Presented to:

21st Annual NDIA Systems and Mission Engineering Conference

Leveraging ERS to Enable Digital Engineering for Rotorcraft Acquisition

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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U.S. Army Aviation and Missile Research, Development, and Engineering Center

AMRDEC Mission

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

FY17

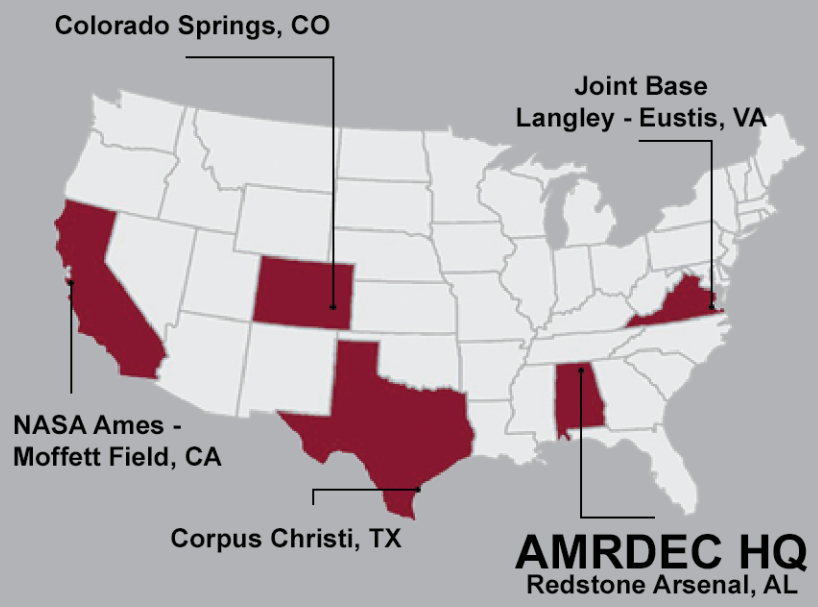
$2,904M

6% Aviation S&T

7% Missile S&T

63% Army

24% Other



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

AMRDEC Priorities

#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

https://www.acq.osd.mil/se/initiatives/init_de.html

- 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.

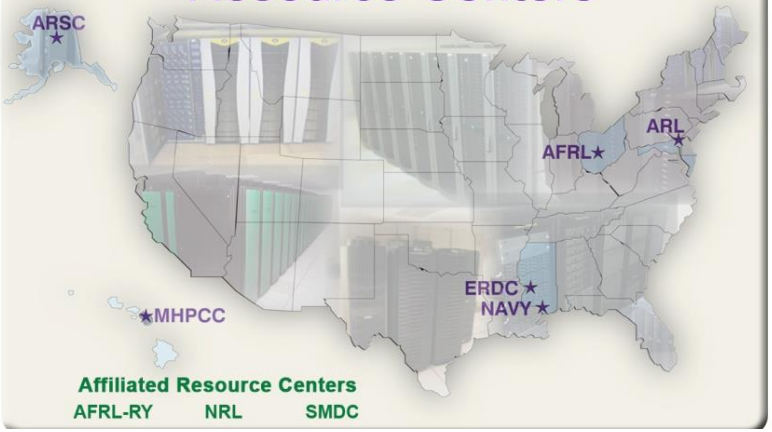
- Digital Engineering evolved to the current concept through increased application of modeling and simulation efforts in traditional acquisition engineering activities, coupled with **increased use of advanced tools and techniques in computational science**.

