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U.S. ARMY RESEARCH LABORATORY ARL 25 YEARS 1992-2017

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Sciences for Maneuver

Elias J. Rigas
Sciences for Maneuver Campaign
U.S. Army Research Laboratory

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Sciences for Maneuver Campaign

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Energy & Propulsion

- Energy storage for mobility
- Power/energy conversion
- Distribution and transfer
- Intelligent power

Vehicle Intelligence

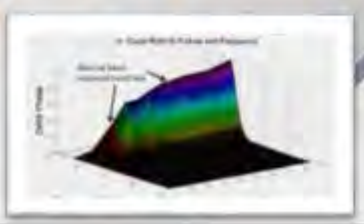
- Perception
- Intelligence & control
- Human-Robot Interaction

Mission

Science and technology to enable air and ground platform capabilities that significantly increase the Army's force effectiveness and rapid expeditionary global responsiveness in complex envirionments.

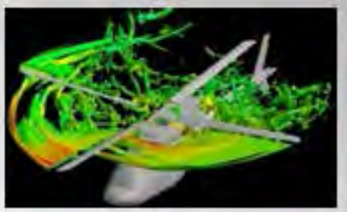
Logistics & Sustainabiity

- Reliability
- Mechanism State Awareness (health)



Platform Mechanics

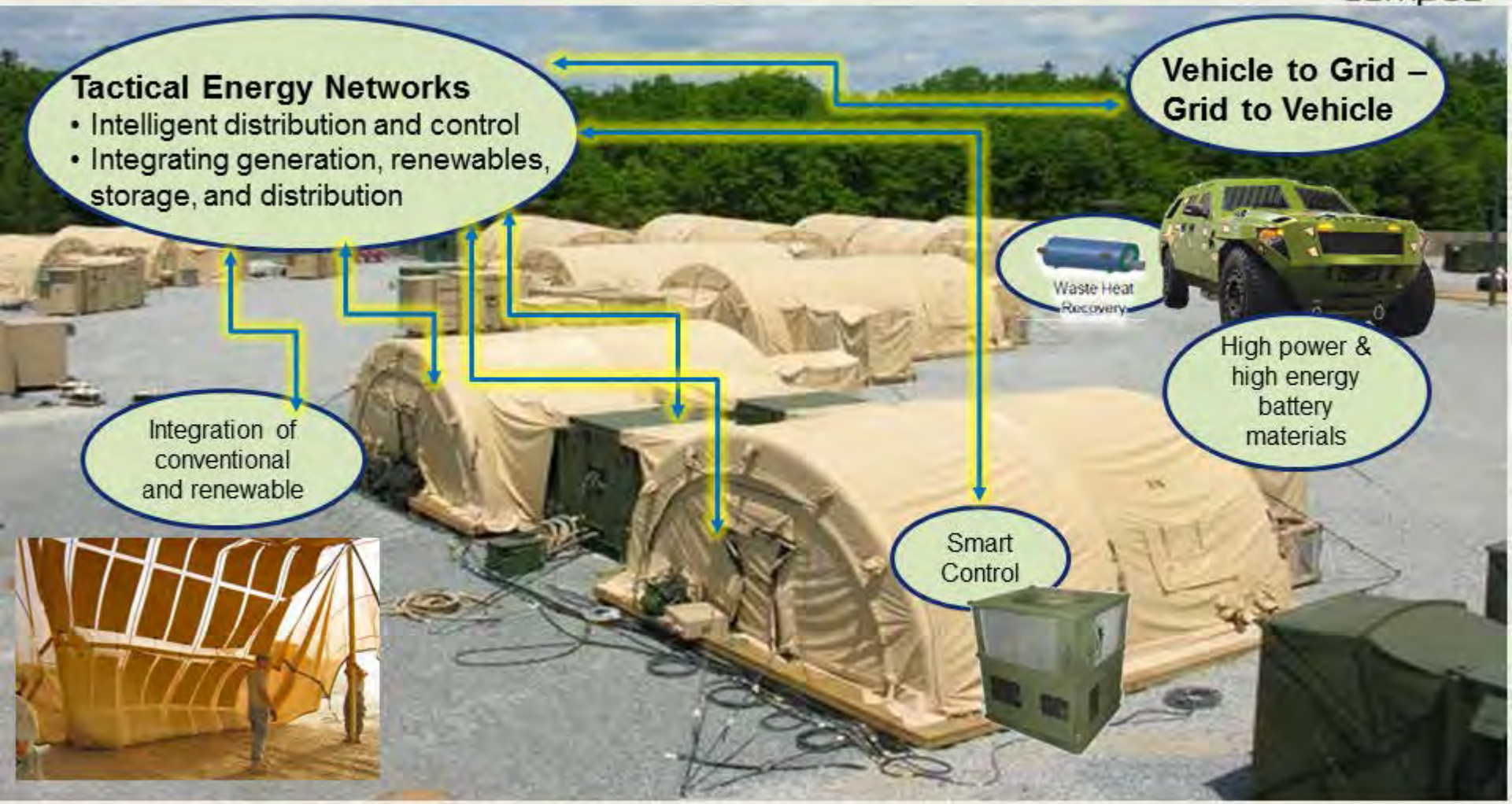
- Fluids, Structures & Dynamics
- Actuation & Mechanisms
- Platform Concepts



