ARL Collaborative Research Alliance Materials in Extreme Dynamic Environments (MEDE)

ARL Multiscale Research of Materials Opportunity Conference
November 19th, 2010
Fairfax, VA

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Presented by:
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Outline

1) Weapons and Materials Directorate Mission
2) Motivation
3) Direction of Materials Science
4) The Materials in Extreme Environments CRA
5) Collaboration
6) Funding
7) MEDE CRA Goals

US ARMY RDECOM

ARL Major Laboratory Programs

Protection
- Materials and Manufacturing Science for Protection
- Vehicle Protection
- Individual Warfighter Protection

Lethality
- Energetic Materials and Propulsion
- Projectiles, Warheads and Scalable Effects
- Materials and Manufacturing Science for Lethality
- Affordable Precision Munitions
- Advanced Weapons Concepts

Human Dimension
- Soldier Sensory-Cognitive Motor Performance
- Neuroergonomics
- Social-Cognitive-Cultural Networks
- Human Robotic Interaction
- Human Systems Integration

Survivability/Lethality Analysis
- Ballistic Vulnerability/Lethality
- Electronic Warfare
- Information Assurance and Computer Network Defense
- Systems of Systems

Networks
- Information Sciences
- Network Sciences
- Battlefield Environment
- Advanced Computing and Computational Sciences

Extramural Basic Research
- Chemistry
- Physics
- Life Sciences
- Network Science
- Environmental Sciences
- Materials Sciences
- Mechanical Sciences
- Mathematics
- Computing Science
- Electronics

Sensors
- RF Technologies
- Electronics Technologies
- EO/IR Technologies
- Non-Imaging Technologies
- Sensor Processing

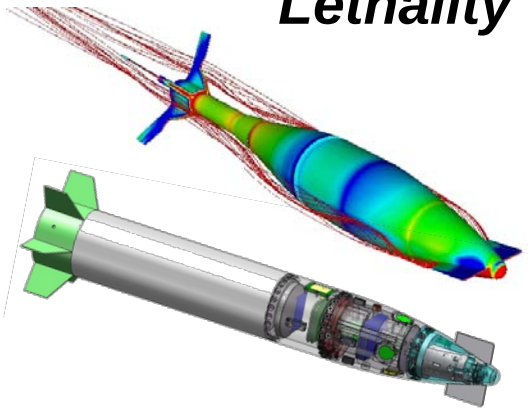
Power and Energy
- Power Generation and Conversion
- Energy Storage
- Power Control and Distribution
- Thermal Management
- Energy Science

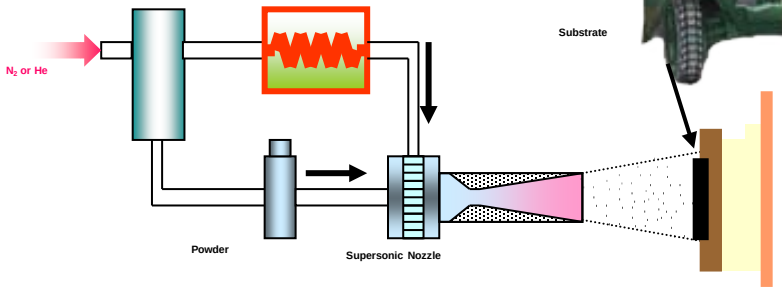
Mobility and Logistics
- Platform Mechanics
- Vehicle Propulsion
- Autonomous Systems
- Reliability

Simulation & Training
- Intelligent Technologies for Training
- Synthetic Environments
- Immersive Learning
- Training Application Environments
- Advanced Distributed Simulation

WMRD Capability Research Areas

Lethality



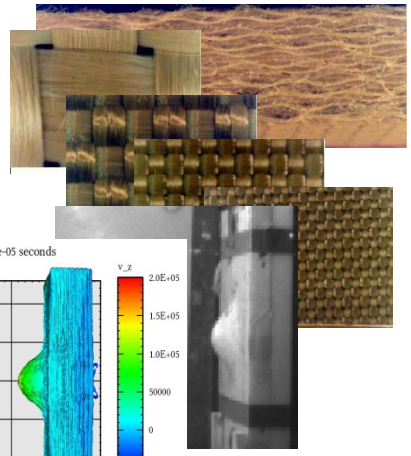


Cold Spray Supersonic Coating

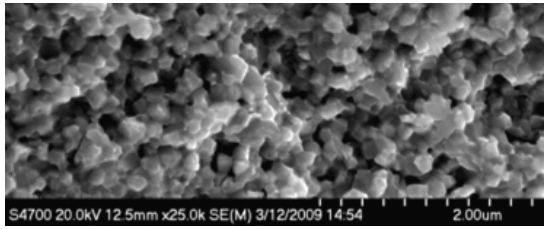
5.56 Green Ammo

Protection

Textile Structure



Sphere impact on 2" of PEFRC at 60 μs



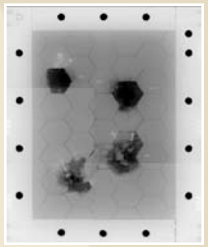
Bulk Nano-Grained Tungsten for DU Replacement

Materials and Manufacturing Science

WMRD RESEARCH CONTINUUM

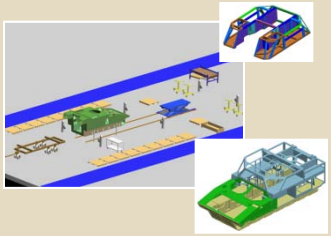
Thrown Object Protection System (TOPS)

Opaque and Transparent Armors for MRAP

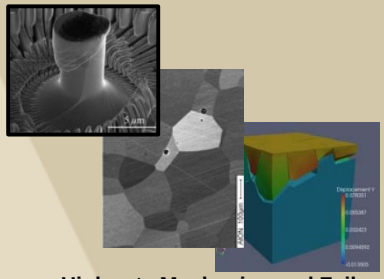


Multi-hit Armor Technologies

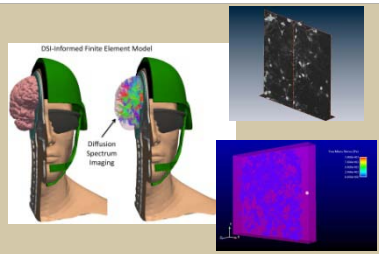
Underbody Protection Modeling



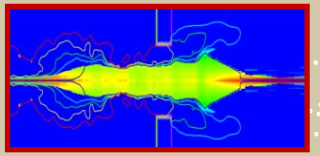
Armor and Structure Manufacturing Technology