- 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



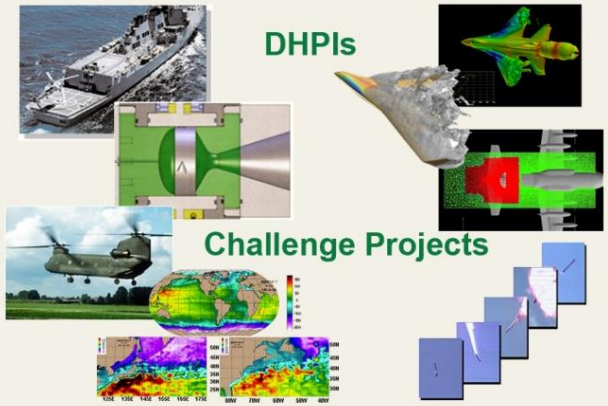
Software Applications Support

Networking

Defense Research & Engineering Network

Resource Management

Requirements & Allocations



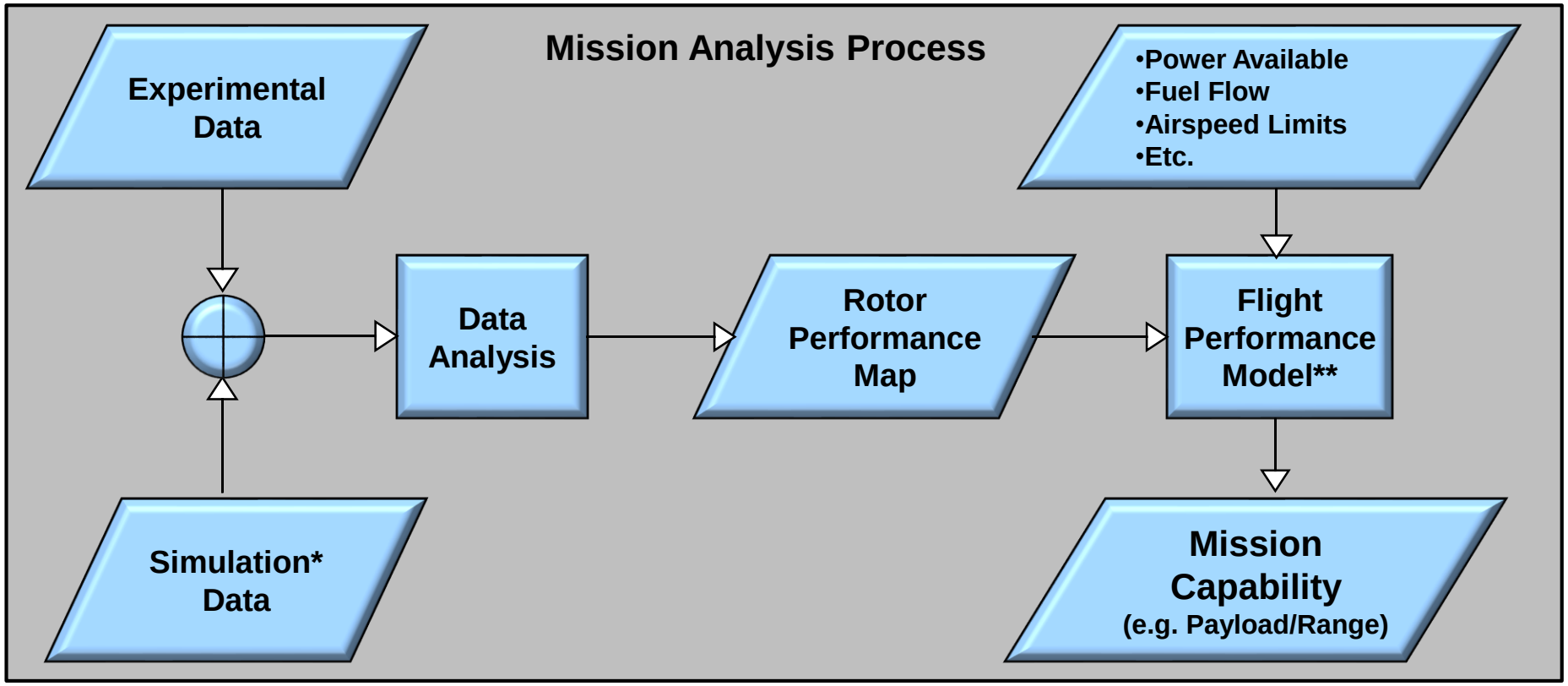
***High Performance Computing**

Engineered Resilient Systems (ERS)

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.

