Blast Loading and Assessment: Sense & Test (BLAST) Enabling Capability & Ongoing D&I Research into mTBI

A brief to/for:
NAVAL CIED Knowledge Network (NCKN)

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Office of Naval Research

ONR Has Six Science & Technology Departments

Warfighter Performance Dept

ONR 34 Warfighter Performance Department Head
Dr. Terry Allard, SES

Deputy
CAPT John Schmidt, PhD

ONR 341 Human & Bioengineered Systems Division Head
Dr. John Tangney, SES

ONR 342 Warfighter Protection & Applications Division Head
CAPT John Schmidt, PhD

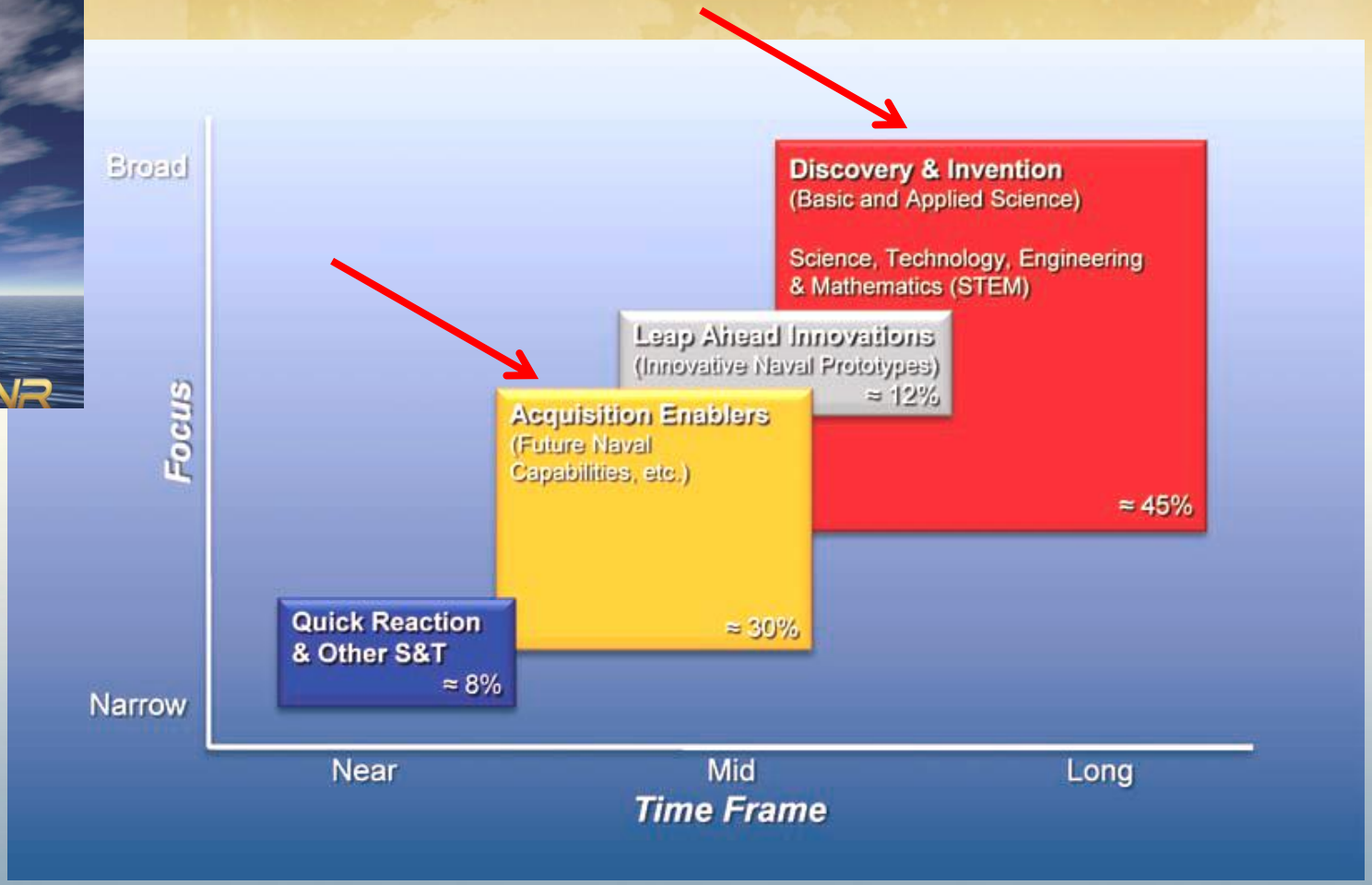
ONR 343 Research Protections Division Head
Dr. Tim Singer

