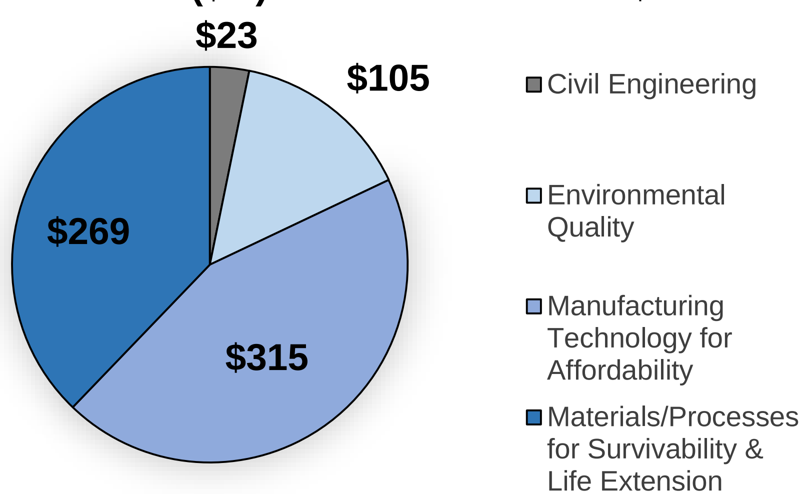
Materials and Manufacturing Processes COI

Dr. John Beatty, OSD (Army)