Goals

Mobility technologies to enable adaptive vehicle configurations and subsystem architectures critical to future Army deployment, maneuverability & sustainment

Advanced Electric Power Technology & Components



- Intelligent Electrical Power Switching, Conversion and Distribution
- Intelligent Power Networks
- SiC Solid-State Circuit Breaker/Contactor

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Advanced Switching & Control for Power Electronics

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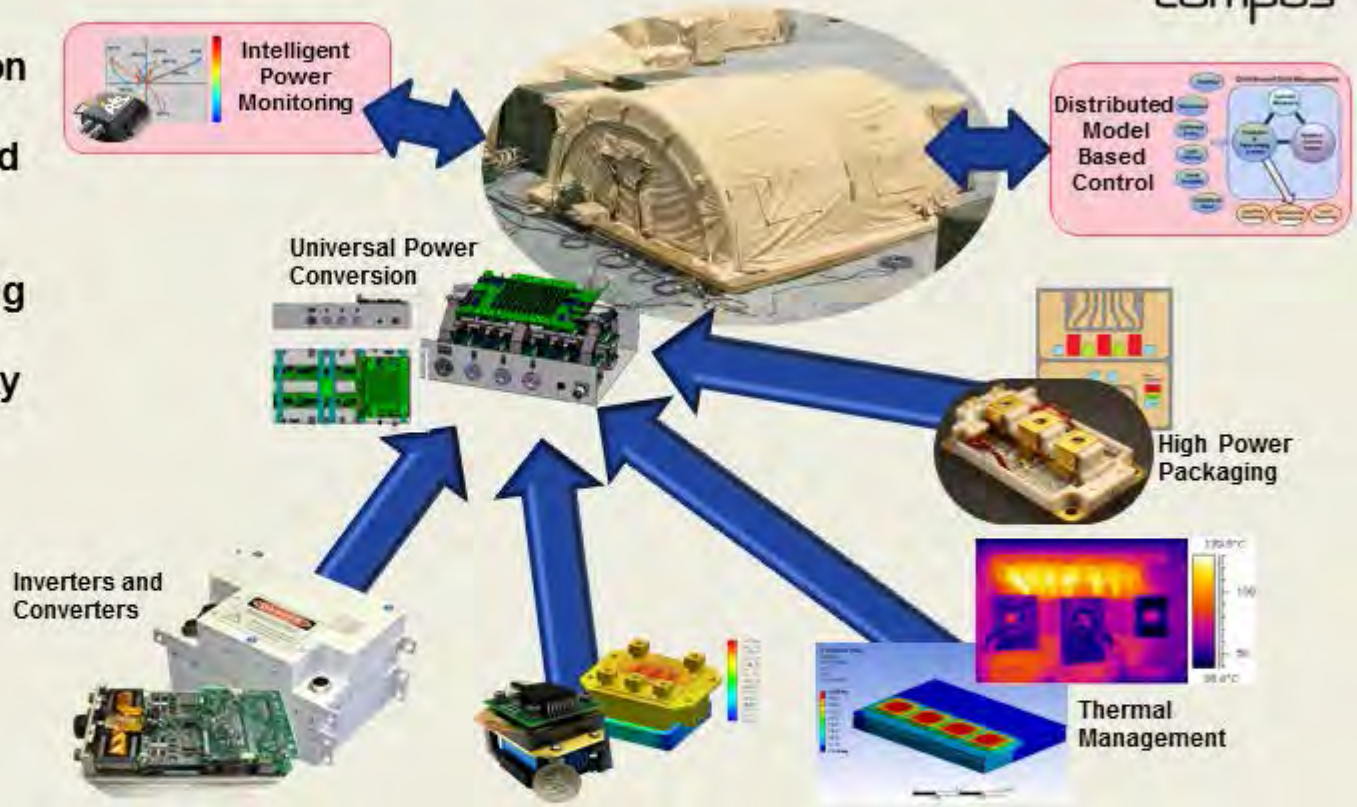
- Universal Power Conversion
- Adaptive and intelligent grid power Algorithms
- Intelligent Power Monitoring
- High Temperature Reliability
- High Power reliability
- Thermal Management
- Fault Protection



