Military Medicine Partnership: Naval Challenges

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ONR Beginnings

**Naval Research Laboratory**
(Appropriations Act, 1916)

“[Conduct] exploratory and research work … necessary … for the benefit of Government service, including the construction, equipment, and operation of a laboratory….”

**Office of Naval Research**
(Public Law 588, 1946)

“… plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power, and the preservation of national security….”

Sustained Support for Science & Technology
The Office of Naval Research
The S&T Provider for the Navy and Marine Corps

• 4,000+ People
• 23 Locations
• $2.1B / year
• >1,000 Partners

Discover → Develop → Deliver → Technological Advantage
Naval S&T
Investment Balance

<table>
<thead>
<tr>
<th>Focus</th>
<th>Current Fleet/Force</th>
<th>Fleet/Force in Development</th>
<th>Future Fleet/Force</th>
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</thead>
<tbody>
<tr>
<td>Narrow</td>
<td>Quick Reaction &amp; Other S&amp;T ≈ 8%</td>
<td>Technology Maturation (FNCs, etc) ≈ 30%</td>
<td>≈ 50%</td>
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<td></td>
<td></td>
<td>2-4 years</td>
<td>4-8 years</td>
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<tr>
<td>Broad</td>
<td></td>
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<td>5-20 years</td>
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<td></td>
<td>Discovery &amp; Invention (Basic and Applied Science) ≈ 50%</td>
<td>Leap Ahead Innovations (Innovative Naval Prototypes) ≈ 12%</td>
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~ 50% Focused on Near & Mid-Term Capabilities
ONR is part of the NR&DE, Providing Full-Spectrum RDT&E

<table>
<thead>
<tr>
<th>RDT&amp;E Budget (6.1-6.7)</th>
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<td><strong>S&amp;T Budget (6.1-6.3)</strong></td>
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<tr>
<td>6.1 Basic Research</td>
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<td>6.2 Applied Research</td>
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<td>6.3 Advanced Technology Development</td>
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<td>6.4 Adv. Comp. Development &amp; Prototypes</td>
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<td>6.5 System Development &amp; Demonstration</td>
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<td>6.6 RDT&amp;E Management Support</td>
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<td>6.7 Operational System Development</td>
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Naval R&D Establishment
(ONR, SYSCOMs and their Warfare Centers, PEOs)

Office of Naval Research

DISTRIBUTION STATEMENT A. Approved for public release.
Naval S&T Focus Areas

Assure Access to the Maritime Battlespace
- Ocean/Atmospheric Sciences
- Underwater Acoustics
- Ocean Sensing

Autonomy and Unmanned Systems
- Robotics
- Machine Learning
- Perception
- Human Machine Interface

Expeditionary and Irregular Warfare
- Situational Awareness
- Decision Making
- Mobility / Logistics
- Soldier Protection

Information Dominance / Cyber
- Communications / Information Technology
- Computer Science
- Mathematics / Data Analytics

Power Projection and Integrated Defense
- Directed Energy
- Energetic Materials

Platform Design and Survivability
- Air/Surface/Subsurface Vehicles
- Materials
- Corrosion / Biofouling
- Manufacturing Technologies

Power and Energy
- Renewable Energy
- Propulsion
- Power Control
- Thermal Management

Electromagnetic Maneuver Warfare
- EM Propagation & Waveforms
- Sensors and Electronics
- Optical Systems

Warfighter Performance
- Biomedical / Bioengineering
- Cognitive / Neural Sciences
- Training Technologies
- Force Health Protection

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Operational Challenges

“Over the horizon force projection with operational reach approaching 240 nautical miles (nm) will ... increase the risk of in-transit clinical degradation of severely wounded casualties.” "The Naval Fleet and the Marine Corps lack the capability to safely transport...over the times and distances expected in Expeditionary Maneuver Warfare”. (USMC ORD for The En Route Care System)

Current C4I systems do not provide operational and clinical situational awareness to nonmedical C4I systems, and patient movement and personnel tracking systems do not interact and are labor-intensive. (NAVY WARFARE DEVELOPMENT COMMAND (NWDC) TACMEMO 4-02.2-14)
"Unlike in the US and other developed countries, medical care in military operations or in disaster relief efforts involves long times and distances before the casualty arrives at a medical center is possible."
Casualty Evacuation Is a Complicated Bi-directional Information Network

Enroute Critical Care System

- Patient status communication between Distributed Navy and Marine Operations ashore and the Seabase
- Constant patient monitoring and treatment during movement of patients during ship to ship, shore to ship and during En route Care flight transfers
- Reduces effects from the “Tyranny of Distance” as we move from CENTCOM to AFRICOM and PACOM Areas of Responsibilities

Patient tracking is not just about moving people, it is about knowing what a person needs so you can make a decision about a person in a quick and organized way. (A MODEL FOR NATIONWIDE PATIENT TRACKING, 2009)
Pivot to the Pacific: A Bigger Place to Maneuver

Pacific Ocean (155,557,000 sq km) Atlantic Ocean (76,762,000 sq km)

The Continents and Greenland in the Pacific Ocean
The Challenges of Africa

11.67 million sq miles (30.22 million km²)

HADR and distributed operations, the number of casualties exceeds medical staff and evacuation capacity.
Medical Transportation
Then......
Medical Transportation
Now......
The Future Transport: CASEVAC by UAV/UGV/USV

“Due to evolution of future Seabasing, ability to support Ship-to-Objective Maneuver (STOM), and establishment of Enhanced Company Operations (ECO), the Corps requires... unmanned platforms” (USMC UNS for UAS)

