• Restrooms

• Emergency Exits

• Silence cell phones

• Hold questions to the end of the briefings

• Breakout Sessions
  – Signup sheet available in the lobby during the afternoon break
  – Limited number of appointment times
  – Limited to one (1) session per company

• Drop name tags off at the end of day
<table>
<thead>
<tr>
<th>TIME</th>
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<tr>
<td>0730-0810</td>
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<td>0810-0815</td>
<td>Administrative Items</td>
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<tr>
<td>0815-0830</td>
<td>Welcome</td>
<td>Dr. Juanita Harris, SES</td>
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<td>0830-0840</td>
<td>Engineering Directorate</td>
<td>Mr. Michael Bieri, SES</td>
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<tr>
<td>0840-0850</td>
<td>Aviation Engineering Directorate</td>
<td>Mr. Dave Stephan</td>
</tr>
<tr>
<td>0850-0900</td>
<td>Systems Simulation, Software, &amp; Integration Directorate</td>
<td>Mr. Jeffrey Langhout, SES</td>
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<tr>
<td>0900-0915</td>
<td>Opening Remarks</td>
<td>Dr. Bill Lewis, SES</td>
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<tr>
<td>0915-0945</td>
<td>Aviation Science and Technology</td>
<td>Mr. Carvil Chalk</td>
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<tr>
<td>0945-1005</td>
<td>Break</td>
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<tr>
<td>1005-1035</td>
<td>ADD - Ft. Eustis</td>
<td>Mr. Ming Lau</td>
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<tr>
<td>1035-1105</td>
<td>ADD - Ames</td>
<td>Dr. Oliver Wong</td>
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<tr>
<td>1105-1135</td>
<td>Joint Multi-Role Technology Demonstration</td>
<td>Mr. Dan Bailey</td>
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<tr>
<td>1135-1300</td>
<td>Lunch</td>
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<tr>
<td>1300-1315</td>
<td>Basic Research</td>
<td>Dr. Mahendra Bhagwat</td>
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<tr>
<td>1315-1345</td>
<td>Sustainment and Structures</td>
<td>Mr. Nate Bordick</td>
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<tr>
<td>1345-1415</td>
<td>Power Systems</td>
<td>Mr. Kevin Kerner</td>
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<tr>
<td>1415-1445</td>
<td>Aeromechanics/Rotors and Vehicle Management &amp; Control</td>
<td>Dr. Mark Fulton</td>
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<td>1445-1505</td>
<td>Break</td>
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<tr>
<td>1505-1535</td>
<td>NexGen Tactical UAS Technology Demo</td>
<td>MAJ Michael Osmon</td>
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<tr>
<td>1535-1605</td>
<td>Autonomy and Unmanned Systems</td>
<td>Mr. Matt Whalley</td>
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<tr>
<td>1605-1635</td>
<td>Mission Systems</td>
<td>Mr. Mike Butler</td>
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<td>1635-1645</td>
<td>Wrap-Up</td>
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**APRIL 11, 2018**

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<td>0800-1200</td>
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Mission

Deliver collaborative and innovative aviation and missile capabilities for responsive and cost-effective research, development and life cycle engineering solutions.

Vision

Be a Warfighter-focused valued team of world leaders in aviation and missile technologies and Life Cycle Engineering.
INCREASED STRATEGIC ALIGNMENT WITH OUR PARTNERS:
Think on enterprise terms – how to support one another and how to do business together in a cohesive, collaborative manner. Systematically communicate with and reach out to the myriad of our Team Redstone, Large Industry, Small Business, Technical Services, DAU, regional University and Research Institute Partners to work toward mutual goals and objectives.
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Presented by:
Matt Whalley
Focus Area Lead
U.S. Army Aviation and Missile Research, Development, and Engineering Center

10 April 2018
Army Aviation S&T Focus Areas

**Platforms**
- Structures
- Sustainment
- Concept Design & Assessment

**Mission Systems**
- Survivability
- Avionics & Networks

**Vehicle Management & Control and Rotors**
- Rotors
- Vehicle Management & Control

**Autonomy and Unmanned Systems**
- Autonomy & Teaming
- Human System Interface

**Major Program Areas**
- Joint Multi-Role Technology Demonstration
- Degraded Visual Environment – Mitigation
- Next Generation Tactical UAS Technology Demonstration

**Power**
- Engines & Other Power Sources
- Drives

**Basic Research**
- Computational Aeromechanics
- Experimental Aeromechanics

**Technology Driven. Warfighter Focused.**
ADD Technical Areas:
- Autonomy and Teaming (ADD-Eustis)
- Human-Systems Interface (ADD-Ames)

Payoffs:
- Effective use of unmanned systems
- Enhanced team communication, collaboration and performance
- Survivability against advanced threats
- Increased lethality
- Situational awareness in all environments
- Maximum human / system performance
Autonomy = Self Governance

Strategic Planning – Autonomous Tactical Operations Center
Mission Planning/Execution – Decomposition of strategic plan
Decision Management – real-time aid/contingency
Route Planning – survivability, effectiveness, airspace mgmt
Reactive Planning – obstacle field navigation, auto land
Waypoint/Path Following – curve fitting and 4D path following
Position/Velocity Stabilization – airspeed/altitude hold
Attitude Stabilization – partial/full authority augmentation
## Aviation Autonomy Topic Areas

<table>
<thead>
<tr>
<th></th>
<th>Today</th>
<th>Mid-Term</th>
<th>Far-Term</th>
<th>Org/TA</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Decision Management</td>
<td>Human full-time</td>
<td>Human confirms; manage-as-required</td>
<td>A&amp;T</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Machine self-managed</td>
<td></td>
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<tr>
<td>2</td>
<td>Airspace Separation</td>
<td>Safe separation; ROS</td>
<td>Close-proximity maneuvering</td>
<td>VMC</td>
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<tr>
<td></td>
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</tr>
<tr>
<td>3</td>
<td>Link Independence</td>
<td>Full-time</td>
<td>Burst (strategic)</td>
<td>CERDEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Performance</td>
<td>Sub-parity with manned A/C</td>
<td>Near-parity</td>
<td>Platforms TA</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Parity or better</td>
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<tr>
<td>5</td>
<td>Perception; Sensor Understanding</td>
<td>None</td>
<td>Automatic target recognition (supervised)</td>
<td>CERDEC</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Automatic target recognition with learning</td>
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<tr>
<td>6</td>
<td>Contingency Tolerance</td>
<td>Brittle</td>
<td>Adaptable</td>
<td>A&amp;T, Sustainment</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Resilient</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Human-Systems Interface</td>
<td>Discrete commands</td>
<td>Tasking, structured voice command</td>
<td>HSI</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Discern intent, natural language</td>
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<tr>
<td>8</td>
<td>Navigation</td>
<td>Waypoints</td>
<td>Mission planner</td>
<td>VMC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Self-rerouting, dynamic mission planner</td>
<td></td>
</tr>
</tbody>
</table>
Effective and efficient teaming with unmanned systems
- Intelligent, intuitive interface
- Natural interaction for mission & objective-level commands

Shared situational awareness
- Exchange information, not just data
- Distributed secure processing

Execute tactical UAS missions in hybrid operating environments
- GPS denied / Data link-free operations
- Systems work with good, bad or no networked communications

Complex, intelligent systems certified quickly
- Established, benchmarked procedures

Advanced team-based planning and execution
- Team member objectives based on environment and platform capabilities
6.2 Unmanned Air Systems Autonomy

- Increase mission effectiveness of UAS through increased Autonomy
- Open Systems Architecture - FACE ECOA standards development
- More capable, more effective small UAS
- Improved autonomous flight controls up through full sized aircraft

6.2 Advanced Teaming Concepts

- Coordinated maneuver
- Collision avoidance
- Trusted Autonomy

6.3 Advanced Teaming Demonstration

- Part of the combined arms brigade combat team
- Limited or intermittent datalink operations
- UAS ops in contested and denied environments
- Ownship awareness and contingency management
- Team-based situational awareness and engagements
- Shared airspace flight

6.3 Synergistic Unmanned-Manned Intelligent Teaming (SUMIT)

Part 1 Open Sys Sim Dev

- Advanced crew station simulation

Part 2 Multirole MUM Technology

- Advanced decision aiding to support MUM teaming
- Crew station recommendations
- FACE/JCA aligned architecture and software applications

Part 3 Flight Test

- Sanctioned future MUM-T CONOPS
- Technology assessment
- Technology investment strategy
Unmanned Air Systems Autonomy

Purpose:
Investigate and research advanced technologies to increase manned and unmanned Army Aviation mission effectiveness through the development and employment of autonomous systems and aircraft. Primary areas of interest are autonomous behaviors, perception, autonomous flight controls, improved manned/unmanned teaming, swarming, and open systems architecture.

Products:
- Demonstration, testing, and comparison of multinational open systems architecture constructs
- Advancements in open systems architecture that enable autonomy development and propagation
- Investigate autonomously aided high speed control of small UAS systems for combined air ground operations
- Autonomous flight control algorithms and systems for Army Aircraft, enabling new capabilities

Payoff:
- More effective, more efficient Manned Unmanned Teaming operations with greater per man mission execution throughput
- Facilitating technologies for the development of optionally piloted aircraft, and a more hands off, mission manager focused pilot role
- Increased compatibility of member nations open systems architecture approaches resulting in increased interoperability

Schedule

<table>
<thead>
<tr>
<th>MILESTONES</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
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<tbody>
<tr>
<td>AMOSA – Alignment of Multinational Open System Architectures</td>
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<tr>
<td>COSA – Collaborative Open Systems Architectures</td>
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<tr>
<td>Autonomous Flight Controls development</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Small UAS Autonomy Dev</td>
<td></td>
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</tbody>
</table>
Crew Decision Aiding Systems Technology (CDAS Tech)

Purpose:
• Develop Future Airborne Capability Environment (FACE) aligned intelligent algorithms that efficiently manage a team of manned and unmanned vehicles with varied mission systems, aid decisions and actions in order to increase situational awareness, decrease cognitive load, and maximize use of on-board and off-board sensors
• Transition autonomous path planning and closed loop target tracking to the small UAS system in order to reduce operator workload

Products:
• Autonomous behaviors ready for transition to program of record
• Market based planner for manned-unmanned teaming ISR, combat, and cargo missions
• Autonomous real time flight path planning which optimizes sensor performance while providing closed loop tracking for small UAS

Payoff:
• Will enable efficient and more affordable implementation and expansion of autonomy & crew aiding functionality
• Autonomy products will transition to the Synergistic Unmanned-Manned Intelligent Teaming (SUMIT) program
• Improved situational awareness by accessing sensor data across platforms with minimal supervisory effort
• Autonomous target tracking and navigation for small UAS

Schedule

<table>
<thead>
<tr>
<th>MILESTONES</th>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
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<tr>
<td>Contract Awards</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Develop market based multi-UAS mission planner</td>
<td></td>
<td></td>
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<tr>
<td>Develop ISR flight controller / mission mngr</td>
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<tr>
<td>Sensor Guided Flight (SGF) for Raven UAS</td>
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<tr>
<td>Flight Tests</td>
<td></td>
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</tbody>
</table>
Synergistic Unmanned Manned Intelligent Teaming (SUMIT)

Purpose:
Evaluate impact of new autonomy, decision aiding, and human machine interface (HMI) technologies on the air mission commander* (AMC) during the execution of missions that utilize manned/unmanned teaming (MUMT).

Product:
PART 1 – SUMIT Simulation Environment Build
• FORCE Simulation testbed aligned with FACE™ and JCA open systems standards

PART 2 – MUMT Evaluation
• Evaluation methodologies, technical metrics for autonomy, evaluation results, findings & recommendations
• Approaches for mission execution using multi-UAS team, autonomy architectures, component technologies, and technology gaps that remain

PART 3 – Flight Demonstration
• TRL6 component technologies for transition to legacy systems
• Technical documentation on candidate technologies

Payoffs:
• Relevant results to inform requirements & specifications for future acquisition
• Aviation missions with increased mission effectiveness due to advanced MUMT techniques
• MUMT technologies matured in relevant domains for future spiral insertion
• Risk reduction for future technology maturation programs using an open systems standards based simulation environment

* Air Mission Commander as used here can be any Airman with mission command of his MUM Team for a particular aviation task, eg; it could be command of a full Air Assault mission or only the Recon / Attack task under the Air Assault mission.

MILESTONE | FY14 | FY15 | FY16 | FY17 | FY18 | FY19 | FY20 | FY21
--- | --- | --- | --- | --- | --- | --- | --- | ---
SUMIT Part 1
Baseline Sim Req & Dev
Scenario Development
FORCE Sim Design & Bld
SUMIT PART 2
BAA Capability Acq
Integr into FORCE sim
User Evals / Data Analysis
Findings & Recommendations
SUMIT PART 3
Demo Environment
System Integration & Test
Flight Demonstration
Air Launched Effects (ALE)

**Purpose:**
Develop and demonstrate the ability to launch a UAS from an Army rotorcraft at tactical altitudes, and to control the UAS from the cockpit or a crew station. Assess the enabled capabilities, and determine their relevance to current Army Aviation engagement and survivability portfolios.

**Products:**
- Assessment of the aircraft integration impacts, challenges, and requirements
- Flight test of the launch and control of a UAS from an Army rotorcraft, hand off capability, and control of multiple UAS
- Integration of multiple tools into the capability demonstration
- Forward-firing, tube-launched UAS with modular payload capability, suitable for low-altitude launch from Army rotorcraft.

**Payoff:**
- Increased effective range for the reconnaissance of hostile areas
- Understanding of areas of further S&T investment for both airframes and payloads
- Multi-vehicle control allows rapid deployment of various payloads over multiple areas.

### Key Milestones

<table>
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<th>FY17</th>
<th>FY18</th>
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<tr>
<td>Air-launched UAS technology capabilities analysis and assessment</td>
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<tr>
<td>Build UAS systems for flight test</td>
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<td>5</td>
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<tr>
<td>Flight Test: Rotorcraft launch, hand-off, multi-vehicle control</td>
<td>5</td>
<td></td>
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<tr>
<td>Design for Army Specific UAS for forward launch</td>
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<tr>
<td>Integrate with UAS</td>
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<tr>
<td>Ground demonstration of UAS control</td>
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</tr>
<tr>
<td>Flight Test: Rotorcraft launch, forward-firing, multi-payload</td>
<td></td>
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</tbody>
</table>
Advanced Teaming

Purpose:
• Develop and demonstrate advanced teaming of manned and unmanned aviation assets to execute tactical missions, while operating as part of the combined arms combat team in contested environments, with minimal human intervention
• Mission sets: RSTA, Utility, Resupply, Decoy, EW, Protection, Aeromedical Evacuation, and Attack

Products:
• Resilient Autonomy for unmanned Army aircraft with datalink independent capability, fault detection, contingency management, and graceful degradation
• Open systems architecture based systems, data management, and simulation environments. Aligned with FACE and JCA open systems standards
• Flight tested, proven mission systems technologies
• Simulation evaluation methodologies, technical metrics for autonomy, and evaluation results
• Intuitive, easy-to-use Human Systems Interfaces that support multi UAS control
• Shared situational awareness capability – relevant information to and from teammates, at the right time

Payoff:
• Robust multi-UAS teamed operations in contested environments – GPS denied, no network
• Enhanced survivability through shared situational awareness
• Increased aviation team lethality

Elements

<table>
<thead>
<tr>
<th>FY19</th>
<th>FY20</th>
<th>FY21</th>
<th>FY22</th>
<th>FY23</th>
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<td>6</td>
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<td>Non-traditional commercial autonomy approaches</td>
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<tr>
<td>Flight Tests (subsystems and systems assessments)</td>
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<td>Type</td>
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<tr>
<td>6.2/6.3 Advanced Teaming Subsystems Tech Development</td>
<td>Development of autonomous technologies to be transitioned to 6.3 flight demos</td>
<td>BAA</td>
<td>$3M (x3-5)</td>
<td>2\textsuperscript{nd} Qtr FY19</td>
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<tr>
<td>6.3 Mission Systems Integration</td>
<td>Prime system integrator</td>
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<td>FY20</td>
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<td>6.3 Non-traditional commercial autonomy approaches</td>
<td>Relevant COTS technologies</td>
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<td>FY20</td>
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<td>6.3 Platform Integration</td>
<td>Platform provider/integrator</td>
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<td>FY20</td>
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</table>
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Army Aviation S&T Administrative Announcements

Presented by:
William D. Lewis, SES
Director
Aviation Development Directorate
U.S. Army Aviation and Missile Research, Development, and Engineering Center