State-of-the-Art Power Components Enable New Capabilities

Affordability…….Logistic Optimization…….Logistic Demand

- Energy & Propulsion - Intelligent Electrical Power Switching, Conversion and Distribution
- Intelligent Power Networks
- SiC Solid-State Circuit Breaker/Contactor

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High-Power-Density & Energy-Efficient Engine and Drivetrain Technologies

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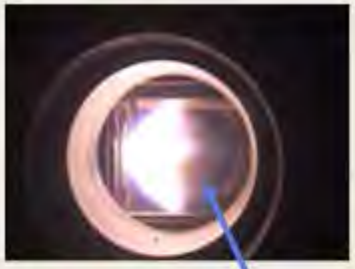
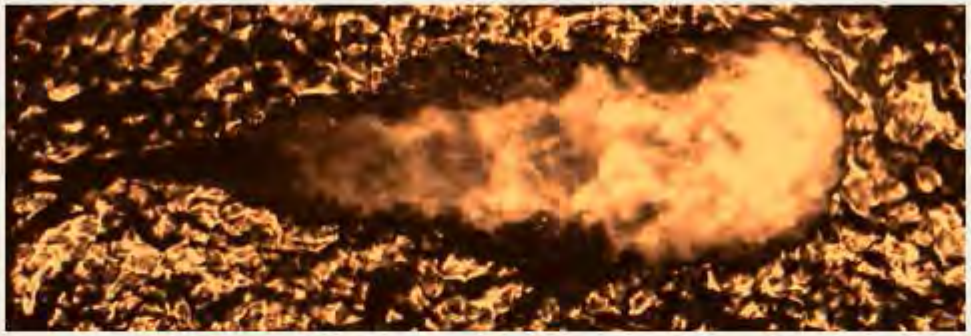
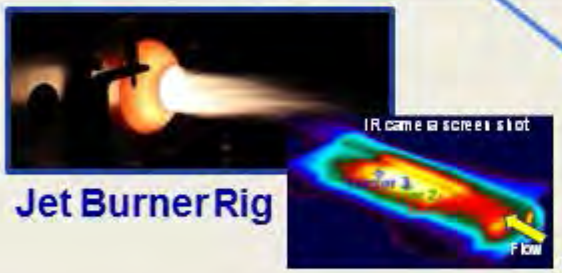


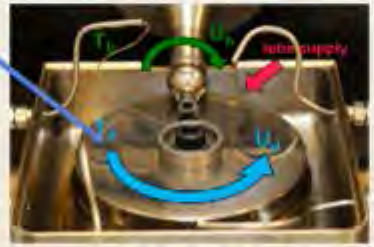
Continuous Combustion



Intermittent Combustion



Jet Burner Rig



Ball-on-Disk Tribometer

Hybrid Gear

Loss of Lubrication

Improve Operational Capabilities: Faster, Further, Leaner and Longer

- Energy Conversion Research Laboratory
- Army Engine Research Center
- High Temperature Propulsion Material Research Facility
- Tribology / Gear Laboratory
- Vehicle Innovative Powertrain Experimental Research (VIPER) Lab

- Fuel Science / Fuel Property Impacts
- Novel Injection / Engine Technologies
- High Temperature Propulsion Materials
- Tribology / Loss-of-Lubrication Environments
- Lightweight Gear and Driveshaft Technologies

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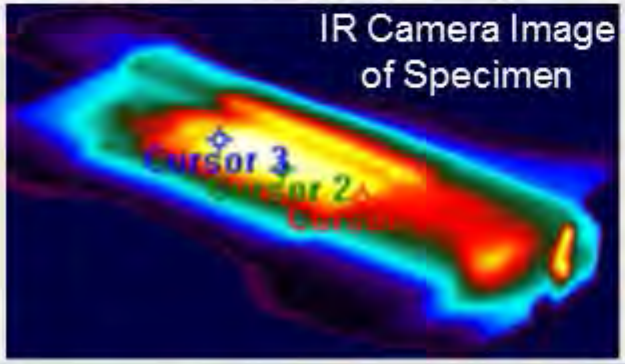
Advanced High Temperature Ceramics for Propulsion Applications

Open Campus Collaboration:

- ARL and Boeing CRADA for Emergent High Temperature Propulsion Materials established for rotorcraft engines.
- Boeing developed Gas Turbine Engine exhaust ceramic matrix composite (CMC) materials. ARL tested these materials at its Vehicle Research Laboratory.

