# Materials & Manufacturing Processes:
## *Technologies that Ensure Capability*

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*Chair, M&MP COI*

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# M&MP COI Portfolio Description

## *Purpose*

Materials and Manufacturing Processes: The purpose of the Materials and Manufacturing Processes COI is to provide National leadership in developing technology-based options for advanced materials and processes for the Department of Defense. The COI delivers technology products as well as the scientific and engineering expertise needed to maintain and enhance U.S. Defense capability.

## *Materials and Manufacturing Processes* is a Technology Focused COI and is inherently broad.

Activities are part of every DoD laboratory and impact every system and platform, and span full technology and manufacturing readiness spectrums.

## *Materials and Manufacturing Processes COI* is a uniquely long-standing community of DoD scientists and engineers operating in an effective framework

- Assess the technical health of DoD Materials & Manufacturing Processes investment areas
- Identify emerging technology opportunities, trends and associated risks
- Engage in multi-agency coordination and collaboration
- Optimize results of engagements with industry and international partners
- Strategize and measure progress

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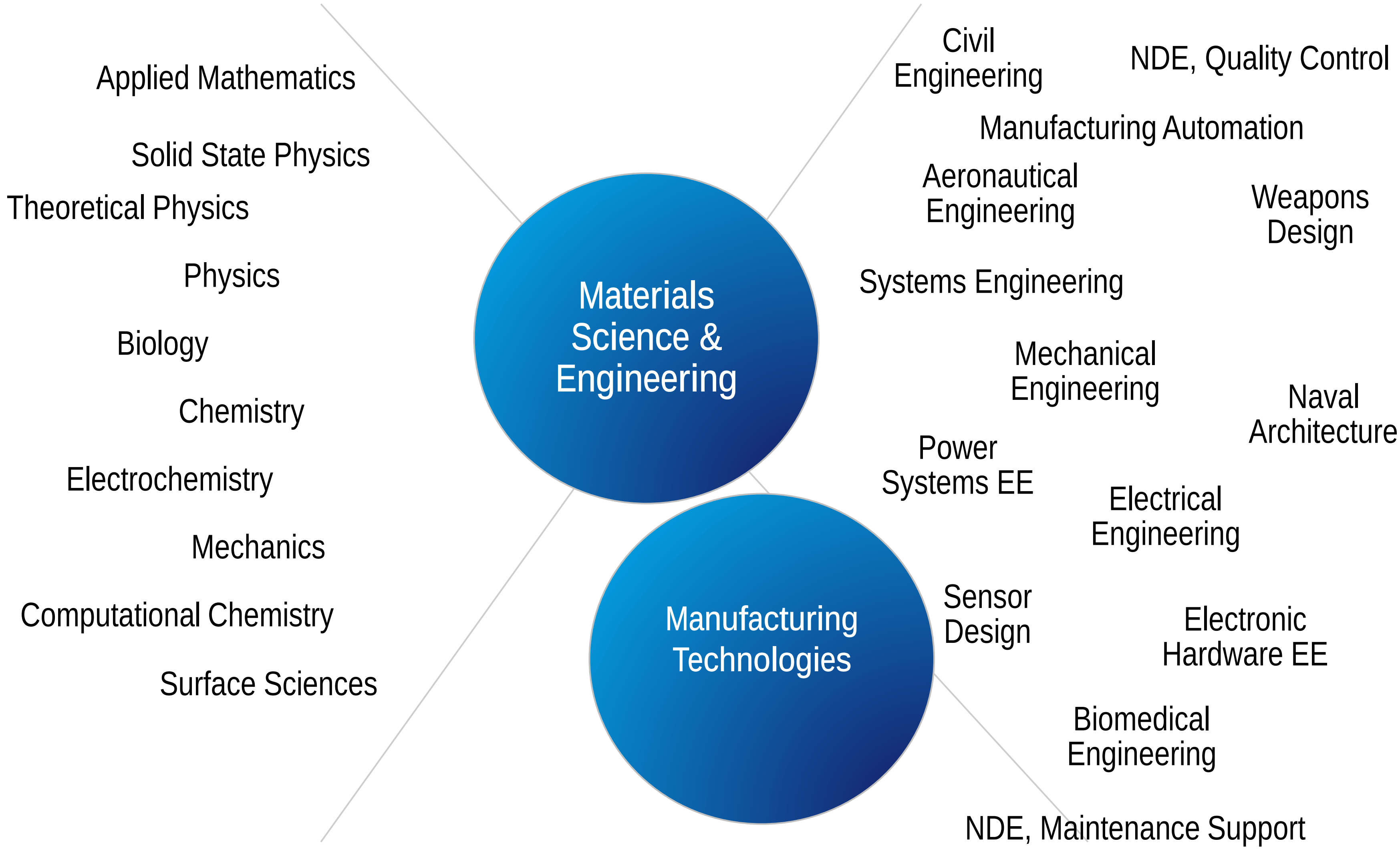
# Materials S&E & Manufacturing
## *in the context of S&E*



# M&MP COI
## *in the context of Reliance COIs*

Materials & Manufacturing Processes

Civil Engineering

NDE, Quality Control

Manufacturing Automation

Aeronautical Engineering

Weapons Design

Systems Engineering

Mechanical Engineering

Naval Architecture

Power Systems EE

Electrical Engineering

Sensor Design

Electronic Hardware EE

Biomedical Engineering

NDE, Maintenance Support

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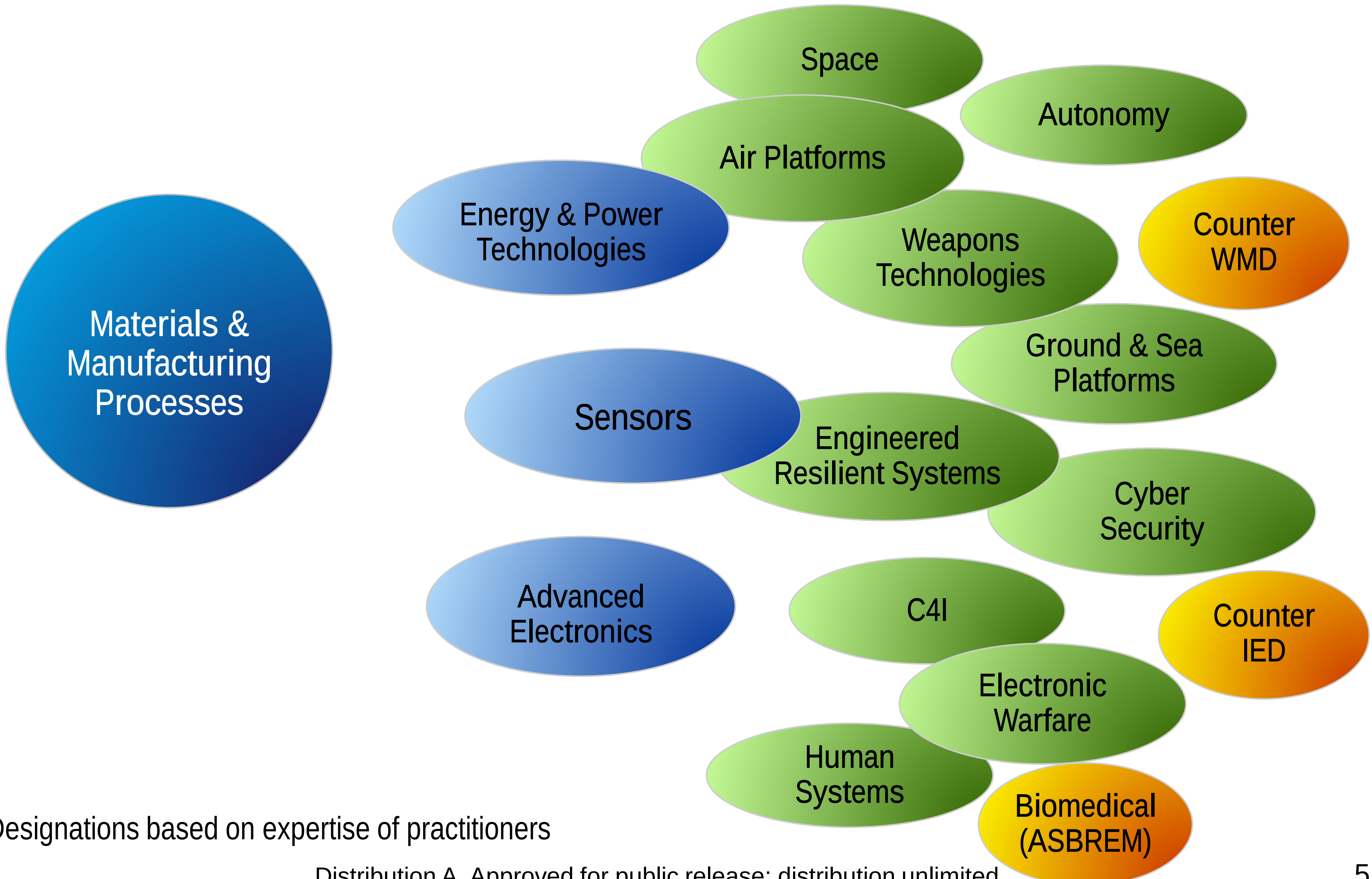
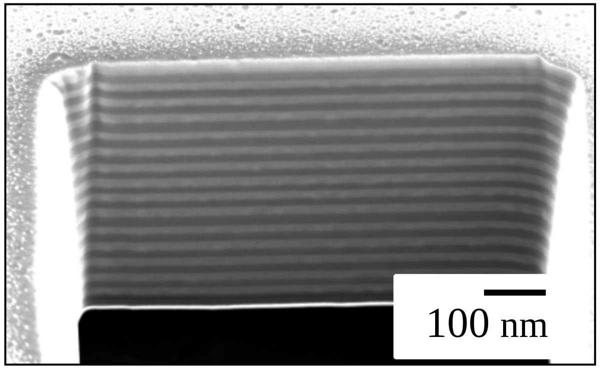
# M&MP COI
## *in the context of Reliance COIs*



