Planning & Priority Setting for Basic Research

Presented to the National Academy of Sciences, 5 May 2010

PE 0601153N – Defense Research Science

PE 0601103N – University Research Initiative

PE 0601152N – In-House Laboratory Independent Research

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Discovery & Invention

KNOWLEDGE

Develop Naval-relevant fundamental knowledge

- Expand the boundaries in traditional Naval interest research areas
- Examine new research directions for future Naval needs
- Encourage risk-taking to seek scientific breakthroughs

TRANSITIONS

Provide the basis for future Navy and Marine Corps systems

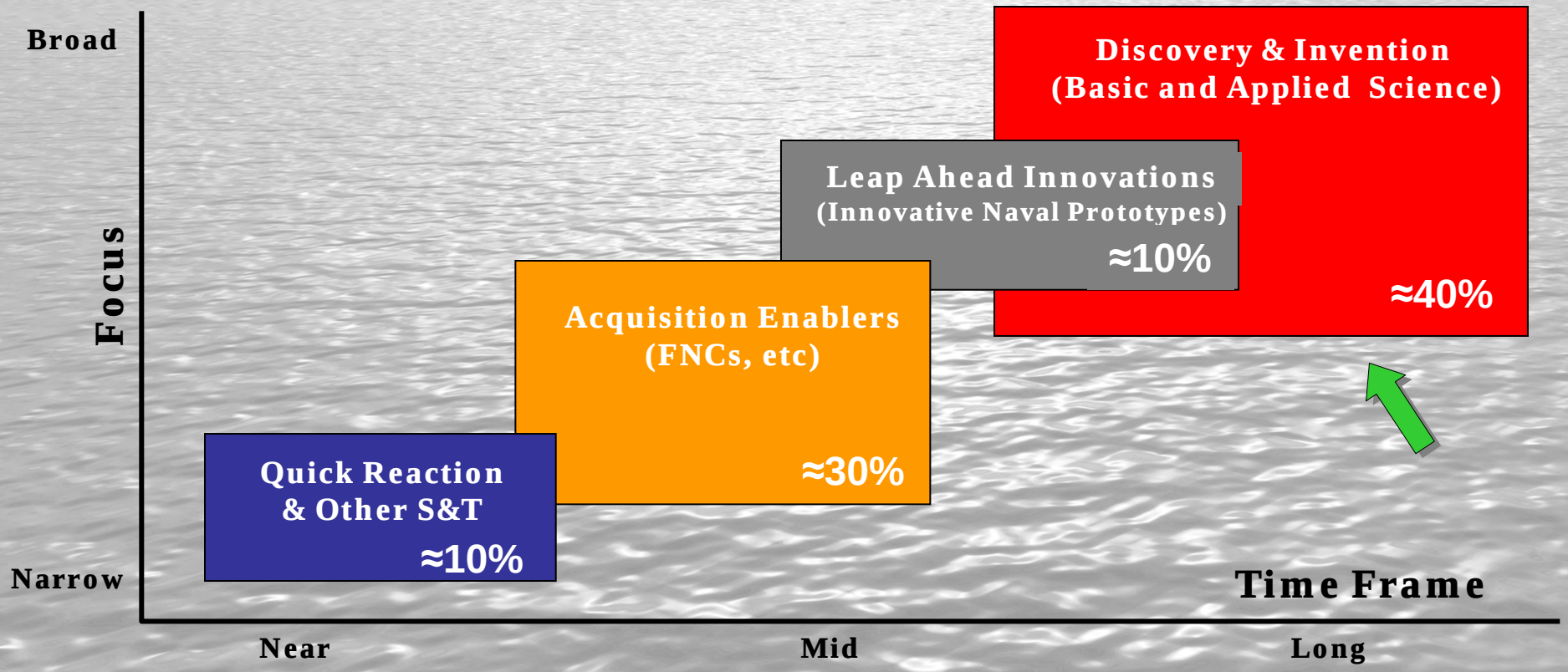
- Ensure research relevancy to Naval S&T strategy
- Transition promising Basic Research to applications
- Use knowledge (even failures) to reduce risk in acquisition

PEOPLE

Maintain the health of the Defense Scientist and Engineer workforce

- Develop and nurture future generation of DoD researchers and engineers
- Ensure continued U.S. advantage in intellectual capital
- Maintain unique/essential research infrastructure

S&T Portfolio Focus to Meet Navy Needs



Quick Reaction

- Tech Solutions
- Experimentation
- MC S&T (MCWL, JNLW, etc.)