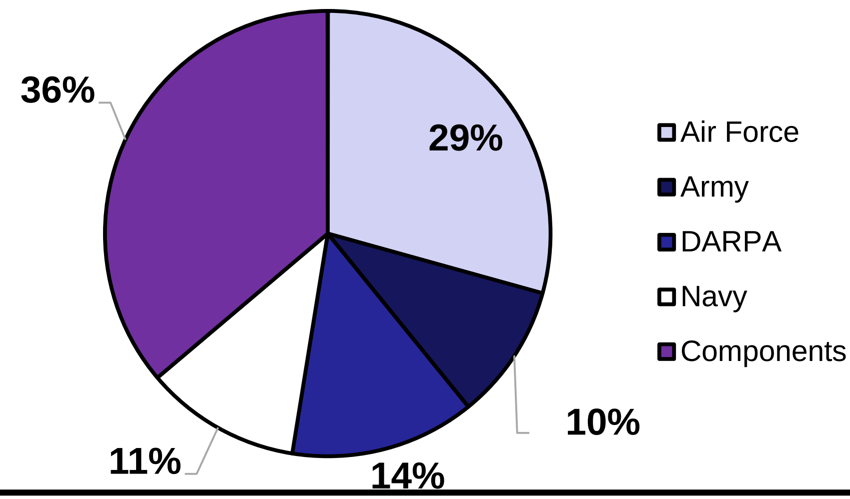
March 20-22, 2018

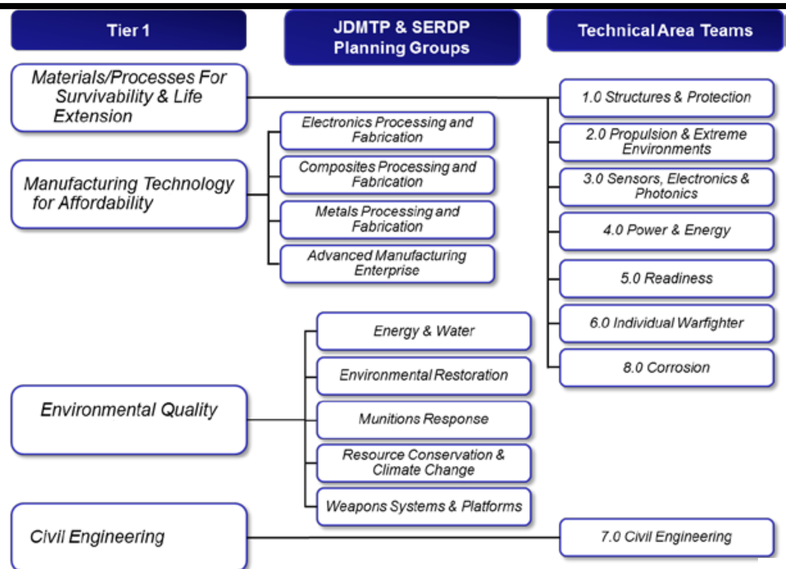
M&MP COI

COI Sub-Areas ($M) — Total = $711M



Component Investment





Leadership

Dr. Tim Bunning, Air Force, Lead
Dr. Julie Christodoulou, Navy
Dr. Mark VanLandingham, Army
Dr. John Beatty, OSD
Dr. Steven Wax, DTRA
Mr. Ellison Urban, DARPA

(J. Russell – JDMTP – AF)
(Robin Nissan - OSD SERDP-ESTCP)

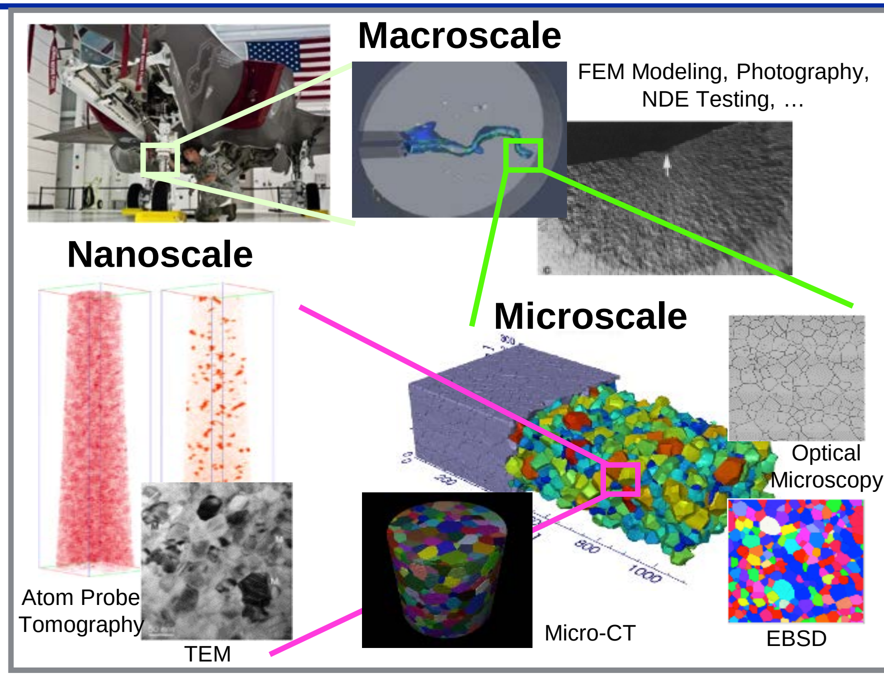
Big Rocks - COI Activity In-Year

- **Briefed NAE – Frontiers of Materials Research: A Decadal Study (due in June 2018)**
  - DMMI workshop on-line
- **Congressional Tasker- Advanced Materials Solutions for Defense Applications**
  - HR115-219, pg 272-273…activities underway to capture input
- **Successful Persh Workshop on "The Interface Between Materials and Biology"**
- **IR&D Exchange with Industry**
- **FiMAR planning (Federal Interagency Materials Representatives)**
- **Manufacturing - Large successful tri-service Defense Manufacturing Conference (DMC) Meeting**
  - High level panel looking forward to next 100 yrs
- **Tri-service Laser Hardened Materials Steering Group (LHMSG) Meeting (Materials for Counter Laser DEW)**
- **Substantial activity in Synthetic Biology for Military Environments (SBME) ARAP**
- **Annual COI meeting in Dayton, Ohio**
- **DoD/DOE Joint Munitions Workshop at Lawrence Livermore National Laboratory (LLNL) (M&MP and Weapons COI)**
- **US-UK Stocktake Principal's request - case studies of AM...initiated FY17, FY18 muscle movements**

