U.S. ARMY RDECOM

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Dr. Philip Perconti

Materials Research Campaign

3 November 2015

Materials Research Campaign

Materials Research cross-cuts ARL's four focused S&T campaigns. Materials are ubiquitous and underpinning for enhancing existing capabilities, developing new capabilities, and mitigating emerging threats.

Example Army Needs*:

- Operate in contested, congested, and competitive environments
- Unburden the Soldier
- Expeditionary Maneuver
- Lighter, more effective protection
- Improved Lethality and Effects

*"The U.S. Army Operating Concept: Win in a Complex World," *TRADOC Pamphlet 525-3-1*, 07 October 2014

Example Technology Gaps:

- Lightweight Materials
- "On Demand" and "Materials-by-Design"
- Disruptive Energetics
- Adaptable and Reconfigurable RF electronics
- Ultra-low power, flexible electronics & communications
- High energy dense Soldier Power

Revolutionary Materials for Army Capabilities Beyond 2030

Materials Research Taxonomy

Materials Research – Fundamental research for scientific discovery and innovation to provide superior materials and devices needed for lasting strategic land power dominance.

Photonics
- Imaging Sensors & Optics
- Chemical Specific Sensing
- Sensor Protection
- UV Optoelectronic
- High Energy & Tactical Laser
- Quantum Information Science

Electronics
- Nano & 2D
- MEMS
- Flexible & Conformable
- Energy Efficient
- RF Active & Passive

Manufacturing Science
- Advanced & Additive Manufacturing
- Polymer Coatings
- Corrosion & Fatigue
- Energy Coupled-to-Matter

Biological and Bio-inspired
- Materials from Biology
- Technology from Biological Systems
- Characterization and Sensors

Structural
- Advanced Platform
- Integrated Structural & Energy

High Strain Rate & Ballistics
- Lightweight & Specialty Metals
- Ceramics & Transparent
- Fabrics & Wearables
- Energy Absorbing
- Composites & Hybrid
- Penetrator & Warhead
- Advanced Mechanics of Materials

Energy & Power
- Energy Storage
- Power Generation & Energy Harvesting
- Fuel Cell
- Thermal Science

Materials Research Campaign

Key Campaign Initiatives:

- *Energy Coupled to Matter for Responsive Materials* – materials modified by application of high-energy fields
- *Lightweight Materials for Army Platforms* – hybridized ceramics, composites, holistic system weight reduction
- *Materials for Soldier and Platform Power Systems* – tactical energy independence
- *Agile Expedient Manufacturing* – materials on demand and by design
- *Energy Efficient Electronics and Photonics* – lead-based topological materials, wideband gap materials, active heterogeneous interfaces, 2D materials
- *Quantum Sciences* – multi-site, multi-node, distributed quantum information using modular quantum networks, communications, and sensing

Core Campaign Enablers:

- *Multiscale Research of Materials* – modeling and experimentation to bridge the scales
- *Living Material Interfaces* – microbial consortia, bacterial-metal binding, materials precursor generation

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Materials Research Campaign
Energy Coupled to Matter for Responsive Materials

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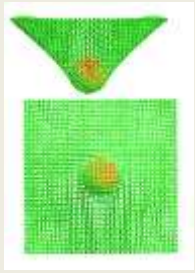
Energy Field

Catch

Launch



NEW MATERIAL

Maintain Overmatch……. Austere Entry and Maneuver …….Unburden the Soldier

CURRENT RESEARCH

- Coherent Grain Alignment
- Field Susceptibility
- Active Phase Transformation

FUTURE TECHNOLOGY

Responsive Mobility Actuation
Structural & Flexible Power
Active Membranes
Smart Protection Materials
Smart Lethality Materials