Future Naval Capabilities:

- **CAPABLE MANPOWER**
- **FORCE HEALTH PROTECTION**

Basic Biomedical Science
Biophysics
Stress Physiology
Naval Biosciences
Undersea Medicine (NNR)
Noise Induced Hearing Loss

Funding at ONR



http://www.onr.navy.mil/About-ONR/~/media/Navy%20and%20Marine%20Strategy%20Plans/Naval-Strategic-Plan-2009.ashx

Force Health Protection
A Continuum of Care

Advanced Forward (Point-of-Injury) Care

- Hemostatic Agents
- Pharmacologic Resuscitation
- Rapid Blood Typing & Pathogen Detection
- TBI detection & Treatment
- Hypoxia Mitigation

En Route and Automated Care

- Closed Loop Fluid & Ventilation System
- Non-pulmonary Oxygenation
- Critical Care System

Pre-Deployment Care & Prevention

- Hearing Loss Prevention & Treatment
- PTSD Prevention & Mitigation
- M&S for Improved PPE
- Submariner Health

Post-Deployment Care, Treatment, and Restoration

- Wound Healing/Repair
- AFIRM: Armed Forces Institute of Regenerative Medicine

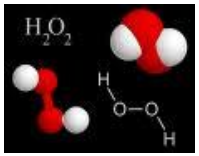
The FY13 Portfolio
Force Health Protection

FHP-FY08-01
Casualty Prevention

Models of Head and Cervical Spine

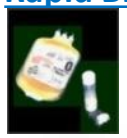
FHP-FY08-02
Advanced Forward Care

Closed Loop Fluid Delivery



Non-Pulmonary Oxygenation

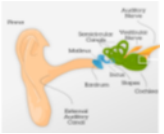
FHP-FY08-03
Rapid Blood Treatment



Hemostatic Agents

Pharmacologic Resuscitation

FHP-FY08-04
Warfighter Restoration



Hearing Loss Prevention and Treatment

Post-Traumatic Stress Mitigation

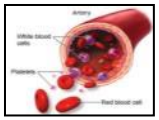
Repetitive Neurotrauma

Wound Healing

FHP-FY10-01
Human Injury Treatment

HIT Model (Medical Planning)

FHP-FY11-01
Multi-Functional Blood Substitute

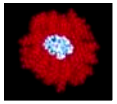


Multifunctional Resuscitation Fluid

FHP-FY12-01
ACCS

Automated Critical Care System

FHP-FY12-02
SEMPer Fi



SEMPer Fi Air

SEMPer Fi Land

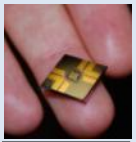
FHP-FY13-02
Extreme Operations

Hypoxia Alert & Mitigation System

FHP-FY14-01
ACCSIL

Acute Care Cover for Severely Injured Limbs

FHP-FY14-02
BLAST



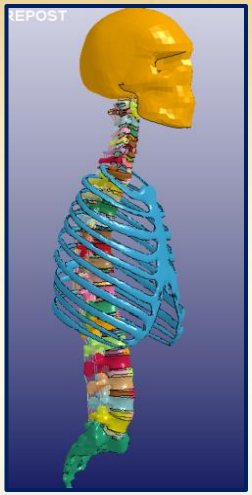
Blast Sensors

Neuro-Cognitive Assessment

Algorithm

Blast TBI Mitigation Efforts

Computational Modeling



- Predictive Modeling
- Blast & Acceleration Forces
- Physiologically-relevant
- Operationally-relevant
- Validated