High-rate Mechanics and Failure in Extreme Environments



Multiscale Modeling of Cellular Damage Mechanisms

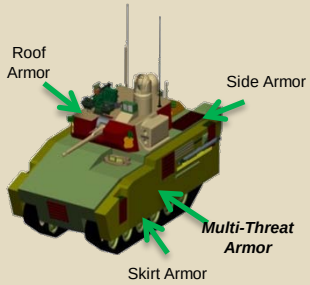


Multi-physics Protective Systems

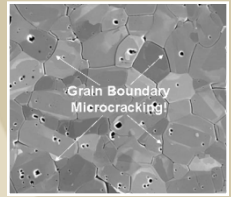
Vehicle Seating Technology

EM Armor

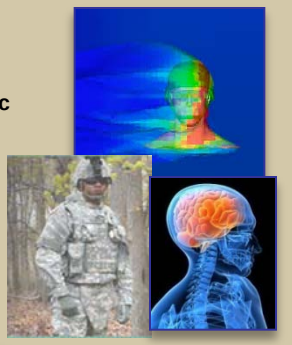
Multifunctional Structures and Coatings



Hybrid Protection



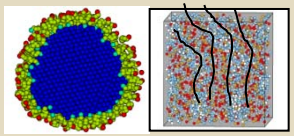
Fundamentals of Ceramic Materials



Tailorable Body Armor

Electrical Protection System (EPS)

Improved Soldier Protection



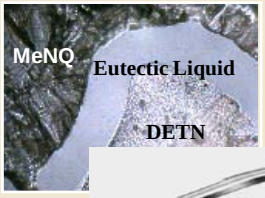
Nanomaterials

Current → **Near Term** → **Future**

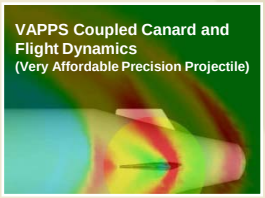
Robust Lightweight Protection Solutions

WMRD RESEARCH CONTINUUM

CONTINUED

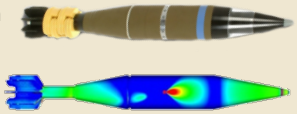


DEMN III Explosive Formulation

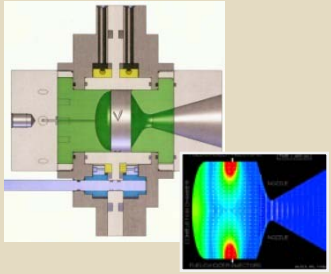


Very Affordable
Precision Projectile

Green Ammunition

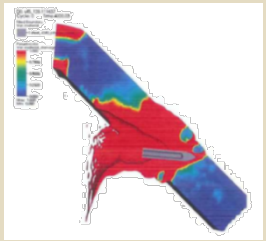


Precision Guided
Mortar Munitions

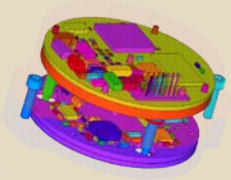


CFD Modeling of Vortex
Rocket Engine

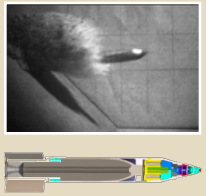
Insensitive Munitions
Technologies



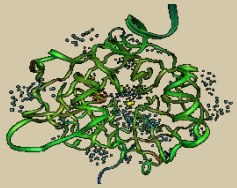
High Performance Simulation
of MOUT Penetration



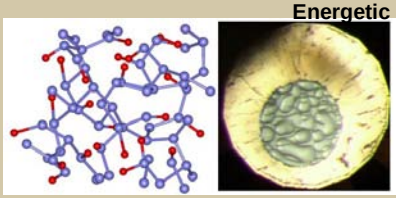
Survivability of Electronics



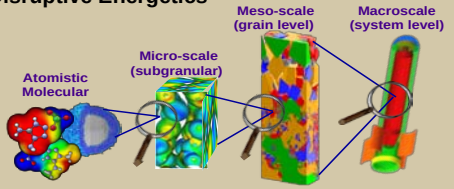
Multi-threat Objective
Projectile Technologies



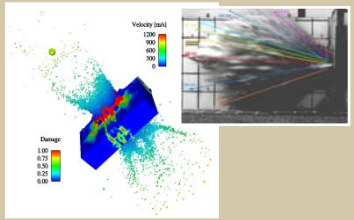
Multidisciplinary Modeling
and Characterization of
Energetic Materials



Disruptive Energetics



Multiscale Modeling for Advanced Materials



Computational Failure Mechanics

Current → Near Term → Future

The Right Lethality at any Place and any Time

Weapons & Materials Research Directorate

Director

Assoc Dir, Science and Technology
Assoc Dir, Program & Plans
Assoc Dir, Operations
Assoc Dir, Protection & Lethality Technical Focus Teams

Management Support Group

Materials & Manufacturing Science Division

Protection Division

Lethality Division

Materials Centers of Excellence

Virginia Tech
Drexel Univ.
Rutgers / PSU / JHU
Univ. of Delaware
Johns Hopkins Univ.