10 Apr 2018

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- Aviation S&T supports both the current helicopter and future rotorcraft fleets in improving survivability, performance, and affordability
- Current efforts are focused on platforms, power, survivability, vehicle management, and operations support and sustainment
- Future efforts are focused on Future Vertical Lift (FVL)
- Joint Multi-Role (JMR) Technology Demonstrator (TD)
- Focus on Transition to PEO Aviation

AVIATION ENGINEERING DIRECTORATE
- Delegated Airworthiness (AW) Authority
- Systems Engineering
- Aeromechanics
- Propulsion
- Structures and Materials
- Mission Equipment
- Maintenance/Sustainment Engineering
- Foreign Military AW Authority Recognitions

ENGINEERING DIRECTORATE
- Systems Engineering
- Test and Evaluation
- Production Engineering
- Product Assurance
- Configuration Management
- Prototype Integration Facility / Rapid Response
- Logistics Engineering
- Industrial Base Assurance
- Life Cycle Cost Reduction
- Manufacturing Technology
- Reliability and Maintainability Engineering
- Quality Engineering
- Quality Management

WEAPONS DEVELOPMENT & INTEGRATION DIRECTORATE
- Life Cycle Management for DoD missile technology
- Conducts research, exploratory and advanced development, technology demonstration and provide engineering and scientific expertise in all aspects of weapon system design, development, improvement and integration for the Army
- Lead Army agent in the execution of the Missile Science and Technology Enterprise

SYSTEMS SIMULATION, SOFTWARE, & INTEGRATION DIRECTORATE
- Hardware-In-the-Loop (HWIL) Models and Simulations for Aviation and Missile Systems
- Conduct Performance and Effectiveness Evaluations for Aviation and Missile Systems
- Design and Develop Virtual Prototyping Facilities for User Evaluations of Aviation and Missile Applications
- Define and Develop Modeling and Simulation Methods and Technologies for DoD Applications
- Computer Hardware/Software Technology
- Independent Verification and Validation (IV&V)
- Aviation Flight Safety/Airworthiness Software Assessments
- Software Development and Sustainment
- Information Assurance/Cyber Security
- Interoperability Engineering and Test (IET)
- Software Fielding/New Equipment Training
- Configuration and Data Management
- Software Quality Engineering

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- Quality Management

**WEAPONS DEVELOPMENT & INTEGRATION DIRECTORATE**
- Life Cycle Management for DoD missile technology
- Conducts research, exploratory and advanced development, technology demonstration and provides engineering and scientific expertise in all aspects of weapon systems design, development, improvement, and integration for the Army
- Lead Army agent in the execution of the Missile Science and Technology Enterprise

**SYSTEMS SIMULATION, SOFTWARE, & INTEGRATION DIRECTORATE**
- Hardware-in-the-Loop (HIL) Models and Simulations for Aviation and Missile Systems
- Conduct Performance and Effectiveness Evaluations for Aviation and Missile Systems
- Design and Develop Virtual Prototyping Facilities for User Evaluations of Aviation and Missile Applications
- Define and Develop Modeling and Simulation Methods and Technologies for DoD Applications
- Computer Hardware/Software Technology
- Independent Verification and Validation (IV&V)
- Aviation Flight Safety/Airworthiness Software Assessments
- Software Development and Sustainment
- Information Assurance/Cyber Security
- Interoperability Engineering and Test (IET)
- Software Fielding/Field Equipment Training
- Configuration and Data Management
- Software Quality Engineering

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
<table>
<thead>
<tr>
<th>Description</th>
<th>Objective</th>
<th>Type</th>
<th>Est. $</th>
<th>Future Award Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Support - Engineering Services for AMRDEC, AED, Maintenance Division</td>
<td>Provide engineering and technical support, including field and depot liaison engineering support for assigned Army, DOD multi-service aircraft, other government entity aircraft, foreign military aircraft and other DOD programs.</td>
<td>TBD</td>
<td>$9.5M</td>
<td>Apr 2018</td>
</tr>
<tr>
<td>Technical Support - Engineering Services for AMRDEC, AED, Apache Division</td>
<td>Provide systems engineering and technical airworthiness support, including fielded and qualification engineering support for the Apache Attack Helicopter Project Manager's Office (AAH PMO), and to other elements of the Life Cycle Management Center (LCMC).</td>
<td>TBD</td>
<td>$14M</td>
<td>Apr 2019</td>
</tr>
<tr>
<td>Technical Support - Engineering Services for AMRDEC, AED, Aviation Systems Division (Fixed Wing)</td>
<td>Provide airworthiness engineering support to fielded and developmental US Army fixed wing aircraft programs and sustainment support to fielded aircraft currently operating both CONUS and OCONUS.</td>
<td>TBD</td>
<td>$6.5M</td>
<td>Jun 2019</td>
</tr>
<tr>
<td>Technical Support - Engineering Services for AMRDEC, AED, Aeromechanics Division</td>
<td>Lead aviation engineering analyses across the Aeromechanics technical disciplines, apply engineering expertise to enable airworthiness qualification of aircraft and aviation systems, and advocate for aeromechanics solutions that unburden aircraft operators and maintainers and enhance their mission capabilities.</td>
<td>TBD</td>
<td>$42.2M</td>
<td>Aug 2020</td>
</tr>
</tbody>
</table>
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www.amrdec.army.mil

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www.facebook.com/rdecom.amrdec

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Deliver collaborative and innovative aviation and missile capabilities for responsive and cost-effective research, development and life cycle engineering solutions.
Who is AMRDEC?

~9,211
FY17 Strength

2,945
Civilian

16
Military

6,250
Contractor

907 / 5343
SETRA Non-SETRA

Core Competencies

- Life Cycle Engineering
- Research, Technology Development and Demonstration
- Design and Modification
- Software Engineering
- Systems Integration
- Test and Evaluation
- Qualification
- Aerodynamics/Aeromechanics
- Structures
- Propulsion
- Guidance/Navigation
- Autonomy and Teaming
- Radio Frequency (RF) Technology
- Fire Control Radar Technology
- Image Processing
- Models and Simulation
- Cyber Security

FY17
$2,904M

6%
Aviation S&T

7%
Missile S&T

63%
Army

24%
Other

NASA Ames - Moffett Field, CA
Colorado Springs, CO
Joint Base Langley - Eustis, VA
Corpus Christi, TX
AMRDEC HQ
Redstone Arsenal, AL
**#1: Readiness**

Provide aviation and missile systems solutions to ensure victory on the battlefield today.

**#2: Future Force**

Develop and mature Science and Technology to provide technical capability to our Army’s (and nation’s) aviation and missile systems.

**#3: Soldiers and People**

Develop the engineering talent to support both Science and Technology and the aviation and missile materiel enterprise.
PLATT FORMS

- Structures
- Sustainment
- Concept Design & Assessment

MISSION SYSTEMS

- Survivability
- Avionics & Networks

VEHICLE MANAGEMENT & CONTROL AND ROTORS

- Rotors
- Vehicle Management & Control

MAJOR PROGRAM AREAS

- Joint Multi-Role Technology Demonstration
- Degraded Visual Environment – Mitigation
- Next Generation Tactical UAS Technology Demonstration

POWER

- Engines & Other Power Sources
- Drives

BASIC RESEARCH

- Computational Aeromechanics
- Experimental Aeromechanics

AUTONOMOUS AND UNMANNED SYSTEMS

- Autonomy & Teaming
- Human System Interface
Ballistics Test Facility
Ft. Eustis, VA
Component Testing

Countermeasures Test Facility
Ft. Eustis, VA
Signature Characterization of Turbine Engines

Structural Test Facility
Ft. Eustis, VA
Rotor-Blade Test Fixture and Structures Backstop for Loads/Fatigue Testing

14-by-22 Foot Subsonic Tunnel
NASA Langley, VA
Helicopter Aerodynamics, Performance and Configurations

National Full-Scale Aerodynamics Complex
Moffett Field, CA
Advanced Testing of Full Scale Rotorcraft

Large Rotor Test Apparatus
Moffett Field, CA
Full Scale Rotorcraft Component Testing

Tiltrotor Test Rig
NASA Langley, VA
Full Scale Tilt-Rotor Testing
Army Aviation S&T

- ADD S&T supports both the current helicopter and future rotorcraft fleets in improving survivability, performance, and affordability
- Current efforts are focused on platforms, power, survivability, vehicle management, and operations support and sustainment
- Future efforts are focused on Future Vertical Lift (FVL)
  - Joint Multi-Role (JMR) Technology Demonstrator (TD)
  - Focus on Transition to PEO Aviation

Army Aviation S&T balances the needs of the current and future fleets
What informs the portfolio?

1. Stakeholder capability needs and technology objectives (PEO, TRADOC, COCOMs, AMCOM, etc.)
2. 2014 Aviation S&T Strategic Plan (ASSP 2014)
3. Army S&T priorities (ASAALT DASA(RT))
4. DoD priorities (OSD)
5. Future Outlooks (TRADOC)
6. Warfighter Outcomes / Wargaming Exercises
7. Future rotorcraft requirements (JMR TD, FVL)
8. Legacy fleet requirements (PORs)
- From the Aviation Science & Technology Strategic Plan (ASSP) 2014:

- Fly faster and farther while carrying more: fully support all FVL initiative capabilities

- Operate in complex environments

- Develop the next generation of UAS

- Demonstrate mature autonomous decision-making capabilities

- Refine the interface between pilot and aircraft

- Support ultra-reliable designs for no maintenance

- Advance engine & drive configuration technologies that move beyond traditional turbo-shaft engine and power transmission architectures

- Reduce fielding timelines and improve transition time from S&T to the field

- Enhance in-house capabilities: sculpt the government workforce, facilities and equipment to develop diverse in-house capabilities

Legacy fleet sustainment while leading future rotorcraft development!
Technology Maturation
Engine Science and Technology

6.2 COMPONENT DEVELOPMENT
IPS

COMPRESSOR
COMBUSTOR
GG TURBINE
POWER TURBINE
CONTROLS/ACCESSORIES

6.3 ENGINE SYSTEM DEMO
Demonstrator Engine Program (TRL 6)

6.4 ENGINE / COMPONENT QUALIFICATION PROGRAMS
Engineering, Manufacturing and Development (EMD) Program Qualification Efforts

Component Technology for technical insertion to upgrade existing engines

e.g. ITEP qualifies AATE technology

New Engine Qualification to meet new platform requirement

TECHNOLOGY TRANSITION & APPLICATION (PRODUCTION)

DISTRIBUTION STATEMENT A
Approved for public release; distribution is unlimited.
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AMRDEC Directorates

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**AVIATION ENGINEERING DIRECTORATE**
- Delegated Airworthiness (AW) Authority
- Systems Engineering
- Aeromechanics
- Propulsion
- Structures and Materials
- Mission Equipment
- Maintenance/Sustainment Engineering
- Foreign Military AW Authority Recognitions

**ENGINEERING DIRECTORATE**
- Systems Engineering
- Test and Evaluation
- Production Engineering
- Product Assurance
- Configuration Management
- Prototype Integration Facility / Rapid Response
- Logistics Engineering
- Industrial Base Assurance
- Life Cycle Cost Reduction
- Manufacturing Technology
- Reliability and Maintainability Engineering
- Quality Engineering
- Quality Management

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<tr>
<td>Product Assurance Engineering</td>
<td>Provide technical expertise in the application of quality; reliability, maintainability, availability (RAM); and system assessment engineering programs in support of weapon system design, development, production, fielding, and disposal</td>
<td>AMCOM EXPRESS T&amp;M</td>
<td>$50M</td>
<td>January 2019</td>
</tr>
</tbody>
</table>
AMRDEC Web Site
www.amrdec.army.mil

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YouTube
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Air Vehicle Demo (AVD)

Mission Systems Architecture Demo (MSAD)

Purpose:
Demonstrate transformational vertical lift capabilities to prepare the DoD for decisions regarding the replacement of the current vertical lift fleet.

Products:
- Technology maturation plans
- Cost analysis for future capabilities
- Two demonstrator test bed aircraft

Payoff:
- A refined set of technologically feasible and affordable capabilities that enable higher speed, better lift efficiency, lower drag (L/De), and improved Hover Out of Ground Effect (HOGE) at high/hot conditions (6K/95)
- Standards, methods and tools that increase SW reuse and reduce SW costs due to bad requirements (missing, non-consistent, etc.)
- Reduced risk for critical technologies
- Acquisition workforce with improved skill sets to develop specifications and analyze technical data
- Data readily available to support future acquisitions

Technology Roadmap

<table>
<thead>
<tr>
<th>MILESTONES</th>
<th>FY11-16</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
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<td>Air Vehicle Demo (AVD)</td>
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<td>Joint Common Architecture (JCA)</td>
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<td>Arch. Integration Process Demos</td>
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<tr>
<td>Capstone Demo</td>
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Milestone Indicators: ▲ TRL or SRL: ● Significant Activities: ▼
Future procurements characterized by systems with highly cohesive, loosely coupled, and severable modules that can be competed separately and acquired from independent vendors.

**Systematic architectural approach used to describe desired system attributes.**
- Government-led overarching and encompassing approach to architecture definition to leverage competitive forces in the procurement and sustainment of aviation systems
  - Incorporates widely supported and consensus-based standards
  - Relies upon defined modularization, key interface definition, and behavioral specification at the boundary of system components

Future makes efficient use of both models and documentation to describe and convey information in a manner that is unambiguous and complete across organizational boundaries
- Sufficient detail for a given phase of development, and to identify issues and defects in the phase where they are easier and more economical to correct.
- Blending of commercially available, open-source, and industry-developed tooling that makes use of standards to support exchange of information

Future program information is discoverable and knowable.
- Use of repositories that allow the management, discovery and use of system information.
- Enable understanding and analysis in a way that crosses specialties and represents, at any particular point in time, an accurate and complete description of the system
Purpose:
Investigate/Mature processes, tools and standards necessary to specify, analyze, design, implement and qualify a Mission Systems Architecture in support of emerging FVL PoR that meets Army business goals

Approach:
– Leverage or develop the standards and tools necessary to successfully implement a mission systems architecture
– Execute a series of increasingly complex demos - Learn by doing

Focus Areas:
– Implementation of Open Systems Architectures (OSA)
  • Joint Common Architecture (JCA)
  • FACE™ Technical Standard
  • Hardware Open Systems Technologies (HOST)
– Application of Model Based Engineering (MBE)
  • Model-based specification/acquisition
– Execution of an Architecture Centric Virtual Integration Process (ACVIP)
  • Predictive performance assessment
**MSAD Demonstrations**

<table>
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<tr>
<th>FY14</th>
<th>FY15</th>
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</table>

**JCA Demo / ACVIP Shadow**

- **Tasks**
  - Scope limited to single component
  - Model Based Acquisition
  - AADL Modeling / Analysis
  - JCA Model Refinement
  - Lab Integration / Testing
  - Report Generation
  - Process Refinement

**Architecture Implementation Process Demonstrations (AIPD)**

- **Approach**
  - Government defined areas of emphasis and goals related to JCA, FACE™, ACVIP and MBE in general
  - Efforts provide “evidence” of ability to meet USG business and process goals and are relevant to industry and Army aviation PM plans
  - High level of collaboration between USG and industry

**Increasingly complex demonstrations using significant industry participation**

**Mission Systems Architecture Capstone Demonstration**

- **Approach**
  - Implementation of a partial, notional mission systems architecture
  - Multiple vendors
  - Model Based Acquisition
  - ACVIP Modeling / Analysis
  - JCA / FACE Validation
  - Scope of implementation limited by available resources (i.e. design only, limited lab implementation / test, etc.)
• No single initiative is sufficient on its own

• Together, JCA, FACE™, and HOST provide an open, interoperable, and upgradeable framework for the acquisition of embedded software and hardware capability

• Promotes reuse and commonality

A blended approach is necessary to achieve desired level of openness
The Capstone Demonstration is:

- Culminating Science and Technology (S&T) effort extending earlier MSAD efforts such as JCA Demonstration and AIPD
- Not intended to produce a prototype FVL cockpit or mission systems architecture
  - Provide a series of opportunities to evaluate and validate, in a relevant lab environment, various open systems enablers and contributors to the next generation of mission systems architectures
- Learning and understanding is more important than system performance
  - System development provides context around which to exercise larger concepts and previous learning

Purpose

- **Demonstrate technical and business enablers** that result in the efficient development, integration, and modification of aviation mission systems
- Focused on the **implementation of MSAD concepts/enablers** in a manner relevant to future programs using a representative acquisition process that includes aspects of safety assessment, airworthiness qualification and information assurance (IA) accreditation
- Opportunity to implement a **Government-led architecture strategy; model-based acquisition, development and analysis**; and the use of the various **methods and technologies** necessary to develop an open and interoperable mission systems architecture
Capstone Demonstration Description