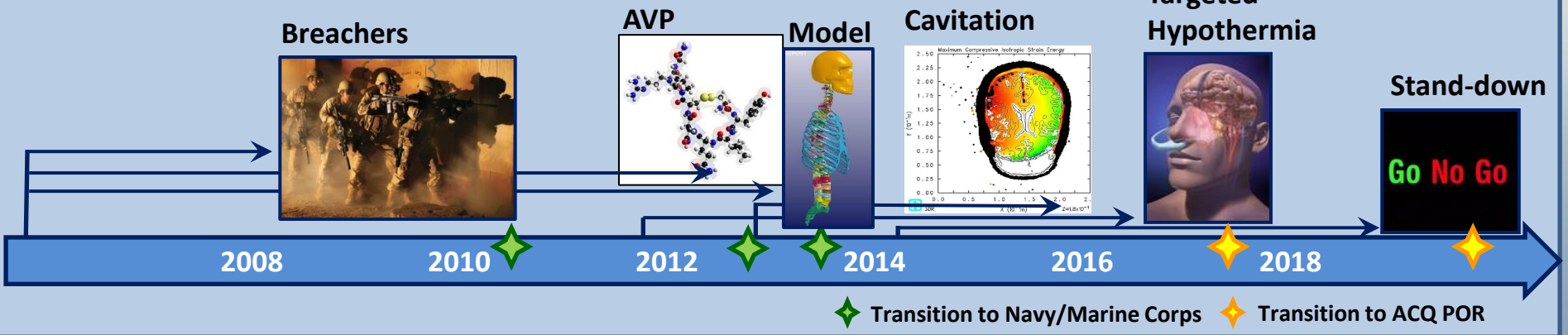
Models of Head and Cervical Spine

Therapies and Treatments

- Targeted Hypothermia
- Perfluorocarbons
- Reduce Metabolism
- Effective in Cardiac Arrest
- Effecting in preliminary animal studies

SEMPer Fi Land

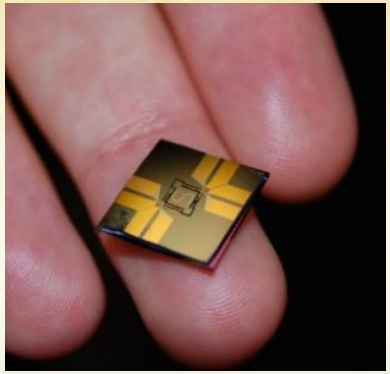
Timeline - Current Portfolio & Recent Successes:



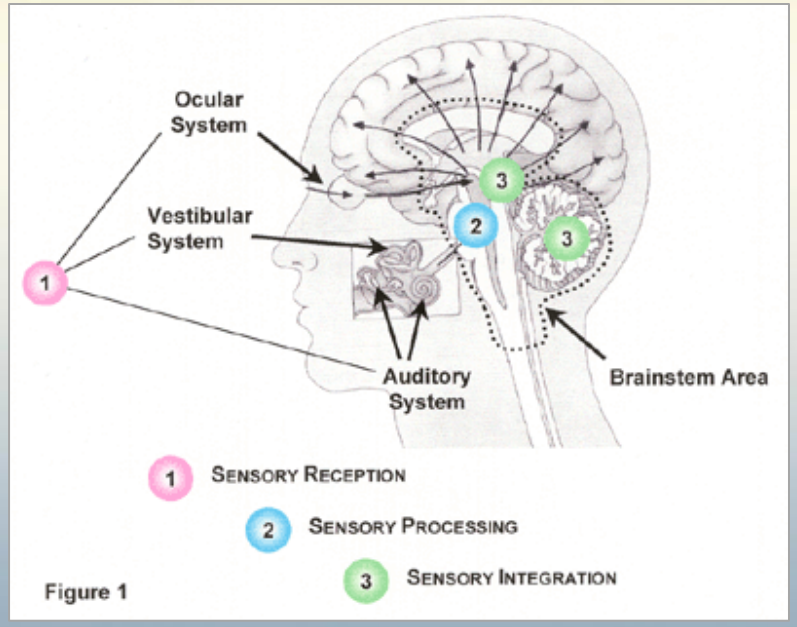
Blast Load and Assessment: Sense and Test (BLAST)

BLAST Program

...will integrate "operational exposure to blast" data using lightweight self-powered sensors...



...with "cognitive evaluation data" using novel objective measurement devices...



...for the development of a deployable algorithm that will produce binary Go/No-Go output...

...in order to provide operational and cognitive rationale to stand down or return to the field following blast events.