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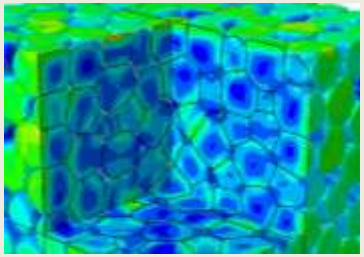
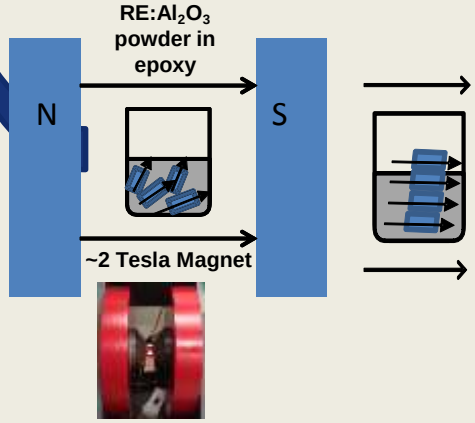
Textured Densification

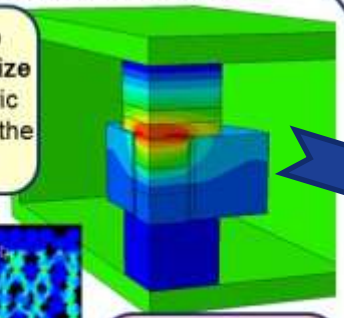


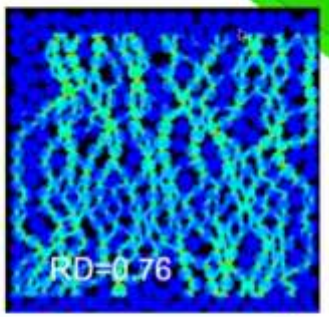
Functional Alignment



Electric Field Assisted Sintering

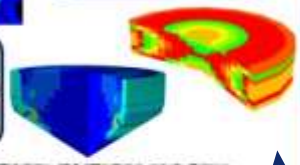
Numerical analysis to **understand and optimize** complex thermal-electric field distributions within the system and compact

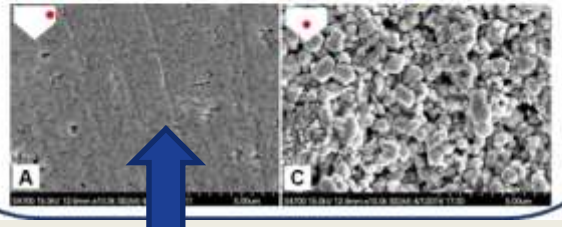




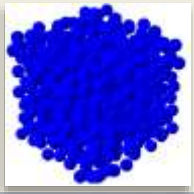
Micromechanical modeling of conductivity evolution during sintering

Non-uniform current & temp distribution; predict net-shape compact densification





Responsive Pulverization



Physical Property (Magnetic, Thermal, Electrical) Measurement System

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Materials Research Campaign
Lightweight Materials for Army Platforms