Boeing Research & Technology



Technical Accomplishments/Impacts:

- Preliminary investigations on Ox-Ox ceramic matrix composite materials show promise for use in future gas turbine engine exhaust and nacelle structures.
- Ongoing collaboration will impact disruptive levels of high power density, durability, reliability and reduced life cycle cost of future, ultra-efficient, Army rotorcraft engines.

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Collaboration Opportunities

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http://www.arl.army.mil/opencampus/activeresearch/maneuver

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Power and Energy	Ed Shaffer, Mike Kweon
Energy for Maneuver	Morris Berman, Don Porschet, Bruce Geil
Self-Sustaining Energy for Robotics and Autonomous Systems	Ivan Lee, Dat Tran, Zachery Dunbar, Casey O'Brien, Luther Mahoney
High Temperature Materials for Propulsion Applications	Anindya Ghoshal, Muthuvel Murugan. Michael Walock
High Efficiency Gas Turbine Engine Components	Waldo Acosta, Anindya Ghoshal, Muthuvel Murugan
Tribology and Lubrication Science for High-Performance Power Transmission	Stephen Berkebile, Brian Dykas
Combustion Sciences for Advanced Propulsion Systems	Jacob Temme, Luis Bravo
Innovative Propulsion Technologies for Unmanned Aircraft Systems	Mike Szedlmayer, Kenneth Kim, Luis Bravo
Probabilistic-Diagnostic Informed Innovations for Power Transmission Lightweighting	Adrian Hood, Brian Dykas
Advanced Propulsion Power Transfer—Components & Concepts	Kelsen LaBerge, Mark Valco

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Virtual Risk-informed Agile Maneuver Sustainment (VRAMS)

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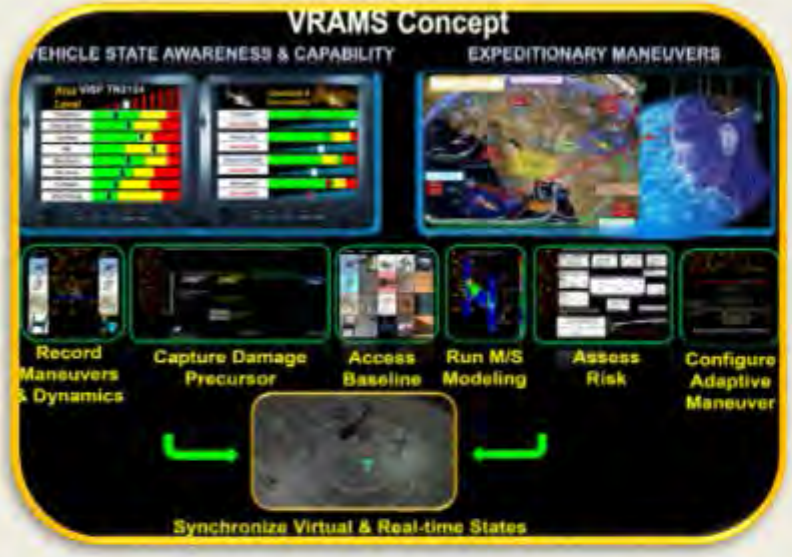
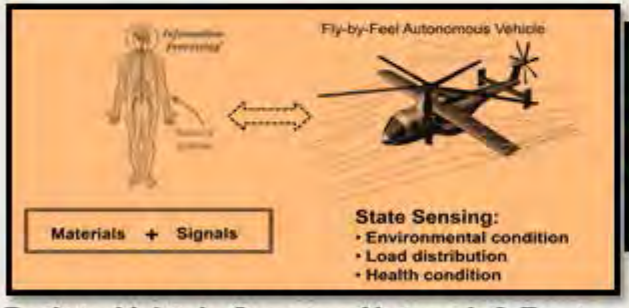
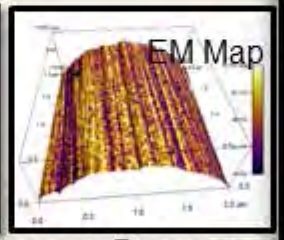
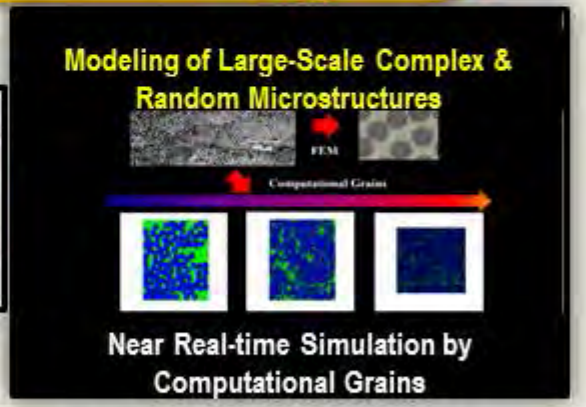