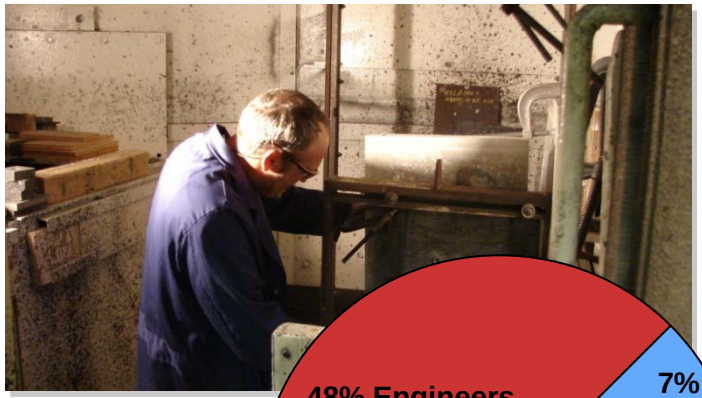
MURIs
CRADAs
TSAs
MOAs
etc

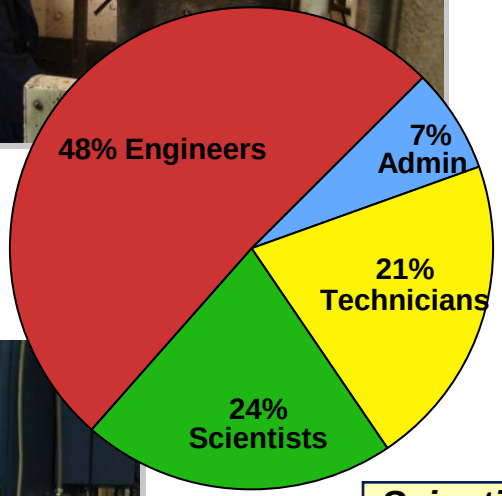
DoD Ordnance and Technology Consortium

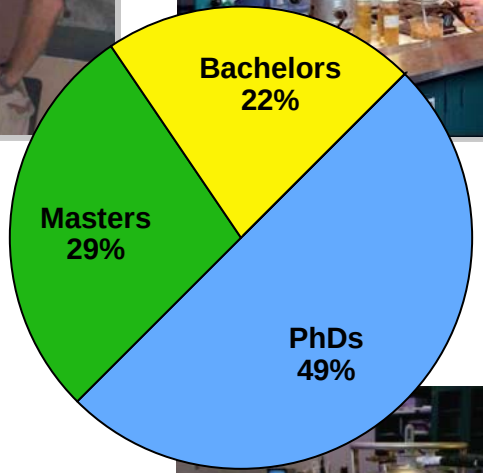
Institute for Soldier Nanotechnologies
UARC
MIT

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

WMRD Staff

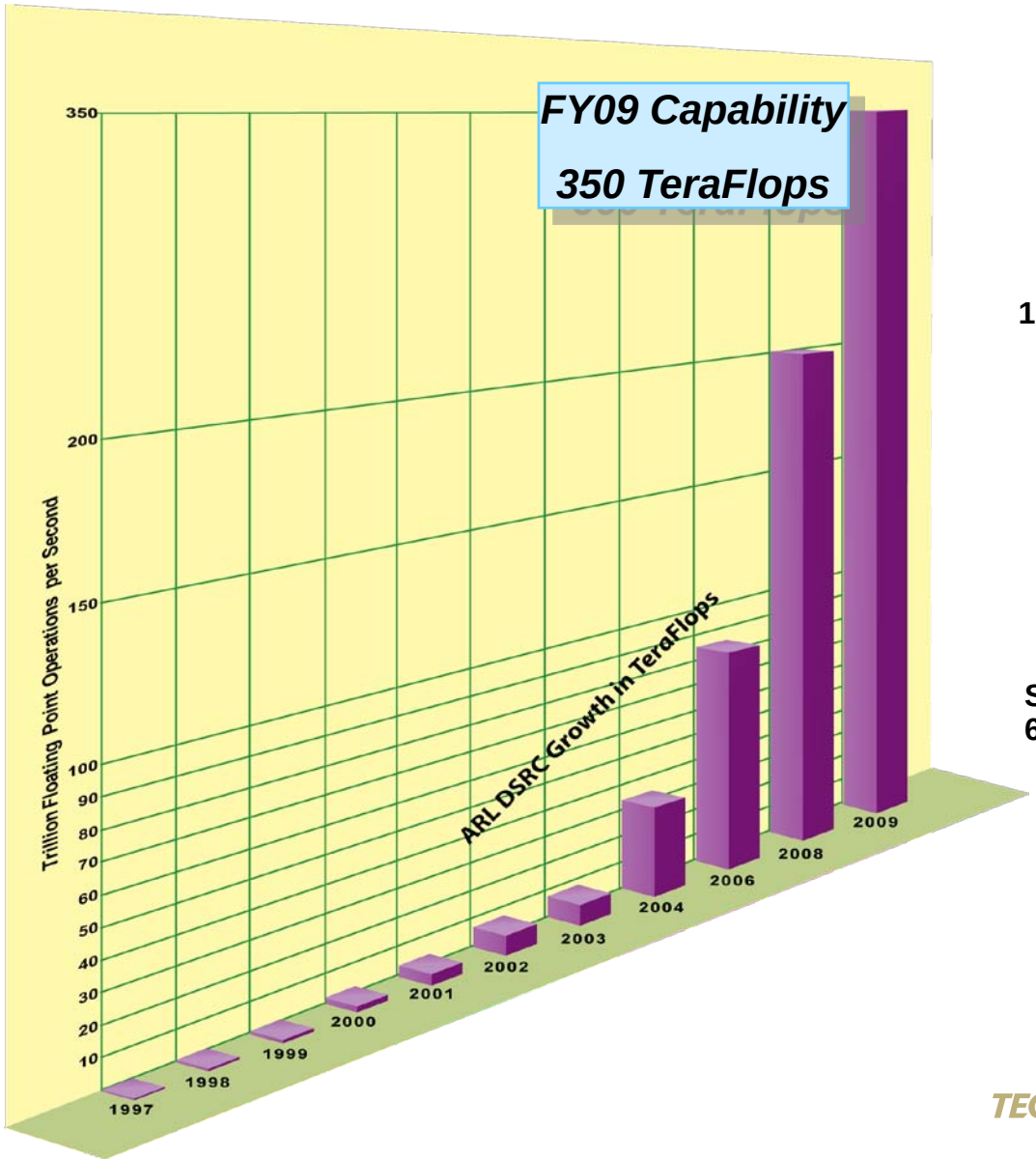






Scientists and Engineers	*318*
Technicians	*92*
Administrative	*31*
Total Civilian Personnel	*441*
Post Doctorates	*30*
Guest Researchers	*8*
Military	*4*
On-Site Contractors	*369*

ARL DSRC Growth in TeraFlops



Cray XT5 Cluster
10,400 core / 41.6 TB

SGI ALTIX ICE
10,752 cores / 32TB

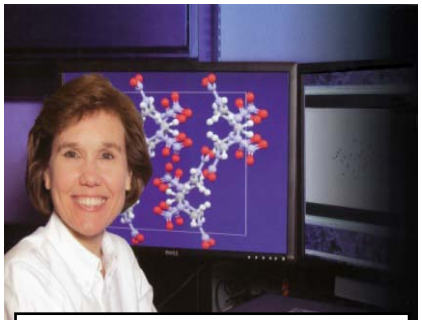
Linux NetworX Advanced Technology Cluster
3368 core/6736 GB