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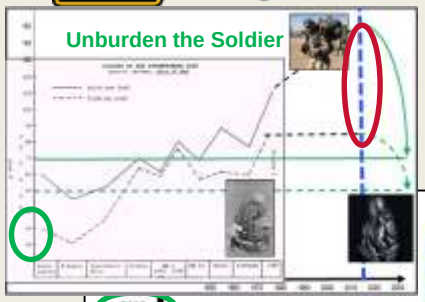
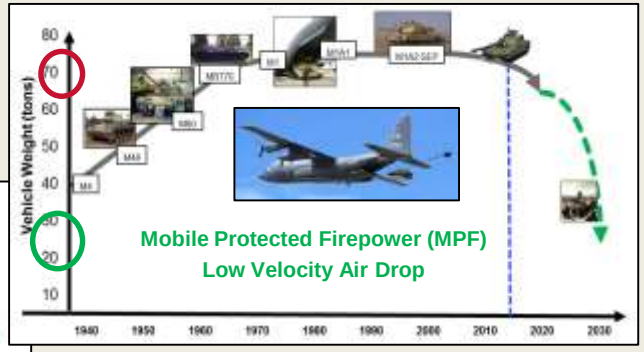
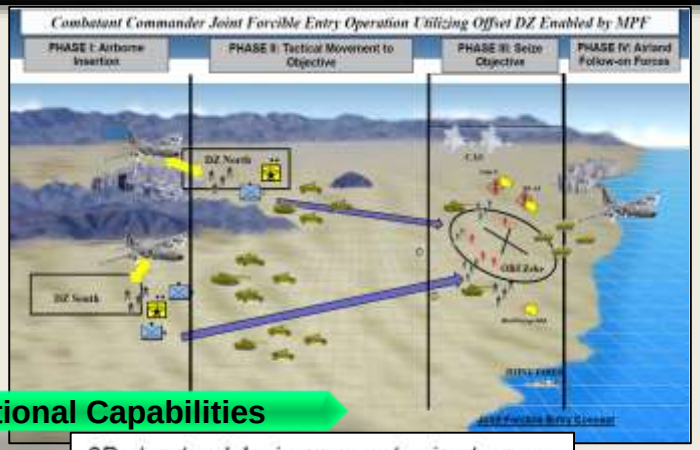
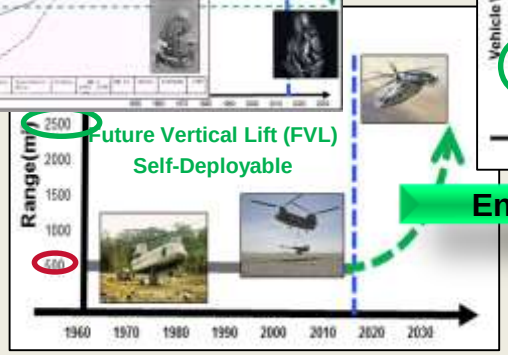


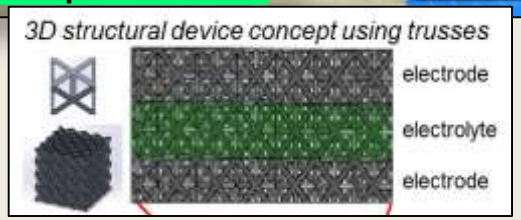


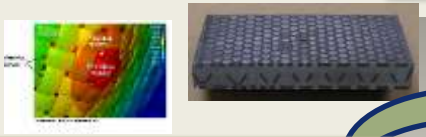


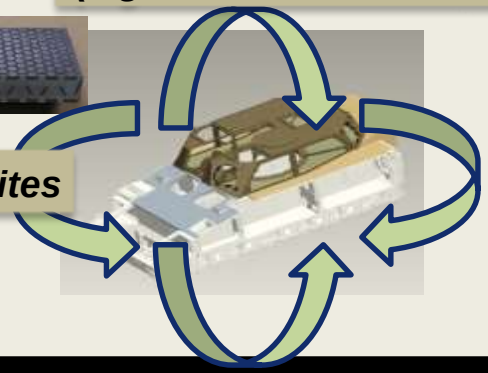


Enabling Requirements- for- Future Operational Capabilities

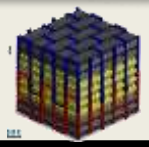
Multi-functional Materials (e.g. Structural Batteries)





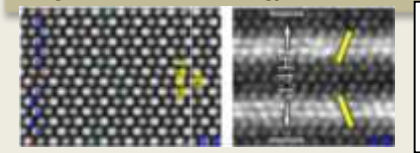


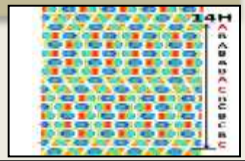
Efficient Lightweight Hybrid Composites



Ultra-strong Magnesium Alloys

(e.g. Long Periodic Stacking Order via Equal-Channel Angular Work Hardening)





