Office of Naval Research
Basic Research Program

Revolutionary Research . . . Relevant Results

DISCOVERY and INVENTION ...where creativity thrives

Innovation in Basic Science

13th Annual Science & Engineering Technology
Defense Tech Exposition
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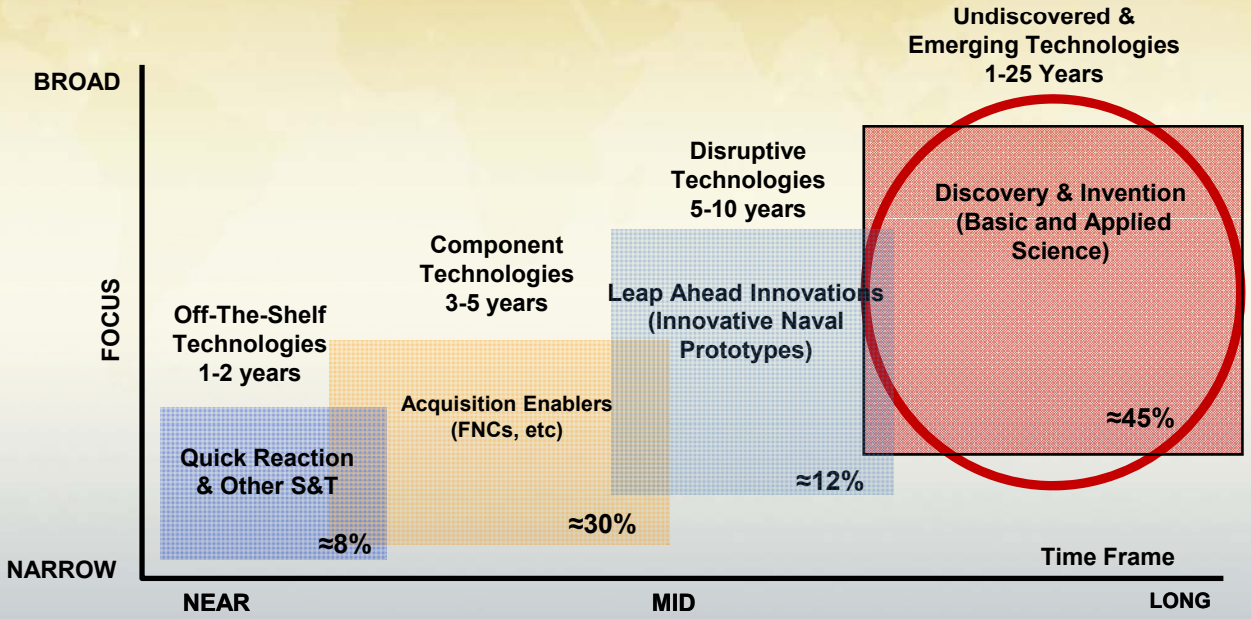
Discovery & Invention Portfolio



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D&I Vision and Objectives

University Research Initiatives

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

In-House Laboratory Independent Research

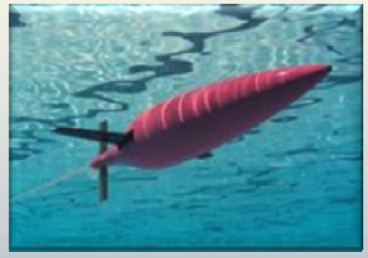
ILIR/IAR programs are focused on providing quality research and revitalizing the competency of the technical workforce.

Defense Research Science

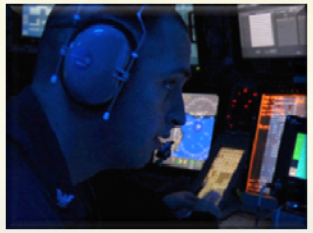
DRS portfolio objectives are: (1) Develop scientific and fundamental knowledge; (2) Provide the basis for future Navy and Marine Corps systems; and (3) Maintain the health of the defense scientist and engineer workforce.

Basic Research Areas of Emphasis

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



- Information Technology Sciences
- Advanced Computing
- Materials
  - --Metamaterials
  - --Integrated Computational Material Sciences
  - --Nano-Manufacturing
- Counter IED Sciences



University Research Initiatives

Multidisciplinary University Research Initiative (MURI)

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

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.

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 Research Sciences

ONR Core 6.1 Programs

•Basic research programs executed by ONR program officers

Basic Research Challenge (BRC)

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

Young Investigator Program (YIP)

•Identify and support academic scientists and engineers who are in a tenure-track position.

Historically Black Colleges and Universities and Minority Institutions

•Increase the quantity and quality of minority scientists and engineers.