Joint-Service Universal Materials Data Fusion and Visualization Structures FY17 - $810K and FY18 – $810K

Issue:

- Tools to enable Integrated Computational Materials Engineering (ICME) are founded on multi-scale, multi-modal materials modeling and characterization.
- Simulation codes and characterization instruments each have their own length scales, reference frames, and distortions and biases.
- This project aims to create a single data-structure for use when merging, analyzing, and visualizing large amounts of spatial and temporal materials data – generated by separate models, sensors, and modalities -- thereby providing a pathway to a more comprehensive understanding of materials performance and decreasing the time to delivery of new systems.



POCs: AFRL - Mike Groeber (michael.groeber@us.af.mil), ARL - James Synder (james.f.snyder.civ@mail.mil), NRL - David Rowenhorst (david.rowenhorst@nrl.navy.mil)

- AM Build specimens - completed. Finalizing design of sample analysis coordinate systems and distribution plans within the next two weeks.
- Transfer specimens from AFRL to ARL and NRL for individual analyses, tracking meta data of 'inspections' - Late Winter/Spring of 18
- Design file and data structure for relating multi-modal datasets - design complete, implementation underway -- tasking with Blue Quartz and Kitware Inc to adapt Kitware's spatial distortion correction framework to operate within DREAM.3D as well as developing spec for recording corrections outside of
- NRL working with BlueQuartz to implement EBSD image montaging and correction within DREAM.3D allowing for fusion of multi-modal SEM/EBSD serial-sections within DREAM.3D. - ongoing.

Roles: **ARL** - mechanical testing with DIC of tensile specimens, CT of specimen; **NRL** - CT of specimen, 3D serial sectioning of sub-specimen, transfer of 3D EBSD montaging and distortion correction tools to DREAM.3D: **AFRL** - CT of specimen, 3D serial sectioning of sub-specimen, modeling of AM processing, guiding development of software tools through BlueQuartz.