Aviation…….Mobile Protected Firepower…….Unburden the Soldier

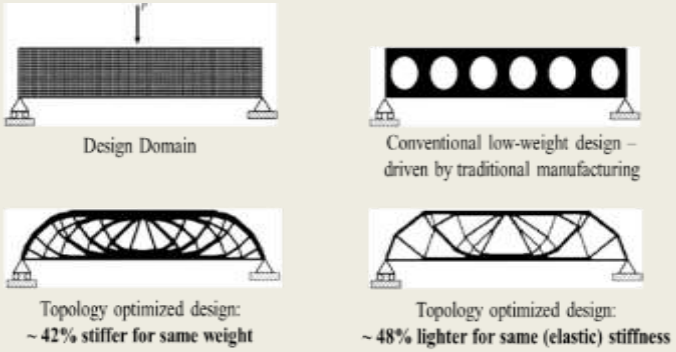
CURRENT RESEARCH

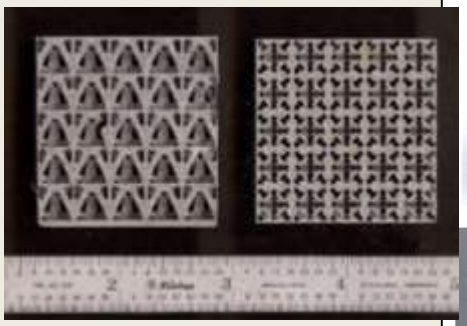
- Multi-Functional (Structural +) Materials
- Hybrid Composites
- Structural Magnesium
- Boron Based Structural Armor Ceramics

FUTURE TECHNOLOGY

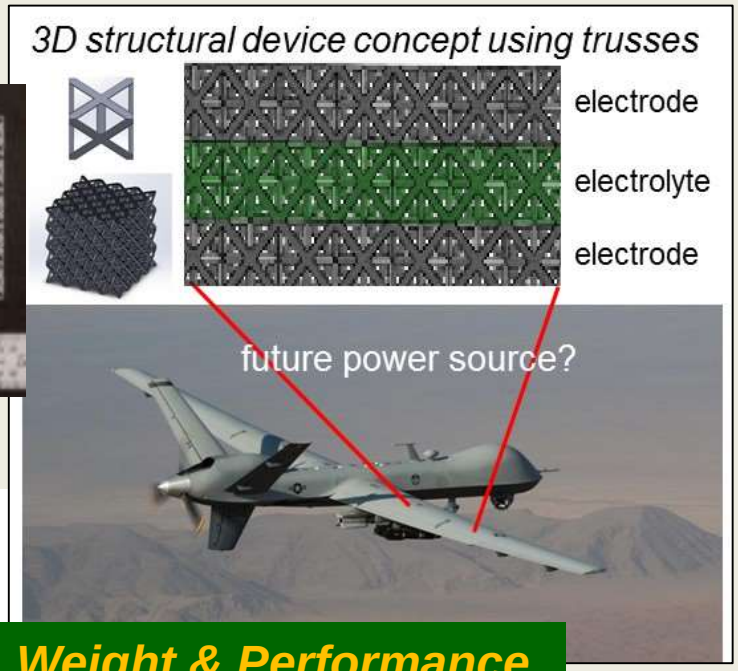
Holistic Design Approach Enabling >50% Structural Weight Reduction