Acquisition Enablers

- Future Naval Capabilities
- Warfighter Protection
- Capable Manpower
- LO/CLO

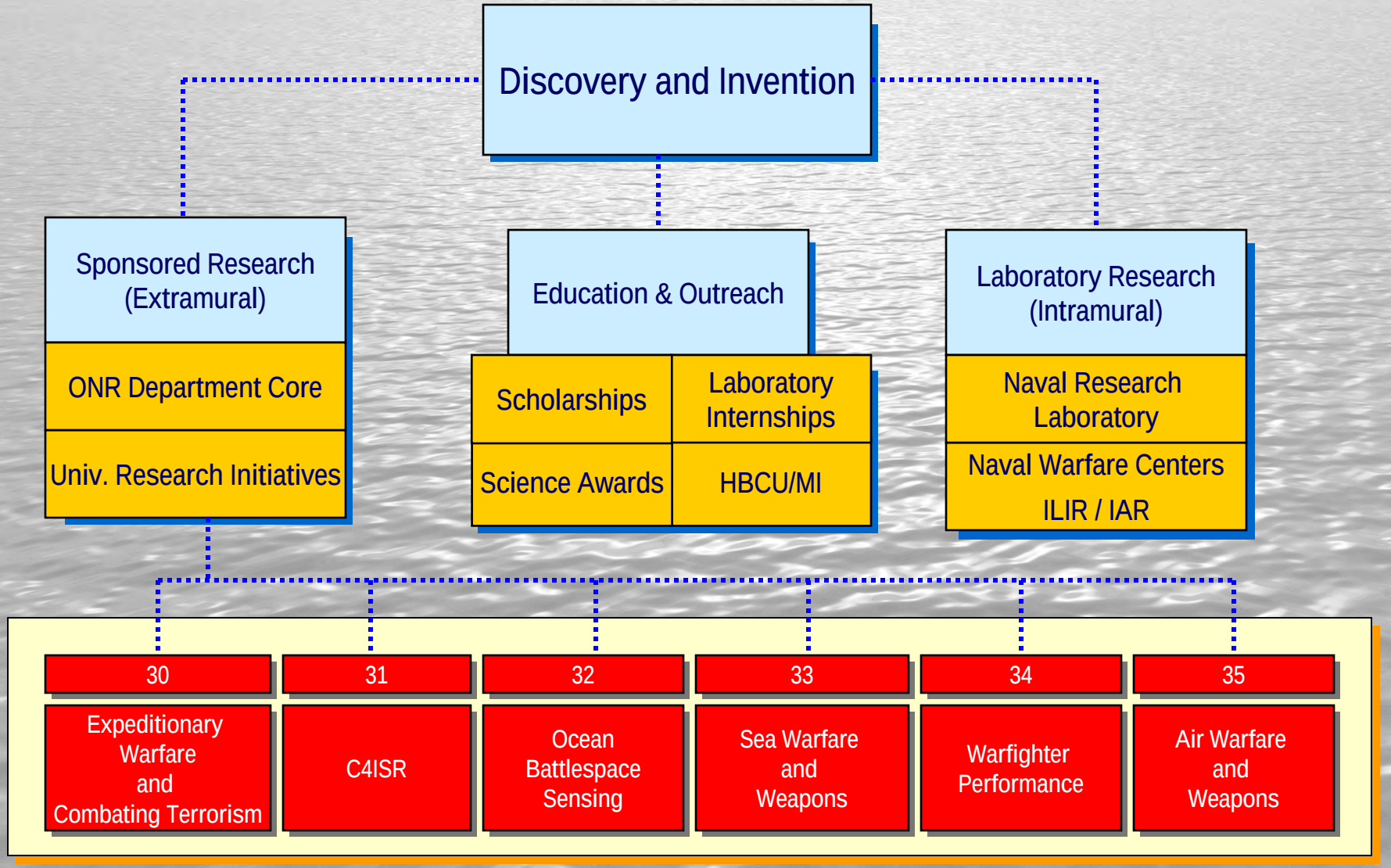
Leap-Ahead Innovations

- Innovative Naval Prototypes
- NSPs
- Swampworks

Discovery & Invention

- Basic & Early Applied Research
- National Naval Responsibilities
- Education Outreach HBCU/MI

D&I Components



DIRECTOR OF RESEARCH

ONR Revolutionary Research . . . Relevant Results

Naval S&T Taxonomy

DISCOVERY and INVENTION ...where creativity thrives

Research Sub-Areas	Research Areas	Research Sub-Areas
Advanced Energetics • Directed Energy • Electromagnetic Rail Gun • High Speed Weapons Tech • IHPRPT • Mining • Non-Lethal Weapons • Precision Strike • Undersea Weaponry	Weapons	• Expeditionary Firepower • Expeditionary Force Protection • Expeditionary Maneuver/ Individual Mobility • Expeditionary Operations Basic Research
• Functional Materials • Structural Materials • Bio-Derived Materials & Systems • Computational Materials Science • Environmental Quality • Manufacturing Science	Marine as a System	• Air Defense • Counter-IED • EW Attach • Land Mine Countermeasures • Large Vessel Stopping • Special Warfare/EOD • Torpedo Defense
• Electro-Optics • Nano-Scale Electronic Devices & sensors • Navigation & Precision Timekeeping • Networked Sensors • Plasma S&T • Solid-State Electronics • Vacuum Electronics	Materials	• Biosensors, Bioprocesses & Bio-inspired Systems • Biometrics • Casualty Care & Management • Casualty Prevention • Human Factors, Organization & Decision Research • Manpower & Personnel • Social, Cultural & Behavior Modeling • Training, Education & Human Performance • Undersea Medicine
• ASW Distributed Search • ASW Performance Assessment • ASW Surveillance • Expeditionary ISR • ISRT-M • Mine Warfare Performance Assessment • WMD Detection • Surveillance, Reconnaissance & Mine Hunting	Countermeasures & Counterweapons	• Communications & Networks • Complex Software Systems Tools • Information Assurance & Anti-Tamper • Network Optimization
• Advanced Sea Platforms • Affordability/Reduced Life Cycle Costs • Air Platform Survivability • Air Propulsion • Air Vehicles • Ground Vehicles • Ship & Austere Site Compatibility • Spacecraft Technology • Sea Platform Survivability	Sensors & Electronics	• Automated Image Understanding • Computational Analysis • Decision Support Tools • Info Processing, Discovery, Integration & Decision Support
• Littoral Geosciences, Optics, & Biology • Marine Mammals • Marine Meteorology • Ocean Acoustics • Physical Oceanography • Space Environmental Effects	Command, Control, Comms & Computers	• Intelligent & Autonomous Systems • Unmanned Air Vehicles • Unmanned Ground Vehicles • Unmanned Sea Vehicles
• Advanced Naval Power systems • Air Platform Power • Personal Power Electronics	Intel, Surveillance & Recon	• Expeditionary Logistics • Seabasing Enablers
	Warrior Performance & Protection	
	Info Analysis & Decision Support	
	Power & Energy Technology	
	Platforms	
	Autonomous Systems	
	Operational Environments	
	Logistics	

Research Areas of Emphasis

- Autonomous Sciences

- Bio-Inspired Sciences
- Cognitive, Neural and Training Technologies

- Information Fusion & Decision Sciences
- Quantum Computing
- Information Assurance
- Materials
  - Metamaterials
  - Integrated Computational Material Sciences
  - Nano-Manufacturing

- Counter IED Sciences

D&I Vision and Objectives

PE 0601153N – Defense Research Science

- DRS portfolio objectives are:
  1) Develop scientific and fundamental knowledge;
  2) Provide the basis for future Navy and Marine Corps systems; and
  3) Maintain the health of the defense scientist and engineer workforce.

PE 0601103N – University Research Initiatives

- URI funds promising new research, stimulates innovation, and attracts outstanding researchers to naval-relevant research projects.

PE 0601152N – In-House Laboratory Independent Research

- ILIR/IAR programs are focused on providing quality research and revitalizing the competency of the technical workforce at the Navy Labs.

D&I Investment Strategy

Demand Signal

- Scientific innovations & Basic Research to support:
  - **Naval Focus Areas**
    - **Research Core Areas**
    - **Research Sub-Areas**
    - **National Naval Responsibilities (NNRs)**
  - **Naval Warfare Enterprises**
  - **Global Innovation & Threat**

6.1 Basic Research
6.2 Early Applied Research

Input

Strategic Alignment

Specialized Programs:

- Multidisciplinary University Research Initiative (MURI)
- In-House Laboratory Independent Research (ILIR)
- Young Investigator Program (YIP)
- Basic Research Challenge (BRC)
- ONR 6.1 Core Programs
- **ONR 6.2 Core Programs**
- **Independent Applied Research (IAR)**

Input

Review & Selection for S&T Programs

Criteria:

- Defense Science & Technology Advisory Board (DSTAG)
- Defense Basic Research Advisory Group (DBRAG)
- Peer Review
- **Program Review & Monitor**
- **Potential for transition to FNC/ INP/ Program Offices**

S&T Output

Measuring Success: Knowledge, Transitions & People

- Publications (Refereed papers)
- Patents & Licenses
- Citations

- 6.1 to 6.2 transitions,
- **Transition to INP & FNC**
- **Transition to Program Offices**

- STEM Program
- Advanced Degrees Completed
- Participants Joining Naval Warfare Labs

D&I Reviews

Assess 6.1 Basic Research portfolio in terms of S&T Quality, Scientific Breakthroughs & Contributions, and Program Risk to determine strengths/ weaknesses of the current portfolio.