SGI ALTIX ICE 8200
6,656 cores / 52.2 TB

Linux NetworX Advanced Technology Cluster
4400 core/8192 GB

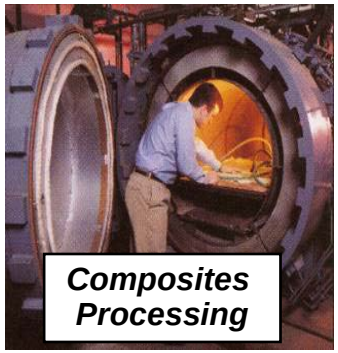
Rodman Materials Research Laboratory

132 Individual Laboratories



Energetic Materials Synthesis

- Composites
- Polymers
- Metals
- Ceramics
- Materials Processing
- Energetic Materials
- Smart Munitions
- Impact Physics



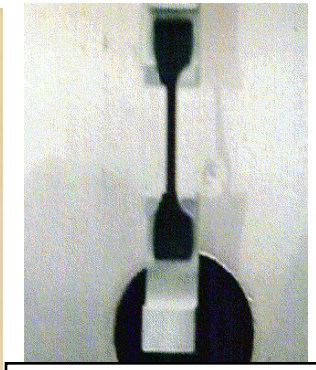
Composites Processing

Specialty Coatings

Sputter Deposition

Impact Physics Tension Hopkinson Bar

Stand-off Detection of Explosives



Mechanical Properties of Energetic Materials

Cold Spray Deposition

Smart Munitions

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

WMRD Ballistic Research Compound Facilities

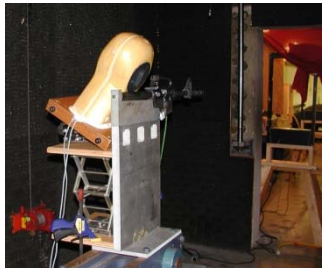
Small Caliber Experimental Facilities for Armor Concepts, Evaluations, and Analysis

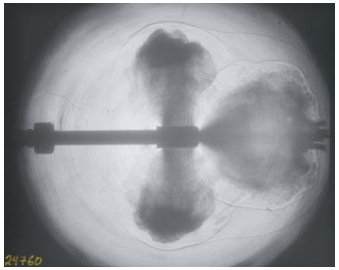
Protection Division Facilities

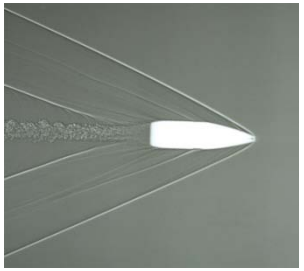
Lethality Division Facilities

Gas Gun Facilities

Instrumented M-16







Propulsion Science Gas Gun Facilities

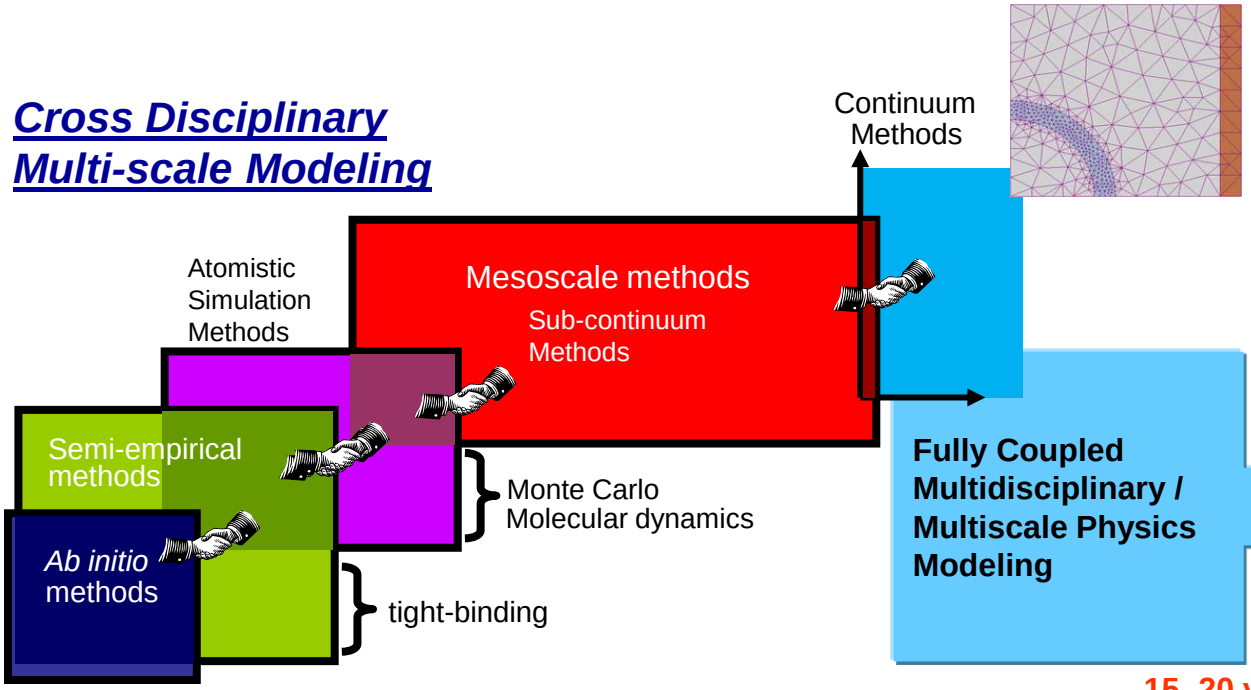
ARL WMRD Aerodynamics Experimental Facility Capture Muzzle to Flight Dynamics