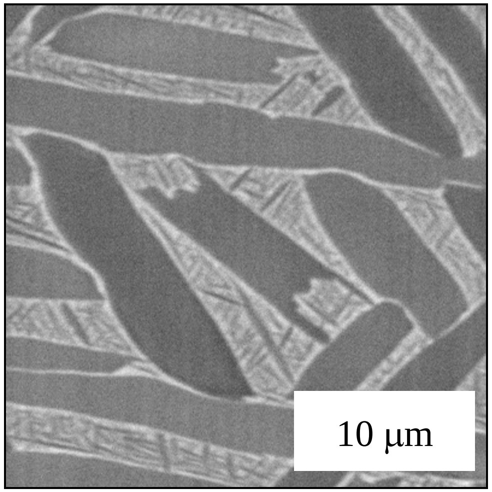

Designations based on expertise of practitioners

# Microstructure

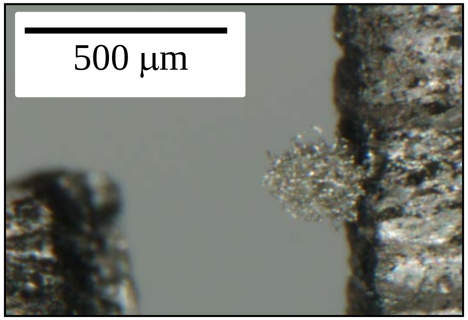
*The Center of the Universe*




*32 layer PC/PVDF-HFP film*




*Ti $\alpha$–$\beta$ microstructure*




*lithium dendrite*

*. . . for some*

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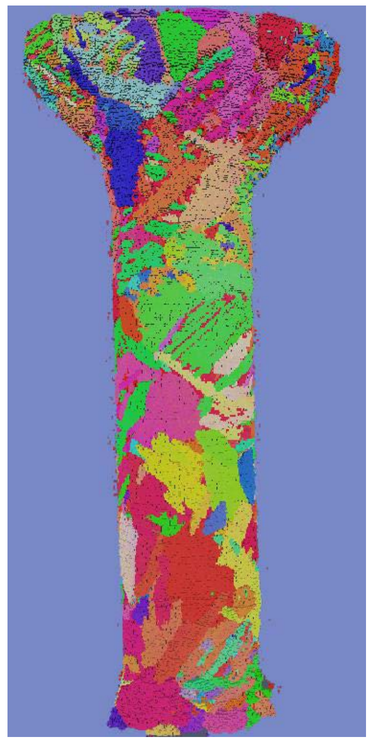
# Mechanical Properties

*Common Engineering Concepts?*

Reality?

EBSD image



MIL-HBK-5H

**Table 5.4.1.0(b). Design Mechanical and Physical Properties of Ti-6Al-4V Sheet, Strip, and Plate**

| Specification | AMS 4911 and MIL-T-9046, Comp. AB-1 | | | | | MIL-T-9046, Comp. AB-1 | | | |
|---|---|---|---|---|---|---|---|---|---|
| Form | Sheet | | Plate | | | Sheet, strip, and plate | | | |
| Condition | Annealed | | | | | Solution treated and aged | | | |
| Thickness, in. | ≤ 0.1875 | | 0.1875-2.000 | | 2.001-4.000 | ≤ 0.1875 | 0.1875-0.750 | 0.751-1.000 | 1.001-2.000 |
| Basis | A | B | A | B | S | S | S | S | S |
| Mechanical Properties: | | | | | | | | | |
| $F_{tu}$, ksi: | | | | | | | | | |
| L | 134 | 139 | 130[a] | 135 | 130 | 160 | 160 | 150 | 145 |
| LT | 134 | 139 | 130[a] | 138 | 130 | 160 | 160 | 150 | 145 |
| $F_{ty}$, ksi: | | | | | | | | | |
| L | 126 | 131 | 120 | 125 | 120 | 145 | 145 | 140 | 135 |
| LT | 126 | 131 | 120[a] | 131 | 120 | 145 | 145 | 140 | 135 |
| $F_{cy}$, ksi: | | | | | | | | | |
| L | 133 | 138 | 124 | 129 | 124 | 154 | 150 | 145 | ... |
| LT | 135 | 141 | 130 | 142 | 130 | 162 | ... | ... | ... |
| $F_{su}$, ksi | 87 | 90 | 79 | 84 | 79 | 100 | 93 | 87 | ... |
| $F_{bru}$, ksi: | | | | | | | | | |
| (e/D = 1.5) | 213[b] | 221[b] | 206[b] | 214[b] | 206[b] | 236 | 248 | 233 | ... |
| (e/D = 2.0) | 272[b] | 283[b] | 260[b] | 276[b] | 260[b] | 286 | 308 | 289 | ... |
| $F_{bry}$, ksi: | | | | | | | | | |
| (e/D = 1.5) | 171[b] | 178[b] | 164[b] | 179[b] | 164[b] | 210 | 210 | 203 | ... |
| (e/D = 2.0) | 208[b] | 217[b] | 194[b] | 212[b] | 194[b] | 232 | 243 | 235 | ... |
| $e$, percent (S-basis): | | | | | | | | | |
| L | 8[c] | ... | 10 | ... | 10 | 5[d] | 8 | 6 | 6 |
| LT | 8[c] | ... | 10 | ... | 10 | 5[d] | 8 | 6 | 6 |
| $E$, $10^3$ ksi | 16.0 | | | | | | | | |
| $E_c$, $10^3$ ksi | 16.4 | | | | | | | | |
| $G$, $10^3$ ksi | 6.2 | | | | | | | | |
| $\mu$ | 0.31 | | | | | | | | |
| Physical Properties: | | | | | | | | | |
| $\omega$, lb/in.$^3$ | 0.160 | | | | | | | | |
| $C$, $K$, and $\alpha$ | See Figure 4.5.1.0 | | | | | | | | |

a The rounded $T_{99}$ values are higher than specification values as follows: $F_{tu}$(L) = 131 ksi, $F_{tu}$(LT) = 132 ksi, and $F_{ty}$(LT) = 123 ksi.