Built-in Vehicle Sensing Network & Fusion



Identification of Damage Precursor



Near Real-time Simulation by Computational Grains

Operating & Sustaining Army Assets in a Complex World at Substantially Lower Costs

- Reliability State Awareness Center (RSAC)
- Prognostics and Diagnostics Lab
- Structural Integrity Lab
- Extremely, Lightweight, Adaptive, Durable, Damage Tolerant (XLADD) Structures
- Real-time Material State Awareness

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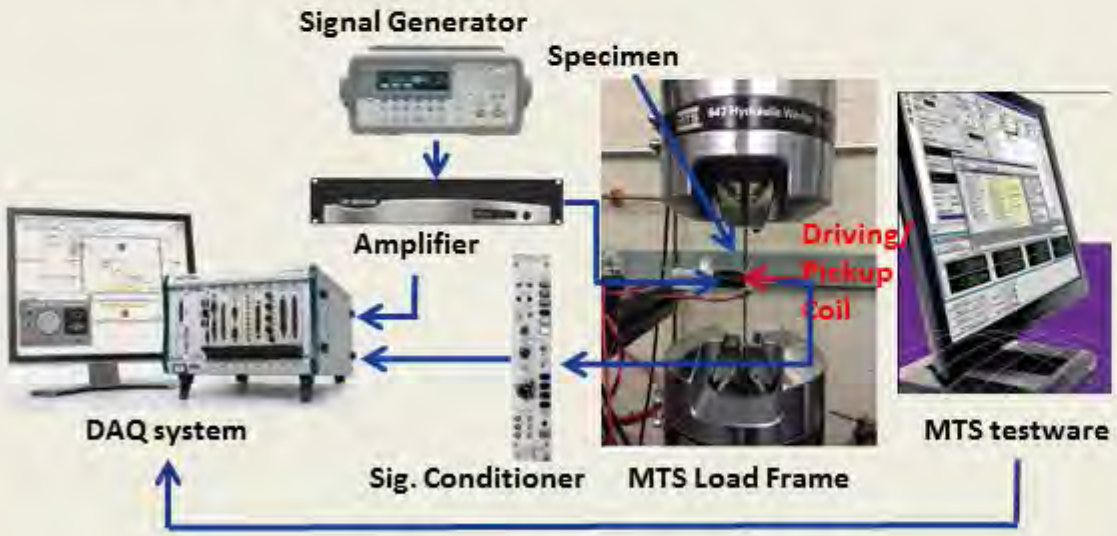
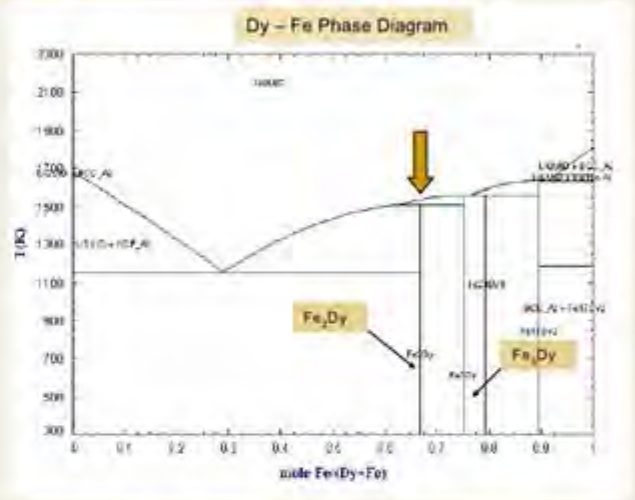
Embedded Sensing of Early Fatigue Damage with Magnetostrictive Materials

Open Campus Collaboration:

- Etrema Products Inc. produced magnetostrictive materials to incorporate into carbon reinforced fiber polymer (CRFP) composites specimens
- ARL diagnosed the onset of early damage in composites with the use of magnetostrictive materials



Experimental Set-up



Technical Accomplishments:

- Embedded sensing with magnetostrictive materials serves as an ideal candidate for sensing early damage.
- Acoustic emission tests and scanning electron microscopy (SEM) have been used to establish the formation of crazes and micro cracks well in advance of visible damage.