BLAST Program

In the Field & Afloat

Multiple micro sensors are embedded in Protective Equipment

At the Base

Radio Frequency Identification (RFID) technology automatically reads individual exposures

NO-GO

Cognitive evaluation with *objective* test

Medical evaluation

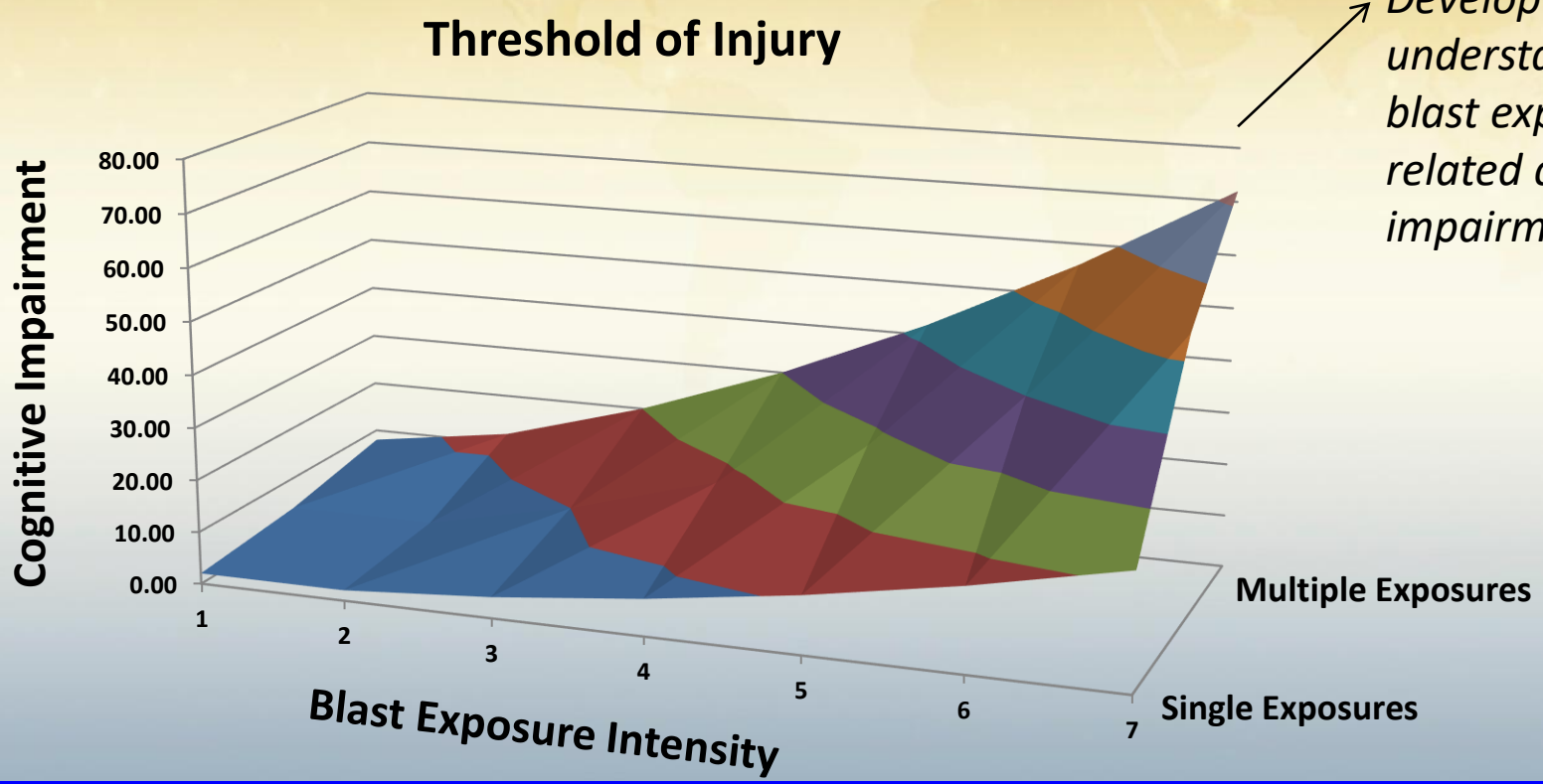
GO

Return to Duty

STAND DOWN and Treatment

BLAST Program

Mapping Blast Exposure to Impairment



Develop an understanding of blast exposure and related cognitive impairment.

Cognitive impairment increases with both blast intensity and repetition in a complex, non-linear fashion.