National Naval Responsibility (NNR)

Established by ONR to ensure areas of Naval importance have steady research investment and a trained S&T workforce for basic research

Enhancing the recruitment, training, and retention of researchers through research awards for graduate, post-docs, and early career faculty

FIVE APPROVED NNRs:

- Ocean Acoustics
- Undersea Weapons
- Naval Engineering
- Undersea Medicine
- Sea-Based Aviation

TWO PROPOSED NNRs:

- Precision Time & Timekeeping
- Underwater Communications

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--APPROVED--

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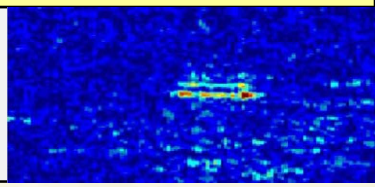
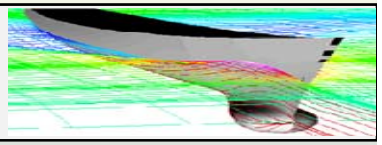
Ocean Acoustics Investments in Shallow Water Acoustics; High Frequency Acoustics; and Long Range/Low Frequency Propagation
Naval Payoffs: Improved Shallow-water ASW, Wide-Area Surveillance, & SSBN security; Rapid environmental assessment



Undersea Weapons Focus on Multidisciplinary Systems Design; Guidance & Control; Undersea Warheads; Counterweapons & Countermeasures; and Super-cavitating Weapons
Naval Payoffs: Improved Guidance and Control capabilities for littoral environment; improved PK & PCK; increased weapons load-out

Naval Engineering Conducts major field experiments that integrate various technologies innovative ship concepts
Naval Payoffs: Improved ship design tools, analytics for platform affordability



Undersea Medicine Focus Areas include Non-recompressive treatment for decompression sickness (DCS), arterial gas embolism; Accelerated decompression; mechanisms of DCS
Payoffs: Extended warfighter reach; Freedom of action (in water column, in thermal extremes & in contaminated water); Optimized submariner & diver performance

Sea-based Aviation: Focus on multidisciplinary systems design; autonomous G&C for TO/landing; shipboard-suitable structures and materials; innovative aircraft concepts
Navy Payoffs: Matching other technology advancements for integration into revolutionary naval aviation systems. continued Navy/Marine Corps leadership in unique capability / mission areas; Reduced development cost and risk

Graphene

Graphane, a chemical derivative of Graphene

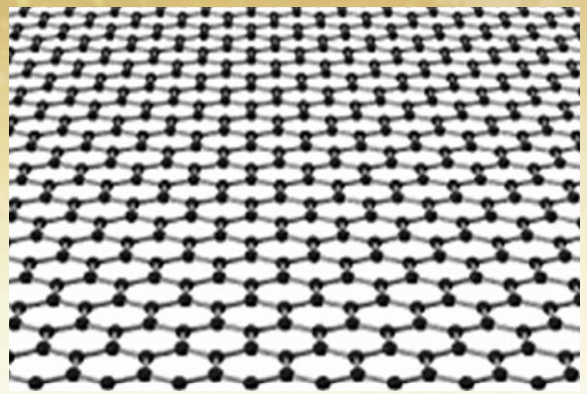
- Formed by attaching a hydrogen atom to each of the carbon atoms in the original graphene sheet
- Hydrogen alternates between above and below the sheet

Graphene and Graphane have drastically different electronic properties

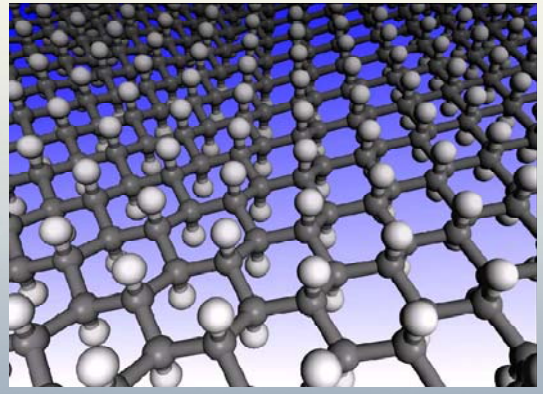
- Graphene is the best conductor known to man (at room temperature)
- Graphane is an electrical insulator

Graphene-Graphane reaction is entirely reversible

ONR Researchers, Geim & Novoselov, Awarded 2010 Nobel Prize in Physics



GRAPHENE (Single-layer 2D Carbon)



GRAPHANE (Single-layer 2D Hydro-Carbon)

- **ONR first in US to fund basic research; initial work general in nature, e.g. entire circuit perspective**
- **ONR & AFOSR work closely via the MURI process**
- **DARPA exploring RF applications**