• Overarching BAA supported by phased, role-specific Calls that outline requirements and evaluation criteria
  – 1 x Architect
  – 1 x JCA Product Developer
  – 4 x Mission System Integrator
  – Suppliers
  – 2 x Single Source of Truth Study Provider

• Period of Performance
  – Jun 2018 – Dec 2020

• Funding
  – $29M of Government available funding

• Description
  – Develop and implement four mission systems architectures for a FoS consisting of attack (ATK) and assault (ASLT) variants derived from a common set of architectural constraints
  – Conduct a series of excursions intended to evaluate the ability of a mission system developed using the MSAD Areas of Emphasis to accommodate high levels of reuse and support efficient development, integration, and modification across the FoS

Not a prototype for any future or current aviation platform…
Operational scenario provides context and operational activities that Capstone Mission Systems perform. Scope of coverage is variable based on vendor’s approach.
Release Schedule

• Overarching BAA (W911W6-18-R-0006) – Released 2/16/18

• Architect Call (W911W6-18-R-0007) – Released 2/16/18

• JCA Product Developer Call (W911W6-18-R-0008) – To be released 4/19/18

• Mission System Integrator Call (W911W6-18-R-0009) – To be released 6/29/18

• Single Source of Truth Study/Demonstration (W911W6-18-R-0010) – To be released 3/8/19

Awards

• Architect - Aug 2018

• JCA Developer – Nov 2018

• MSIs – Jan 2019

• SSoT – Aug 2019
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Mission Systems

Presented by:
Michael Butler
Focus Area Lead
U.S. Army Aviation and Missile Research, Development, and Engineering Center

10 April 2018
Armed Aircraft S&T Focus Areas

**Platforms**
- Structures
- Sustainment
- Concept Design & Assessment

**Mission Systems**
- Survivability
- Avionics & Networks

**Vehicle Management & Control and Rotors**
- Rotors
- Vehicle Management & Control

**Autonomous and Unmanned Systems**
- Autonomy & Teaming
- Human System Interface

**Major Program Areas**
- Joint Multi-Role Technology Demonstration
- Degraded Visual Environment – Mitigation
- Next Generation Tactical UAS Technology Demonstration

**Power**
- Engines & Other Power Sources
- Drives

**Basic Research**
- Computational Aeromechanics
- Experimental Aeromechanics

**Technology Driven. Warfighter Focused.**
Develop / integrate capabilities that enable the warfighter to safely and effectively conduct missions in increasingly complex environments

Technical Areas:
- Avionics and Networks
- Survivability

Payoffs:
- Situational awareness in all environments
- Survivability against advanced threats
- Increased lethality
- Effective use of unmanned systems
- Enhanced team communication, collaboration and performance
- Resilient / reconfigurable platforms

Goal: Increase Mission Effectiveness
Mission Systems Portfolio Emphasis

UAS Survivability Concepts

Survivability Against Integrated and Networked Threats

Advanced Teaming

Integrated Mission Systems for Vertical Lift

Thrust Areas

Architectures
Advanced Decision Making
Human/Machine Interaction
Integration of complex systems
Increased Situational Understanding
UAS and Manned Platform Survivability

Mission Equipment Package

- Vehicle Management
- System Health & Monitoring
- Situational Awareness
- Mission Management
- Infrastructure
- Communications
- Cabin
- Cargo/Payloads
- HMI/Controls/ Displays
- Intelligent Agent
- Navigation Management
- Survivability & Safety
- Sensors & Surveillance
- Weapons/Effects & Engagements

Mission Systems S&T Portfolio supports the Future Vertical Lift CFT and MUM-T, Asymmetric Vision and Decide Faster Thrusts
1. **Fly faster and farther while carrying more:** fully support all FVL initiative capabilities as part of an overall integrated family of systems to include the current fleet, FVL Family of Systems (FoS) aircraft and Unmanned Aerial Systems (UAS)

2. **Operate in complex environments:** beyond just the night, own the weather and other complex environments

3. **Develop the next generation of UAS:** actively engage in the development of the next generation of vertical lift UAS capabilities

4. **Demonstrate autonomy:** mature autonomous decision-making capabilities and confidence to allow traditionally manned missions to become unmanned, and for all systems to operate in complex, denied-link environments

5. **Redefine the interface between pilot and aircraft:** develop adaptive cyber-physical interfaces between the pilot and the aircraft

6. **Balance low- and zero-maintenance:** support ultra-reliable designs for no maintenance over a significant useful life, and optimize selection of maintenance approaches to balance between zero maintenance and rapid, efficient maintenance actions, as part of an overall reduction in required logistics and sustainment costs

7. **Shift the propulsion paradigm:** advance engine/drive configuration technologies that move beyond traditional turbo-shaft engine and power transmission architectures to provide significant changes in platform mission capability

8. **Reduce fielding timelines:** improve transition time from S&T to the field by enabling shorter certification durations and contributing to improvements in the airworthiness certification process

9. **Enhance in-house capabilities:** sculpt the government workforce, facilities and equipment to develop diverse in-house capabilities

* Thrust areas red are thrust areas in currently addressed within the Mission Systems Portfolio
Assess, develop and / or integrate new or improved COM / NAV / IFF, controls, displays, general purpose processors, data buses and associated software on army aviation platforms

Capabilities and Experience:

- Open Systems Architectures
  - Hardware and software OSA standards
  - Tools, Processes, and procedures
- Computer Processing and Operating Environments
- Antenna Technologies and RF Subsystems
- Networks and Interoperability
- Communications and Navigation
- Multi Level Security and Cyber Security
- Anechoic Chamber (full EMI/limited Antenna ranges)
- Computational Electromagnetic Modeling Software
- Impedance Match and Antenna Coupling
- Vector Network Analyzer (30 kHz – 7 GHz)
- Mobile Communications Test Vehicle
**Integrated Mission Equipment for Vertical Lift Systems**

**Purpose:**
- Investigate, develop and demonstrate an architectural approach that enables innovation, integration and continuous improvement of mission systems agnostic of the air platform.
- Demonstrate an agile and resilient digital backbone for multiple complex mission sets in a rapidly changing threat environment including the digital battlefield.
- Identify and mature Model Based Engineering (MBE) methods to keep up with massive growth of system complexity due to highly integrated & software intensive systems.

**Products:**
- Reconfigurable and flexible tiered architectures for integrated mission systems.
- Flying testbed with a open architecture based mission system for Future Mission Systems S&T efforts.
- Digital Backbone definition / description.
- Agile Cybersecurity and Airworthiness approaches.
- MBE methodologies for lifecycle system management.
- Open architecture laboratory with an Architecture Verification Environment (AVE) for use by other S&T efforts.

**Payoff:**
- Matured architectural strategy for future aviation mission systems.
- Flight tested platform agnostic mission system developed to open system architecture principles.
- Demonstrated MBE methods to keep up with massive growth of complexity for highly integrated & software intensive systems.
- Digital Backbone implementation for agile mission systems that can outpace emerging physical and cyber threats.

**Task FY19 FY20 FY21 FY22 FY23 FY24**

<table>
<thead>
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<th>TASK</th>
<th>FY19</th>
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<td>Architecture Impact Studies</td>
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<td>Identify Mission Systems Capabilities</td>
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<td>Architecture Verification Environment</td>
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<td>Procure Capabilities</td>
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<td>Digital Backbone Core Capabilities</td>
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<td>IME Demo</td>
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<td>Govt Architecture Dev Requirements Design/Build Integration/Test Lab/Flight Demos</td>
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**IME will provide the foundation to ensure capability overmatch in the multi-domain battlespace**
Survivability TA

Background:

- Threats are increasing significantly in capability/lethality
- Current aircraft survivability concepts, structured around federated systems approach to survivability and mission effectiveness, are not effective in the future vertical lift threat environment

Areas of Emphasis:

1. ASE & signature management capabilities
2. Vulnerability reduction technologies
3. Decision making capabilities (holistic situational awareness, real-time route planning, autonomy and teaming for survivability)
4. Enhancing modeling and simulation
5. Evaluating survivability in threat environment
6. Integration approach / architecture

Develop and demonstrate holistic survivability capabilities to address advanced integrated and networked threat environment
We have significant challenges in equipping our fleet to fight and prevail in the new air defense environment.

Adversaries are investing in and proliferating air defense systems that will continue to challenge our ability to maintain combat overmatch.

Russia Exporting Advanced MANPADS

Advanced Millimeter Wave (mmw) Threats Challenge Legacy ASE

Peer Competitors Exporting Advanced Long-range SAMS

Advanced Attack Helicopters Able to Engage Our Aircraft

Developing directed energy threats to aviation

We have significant challenges in equipping our fleet to fight and prevail in the new air defense environment.
### Purpose:
- Adversarial aviation threat evolution is outpacing DOD’s ability to develop and field tailored, threat specific defensive technologies. The SAINT program will explore, develop and demonstrate an enhanced survivability capability to avoid, deceive or defeat adversarial integrated and networked threat systems.

### Products:
- Develop survivability technologies to avoid, deceive or defeat adversarial integrated and networked threat systems
- Demonstrate survivability decision making behaviors
- Demonstrate system as part of an integrated survivability suite
- Develop and demonstrate a team based approach to aircraft survivability

### Payoff:
- Assured aviation survivability in emerging threat environments
- Transitions to current and future vertical lift

### Schedule & Funding

<table>
<thead>
<tr>
<th>Elements</th>
<th>FY18</th>
<th>FY19</th>
<th>FY20</th>
<th>FY21</th>
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<td>6.3 SAINT</td>
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<td>Req Dev for Surv against Int. Threat Sys</td>
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<td>Dev component tech</td>
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<td>Develop Ownship /Team Behaviors</td>
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<tr>
<td>Develop Survivability Correlator</td>
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<tr>
<td>Platform Integration</td>
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<tr>
<td>SIL, Flight Demos</td>
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</table>

- **Big 6+1:** Future Vertical Lift & Advanced Protection
  - AWFC: 1, 2, 7, 11, 12, 13, 15, 16

**Key Events**

- Award Dates

**TRL**

- # Technology Readiness Level
**Purpose**
Demonstrate team based aviation survivability in an advanced IADS environment through a multi-layered approach.

**Products**
**Integrated Technologies**
- Full spectrum susceptibility and vulnerability reduction
- Seamless high fidelity team based survivability planning
- Multifunction defensive weapons capability
- Cyber security

**Leveraging**
- SAINT – Team based survivability
- Advanced ASE and Expendables (CERDEC/ARDEC/NRL)
- Signature Management (ARL/AMRDEC)
- Multifunction Weapons (ARDEC)

**Payoff**
- Increased survivability of warfighter & team aircraft against robust spectrum of threats
- Transitions to FTAUS and FVL

---

### Schedule & Funding

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<tr>
<th>Elements</th>
<th>FY19</th>
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<tbody>
<tr>
<td>6.2 Advance Surv Concepts</td>
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<td>6.3 Integrated Survivability</td>
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<td>Team Based Planner Req</td>
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<td>E2E and Sensor Planner Dev</td>
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<td>Design and Implement Team Arch for Surv</td>
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<td>Lab Integration</td>
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<td>E2E T-Based Surv Planner Lab Demo</td>
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<td>Full Spectrum Surv Req</td>
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<td>SR and VR Tech Development</td>
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<td>SIL Integration and Demo</td>
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<td>Flight Demo and Evaluation</td>
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</table>

**Milestone Indicators:**
- TRL or SRL:
- Significant Activities:

**Award Dates**

---

**Big 6+1: Future Vertical Lift & Advanced Protection**
AWFC: 1, 2, 7, 11, 12, 13, 15, 16
## FY17 FY18 FY19 FY20 FY21 FY22 FY23 FY24 Payoffs

<table>
<thead>
<tr>
<th>JCA</th>
<th>Integrated Mission Equipment for Vertical Lift</th>
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<tbody>
<tr>
<td></td>
<td>• Resilient, Agile MEP Arch</td>
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<td></td>
<td>• Reduced MEP integration time</td>
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<td>• Increased Mission Effectives</td>
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</table>

<table>
<thead>
<tr>
<th>DVEM</th>
<th>Advanced Surv Concepts</th>
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<tbody>
<tr>
<td></td>
<td>Reduced Aircraft Loss Rates &amp;</td>
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<tr>
<td></td>
<td>Increased Mission Effectiveness Through:</td>
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<td></td>
<td>• Increased CM Effectives</td>
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<td></td>
<td>• Increased Battlespace Awareness</td>
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<td></td>
<td>• Team Based Survivability</td>
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<td>• Decreased Decision-making time line</td>
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<td>• Optimized Man/Machine Perf.</td>
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<td>• Operational Availability</td>
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<table>
<thead>
<tr>
<th>SRAT</th>
<th>ROSAS Survivability Against Integrated &amp; Networked Threats</th>
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<tbody>
<tr>
<td></td>
<td>Develop decision making capability for defensive engagements during man/unmanned team operations in an advanced threat environment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UAS Survivability Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop and demonstrate Unmanned Aerial System (UAS) with mission tailored survivability capabilities that enable operations in contested environments against advanced threats.</td>
</tr>
</tbody>
</table>

### Portfolio Supports
Future Vertical Lift: CS1, CS3, AUAS
6.2 UAS Survivability Concepts

Purpose:
- Develop and demonstrate Unmanned Aerial System (UAS) with mission tailored survivability capabilities that enable operations in contested environments against future peer/near peer threats.

Products:
- Holistic UAS survivability principles including:
  - Tailored signature management for UAS missions
  - Survivability-enhanced mission profiles
  - Team-based survivability behaviors
  - Resilient systems and architectures

Payoff:
- Survivable UAS systems in contested environments
- Informs new control station concepts
- Informs Tactics, Techniques and Procedures

Schedule & Funding

<table>
<thead>
<tr>
<th>Elements</th>
<th>FY21</th>
<th>FY22</th>
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</thead>
<tbody>
<tr>
<td>UAS susceptibility/vulnerability system analysis</td>
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<tr>
<td>Damage tolerant systems components</td>
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<tr>
<td>Development of mission tailored Sig management</td>
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<tr>
<td>EW Resilient UAS Architecture</td>
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<tr>
<td>Lab and SIL Demonstration</td>
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Big 6+1: Future Vertical Lift & Advanced Protection
AWFC: 1, 2, 7, 11, 12, 13, 15, 16
<table>
<thead>
<tr>
<th>Description</th>
<th>Objective</th>
<th>Type</th>
<th>Est. $</th>
<th>Future Award Date</th>
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<tbody>
<tr>
<td>6.3 Integrated Mission Systems, Comprehensive</td>
<td>Perform analysis on development, exchange, analysis, and management of</td>
<td>BAA</td>
<td>$500K (Initial Award)</td>
<td>2nd Qtr FY19</td>
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<tr>
<td>Model Vision</td>
<td>disparate modeling tools and methods between govt approaches [ACVIP] and</td>
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<td>corporate systems engineering processes/state of the art</td>
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<tr>
<td>6.2 Advanced Survivability Concepts</td>
<td>Exploration and initial development of aircraft survivability decision</td>
<td>VLC OTA</td>
<td>$1-2M</td>
<td>2nd Qtr FY19</td>
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<td>making capabilities to address Army aviation team-based operations in</td>
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<tr>
<td></td>
<td>an integrated air defense system environment</td>
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<tr>
<td>6.3 Survivability Against Integrated and Networked Threats</td>
<td>Develop survivability technologies to avoid, deceive or defeat</td>
<td>BAA</td>
<td>$900K (Initial Award)</td>
<td>2nd Qtr FY19</td>
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<td>adversarial integrated and networked threat systems (topic call being</td>
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<td>developed)</td>
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Next Generation Tactical UAS Technology Demonstration Program (NexGen TUAS TD)

Presented to: AMRDEC Industry Days

10 April 2018

Presented by:
MAJ Michael Osmon
Experimental Test Pilot
U.S. Army Aviation and Missile Research, Development, and Engineering Center
Army Aviation S&T Focus Areas

Platforms
- Structures
- Sustainment
- Concept Design & Assessment

Mission Systems
- Survivability
- Avionics & Networks

Vehicle Management & Control and Rotors
- Rotors
- Vehicle Management & Control

Autonomous and Unmanned Systems
- Autonomy & Teaming
- Human System Interface

Major Program Areas
- Joint Multi-Role Technology Demonstration
- Degraded Visual Environment – Mitigation
- Next Generation Tactical UAS Technology Demonstration

Power
- Engines & Other Power Sources
- Drives

Basic Research
- Computational Aeromechanics
- Experimental Aeromechanics

Technology Driven. Warfighter Focused.
Army Aviation used for three primary functions in support of ground maneuver:
- Find things
- Kill things
- Move Things (Troops and Cargo)

Conditions are changing. Where is the technology to provide overmatch to maintain lethality in contested domain warfare?