Collaboration Opportunities

http://www.arl.army.mil/opencampus/activeresearch/maneuver

Logistics & Sustainability	LTC Keith Morgan
Extremely Lightweight, Adaptive, Durable, Damage Tolerant (XLADD) Structures	Rob Haynes, Mark Bundy, Todd Henry, Terrence Johnson
Damage Mechanics and Diagnostic Sciences	Asha Hall, Dan Cole, Latha Nataraj, Michael Coatney
Next Generation Fatigue Design and Risk Management	Michael Shiao, John Chen, Mulugeta Haile
Risk-based, Damage Adaptive, Sustainment for Maintenance Free Operational Interval	Mulugeta Haile, Rob Haynes

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Discover & Advance VTOL Innovations, Novel Concepts, and Ideas (DaVINCI)

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Enabling manned/unmanned vertical flight platforms from nano to large scale size

- Higher speed, longer range platforms
- Enhance maneuverability in all environments
- Greater payload capacity, fuel efficiency
- Expeditionary maneuver with forces
- Gain and maintain situational awareness
- Protect Soldiers

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Mechanics & Dynamics of Complex Systems

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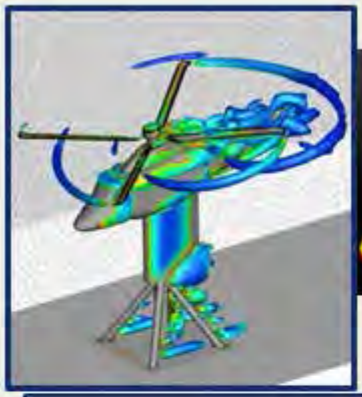
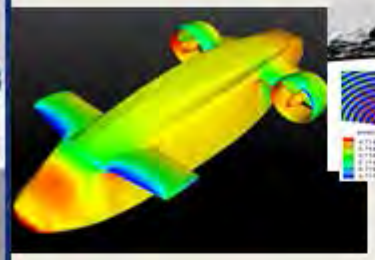
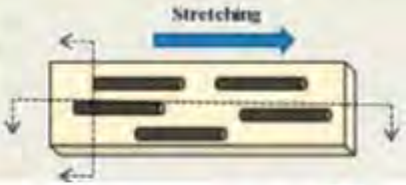
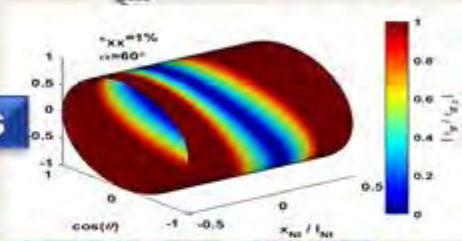


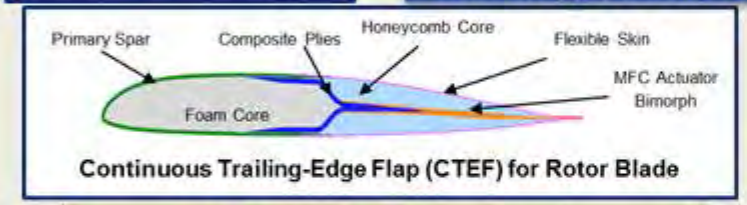


Dynamics of Fluids and Structures



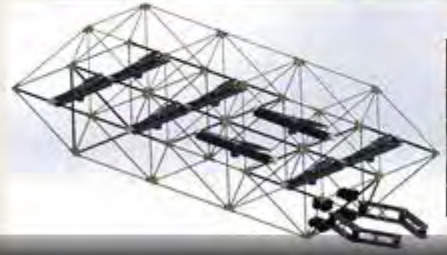


Enabling Technologies for Future Operational Capabilities



Continuous Trailing-Edge Flap (CTEF) for Rotor Blade

Morphing Structures



Interactive Technology Impacts

Aviation Technologies.....Full Scale to Micro.....Immersive Analysis

- Actuating-Morphing Structures
- Advanced Manipulation
- Interdisciplinary Mechanics
- Design Decision Science
- Interactive Analysis
- Acoustic and Structural Damping
- High Performance Computational Fluid Dynamics
- Unique mobility modes