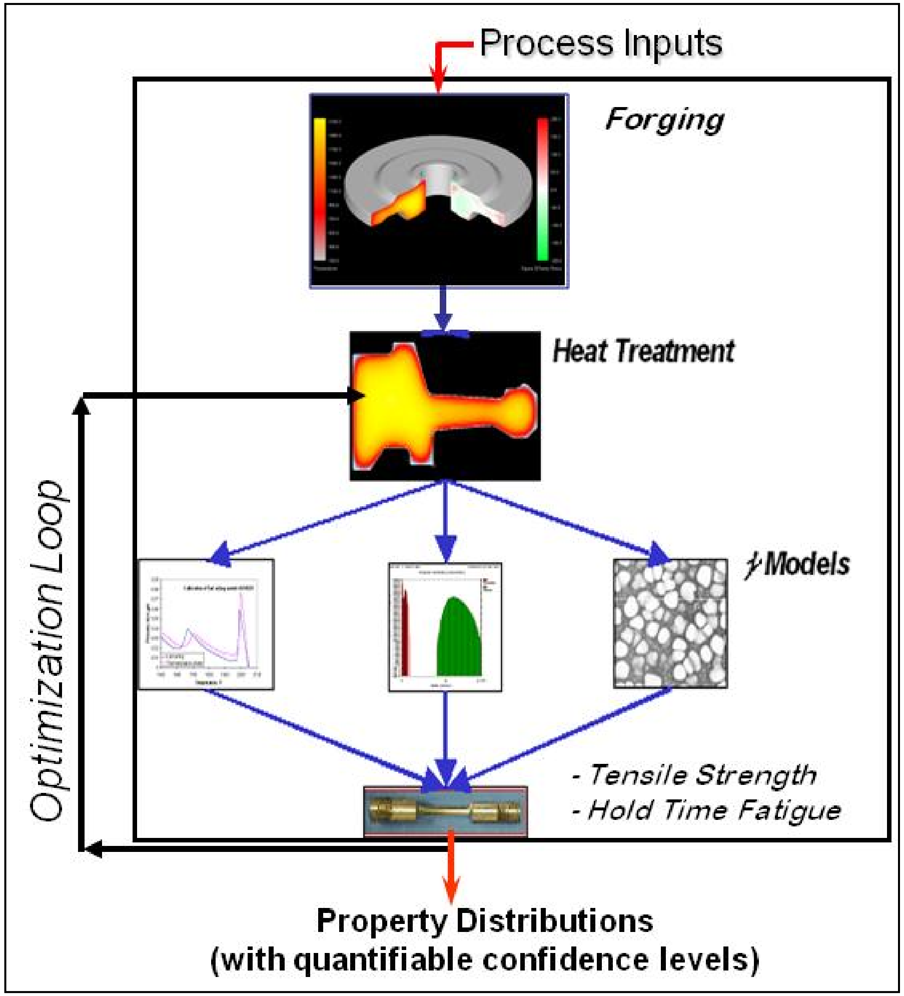
b Bearing values are "dry pin" values per Section 1.4.7.1.

c 8%—0.025 to 0.062 in. and 10%—0.063 in. and above.

d 5%—0.050 in. and above; 4%—0.033 to 0.049 in. and 3%—0.032 in. and below.

Adapted from D. Furrer, April 2013

# Processing to Design to Manufacturing in ICME




AIM Materials Development

- Optimized between computation and testing
- Utilizes focused testing
- Uncertainty is managed
- Models linked across time and length scales
- Rapid development and lower cost

Efficient use of models, experiments, and experience reduces design challenges and enables performance probability distribution predictions and reliable confidence levels

iSIGHT: Integrated design tool enables virtual manufacturing and property distribution prediction.

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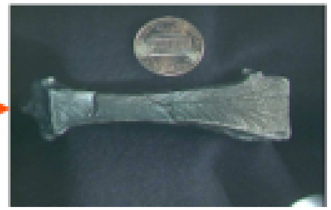
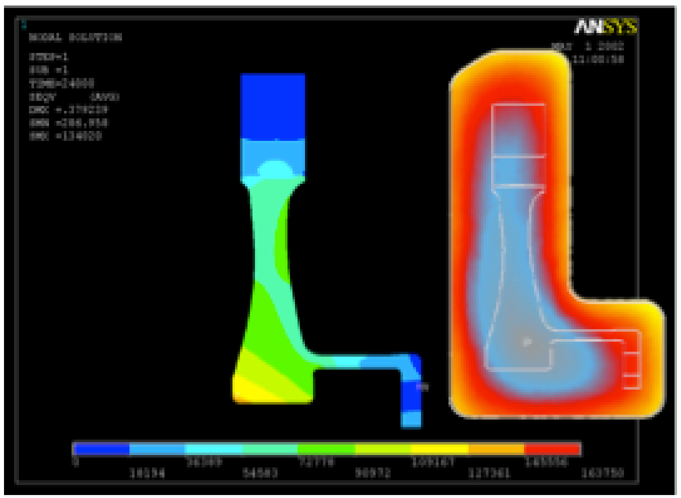
# Full AIM Tool Demonstration at the Component Level

Rim initiated fracture






Bore initiated fracture

Allowing concurrent optimization of processing/microstructure and disk geometry enabled
~ 20% Part Weight Reduction &
~19% Burst Speed Increase.

Integrated tool & models reduced development and test cycle by greater than 50%

- demonstrated improved design capability (5% in speed)
- identified and tested process outside of experience base
- eliminated subscale experimentation
- mapped & integrated material property spatial variation into structural performance
- provided insight into material impact (failure location)
- readily integrated and responded to evolving model capability

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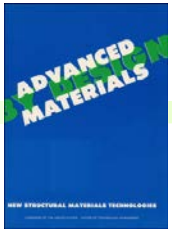
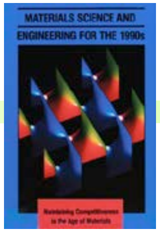
# Historical Perspective

***Computational Tools for Better Implementation of Materials Research Products***

1988




COTA: *Advanced Materials by Design*



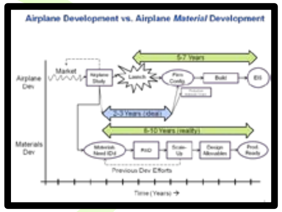

1989

NRC: *Materials Science & Engineering for the 1990s*

DOE: Advanced Strategic Computing Initiative

1995

The Problem




2004
ONR-D3DDS

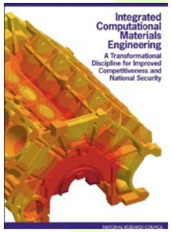
D 3-D digital structure

2001
AFOSR-MEANS

1999
DARPA-AIM

AIM
Accelerated Insertion of Materials

NRC-*ICME*

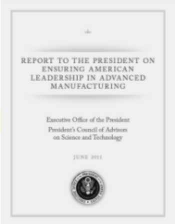



2008

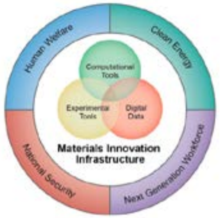
DOE-CMS&C

2010

NSTC-AMP

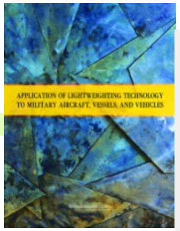



NSTC-MGI




2011

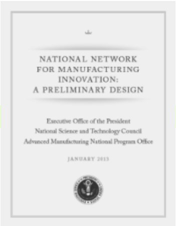
NRC-Lightweighting



NSTC-AMP


2012

NSTC-NNMI




2013

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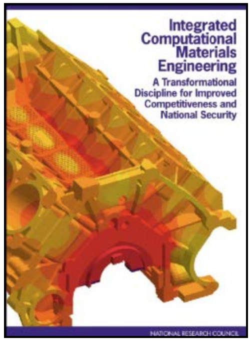
**Adapted from T. Pollock, July 2011**

# Integrated Computational Materials Engineering

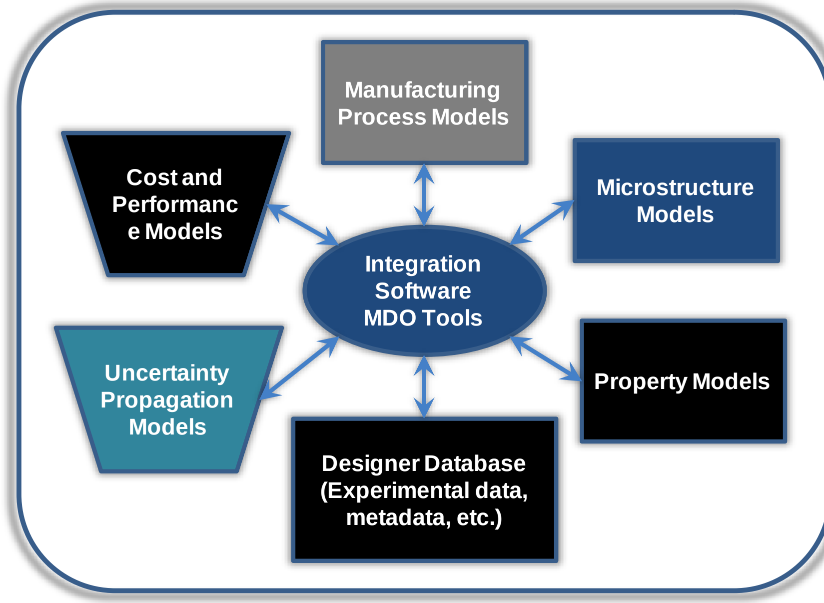



*Selected Findings of the NRC Report on ICME (2008)*

ICME: Integrated Computational Materials Engineering (ICME) is the integration of materials information, captured in computational tools, with engineering product performance analysis and manufacturing-process simulation.