Numerous Successes

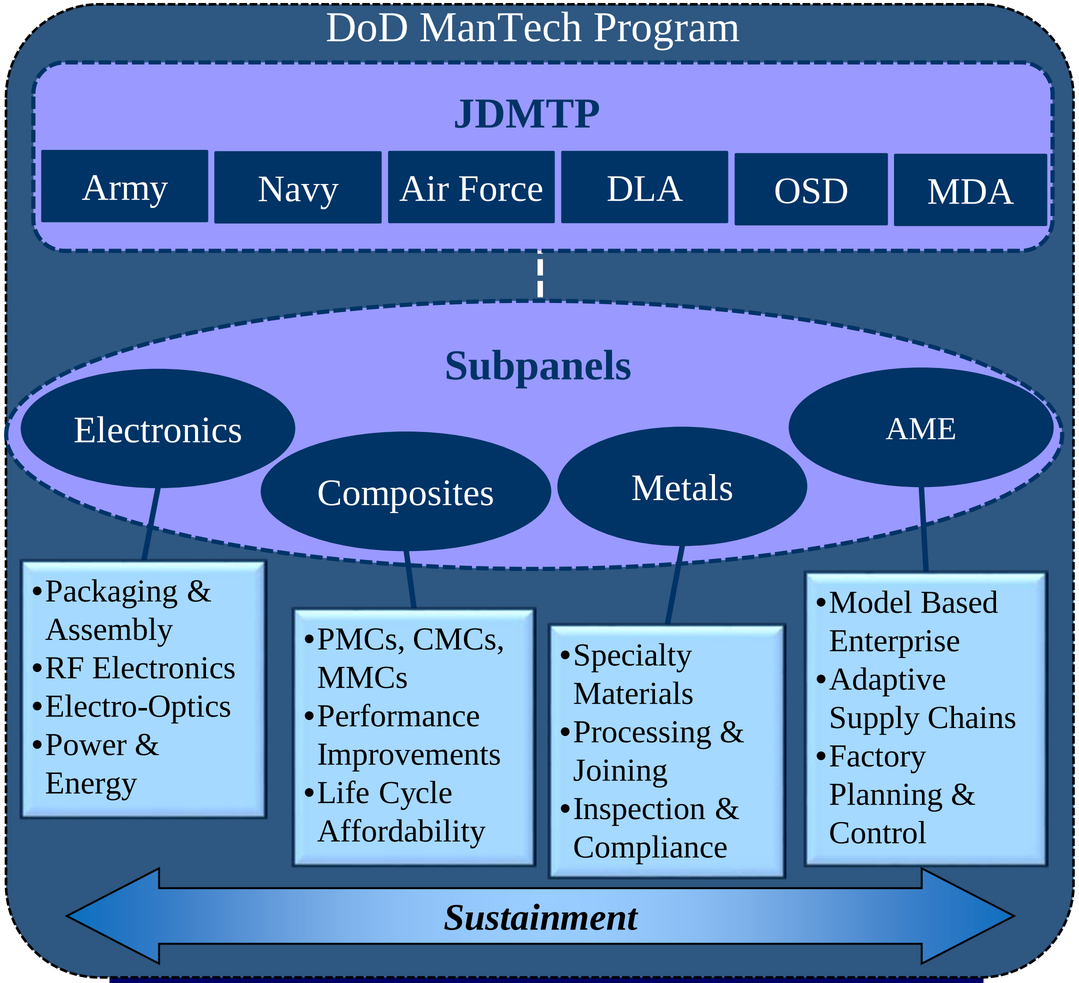
- **Composite damage prediction tools are enabling multi-service component design, materials development, lifing, and certification (Air Force, Army, Navy)**
- **Manufacturing of Carbon-Carbon Composites for Hypersonic Applications (TAT and JDMTP)**
- **Graphene on 3C-SiC on Si for Low-Loss Nanophotonics (Air Force, Navy Army)**
- **Advanced Energy Efficient Shelter System (Air Force, Army)**
- **Laser Eye Protection (Air Force, Army, Navy, DHS)**
- **Port Improvement via Exigent Repair (PIER) Joint Capability Technology Demonstration (JCTD) SPIRAL 1 DEMO (Army, Navy)**
- **Tri-service Corrosion capabilities soon to be on-line: ACES (Accelerated Combined Effects Simulation) and C-COAST (Army, Navy, Air Force)**

M&MP COI

- **Key leverages (some examples) :**
  - Air Force, NAVY armor - leverage Army
  - Air Force, Navy individual warfighter - leverage Army
  - Navy, Army next generation propulsion mtls - leverage Air Force
    - Air Force/ARMY environmental/thermal barrier coatings - leverage Navy
  - Air Force, Army corrosion - leverage Navy
  - Army, Navy aerospace composites - leverage Air Force
  - Army, Navy laser hardened matls - leverage Air Force
  - Air Force, Navy civil engineering - Army

- **Concerns**
  - Confluence of artificial intelligence (AI), robotics, digital composition exploration next fiver years
  - AM
  - Future warfare foci (bio, cyber, quantum (new new vs new old)) – portfolio shifts?
- **'Big' CY 18 activities**
  - Defense Materials, Manufacturing and Infrastructure (DMMI) workshop(s)
  - Congressional Tasker
  - COI Annual Meeting, Defense Manufacturing Conference (DMC) Conference, Stocktake Additive Manufacturing, OSD Additive Manufacturing

Mantech – Organization (JDMTP)



