Leveraging ERS to Enable Digital Engineering for Rotorcraft Acquisition

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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
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
#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.
Digital Engineering (DE) (closely related to model-based engineering or model-based systems engineering) is an initiative championed by the Office of the Deputy Assistant Secretary of Defense for Systems Engineering ODASD(SE).

Digital Engineering is intended to help streamline the way the DoD designs warfighting systems, conducts design trade-off analyses, and collects, retains, and shares data via models (which take the form of data, process, and/or algorithm), with increased use of interoperable engineering tools and virtual environments in the design process.

Digital Engineering evolved to the current concept through increased application of modeling and simulation efforts in traditional acquisition engineering activities, coupled with increased use of advanced tools and techniques in computational science.

Use of modeling and simulation (M&S) in engineering, or in engineering support to acquisition, is now a subset of Digital Engineering.

Digital Engineering will accelerate the development of Future Vertical Lift
DoD HPC* Modernization Program

DoD Supercomputing Resource Centers

Software Applications Support
- Institutes/Portfolios
- Education & Outreach
- CREATE
- SPI

Networking
Defense Research & Engineering Network

Resource Management Requirements & Allocations
- DHPIs
- Challenge Projects

*High Performance Computing
ERS is a combination of people, processes, and tools working together to streamline the integration of technological innovations into credible acquisition models that can then support digital engineering across the lifecycle of the system. ERS uses process-flow mechanics, high-fidelity physics models, and advanced computing to quickly generate complete tradespace environments. ERS data analytics tools and visualization techniques compliment experimentation, prototyping, and physical testing to complete our understanding of complex systems.
Cargo PM Requirements:
- Create an M&S plan to predict mission performance for the CH-47 helicopter with new blades
- Provide formal Verification, Validation, and Accreditation (VV&A) documentation IAW AR 5-11

** Helios: High-fidelity, full vehicle, multi-physics analysis tool for rotary-wing aircraft
** HELOP: Flight/mission performance analysis tool
**M&S Requirement (Cargo PM)**

Predict mission performance for the CH-47 helicopter with new blades using Helios-based rotor map.

**Software Basis**

Helios v4.0, HELOP 68.0

**Validation Data**

Wind tunnel data for model-scale, isolated rotors. Legacy flight test data. Will compare with flight test data when available.

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**Sample Mission**

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**Schedule**

<table>
<thead>
<tr>
<th>Task ID</th>
<th>Task Name</th>
<th>Q1 14</th>
<th>Q2 14</th>
<th>Q3 14</th>
<th>Q4 14</th>
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<th>Q2 15</th>
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<td>4</td>
<td>CH-47F w/ ACRB Mission Analysis</td>
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<td>4.1</td>
<td>Thrust Sweep - Hover</td>
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<td>4.6</td>
<td>Perform Mission Analysis</td>
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**Acquisition Support**

- Initial predictions based on expert consensus
- Procedures/models developed and then validated against legacy flight test data (Task 3).
- Validated simulation-based predictions are defensible and repeatable (substantiation data)
- Digital Engineering supported a critical programmatic decision to proceed with acquisition
Objective: Develop plans for CREATE-AV activities that build bridges to organizations which own targeted acquisition processes and that facilitate effective transfer of CREATE-AV technology and software into the respective acquisition engineering workforces.

- JHL Concept Refinement (2009, ADD)
- MH-60M Flight Simulation Database (2010, Aviation Engineering Directorate-AED)
- Performance Validation of CH-47 Rotor Blade (2011, AED)
- CH-47 Installed Rotor Performance (2013, AED)
- OH-58 Tail Loading (2013, AED)
- UH-60 In Ground Effects (2013, AED)
- Dynamic Hub and Pitch Link Loads on the CH-47 (2014, AED)
- Tail Rotor Effectiveness During High/Hot Low Speed Turns (2014, AED)
Objective: Develop plans for CREATE-AV activities that identify and prioritize a set of high profile opportunities to clearly show the impact on defense acquisition programs that is possible using CREATE software and HPCMP computers.