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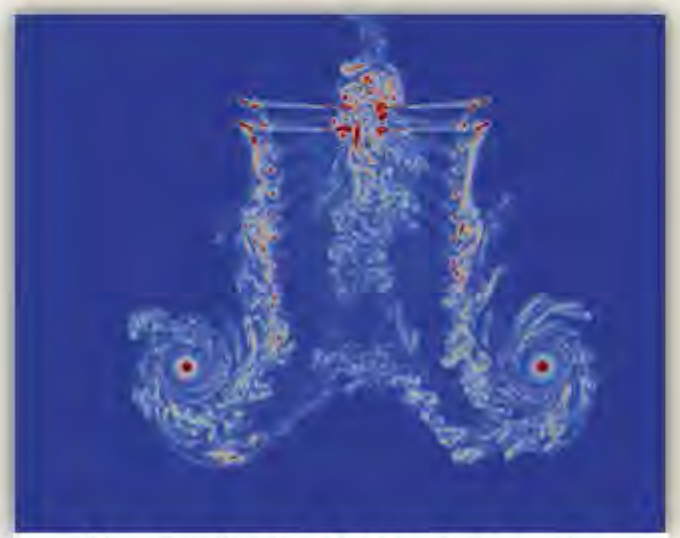
Coaxial Rotor Aeromechanics

Open Campus Collaboration:

- Collaborations established with University of Maryland College Park and University of Texas, Austin
- Universities conducted experimental investigations of coaxial rotors in hover and forward flight
- ARL performed High Performance Computing (HPC) simulations of the model rotor

University of Texas's coaxial rotor test stand in the UMD wind-tunnel



Flow visualization of coaxial rotor wake

Technical Accomplishments/Impacts:

- Advanced the state of the art in understanding the unsteady aerodynamics of coaxial rotor systems
- Developed the capability to evaluate candidate configurations for the Future Vertical Lift program
- Collaboration will enable development of technologies for high-speed and long-range rotorcraft

Collaboration Opportunities

http://www.arl.army.mil/opencampus/activeresearch/maneuver

Platform Mechanics	
Aeromechanics for Rotorcraft and Unmanned Aerial Systems	Rajneesh Singh, Matt Floros
Mission-Driven, Small UAS Design and Validation	Nate Beals, John Gerdes, Eric Spero
Mechanics of Handheld Aerial Mobility and Aerodynamics Research Facilities	Chris Kroninger
Rotorcraft Capability Assessment and Tradeoff Environment	Eric Spero, Rajneesh Singh
Advanced Rotorcraft Aeromechanics Research	Hao Kang, Matt Wilbur
Mobility and Manipulation for Next-Generation Unmanned Systems	Harris Edge

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Force Projection & Augmentation through Intelligent Vehicles

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MAINTAIN OVERMATCH & ENHANCE EXPEDITIONARY CAPABILITIES

Research to create software algorithms that
- *Semantically label objects & behaviors*
- *Enable cognitive reasoning & life-long learning*
- *Create common ground through human behavior models*
- *Enable intuitive communication between man & machine*

Develop technologies to:
- *Understand the tactical environment*
- *Reason like Soldiers*
- *Learn from experience*
- *Build transparency and trust*

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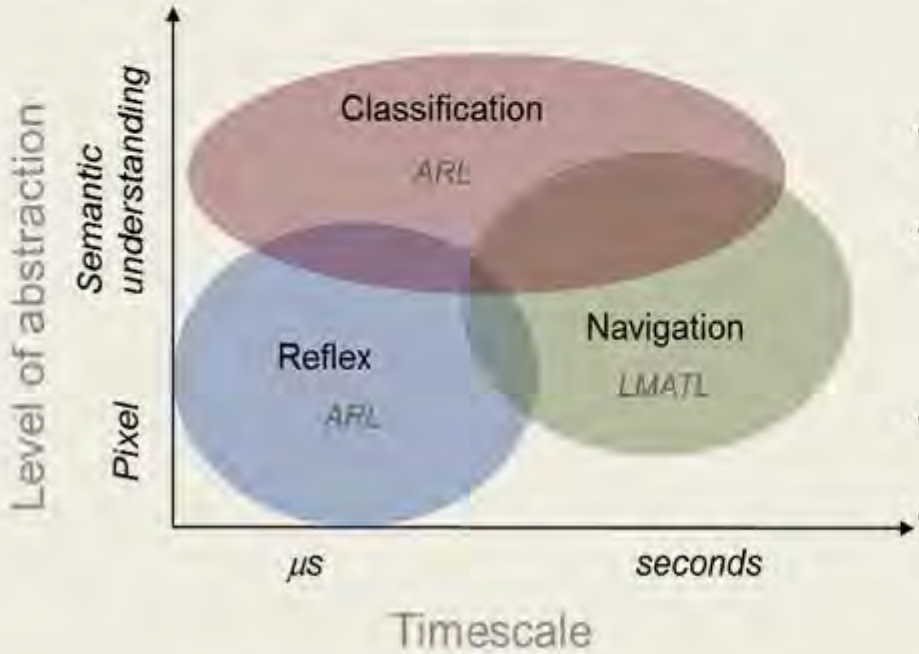
Neuromorphic Computing for Adaptive Control of Robotic Systems

Open Campus Collaboration :

- CRADA established with Lockheed Martin's Advanced Technology Laboratories (LMATL)
- LMATL researcher approved for a one year research sabbatical to ARL
- Complimentary projects funded at ARL and ATL. ARL team has members from ALC and APG.