The ACCS is an essential enabler of CASEVAC by unmanned platforms
Today’s Ships
Challenge Patient Movement onboard
Medical Space Unique Challenges onboard Naval Platforms
Strategic Guidance is the Foundation for our Naval S&T

National & Naval Strategy/Direction

Warfare Enterprise’s S&T Objectives
A Sample of Guiding Documents

Initial Capabilities Documents
i. Navy Expeditionary Health Support Services
ii. USMC Expeditionary Health Support Services
iii. Combat Casualty Care Devices and Products
iv. Joint Force Health Protection

Science and Technology Strategic Plan
i. USMC S&T Plan
Navy Diving “State of the Art”
Biometric Monitoring desired because of the extreme environment

- Need for a breathing apparatus
- Hyperbaric pressure
- Thermal stress
- Dark with limited means of communication

Start with basic physiological measurements

- Respiration rate
- Heart rate/variability
- Core temperature

Technical challenge

- Seawater and sensors/electronics don’t mix
- Can’t use wireless
Challenges of Blast / High Energy Events
MEMS Sensors for BLAST
MEMS: Micro-Electromechanical Systems

• Objective
  – To design and demonstrate minimally powered (or un-powered) inertial and pressure sensors to detect and quantify blast loads capable of inflicting mTBI.

• Proposed solution
  – Develop threshold MEMS sensors with mechanical switch closures to indicate blast exposure
  – Momentary contact for minimally powered version
  – Latching switch for un-powered version

• Status
  – Conducting laboratory testing of sensors and electronics
  – Tactical prototype expected Q4 FY16

• Technical Gap
  – Current sensors require power to operate
    • Battery life causes service life limitation
    • Larger batteries become too bulky
  – Commercial sensor approach requires data reduction
    • While detailed data is good for blast wave analysis, it may be burdensome when a quick yes/no exposure is desired
**What is SHMH?**

Structural Health Monitoring is the process of developing a damage assessment capability for aerospace, civil and mechanical infrastructure.
Enabling vision: Body Area Networks

Bio-interface, communication, and power management required

[Merrier, ISSCC 2010]
[Merrier, JSSC 2011]
20% personnel suffered altitude illness during Op Anaconda

Half of Afghanistan is over 2000m, with an average elevation of 4500m, resulting in mild- to life-threatening altitude sickness in un-acclimatized Warfighters.

US Security Analysis: > 60 world-wide high altitude areas for possible military engagement

HAPE/HACE may reach as high as 15%, and one incident can compromise an entire unit.

Current treatments are a logistical burden and have side-effects.
HYPOXIA – lack of oxygen to tissue

Neurological side effects
- Anxiety / Euphoria
- Confusion
- Impaired Judgment / Memory
- Dizziness
- Fatigue
- Headache
- Hot/Cold Flash
- Difficulty Communicating
- Loss of Muscle Coordination
- Numbness
- Visual Impairment
- Loss of Peripheral Vision
- Loss of Consciousness

Oxygen deprivation
Cells/tissues fail/die

Hypoxic Conditions

Signs and Symptoms are similar for other physiologic events, such as A-LOC, G-LOC, SD

How to measure or predict hypoxia?
Printed 3D Flexible Electronics: DoD Relevance

Printed 3D flexible electronics will enable a new generation of systems capable of sensing, actuating, recording, processing and communicating with their surroundings in ways unfeasible today.

**Areas of Implementation**

- **Mission specific devices on-demand**
- **Bio-electronic implants and interfaces**
- **Smart skins & wearable electronics**
- **Structure health monitoring**
- **Reconfigurable autonomous systems**
- **Tunable treatments for low observables**
- **Tracking, tagging & locating**

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**Printed 3D Flexible Electronics**

- **Flexible Electronics**
- **DoD Relevance**
- **Smart skins & wearable electronics**
- **Structure health monitoring**
- **Reconfigurable autonomous systems**
- **Tunable treatments for low observables**
- **Tracking, tagging & locating**

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**Printed 3D flexible electronics**

- **Sensing**
- **Actuating**
- **Recording**
- **Processing**
- **Communicating**
A Solution - Automated Critical Care System
Mobile Casualty Monitoring and Care

**Automated Critical Care System (ACCS)**

The ICU in a Suitcase
Treating multiple systems in a single patient

Therapeutic interventions:
- Open loop or human in the loop
- Semi-closed or human on the loop
- Closed Loop or human supervising the loop

**Challenges:**

**Hardware Issues:**
- Interoperability of equipment
- Autonomous Transport Platform Development
- Battery Technology
- Lightweight Oxygen Generation

**Telemedicine issues:**
- Data prioritization / Metering
- Bi-directional Communications
- Cybersecurity – Protection from nefarious acts
- Data Presentation – Easily Understood

**Monitoring Capabilities**
- IV Fluid input
- SPO2
- Non Invasive Blood Pressure
- Cardiac Output
- Ventilation to include Volume, Rate Pressure (PEEP)

**Therapeutics**
- Mechanical Ventilation
- Supplemental Oxygen
- Physiological Monitoring
- Casualty and Fluid Warming
- Analgesia / Sedation Therapy
- Fluid and Drug Infusion
Example of Technology Desires

**Hardware**
- Lighter / More Power / Faster Charging Battery Technology
- Lightweight Single man Oxygen Generation
- Sensor / Hardware Interoperability
- Hypoxia monitoring / Prediction / Resilience to extreme environments

**Telemedicine issues**
- Data prioritization / Metering
- Bi-directional Communications
- Cybersecurity – Protection from nefarious acts
- Big Data Presentation – Easily Understood
Questions??