Future Vertical Lift (FVL) Cross Functional Team (CFT)
- Innovative, agile, and working things in parallel to transition technology and deliver capability to the warfighter
- Vision for future Army Aviation
  - Optimized and lethal in full scale combat operations at extended ranges
  - Reach (speed range, endurance), protection, and is adaptable
  - Holistic situational awareness to reduce human operator workload
  - Mature autonomous decision making
  - Support ultra-reliable designs and maintenance-free operating areas
  - Cost considerations are paramount
• AUAS identified as key Line of Effort for FVL CFT
  – Purpose Built with multiple form factors; not “one-size-fits-all”
  – Key attributes that allow operation in contested airspace / C-IADS
    • Low Observable
    • Survivable or throw away
    • Swarming
    • Runway independent
    • Deliver targeting information to lethal fires (to include LRPF)
    • Non-lethal effects (e.g. Electronic Attack)
    • Stimulate, spoof, jam, hunt, and kill radars

• AUAS forms advanced team with Attack/Recon helicopter
  – Deepen interoperability between ground force and fires team to detect threats, deliver effects, and assess effects
Future UAS must be capable of...
...performing a diverse set of missions...
...in contested airspace...
...against near-peer adversaries...
...on a multi-domain battlefield.

Multi-role UA family with advanced autonomy, delegated control, and decision aiding

Operational parity with future manned fleet for advanced teaming; holistic survivability

Expected capabilities include:
• Expeditionary maneuver and mobility
• Runway independent, confined areas
• Unassisted takeoff and landing, 4k/95F
• Assured PNT; Degraded weather
• Highly maneuverable; Terrain flight capable
• Soldier maintainable in austere conditions

Expanded mission sets include: electronic warfare (EW), counter integrated air defense (C-IAD), armed reconnaissance, intelligence, surveillance, attack, and communications relay

The Next Generation Tactical Unmanned Aircraft System Technology Demonstration program (NexGen TUAS TD) is a Science and Technology (S&T) effort supporting the development of a Future UAS (FUAS) for a PEO-Aviation Program of Record
• S&T focus is to mature and demonstrate air vehicle technologies that overcome key barriers to desired FUAS performance, survivability, and reliability
Baseline Roadmap

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**Air Vehicle Tech Demo**

- **Concept Study**
  - Refine employment concepts and desired platform capabilities
  - Define the available trade space
  - Draft MPS used for conceptual designs in CDTA

- **Configuration Trades and Analysis**
  - Conceptual design of vehicle configurations
  - Assess concepts and effects of technology insertion
  - Determine critical enabling technologies for a technology demonstration

- **Design, Build, and Fly**
  - **BAA**
    - Design, fabricate and test advanced UAS air vehicle(s) enabling technologies
    - Technology characterization
    - Value and readiness assessments
  - **CDR**
  - **First Flight**

- **Tools Development**
  - Decision support tools
  - Design and analysis tools
  - Cost models

**Legend:**
- **Set of S&T Activities that build to transition point**
- **Key Events**
- **# TRL**
Phase 1 Concept Study

This study is aimed at understanding the effects that certain potential requirements or capabilities (Topics, below) would have on the following unmanned air vehicle (UAV) properties: Size (empty weight, operating weight, installed horsepower, operating dimensions, etc.), System performance, Survivability / vulnerability, Reliability, maintainability and reparability, Downwash / outwash, Transportability, Unit cost, Operations and sustainment (O&S) cost, and Aircraft airworthiness qualification implications.

PoP: 7 months (Q1FY18 to Q3FY18) – **Study results to be out-briefed 22-24 May 2018**

Teams: 5 teams, administered through the Vertical Lift Consortium (VLC) Other Transactions Agreement (OTA)

Topics:
1. Launch and Recovery Methods: Assisted through VTOL
2. Design Sensitivities and Trade-offs: Performance, Cost, SWaP
3. Autonomy / AI
4. Adverse Weather Capabilities
5. Advanced Teaming Concepts

* Indicates Team Lead/Prime
The purpose of the NexGen TUAS TD Phase 2 Conceptual Design and Technology Assessment (CDTA) is to:

- **Size the Concept** - Provide size, weight, cost, and performance information to inform requirements
- **Map the Route** - Show promising approaches to meet desired capabilities & attributes
- **Estimate the TRL** - Quantify technology readiness
- **Bound the Program** - Establish credible cost, schedule and technical performance parameters
- **Describe the Vehicle** - Define an objective aircraft
- **Enable the Development** - Identify capability enabling technology demonstrations
Industry Opportunities

- **FUAS Concept Studies – FY17/18**
  - Answer operational and technical study questions regarding current state of the art and emerging technologies in key areas
  - Develop and validate new operational concepts, including challenging performance objectives (help define the trade space)

- **FUAS Conceptual Design and Technology Assessment – FY18-19**
  - RFP 3QFY18, Award 4QFY18, ~12 mo PoP
  - Generate and mature feasible conceptual+ designs for Objective FUAS
  - Identify critical technologies required to achieve design/performance objectives

- **NexGen TUAS Technology Demonstration – FY19-23**
  - Competitive award(s) to design, build, demonstrate key enabling air vehicle technologies
  - Informed by Configuration Trades
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Platforms S&T: Sustainment & Structures

Presented by:
Nate Bordick
Aviation Development Directorate
U.S. Army Aviation and Missile Research, Development, and Engineering Center

10 April 2018
Army Aviation S&T Focus Areas

MAJOR PROGRAM AREAS
- Joint Multi-Role Technology Demonstration
- Degraded Visual Environment – Mitigation
- Next Generation Tactical UAS Technology Demonstration

PLATFORMS
- Structures
- Sustainment
- Concept Design & Assessment

MISSION SYSTEMS
- Survivability
- Avionics & Networks

Vehicle Management & Control and Rotors
- Rotors
- Vehicle Management & Control

Autonomous and Unmanned Systems
- Autonomy & Teaming
- Human System Interface

Basic Research
- Computational Aeromechanics
- Experimental Aeromechanics

Power
- Engines & Other Power Sources
- Drives
Army’s #1 Priority is Readiness:
“making sure we are ready to deploy, fight and win against a high-end threat, tonight” (Army Secretary Esper)

Sustainment & Structures S&T Focus:
Develop and apply capability enhancing technology solutions that improve the readiness of the future family of vertical lift aircraft
- Unsustained operation in the multi-domain battle space
- Rapid and agile aviation sustainment
- Increased aircraft performance
- Uncompromised reliability and integrity
- Affordable life cycle cost

Optimized balance of Maintenance Free Operating Period, Operational Availability, Aircraft Performance and Affordability
**Vision:**
Revolutionary change in aviation sustainment that enables extended periods of unsustained operation in the multi-domain battle space along with a rapid and agile sustainment capability.

**Major Identified Gaps:**
- Current rotary-wing platforms require continual maintenance and fall short of desired readiness.
- Complex logistics footprint inhibits rapid deployment and agile battlefield sustainment.
- Near-peer adversaries add risk to front-line sustainment.
- O&S dominates the life cycle costs.

**Technical Focus:**
- *Zero-maintenance* paradigm shift.
- Integrated, durable, tolerant, reliable design.
- Aircraft & fleet health state awareness.
- Adaptive aircraft & enterprise systems.
- Integrated sustainment concept.

---

**Sustainment Technology**

- Ultra-Reliable Design
- Holistic Health State Awareness
- Adaptive Aircraft & Maintenance
- Agile Sustainment Construct

---

**DISTRIBUTION STATEMENT A**
Approved for public release; distribution is unlimited.
**Vision:**

Rotary-wing platform rotating and non-rotating structures must provide *lightweight, durable, and reliable* performance and operate in extreme environments, damaging conditions and high op-tempo scenarios.

**Major Identified Gap:**

Current rotary-wing platforms fall short of desired performance (range & payload), durability, invulnerability, and operational availability.

**Technical Focus:**

- Durable, damage tolerant and repairable structures
- Enhanced structural weight efficiency
- Multifunctional and adaptive structures
- Crash energy attenuation
- Improved stress and load prediction accuracy
- Fast, accurate design and analysis methods
- Affordable structures and manufacturing
Sustainment S&T:

- **6.2 Rotorcraft Automated Component Tracking (RACT)**
  - Objective: develop autonomous configuration management and aviation records
  - Status: announcement closed, award planned for June 2018

- **6.3 Future Embedded Rotorcraft Sustainment Technologies (FERST)**
  - Objective: demo integrated aircraft solution to enable extended periods of unsustained operation
  - Status: announcement closed, phase 1 award(s) planned for July 2018

Structures S&T:

- **6.2 Analytical Tools for Aeromechanical Load Assessment (ATALA)**
  - Objective: develop tools capable of predicting internal rotorcraft structural loads and stresses
  - Status: announcement closed, award made September 2017

- **6.2 Adaptive Biomimetric Aircraft Structures (ABAS)**
  - Objective: develop adaptive structures that improve performance without compromising integrity
  - Status: announcement closed, award(s) planned for May 2018

- **6.3 Aircraft and Aircrew Protection (A&AP)**
  - Objective: demo effective total survivability without decreasing aircraft performance
  - Status: announcement closed, phase 2 award made September 2017
Sustainment S&T:

- **Partnership Intermediary Agreement (PIA): Science of Integrated Sustainment**
  - Workshop 1 (March 2018) - inform integrated sustainment requirements for FVL; refine Army Aviation’s Zero-Maintenance S&T Strategic Plan; develop a robust strategy for implementation
  - Workshop 2 (Summer 2018) - TBD

Structures S&T:

- **Rotorcraft Structural Integrity Program (RSIP)**
  - **MIL-STD**
    - Completed draft v5x
    - Published MIL-STD Standard Practice this summer
    - Revision A planned within next couple years
Sustainment S&T:

- No new business opportunities planned through FY19

Structures S&T:

- No new business opportunities planned through FY19
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Army Aviation S&T Focus Areas

**Platforms**
- Structures
- Sustainment
- Concept Design & Assessment

**Mission Systems**
- Survivability
- Avionics & Networks

**Vehicle Management & Control and Rotors**
- Rotors
- Vehicle Management & Control

**Autonomous and Unmanned Systems**
- Autonomy & Teaming
- Human System Interface

**Major Program Areas**
- Joint Multi-Role Technology Demonstration
- Degraded Visual Environment – Mitigation
- Next Generation Tactical UAS Technology Demonstration

**Power**
- Engines & Other Power Sources
- Drives

**Basic Research**
- Computational Aeromechanics
- Experimental Aeromechanics

**Technology Driven. Warfighter Focused.**
Explore, develop and transition critical engine, drive system, and other power technologies that enhance the effectiveness of Army Aviation.

Objectives:

- Improve the power-to-weight ratio, specific fuel consumption, durability, reliability, maintainability and cost of engines & other power sources
- Improve the weight, noise, durability, maintainability and cost of rotorcraft drives and power transmission systems

Payoffs:

- Increased mission radius/endurance
- Increased payload capability
- Significant O&S cost savings
- Decreased maintenance downtime
- Increased readiness / OPTEMPO
- Reduced crew fatigue
Provides Superior Mission Capability for Current and Future Rotorcraft

- Enables Effective High / Hot Operation
- Improved Speed / Range / Payload
- Improved Time-on-Station / Loiter
- Improved Rate-of-Climb Capability

GAPs Addressed: FOC -04-02: Effective Aviation Operations in the Contemporary Operating Environment
FOC -08-02: Enable Theatre Access

Provides for Energy Efficiency / Significant O&S Cost Reduction for Rotorcraft

- Reduced Logistics Footprint
- Reduced Production & Maintenance Costs
- Improved Sand Tolerance / Durability

GAPs Addressed: FOC -04-01: Responsive & Sustainable Aviation Support
FOC -09-04: Readiness, Reliability, Maintainability, and Commonality for Sustained Operational Tempo

Key Demonstrations / Transition:

PE 63003, Project 447, Task 4: Advanced Affordable Turbine Engine: (FY08-FY14):
Transitioned to ITEP FY16

PE 63003, Project 447, Task 3: Future Affordable Turbine Engine: (FY12-16):

PE 63003, Project 447, Task 7: Alternative Concept Engine: (FY17-21):
Reliable Advanced Small Power Systems (FY17-22)

Future Engine Attributes
Wide-Operating Range Efficiency
High Specific Power
Intelligent / Adaptive Features

Future Vertical Lift, Future UAS, and Current Force Upgrades

DISTRIBUTION STATEMENT A
Approved for public release; distribution is unlimited.
Army Engine S&T Roadmap

Integral Part of Versatile Affordable Advanced Turbine Engine (VAATE) Program

FY12 | FY13 | FY14 | FY15 | FY16 | FY17 | FY18 | FY19 | FY20 | FY21 | FY22 | FY23
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---

ARL Engine Component Technologies

- Shaped Cooling Holes
- CMAS Resistant TBCs
- D-Strut™ Rotor Support
- Advanced Turbine Cooling

High Efficiency Engine Component Technologies

- Highly Loaded, 3-D Axial Compressor
- Hybrid Turbine Engine Concept Assessments
- Future Advanced Combustor Technology
- Alternative Engine Conceptual Design & Analysis

AATE

Future Affordable Turbine Engine (FATE)

- Full Engine Demo

Advanced Concept Engine Components

- Rotorcraft Advanced Engine Integrated Controls System
- Smart Adaptable Efficient Filtration System
- Adaptive Vertical Lift Engine (AVLE) Conceptual Design & Analysis
- Platform Integrated Energy Management Tech

Advanced Variable Speed Power Turbine

Advanced High Perf Engine Components

- Reliable Advanced Small Power Systems
- Future Vertical Lift / FUAS / Current Force Upgrades

Improved Turbine Engine / Future Vertical Lift

Integral Part of Versatile Affordable Advanced Turbine Engine (VAATE) Program

DISTRIBUTION STATEMENT A
Approved for public release; distribution is unlimited.
Provides improved horse power to weight capability
Provides multi-speed capability
Provides reduced O&S costs
Provides improved oil-out time, component life, and diagnostic capability

Key Demonstrations / Transition: PE 63003, Proj. D313

Future Advanced Rotorcraft Drive System (FARDS):
- Provides the designers of the aircraft drive train a wide variety of validated approaches for significantly improving Hp/wt, reducing noise and cost versus the existing fleet.
- Approaches encompass advances in gearing, lubrication, housings, bearings and shafting and materials
- Transitions to UH-60 and Future Vertical Lift (FVL)

Next Gen Rotorcraft Transmission:
- Provides multi-speed, multi-engine drive train technology for slowed rotors enabling higher aircraft speeds and improved efficiency for FVL-M aircraft.
- Approaches encompass advances in materials for lighter-weight systems for conventional and non-conventional configurations
- Transitions to Future Vertical Lift
### Rotorcraft Drives S&T Roadmap

<table>
<thead>
<tr>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
<th>FY20</th>
<th>FY21</th>
<th>FY22</th>
<th>FY23</th>
<th>FY24</th>
<th>FY25</th>
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<tbody>
<tr>
<td>6.1/6.2</td>
<td>VLRCOE– Lubrication Models &amp; High Ratio Concepts</td>
<td>Robust, Failure Averse Tribological Interfaces</td>
<td>Disruptive Tribological Materials</td>
<td>Liquid Lubricant-Free Interfaces</td>
<td>Non-Steel Gears</td>
<td>Hybrid and Electric VTOL Propulsion</td>
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<tr>
<td></td>
<td>Gear and Bearing Loss of Lubrication</td>
<td>ARL Drives Laboratory</td>
<td>Magnetic Gears</td>
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<tr>
<td>Ongoing Efforts:</td>
<td>Advanced Variable Speed Transmission</td>
<td>Corrosion Resistant Gears</td>
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<tr>
<td></td>
<td>Multi-Speed Modeling</td>
<td>Multi-Speed Preliminary Designs</td>
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<tr>
<td></td>
<td>Advanced Materials (Integral Bearings/Gas Quenching)</td>
<td>Fully Ceramic Bearings</td>
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<td></td>
<td>Lightweight Generator for Multi-Speed</td>
<td>High Hardness CRES (Bearings &amp; Shafts)</td>
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<tr>
<td><strong>VLC Drive System Technology Development</strong></td>
<td>Pericyclical Transmission, Multi-Speed Clutches, Gearbox Noise Models/Tools, Loss of Lubrication Performance Models, Advanced Gear Coatings for Loss of Lubrication Performance</td>
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<tr>
<td><strong>Future Advanced Rotorcraft Drive System</strong></td>
<td>Future Advanced Rotorcraft Drive System (FV- X)</td>
<td>UH-60, &amp; FVL</td>
<td>Next Generation Rotorcraft Transmission (NGRT)</td>
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</tbody>
</table>

**DISTRIBUTION STATEMENT A**
Approved for public release; distribution is unlimited.
• No solicitations for 6.2 or 6.3 engine or drive system S&T new starts planned in FY18 and FY19

• One Drive Systems 6.3 S&T program entitled “High Reduction Ratio Transmission” is tentatively planned to be solicited in Mid-FY20 for FY21 award
AMRDEC Web Site
www.amrdec.army.mil

Facebook
www.facebook.com/rdecom.amrdec

YouTube
www.youtube.com/user/AMRDEC

Twitter
@usarmyamrdec

Public Affairs
AMRDEC-PAO@amrdec.army.mil
Purpose:
- Develop a high power density transmission capable of an 60:1 reduction ratio within two stages (current technology requires 3 or 4 stages) for increased operational capability of future Army aircraft.