Technical Support Working Group (TSWG)

Low-Level Repeated Blast (LLRB)
Brain Injury Criteria

LLRB Exposure Criteria

Exposure criteria will ultimately be applicable to:

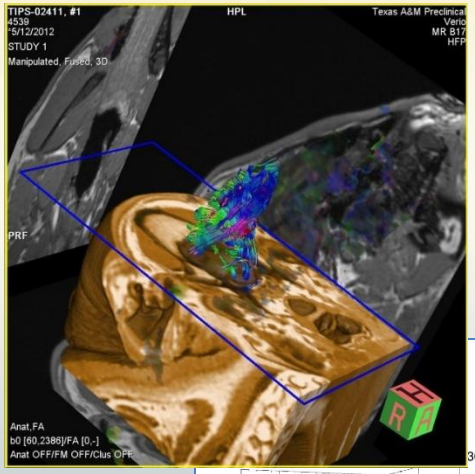
- Enemy Attacks *(SINGLE, LARGE EXPOSURE)*

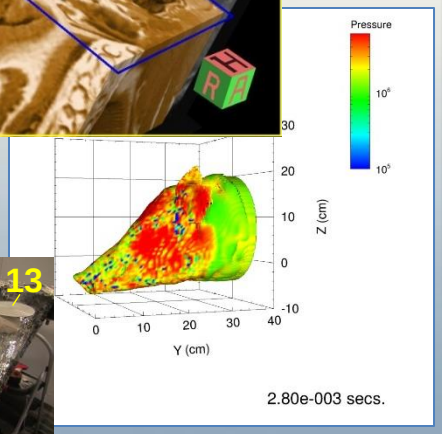
- Use of Explosives *(REPEATED, MODERATE-LEVEL EXPOSURE)*

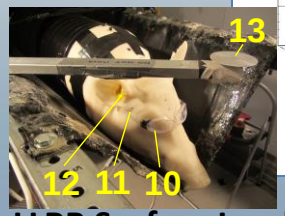
- Weapons Back-Blast *(REPEATED, LOW-LEVEL EXPOSURE)*

Repeated exposure to Blast will result in injury in proportion to:

- Number of exposures
- Exposure frequency
- Magnitude of each event







LLRB Surface Loading

Incapacitation Prediction for Readiness in Expeditionary Domains: an Integrated Computational Tool (I PREDICT)

Proposed Enabling Capability for FY16

I PREDICT

...is a software tool based on

human physiology, response to injury *and* operationally-relevant injury criteria...

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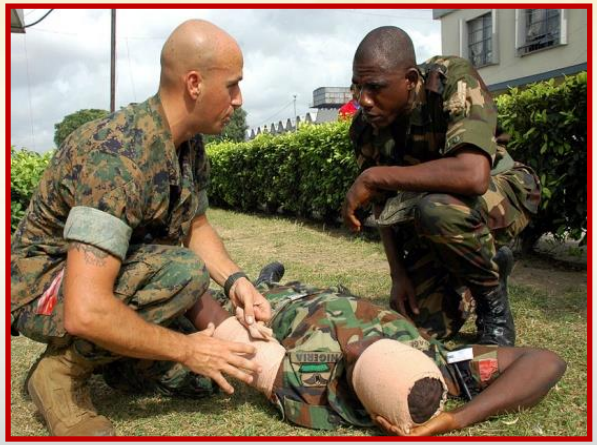

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...to provide an integrated human model for medical response planning, injury prevention and treatment CoAs, and PPE validation and testing *in silico*

Virtual testing via a digital human will save time, save money, and provide methods of injury avoidance.