JDMTP Focus: Joint Collaboration

- **Roles of the Panel**
  - Conduct reviews and assessments of the program and related manufacturing issues
  - Strategic planning to identify joint opportunities
  - Information exchange with government, industry, academia, professional associations

John Russell, Air Force
John Carney, Navy
Andy Davis, Army
Jason Jouet, OSD
Kelly Morris, DLA
Rhonda Morgan, MDA

Timeline to Create Manufacturing USA

WH Advanced Manufacturing Partnership (AMP) Recommendation: "Create Public-Private Partnerships on Advanced Manufacturing"

Announcement of National Network for Manufacturing Innovation (NNMI) Concept and a "Pilot" Institute

NNMI: A Preliminary Design Report Issued by Dept. of Commerce

2013 and 2014 "State of the Union" Calls for NNMI

Revitalizing American Manufacturing Initiative (RAMI) Act Signed into Law

NNMI Rebranded to ***Manufacturing USA***

2011 | **2012** | **2013** | **2014** | **2015** | **2016** | **2017**

DoD Institutes

Significant AFRL Leadership

America Makes
Additive Manufacturing
Youngstown, OH

DMDII
Digital Manufacturing and Design
Chicago, IL

lift
Lightweight Metals
Detroit, MI

NEXTFLEX
Flexible Hybrid Electronics
San Jose, CA

AIM photonics
Integrated Photonics
Albany and Rochester, NY

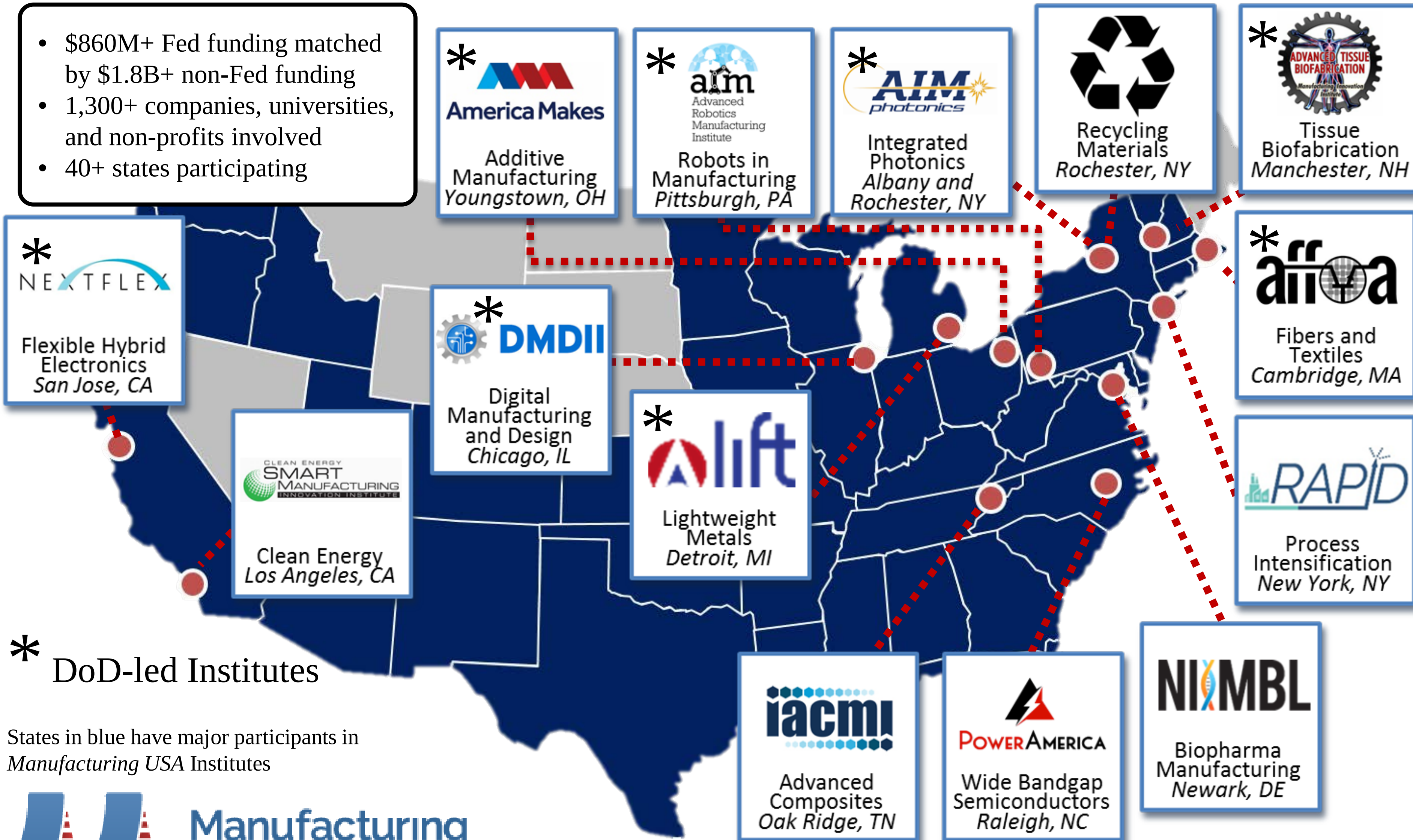
affoa
Fibers and Textiles
Cambridge, MA

Advanced Tissue Biofabrication
Tissue Biofabrication
Manchester, NH

arm
Advanced Robotics Manufacturing Institute
Robots in Manufacturing
Pittsburgh, PA

Manufacturing USA

- $860M+ Fed funding matched by $1.8B+ non-Fed funding