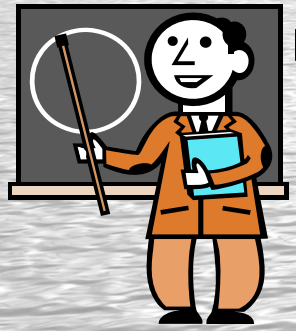
- Every ONR basic research program will be peer-reviewed during the 2nd to 3rd year from its inception.
  - ONR Program Officers will schedule an off-site review of their programs
  - ONR Program Officers will convene Peer Review Boards comprised of recognized scientific/technical experts
  - Principal Investigators will present their work
  - 03R will compile Review Panel comments for each program
  - Director of Research, Department Head, and Program Officer will review Panel comments and adjust program as needed
- Peer Review of basic research programs began with Code 32 Environmental Optics program in Feb 2010.
- ONR Peer Review Instruction is being circulated for comment.

Investment Balance Review (IBR)

September

Departments identify program issues requiring funding changes (up or down)

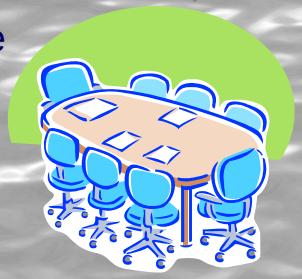
December



Over several days, departments give briefings on each program issue

Over several more days, ONR directors & department heads assess impacts of IBR briefings on their own portfolios and submit recommendations

Designated Officials vote on IBR issues



Voting officials meet and decide which issues are highest priority and how to fund:

- Reallocate money within a department
- Reallocate money across organization
- Request new money (unlikely)

Defense Research Science

Basic Research Challenge (BRC)

- Select and fund promising research programs in new areas not addressed by the current basic research program.

Historically Black Colleges and Universities and Minority Institutions

- Increase the quantity and quality of minority scientists and engineers

Young Investigator Program (YIP)

- Identify and support academic scientists and engineers who have received Ph.D. or equivalent degrees within the last five years

ONR Core 6.1 Programs

- Basic research programs executed by ONR program officers

Defense Research Science

Basic Research Challenge

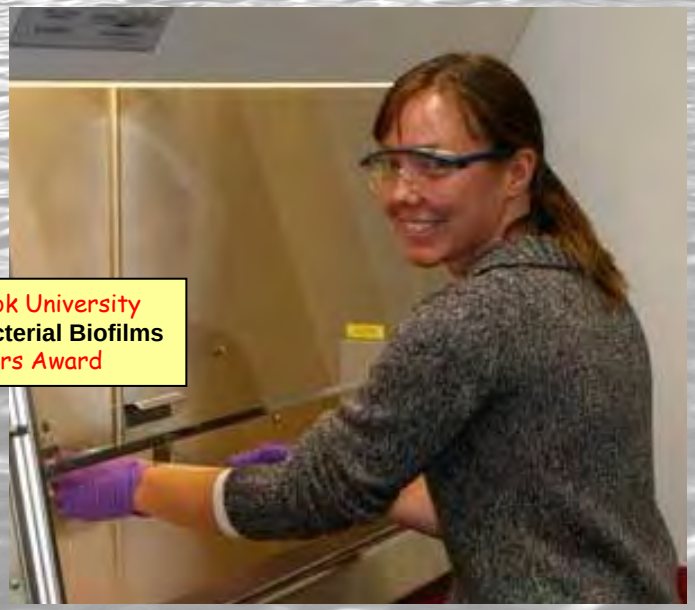
- Competitively funds promising research programs in new areas not currently addressed by the Basic Research program.
- Stimulates new, high-risk Basic Research projects in multi-disciplinary and Departmental collaborative efforts.
- 4-year grants, $1.5M/year
- FY2010 Basic Research Challenge BAA topics:
  - Biologically-inspired Intelligent Metamaterials
  - Computing with Natural Language
  - The Micro-physics of a Liquid-Solid-Gas Interaction
  - Acoustical Uncertainty due to Marine Mammals and Fish

HBCU/MI Programs

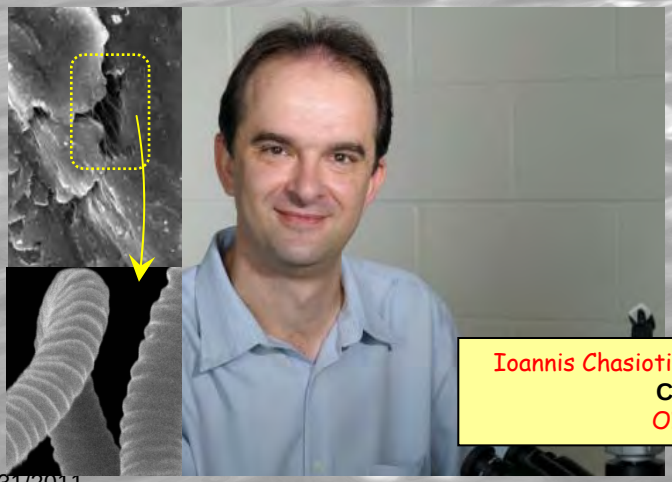
- HBCU/MI Matching Funds for Research – Provided to the ONR S&T codes as an incentive to promote more HBCU/MI participation in naval research.
- Research and Education Partnership Program (REPP) –Students are exposed to Navy civilian S&E careers through summer internships at Navy laboratories.
- HBCU/MI Summer Faculty – S&E faculty members participate in research at Navy laboratories for 10 weeks during the summer.

Young Investigators Program (YIP)

- Attracts outstanding new faculty researchers to naval-relevant research
- Encourages their teaching and research careers
- 17 awards In FY2010
- The Young Investigator Program (YIP) process
  - Broad Agency Announcement in October
  - Proposals are due January via grants.gov
  - Grants begin in June
  - Funding available: $7.5M over three years