- ICME is an emerging discipline, in its infancy
- ICME can provide a significant positive return on investment; 7:1 to 10:1
- Successful model integration involves distilling information at each scale
- Experiments are key to the success of ICME
- Achieving the full potential of ICME requires sustained investment
- ICME requires a cultural shift

Emphasis on “I” and “E”




*Development of ICME requires cross-functional teams focused on a common goal or "foundational engineering problem”*

# M&MP Standard Operations

## Within the Community

- Spring Planning Meetings
  - Held annually and continuously since 2000
  - Forum for peer-peer networking, personnel development, resource sharing, coordination and collaboration
  - Next meeting June 28-29, 2016
  - This year's emphasis
    - TTCP & International liaison, JDMTP & SERDP engagement, DoD Innovative Manufacturing Institutes
- Joint Program Plan (since 2000)
  - Living document
  - Mission goals and objectives
  - COI structure and taxonomies
  - Portfolio assessments
  - Points of contact
- Annual Persh Workshop (1st in 2008), typically 80-100 participants
  - Next workshop is Winter/Spring 2017: *Interfaces of Biology and Materials*

# M&MP Standard Operations

## Beyond the DoD Community

- Federal Interagency Materials Representatives Meeting (FiMAR)
- Federal Interagency Representatives Meetings for VAATE, Ceramics and Chemistry (long standing)
- Structures & Materials Intelligence Seminar
- National Innovation Initiatives
  - National Nanotechnology Initiative
  - Materials Genome Initiative
  - Critical and Strategic Mineral Supply Chain Subcommittee
  - National Network of Manufacturing Institutes
- The National Research Council
  - Sponsored studies and workshops with the National Materials and Manufacturing Board and the standing committee on materials for defense, the DMMI
- The Technical Cooperation Program (TTCP) Materials Group
- International Engagements

# M&MP COI Tier 1 Taxonomies

- Materials & Manufacturing Processes
  - Materials/Processes for Survivability & Life Extension
  - Civil Engineering
  - Manufacturing Technology for Affordability
  - Environmental Quality

**Materials/Processes for Survivability & Life Extension** is comprised of all materials and processes that enable mission operations. This contains M&MP COI technical area teams for structures and protection; propulsion and extreme environments; sensors, electronics and photonics; power and energy; the individual warfighter; corrosion; and readiness.

**Civil Engineering** supports all aspects of technology necessary for force protection, force projection, and sustainment, including logistics planning, amphibious assault and rapid port enhancement, base and in-theater infrastructure, and force protection on the battlefield and at installations and bases with an emphasis on expedient protection systems. Projects are reported in the M&MP technical area team, Materials and Processes for Civil Engineering.

**Manufacturing Technology for Affordability** contains the materials, processing and fabrication techniques to significantly change the manufacturing cost curve. This includes but is not limited to processing and fabrication of electronics, composites and metals, as well as emerging capabilities developed within the advanced manufacturing enterprise. This is coordinated via the Joint Defense Manufacturing Technology Panel (JDMTP) and efforts are integrated into M&MP technical area teams' roadmaps for Materials/Processes for Survivability & Life Extension.

**Environmental Quality** reflects the DoD activities conducted within the framework of the DoD-DoE-EPA Strategic Environmental Research and Development Program (SERDP). This includes research and development in five program areas: energy and water; environmental restoration; munitions response; resource conservation and climate change; and weapons systems and platforms.

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# Technology Area Teams (TATs)
# Tier 2 Taxonomy

## *Materials/Processes for Survivability & Life Extension*

| 1 Structures & Protection | 2 Propulsion & Extreme Environments | 3 Sensors, Electronics & Photonics | 4 Power & Energy | 5 Readiness | 6 Individual Warfighter | 7 Civil Engineering | 8 Corrosion |
|---|---|---|---|---|---|---|---|
| Platform M&MP | Turbine Engines | Sensors | Power Generation & Energy Conversion | NDE/I | Warfighter Protection | Force Protection for Facilities | Corrosion Mechanisms |
| Survivable Structural M&MP | Missile Propulsion Systems | Next - Generation Devices | Electromechanical Conversion | Prognostics | Materials for Logistics | Force Projection and Maneuver | Surface Protection |
| Multifunctionality | Hypersonic Capabilities | EM Transparencies | Energy Storage | Wear Resistance Hard Coatings, Fluids, Lubes | Warfighter Enhancement | Sustainability of Critical Infrastructure | Corrosion Modeling |
| | EM-Railgun/Directed Energy | Photonics | Power Control & Distribution | Repair | Bio/Bio Inspired Materials | | In-situ Corrosion Detection |
| | Reactive/Energetic Materials | | | | | | Corrosion Repair |

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# TAT 1 M&MP for Structures & Protection

## Objectives

Confident design of materials, joining technologies and integration tools for damage tolerant, survivable, structurally efficient assets

## Program Overview

- ❑ Platform M&MP
- ❑ Survivable Structural M&MP
- ❑ Multifunctionality




## Key Technical Challenges

- Lack of material models to enable rapid material qualification – metal, composite, ceramic, hybrid & multifunctional materials
- Material failure/fracture modeling for blast and ballistic impact
- Difficulty joining dissimilar materials – modeling and manufacturing challenges
- Limited availability of strategic raw materials
- Agile laser protection

## Operational Opportunities

- Increased platform survivability, lethality, and mission capability
- Ability to anticipate/forecast warfighter structures and protections needs
- Adaptive response to emerging threats & needs – 50% reduction in time from idea to implementation
- Transition leading edge technology for affordable acquisition and sustainment – 50% R&D cost savings

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# Development Strategy of 3D-TTR Technology for Protection Applications

**MODELING , SIMULATION, DESIGN**

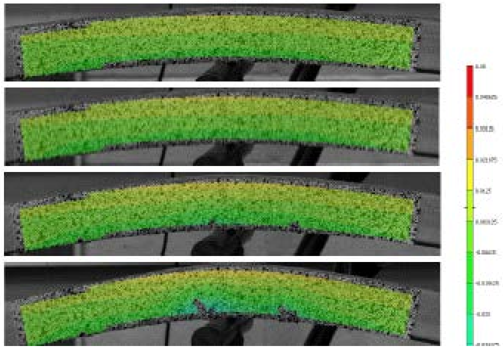
- Multi-scale modeling: fiber properties to ballistic performance
- 3D composite characterization
- Progressive failure modeling
- Ballistic simulation/validation

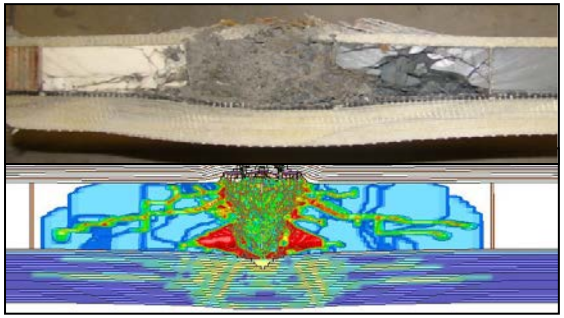
**FABRICATION TECHNOLOGY**

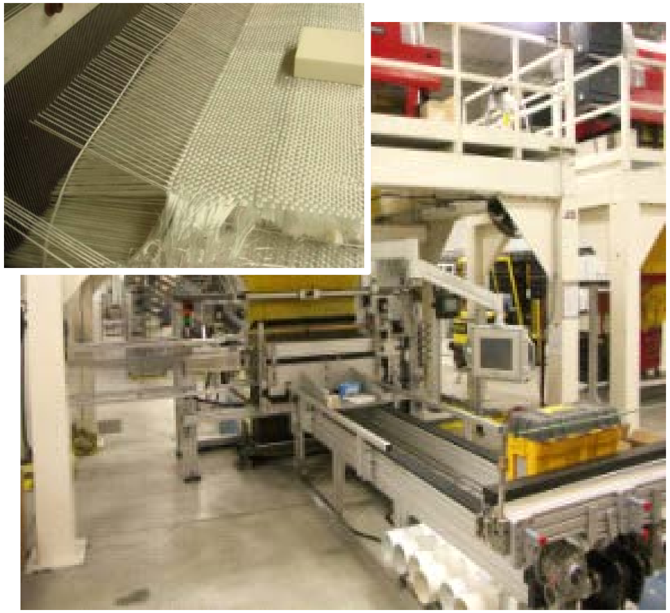
- MANTECH
- Scale 3D-TTR for armor sizes
- Gap control & on-loom insertion
- CAD/CAM automation
- Weaving process modeling for higher fabrication accuracy and efficiency

**ARMOR APPLICATIONS**

- Mission & Customers
- Armor for various threats:
  - GCV
  - DARPA
  - TARDEC JLTV
  - AATD helicopter