- Engineering Analysis for Engine/Airframe Integration of the Improved Turbine Engine (ITE) Program (2015, AED)
- CH-47 Steady State Flight Envelope (2016, AED)
- Gray Eagle Flight Performance* (2016-17, AED)
- Comprehensive Analysis of a Single Main Rotor, Winged, Compound Helicopter* (2017-18, AED/ADD)
- Modeling V-280 Tiltrotor Transition using Helios* (2017-18, ADD)
- UAS Shadow Analysis-Test Performance Correlation* (2017-18, AED/S3I)

* Funded by the Engineered Resilient Systems (ERS). The purpose of the ERS is to facilitate the use of DoD S&T investments for challenges within the DoD Acquisition Community.
Cargo Mission Analysis Timeline

**Boeing ACRB Wind Tunnel Activities**
- H47 & ACRB - Test & Data Reduction
- H47 & ACRB - Test & Data Reduction

**AED CH-47F Helios Model - Development**
- Shadow*: H47 & ACRB - Tool Assessment (Hover)
- Shadow: H47 & ACRB - Parametric Study (Hover)
- STAR**: FY-11: H47 & ACRB - Detailed Design Study (Hover)
- Shadow: H47 & ACRB - Detailed Design Study (Forward Flight)
- STAR FY-13: CH-47F - Hover
- STAR FY-14: CH-47F - Loads Analysis
- CH-47F Performance Model Development Complete

**CREATE-AV Helios Development Milestones**
- Helios v1.2 - Isolated Rotor w/o Trim
- Helios v2.0 - Isolated Rotor w/ Trim
- Helios v3.0 - Tandem Helicopter w/o Trim
- Helios v4.0 - Tandem Helicopter w/ Rotor Trim
- Helios v5.0 - Performance Enhancements

**AED CH-47F Helios Model - Engineering**
- Task 1: H47 & ACRB - Isolated Rotor Performance
- Task 2: CH-47F Performance Model
- Task 3: CH-47F Mission Analysis
- Task 4: CH-47F w/ ACRB Mission Analysis Prediction

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**Building Bridges**

**Impacting Acquisition**

*Note: Dates are placeholders and may vary in actual production.*
ODASD(SE) asserts that DE has the potential to promote greater efficiency, increased coherence, and reduced risk in defense programs by ensuring stakeholders have access to accurate, relevant, and consistent information, coupled between technical and programmatic, throughout the life of a program.

Army Regulation (AR) 5-11 mandates VV&A of models.

Department of Army Pamphlet 5-11 gives procedures to assist the M&S developer, proponent, and application sponsor in conforming to the VV&A policies.

- VV&A establishes the credibility of M&S to effectively support Army decisions.
- All models, simulations, and associated data developed, made available, managed, or used by the Army to support Army or DoD processes, products, and decisions will undergo verification and validation throughout their lifecycles and be accredited for the intended use.
- Cargo PM identified a requirement for M&S IAW AR 5-11.
- Procedure development started with the CH-47 Block 2 efforts and continues to evolve.
• VV&A establishes the credibility of M&S to effectively support Army decisions.
• All models, simulations, and associated data developed, made available, managed, or used by the Army to support Army or DoD processes, products, and decisions will undergo verification and validation throughout their lifecycles and be accredited for the intended use.

**Verification:** The process of determining that a model or simulation implementation and its associated data accurately represents the developer’s conceptual description and specifications.

**Validation:** The process of determining the degree to which a model or simulation and its associated data are an accurate representation of the real world from the perspective of the intended uses of the model.

**Accreditation:** The official certification that a model, simulation, or federation of models and simulations and associated data is acceptable for use for a specific purpose.
AoA (Milestone A): Future Vertical Lift (FVL) Future Long Range Assault Aircraft (FLRAA)

- TRAC (TRADOC Analysis Center) requested to assess fielded and conceptual models in existing performance planning tools.

- AMSAA (Army Materiel Solution Analysis Activity) requires fielded aircraft data for baseline and alternative assessments.