WMRD Experimental Facilities

Spesutie Island

Long-Term Core Scientific Thrust
Multidisciplinary // Multiscale Physics

Cross Disciplinary Multi-scale Modeling

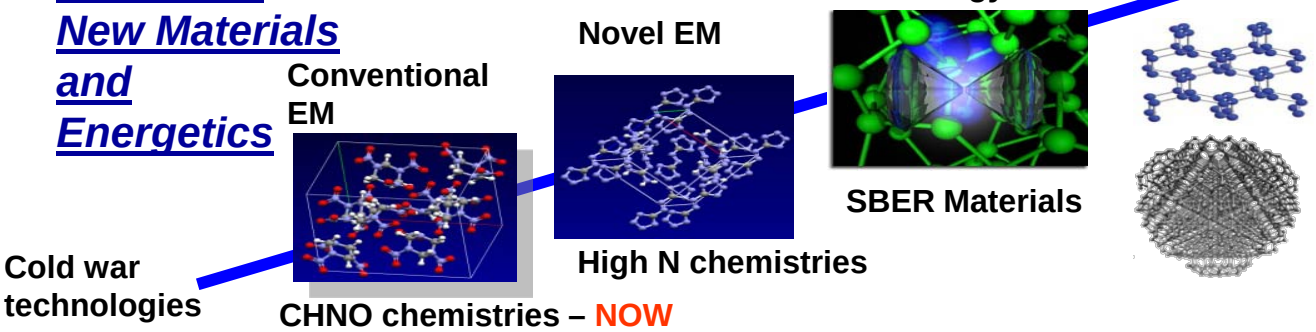


Fully Coupled Multidisciplinary / Multiscale Physics Modeling

Key Disciplines for Lethality & Survivability

- *Electromagnetics*
- *Structures*
- *Fluids*
- *Materials*
- *Chemistry*
- *Dynamics*
- *Heat Transfer*
- *Physics of Failure*
- *GN&C*
- *Numerical Methods*
- *Visualization*
- *Coupling Algorithms*

Disruptive New Materials and Energetics



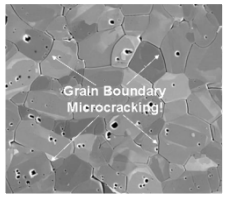
Technical Synergies

Multi-Scale Mat. Behavior in Ultra High Loading Rate Environments

- *Investigate bridging scales*
- *Develop models & simulations*
- *Develop innovative experimentation & validation techniques*
- *Define multiscale material metrics*
- *Perform processing & synthesis*

Electronic Materials

- *Investigate and develop heterogeneous metamorphic electronics*
- *Explore material designs for electrochemical energy, hybrid photonic, spintronic devices*



Fundamentals of Ceramic Materials

Designer Microstructure Composites

Protection Materials

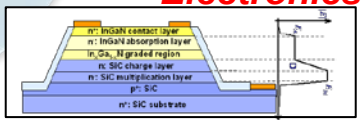
•Army-relevance

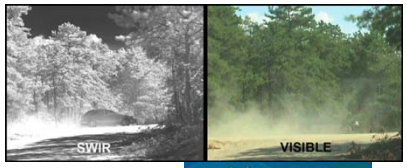
•Underpinning science infusion

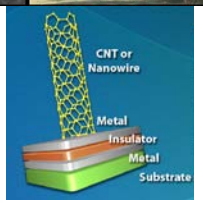
Opto-electronics

•Army-relevance

Electronics







Power & Energy

In-house Cross-Disciplinary Multiscale Research of Materials Initiative

- ***Underpinning Multiscale Physics & Chemistry Fundamentals***
- ***Computational Science Environments, Codes & Software Tools***
- ***Validation & Verification***

Motivation

History of Armored Vehicles

Monocoque

Appliqué

Integral

Structure (A) + Armor (B)

Functional Requirements

- **weight (lighter)**
- **range of protection levels**
- **ballistic and blast performance**
- **damage tolerance**
- **structural performance**
- **fire performance**
- **Electromagnetic properties**
- **maintainability**
- **affordability**

Goal: Highest Protection at Lowest Possible Weight

Strategy

Soldier
Systems
Flexible Armor

Threat Protection
At 1/3 the Weight

Air Systems
Ultra Light Weight

Materials

Mechanisms
Properties
Characterization
Processing
Manufacturing

Threat
and
System
Energy Management

Armor Mechanics/Design

Passive Armor
Hybrid Armor Systems
Multidisciplinary Concepts
EM Armor
Reactive Armor
Vehicle Structures
Vehicle Response

Time after impact

0.5 μs ***(Material Scale/Response)*** ***(Vehicle Scale/Response)*** ***Seconds***

Paradigm Shift

Fundamental Understanding of Material Science within Extreme Dynamic Environments

Protection
Fundamental understanding of materials at "Ultra High Loading Rates" across all relevant scales