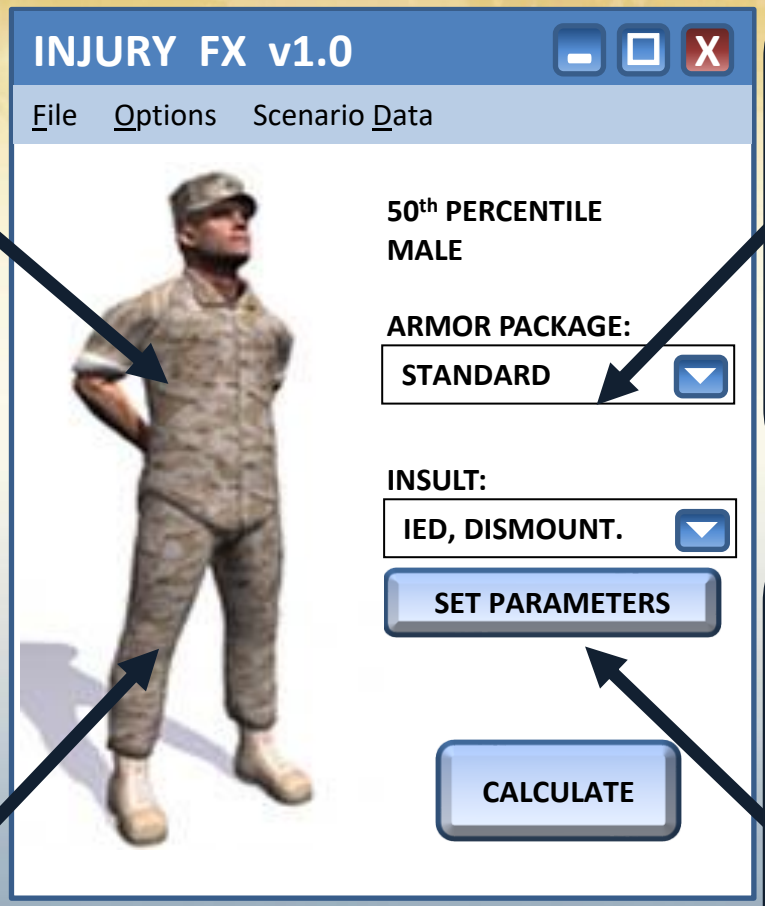
I PREDICT

INTEGRATE PRIOR INVESTMENTS

- **ONR** (EMW & FHP FNCs, STTR)
- **NAVAIR** (Injury Models)
- **Army** (WIAman)
- **Air Force** (HE-MAP)
- **Academia** (e.g. Univ of Iowa, JHU/APL)
- **Industry** (e.g. SwRI, CC)

LEVERAGE INJURY EPIDEMIOLOGY

- **Combat Trauma Registry**
- **Joint Theater Trauma Registry**
- **JTAPIC**
- **Dismounted Injuries Analysis Team**
- **Naval Health Safety Center**
- **Injury Surface Mapping Program (TSWG)**



FILL GAPS

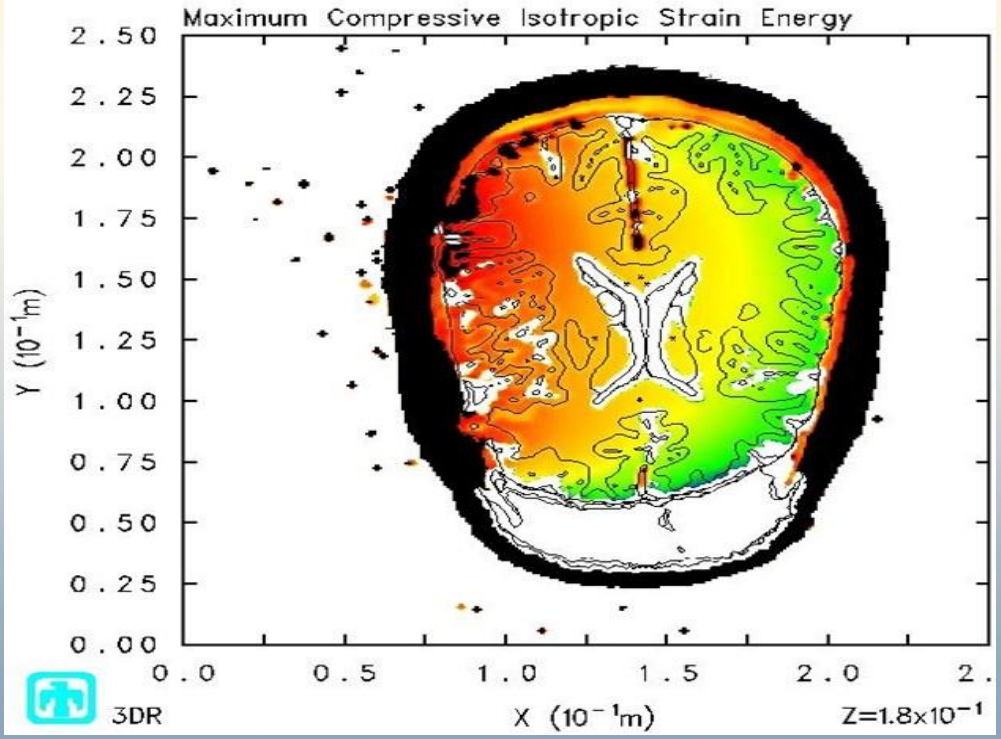
- **Tissue response to high strain rate events**
- **Model of practical injury effects**
  - **Immediate incapacitation**
  - **Short-term disability**
  - **Injury effects over time, under TC3, etc.**

CONDUCT MODEL Validation, Verification & Accreditation

- **Validation against animal and human tissue**
- **Validation of predictions against new epidemiological data**

