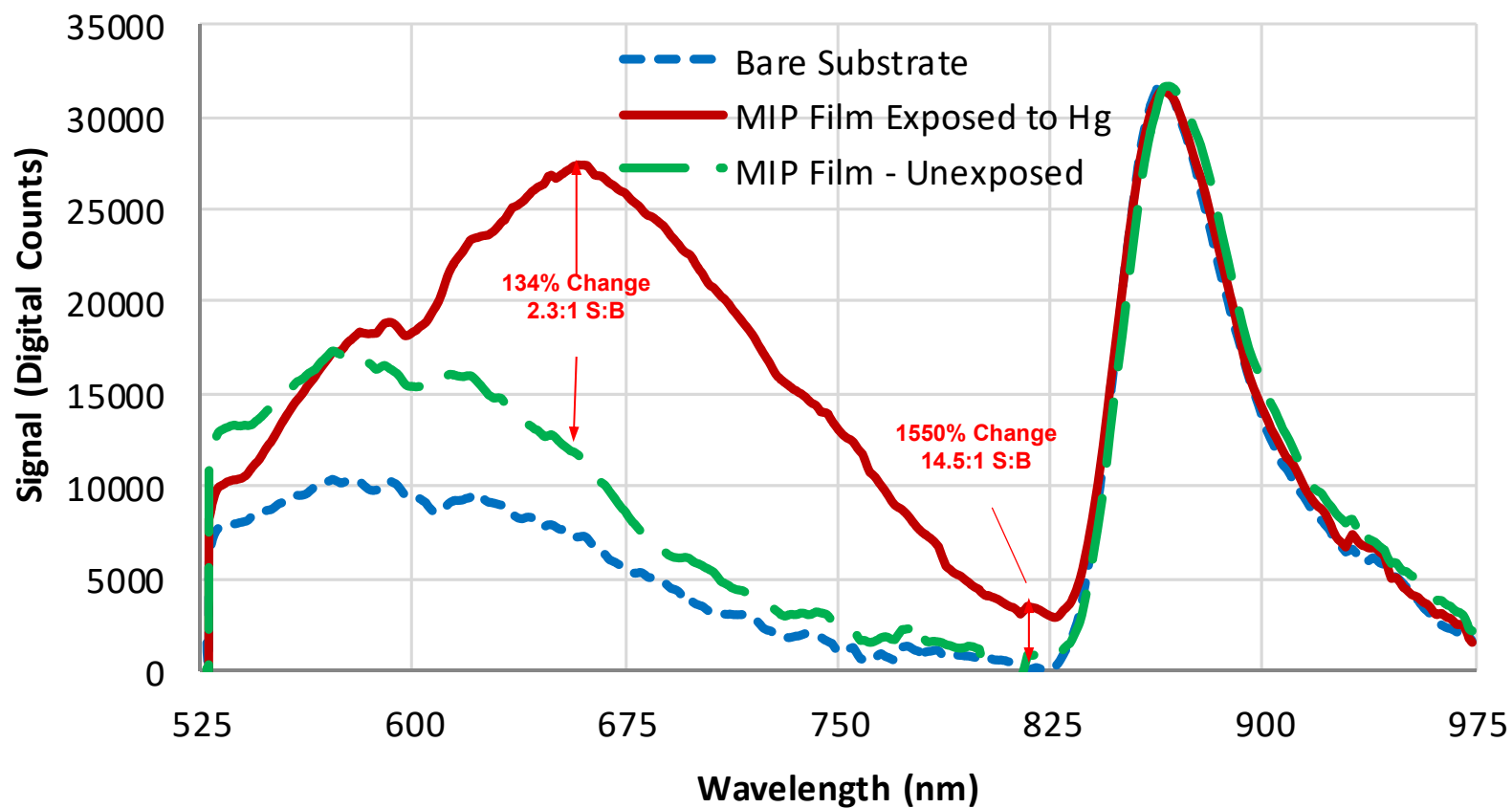


## Heavy Metal MIP Development

- Emphasis on MIP development in year 1 of Phase II
- A subset of candidate MIPs/IIPs synthesis methods identified & trialed
  - Early focus on selectivity
  - Synthesis process scale up and tailoring robustness in year 2
  - Several system emerged as good candidates moving forward
    - Mercury, Lead, and Cadmium current focus