Target

Performance Metrics

Revolutionary

Soldier Systems Flexible Armor

Ground Systems

Air Systems Ultra Light Weight

Evolutionary Current Path

Current Trajectory

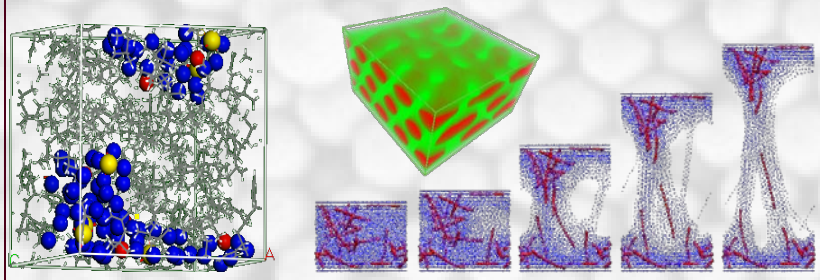
2007 2010 2013 2019 Time

Ultra-lightweight Effective Protection Materials

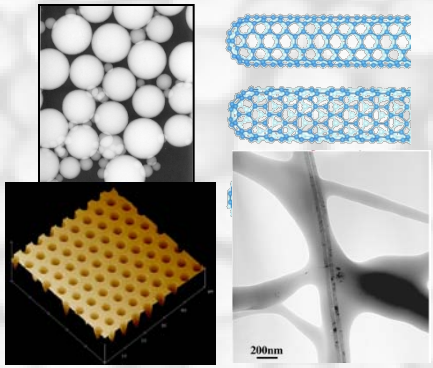
Material SOA

The Army is Capitalizing on Revolutionary Advances in the Materials Community

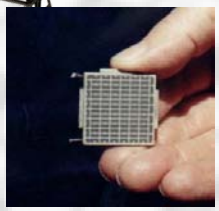
Computational Materials Science



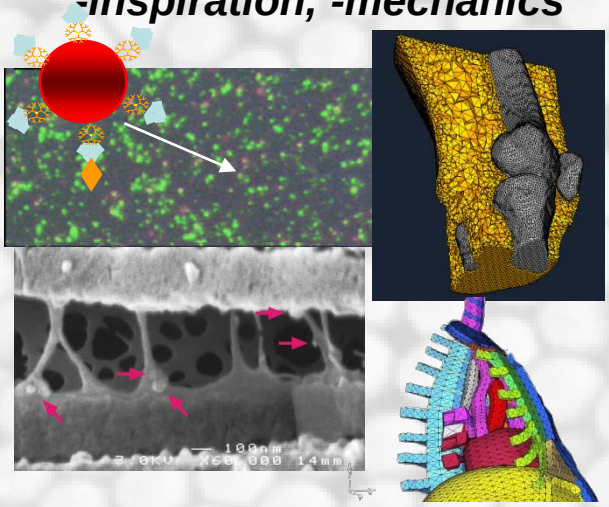
Miniaturization and Multifunctionality



structural fuel tank



Bio: -materials, -mimetic, -inspiration, -mechanics



Increasing sophistication of processing and characterization techniques

Materials Technologies - Critical enablers for lightening the force

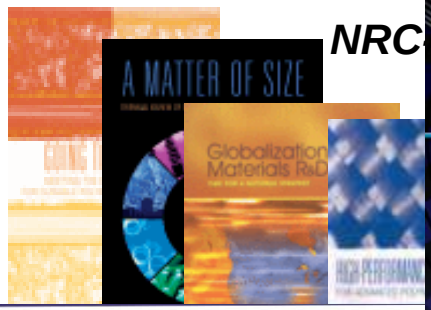
What is the Direction of Materials Research?

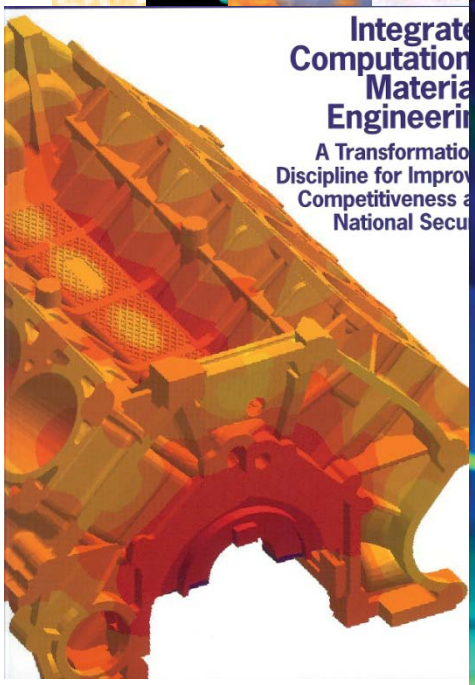
Numerous studies and groups work this question

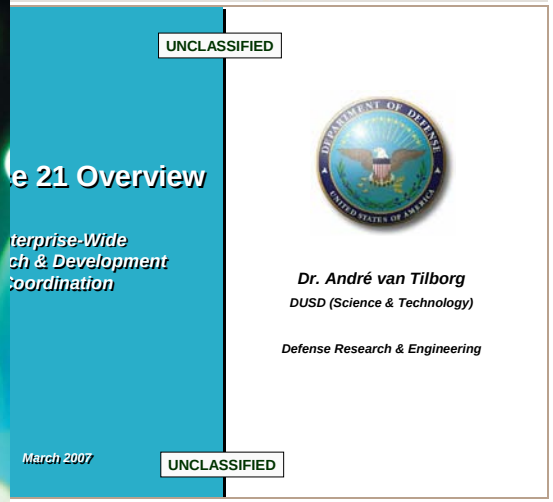
Broader Communit

NRC

Army and DoD







Research and Tec materials research community enables the Army to track and directly influence trends

Workshop

MAJOR GAPS IN THE CURRENT STATE OF THE ART

1) A limited ability to relate materials chemistry, structure, and defects to materials response and failure under extreme conditions

2) An inadequate ability to predict the roles of materials structure, processing, and properties on performance in relevant extreme environments and designs

3) The lack of experimental capabilities to quantify multiscale response and failure of materials under extreme conditions

Workshop - Recommendations

PRINCIPLE WORKSHOP RECOMMENDATIONS

1) The ability to perform quantitative concurrent spatial and temporal modeling and characterization of materials across multiple scales would revolutionize material design

2) The Army should challenge the community to develop fully predictive multiscale materials-by-design approaches for high loading rate applications

3) Successful materials-by-design approaches will require quantitative methods (i.e., figures of merit) to link material performance in systems to material properties, microstructure, and processing

4) A systems approach to fundamental research that links, coordinates, and leverages the many excellent research projects towards materials-by-design concepts and capabilities will make all efforts more effective

MEDE CRA Objective

MATERIALS IN EXTREME DYNAMIC ENVIRONMENTS

The U.S. Army wants to develop the capability to design, create, synthesize, process and manufacture high strain rate tolerant material and material systems to enhance the performance, lethality and survivability of soldier and ground combat systems.

- Execute a focused basic research program to realize a materials by design capability

- Drive forward and expand the fundamental understanding in the area of multi-scale/multidisciplinary materials behavior to directly improve the performance of materials in ultra-high loading rate environments

- Develop this capability for the following material classes and systems: metals, ceramics, polymers, composites and hybrids such as metal matrix composites, ceramic matrix composites and hybrids

- Create a framework that enhances and fosters cross disciplinary and cross organizational collaboration that brings a team of academia, industry and government together to address critical focused research in Materials in Extreme Dynamic Environments

MEDE CRA Core Elements

- **Modeling and Simulation:** Validated multiscale modeling of materials in extreme dynamic environments to design materials and predict performance by exploiting the hierarchy of scales in a multidisciplinary environment

- **Bridging the Scales: Analysis, Theory and Algorithms:** Validated theoretical and analytical analyses to effectively define the interface physics across length scales and disciplines

- **Advanced Experimental Techniques:** Comprehensive validated experimental capabilities bridging time and space for probing the physics and mechanisms of materials subjected to extreme dynamic environments and for validation of multiscale/multidisciplinary physics modeling

- **Multiscale Material Properties:** A comprehensive set of multiscale/multidisciplinary material characteristics and property metrics that characterize high loading rate tolerant material systems and enable their processing and manufacture

- **Processing and Synthesis:** Validated modeling and techniques for the synthesis and processing of high loading rate tolerant materials

MEDE CRA Strategy

Approach

Cohesive multidisciplinary collaborative research linking the role of materials across length & time scales to specific performance metrics by validated modeling, dynamic characterization and processing