- 1,300+ companies, universities, and non-profits involved
- 40+ states participating



* DoD-led Institutes

States in blue have major participants in *Manufacturing USA* Institutes

Manufacturing USA℠

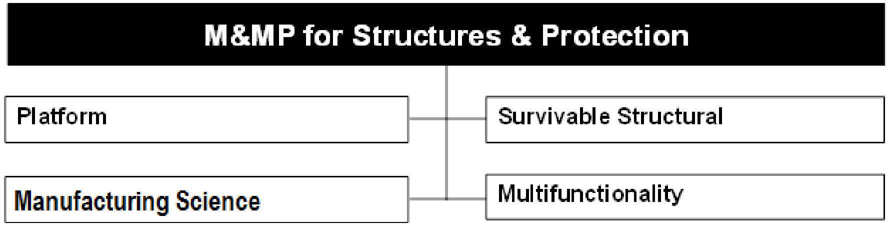
TAT 1 M&MP for Structures & Protection

Objective:

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

Garth Wilks, Air Force, garth.wilks.1@us.af.mil
William Mullins, Navy, william.m.mullins@navy.mil
TBD, Army

Program Overview:



Key Technical Challenges:

- Material models to enable rapid structural material certification & qualification – metals, composites, ceramic, hybrid, & multi-functional materials.
- Feedstocks, process modeling and cert/qual for Additive Manufacturing
- Difficulty joining dissimilar materials without a common processing window – modeling & manufacturing.
- Structural Protection
- Structures Affordability

Operational Opportunities:

- Increased platform survivability, lethality, and mission capability.
- Ability to anticipate/forecast warfighter structures and protection needs
- Platform SWaP constraints driving multifunctional materials.
- 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

TAT 2.0 M&P for Propulsion and Extreme Environment Materials

Objective:

Advanced M&MP for components with higher temperature and performance capabilities to enable advanced systems for increased power projection and lethality

Eric Wuchina, Navy
Donna Ballard, Air Force
Brad Forsch, Army
Jon Davis, OSD

Program Overview:

- Turbine Engine
- Missile Propulsion
- Hypersonic Materials
- Reactive/Energetics
- Electromagnetic Railgun