60:1 ratio in two stages
65% increase in power density

Products:
- Demonstration of a reliable, high power density, high efficiency transmission capable of an 60:1 speed reduction ratio within two stages to a TRL6 for application to CAB-sized UAS (scalable to FVL Cap Set 1 sized aircraft)
- Demonstration of additive manufacturing capability for UAS rotorcraft transmission components

Payoff:
- Increased HP/Wt provides increased payload and range capability
- Reduced part count provides cost reduction and increase in reliability
Presented at:
AMRDEC Industry Days

Systems Simulation, Software and Integration (S3I)

Presented by:
Jeffery Langhout, SES
S3I Director
Aviation Engineering Directorate
U.S. Army Aviation and Missile Research, Development, and Engineering Center

10 Apr 2018

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.
S3I develops and delivers responsive aviation and missile total life cycle cyber, software, protective technologies, and systems simulation engineering to enable readiness and ensure modernization of the United States Army to optimize joint warfighter capabilities at the point of need.
Provisional S3I Structure

- Senior Technical Advisor for System Security Engineering
- Senior Technical Advisor for Systems
- RDMR-SI
  - S3I
  - Director, Deputy Director
- Business Transformation Office
  - IT / IA
- Business Division
  - Lifecycle Software Engineering
  - Software Mission Assurance
  - Modeling / Simulation
  - Matrix Support
  - HWIL / Virtual Simulator
  - System Security
- Total Population: 611
<table>
<thead>
<tr>
<th>Description</th>
<th>Objective</th>
<th>Type</th>
<th>Est. $</th>
<th>Future Award Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation and Unmanned Aviation Systems Engineering and Analysis TORFQ 2017T-17</td>
<td>To perform engineering analysis under the full range of Aviation and Unmanned Systems operational environments. Analysis will encompass data derived from requirements, ground and flight tests, simulation results, and actual combat operations.</td>
<td>TBD</td>
<td>$220M</td>
<td>Jun 2018</td>
</tr>
<tr>
<td>System Simulation and Development Directorate Modeling and Simulation Experimentation TORFQ 2017T-8</td>
<td>Apply modeling and simulation techniques, technologies, integration and experimentation through all phases of current and future customer developed systems.</td>
<td>TBD</td>
<td>$390M</td>
<td>Jun 2018</td>
</tr>
<tr>
<td>DEVELOPMENT, OPERATIONS, MAINTENANCE AND SUPPORT (DOMS) - AVIATION AND AERODYNAMIC TECHNOLOGY ELEMENT SIMULATION (AATES)</td>
<td>To Enhance and maintain current missile modeling simulations, aviation and Aerodynamic Technology facilities.</td>
<td>TBD</td>
<td>$185M</td>
<td>Jun 2018</td>
</tr>
<tr>
<td>Description</td>
<td>Objective</td>
<td>Type</td>
<td>Est. $</td>
<td>Future Award Date</td>
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<tr>
<td>Weapons Systems Development, Analysis and Simulation Support-Tactical Missile Systems TORFQ 2017T-16</td>
<td>Provide technical expertise in support of weapon systems development and analysis of tactical missile systems, close-in area defense missile systems, and survivability systems. This analysis and support will primarily utilize modeling and simulation development, missile component modeling, environmental modeling, simulation execution, Verification, Validation and Accreditation (VV&amp;A), system/subsystem and component testing, Independent Verification and Validation (IV&amp;V) of weapon system software/firmware, static analysis and data rights analysis of software and firmware, target and terrain modeling and signature development, scene generation development, development of tools to perform the analysis and configuration management of hardware and software products required to conduct and document analysis. Analysis shall be performed at the component, subsystem, and system level for all phases of the acquisition life cycle which includes the conceptual design phase through product improvements for the full range of missile system operational environments.</td>
<td>T&amp;M</td>
<td>$147M</td>
<td>Mar 2018</td>
</tr>
</tbody>
</table>
• All current contracts will remain in place.

• All RFPs that have been released and are under evaluation or being prepped for evaluation will proceed as planned.

• Future efforts that have NOT already been released to ACC-R are under review for simplification across the formation.
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Vehicle Management & Control (VM&C) and Rotors Focus Area Portfolio

DISTRIBUTION STATEMENT A.
Approved for public release. Distribution is unlimited.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Presented by:
Mark V. Fulton
Focus Area Lead
U.S. Army Aviation and Missile Research, Development, and Engineering Center

10 April 2018
Outline

- Mission / Scope
- Technology Development Plans
- Business Opportunities
- Summary / Questions
Army Aviation S&T Focus Areas

**Platforms**
- Structures
- Sustainment
- Concept Design & Assessment

**Mission Systems**
- Survivability
- Avionics & Networks

**Vehicle Management & Control and Rotors**
- Rotors
- Vehicle Management & Control

**Autonomous and Unmanned Systems**
- Autonomy & Teaming
- Human System Interface

**Major Program Areas**
- Joint Multi-Role Technology Demonstration
- Degraded Visual Environment – Mitigation
- Next Generation Tactical UAS Technology Demonstration

**Power**
- Engines & Other Power Sources
- Drives

**Basic Research**
- Computational Aeromechanics
- Experimental Aeromechanics

**Technology Driven. Warfighter Focused.**
Facilities & Capabilities

- Subject Matter Expertise in Flight Control Design and Optimization, UAVs and Autonomy including Obstacle Field Navigation (OFN) and Safe Landing Area Determination (SLAD), Flight Mechanics Modeling and Simulation, Handling Qualities Requirements Development, System Identification, Wind Tunnel and Flight Testing, Active Rotor Technology, and Rotor Blade Durability Technology

- Analytical Tools and Simulation Software
  - CIFER® Comprehensive Identification from FrEquency Responses
  - CONDUIT® CONtrol Designer's Unified InTerface
  - RIPTIDE Real-time Interactive Prototype Technology Integration/Development Environment
  - libOFN / libSLAD

- Two H-60 Research Helicopters

- Environmental and Durability Test

- Structural / Dynamic Test
  - Component and Full-scale Static
  - Component and Full-scale Fatigue
  - Full-scale Dynamic

- Evaluation and Qualification Flight Testing
  - Flight test engineering
  - ADS-33 MTE course
Vision
- Exploit FBW and active control technologies in legacy-upgrades and new configs for unrestricted environmental ops, reduced weight and O&S costs.
- Demonstrate FVL capability flight controls, mission-adaptive autonomy, OPV concepts, multi-ship/manned-unmanned teaming, and VMS technologies.

Major Thrust
- Mission configurable flight controls for superior handling qualities and pilotage
- Autonomous flight controls for manned, optionally manned, and unmanned operations plus DVE solutions
- Advanced modeling techniques to simulate compounds/advanced concepts
- Vehicle management systems with real-time adaptation to aircraft state changes

Benefits
- Validated simulation models for compound / high-speed configurations
- Improved control laws, handling qualities requirements and characteristics, and pilotage for unique future configurations and unrestricted environmental ops
- Increased mission effectiveness and aircraft robustness for reduced O&S costs
- Demonstrated FVL capability flight controls and VMS technologies
RASCAL JUH-60A Black Hawk
Programmable, Full-authority, FBW + Mechanical Controls
Description:

- Sophisticated instrumentation and data acquisition system
- Numerous research systems in cabin mounted computer racks
- Glass cockpit and helmet mounted displays for evaluation pilot
- Integrated aural and tactile cueing systems
- Standard UH-60L partial authority flight control system
- HH-60G collective trim servo & collective grips; UH-60M cyclic grips
- Nose sensor mount
U.S. Army ADD tools to assist/optimize your design

https://nams.usra.edu/flight-control/

Flight Control
- System Identification ~ CIFER®
- Control design, evaluation, optimization, and integration ~ CONDUIT®
- Desktop simulation environment ~ RIPTIDE

**DoD Licensed Software** Approximately 75+ licenses currently

Autonomous Flight Control
- Obstacle Field Navigation ~ libOFN®
- Safe Landing Area Determination ~ libSLAD®
- VTOL UAS flight test resource

**CRADA**

In-flight Simulation / Evaluation
- Variable-stability full-authority Black Hawk ~ RASCAL
- Programmable EH-60L Black Hawk
- VTOL flight test resource (with ADS-33 course)

**CRADA or TSA**
Vision

• Demonstrate durable, integrated rotor system technologies that enable highly efficient performance throughout the flight envelope.

Major Thrust

• Rotor performance
• Rotor durability
• Rotor vibratory loads and fuselage vibration

Benefits

• Increased speed and range
• Increased robustness
• Reduced O&S costs
Purpose:
Integration and maturation of applied rotors/VMS technologies to:
• Improve performance (lift, cruise, hover, speed, maneuverability)
• Alleviate adverse forces (drag, download, and high oscillatory loads)
• Improve capability in operational environments

Products:
• High speed, low drag, and low weight rotor and hub configurations
• Control architectures to limit structural loads to prevent damaging loads
• Control architectures of advanced rotor systems
• Co-axial rotor plane separation reduction and control
• Individual blade control/swashplateless actuation
• Innovative, low drag rotors and propulsors for next generation UAS

Payoff:
• Development of applied technologies (TRL 4/5) to enable high speed, highly efficient configurations for next generation rotorcraft
• Innovative Rotors Technologies
  – Objective: Develop applied technologies that enable high speed, highly efficient configurations for next generation rotorcraft.

• **UAS Rotors/Propulsors**: increased efficiency, durability, and part consistency

• **Individual Blade Control (IBC) Technology**: reduced actuator weight and size, improved thermal management, and increased reliability

  – Contract Type: TIA and/or CPFF
  – Government Funding Est.: $2.5 M
  – Duration Est.: 36 months
  – BAA Issue: May 2018
  – Award: Oct 2018 (FY19)
• S&T developments via in-house tasks and collaborative agreements, advancing readiness and developing technical capability for modernization, FVL, soldiers and people.
• RASCAL JUH-60A and EH-60L Research Black Hawks enable flight testing of VM&C Technical Area and others.
• Other critical facilities (e.g. structures lab and wind tunnels) are also available.
• Discussions about research collaborations are welcome.
• BAA planned: Innovative Rotors Technologies – May 2018.
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YouTube
www.youtube.com/user/AMRDEC

Twitter
@usarmyamrdec

Public Affairs
AMRDEC-PAO@amrdec.army.mil
Rapid Desktop-to-Flight Development Pathway

- **Sim Models**
  - CIFER SYS ID
  - DATCOM+WT
  - Gen Hel
  - RCAS

- **Integrated tools/methods developed via sustained S&T investment**
- **Applied to numerous S&T and production programs**
- **Key to flight control system risk reduction for advanced concepts and fleet upgrade programs**
- **Originally developed for full-scale manned helicopters – now in wide use for fixed-wing and UAVs**
- **Deployed tools to industry, government agencies, academia**
  - 50+ active US and international users

=> **Key S&T transition path**
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ADD</td>
<td>Aviation Development Directorate</td>
</tr>
<tr>
<td>ADS-33</td>
<td>Aeronautical Design Standard 33 (Handling Qualities Requirements for Military Rotorcraft)</td>
</tr>
<tr>
<td>AMRDEC</td>
<td>Aviation and Missile Research, Development, and Engineering Center</td>
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<tr>
<td>AWFC</td>
<td>Army Warfighting Challenge</td>
</tr>
<tr>
<td>BAA</td>
<td>Broad Agency Announcement (competitive solicitation procedure)</td>
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<tr>
<td>CIFER®</td>
<td>Comprehensive Identification from FrEquency Responses</td>
</tr>
<tr>
<td>CONDUIT®</td>
<td>CONtrol Designer’s Unified InTerface</td>
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<tr>
<td>CPFF</td>
<td>Cost-Plus-Fixed-Fee (contract type)</td>
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<tr>
<td>CRADA</td>
<td>Cooperative Research And Development Agreement</td>
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<tr>
<td>DATCOM</td>
<td>Data Compendium (U.S. Air Force stability and control program)</td>
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<tr>
<td>DVE</td>
<td>Degraded Visual Environment</td>
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<tr>
<td>DVMC</td>
<td>Digital Vehicle Management and Control</td>
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<tr>
<td>FA</td>
<td>Focus Area</td>
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<tr>
<td>FBW</td>
<td>Fly-by-Wire</td>
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<tr>
<td>FVL</td>
<td>Future Vertical Lift</td>
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<tr>
<td>Gen Hel</td>
<td>General Helicopter Flight Dynamics Simulation</td>
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<tr>
<td>IBC</td>
<td>Individual Blade Control</td>
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<tr>
<td>MC²</td>
<td>Mission Configurable Control</td>
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<tr>
<td>MTE</td>
<td>Mission-Task-Element</td>
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<tr>
<td>O&amp;S</td>
<td>Operating and Support (costs)</td>
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<tr>
<td>OFN</td>
<td>Obstacle Field Navigation</td>
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<tr>
<td>OPV</td>
<td>Optionally Piloted Vehicle</td>
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<td>RASCAL</td>
<td>Rotorcraft Aircrew Systems Concepts Airborne Laboratory</td>
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<tr>
<td>RCAS</td>
<td>Rotorcraft Comprehensive Analysis System</td>
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<tr>
<td>RDECOM</td>
<td>U.S. Army Research, Development and Engineering Command</td>
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<tr>
<td>RIPTIDE</td>
<td>Real-time Interactive Prototype Technology Integration/Development Environment</td>
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<tr>
<td>S&amp;T</td>
<td>Science and Technology</td>
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<tr>
<td>SLAD</td>
<td>Safe Landing Area Determination</td>
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<td>Technical Area</td>
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<td>TIA</td>
<td>Technology Investment Agreement</td>
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<td>TRL</td>
<td>Technology Readiness Level</td>
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<td>Test Services Agreement</td>
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<td>UAS</td>
<td>Unmanned Aircraft System</td>
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<td>VM&amp;C</td>
<td>Vehicle Management and Control</td>
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<td>VMS</td>
<td>Vehicle Management System(s)</td>
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<tr>
<td>WT</td>
<td>Wind Tunnel</td>
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</tbody>
</table>
Who is AMRDEC?