Dynamically Tolerant Materials for U.S. Army Systems

Multiscale/Multi-Disciplinary Materials Design Loop

Ultra Light Weight Dynamically Tolerant Materials

Modeling &Simulation (1)

Verification, Validation and Prediction across multiple scales

Bridging the Scales (2) Analysis, Theory and Algorithms

Theoretical and analytical analysis to define the interface physics across scales

Synthesis and Processing (5)

Novel techniques to achieve damage tolerant materials with controlled structure / properties

Multiscale Material properties (4)

New and novel metrics to define characteristics and properties

Advanced Experimental Techniques (3)

Quantitative material and response characterization concurrently in space and time at high strain rates

MEDE CRA Program Announcement (PA)

- Formulate a program to demonstrate the ability to achieve the research and programmatic goals of the CRA as outlined in the PA

- Define and outline the strategy for executing the materials by design loop and identify how the program will achieve the specific research goals in the five core elements and how they will be integrated and interfaced within the materials by design loop (design loop Figure 2 page 12 of PA)

- Address the following material systems: metals, ceramics, polymers, composites and hybrids such as metal matrix composites, ceramic matrix composites and hybrids

- Define the metrics by which success is expected to be measured

- Identify the strategy, plans and methods for collaboration essential to the success of the CRA

- Identify the optimal scientific, technical, programmatic and administrative team (expected to be comprised by a number of members) with the expertise to achieve the stated research goals and to oversee and manage finances, reporting, data, meetings, reviews and intellectual property

MEDE CRA Collaboration

Collaboration to Achieve the CRA Research Goals

- ARL Enterprise for Multiscale Materials
- ARL WMRD Mission Program
- Internal to the CRA

Staff Rotation

Lectures, Workshops, and Research Reviews

Education

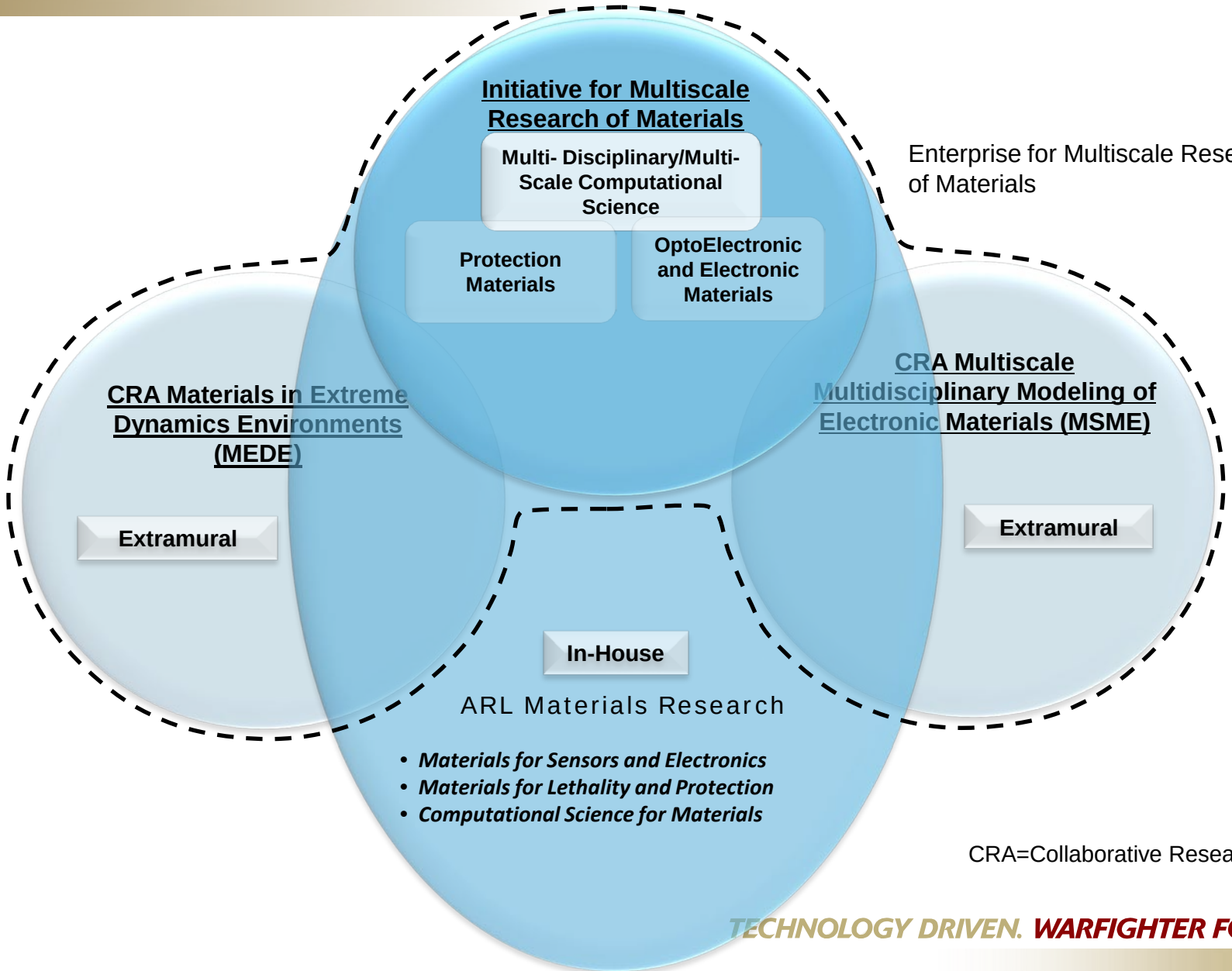
- Opportunities for Government Personnel
- Student Engagement with ARL Research Environment

Industry Partnership + Collaboration

Other Collaboration Opportunities

- High Performance Computing DoD Supercomputing Resource Center (HPC-DSRC)
- HPC (High Performance Computing) Software and Application
- Institute (HSAI) for Multi-Scale Reactive Modeling and Simulation of Insensitive Munitions (MSRMS-IM).
- Other Government Agencies (OGA's)