New ways of constructing 2D electron devices and circuits

Precision Time & Timekeeping

Revolutionary Research . . . Relevant Results

DISCOVERY and INVENTION ...where creativity thrives

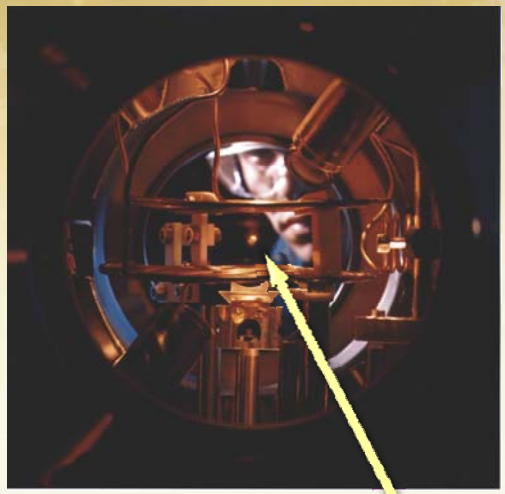
ONR research support produced:

- Three Nobel Prizes (1997, 2001, & 2005)
- Four ONR Nobel Laureates
- Two orders of magnitude improvement in Naval Observatory primary clock

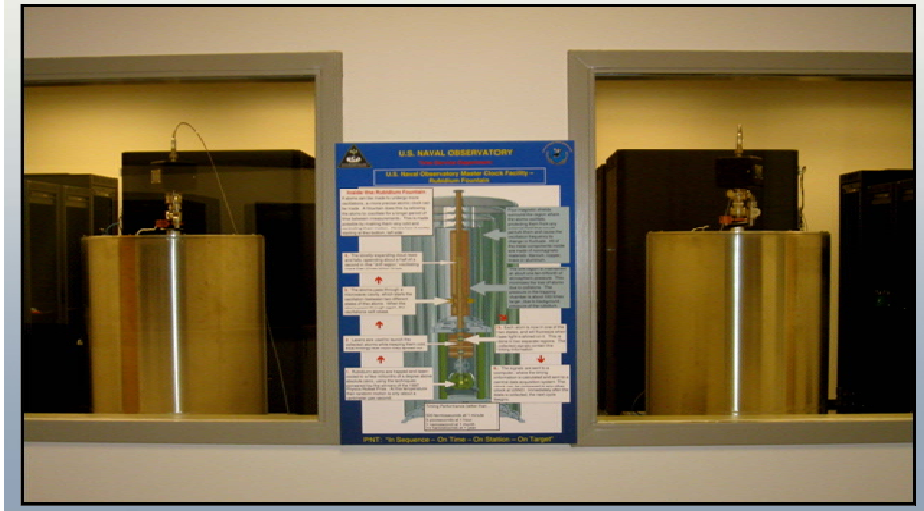
1997
Phillips

2001
Kettlerly
Wieman

2005
Hall



Ball of Laser-Cooled Atoms



Precision Time and Timekeeping (PTT):

- ONR funding for basic research in atomic clocks has led to significant advances in PTT.
- The US Naval Observatory (USNO) maintains the DoD Master Clock with 60 Cs (Cesium-133) atomic clocks, 20 Hydrogen maser clocks, and two Cesium Fountain atomic clocks.
- The DoD Master Clock is a Critical National Defense Technology (MCTL Section 16).

Wide Bandgap Semiconductors

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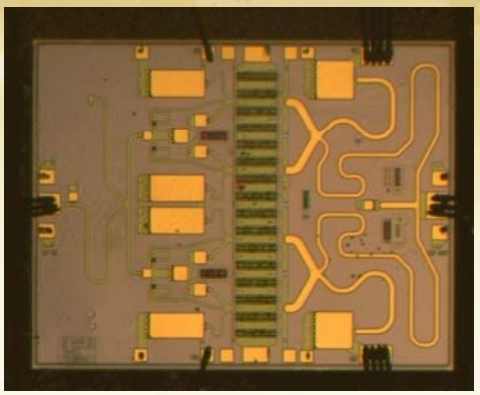
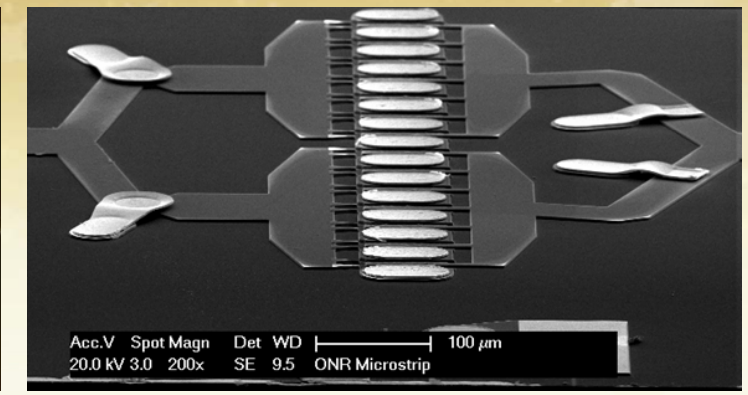
GaN & SiC Components—

•ONR funded basice research on Si & GaN components led to the development of the wide bandgap semiconductors.