Key Technical Challenges

- C/C and CMC affordability and scale up – automation/rapid manufacturing and repair
- Domestic SiC (2400-2700˚F) Fiber Sources
- Rayon replacement for structural insulators
- In-process NDE
- Oxidation and corrosion resistance
- Longer Term – Integration of ICME tools into manufacturing for scaleup & process optimization

Operational Opportunities

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

TAT 3.0 M&MP for Sensors, Electronics, & Photonics

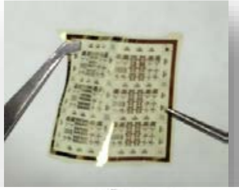
Objective:

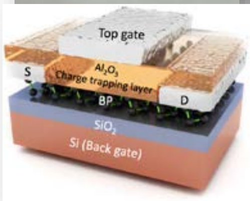
Advanced M&MP for energy efficient, ultra light-weight, conformal electronics, photonics, and sensing devices

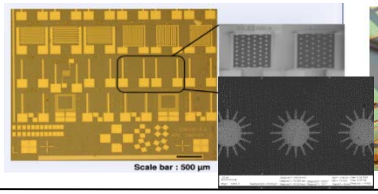
Shashi Karna, Army
John Boeckl, Air Force
Ivgeniya Lock, Navy

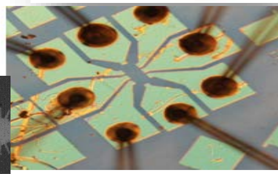
Program Overview

- Energy Efficient Electronics with 2D Materials
- Printable, Flexible Electronics
- Neuromorphic and Synaptic Devices
- 2D Material-based Quantum Computing and Sulphur Detection
- Van der Waals Solids for Photonics









Key Technical Challenges

- Scaled-up, low-cost production of defect-free Two-Dimensional (2D) Materials
- “Inkable/Printable” 2D Materials
- Theoretical understanding of new physical phenomena e.g. Spin quantum Hall effect, electron-phonon coupling induced pseudo-magnetic field in strained 2D materials)
- Modeling and simulation tools for device physics, transport properties, and manufacturing process development
- Material stability in ambient and extreme (T, ballistic impact, ionizing and non-ionizing radiation) environment

Operational Opportunities

- Ultra Light-weight, conformal, energy electronics, photonics, and sensors
- Point-of need manufacturing of components and devices
- High-frequency RF devices
- Quantum encryption and safe communication for protection against EW
- Reduced weight, foot-print, and power requirements in contested environment

TAT 4.0 M&MP for Power & Energy

Objective:

Advanced M&MP for affordable, safe, efficient, light-weight, long-endurance, and rugged power & energy devices.

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Michele Anderson, Navy, michele.anderson1@navy.mil
Reza Salavani, AFCEC, reza.salavani@us.af.mil

Program Overview

- Integrated Computational Engineering (ICME) of Materials & Devices
- Dielectric Materials and Films for Pulse Power
- Thin Film Photovoltaics
- Batteries
- Fuel Cells

Key Technical Challenges

- Improved cycle-life, safe, and extended temperature 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

TAT 5.0 M&MP for Readiness

ICMSE Life-Cycle Models

System-scale
Structural Design

Specifications Air Force: ASIP / PSIP Army/Navy: FLE

Macro-Scale
Uncertainty Engineering Bayesian Analysis

Meso-scale
Mechanisms of Risk

Micro-scale
Uncertainty Physics

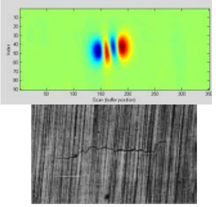
Nano-scale

Characterization, Sensing and Analytics

Airframe Sustainment

Propulsion Sustainment

Understand & reduce life-cycle uncertainty



Characterization Technology

Wear Coatings and Lubrication

Tools for improved mx/repair processes

Key Technical Challenges

- Understanding of fundamental material behavior beyond design life
- Inspection techniques and detection / assessment of damage precursors
- Qualification of SHM technologies
- Fundamental understanding of material behavior in complex environments
- Understanding of slight damage / perturbations / gradual degradation to legacy and new materials.