Materials Research Campaign
Lightweight Materials for Army Platforms

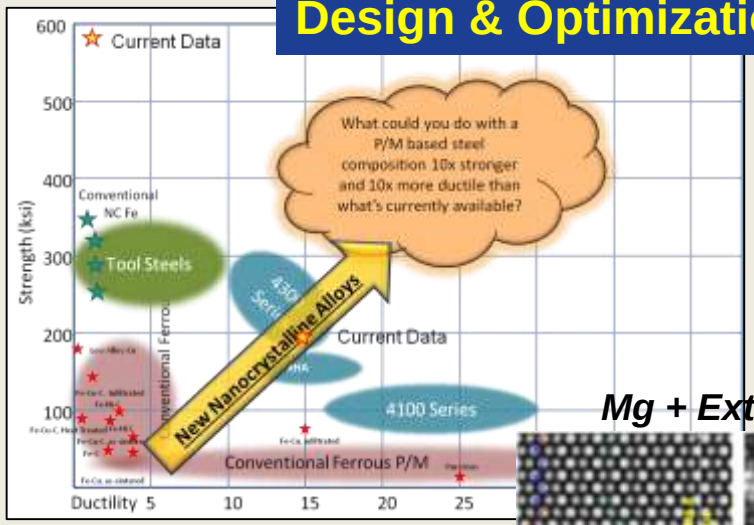




Fabrication



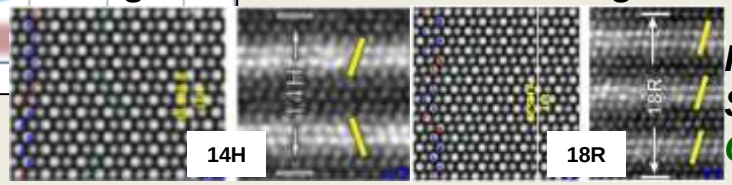
Design & Optimization



Weight & Performance Optimization

e.g. CRADA on TBI

Mg + Extreme Work Hardening



Increase Fault Area= More Slips= More Ductility + Greater Strength

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Agile Expedient Manufacturing

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Battle for AFFORDABILITY w/ Agility; Flexibility & Readiness

New Materials by Design

Factory of the Future

Model Based Enterprise

Materiel on Demand

Rapid delivery back to the field

Adaptive Materials On-Demand & By-Design for an Expeditionary Force

Affordability…….Logistic Optimization…….Logistic Demand

Indigenous Resourcing *3D Flexible Electronics* *3D Additive Manufacturing* *3D Sensors*

Accelerated Certification *Low Cost Near-Net-Shape* *Alternative Water & Fuel*

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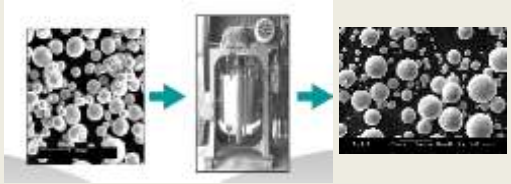
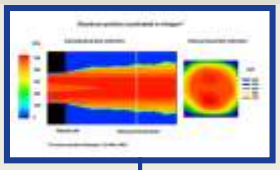
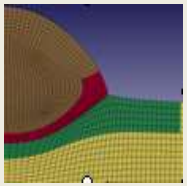
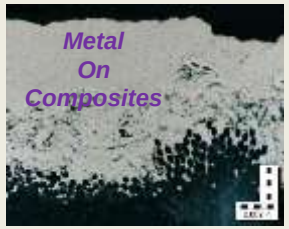


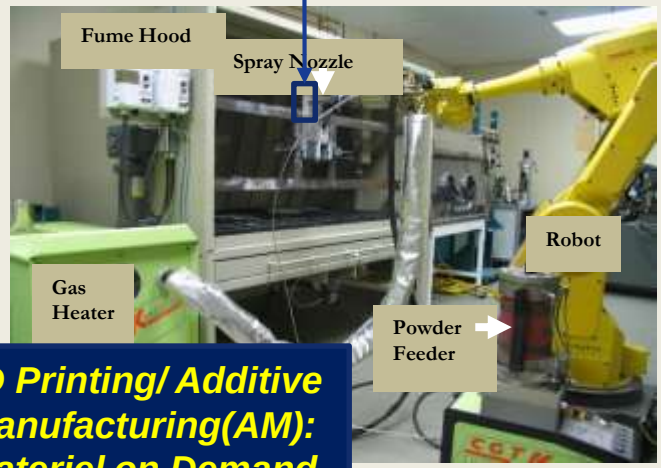
Synthesis Science: Precursors
(e.g. Polymer, Metal,, Ceramic Nano-morphologically designed)