•Breakthrough technology necessary to meet performance parameters within the space and weight constraints of the E-2D surveillance system design specification.





E-2D


Nulka

ONR research produced wide bandgap semiconductors which:

- Led to compact, high power RF amplifiers for E-2D
- Is enabling development for high frequency, power amplifiers for Nulka and SEWIP

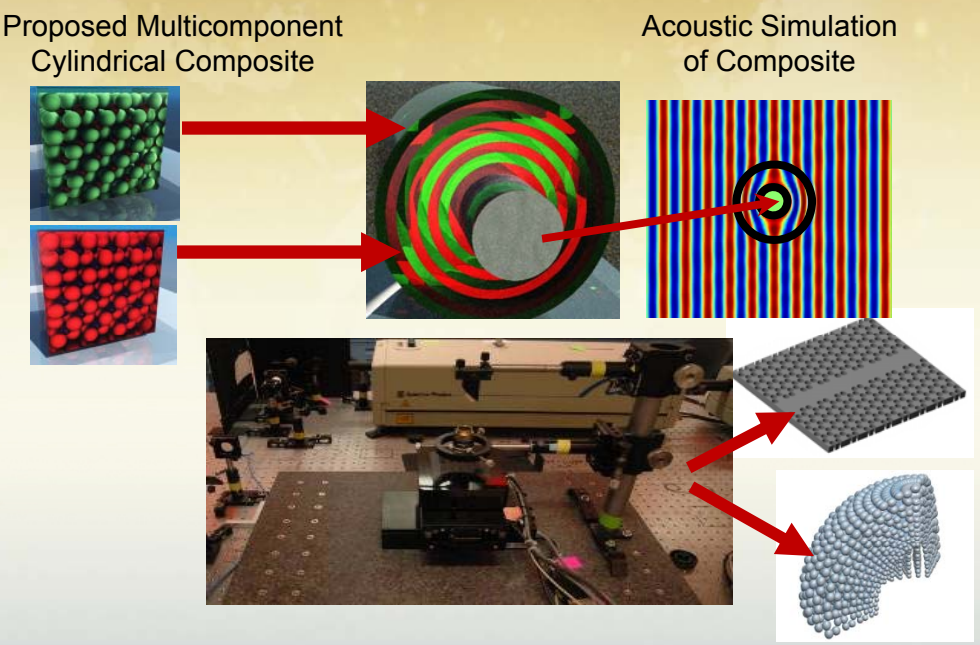
Acoustic Metamaterials

Basic Research Objective:

- Design engineered elasto-acoustic materials exhibiting anisotropic density and stiffness
- Develop phononic crystal and resonator systems with tunable bandgaps exhibiting negative refractive properties

Technical Approach:

- Hybrid materials with effective negative density and bulk modulus
- Composites of pentamode and orthotropic bimodal materials
- Physics of multiple scattering induced anisotropy in the homogenization limit ($\lambda > 4a$)
- Three-dimensional lithographic, modeling, & simulation tools



High-speed, high precision 3D fabrication system for phononic crystal (top) and pentamode materials (bottom)

- **ONR is uniquely supporting work on acoustic metamaterials for underwater environments**
- **AFRL has an applied research program focused on identifying near-term applications of metamaterials**

S&T Products (Warfighter Payoff):

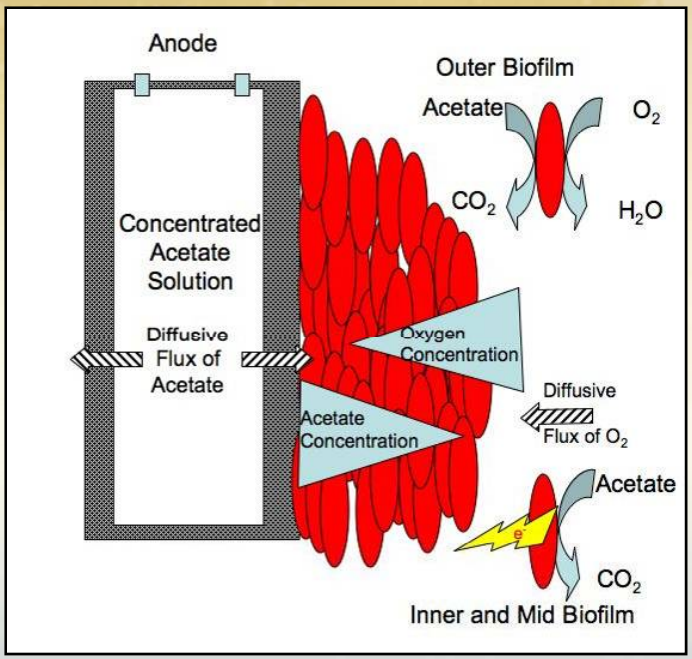
- Large-scale rapid 3D fabrication tools
- Acoustic hyperlens for underwater detection
- Next-generation acoustic vector sensors
- Advanced noise/vibration reduction
- Active and passive acoustic stealth coatings