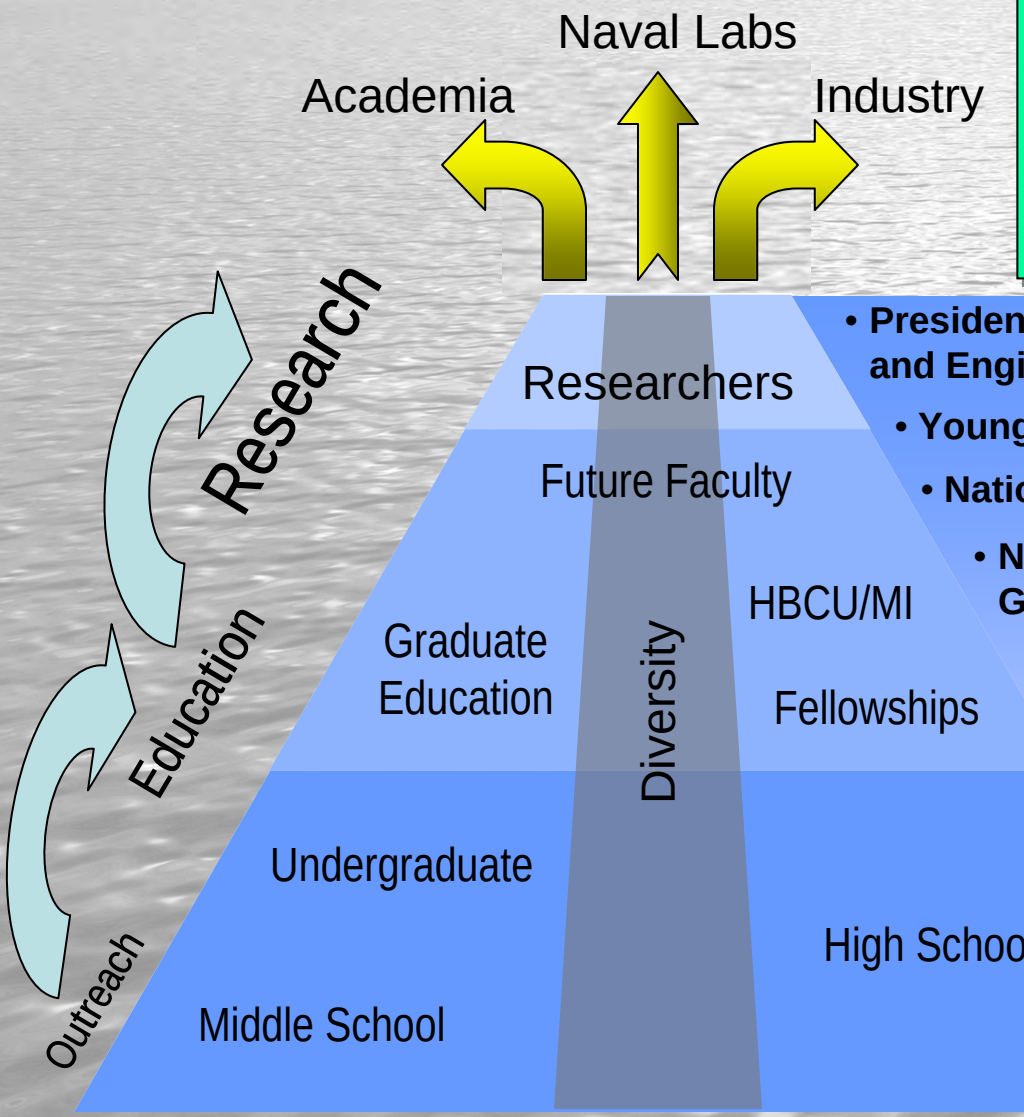
Elizabeth Boon, Stony Brook University
Nitric Oxide Signaling in Bacterial Biofilms
ONR Young Investigators Award



Ioannis Chasiotis, University of Illinois at Urbana-Champaign
Continuous Carbon Nanofibers
ONR Young Investigators Award

Education and Outreach

Nurture the pipeline of U.S. science & engineering in Naval-relevant disciplines and expand diversity of researchers and research institutions



- **Presidential Early Career Awards for Scientists and Engineers**
- **Young Investigator Program**
- **National Naval Responsibilities (ULI-STEM)**
- **National Defense Science & Engineering Graduate Program**
- **Science, Mathematics And Research for Transformation**
- **Historically Black Colleges and Universities & Minority Institutions**
- **Naval Research Enterprise Intern Program (NREIP)**
- **Naval Science Awards Program**
- **Science & Engineering Apprentice Program (SEAP)**

Overview of Naval STEM Portfolio

Data as of March 15, 2010

FY 09 Investment in STEM: $39.7M ***[plus an additional $108M invested in University Research Initiatives]***

- 156 programs
- Conducted by 24 Naval organizations
- Reaching more than 59,000 students annually ***[plus an additional 100K through science fairs]***
- Participants come from all 50 states and several territories
- Portfolio covers all stages of the STEM pipeline:
  - K-12 Outreach and Awareness
  - Middle School—Hands-on Learning
  - High School—Internships and research experiences
  - Undergraduates, Masters and Doctoral Students: Employment, Scholarships, Fellowships and Internships
  - Faculty research experiences
  - Naval STEM employees: Professional development
  - Professional development for high school teachers

Defense Research Sciences FY 10 Funding Summary

PE 0601153N

• Air, Ground and Sea Vehicles	$52.3M
• Atmosphere and Space Sciences	$30.0M
• Counter Improvised Explosive Device (IED) Sciences	$22.7M
• Human Systems	$16.6M
• Information Sciences	$33.9M
• Materials/Processes	$61.5M
• Medical/Biology	$17.4M
• Ocean Sciences	$80.9M
• S&E Education, Career Development and Outreach	$26.4M
• Sensors, Electronics & Electronic Warfare (EW)	$51.8M
• Weapons	$18.5M
• Congressional Plus Ups	$17.1M
TOTAL:	$429.1M

University Research Initiatives

Defense University Research Instrumentation Program (DURIP)

- Funds ($.5M to $1M) will be used for the acquisition of major equipment to augment current or develop new research capabilities in support of DoD-relevant research.

Multidisciplinary University Research Initiative (MURI)

- Teams of researchers investigating high-priority topics that intersect more than one technical discipline.

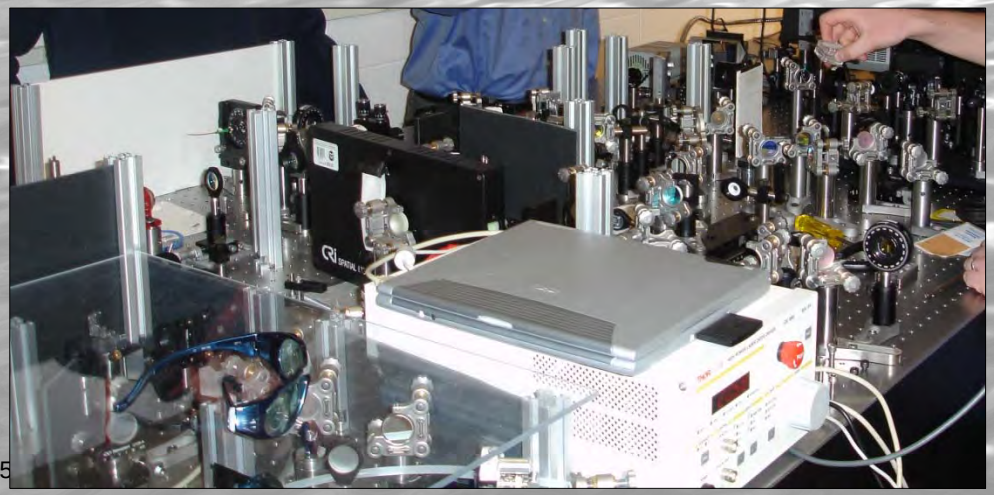
Presidential Early Career Award for Scientists and Engineers (PECASE)

- Honors and supports the extraordinary achievements of young professionals at the outset of their independent research careers in science and technology.