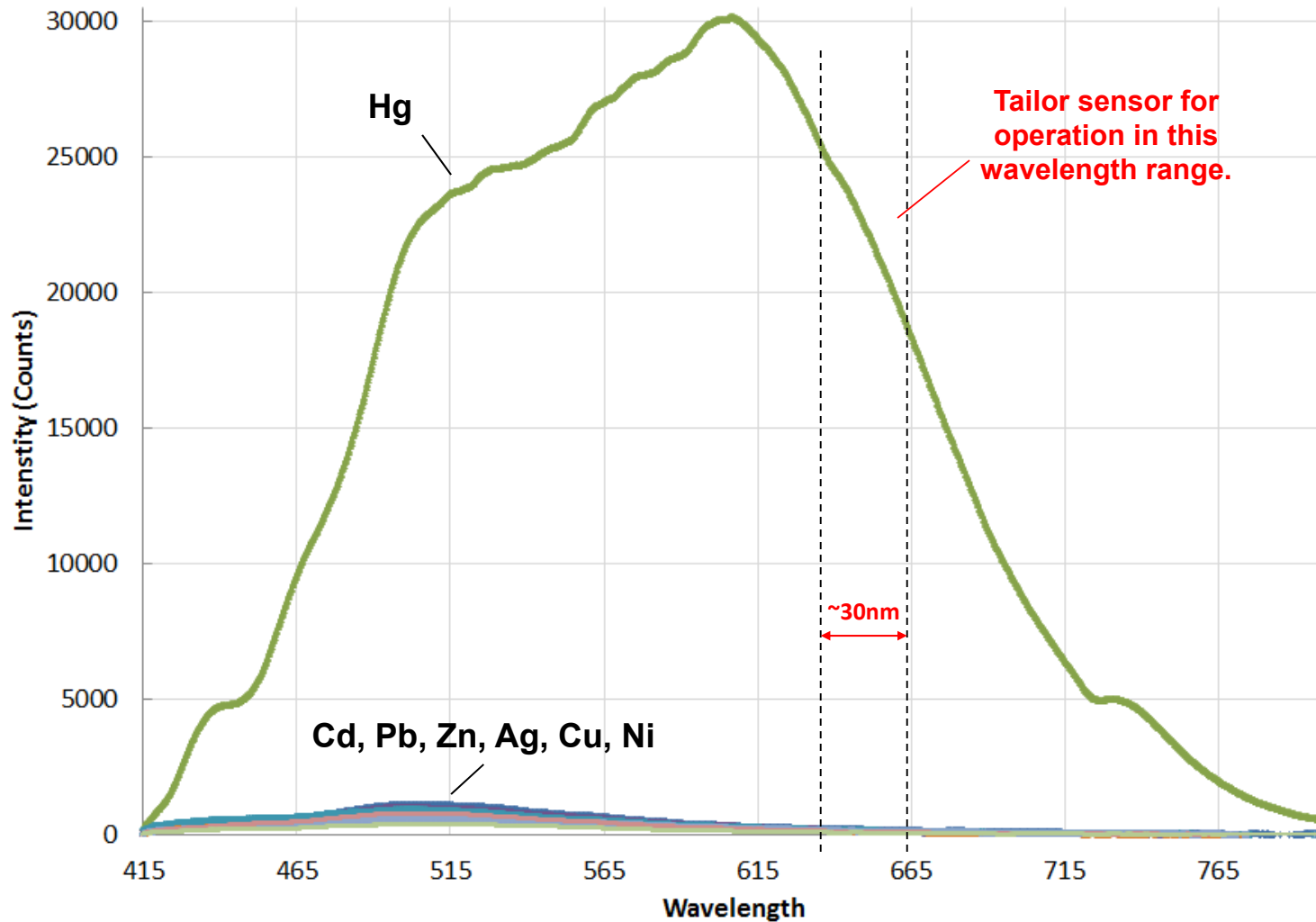


## Review of Phase I– Signaling Testing





# Recent Hg Signaling Data -Selectivity

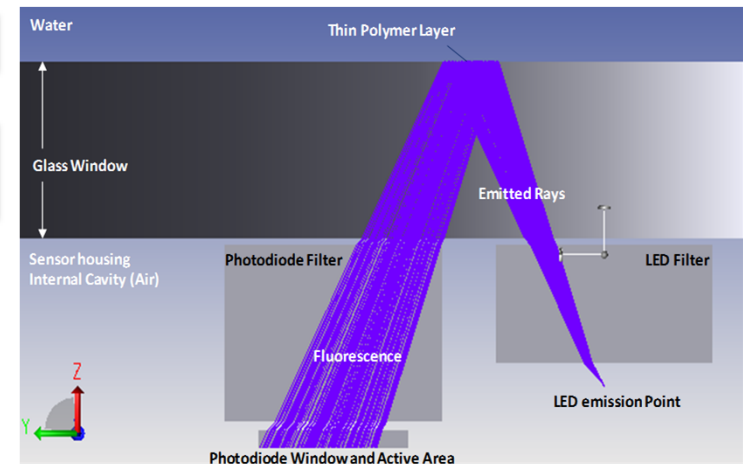
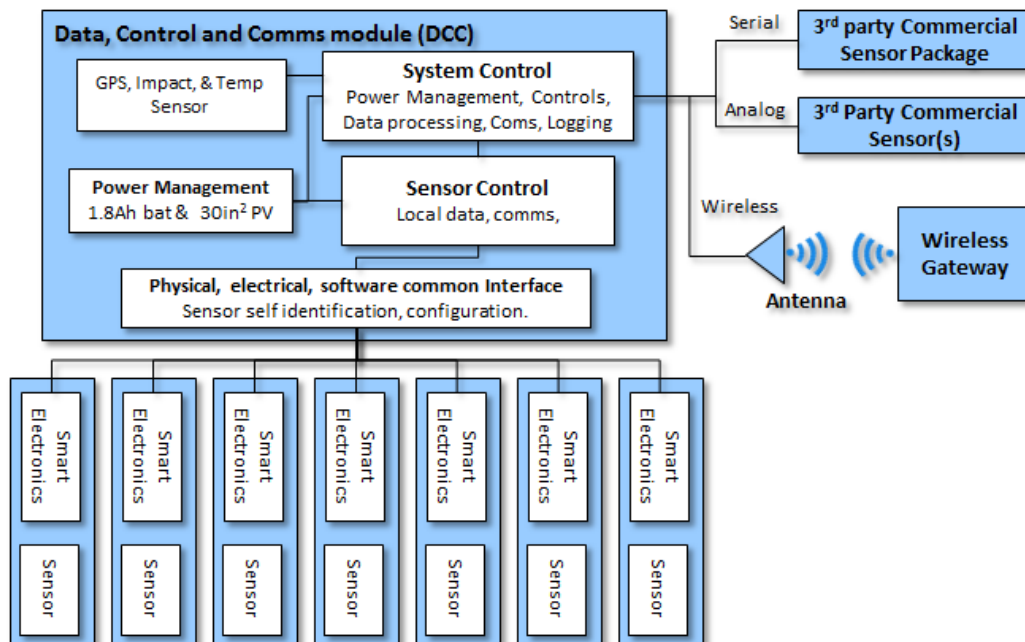


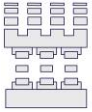




# Hardware/Electronics/Software Development

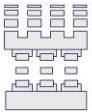
- Year 1 focus – system architecture revision
- Revised System Architecture Development
  - Modified to support additional sensors
  - Implemented a standard “smart” sensor interface for configurability
  - Incorporated new/emerging components
- Dedicated heavy metal sensor hardware/Optoelectronics packaging design
  - Modeling, component sourcing
- Review new COTS sensors - Make vs buy decisions





## Phase II Plan

- **Continue working with technical partners and potential end users**
  - Colorado Springs Utilities, CH2M, Colorado School of Mines (CSM), CB&I, and others
- **Optimize the MIPs/IIPs, expand development to include MIPs for additional RCRA 8 heavy metal targets**
- **Scale up processes, optimize robustness for relevant environmental conditions**
- **Develop revised hardware, electronics, and firmware designs for buoy and inline-based systems**
- **Prototyping and lab-scale testing of the revised buoy/inline monitoring systems**
- **Work with technical/industry partners to field-test and demonstrate the developed system in a relevant application/field environment**
  - Advanced Water Technology Center (CSM)
  - Field testing at surface water sources and water systems - Colorado Springs Utility
  - Field testing supported by CH2M Hill
