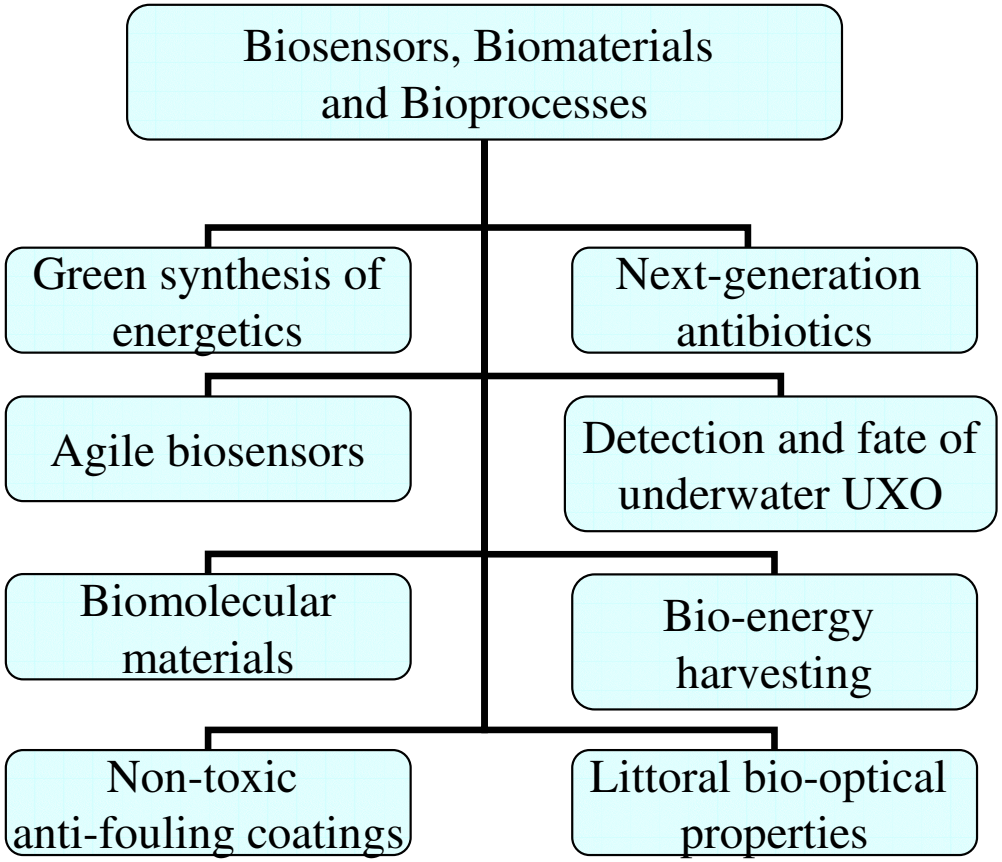
Biosensors, Biomaterials & Bioprocesses Overview

***Focus**: Bio-based capabilities to support the Naval warfighter and reduce operating costs*



Green synthesis of Hellfire missile propellant

AUV with TNT sensor and plume tracking analyzer

Customers:

N093, N096, N7, PMS EOD, N45, NAVFAC, PEO LMW, NAVSEA, 05M, MEF, REC, BUMED, NOAA, NATO, USAMRMC, NIAID, NSWC-IH, DARPA, JSTPCBD, Industry (Marine Coatings, Pharmaceuticals)

Biosensors, Biomaterials & Bioprocesses Overview

Problems:

- Costly manufacturing of Naval materials
- Warfighter vulnerability to multi-drug resistant pathogens
- Current hand-held biosensors do not meet operational needs
- Difficulty locating underwater unexploded ordnance (UXO) in littorals
- Coastal environmental compliance issues impact operational readiness.
  - Aquatic ranges (corroding UXO) – sustainability?
  - Ship/shore contaminants – regulatory issues
- Inability to indefinitely power unattended sensor networks
- Inability to predict coastal water optical properties impedes stealthy amphibious operations

Green Synthesis of Energetics

Navy/Army currently dependent on dangerous but affordable nitroglycerin for use in missile propellants

- Expanded operational needs for butanetrioltrinitrate (BTTN) in propellants cannot be met with current synthetic methodologies
  - Navy/Army potential uses will increase material requirement 10-fold
    - Need less costly, high-yield method for production of BTTN
- Genetically engineered microbes developed to produce BTTN precursor from renewable feedstock (corn fiber)

Impact:

- Demand for Naval and Army propellant needs can be met with this technology
- Enables phase-out of economic but dangerous nitroglycerin with **4X reduction in cost**
- Sets stage for increasing independence from petroleum-based materials

Green Synthesis of Hellfire missile propellant

Detection and Fate of Underwater UXO

Naval coastal range operation results in UXO in water, presenting human and eco-risk – range sustainability & training capabilities are affected

- Near-shore clutter requires non-magnetic/non-acoustic methods of detecting UXO:
  - Development of sensors for TNT/DNT detection in seawater
  - Algorithms for TNT/DNT plume tracing in turbulent water validated
  - Sensor payloads installed/tested on REMUS AUVs
- Understanding of fate and effects of UXO on ecosystem required for mitigation and sound policy development:
  - Microbial and algal degradation of TNT, DNT, etc
  - Effects on marine biota

Impact:

–Capability to detect and track chemical plumes to locate UXO source in water

–Data to support defensible Navy policy on UXO

AUV with TNT sensor and plume tracking analyzer

Bio-Energy Harvesting

Naval operations rely on devices powered (short-term) by batteries

- Need for sustained, autonomous power sources for sea-floor sensor networks
  - Developed microbial fuel cell that operates **indefinitely** at sediment/water interface *(PI Lovley nominated for National Medal of Technology, 2004)*
- Need for warfighter monitoring (location, status, etc.)
  - Discovered sugar-powered micro-biofuel cells that use enzyme or bacterial components

Impact:

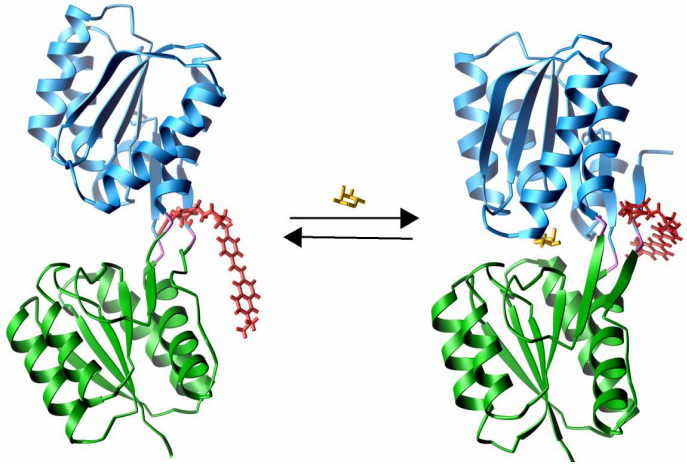
• Capability to provide power on demand in aquatic environment

• Enable use of miniaturized sensors *in vivo* or on small platforms

Sediment fuel cell powered by microbial reactions

Agile Biosensors

- Developing sensor modalities based on biology:
  - Computational/experimental design of modular, reagentless, optoelectronic biosensors based on proteins (analog response)
  - Protein-engineered transmembrane pores for single molecule detection (stochastic-digital)
  - Capability to provide real time chemical classification and quantification – from metal ions to viruses
- Impact:
  - –Ability to produce sensor to classify and quantify CB analytes for force protection and homeland security applications



Engineered TNT-binding protein

Next-Generation Antibiotics

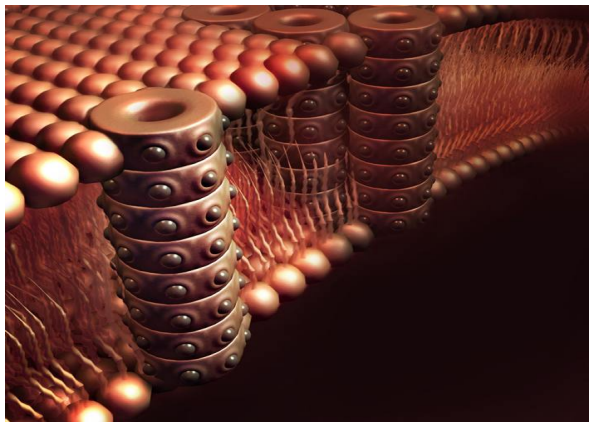
Naval warfighters are susceptible to multi-drug-resistant pathogens – illness reduces mission readiness

Need to mitigate threat of multi drug-resistant pathogens :

- Development of antibiotics that are designed to avoid drug resistance by targeting non-mutatable regions (e.g., membrane) of the pathogen.
- Development of methods to reverse pathogen drug resistance allowing continued use of clinically-approved antibiotics
- Development of "co-drugs" to block onset of drug resistance

Impact:

- Increase warfighter protection from infectious disease and BW threats
- Regain mission readiness



Schematic of self assembling peptide nanotube inserted into bacterial membrane

Biomolecular Materials

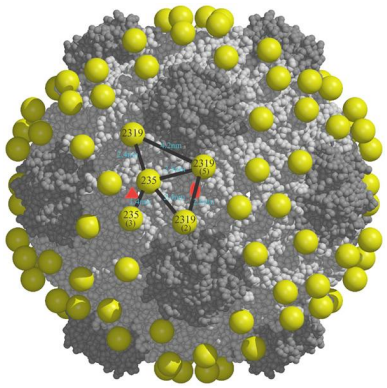
Miniaturized Naval sensors are desired for platforms such as AUV's, AAV's, UUV's and UAV's, e.g., Dragon Eye

- Requirement for reduced size and power demand for sensor payloads to enable multi-functionality and greater range
  - Need to extend MEMS technology to nanoscale (NEMS) – technology doesn't exist
  - Develop methods to address specific sites in 2D/3D space at nanometer scale to allow assembly of 'scaffolds' for NEMS:
    - Designed DNA-based structures
    - Viral particle functionalization

Impact:

•Order of magnitude reduction in size and corresponding reduction in power requirements for sensors

•Capability to multi-task platforms with increase in range



2 nm Au particles
on virus capsid

Biosensors, Biomaterials and Bioprocesses: The Look Ahead

- Desirable and affordable energetics
- Novel antibiotics to reduce warfighter downtime
- Increased flexibility for unattended operations by decreasing reliance on conventional power sources
- Improved capability to detect UXO in the littoral zone
- Improved threat detection via sensitive, ‘agile’ biosensors for CW, BW, and energetic materials
- Environmental Compliance:
  - Navy will have data to support sound, science-based environmental policy
  - Minimized operational impacts and costs associated with ship/shore discharges