Core Competencies

- Life Cycle Engineering
- Research, Technology Development and Demonstration
- Design and Modification
- Software Engineering
- Systems Integration
- Test and Evaluation
- Qualification
- Aerodynamics/Aeromechanics
- Structures
- Propulsion
- Guidance/Navigation
- Autonomy and Teaming
- Radio Frequency (RF) Technology
- Fire Control Radar Technology
- Image Processing
- Models and Simulation
- Cyber Security
Army Aviation S&T Focus Areas

**Platforms**
- Structures
- Sustainment
- Concept Design & Assessment

**Mission Systems**
- Survivability
- Avionics & Networks

**Vehicle Management & Control and Rotors**
- Rotors
- Vehicle Management & Control

**Autonomous and Unmanned Systems**
- Autonomy & Teaming
- Human System Interface

**Major Program Areas**
- Joint Multi-Role Technology Demonstration
- Degraded Visual Environment – Mitigation
- Next Generation Tactical UAS Technology Demonstration

**Power**
- Engines & Other Power Sources
- Drives

**Basic Research**
- Computational Aeromechanics
- Experimental Aeromechanics
Lead Aviation S&T in:
- Basic Research
- Computational & Experimental Aeromechanics
- Rotors
- Vehicle Mgt Sys / Flight Control
- Concept Design & Assessment

Contribute to Aviation S&T in:
- Teaming & Autonomy
- Human-System Integration
- FVL/Joint Multi Role TD • DVE

Administer:
- DoD High Performance Computing Modernization Programs for Rotorcraft
- International Bilateral Agreements (FR, GE, IS)

Support:
- Fleet Problem Solving & Upgrade

LOCATION:
- Co-located with NASA’s Ames & Langley Research Centers in VA & CA
Established at NASA-Ames in 1965
Extended to NASA-Glenn & Langley in 1970
NASA provides facilities, services, office space, & equipment under lease agreement
DoD / NASA model for interagency reliance

- Highly integrated S&E work force attains critical mass in key rotorcraft technologies
- Benefits military, civil, and dual-use programs
- Priority access to NASA expertise and facilities

A unique agreement for Collaborative Research in Aeronautics
Re-signed by Secretary of the Army and NASA Administrator in 2007
Broad Aeronautics Science & Technology Capability
Leveraging Multi-agency Facilities and Expertise
Key Facilities @ Ames - Simulation & Ground Test

• 7 X 10 Foot & Boundary Layer Wind Tunnels
• Rotorcraft Hover Chamber

Ideally Suited for Basic Research Inquiries

• Helicopter Overset Simulation Software & Numerical Aerodynamic Simulator (NAS)

Among World’s Most Powerful Computational Facilities

• Human Factors Research Facilities
• Vertical Motion Simulator & Future Flight Central

World’s Largest Amplitude Moving-Base Simulator

Virtual ATC Tower Simulator
NFAC is a unique national asset for full/large scale testing

- **Diverse Capabilities**
  - Powered test capabilities
  - High-speed Data Acquisition System
  - Anechoic test environment
  - Standard or customized mounting systems

- **Operated by U.S. Air Force – Arnold Engineering and Development Center**

40-by 80-foot test section
- Dynamic Pressure: 0 to 262 PSF
- Velocity: 0 to ~300 knots

80-by120-foot test section
- Dynamic Pressure: 0 to 33 PSF
- Velocity: 0 to ~100 knots
Key Facilities @ Langley

14x22ft and Transonic Dynamics Wind Tunnels

3D Audio Exterior Effects Room

Mobile Acoustics Facility
Rotorcraft In-Flight Laboratory (RIFL)
Program Office @ Ft. Eustis

RASCAL JUH-60A
- Full Authority Fly-by-wire UH-60
- Programmable Active Inceptors
- Fail-Safe Mechanical Backup
- Highly Reliable Safety Monitors
- Extensive Instrumentation

EH-60L
- Extensive Instrumentation
- Air Data Boom
- 1553 Avionics Bus
- Upgraded Avionics
- External Stores Support Sys

Autonomous Rotorcraft Project RMAXs
- In-house developed flight control system
- Autonomous Guidance
- Stereo Vision Cameras
- Scanning Laser

OH-58C
- SkyWatch ® Traffic Collision Avoidance System
- GPS With Moving Map and Airspace Database
- Pallet Instrumentation System
Engagement

- Aviation Development Directorate - Ames in-house work often utilizes NASA Task Order contracts advertised via FedBizOps (software development, graduate student interns, research support, model fab & instrumentation)

- Army 6.1 – 6.3 program contracting pursued via ACC-Ft. Eustis
  - (SBIRs, BAAs, Cooperative Agreements)

- Other business opportunities within ADD-Ames technical areas
  - Test Services Agreements, CRDAs, Software Transfer Agreements
  - Reimbursable Space Act Agreements (if joint with NASA)

  - Wind Tunnel Testing (multiple scales, 7x10 ft through NFAC)

  - Flight Control Tools (CIFER, CONDUIT, RIPTIDE, libOFN/SLAD)

  - CFD, Comprehensive Analysis (HELIOS, RCAS)

  - Concept Design (NDARC)

  - Flight Testing (Acoustics, Autonomy, Aerodynamics, Control, etc)

Pursue with our Focus Area, Technical Area or Facility leads
AMRDEC Web Site
www.amrdec.army.mil

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www.facebook.com/rdecom.amrdec

YouTube
www.youtube.com/user/AMRDEC

Twitter
@usarmyamrdec

Public Affairs
AMRDEC-PAO@amrdec.army.mil
Who is AMRDEC?

~9,211
FY17 Strength

2,945
Civilian

16
Military

6,250
Contractor

907 / 5343
SETA Non-SETA

Core Competencies

- Life Cycle Engineering
- Research, Technology Development and Demonstration
- Design and Modification
- Software Engineering
- Systems Integration
- Test and Evaluation
- Qualification
- Aerodynamics/Aeromechanics
- Structures
- Propulsion
- Guidance/Navigation
- Autonomy and Teaming
- Radio Frequency (RF) Technology
- Fire Control Radar Technology
- Image Processing
- Models and Simulation
- Cyber Security

FY17
$2,904M

6%
Aviation S&T

7%
Missile S&T

63%
Army

24%
Other

Colorado Springs, CO
NASA Ames - Moffett Field, CA
Corpus Christi, TX
Joint Base Langley - Eustis, VA
AMRDEC HQ
Redstone Arsenal, AL
Mission: Develop, demonstrate and transition critical technologies that enhance and sustain Army Aviation as the premiere land force aviation component in the world.

- Execute the Army Aviation Science & Technology portfolio
- Provide innovative solutions, rapid prototyping, engineering support, and test services to the Aviation Enterprise for technology maturation, risk reduction, proof-of-concept and urgent Warfighter requirements
- Collaborate across the government / industry / international Vertical Lift Enterprise

73 Years of Quality Work – Excellent People – Soldier Focus
Began as the Transportation Corps Board in 1944; Fort Eustis since 1950
ADD Fort Eustis Organization

Director

Operations

ACC Contracting Cell

Business Management / Personnel

Office of Counsel

Mission Systems
- Avionics & Network
- Autonomy & Teaming
- Survivability
- Human Systems Interface

Platform Technology
- Structures
- Drive Systems
- Engines
- Sustainment

Flight Test
- Deputy Chief of Flight Test
- Aviation Maintenance Lead

Tech Support
- Design/Analysis
- Fabrication & Instrumentation
- Engineering Test / QC / Project Logistics

Broad Engineering Experience & Capability for Science & Technology and Rapid Prototyping
• **Complete “In-House” Capability**
  – Extensive S&T expertise in Aviation core competencies
  – Engineering design & analysis
  – Mechanical fabrication
  – Structural testing
  – Component testing (environmental, E3, etc.)
  – Instrumentation
  – Airworthiness authority for research & development, demonstration, user evaluations, and contingency ops
  – Experimental flight test
  – Ballistics testing
  – Contracting (includes CRADA, TIA, etc.)
Other Opportunities

• **Cooperative Research & Development Agreements (CRADA)**
  
  – Pursue efforts of interest to both commercial company and Government – particularly demonstrations of maturity/feasibility for new/innovative technologies

  – Resource contributions from both commercial company and Government – does *not* allow transfer of funds from Government to commercial company

• **Test Service Agreement (TSA)**

  – Government performs testing for a commercial company – all Government costs are paid by the commercial company

  – Intended for areas where the Government has unique capabilities and/or expertise, not direct competition with the domestic private sector
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Basic research is a systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and observable facts without specific applications towards processes or products in mind.

Highly collaborative research
- Coordination both within and outside AMRDEC to identify capability gaps
- Leverage areas of joint interest with NASA, Navy and ARL/ARO
- Industry collaborations through Army’s SBIR & STTR programs and NRTC
40 tasks, 3 University Centers: GIT, PSU, UMD

**Purpose:**
Combine basic research with graduate education to strengthen academia's contribution to rotorcraft research and technology

**Products:**
- Unconstrained basic research development at the universities in collaboration with government S&Es
- Next generation of scientists & engineers

**Payoff:**
- Increased research collaborations on high risk high payoff basic research
- Leverage NASA and NAVY funding

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>BAA</th>
<th>Award</th>
<th>Year 5</th>
<th>Final report</th>
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**2017-2021 Centers of Excellence**
40 research tasks at 3 University teams in focus areas of government interest.
Georgia Tech (w/ Michigan, Iowa State, Ohio State, Washington U., Purdue, U Texas-Arlington) 10 Tasks,
Penn State (w/ U Tennessee Knoxville, U California Davis) 14 Tasks,
Univ. of Maryland (w/ U Texas Austin, Texas A&M U, US Naval Academy) 16 Tasks

• “Cooperative agreement” – strong potential for government/industry collaborative participation
  – Government SMEs closely involved with several tasks
  – Industry participation with follow-on collaborative research through NRTC

• Basic research collaborations with international partners: Technion – Israel Institute of Technology,
  University of Liverpool, Technical University Munich, Roma Tre University
**Purpose:**
Lays the foundation for future developmental efforts by identifying fundamental principles governing various phenomena and appropriate pathways to exploit this knowledge.

**Products:**
Catalysts for major technology breakthrough by providing lab directors flexibility on novel ideas.

**Payoff:**
- Technology “proofed” for transition
- Attract and retain new S&E talent

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<tr>
<td>Boundary Layer &amp; Flow Control Physics</td>
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<td>Wake Physics &amp; Interactions</td>
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<td>CFD Algorithm Development</td>
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<td>Innovative Concepts</td>
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**Purpose:**
Basic research towards developing improved methods to understand and analyze **rotorcraft-unique aerodynamic phenomena**

**Products:**
- Critical test data for M&S validation
- **Technology transition** to 6.2 programs including new methods as well as new hardware/design

**Payoff:**
Research into technologies that can improve tactical mobility, reduce logistics footprint, and increase survivability for rotary wing aircraft

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### Interactional Aerodynamics

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### Measurement & Diagnostics

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### Numerical Methods & Algorithm

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Rotary-wing unique aeromechanics phenomena

Identify, measure and model the underlying flow physics
Accurate measurement & diagnostics technique combined with high-fidelity modeling & simulation tools
**Purpose:**
Provide for fast and accurate prediction of high-fidelity full-vehicle rotorcraft aeromechanics in all flight regimes to help design and build safe, cost-effective, and efficient rotorcraft.

**Products:**
- Accurate, easy-to-use, and well validated aeromechanics modeling, simulation, and design tools based on high-fidelity computational fluid and structural dynamics on high-performance parallel computers.
- Fully-automated setup, execution, and post-processing to enable high fidelity computational simulations for routine engineering.

**Payoffs:**
- Greatly reduced time, cost, and risk for advanced aircraft design and development for Future Vertical Lift.
- Ensure that new rotorcraft designs and fleet upgrades meet their design requirements prior to the start of expensive and time-consuming flight testing.

**Activities**
- New 3-D finite element modeling for rotor dynamics
- High-order spatial accuracy in flow solver
- Automated volume grid generation technology
- Enhanced software scalability on emerging computer architecture
- Helios accuracy, efficiency & user enhancements
**Experimental Aeromechanics for Advanced Configurations**

**Activities**
- Advanced measurement & diagnostics techniques
- Interactional aerodynamics
  - Multi-rotor interactions
  - Advanced winged configurations
- Active flow control
  - Rotor performance
  - Adverse force reduction, e.g. hub/pylon drag.
- Blade structural loads measurements & predictions
- Advanced rotor design & optimization

**Purpose:**
Provide world class aeromechanics testing and test methods for legacy and future advanced manned and unmanned rotorcraft to enable aeromechanics modeling accuracy & productivity enhancements for rotor performance improvements and adverse force, noise & vibration reduction.

**Products:**
- Critical test data for M&S validation of next generation aeromechanics concepts relevant to Future Vertical Lift
- Comprehensive knowledge of aeromechanics including fundamental physical understanding of interactional aerodynamics phenomena across the size spectrum (ASSP classes 1 through 6)
- Advanced measurement & diagnostics technology for aerodynamics and source noise acoustics

**Payoffs:**
- Workforce trained for knowledge transition in advanced technologies and emerging configurations relevant to Future Vertical Lift
- Critical experimental knowledge base to reduce developmental and procurement risk to both current fleet and future platforms

**Experimental Aeromechanics for Advanced Configurations**

**Activities**
- Advanced measurement & diagnostics techniques
- Interactional aerodynamics
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- Advanced measurement & diagnostics technology for aerodynamics and source noise acoustics

**Payoffs:**
- Workforce trained for knowledge transition in advanced technologies and emerging configurations relevant to Future Vertical Lift
- Critical experimental knowledge base to reduce developmental and procurement risk to both current fleet and future platforms
High-Fidelity Aeromechanics Modeling for Future Vertical Lift

Purpose:
- Apply computational aeromechanics advancements to analyze and improve the designs and performance of both the current fleet and emerging configurations and designs
- Demonstrate high-fidelity computational aeromechanics modeling and simulation tools for complete rotorcraft configurations in both cruise and maneuvering flight

Products:
- Targeted high-fidelity interactional aerodynamics modeling & simulation technology applications to advanced configurations for Future Vertical Lift
- Validated, fast, and accurate computational analysis tools for modeling complete aircraft aerodynamics and dynamics in all flight regimes

Activities
- Interactional aerodynamics of advanced configurations
- Blade loads & stability analysis
- Aeromechanics analysis for platform modifications
- Modeling transitional flight and aggressive maneuvers
- Design & Optimization
- Uncertainty quantification

Payoff:
- The use of well-validated aeromechanics modeling and simulation tools will reduce risk and improve the performance of existing platform modifications and new designs for Future Vertical Lift
- Improved accuracy & productivity of aeromechanics modeling & simulation tools across entire flight spectrum
• Aeromechanics core competency built on a solid basic research foundation leverages
  – Computational Aeromechanics
  – Experimental Aeromechanics

• University engagement helps explore high risk, high-payoff ideas and attract new talent

• Industry engagement through SBIR & STTR programs
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YouTube
www.youtube.com/user/AMRDEC

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@usarmyamrdec

Public Affairs
AMRDEC-PAO@amrdec.army.mil
Presented by:

DR. MICHAEL S. RICHMAN
ASSOCIATE DIRECTOR, MISSILE DEVELOPMENT
WEAPONS DEVELOPMENT & INTEGRATION DIRECTORATE
AVIATION & MISSILE RESEARCH, DEVELOPMENT & ENGINEERING CENTER

11 April 2018
**Air & Missile Defense**

Technologies for the development of mobile air defense systems that reduce the cost curve of missile defense, restore overmatch, survive volley-fire attacks, and operate within sophisticated A2AD and contested domains.

**Long Range Fires**

Technologies for the development, integration and delivery of long range fires at the tactical, operational, and strategic echelons to restore overmatch, improve deterrence, and disrupt A2AD on a complex, contested and expanded battlefield.

**Future Vertical Lift**

Technologies for the development, integration, and delivery of aviation launched air-to-ground and air-to-air missile systems to restore overmatch within sophisticated A2AD and contested domains.

**Next Generation Combat Vehicle**

Technologies for active protection systems that will increase our ability to survive and win in the complex and densely urbanized terrain of an intensely lethal and distributed battlefield where all domains are continually contested.

Technologies for enhanced lethal effects that will increase our capability to win in the complex and densely urbanized terrain of a lethal and distributed battlefield.