Digital Engineering Application
Cargo Mission Analysis

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

Collaborative M&S Plan
Cargo Mission Analysis

M&S Requirement (Cargo PM)

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

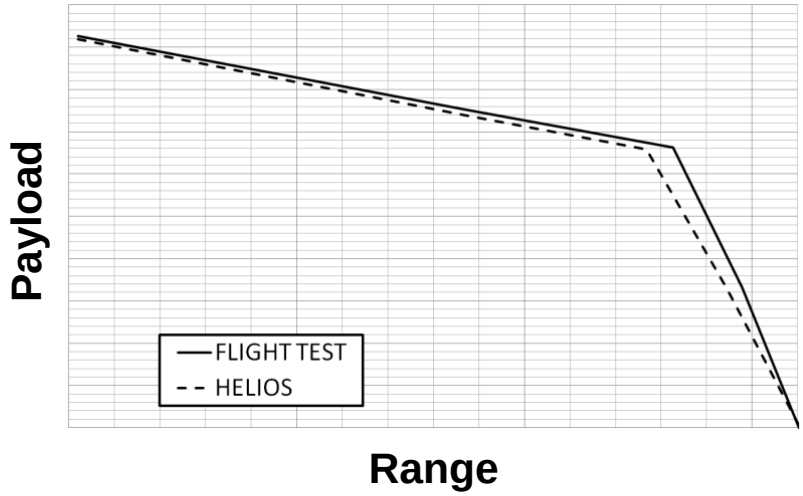
Software Basis

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.

Sample Mission



Schedule

Task ID	Task Name	Q1 14 J F M	Q2 14 A M J	Q3 14 J A S	Q4 14 O N D	Q1 15 J F M	Q2 15 A M J
4	CH-47F w/ ACRB Mission Analysis						
4.1	Thrust Sweep - Hover						
4.2	~~Thrust Sweep - 200 ft/min VROC~~						
4.3	Speed Sweep - High Gross Weight						
4.4	Speed Sweep - Mid Gross Weight						
4.5	Speed Sweep - Low Gross Weight						
4.6	Perform Mission Analysis						
4.7	Report						

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*

Strategic TARgeting (STAR) Projects
2008-2014

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.*

- CH-47 Advanced Rotor Blade Design (2009, Aviation Development Directorate-ADD)
- JHL Concept Refinement (2009, ADD)
- MH-60M Flight Simulation Database (2010, Aviation Engineering Directorate-AED)
- Performance Validation of CH-47 Rotor Blade (2011, AED)
- OH-58D Rotor Power Effects (2012, 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)