Microbial Fuel Cell

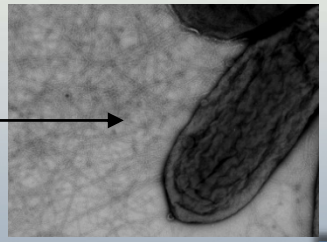
MFCs generate small amounts of electricity and are useful for powering undersea sensors and other small devices.

ONR Research has

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



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



Time Magazine named MFC one of the Top 50 Inventions of 2009

- 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)

Tropical Cyclone Formation & Intensity Forecasts

Revolutionary Research . . . Relevant Results

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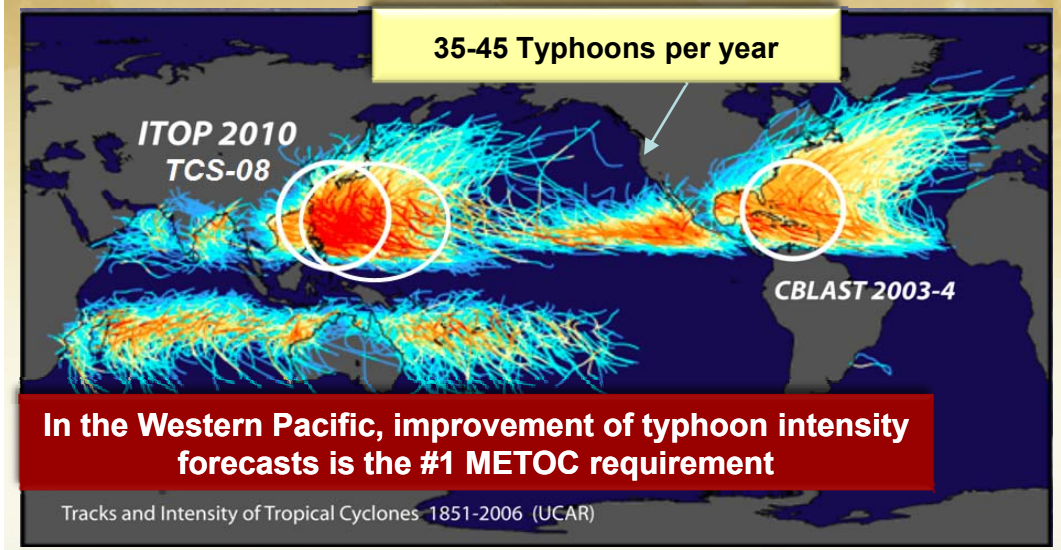


Basic Research Efforts

2003-2004:
- 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

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:
- Examined cold wake evolution and decay for ASW
- Investigated interaction of storm, wake, and eddy fields
- Fielded 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