**Engage First**

**Expand the Dome**

**On the Move**

**Technology Driven. Warfighter Focused.**

18-0029
Missile S&T Addressing the CSA Priorities

- Engage First [Long Range Precision Fires]
- Expanding the Dome [Air & Missile Defense]
- On the Move [LRPF & AMD]
Long Range Precision Fires Objective

Provide capability to engage targets at extended range.
AMD Objective

Provide Capability to Engage Targets at Extended Range
AMRDEC Missile S&T Aligned to Army Priorities

LONG RANGE FIRES
- Tail Controlled GMLRS (TCG) Tech Insertion
- Low-Cost Tactical Extended Range Missile (LC-TERM)
- Land-Based Ship Missile (LBASM)
- Long Range Maneuverable Fires

NEXT GENERATION COMBAT VEHICLE
- Enhanced Single Multi-Mission Attack Missile (E- SMAM)
- Multiple Simultaneous Engagement Technologies (MSET)
- Hard Kill Active Protection System (APS)

FUTURE VERTICAL LIFT

AIR & MISSILE DEFENSE
- Modular Missile Technologies (MMT)
- Open Systems Architecture
- Low-Cost Extended Range Air Defense (LowER AD)
- Next Generation Air-to-Ground Missile
- Digital Array Radar Testbed (DART)
- Maneuver Air Defense Tech
- NexGen Lower Tier Missile Technologies
Missile S&T Collaboration

Industry & Academia interacts with CALs and TALs
AMRDEC Missile S&T
Aligned to Army Priorities

Long Range Fires
- Tail Controlled GMLRS (TCG) Tech Insertion
- Low-Cost Tactical Extended Range Missile (LC-TERM)
- Land-Based Ship Missile (LBASM)
- Long Range Maneuverable Fires

Next Generation Combat Vehicle

Future Vertical Lift

Air & Missile Defense
- Enhanced Single Multi-Mission Attack Missile (E-SMAM)
- Multiple Simultaneous Engagement Technologies (MSET)
- Hard Kill Active Protection System (APS)

Modular Missile Technologies (MMT)
- Open Systems Architecture

Low-Cost Extended Range Air Defense (LOWER AD)
- Digital Array Radar Testbed (DART)
- Maneuver Air Defense Tech
Fire Support S&T Focused on Army #1 Modernization Priority

1. Long Range Precision Fires
   - Capabilities that restore US Army dominance surface-to-surface fires in terms of range, munitions, and target acquisition

2. Next Generation Combat Vehicle
   - Close combat capabilities in manned, unmanned, and optionally manned variants with the modern firepower, protection, mobility, and power generation capabilities

3. Future Vertical Lift
   - Attack, lift, and recon in manned, unmanned, and optionally-manned variants that are survivable on the modern and future battlefield

4. Army Network
   - Hardware, software, and infrastructure sufficiently mobile and expeditionary that can be used in any environment where the electromagnetic spectrum is denied or degraded

5. Air & Missile Defense
   - Capabilities that ensure our future combat formations are protected from modern and advanced air and missile delivered fires, including drones

6. Soldier Lethality
   - Next generation individual and squad combat weapons, but also improved body armor, sensors, radios, and load bearing exoskeletons
“There is a real need to modernize our surface-to-surface fires at echelon to be able to guarantee a clear overmatch against any potential adversary both on the modern and future battlefield. To that effort, we are looking at how do we increase our range, how do we increase our lethality, and how do we increase our volume of fires...”

– Brig. Gen. Stephen Maranian, LRPF CFT Lead

CLOSE FIRES
Evolve the current M109A7 self-propelled howitzer into extended-range cannon artillery

- Improved: mobility, protection, survivability
- Growth: automotive, power, open architecture

FUTURE WHEELED HOWITZER

DEEP FIRES
Accelerate development and fielding of initial increment of Precision Strike Missile (formerly known as LRPF)

- Extended range
- Increased rate of fire
- Reduced logistics
- Lower cost

GMLRS-ER
- Defeat integrated air defense targets
- Cross-domain capable moved/moving land and maritime targets
- Loitering payloads and sub-munitions

PRISM
- Spiral upgrades to Precision Strike Missile and GMLRS-ER

STRATEGIC FIRES
Strategic deep strike offensive and defensive weapon capability that is treaty compliant

- INF Treaty compliant
- Penetrate sophisticated A2/AD environments to engage targets such as integrated air defense
- Provides cross-domain fires that open corridors enabling timely naval and air operations

NOTIONAL STRATEGIC FIRES MISSILE
PAYLOADS  
(LC-TERM, LRMF)

Payload technologies for engaging imprecisely located point and large area targets including mechanized targets

Multi-effects Warhead and Fuze Tech
Future Loitering Munitions
Lightweight Fiber and Resin Tech

SENSORS/SEEKERS  
(UTAH, LBASM, LRMF)

Sensor technology for precision engagement of moving and moved targets in the land and maritime domains

RF and IIR Tech
High Temperature Dome/Window Tech

NAVIGATION  
(LC-TERM)

Inertial measurement unit (IMU) and anti-jam (AJ) technologies for precision in GPS challenged environments

Inertial Devices
AJ Electronics

ADVANCED PROPULSION  
(LC-TERM, LRMF)

Propulsion and material technologies to increase energetic performance resulting in increased range

High Energy Propellant Tech
Air-breathing/High Speed Propulsion Tech

SURVIVABILITY  
(LC-TERM, LRMF)

Technologies to enhance missile survivability against enemy air defenses through increased speed and maneuverability

Injection (M-3)
Combustion chamber
Exhaust (M-1)
Compression (M-3)
Fuel injection frame holder
Nitride (M-1)

Technology Development for Spiral Insertion into GMLRS-ER and PrSM
AMRDEC Missile S&T
Aligned to Army Priorities

LONG RANGE FIRES
- Tail Controlled GMLRS (TCG) Tech Insertion
- Low-Cost Tactical Extended Range Missile (LC-TERM)
- Land-Based Ship Missile (LBASM)
- Long Range Maneuverable Fires

NEXT GENERATION COMBAT VEHICLE

FUTURE VERTICAL LIFT

AIR & MISSILE DEFENSE
- Enhanced Single Multi-Mission Attack Missile (E-SMAM)
- Multiple Simultaneous Engagement Technologies (MSET)
- Hard Kill Active Protection System (APS)

MODULAR MISSILE TECHNOLOGIES (MMT)
- Open Systems Architecture

LOW-COST EXTENDED RANGE AIR DEFENSE (LOWER AD)
- Digital Array Radar Testbed (DART)
- Maneuver Air Defense Tech
- NexGen Lower Tier Missile Technologies
Close Fires S&T Focused on Army
#1 Modernization Priority

1. **Long Range Precision Fires**
   Capabilities that restores US Army dominance surface-to-surface fires in terms of range, munitions, and target acquisition

2. **Next Generation Combat Vehicle**
   Close combat capabilities in manned, unmanned, and optionally manned variants with the modern firepower, protection, mobility, and power generation capabilities

3. **Future Vertical Lift**
   Attack, lift, and recon in manned, unmanned, and optionally manned variants that are survivable on the modern and future battlefield

4. **Army Network**
   Hardware, software, and infrastructure sufficiently mobile and expeditionary that can be used in any environment where the electromagnetic spectrum is denied or degraded

5. **Air & Missile Defense**
   Capabilities that ensure our future combat formations are protected from modern and advanced air and missile delivered fires, including drones

6. **Soldier Lethality**
   Next generation individual and squad combat weapons, but also improved body armor, sensors, radios, and load bearing exoskeletons
Long Range Precision Fires Priorities

**LRPF Close Fires**

**Enhanced Single Multi-Mission Attack Missile (E-SMAM)** - enabling technologies for a medium range NLOS precision loitering missile with man-in-the-loop for situational awareness, targeting, and lethal effects against hard armor/high-value targets

- Expeditionary, Platform agnostic: manned/unmanned ground or air
- Capable in RF/GPS denied environments

**Missile Multiple Simultaneous Engagement Technologies (MSET)** - rapidly defeat swarming and/or disbursed hard armor/high-value targets with LMAM/SMAM simultaneous multiple launch, control, and supervised autonomous terminal engagement

- 20+ Simultaneous Engagements
- Supervised autonomous terminal engagement

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**Provide BCTs with Extended Range, Organic Overmatch with Increased Autonomy and Soldier Survivability for Multi-Domain Battle**

**Technology Driven. Warfighter Focused.**
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<th>PROPULSION SYSTEM</th>
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<td>• Affordable, lightweight multi-mode propulsion with long shelf life; short time of flight for LOS targets/extended range for NLOS targets</td>
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<td>• Increase range and reduce time of flight of minimum signature propellants</td>
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<td>• Maximize IM compliance without compromising performance</td>
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<td>• Multi-mode warhead &amp; fuzing (tailorable effects) for lethal effects against the following threats:</td>
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<tr>
<td>• Next Gen Main Battle Tank (w/ERA, APS) — Light Skinned Vehicles</td>
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<tr>
<td>• Personnel in Open and Defilade — Structures</td>
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<tr>
<td>• EW Payloads</td>
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<td>• Maximize IM compliance without compromising performance</td>
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<th>SEEKER</th>
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<td>• SWAP-C EO/IR Sensor Technologies</td>
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<td>• Affordable, small form factor gimbals or electronic alternatives</td>
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<th>IMAGE-BASED TRACKER / PRECISION TARGETING (for A2/AD environment)</th>
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<td>• Supervised Autonomous Terminal Engagement Technologies</td>
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<td>• GPS-denied Navigation</td>
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<td>• Enhanced Security features (encryption, anti-jam)</td>
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<td>• Increased LOS/BLOS range</td>
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<td>• Swarm: Multi-munition control, networked cross-munition comms, increased bandwidth</td>
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<th>AERODYNAMICS</th>
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<td>• In flight adaptable airframe/control surfaces to optimize performance in high speed flight, transitioning to maneuverable, low speed flight and extended range</td>
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AMRDEC Missile S&T
Air & Missile Defense

LONG RANGE FIRES

- Tail Controlled GMLRS (TCG) Tech Insertion
- Low-Cost Tactical Extended Range Missile (LC-TERM)
- Land-Based Ship Missile (LBASM)
- Long Range Maneuverable Fires

NEXT GENERATION COMBAT VEHICLE

- Enhanced Single Multi-Mission Attack Missile (E-SMAM)
- Multiple Simultaneous Engagement Technologies (MSET)

FUTURE VERTICAL LIFT

- Hard Kill Active Protection System (APS)

AIR & MISSILE DEFENSE

- Modular Missile Technologies (MMT) Open Systems Architecture
- Next Generation Air-to-Ground Missile

- Low-Cost Extended Range Air Defense (LWER AD)
- Digital Array Radar Testbed (DART)
- Maneuver Air Defense Tech
- NexGen Lower Tier Missile Technologies
1. Long Range Precision Fires
   Capabilities that restore US Army dominance surface-to-surface fires in terms of range, munitions, and target acquisition

2. Next Generation Combat Vehicle
   Close combat capabilities in manned, unmanned, and optionally manned variants with the modern firepower, protection, mobility, and power generation capabilities

3. Future Vertical Lift
   Attack, lift, and recon in manned, unmanned, and optionally manned variants that are survivable on the modern and future battlefield

4. Army Network
   Hardware, software, and infrastructure sufficiently mobile and expeditionary that can be used in any environment where the electromagnetic spectrum is denied or degraded

5. Air & Missile Defense
   Capabilities that ensure our future combat formations are protected from modern and advanced air and missile delivered fires, including drones

6. Soldier Lethality
   Next generation individual and squad combat weapons, but also improved body armor, sensors, radios, and load bearing exoskeletons
"Our competitors are seeking to alter global strategic realities for their own benefit.... Russia and China continue to assert themselves in an effort to gain dominance in key regions, and are developing advanced weapons to achieve parity both strategically and in close combat."

-- Mark T. Esper, Secretary of the Army and General Mark A. Milley, Chief of Staff of the Army, 15 March 2018

Limited capability to sense, engage, and destroy RAM, TBM, cruise missiles, and aerial threats throughout 360 degrees.

September 2017: Russia “conducted a successful training launch of a RS-24 Yars road-mobile intercontinental ballistic missile. The test was designed to verify the reliability of the weapon.... possible that the new RVs are maneuverable reentry vehicles or MARVs—which are designed to defeat missile defenses.”

-- The National Interest, 20 September 2017

Limited detection and engagement ranges to defend against UASs.

"With help of unmanned air vehicles, we have been monitoring the situation across almost the entire Syrian territory all day round," a defense ministry official stated. During almost two years since the Russian expeditionary force first arrived at Khmeimeem air force station in Latakia, the grand total of UAV flights has exceeded 14,000.”

-- Russian Defense Ministry Official, September 2017

We will “ensure our future combat formations are protected from modern and advanced air and missile delivered fires, including drones. We are focusing on capabilities that include Mobile Short-Range Air Defense with directed energy and advanced energetics.”

-- GEN Mark A. Milley, CSA, Statement to House Appropriations Committee, on FY19 Army Budget, 15 March 2018

Focused on Army’s AMD Modernization Priority
**MANEUVER AIR DEFENSE**

Development of technologies that support low cost, small form factor air defense interceptors for the maneuver force.

**ADVANCED PROPULSION**

- Advanced Divert and Attitude Control Systems
- Air-breathing/High Speed Propulsion Tech

Propulsion technologies to increase interceptor range, velocity, and maneuverability.

**FIRE CONTROL**

Fire Control hardware and software to optimize the integration of current systems, enable “shoot on the move,” and facilitate engagements of advanced threats.

**SENSORS/SEEKERS**

Seeker technology and algorithms to support the broad air defense mission set.

**RESILIENCY**

Technologies to enable air defense performance in all environments.
AMRDEC Missile S&T
Future Vertical Lift

LONG RANGE FIRES
Tail Controlled GMLRS (TCG) Tech Insertion
Land-Based Ship Missile (LBASM)

NEXT GENERATION COMBAT VEHICLE
Enhanced Single Multi-Mission Attack Missile (E-SMAM)

FUTURE VERTICAL LIFT
Low-Cost Tactical Extended Range Missile (LC-TERM)
Multiple Simultaneous Engagement Technologies (MSET)

AIR & MISSILE DEFENSE
Hard Kill Active Protection System (APS)

Modular Missile Technologies (MMT)
Open Systems Architecture

Low-Cost Extended Range Air Defense (LOWER AD)
Digital Array Radar Testbed (DART)
Next Generation Tier Missile Technologies
Maneuver Air Defense Tech

NEXT GENERATION
Air-to-Ground Missile
Long Range Precision Fires
Capabilities that restore US Army dominance in surface-to-surface fires in terms of range, munitions, and target acquisition.

Next Generation Combat Vehicle
Close combat capabilities in manned, unmanned, and optionally manned variants with modern firepower, protection, mobility, and power generation capabilities.

Future Vertical Lift
Attack, lift, and recon in manned, unmanned, and optionally manned variants that are survivable on the modern and future battlefield.

Army Network
Hardware, software, and infrastructure sufficiently mobile and expeditionary that can be used in any environment where the electromagnetic spectrum is denied or degraded.

Air & Missile Defense
Capabilities that ensure our future combat formations are protected from modern and advanced air and missile delivered fires, including drones.

Soldier Lethality
Next generation individual and squad combat weapons, but also improved body armor, sensors, radios, and load bearing exoskeletons.
Modular Open Systems Architecture Missile Technologies delivering scalable/tailorable lethal overmatching fires with multi-role capability to maximize stowed kills across domains.