MEDE CRA Collaboration



Enterprise for Multiscale Research of Materials

CRA=Collaborative Research Alliance

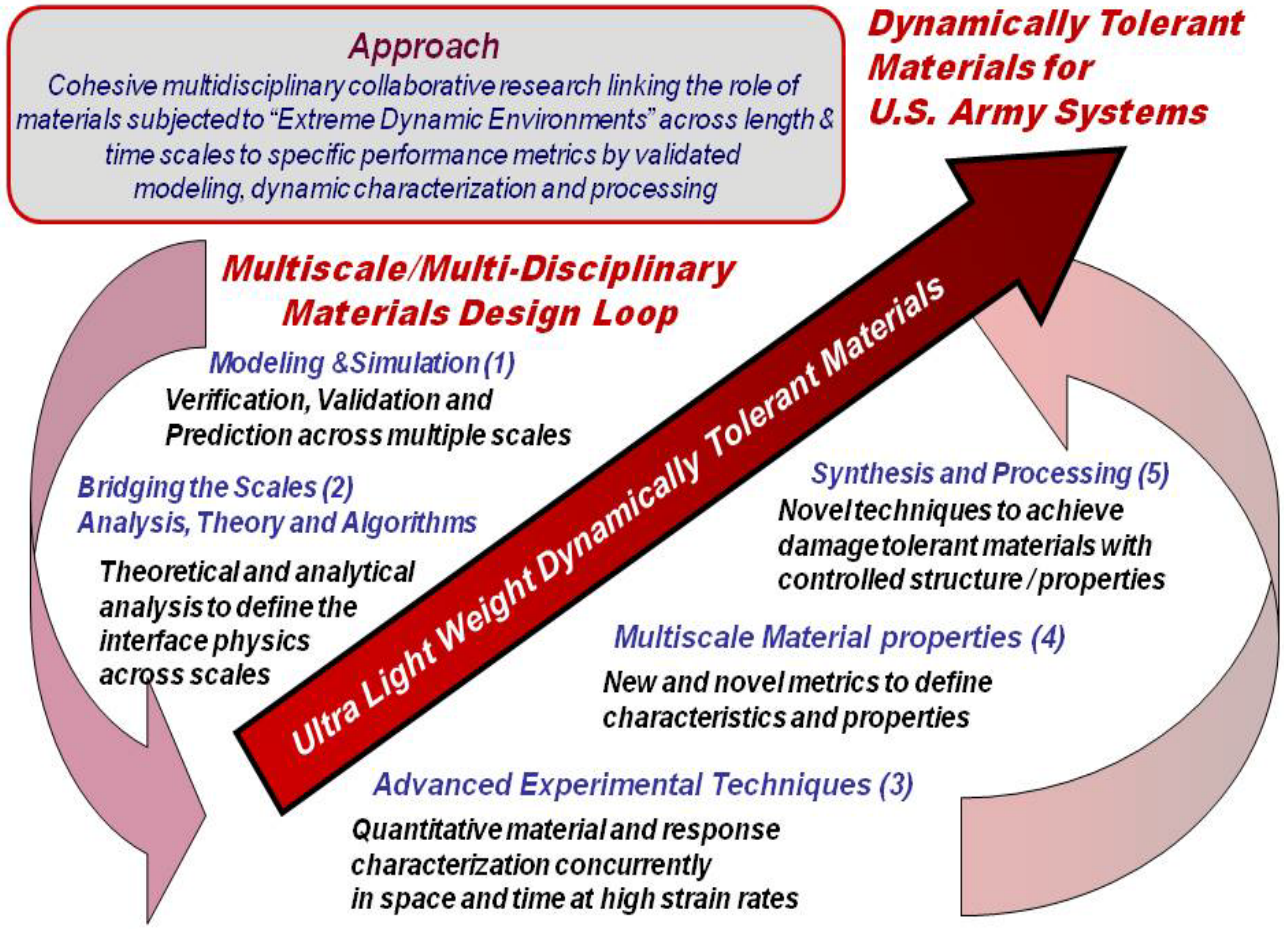
Collaboration

The collaboration strategy for executing the materials by design loop

The integration of the five core elements into the loop
(Are all the core elements constructively working to the strategic goal?)

The strategy for collaboration within a core element

The techniques and metrics proposed to verify the loop strategy is working



MEDE CRA Funding

CRA Basic Research Program

- Basic Program funded for 5 Years with a 5 Year Option
- Start Second Quarter FY12
- Budget includes research costs, costs to manage the program, costs to collaborate and enable research transition
- Funding outlined in the PA are for planning purposes only
- Final funding is subject to Program Objective Memorandum Approval

CRA Enhanced Basic and Applied Research Program

- As the CRA proceeds it is anticipated that other Government agencies will be able to provide funding for specific research of interest
- This is currently unfunded

Total Funded 5 Year Core Program $33.1M /Total Funded 10 Year Core Program $73.1M

Upcoming Events

WMRD Mission Program and Capabilities

Poster Session - Today

ATRIUM from 12:00 to 2:00 PM
Dr. Patrick Baker
Mr. Bob Dowding

WMRD MEDE Open House

Sign up in the Atrium

Wednesday December 16th 2010
7:30 Arrival
8:30 WMRD Research Program
Tours of the relevant major facilities in the Rodman Materials Research Laboratory
Aberdeen Proving Ground, MD 21005

MEDE CRA Goals

Create a framework that enhances and fosters cross disciplinary and cross organizational collaboration that brings a team of academia, industry and government together to address, integrate and transition critical focused research in Cross-Disciplinary/Multi-scale Modeling of High Stress/Strain Rate Tolerant Materials

2 Year Goal

Advance fundamental understanding and discovery in materials science by multi-scale and cross disciplinary basic research that enables modeling and simulation capability that is validated experimentally in time and space resulting in the foundation for the design of high stress/strain rate tolerant metals, ceramics, fibers, polymers and composites that are uniquely characterized, synthesized and processed.

5 Year Goal

Integrate new multidisciplinary /multi-scale physics to enable multi-scale modeling and simulation capability that is validated experimentally in time and space to apriori design new high stress/strain rate tolerant metals, ceramics, polymers and composites that are uniquely characterized, synthesized and processed.

10 Year Goal

Deploy cross disciplinary multi- scale modeling and simulation, validation, characterization and synthesis capability to ARL, the ARL Enterprise and the Army to apriori predict dynamic material properties, design and optimize new ultra light weight dynamically tolerant material solutions enabling ground, soldier and air combat systems at 1/3 the weight.

Why We're Here!

Soldiers from Company A, Special Troops Battalion, 101st Airborne Division, air assault into a village inside the Jowlzak valley in the Parwan province of Afghanistan. Afghan National Police searched the village while Soldiers provided security and conducted key-leader engagements. Posted on AKO. (Photo by Spc. Scott Davis)