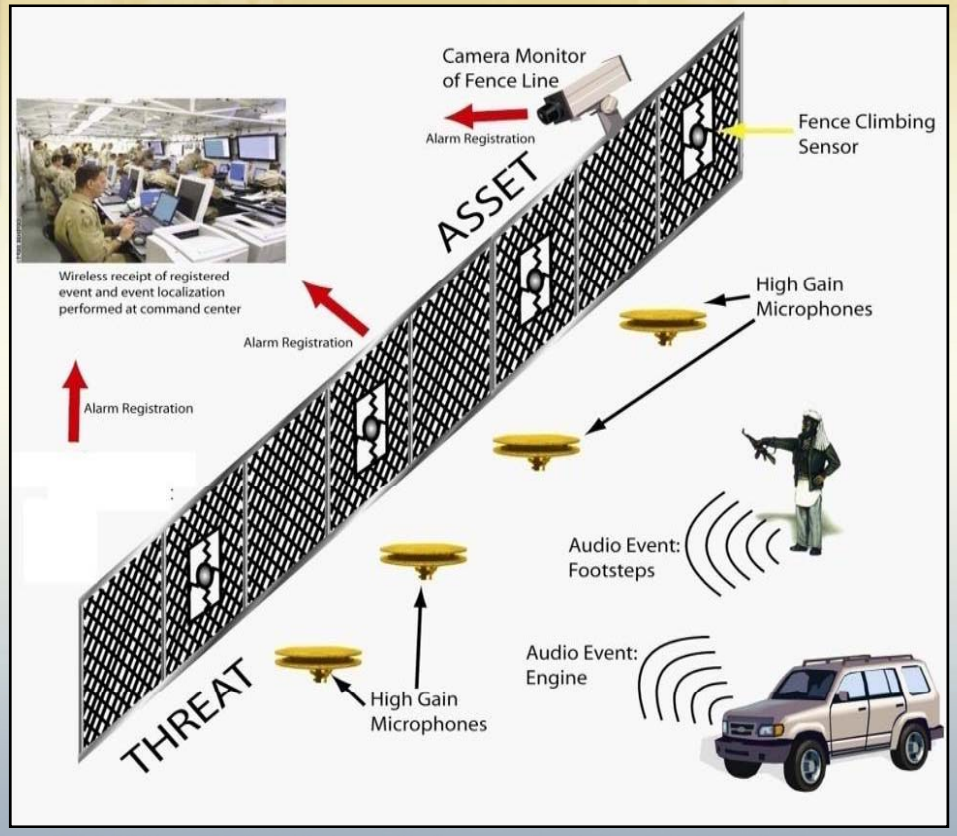
Computational Neuroscience

Early basic work:

Bio-inspired auditory/visual/motor abilities:

- Auditory – sniper localization
- Visual – object detection & identification
- Motor – hydrodynamics & neural controller

Ghost Swimmer



Led to Autonomous/underwater robotic systems and Smart Fence

Wavelets: From Theory to Operational Use

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Beyond 6.3 & Civilian

6.3

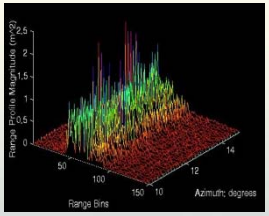
6.2

6.1

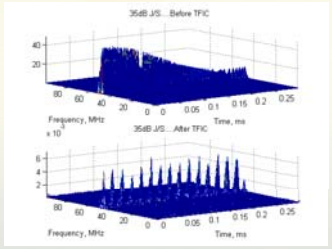
Surgical Strike Datalink Project (6.3 Demo)
Use video compression, Eliminate the 682 lb AN/AWW13 video datalink pod
NAWCWD, Rockwell, Boeing

FBI Fingerprint Compression Standard

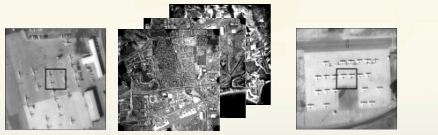
JPEG2000 compression for Special Operations Forces



Wavelet Radar Analysis for HRR and SAR



Comms through IED Jammers



Query Example | Image Library | Search Result

Image Database Browsing With Complex Wavelets

University Research on wavelet theory, multi-resolution analysis, mathematical and computational tools

1st. Federal grant on wavelet research **1986** → Broadened research efforts at academia, DoD labs/centers, and industry **~1988** → Emergence of DoD and Civilian Applications **~1997** → Industry compression standard JPEG 2000 **2001** → Numerous DoD & Civilian Applications **2000 +**

Materials Research into High Fracture Toughness

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Capabilities

- Weapon effects data
- Integrated design of body armor
- Operational environment data
- Data for injury models

Measurement System

- Portable data acquisition
- Dynamic response calibration
- Signal processing of internal responses

Anatomical Features

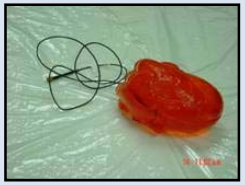
- Relevant bones and organs
- Pressure sensor and accelerometer instrumentation suite

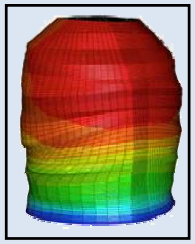
Surrogate Materials

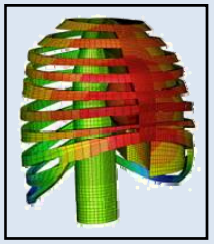
- Dynamic responses simulate
- Human tissues and organs
- Durable, multiple use, long shelf life

Thoracic Surrogate System

- Development began in FY01
- Data from >100 blast tests for sponsors



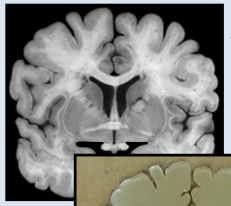




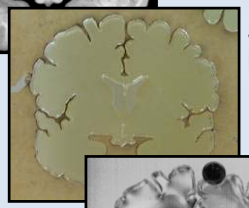
Blast Pressure Ballistic Fragments

Brain Surrogate System

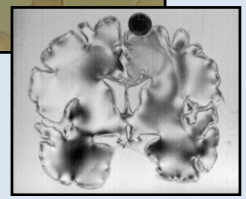
- Development began in FY06
- Focusing on helmet-brain response