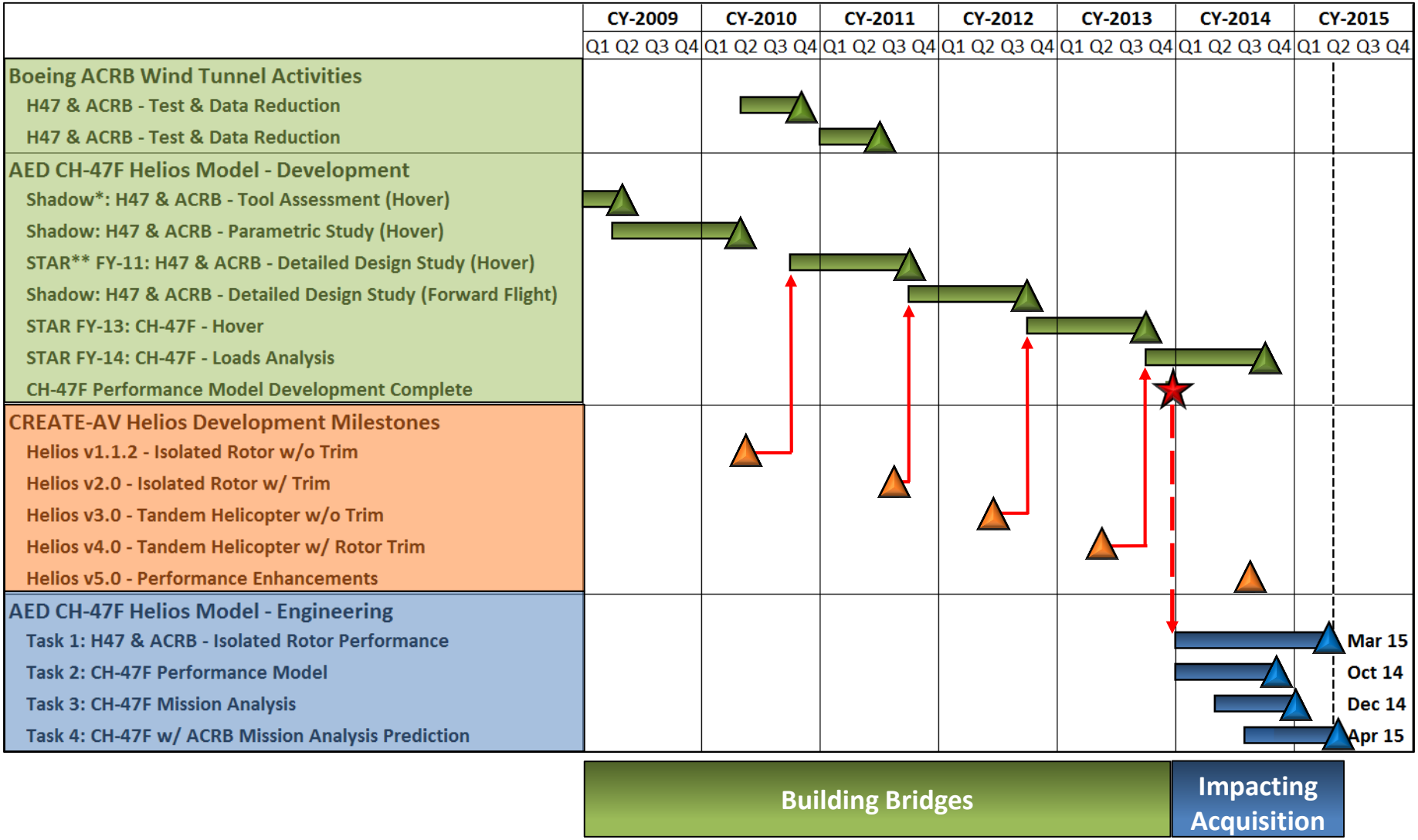
Impacting Acquisition Programs
2014-2017

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.*

- Modeling and Simulation Effort to Support the CH-47 Block II Program – ACRB Flight Performance* (2014-15, AED)
- 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



Digital Engineering Requires Verification, Validation & Accreditation

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.