Discovery & Invention:

Micro-Cavitation as a Mechanism of Neuronal Injury



Cavitation is Destructive

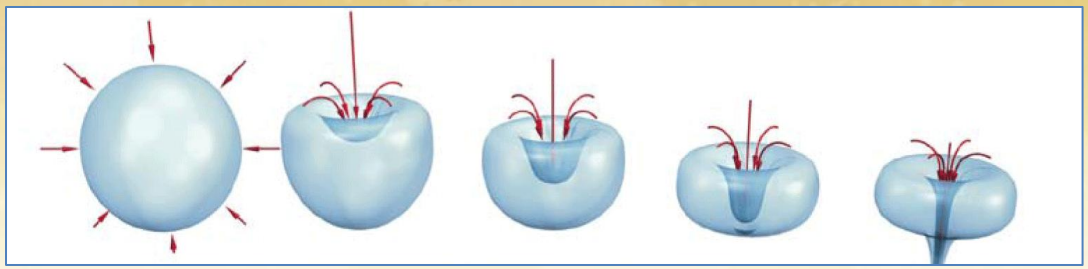
BLAST ⟶ Hydrodynamic Cavitation ⟶ Localized Brain Injury

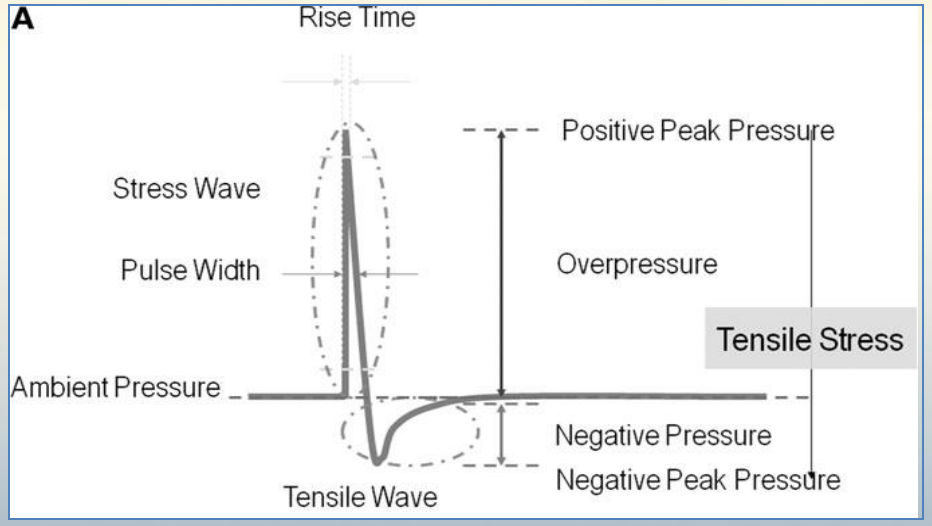
Mantis or Pistol Shrimp produce cavitations with their high speed claws. Microbubble collapse helps smash the prey's shell.

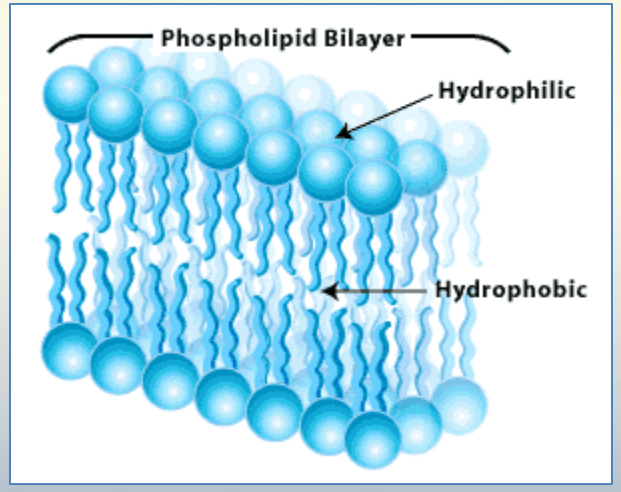
Cavitation can tear apart steel propellers