Anatomical Data



Surrogate Materials



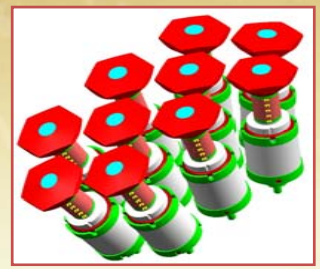
Dynamic Response

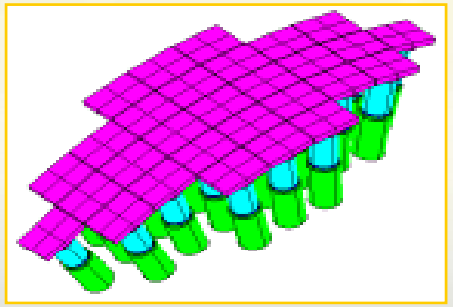
ONR & ARO CO-Sponsor research in this area at Cambridge University

Single Crystal Transduction Materials

Early basic work:

- Single crystal materials for sonar projector
- Dual-frequency:
  - High Frequency for high-resolution imagery
  - Broadband for buried & false alarm rejection





Single Crystal Acoustic Array

SSAM

Led to Small Synthetic Aperture Minehunter (SSAM), Countermeasure Weapons, and the Anti-Torpedo Torpedo

Sensors & Sonar Systems

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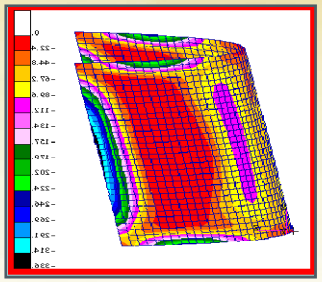
Basic Research
- Structural Acoustics
- Transduction Materials

Acoustically transparent structurally strong windows [NUWC Newport]



High Frequency Array Window

Flextensional transducers [NSWC Panama City]

ADC Mk 3/4

Sonar & torpedo countermeasures installed on USS VIRGINIA

NAVGUARD Corrosion Preventive Compound

Revolutionary Research . . . Relevant Results

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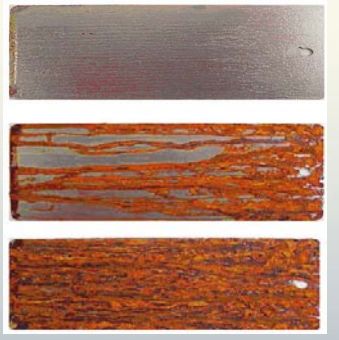
"From benchtop to fleet in 5 years"

- Started in 2002 with ONR-TOC funding
  - New CPC developed in Coatings Labs
  - Formula optimized from 2002 to 2005
  - Exceeded corrosion requirements of MIL-C-81309
- Continued with field demonstration and validation
  - Multi-year F/A-18 Field Test underway
    - Also assessed on Marine Corps Expeditionary Fighting Vehicle (EFV)
  - Product Licensed to Industry in 2006: two non-exclusive licensees (Armick & Corrosion Technologies)
    - Commercial products being tested against requirements of MIL-PRF-81309 Type II and III



NAVGUARD

(MIL-C-81309)
Corrosion Preventive Compounds, Ultra Thin Film

(MIL-PRF-32033)
Lubricating Oil, General Purpose Preservative

CPC Product on Steel Panels Following Seven Days at ASTM B117 Salt Spray Test

Implementation

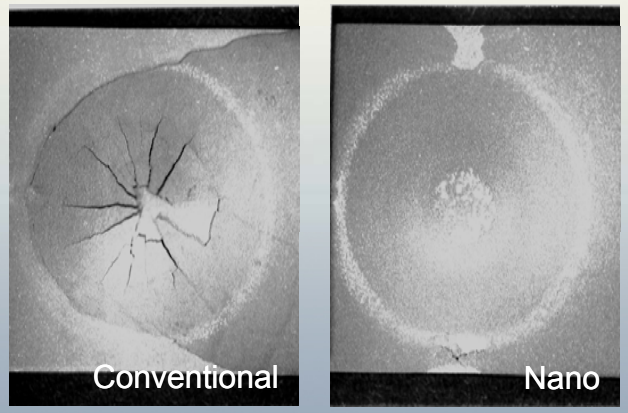
- Licensed products available through Qualified Products List in 2008/2009
- Specified for EFV by General Dynamics

Ceramic Nanocomposite Coatings

- *n*-Al2O3-13TiO2 coatings fabricated by conventional plasma spray
- 2X the bond strength and 4X the wear resistance
- Extraordinary deformability without failure
- Direct transition to fleet and industry (fully commercial)

MCM shafts fail after 18-months service requiring dry docking for weld repair

Uncoated shaft experiences severe scoring damage



No failure even after severe deformation

No visible damage after four years of service

Skewed Propeller

RESEARCH

- FY71 ILIR Project "Development of Reduced Skewed Propeller
- FY72-73 ILIR Project "Noise Reduced Skewed Propeller for ASW Ship Design Theory for Highly Skewed Propellers"