Manufacturing Science: Processing-Microstructure Design
(e.g. Non-equilibrium Solidification; Hydrodynamic Phase Stabilization; Thermomechanical Hardening)







3D Printing/ Additive Manufacturing(AM): Materiel on Demand

Standards: Expedient

Microstructure - Performance (e.g. Probabilistic – based) Prediction

Solution: By-Design

The Unknown Challenge

e.g. CRADA on AM

3DSYSTEMS

The Nation's Premier Laboratory for Land Forces

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Core Campaign Enabler
Multiscale Research of Materials

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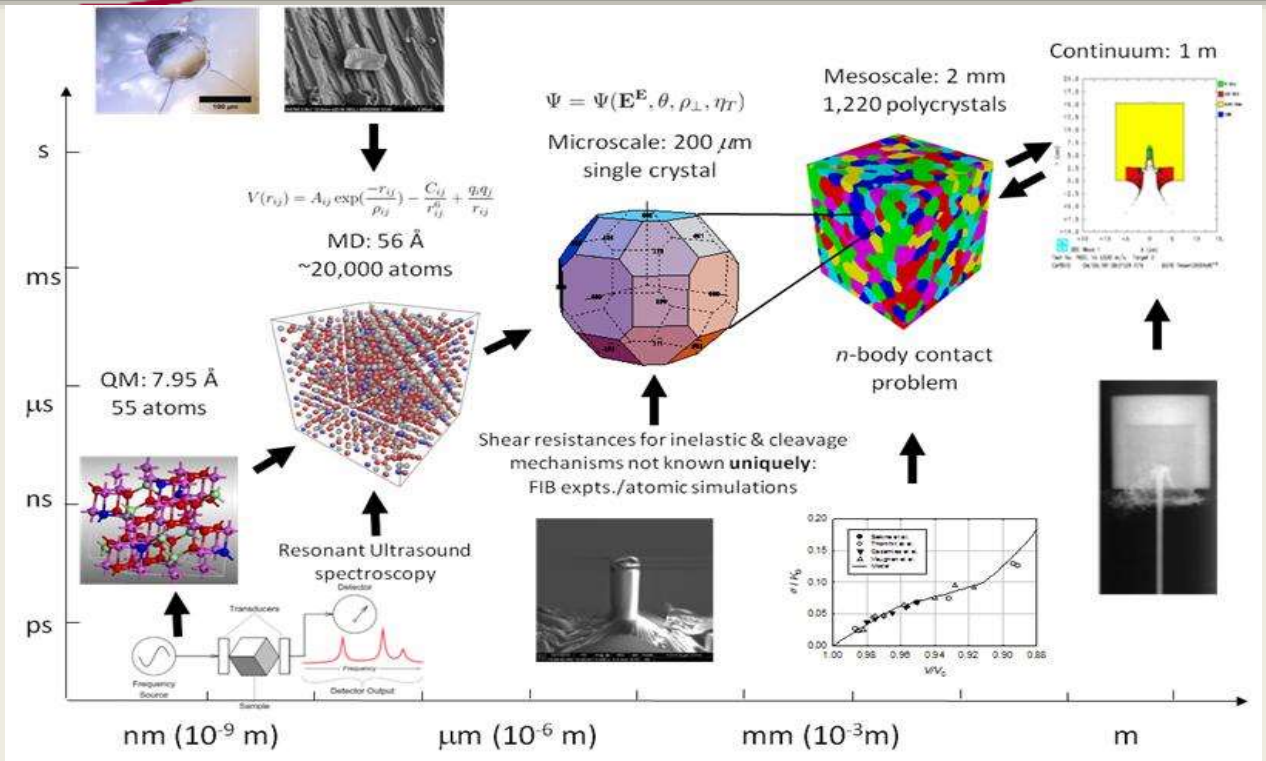
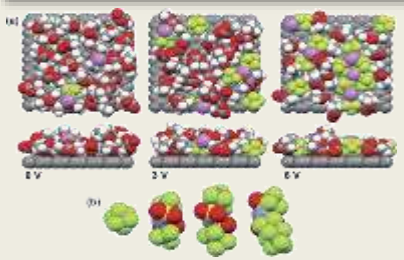
Time Scale