Cavitations formed by lithotripters destroy kidney stones

Primary Blast Pressure Wave Generation Can Lead to Cavitation

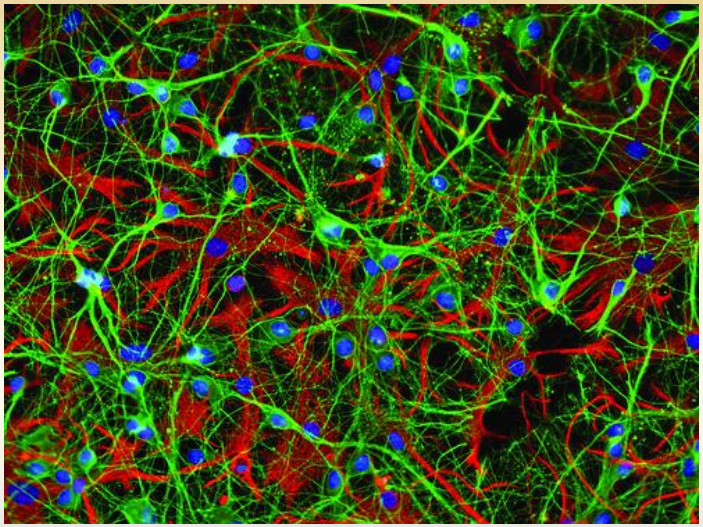






- Large-scale molecular dynamics simulations
- Interaction of shock waves with lipid bilayer
- Systematic study of shock wave induced bubble collapse

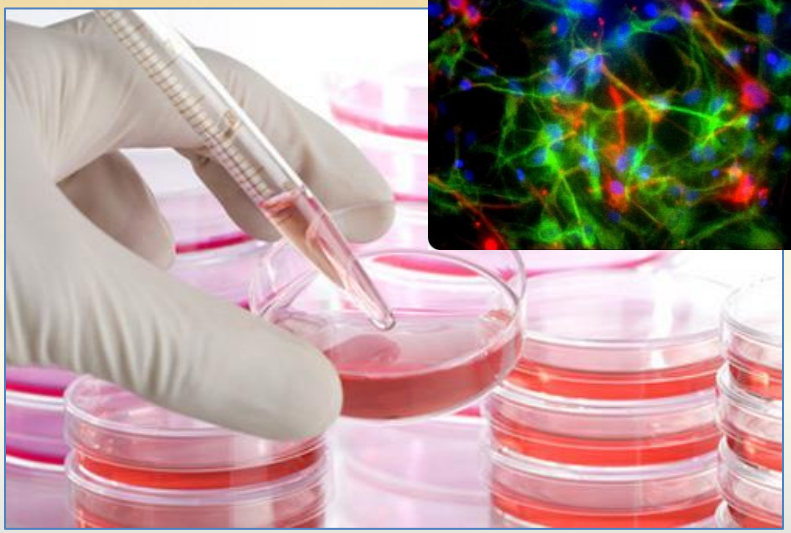
Elucidating Mechanisms: Shockwaves and Micro-Cavitation



- **2D & 3D Neuron + Astrocyte cultures**
- **Generate micro-cavitation bubbles**
- **Real-time cellular and subcellular responses**
  - mechanical deformation
  - morphological changes
  - altered membrane potential
  - loss of neurites, axonal shearing
  - production of neurotransmitters
  - cytoskeleton reorganization,
  - necrotic cell death & apoptosis

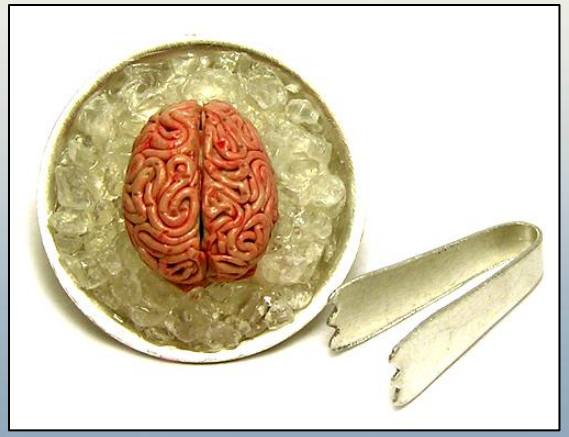
Define the threshold shockwave parameters that lead to elucidation of the coupling mechanisms

Protection Against Cavitation



- Physiologically-realistic
- 3D *in-vitro* cultures
- Spatial and temporal changes in neuronal viability & morphology
- Neuroprotective effects of mild hypothermia

- Diffuse Axonal Injury
- Axonal Swelling
- Apoptosis
- Necrosis/Degeneration



Back-Up

Future Naval Capabilities Program