COLLABORATION

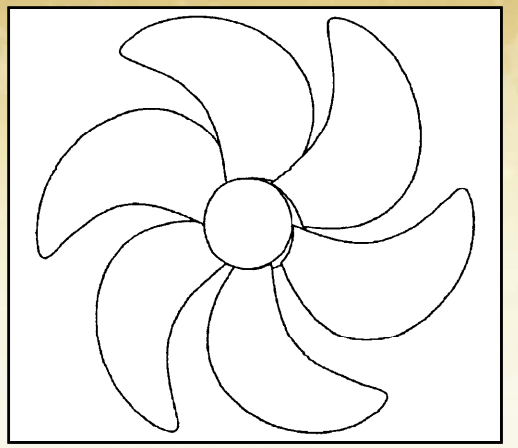
- MIT collaboration during FY74-76

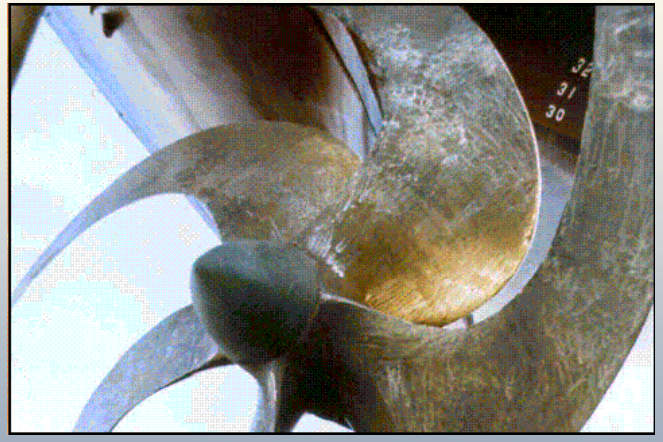
PAYOFF

- 10X reduction in propeller-induced vibration noise and forces

TRANSITION

- Improved habitability and reduced maintenance led to adoption by the commercial sector.





All submarines and most Naval auxiliary ships incorporate significant propeller skew.

Stern Flaps for Surface Ship Energy Savings

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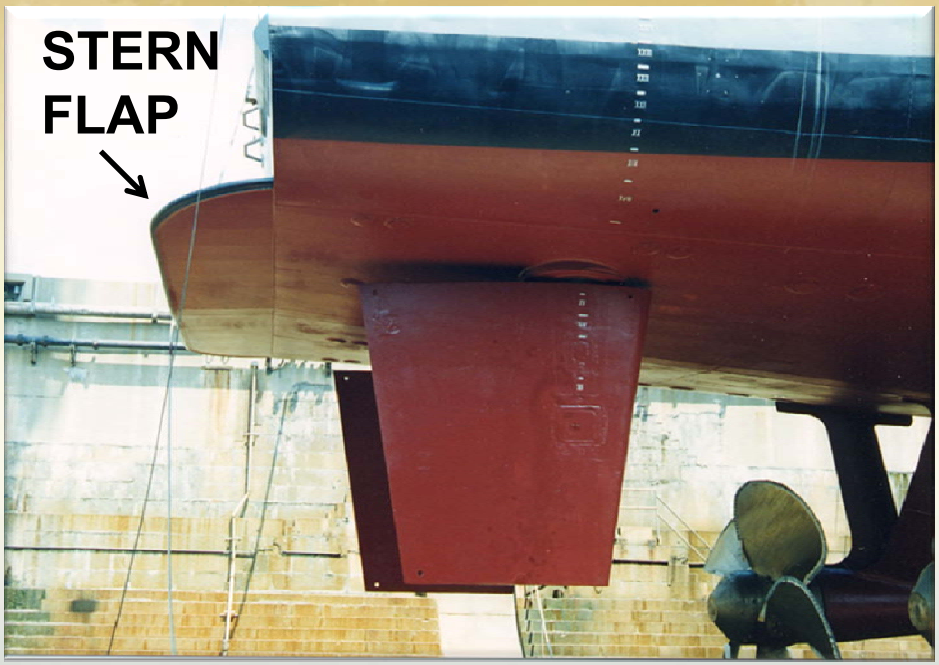
The Stern Flap has been installed on over 170 Navy and Coast Guard vessels with an estimated fuel savings of over $795M as of 28 Feb 2012.

- ILIR Research in the 1980s developed the computational hydrodynamic tools that enabled development of the Stern Flap.
- These tools allowed modeling that improved the understanding and fidelity of the model tests so they could be transitioned with confidence to an efficient full-scale design.



NAVSEA
WARFARE CENTERS
Carderock Division