Defense University Research Instrumentation Program (DURIP)

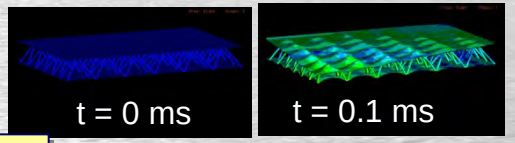
supports university research infrastructure essential to high-quality Navy-relevant research

- Proposals may request $50,000 to $1,000,000
- Funds will be used for the acquisition of major equipment to augment current or develop new research capabilities
  - Over 260 proposals were submitted for FY2010
  - 61 proposals totaling approximately $17.9M were recommended to DDR&E
  - Final awards were announced in March 2010

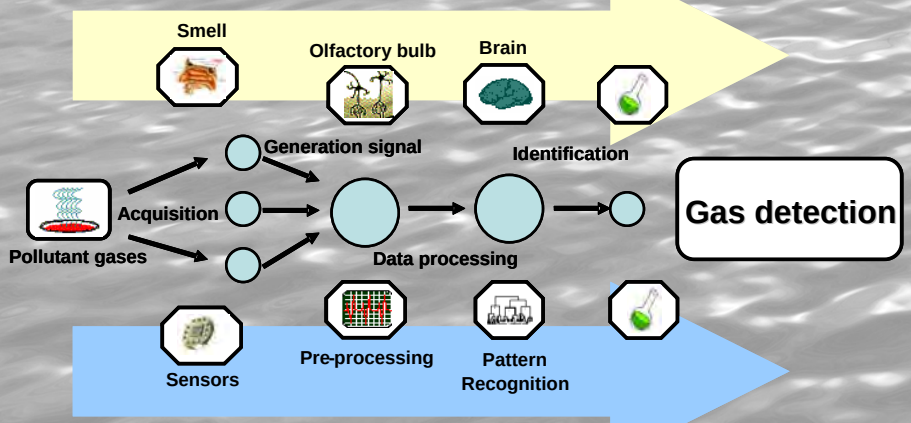


Multidisciplinary University Research Initiative (MURI)

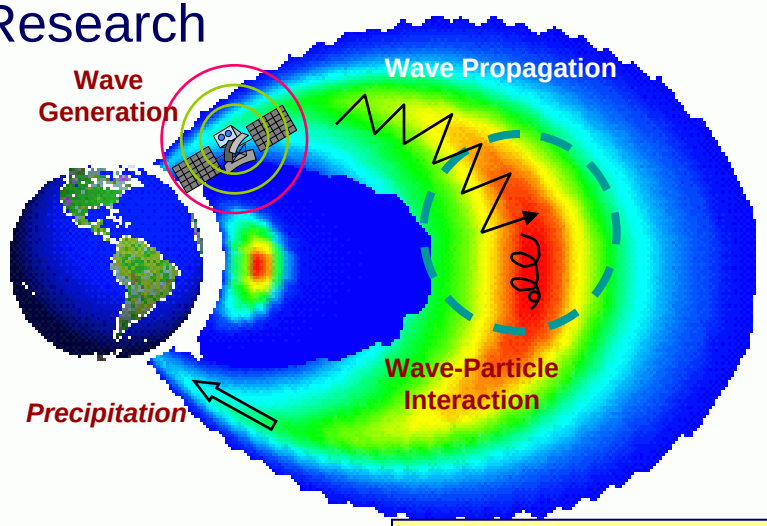
- Multiple institutions investigating high priority topics
- Stimulate innovations
- Accelerate research progress
- Expedite transition of results into naval applications
- Eight MURI grants were initiated in FY2009.
- For FY2010, proposals will be solicited in research areas determined by DDR&E Director of Basic Research



MATERIALS APPROACH to FORCE PROTECTION
MURI: UVA/Harvard



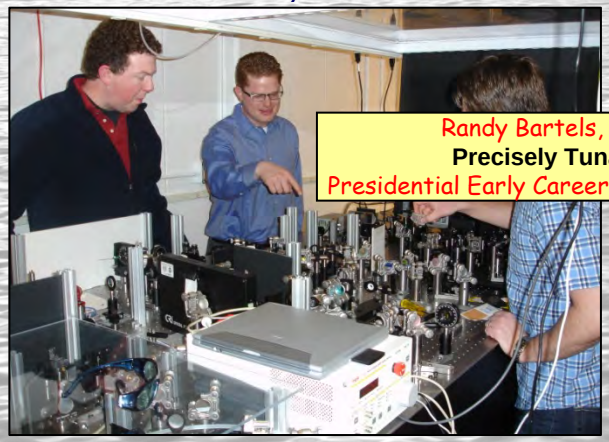
BIO-BASED OLFACTORY PROCESSING
MURI: UCSD/Cal. Tech./U. Pittsburgh



RADIATION BELT DYNAMICS
MURI: UCLA/U. Maryland

Presidential Early Career Award for Scientists and Engineers (PECASE)

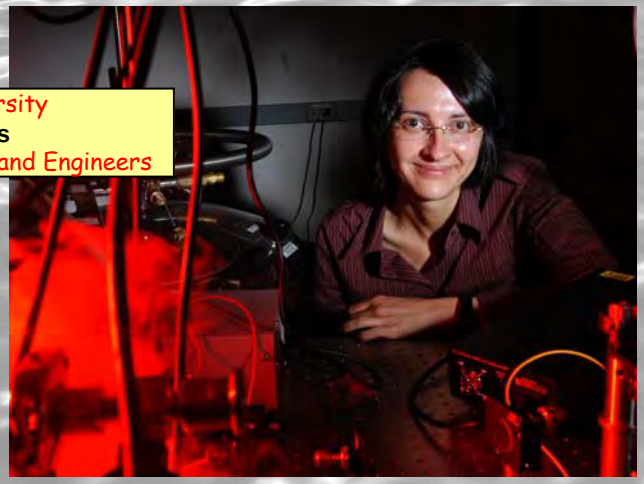
- The PECASE award recognizes and honors outstanding scientists and engineers at the outset of their independent research careers.
- In FY2009, 15 ONR awardees were announced, selected for their work in the following areas:
  - Chemistry
  - Fluid Dynamics
  - Distributed Learning
  - Biomimetics
  - Marine Mammals
  - Modeling and Simulation



Randy Bartels, Colorado State University
Precisely Tunable Optical Frequencies
Presidential Early Career Award for Scientists and Engineers

Dr. Kelly J. Benoit-Bird, Oregon State University
Predator effects on dense zooplankton aggregations
Presidential Early Career Award for Scientists and Engineers

Prof. Jelena Vuckovic, Stanford University
Quantum Dots in Photonic Crystals
Presidential Early Career Award for Scientists and Engineers



University Research Initiatives FY10 Funding Summary

PE 0601103N

• Defense University Research Instrumentation Program	$20.3M
• Multidisciplinary University Research Initiative (MURI)	$72.4M
• Presidential Early Career Awards	$6.3M
• Congressional Plus Ups	$3.2M
TOTAL:	$102.2M

In-House Laboratory Independent Research

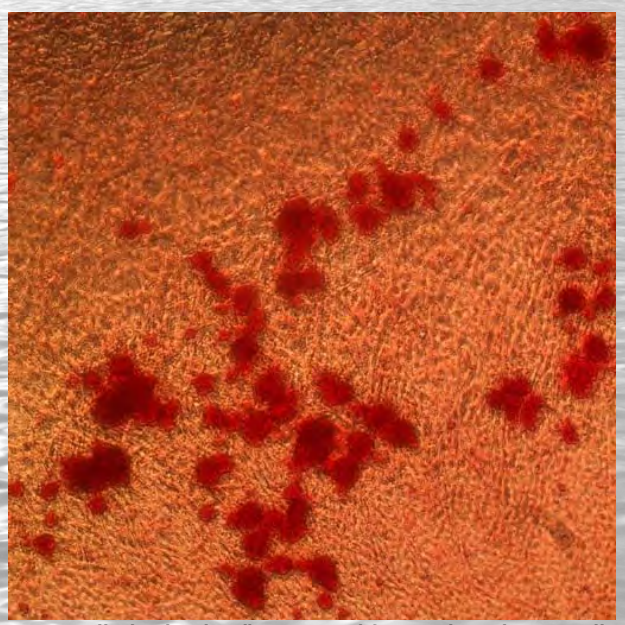
- *Provides Navy laboratory directors the ability to invest in basic research of technical interest to meet laboratory mission elements*
- *ONR funding provided through the Naval S&T for America's Readiness (N-STAR) program office*
- *Broadens Navy S&T perspective to avert technological surprise*
- *Provides means for PIs to interact more directly with academia on topics of interest*