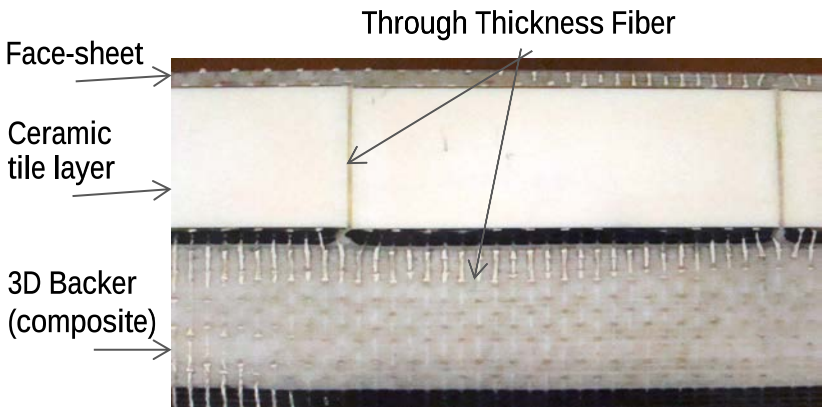





# Development Strategy of 3D-TTR Technology

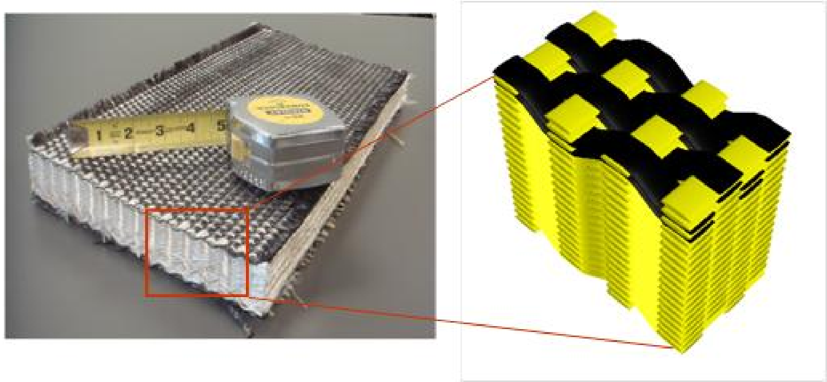
Technological Breakthrough - successful multi-hit demo in ceramic composite armor

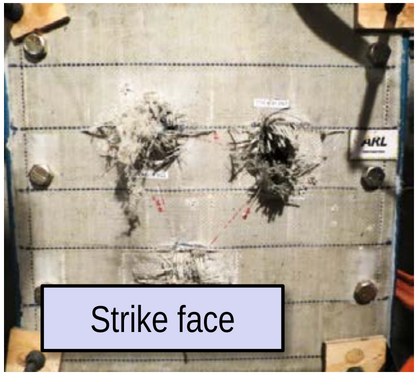
- Enabled by advanced material hybridization, 3D fiber architecture & TTR weaving
- Successful implementation of multi-scale material computational modeling procedure
- Co-developed with academic partner and transitioned to industry through MANTECH

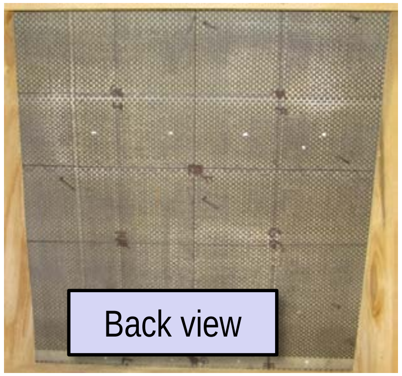



3D-TTR Ceramic Composite Armor Panel

65% lower cost, 20% lighter weight than existing armor solutions





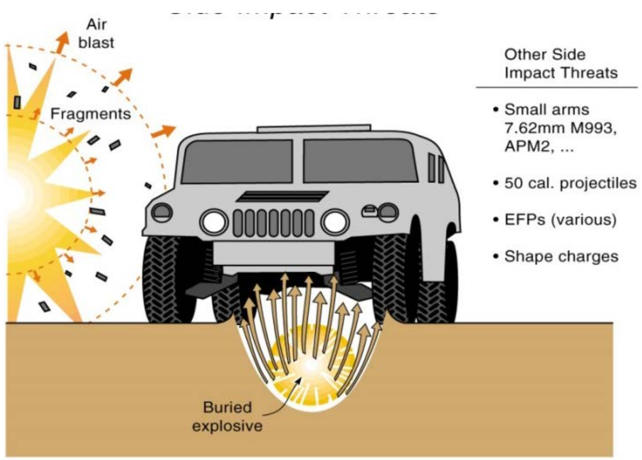




Successfully demonstrated multi-hit capability against a KE threat. Winner (3/3)

# Ceramic Damage in Response to Blast Understood

*Coupling International Collaborations & ARL with Navy MURI pays dividends*

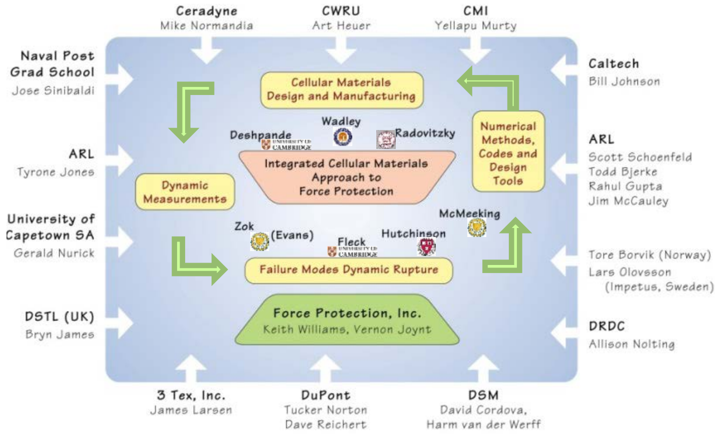
- Developing the fundamental (micromechanics) understanding of air/soil impulse and projectile impact on composite cellular structures with ceramic/polymer hybrid cores.
- Incorporating this fundamental understanding into constitutive to inform armor design capabilities




Micromechanics-based impact constitutive models for ceramics and hybrid cellular structures transitioned into The *National Armor Design Codes* (ALEGRA via Sandia National Laboratory and EPIC via SRI)

- Deshpande (UK) – Evans (UCSB) ceramic impact model

UVa, UCSB, MIT, Harvard + Cambridge (UK)



# TAT 2 M&MP for Propulsion and Extreme Environment Materials

## Objective

Advanced systems for increased power projection and lethality enabled by high performance materials

## Program Overview

- ❑ Turbine Engines
- ❑ Missile Propulsion Systems
- ❑ Hypersonic Capabilities
- ❑ EM-Railgun/Directed Energy
- ❑ Reactive/Energetic Materials

## Key Technical Challenges

- C/C and CMC affordability and scale up – automation/rapid manufacturing and repair
- Lack of Domestic SiC (2400-2700˚F) fiber sources
- Cyclic oxidation and corrosion resistance at >1800˚F in marine (salt-ladden) environments
- In-process quality assurance of small lots
- Better understanding of the role of bonding in high temperature materials to allow design of structure and reduced reliance on scarce materials

## Operational Opportunities

- Enable increased range, fuel efficiency, and loiter time for military flight vehicles
- Increased standoff distance for warfighter
- Mitigate/Control Corrosion and CMAS attack in turbine engine systems for increase time between maintenance cycles
- Enable CPGS and hypersonic systems into arsenal
- Enable EMRG for theater defense & fleet use
- Increase warhead lethality and reduce mass with improved energetics and reactive warhead/case

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# Non-line of Sight VPD delivers Reliable Thermal Barrier Coatings

ONR 6.1/ Thermal Barrier Coatings (TBC) MURI 2000-2007

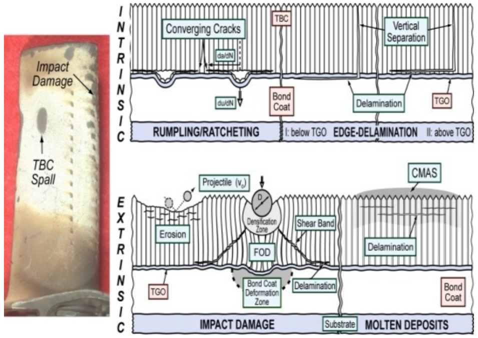
- Initialized multi-dimensional, interdisciplinary physics-based mechanistic understanding of TBC durability
- Designed models and codes that was incorporated into OEM lifing code
- Identified and developed new routes to advanced materials and coatings

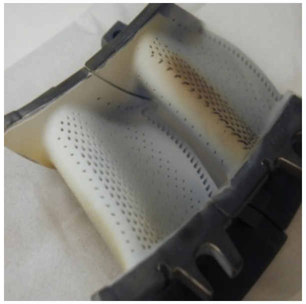
DVD Benefits

- Cost reductions by reduced processing time for complex-shaped parts
- Reduced doublet vane cooling air requirements with thicker TBCs in shadowed regions of airfoils
- Extended time between engine removals