Army Regulation 5-11
Management of Army Models and Simulations

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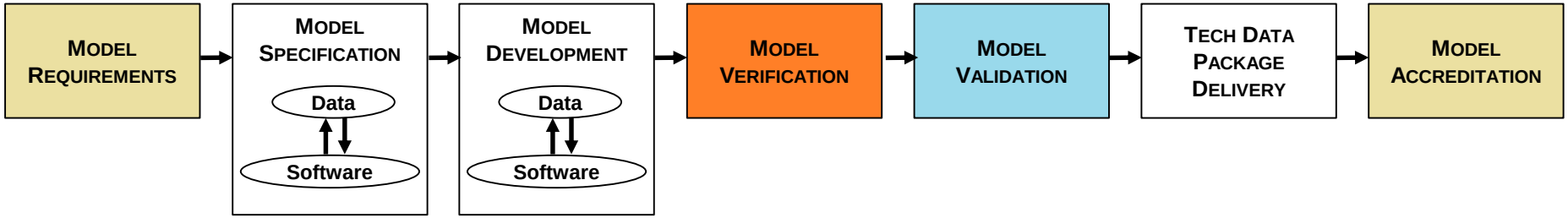
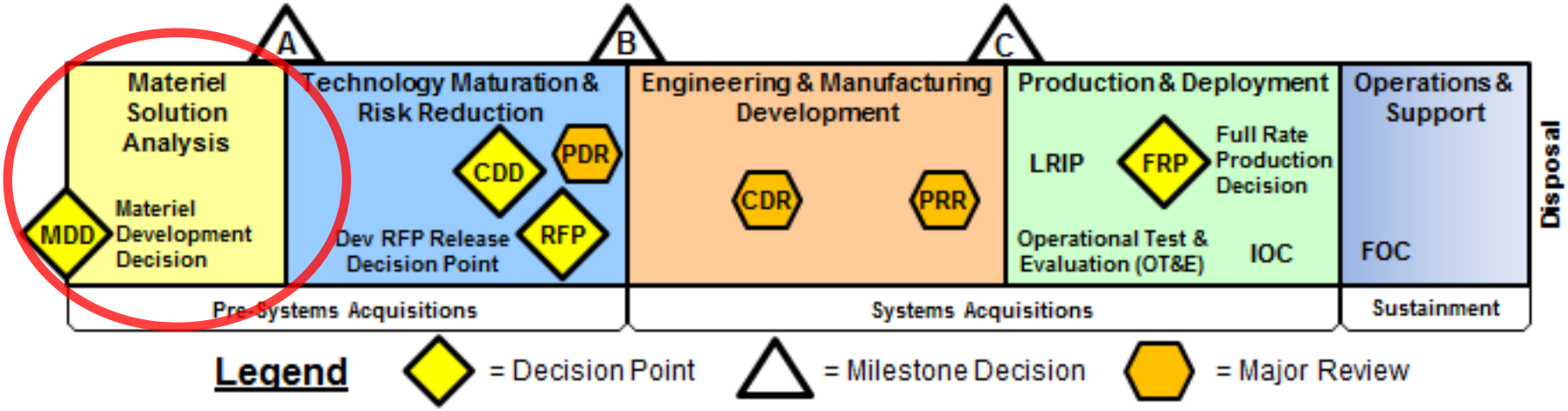


Verification: The process of determining that a model or simulation implementation and its associated data accurately represents the developer's conceptual description and specifications.

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.

Application of VV&A Procedure
Analysis of Alternatives (AoA)

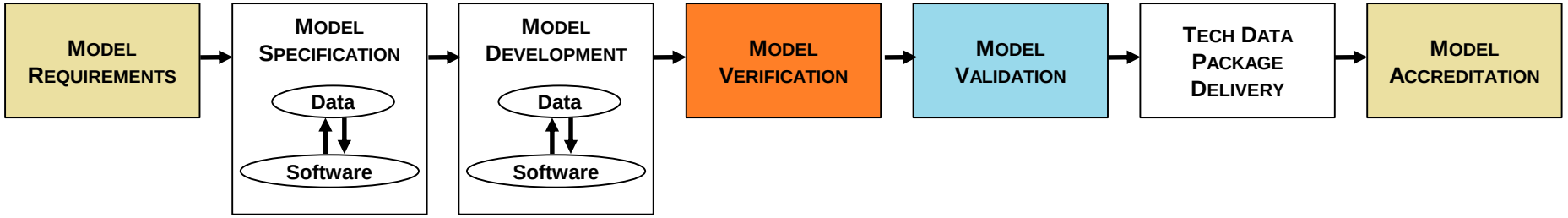


AoA (Milestone A): Future Vertical Lift (FVL) Future Long Range Assault Aircraft (FLRAA)