- Designed to develop and maintain a cadre of subject experts and technologists at the Navy Warfare Centers
- Technical focus is determined by laboratory TD and CO as it relates to mission areas and responsibilities
- All FY09 projects map to the Naval S&T strategic plan

- ILIR provides funding for education & outreach programs
  - Virginia Demonstration Project for 7th graders (Congressional)
  - Science and Engineering Apprentice Program (High School)
  - Naval Research Enterprise Internship Program (BS, MS, PhD)

Repair/Replacement of Damaged Tissue

- ONR-funded In-house Laboratory Independent Research (ILIR) effort at the Navy Medical Research Center is paving the way to
  - identify the factors which guide the differentiation of stem cells into tissues such as bone, fat, and muscle
  - develop treatments to reduce the incidence of abnormal bone growth in war-injured personnel
- Using functional genome profiling to identify changes in genetic markers associated with the transition from stem cells to committed progenitor cells



Bone cells (stained red) generated from cultured stem cells

This ONR-funded cutting-edge research is part of a multidisciplinary effort to expand the horizons of regenerative medicine

ILIR FY 10 Funding Summary

PE 0601152N

• Advanced Materials	$3.5M
• Electronics Sensor Sciences	$2.6M
• Energy Sciences	$1.4M
• Human Performance Sciences	$2.2M
• Information Sciences	$2.2M
• Naval Platform Design Sciences	$1.5M
• Ocean/Space Sciences	$4.6M
• Congressional Plus Ups	-
TOTAL:	$18.0M

Summary

D&I is about

- *Generating Knowledge…*
- *Creating the base for technology…*
- *Nurturing new/future researchers…*

Backups

D&I Investment Process

Understand and balance science opportunities and Naval Needs

Program Officer
- World class scientists & engineers
- Judgment of investments for Naval unique problems

"Competitive" new start process
- At ONR & NRL to solicit and vet the best ideas
- Exploits the combined talents of the ONR Scientific Officers, NRL/Warfare Center bench scientists

Basic Research Output
- 6.2/6.3 programs influenced
- Direct transition to acquisition & operation

Regularly scheduled Internal and External Reviews of individual programs
- Periodic Internal – annually
- Periodic External – 3 years

IBR as mechanism for annual command review of entire program
- Balance in investment
  - Important areas without coverage
  - Innovative ideas with high payoff/high risk
- Impact from investment

S&T Oversight Criteria

- Thrust areas are coordinated /aligned between ONR & NRL
- Thrust areas are not platform centric
- D&I goals
  - Create overwhelming technological superiority
  - Prevent technological surprise
  - Align future Naval capabilities with Naval S&T Grand Challenges, National Naval Responsibilities
  - Important and unique Naval S&T areas, and enables transition of product to Naval and Joint customers
- Leverage other agencies investment for Naval application
- Balance annually reviewed at Investment Balance Reviews (IBR)

Context

ONR

Corporate Lab
NRL

Basic Research
through
Prototypes

Performers:
- Academia
- Industry
- Other Gov Labs

Sponsors:
- NSF
- DARPA
- NOAA
- Industry
- DoE
- Etc.

Systems Commands:
- NAVSEA
- NAVAIR
- SPAWAR
- NAVFAC
- NAVSUP

Warfare centers

R&D Tech Demos
Acquisition
Procurement

TRL 1-6 → **TRL 7-9**

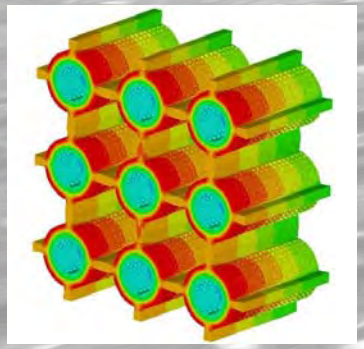
Examples of cutting-edge Basic Research at ONR (PE 0601153N)

- Code 31: Fast Multipole Methods
  Reversible Hydrogenation of Graphene
- Code 32: Tropical Cyclone Formation and Intensity Forecasts
  Effects of Sound on the Marine Environment
- Code 33: Desorption Electrospray Ionization
- Code 34: Microbial Fuel Cell

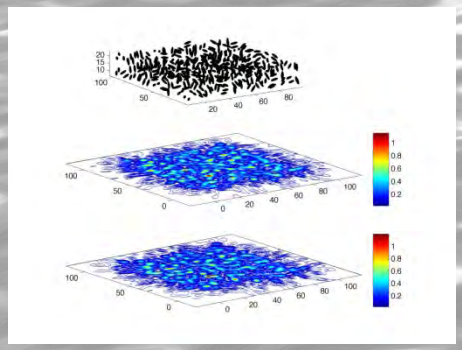
Fast Multipole Methods (ONR 31)

- Adaptive, multi-scale methods reduce the cost of many-body interactions from $O(N^2)$ to O(N log N) with user-controlled precision
- Applicable to electromagnetics, gravitation, CFD, acoustics, elasticity, heat transfer, chemistry
- Provide orders of magnitude speedup over direct methods
- Integrated into numerous commercial codes in aerospace, automotive, semiconductor, and chemical industries

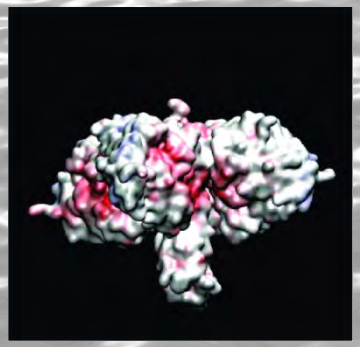
Applications



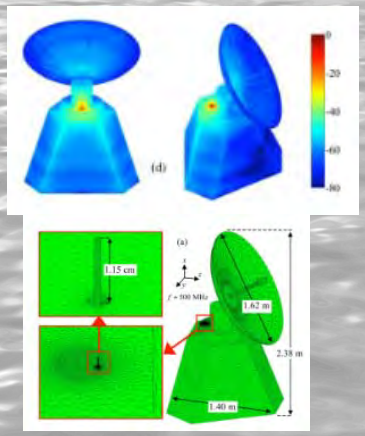
Thermal analysis of fuel cells
(Y. Liu)



Electromagnetics of microstructured materials
(Gimbutas, Greengard)



Molecular electrostatics
(Lu, Cheng, Huang, McCammon)



Radiation from multiscale structure
(E. Michielssen et al.)