DVD Approach

- Created fluid dynamic models to predict coating flow over complex structures
- Combined high pressure and coaxial gas stream to entrain and focus vapor plume to improve deposition rate, ensure more molecule collisions, and enable non line-of-sight coating of complex geometries
- Spin-off DVD technology via forming new company (DVTI) funded with 6.2 and SBIR/STTR $



DVD-Coated F35 Doublet

**P&W licensed DVD technology 26 June 2009**

**DVTI negotiating to install DVD at North Island NAS, San Diego**

(ONR-led Programs)

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# TAT 3 M&MP For Sensors, Electronics, and Photonics

Level 1 Roadmap

## Objectives

New materials and heterostructures designs for increased speed, agility and reduced power needs of sensors for computation, communication and weapons systems

## Program Overview

- ❑ Sensors
- ❑ Next Generation Devices
- ❑ EM Transparencies
- ❑ Photonics

TODAY

~2 inch device
Large & Bulky

TOMORROW

Voltage Controlled Magnetism (VCM)
Integrated Device ~3mm x 3mm

## Key Technical Challenges

- FM films to enhance E-field penetration & ME coupling
- Modeling/simulation to guide the experimental methods for VCM heterostructures
- Increasing scale and reliability of fabrication
- CMOS compatibility: low temperature (Tp≤ 500 C) integration between FM and high K dielectric films
- Minimal data/results and technical demonstrations of incremental advancements

## Operational Opportunities

- 30-40% improvement in SWaP Figure- of-Merit for non-reciprocal devices
- Lowers production costs by 40%; Enables low cost and rapid device calibration
- Offers frequency agility of non-reciprocal devices; Extends the effective band width by at least 15%

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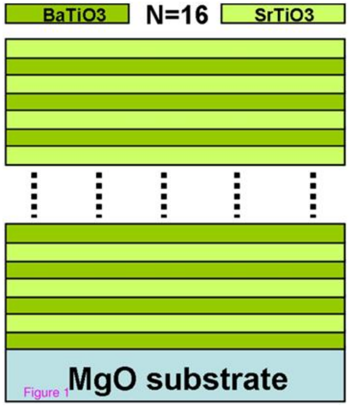
# Artificial Multilayer Superlattice Structures to Enable Enhanced Performance Next Generation Communications Systems

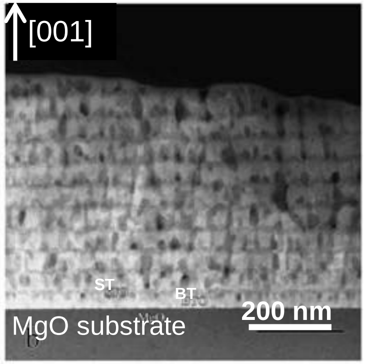
Designed, developed & demonstrated a non-linear complex oxide *Artificial Multilayer Superlattice Structure*, i.e., optimized $[(BaTiO_3)_{0.5}/(SrTiO_3)_{0.5}]_{16}$ with N (repeat) =16, for tunable varactor elements to enable next generation low-cost widely tunable devices which simultaneously possess a high dielectric permittivity to enable miniaturization while maintaining low losses to minimize signal attenuation.

<u>IMPACT</u>: Demonstrated, <u>for the first time</u>, artificial multilayer BT/ST superlattices in the frequency range of 10-13 GHz (X-band). The optimized dielectric constant of 445 with low dielectric loss of 0.01 and tunibility of 35% exceeds the impedance matching device requirements while achieving low loss and high tunability required for room temperature MW tunable elements in phase array antennas & radar within the system operational frequency.

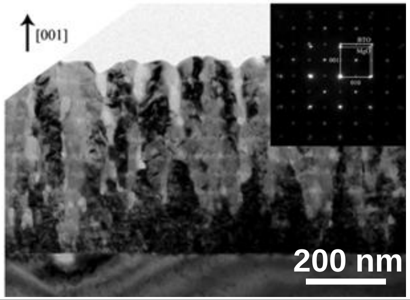
Design Space




BT/ST superlattice

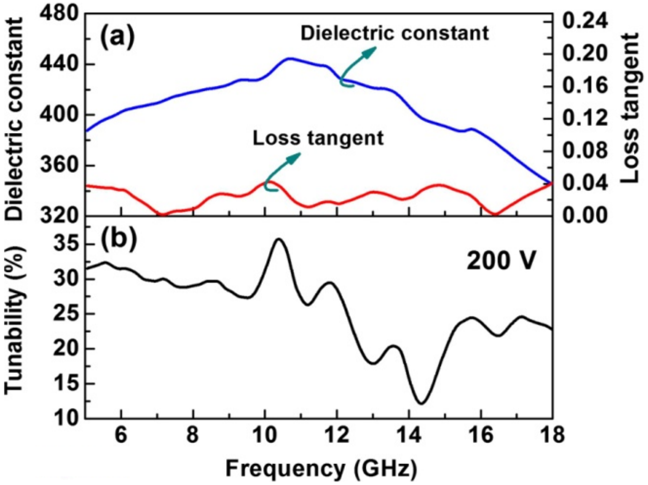



High-Angle Angular DF-STEM image: BT/ST superlattice




Dielectric constant & loss tangent →

Tunability BT/ST superlattices →




TEM BF image & SAD pattern from film/substrate interface The interface relationship of the BT/ST ML is (001)BTO/STO//(001)MgO & [100]BT/ST//[100]MgO with respect to the MgO substrate.

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# TAT 4 M&MP for Power & Energy

## Objective

Material and process optimization and integrated device design protocols for affordable, safe, efficient, light-weight, long-endurance, and rugged power & energy devices

## Program Overview

- ❑ Power Generation and Energy Conversion
- ❑ Electromechanical Conversion
- ❑ Energy Storage
- ❑ Power Control and Distribution

## Key Technical Challenges

- Improved cycle-life, additional organic electrolytes, and new electrode materials for high energy density (> 500 Wh/kg) battery chemistries
- Computational tools for modeling multi-material and multi-scale devices as well as electrochemical processes
- Dielectric materials with both ms and ms response times that enable high energy density (> 4 J/cc) devices
- Organic photovoltaic donor & acceptor materials that enable devices with high efficiency (15%) and air stability
- Sulfur-resistant materials for fuel cells

## Operational Opportunities

- Light-weight, safer, energy dense batteries for autonomous vehicles, reduced carried weight, and longer missions
- High-temperature, high energy density capacitors for directed energy and power conditioning applications
- Energy generation and storage technologies for more agile power networks for more electric aircraft/ships and FOB or infrastructure applications
- Low-cost, high efficiency solar panels to reduce FOB refueling logistics and reduce battery carried weight
- Logistic-fuel compatible fuel cells for ultra-long endurance autonomous vehicle operation and tactical power needs

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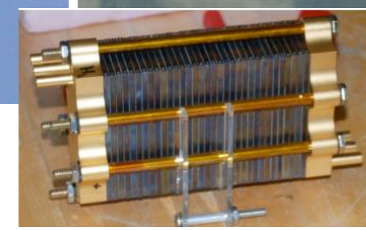
# Fuel Cell Powered Small Unmanned Aircraft Systems (SUAS)

## Cross-Service Demo & Development of Fuel Cell Materials & Components

- History of collaborative multi-service efforts focused on fuel cell membranes, materials, components, reformers, modeling approaches
- Developed & demonstrated in-situ characterization techniques for fuel cell materials
- Demo'd additive manufacturing for rapid prototyping and testing of fuel cell stack bipolar plate technology
- Demonstrated higher temperature membranes for PEM fuel cells
- Demonstrated higher thermal cycle tolerant interconnect materials and a ruggedized stack design

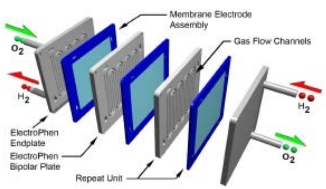
## ONR & NRL





500 W Fuel Cell Stack with Additive Manufacturing Components

Fuel Cell SUAS can provide 6-24+ hrs. flight endurance.