Length Scale

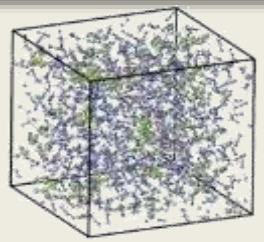


Electrochemistry

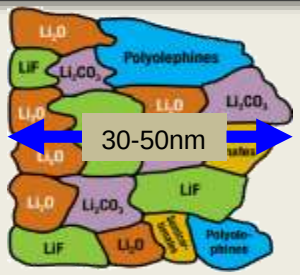
electronic	molecular	mesoscale	continuum



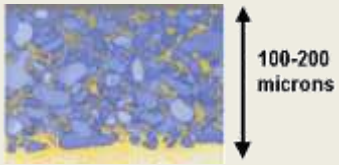
Model potentials & reactions



Simulate bulk electrolyte and SEI component transport



Model Solid Electrolyte Interphase (SEI) formation & properties



Electrochemical Continuum Modeling: transport in composite electrodes and electrochemical cells

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Core Campaign Enabler
Living Material Interfaces

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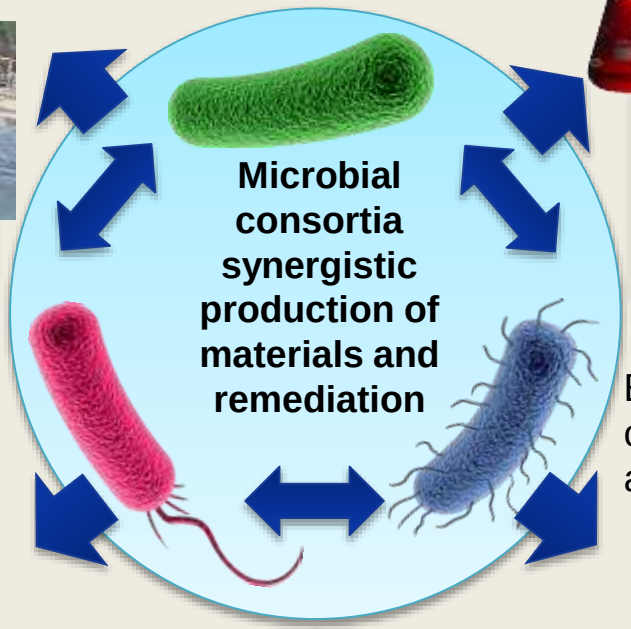
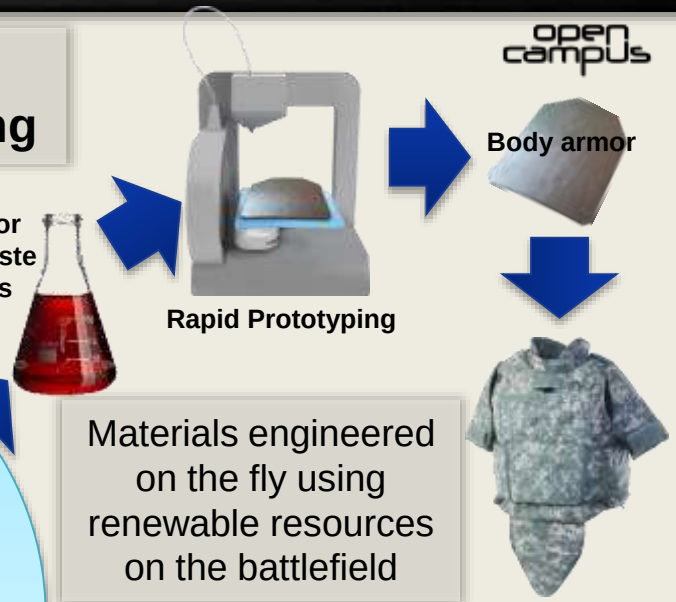
Waste to Energy/Biofuel Synthesis