- IAW AR 5-11, AMRDEC developed a VV&A procedure to wrap performance data in simplified engineering flight models to meet requirements.
FLRAA AoA Fielded Alternatives

Alternatives

Baseline | Upgrades | Compounds | Tiltrotors

MODEL REQUIREMENTS

MODEL SPECIFICATION
Data
Software

MODEL DEVELOPMENT
Data
Software

MODEL VERIFICATION

MODEL VALIDATION

TECH DATA PACKAGE DELIVERY

MODEL ACCREDITATION

AED / Simulation & Aerodynamics Branch

AED / Flight Performance & Mass Properties Branch

Army Materiel Solution Analysis Activity (AMSAA)
FLRAA AoA Conceptual Alternatives

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Upgrades</th>
<th>Compounds</th>
<th>Tiltrotors</th>
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</thead>
</table>

MODEL REQUIREMENTS → MODEL SPECIFICATION → MODEL DEVELOPMENT → MODEL VERIFICATION → MODEL VALIDATION → TECH DATA PACKAGE DELIVERY → MODEL ACCREDITATION

AED / Simulation & Aerodynamics Branch
ADD / Conceptual Design & Assessments Technical Area
Army Materiel Solution Analysis Activity (AMSAA)
FLRAA AoA
Digital Engineering Process

M&S Requirement: Accredited flight performance models for FVL assessments.

Aviation Data
- Flight Test
- Wind Tunnel
- OEM Concept (JMR)
- Engine Decks
- M&S output

Hardware and Software
- High Performance Computing (HPC)
- Computer Scientists
- Applied Mathematicians

Data Science
- Pre-processing input data sets for AMSAA MATLAB and EFMs
- Data expansion
- Model requirements development
- Data visualization

Modeling and Simulation
- Helios Model
- NDARC Conceptual Models
- Engineering Flight Models

PEO Support to Soldier

Support to PEO
- Flight Performance data sets and specifications for AMSAA modeling
- FLRAA Engineering Flight Models (Baseline, Upgrades, Compounds, Tiltrotors)
M&S Requirement: Predict mission performance for the CH-47 helicopter with new blades.
Army Aviation DE Process for Acquisition Support

Process entry requires a definition of PEO M&S requirements

Aviation Data
- Operations
- Flight Test
- Wind Tunnel Test
- Logistics
- M&S output (CFD, EFM, …)

Hardware and Software
- High Performance Computing (HPC)
- Computer Scientists
- Applied Mathematicians

Data Science
- Data Management
- Data Reduction
- Data Visualization

Modeling and Simulation
- Tools (CREATE, NDARC, HELOP, …)
- Physical Models
- Empirical Models

PEO Support to Soldier

Support to PEO
- Maintenance Strategy
- Spec Compliance, KPP's
- Requirements Development
- AoA Support
- Evaluation of Aircraft Mods
- Operational Guidance
- …

VV&A (AR 5-11)

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
PEO Chief Engineers Forum (Technical Chiefs from each PM)

- 27 October 2016: “AMRDEC’s Modelling and Simulation Support for Army Aviation Acquisition”

- 19 October 2017: “Verification, Validation and Accreditation for M&S”

Individual PM Technical Chief Briefings

  Having an accredited performance model would allow the documentation of predicted performance characteristics and capabilities … Having this model can aide the acquisition strategy by:
  1) Enabling the execution of conceptual design trades for a defined Capability Set
  2) Providing quantifiable information that can be scored in an AoA
  3) Providing guidance for developing Specification Criteria

  Integration of M&S into the acquisition strategy requires identification of how M&S is able to support each Decision Point, Milestone Decision and Major Review in the acquisition process.
Impact of Digital Engineering on the acquisition process has been demonstrated:
- FVL FLRAA AoA Support: Early phase acquisition
- Cargo Mission Analysis Support: PDR, CDR and Milestone B Decision

To realize the benefits of Digital Engineering, VV&A procedures were developed to ensure accurate, relevant, and consistent information.

Defining M&S requirements are key to the success of Digital Engineering implementation:
- Processes and procedures will continue to evolve (includes Tools)
- Need to assist PEO (accreditation authority) in developing M&S plan and obtaining digital artifacts (e.g. outer mold line, etc.)

Future Vertical Lift: FARA, Future UAS, FLRAA, …
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