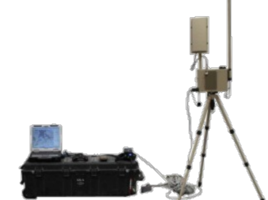

## AFRL

SURGE-V
(LMCO Desert Hawk EER)

**LMCO** Stalker **XE UAS**

Field Support Kits

Solid Oxide Fuel Cell (SOFC) Power Supply



Ground Control System

## DARPA, ARO, ARL

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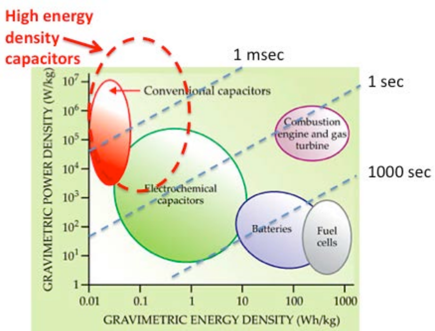
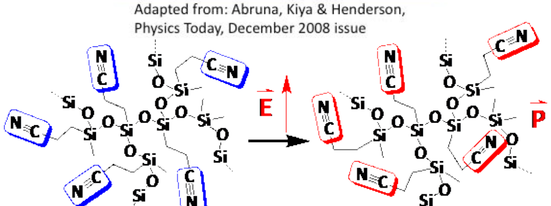
# Dielectric Materials for Pulse Power Capacitors

## Dielectric Materials Development

BOPP, PVDF, alkali-free glass, nanocomposites




Adapted from: Abruna, Kiya & Henderson, Physics Today, December 2008 issue



ONR AFOSR ARO

SBIR / STTR

## Capacitor Film & Fabrication Process Development

- Manufacturing scale-up or roll-to-roll processes
- Fabrication and test of packaged capacitors for Army, Navy and Air Force applications


Coextrusion Process


8 µm thick, 3000 ft roll


250 kJ, 2J/cc
10,000 shots


Film Metallization


Capacitors

AFRL ARL ONR Army ManTech

## High Impact Applications


Air Force HPM


Army EM Armor


Navy Rail Gun

Tri-Service investments will enable pulse power applications with needed range of discharge & temperature capabilities.

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# TAT 5 M&MP for Readiness

## Objectives

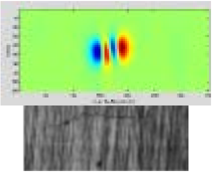
Damage diagnostics, repair and life-extension technologies for asset readiness

## Program Overview

- ❑ NDE/I
- ❑ Prognostics
- ❑ Repair
- ❑ Wear Resistance, Hard Coatings, Fluids, Lubricants

*Tools for improved mx/repair processes*

*Wear Coatings and Lubrication*



*Characterization Technology*

## Key Technical Challenges

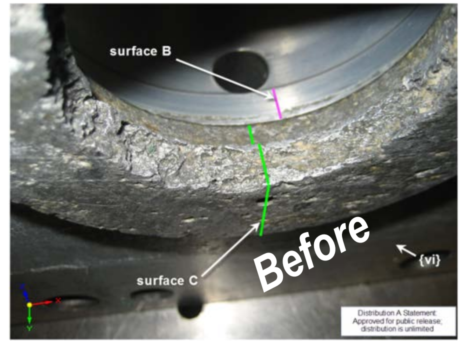
- Damage modeling and prediction within 95% accuracy for degradation mechanisms in legacy and new materials
- Probability of detection less than ~1mm with inspection techniques and detection / assessment of damage precursors
- Reliable fabrication and integration of structural health monitoring systems

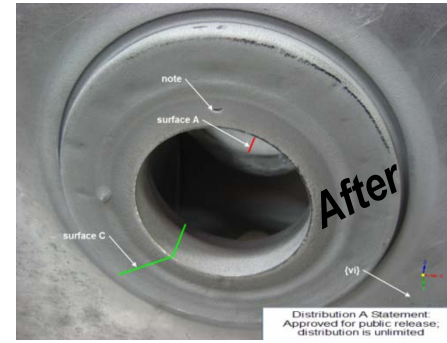
## Operational Opportunities

- In-situ non destructive techniques and advanced computational tools for lifing to increase operational availability
- Advanced structural health monitoring sensors for condition based maintenance and remaining life
- Damage diagnostics for asset/platform maintenance and/or repair at the depot level
- Advanced coatings to mitigate wear in severe loading and harsh operational environments for extended platform life and extended time between maintenance cycles

# Multi-Service Efforts Advance Cold Spray Repair

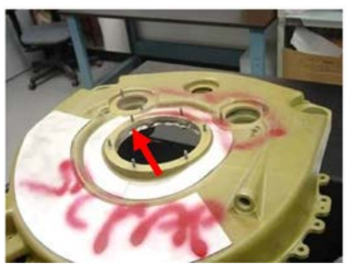
Cold spray technology enabled reclamation of parts otherwise scrapped due to wear and corrosion; i.e. the Army Research Laboratory (APG) repaired a TD-63 Actuator from a Navy submarine for the Puget Sound Naval Shipyard & Intermediate Maintenance Facility (NAVSEA).

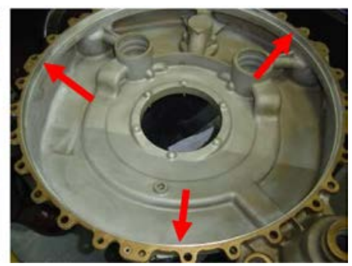


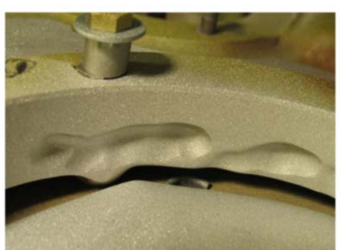

TD-63 Actuator repair

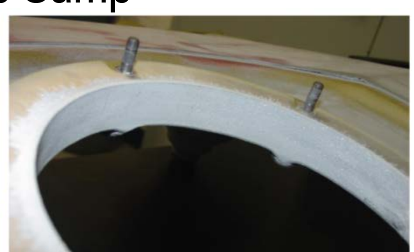
Cold spray repair of a UH-60 Main Rotor Sump





UH-60 Sump





Annual Savings $860K

1. Maintenance Engineering Order (MEO) T7631 UH-60 Sump Repair
   - Army Aviation & Missile Research, Development & Engineering Center (AMRDEC)
   - Program Office –UH-60 Blackhawk-Rios Merritt
   - Corpus Christi Army Depot-SAFR Program Office-Mark Velazquez
2. Overhaul Repair Instruction (ORI) SS8491 UH-60 Sump Repair
   - Sikorsky Aircraft Company-Technology Integration-Bill Harris and Eric Hansen

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# LO Handheld Imaging Tool

Handheld

F-35 LO Health Assessment System (LOHAS)

Technician on the flight line and maintenance supervision

## Program

- ATD delivering technical data and a fully functional residual prototype for a handheld zonal LO NDE tool capable of imaging 100% of the aircraft
- In-situ RF imaging capability with easy to use graphical user interface

## Status & Impact

- Tech Availability 1Q FY15
- Solves current F-35 JCS requirement shortfall by providing capability to image 100% of aircraft surface
- Common NDE solution for AF, Navy & Marines
- Provides quality signature assessment data at field level
- Eliminates unnecessary maintenance, potentially increasing mission capability rates
- F-35 SPO wants 6 more

LOCKHEED MARTIN
NORTHROP GRUMMAN

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# TAT 6 M&MP for the Individual Warfighter

## Objectives

High performance lighter-weight materials including advanced textiles and soft materials to protect, sustain and enhance the performance of the individual warfighter

## Program Overview

- ❑ Warfighter Protection Systems
- ❑ Materials for Logistics
- ❑ Warfighter Enhancement
- ❑ Bio/Bioinspired Materials


## Key Technical Challenges

- Multi-threat protection without overburdening the warfighter
- Durable ballistic, blast and agile laser eye protection system
- Low-cost, wearable sensors and wearable energy sources to power them
- Selectively permeable reactive textiles and use them to design low thermal burden chem/bio protective garments

## Operational Opportunities

- Increased mobility of individual warfighter by enhancing/ optimizing protection at lower weight
- Improved situational awareness of the individual warfighter through networked individual sensors
- Operational capability with a minimal thermal burden in a CBRNE environment
- Improved capability for individual sustainment independence/“self-sufficiency” and reduction of sustainment demands at contingency bases

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# Advanced Eye Protection

## Goals for Vision Protection

Variable Transmission Lens

- High light-dark contrast ratio (85%-15%)
- Fast light-dark transition time (<3s)

Frequency-Agile Laser Protection

- Combination fixed-line/tunable
- Laser eye protection against
    - Laser Dazzle
    - Continuous wave lasers
    - Pulsed Laser

Ballistic Fragmentation Platform Integration

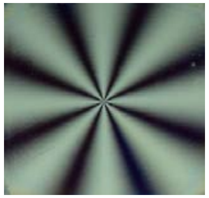
Environmental Hardening

Anti-fog coating

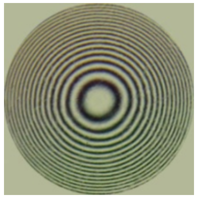
## New Waveplate Optics

- Manipulate light in micron thin layers
- Resolve issues with clarity, substrate compatibility, manufacturability
- Automatically diffract specific wavelengths
- Provide optical correction and magnification on demand

Cycloidal Waveplate



Axial Waveplate



Waveplate Thin Film Lens

## Pixelated Lens Structure

Provides laser dazzle/flash protection via active control of localized transmission through threat-relevant portion of lens area, thus maintaining peripheral vision