Reversible Hydrogenation of Graphene (ONR 31)

Graphane, a chemical derivative of Graphene

- Formed by attaching a hydrogen atom to each of the carbon atoms in the original graphene sheet
- Hydrogen alternates between above and below the sheet

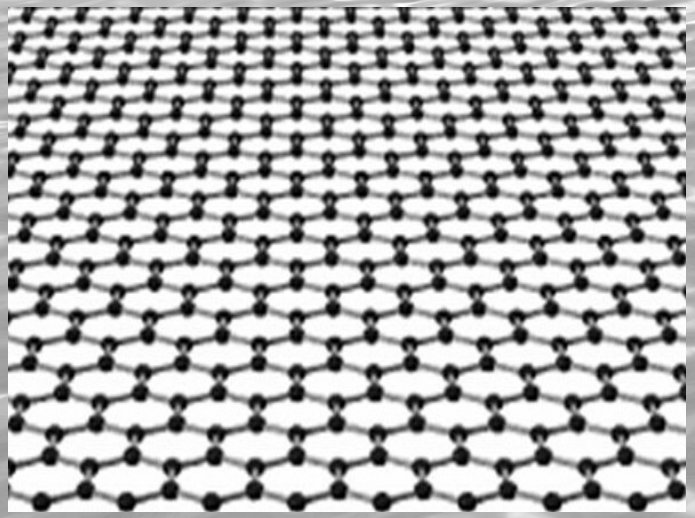
Graphene and Graphane have drastically different electronic properties

- Graphene is the best conductor known to man (at room temperature)
- Graphane is an electrical insulator

Graphene-Graphane reaction is entirely reversible

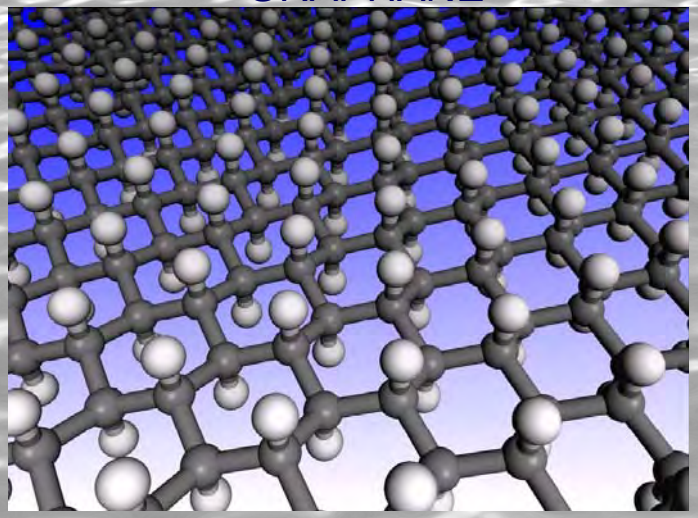
New ways of constructing 2D electron devices and circuits

GRAPHENE



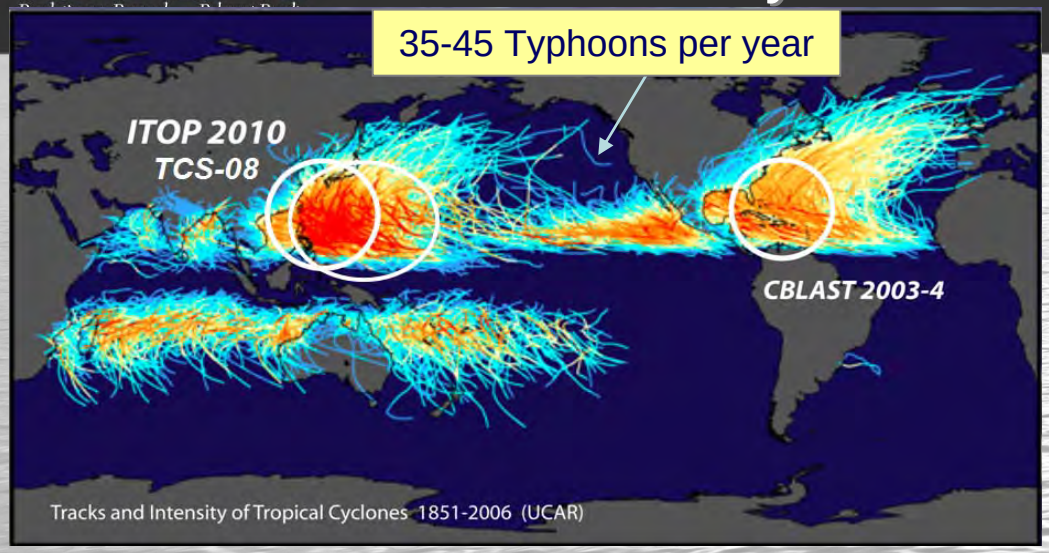
Single-layer 2D Carbon

GRAPHANE



Single-layer 2D Hydro-Carbon

Tropical Cyclone Formation & Intensity Forecasts (ONR 32)



Basic Research Efforts

CBLAST (2003-2004) Field Program

- Confirmed coefficient of drag drop at high winds
- Demonstrated need to include waves in coupling physics
- Developed new class of air deployable sensors to observe upper ocean in high wind conditions

In the Western Pacific, improvement of typhoon intensity forecasts is the #1 METOC requirement

TCS-08 Field Program (2008)

- Observed storm formation in WestPac
- Characterized storm interaction with ocean eddy field
- New technology to observe development of convection

ITOP 2010 Field Program will

- Examine cold wake evolution and decay for ASW
- Investigate interaction of storm, wake, and eddy fields
- Field new sensors for tropical cyclone conditions

2004-2012

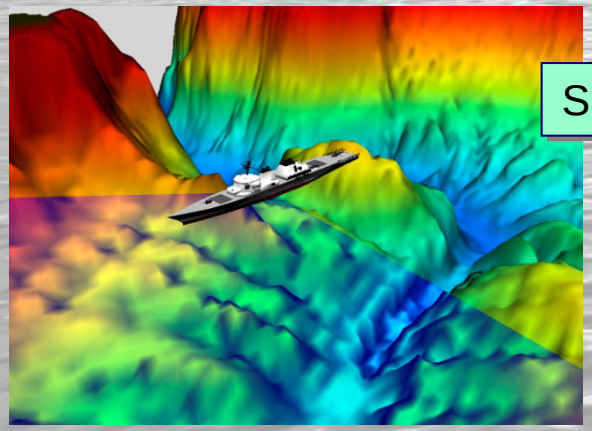
6.2 Transition: Enhance the Coupled Atmosphere-Wave-Ocean Model for Operational Evaluation

2009-2012

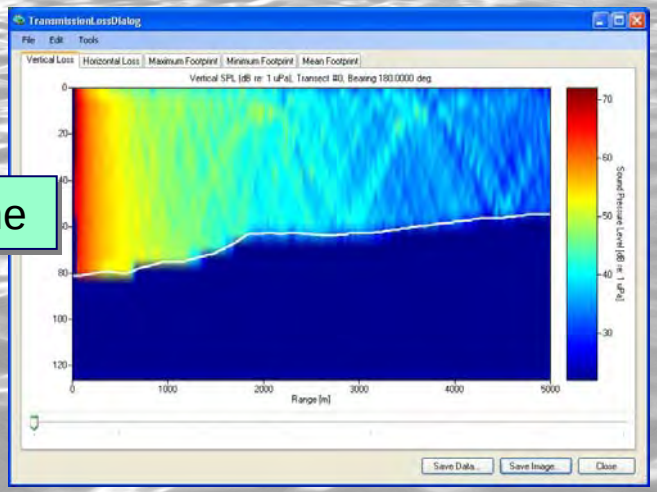
Joint 6.2/6.4 Rapid Transition Program: Collaborate with operational centers to transition research model to full operational status in 3 years for all typhoon, cyclone, and hurricane forecasts for global Fleet support