  - Other testing opportunities in relevant environments will also be pursued



Task #	Task Description	Phase II (Quarters)							
		8/1-10/31	11/1-1/31	2/1-4/30	5/1-7/31	8/1-10/31	11/1-1/31	2/1-4/30	5/1-7/31
<b>Phase I</b>									
<b>1</b>	<b>Work w/technical partners to guide the development &amp; facilitate transition.</b>								
1.1	Work w/stakeholders to guide development & transition.	█	█	█	█	█	█	█	█
1.2	Develop revised economic analysis and post Phase II transition roadmap							█	█
<b>2</b>	<b>Optimize Phase I developed MIPs &amp; expand to include additional RCRA targets</b>								
2.1	Optimization of Phase I developed MIP	█	█						
2.2	MIP development and optimization for additional targets		█	█	█	█			
<b>3</b>	<b>Scale up synthesis processes, &amp; tailor materials for improved robustness.</b>								
3.1	Process scale up evaluation and development					█	█		
3.2	Tailor/Optimize materials for robustness					█	█		
<b>4</b>	<b>Develop revised component &amp; system hardware, electronics, and firmware designs.</b>								
4.1	Develop an verify subsection level designs		█	█	█				
4.2	Develop final fully integrated system designs				█	█			
<b>5</b>	<b>Prototyping and lab-scale testing of the revised buoy/in-line monitoring systems</b>								
5.1	Composite system fabrication and integration testing				█	█	█		
5.2	System performance and environmental testing					█	█	█	
<b>6</b>	<b>Field-test and demo systems in a relevant application/field environment</b>								
6.1	Field-test and demo systems in a relevant application/field environment							█	█



# Questions/Discussion