**AVIATION MISSILES FOCUS**

**SEEKERS**
Sensor technology for precision engagement of surface and aerial threats

**PAYLOADS**
Payload technologies for engaging soft-to-medium surface and aerial threats

**PROPULSION**
Propulsion technology for increased agility and range.
Pervasive Technology strives to identify transition and collaboration opportunities for emergent technologies.
Transitions

Technologies are transitioned in the form of prototypes, software/algorithms, or knowledge products, etc. to AMRDEC Labs, other S&T programs, or Industry.
## Key Enabling Technologies

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<tr>
<th>Technology Area</th>
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<th>#2</th>
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<td>Cost estimating techniques for missile launchers</td>
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<td>Technology</td>
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<tr>
<td>Aerodynamics</td>
<td>Prediction methodologies and metrics for high speed aerodynamics</td>
<td>Development and analysis of highly maneuverable airframes across varied flight regimes</td>
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<td>Control Systems</td>
<td>High Efficiency/ Low Inertia Gear Systems</td>
<td>Higher Temp Electric Motors and Components</td>
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<td>Datalinks</td>
<td>Miniature Optical, High Speed, Power Amplifiers</td>
<td>Low Cost Avalanche Photo Diode Arrays</td>
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<td>Computational Guidance &amp; Control Techniques</td>
<td>Cooperative-Collaborative-Intelligent Guidance</td>
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<td>Launcher</td>
<td>Energy harvesting devices to power small electronics package capable of logging in service hours</td>
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<tr>
<td>Lethality</td>
<td>Combined Effects Modeling for Multiple Defeat Mechanisms</td>
<td>Additive effects Modeling of reactive materials</td>
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<td>Missile Electronics</td>
<td>Electronics thermal management techniques (hot and cold environments)</td>
<td>Electronics 3D Printing and design implications</td>
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<tr>
<td>Materials &amp; Structures</td>
<td>High temperature structural and insulation materials</td>
<td>Low-cost repeatable manufacturing processes for composite tubes</td>
</tr>
<tr>
<td>Modeling &amp; Simulation</td>
<td>IR projector systems that can support update rates greater than 400Hz</td>
<td>Digital Scene Generation algorithms that enable rapid update of signatures and clutter models</td>
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<tr>
<td>Navigation</td>
<td>Non-GPS Navigation aids</td>
<td>Reduced SWAP+C high accuracy IMUs</td>
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<tr>
<td>Power</td>
<td>Small volume and flexible form-factor, high-power reserve battery technologies</td>
<td>Extended storage life rechargeable battery technologies</td>
</tr>
<tr>
<td>Propulsion</td>
<td>Minimum smoke propellants and ignition materials</td>
<td>High performance propellants (smoky and reduced smoke)</td>
</tr>
<tr>
<td>Protection &amp; Survivability</td>
<td>Resilience in a Cyber Contested Environment</td>
<td>Integrated Cyber/EW Capabilities</td>
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<tr>
<td>Radar</td>
<td>Low cost T/R modules</td>
<td>Processing Speed for Swarms</td>
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<tr>
<td>Reliability/Maintainability</td>
<td>Machine Learning</td>
<td>Low Power/Weight/Volume HMU Sensors</td>
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<tr>
<td>Sensors</td>
<td>Solid State Sensors</td>
<td>Real-time Signal Processing</td>
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<tr>
<td>Warhead/Fuze</td>
<td>High Performance Anti-Armor Warheads</td>
<td>Low Cost Fuzing and Motor Ignition Systems</td>
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</table>
Presented by:
GREG REYNOLDS
ELECTRONICS ENGINEER
WEAPONS DEVELOPMENT & INTEGRATION DIRECTORATE
AVIATION & MISSILE RESEARCH, DEVELOPMENT & ENGINEERING CENTER

11 April 2018
Basic Integrated Navigation Architecture

**Timing**
Precise Time Made Available to Systems as a Common Timing Source Used to Synchronize Signals/Data to Enable Advanced Capabilities (RADAR, Comms, etc.) using:
- GPS
- Chip Scale Atomic Clock
- Crystal Oscillator

**Inertial Measurement Units**
Measures rotations and translations that are integrated from a known initial state to maintain Position, Velocity and Attitude using sensors such as:
- Optical
- Vibratory
- Atomic

**Positioning**
Determine position based on external sources such as:
- Terrain Feature Matching
- Terrestrial RF Transmitters
- GPS & Global Navigation Satellite Systems (GNSS)
- Pseudolites
- Radio Navigation
- Anti-Jam Antennas

**Aiding Sensors**
Additional Sensors that Provide Measurements Used to Correct Errors/Deficiencies in the Primary Navigation Method such as:
- RF Ranging
- Vision-Based Nav
- Network Assisted Navigation
- Magnetometer
- Velocimeter

**Navigation System Architecture**

**Sensor Fusion**
Integration of All Navigation Sensors into a Single Navigation Solution to Provide PNT Information to Users
- Deduced Reckoning
- Basic 6 Degree of Freedom (DOF) Navigation
- Multi-Sensor Integration
Indirect Fires Low-Cost
(From Weapons COI GNC&DL Briefing)

Projected Evolution vs Threat

- GPS
- IMU + M-Code
- AJ
- SDR
- Pseudolites
- VBN
- uPNT
- CSAC

Timeframe:

- 2015

Threat vs Capability
### Technology Limitations

**THREATS**
- GPS Denial/Spoofing
- Asymmetric Warfare
- Warfighter Exposure Time
- Battlefield Landscape
- Logistics Burden
- Advancements in Missile System Technology (Extreme Dynamics, Longer Flight Times, Faster Reaction Times, and Miniaturization)

**GAPS**
- GPS Accuracy in Jammed Environment
- Robust GPS Performance in GPS-Challenged Environments
- Decreased Reliance on GPS Technologies
- Inertial Navigation Accuracy
- Blended Navigation Solutions (aids, signals of opportunity and data fusion)
- Size, Weight, and Power plus Cost (SWAP-C)
- Startup Times
- Alignment Times/Precision Pointing
- Operational Capabilities/Performance over High Dynamic Environments
- Reliability (Shelf Life)

### Desired Technology Attributes

- GPS Accuracy in a Jammed Environment
- Robust GPS
- Low Cost Inertial Sensors/Systems
- Fast, Accurate Northfinding to Support Target Location and Weapon System Initialization
- Low Cost Land Navigation (POS/NAV)
- Technology Refresh
- Improved Guidance and Control (Autopilot)
- Improved Seeker Line-of-Sight Stabilization

**Pervasive Navigation S&T Objectives:**
- Reduce Size, Weight, and Power
- Lower Cost
- Improve Accuracy
- Increase Reliability

### Enabling Technology

**Inertial Sensors/Systems**
- Enhanced Ring Laser Gyro (Fast Light)
- Hollow Core FOG (Photonic Band Gap Fiber)
- Quantum Inertial Sensor (Cold Atom)
- MEMS Nav-grade Gyros / Accels
- COTS for Military Requirements
- Micro Navigators / Gyrocompass
- ASURES (Survey / Emplacement)
- Self Calibrating Systems
- Hypersonic Systems
- Nuclear Magnetic Resonance Gyro
- Magneto-Hydro-Dynamic Systems

**Next Generation GPS Design/Development**
- Anti-Jam, Anti-Spoofing
- GPS Pseudolites Integration
- Miniature GPS Receivers
- Next Generation GPS Receivers (M-code)
- Software Defined Radio (GPS/AJ)
- Nano Satellites

**Alternate Navigation/Architecture/Algorithm Development**
- Data Fusion Algorithms
- Vision-based Sensors
- Stellar Tracker
- RF Ranging
- Terrain Aiding
- Timing
- Signals of Opportunity
- Polarization
- Magnetic Sensor Aiding
Navigation technology is being driven by harsher environments.

The need to address the A2AD environment is real and not going away.

The replacement for GPS will include more-robust GPS.

There is not likely to be a single, one-size-fits-all replacement for GPS.

We are developing / investing in multiple technologies that will help mitigate the A2AD environment.

- Inertial Sensors
- Robust GPS
- Alternate Navigation Aids

We are looking for novel solutions, not just alternate approaches.
11 April 2018

Presented by:

DR. JEREMY RICE
AEROSPACE ENGINEER
WEAPONS DEVELOPMENT & INTEGRATION DIRECTORATE
AVIATION & MISSILE RESEARCH, DEVELOPMENT & ENGINEERING CENTER
The US Army Aviation & Missile Research, Development & Engineering Center (AMRDEC) utilizes new and innovative propulsion technologies to meet the Army modernization objectives:

- Develop high performance propellant fuels, ingredients, and hardware components/configurations to support missions requiring extended range and speed.
- Support a focus on emerging materials, controllable thrust, reduced sensitivity, and safety/environmental compliance.
- Maintain the necessary experience and facility capabilities in research, development, and testing of propulsion technology to perform Research and Development for…
  - Emerging Army requirements for long range precision fires and enhanced air defense systems.
  - Size ranges encompassing propulsion systems for small diameter aviation rockets/missiles up to tactical fire support/air defense missiles.
Army Rocket Propulsion Investment Areas

Rocket Propellants
Energetic materials (oxidizers & fuels) combined with binders, burning rate/combustion modifiers, and stabilizers

Supported Goals:
• Increased performance
• Expand operating temperature bounds
• Improved safety & environmental compliance

Propulsion Component Technology
Propellant grain designs, propellant bond-liner systems, motorcases, ignition devices, nozzles, case insulation, and energy management devices

Supported Goals:
• Smaller physical package
• Increased range
• Reduced time-of-flight

Propulsion Affordability
Processing improvements, efficient characterization of propellant behavior, improved aging models, and health monitoring approaches:

Supported Goals:
• Extended service life
• Cost reduction
• Improved reliability

Rocket Propulsion Systems R&D
Integration and Evaluation of Rocket Propulsion elements

Supported Goals:
• Extended range & mission flexibility
• Smaller & more affordable propulsion systems
• Multi-mission propulsion approaches
• Reduced propulsion system size & mass
• Enhanced life-cycle affordability

Structural Analysis of Configured Grain

Example: Sensitivity of Thrust to Temperature

Safety Improvements through Insensitive Munitions (IM) design

Motor Static Test

Range Improvement via Energy Management

“Smokey/Reduced Smoke” High Performance Propellants for Protection & Fires

“Minimum Smoke” Propellants for Aviation & Close Combat

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
# Propulsion Technical Area
## Propulsion Technology for the Future Force

### LONG RANGE FIRES

<table>
<thead>
<tr>
<th>High Performance Propulsion</th>
<th>Minimum Smoke Propulsion</th>
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<tbody>
<tr>
<td>• Long Range Precision Fires (LC-TERM, 400km+) Technologies</td>
<td>• Future Close Combat Msl</td>
</tr>
<tr>
<td>• Increased Stowed Kills</td>
<td>• Tech. for Close Combat Missile Modernization</td>
</tr>
<tr>
<td>• Highly Maneuverable Field Artillery / Future Deep Strike</td>
<td>• Improved safety &amp; range performance</td>
</tr>
<tr>
<td>• Low-cost combined cycle propulsion solutions for Multi-Domain Fires</td>
<td>• Multi-role/modular munitions</td>
</tr>
<tr>
<td></td>
<td>• Next Generation Soldier Launched Weapon (NGSLW)</td>
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<td></td>
<td>• JAGM Spiral Tech. Insertion (extended range &gt; 12 km)</td>
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### PERVASIVE SCIENCE & TECHNOLOGY

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<table>
<thead>
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<tbody>
<tr>
<td>• Nozzle &amp; Insulation Materials</td>
<td>• Energy/Thrust Management Devices</td>
<td>• Alternate Grain Designs</td>
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<tr>
<td>• Case Design &amp; Fabrication</td>
<td>• Physical Burn-Rate Augmentation</td>
<td>• Predictive and Analysis Tools</td>
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<tr>
<td>• Propellant Ballistics Tailoring</td>
<td>• Improved Propellant Mech. Properties</td>
<td>• Ingredients/Ballistics Modifiers</td>
</tr>
<tr>
<td>• Ignition Technologies</td>
<td>• Simulation &amp; Optimization Tools</td>
<td>• Insensitive Munitions Approaches</td>
</tr>
</tbody>
</table>
# Propulsion Technology

## Technology Limitations

**Threats**
- Extended Range Requirements
- Time-Critical Engagements
- Increased Mobility Needs (Reduced Size/Mass)
- Cost (Development and Life-Cycle)
- Extended Life-Cycle (systems in inventory longer)
- M and Ignition Safety Requirements
- Expanded Target Set for Munitions (multi mission capability)
- Signature Requirements (e.g., minimum smoke)

**Gaps**
- Non-Detonable, High Performance Minimum Smoke Propulsion
- Low-Cost Airbreathing (Integral Rocket Ramjet) Technology for Time Critical Engagements
- Materials Obsolescence / Domestic Sourcing for Critical Materials
- Declining Industrial Base
- Cost reduction for low to moderate quantities
- Low-cost, High Performance Materials – hot structures
- Low-cost Energy Management Techniques
- Transition Opportunities for Technology Insertion
- 10-15 Year Shelf-Life for Cast Minimum Smoke

## Desired Technology Attributes

- **Minimum Smoke** propellants and ignition materials required for close combat and rotary-wing aviation
- **High Performance** propellants (smokey & reduced smoke) propellants for fires/air defense applications
- Ballistic & mechanical properties tailoring for next generation propellants
- New ignition materials and concepts
- Improved processing & manufacturing capability
- Environmentally-friendly (replace lead & RDX, Ammonium Perchlorate alternatives)
- New class of very high performance Minimum Signature propellants with improved safety
- Approaches/processes for improved implementation of lightweight energy management for next generation extended range propulsion systems
- Maximize Volume Fraction, Minimize Size and Mass

## Enabling Technology

### Rocket Propellant R&D
- Incorporate emerging minimum smoke ingredients
- Tailoring of High Performance Propellants (burn rate and exponent)
- Monopropellants / Bi-propellants

### Propulsion Component Technology
- Pulse Motor Ignition
- Physical Burn-Rate Augmentation
- Pulse Barrier/Bulkhead Technology
- Design for IM and Ignition Safety
- Grain Surface-Forming Techniques
- Thrust Control devices

### Propulsion Affordability & Sustainment
- Predictive Models
- Data Collection Methods
- Process selection and optimization for low-cost

### Supporting Tools
- System Performance Models
- Interior Ballistics and Thermal
- Highly-coupled Structural/Thermal Analyses
- Non-solid Duty Cycles (ramjet, monoprop)

### Propulsion System R&D
- Airbreathing propulsion cycles
- Thrust control systems
- Integration of properly-matured component and propellant technology (6.3)
- Requirements development through detailed trade-off analyses

### Pervasive S&T Objectives:
- Reduce propulsion system size and weight through improved performance
- Enhance system safety performance
- Increase range and minimize time-of-flight
- Decrease life-cycle cost
- Enable highest degree of multi-mission capability
**WHAT IS IT?**
Advanced minimum smoke propellants for improved performance (impulse, density-impulse, and burning rates) and reduced shock sensitivity

**WHAT DOES IT OFFER?**
- Improved burning rates
- New class of Minimum Smoke propellants with balance between performance and shock-sensitivity for Insensitive Munitions (IM)
- Reduced temperature sensitivity for less shock-sensitive formulations
- Improved Safety and Cost Reduction of Minimum Signature Propellant Burn Rate Modifiers

**TECHNICAL APPROACH:**
- Nitrocellulose studies toward extruded properties in castable formulations – would be breakthrough
- Coating of legacy solids to achieve lower shock sensitivity and improved burning rate response
- Novel, low-cost energetic plasticizers for improved aging and lower shock sensitivity

![Nitrocellulose Fibers](image1)
![Nitroglycerin](image2)
![Encapsulated RDX](image3)
**WHAT IS IT?**

High-performance propellants with improved energy density, utilizing novel ingredients and processing to tailor burn rate characteristics, to extend range and performance against emerging and future threats.

**WHAT DOES IT OFFER?**

- Improved burning rate control – low exponent for use at high pressures
- Maximized solids loading for boosting propellant density – Pack more energy into the bottle!
- Novel ingredients to harness full combustion for improved delivered performance
- Mechanical properties capable of intricate grain geometries for increased volumetric loading

**TECHNICAL APPROACH:**

- Evaluation of high energy materials such as fine AP, CL-20, PGN and other emerging ingredients such as nano-metallics and energetic coolants.
- Explore coatings or other surface treatments of under-utilized, hard to use ingredients such as ADN.
- Utilization of emerging technologies for mixing and processing to boost propellant density.
- Demonstration of burning rate/exponent control.

<table>
<thead>
<tr>
<th>Goals</th>
<th>rho Isp</th>
<th>Burn Rate</th>
<th>Exponent</th>
<th>Slope Break</th>
<th>Strain@ Max Stress</th>
</tr>
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<tbody>
<tr>
<td>20 lbf-sec/in³</td>
<td>~ .45 ips @ 1500 psi</td>
<td>&lt;0.45</td>
<td>&gt;4000 psi</td>
<td>75%</td>
<td></td>
</tr>
</tbody>
</table>
**WHAT IS IT?**
Development of low-cost integral rocket solid ramjet motor technology for greatly enhanced missile propulsion section performance.

**WHAT DOES IT OFFER?**
- Increased range and survivability
  - Improved block speed
  - Extended range while maintaining magazine depth
- Greater standoff enhancing survivability
- Shorter time-of-flight
- Enhanced end-game performance

**TECHNICAL APPROACH:**
- Development of solid ramjet fuel that exhibits favorable decomposition and combustion characteristics at free-stream enthalpy conditions over a broad operational range
- Concentric HTPB composite propellant booster grain and solid-fueled ramjet grain utilize a common combustion chamber and bi-material throat for cost and design efficiency
- Designed approach will utilize existing launcher/tube configurations and cost will be comparable to current high performance tactical propulsion solutions
**WHAT IS IT?**

Demonstrate improved thrust flexibility by developing dual-pulse propulsion and/or dual thrust-level propulsion solutions for multi-mission/multi-domain tactical missile applications in the extended-range close combat lethality mission space.

**WHAT DOES IT OFFER?**

- Close combat lethality - increased range and mission flexibility
  - Meet current system performance requirements
  - Extend range ≥ 60% compared to legacy systems
  - Flexible end-game scenarios
  - Shorter time-of-flight to intermediate ranges
- BLOS/NLOS effects
  - Highly mobile Fire Support
- Counter UAS

**TECHNICAL APPROACH:**

- Two or more pulses (multiple levels desired)
- High turn-down boost sustain
- Active/passive throat area control combined with pulse motor and/or boost sustain
- Compatible with less shock-sensitive minimum signature propellants
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YouTube
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Twitter
@usarmyamrdec

Public Affairs
AMRDEC-PAO@amrdec.army.mil