Effects of Sound on the Marine Environment (ONR 32)

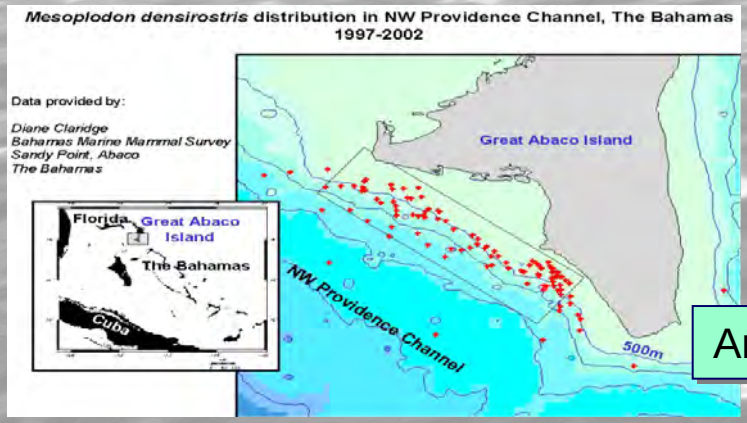
- A 6.1 environmental simulation and modeling 'engine' developed to determine how sound propagates and interacts with marine mammals
- Multidisciplinary acoustic model using state-of-the-art science to estimate risk to marine life from sound exposure
- Component of single Navy environmental effects model



Ship track with bathymetry



Sound field in 3D and over time



Animal distributions, behaviors, & exposures

Desorption Electrospray Ionization (ONR 33)

Establish mass spectrometry (MS) as a technique for routine in-situ chemical analysis

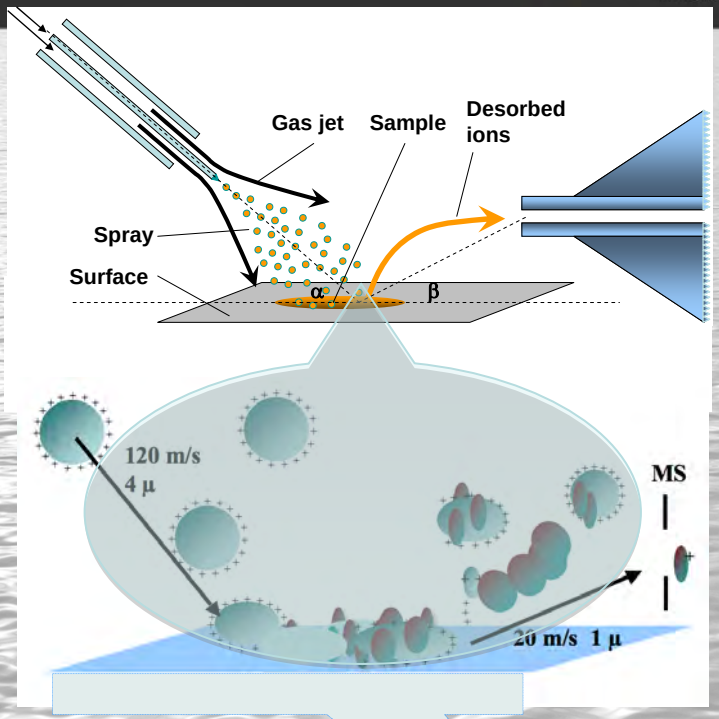
- Explore analytical performance for various trace organic chemicals

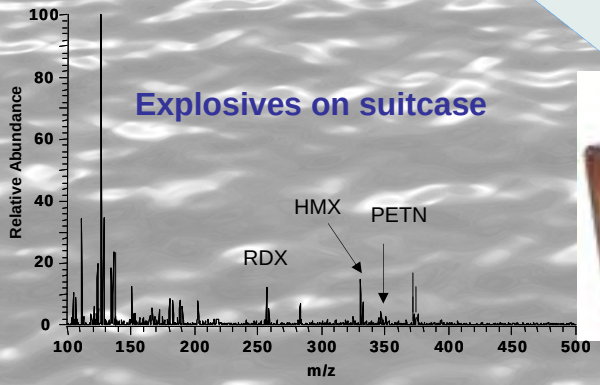
Develop interface between the mass spectrometer and the environmental sample

- Simulate the desorption ionization process
- physico-chemical measurements to elucidate ionization and ion transport mechanicsms

Implement DESI technology on portable MS

- Develop analysis-at-a-distance capability





Explosives on suitcase

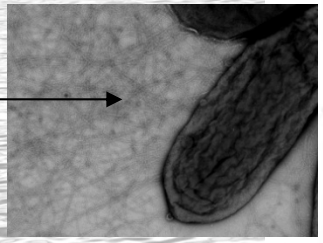
Microbial Fuel Cell (ONR 34)

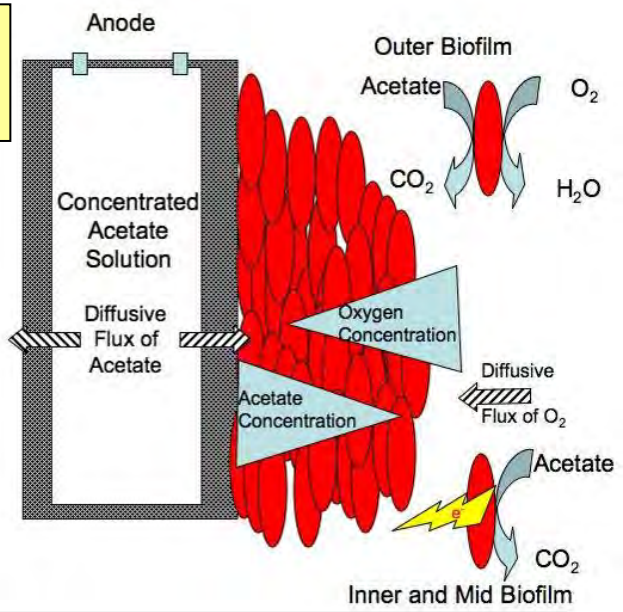
MFCs generate small amounts of electricity and are useful for powering undersea sensors and other small devices.

ONR Research has

- Identified a strain of bacteria that yields 8X the power of the original strain

Geobacter bacteria produce protein-based 'nanowires' which conduct electricity





- Showed that bacterial 'nanowire' structures conduct electricity in biofilms
- developed MFC design that allows sustained operation in air, even with bacteria that can't tolerate air
- Developed strategies for evaluating which bacterial genes are important for electricity production
- Gained understanding of electron transfer reactions at the cathode which will allow optimization of MFC

- MFC now operable in air for extended periods
- Fundamental knowledge of microbial physiology enables improved power and efficiency
- MFC is non-hazardous (no H_2 gas, no explosive reactants)
- Time Magazine named MFC one of the Top 50 Inventions of 2009