Technical Plans/Impacts:

- Develop sensors and embedded methods to extract salient information from the sensed environment to enable high-speed autonomous vehicle operation, improved soldier-borne localization, and real-time adaptive model learning and refinement in unknown environments.
- Leverage event-based neuromorphic imaging sensors and deep CNN-based predictive models
- Dynamic vision sensor (DVS) cameras capture images at temporal resolutions orders of magnitude greater than conventional electro-optical (EO) cameras
- Utilizing patterns inherent to motion fields to distinguish between and classify objects of interest
- Multiple time scales and levels of abstraction will allow for human-like interactions with a complex world, better enabling human-robot teaming

Collaboration Opportunities

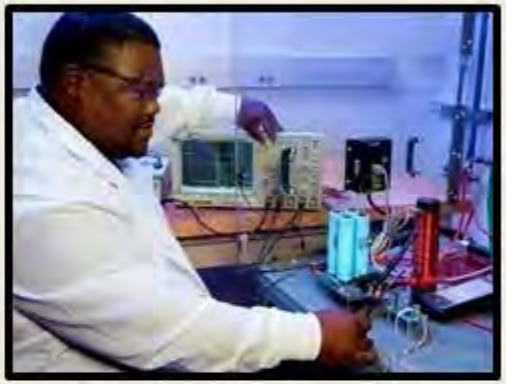
http://www.arl.army.mil/opencampus/activeresearch/maneuver

Vehicle Intelligence	Jon Bornstein
Meta-Cognition, Self-reflection and Proprioception	MaryAnne Fields
Semantic Spatial Understanding	Phil Osteen, Jason Owens, MaryAnne Fields
Intelligent Vehicle Technology Experimentation	Marshal Childers, Craig Lennon
Human-Robot Interaction (also under Human Sciences)	Bill Evans
Computational Intelligence (also under Computational Sciences)	Stuart Young
Reasoning and Decisionmaking Under Uncertainty (also under Computational Sciences)	Doug Summers-Stay
Atmospheric Characterization, Analysis and Effects (under Information Sciences)	Robb Randall

Primary Research Facilities for Sciences for Maneuver Collaborations

Intelligent Systems Research
Adelphi, MD

ARL Vehicle Research Laboratory
Aberdeen Proving Ground, MD



Energy & Power Research
Adelphi, MD

Autonomous Systems Research
Aberdeen Proving Ground, MD

Robotics Research
Ft. Indiantown Gap, PA

Propulsion Research
(ARL Field Element)
NASA Glenn Research Center

Aeromechanics Research
(ARL Field Element)
NASA Langley Research Center

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ARL Intelligent Vehicle Systems Research Center

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Technology Discovery & Innovation for Future Army Intelligent Unmanned Vehicles

Artificial Intelligence
- Semantic Perception
- Machine Learning
- Abstract Reasoning

Human-Machine Interaction
- Cognitive Models
- Human-Machine Communication
- Trust

Multi-Modal Control
- Distributed/Embedded
- Hybrid Mobility/Manipulation

Cognitive Robotics Lab at APG, MD

Free Flight Facility at APG, MD

Micro-Systems Wind Tunnel at APG, MD

Indoor Experimentation Facility (Bldg 507) at Adelphi, MD

Robotics Research Facility at Ft. Indiantown Gap, PA

Multi-Disciplinary / Multi-Campaign

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Collaborations Underway

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GE

GM

NAVAIR

NASA

BOWIE STATE UNIVERSITY 1865

THE UNIVERSITY OF AUCKLAND NEW ZEALAND

Penn Engineering GRASP LABORATORY General Robotics, Automation, Sensing & Perception Lab

BOEING

UTSA The University of Texas at San Antonio™

BOISE STATE UNIVERSITY

LOCKHEED MARTIN

NECST lab

UNIVERSITY OF MARYLAND

MIT

TEXAS The University of Texas at Austin

isn Institute for Soldier Nanotechnologies

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