Microbial Enabled Expeditionary Processing

Water Purification & Recycling



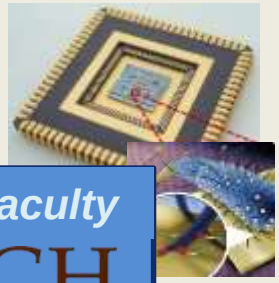


Materials engineered on the fly using renewable resources on the battlefield

Biohybrid Materials

Evolving today's re-healable materials concepts to enable self-assembling and healing electronics in 2040

Self-assembling and healing electronics



Probiotic enhanced food for Soldier Productivity

Decreased down time due to gut ailments

Bacterial Healing of Concrete

Cement and Concrete Composites, **33(7)**, 763-770 (2011)

FY15 visiting Faculty

LEHIGH UNIVERSITY

Materials Research Facilities

Rodman Materials Research Lab, APG

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

Zahl Physical Sciences Lab, ALC

- Nanobiotechnologies
- Flexible electronics
- Advanced specialty electronics material growth
- Nonlinear material research & characterization
- Power electronics

Aberdeen Proving Ground, MD

Expeditionary Manufacturing Science Center

Adelphi Laboratory Center, MD

Expeditionary Manufacturing Science Center

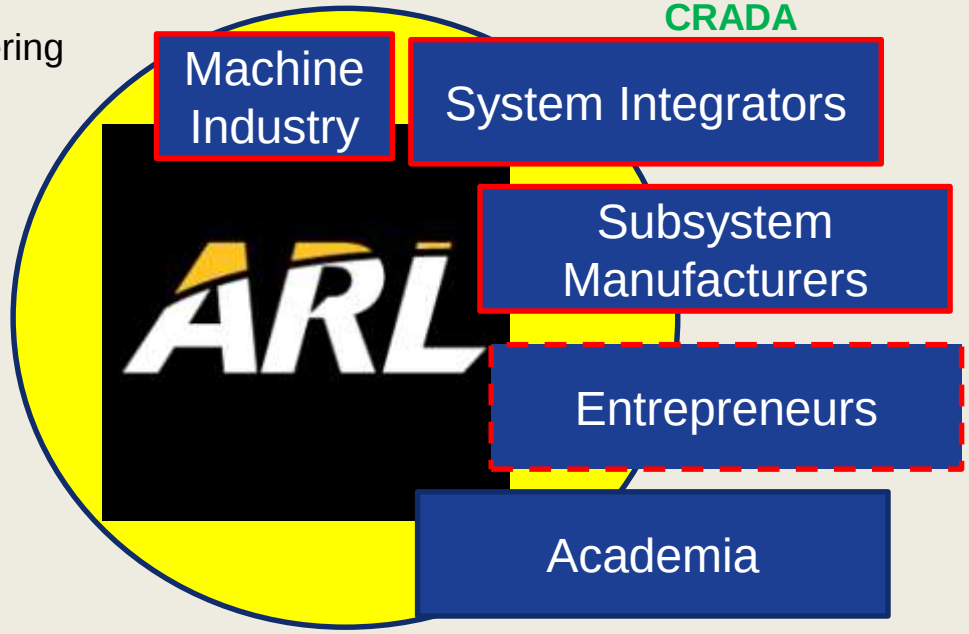
2017

New building sites in office park for consortium facility

Capabilities (partial):

- Selective Laser Sintering
- System Direct Metal Laser Sintering
- Hybrid AM system
- Stereo Lithography
- Multi-Jet Printer
- Wire Arc Additive Manufacturing
- Polymer powder production
- Measuring Metrology System
- Powder rheometer/flow
- Powder degassing system
- X-ray CT systems (+ other Characterization Capabilities)

Consortium Partnership CRADA + Individual CRADA



Questions?