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# TAT 7 M&MP for Civil Engineering

## Objectives

Efficient plans, designs, construction, operations and maintenance that are mission ready, energy & water secure, highly sustainable and low lifecycle cost for installations

## Program Overview

- ❑ Force Protection for Facilities
- ❑ Force Projection and Maneuver
- ❑ Sustainability of Critical Infrastructure


## Key Technical Challenges

- Need for greater force protection that is lighter and easily constructed
- Need to achieve operational maneuverability through lighter weight surfacing in austere environments
- Need for sustainable bases in all operational environments using indigenous materials

## Operational Opportunities

- New capabilities to protect the Warfighter and critical assets
- Proactive means to ensure Joint Forces can deploy and freely enter the theater of operations
- Improved ability to design, construct, and operate sustainable bases

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# Passive Protection

## Deployable Force Protection S&T Program

Technologies

- Modular Protective Systems (MPS) for critical assets
- Retrofits and structural upgrades
- Expedient and low-logistics vehicle stopping
- Low-logistics guard towers and fighting positions
- Camouflage, concealment, and deception for critical assets

Developers

USAERDC, NSRDEC

Transition

- JPEO-CBD/JPMG draft TTA and in-theater evaluations
- PEO-CS&CSS/PdM FSS MoA
- Procured by REF (i.e. 82nd ABD, 1BCT)

Funding: $32M

**Complete MPS demonstration at PdM Force Protection Systems, Redstone Arsenal**

**MPS w/ Overhead Cover for Critical Assets**

**Survivability tests with mortar & rocket**

**Multi-Purpose Guard Tower**

**Modeling vehicle stopping**

**Light protection against small arms**

**9 products ranging from materiel to knowledge information**

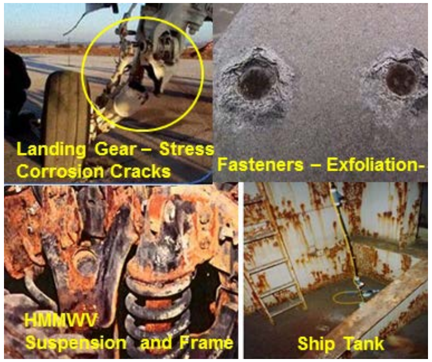
# TAT 8 M&MP for Corrosion

## Objectives

- Application of robust phenomenologically based models for holistic system-design and protection

## Program Overview

- ❑ Corrosion Mechanisms
- ❑ Surface Protection
- ❑ Corrosion Modeling
- ❑ In-situ Corrosion Detection
- ❑ Corrosion Repair




## Key Technical Gaps

- Mechanistic study of corrosion in materials/ structures under environment
- High performance coatings technology that is universal and/or application specific and environmentally safe
- Science based multi-scale corrosion models
- Prediction of materials performance/service life
- Sensors and processes

## Operational Opportunities

- Reduce O&S corrosion cost to enable asset recapitalization and modernization (35%)
- Extend service life of DoD assets (1.5X) beyond original design
- Increase readiness (2X) for present and future missions while reducing resource requirements

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# Army ManTech

## Enabling Hybridized Manufacturing Process for Lightweight Body Armor

Army ManTech partnered with DMS&T, Army S&T and PM SPIE (Project Manager Soldier Protection and Individual Equipment) to enable new body armor processing methods resulting in a 10% weight reduction over current body armor systems. The manufacturing technology transitioned to PM SPIE in September 2014 for use on the SPS (Soldier Protection System).


## Affordable Chemical/Biological Resistant Fabric

Army ManTech enabled new fabric processing methods to successfully achieve target weight and cost goals of CBRN (chemical, biological, radiological, nuclear) shelter liners. The manufacturing technology transitioned to JPM (Joint Project Manager) Protection for production starting in FY15.

## Chip Scale Atomic Clock (CSAC)

Army ManTech partnered with DMS&T to improve CSAC manufacturing processing methods resulting in 20% fewer parts, increased production capability, and cost reductions from $8,700/unit to $200/unit for production volumes. The manufacturing technology transitioned to PD PNT (Product Director Positioning, Navigation & Timing) in 2014.

## Low Light Level Sensor

ManTech helped to increase low light level sensor production yield, optimize processes for better performance and automate production steps resulting in sensor cost reductions of over 60% and increased production capacity 20 times over previous production capacities. The manufacturing technology transitioned to PM Apache starting in late 2013 for initial production and continued through FY14 with FRP (Full Rate Production) and FUE (First Unit Equipped) for equipping the 1stBattalion, Apache 82nd Combat Aviation Brigade (CAB).

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# Navy ManTech

## VIRGINIA Class Submarine Affordability Initiative


- On track to save over $500M through Block IV POR
  - Potential for $600M additional pending approval to expansion to 48 hulls
- Projected acquisition savings: $36.5M/hull
  - Cost savings to date:  $32.4M/hull
  - 36 implemented projects per Electric Boat (8/2014)
- Projected class maintenance/repair cost savings: $100+M
- Won 2013 DOD Value Engineering Achievement Award (Jun 2014)
  - Presented to ONR ManTech, VCS Production Cost Reduction Team (PMS 450), and Electric Boat
- Annual Navy ManTech budget returned with yearly VCS cost savings of >$60M

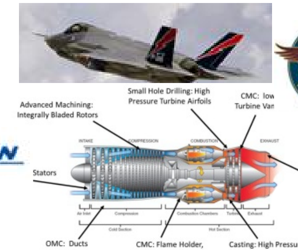
## Joint Strike Fighter (JSF) Affordability Initiative


- Navy impact – projected $700M savings for DoD aircraft
- Joint Navy, Air Force and OSD ManTech collaboration
- Project highlights --
  - Canopy Thermoforming Automation - $75-125M DoD
  - Automated Fiber Placement of BMI Materials - $100M+ DoD
  - Controlled Volume Molding (CVM) – $20M+ DoD savings

# Air Force ManTech

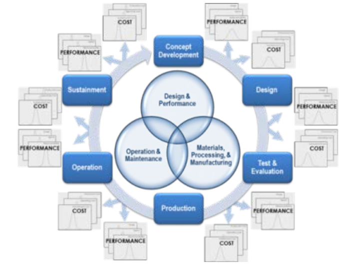
AESA Radar Mfg Assembly Improvements for F35: $380M Impact

1st High-Precision Robotics for Aerospace: F-35 inlet duct drilling cycle time reduced 4X




Major Suppliers

New Materials and Mfg Processes for Turbine Engine Industry: $1B Impact



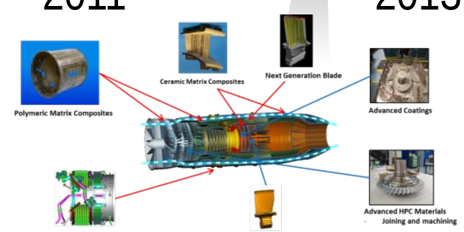

Launched Digital Thread Pilot for EMD Efficiencies

2005 | 2007 | 2009 | 2011 | 2013 | 2015

Engine Rotor Life Extension


Life Extension to 12,000 Cycles Cost Avoidance: $1.1B

Record 30% Efficiency for Production Space Solar Array




Mfg Readiness Level Risk Reduction for AETD Transition to EMD


ManTech Leads Establishment of 1st Nat'l Mfg Innovation Institute

# Innovative Manufacturing Institutes

## Advanced Manufacturing Partnership- Active and Planned Institutes

- National Additive Manufacturing Innovation Institute (NAMII)
  - a.k.a. America Makes (DoD/DOE) FY12
- Digital Manufacturing and Design Innovation Institute (DMDII)
  - (DoD) FY14
- Lightweight and Modern Metals Manufacturing Innovation Institute
  - a.k.a. LIFT(DoD) FY14
- Next Generation Power Electronics Manufacturing Innovation Institute
  - a.k.a. Power America (DOE) FY14
- Institute for Advanced Composites Manufacturing Innovation (IACMI) (DOE) FY15
- American Institute for Manufacturing Integrated Photonics (AIM Photonics) (DoD) FY15
- NextFlex, the Flexible Hybrid Electronics Manufacturing Innovation Institute (DoD) FY15
- Advanced Functional Fibers of America (AFFOA) Institute (DoD) FY16

**http://manufacturing.gov**

America Makes

National Additive Manufacturing Innovation Institute

DMDII

DIGITAL MANUFACTURING AND DESIGN INNOVATION INSTITUTE

lift

NEXTFLEX

America's Flexible Hybrid Electronics Manufacturing Institute

AIM photonics

AMERICAN INSTITUTE for MANUFACTURING INTEGRATED PHOTONICS

iacmi

Institute for Advanced Composites Manufacturing Innovation

POWERAMERICA

# Impact of M&MP COI