Objectives

- MSA-NDI/NDT capability improvements for the field/depot that assure structural components perform their function in a reliable and cost effective fashion
- Reduce uncertainty and expand options for safe and cost-effective life cycle management of legacy and future turbine engines and A/C structures
- Specialty materials and coatings affordability through improved inspections and repair methods

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Marc Pepi, Army, marc.s.pepi.civ@mail.mil
Ignacio Perez, Navy, ignacio.perez1@navy.mil

Operational Opportunities

- Inspectability / Repairability / Replaceability
- Material-level data (i.e. material state awareness) for future vision of Health Assessments
- Improved NDI capability/reliability/efficiency
- Damage diagnostic that is actionable information for asset/platform maintenance and/or repair

Keys to success: ICMSE, Digital Thread, Analytics, State Awareness, Life Prediction, Prognostics, V&V

TAT 6.0 M&MP for the Individual Warfighter

Objectives

M&MP for the Individual Warfighter supports materials-related needs, ensuring success by addressing critical requirements including survivability, sustainability, mobility, combat effectiveness, and quality of life.

Diane Steeves, Army, diane.m.steeves.civ@mail.mil
Peter Matic, Navy, peter.matic@nrl.navy.mil
Matt Lange, Air Force, matthew.lange@us.af.mil

Program Overview

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

Key Technical Challenges

- Multi-threat (ballistic, blast, FR, DE, microbial, chem-bio, etc) protection without overburdening the Warfighter
- Warfighter enhancement technologies to increase speed, strength, endurance, mobility and survivability
- Low cost wearable sensors and wearable energy sources (PV, thermoelectric, piezoelectric) to power them
- Bio-functionalized textiles, self-cleaning omniphobic textiles, next generation protective garments (e.g. DTRA Second Skin program, selectively permeable membranes)

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

TAT 7.0 M&MP for Civil Engineering

Objectives

- Lead DOD in providing integrated protection solutions across the operational spectrum to include stability and support capabilities
- Provide force projection technologies and modeling and simulation capabilities for entry and maneuver planning, construction, and assessment
- Develop more efficient plans, designs, construction, operations and maintenance of installations, including contingency bases, that are mission ready, energy & water secure, highly sustainable and low lifecycle cost

Program Overview

- Expeditionary and Fixed Facility Protection
- Force Projection and Maneuver
- Sustainable Bases and Installations

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
- Need for highly scalable materials and manufacturing processes
- Modeling and simulation from nm-m of materials and systems

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
- Dual-use materials / capabilities – protect the homeland
- Position DOD to defend from and understand capabilities of near-peer adversaries

TAT 8.0 M&MP for Corrosion

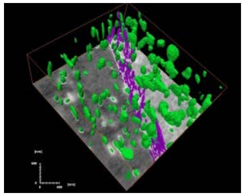
Objectives:

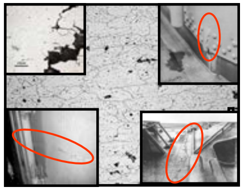
Reduce corrosion and corrosion-related maintenance cost of DoD assets during design, construction and service without compromising affordability, readiness, safety and service life expectancy

Airan Perez, Navy
Ron Pendleton, Air Force
Brian Placzankis, Army

Program Overview:

- Surface Protection and Modification
- Corrosion Resistant Materials
- Corrosion Prediction





Key Technical Challenges:

- Lack of mechanistic corrosion damage evolution model
- Inability to govern corrosion informed materials selection and design
- Inability to validate predictive performance
- Inability to assess and predict real-time in service

Operational Opportunities:

- Reduce O&S corrosion cost to enable 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
- Provide capability to meet design requirements for future DoD platforms