- 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



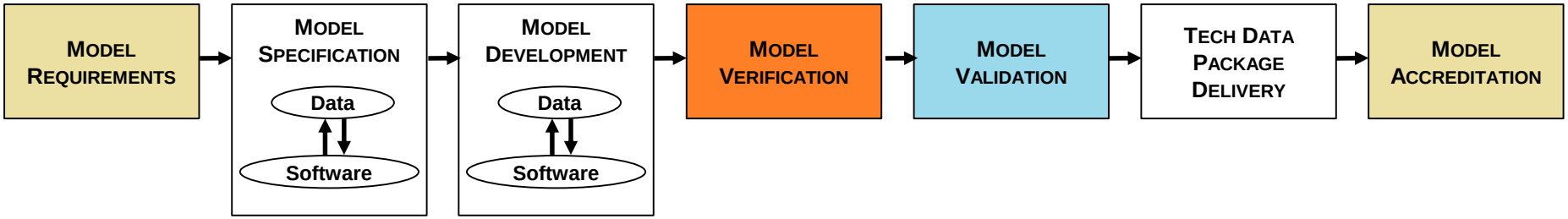
AED / Simulation & Aerodynamics Branch

AED / Flight Performance & Mass Properties Branch

Army Materiel Solution Analysis Activity (AMSAA)

FLRAA AoA Conceptual Alternatives

	Alternatives		
Baseline	Upgrades	Compounds	Tiltrotors



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

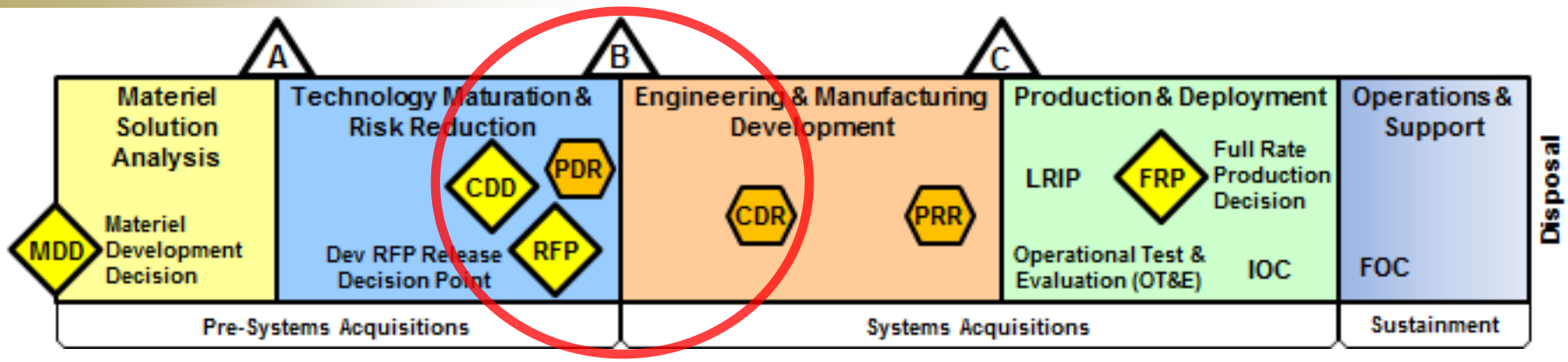
PEO Support to Soldier

Support to PEO

- Flight Performance data sets and specifications for AMSAA modeling
- FLRAA Engineering Flight Models (Baseline, Upgrades, Compounds, Tiltrotors)

V V & A (AR 5-11)

Cargo Mission Analysis
Digital Engineering Process



M&S Requirement: Predict mission performance for the CH-47 helicopter with new blades.

Aviation Data

- Legacy Flight Test
- CH-47F Flight Test
- Wind Tunnel Test
- M&S Output

Hardware and Software

- High Performance Computing (HPC)
- Computer Scientists
- Applied Mathematicians

Data Science

- Data Management
- Data Reduction
- Data Visualization

Modeling and Simulation

- Helios CH-47 Model
- Helios new blade Model
- CH-47 w/new blade Model

PEO Support to Soldier

Support to PEO

- Evaluation of Flight Performance.
- Comparison to Spec.
- Evaluation of proposed LCTA modifications.

V V & A (AR 5-11)

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
- …

V V & A (AR 5-11)

PEO M&S Requirements

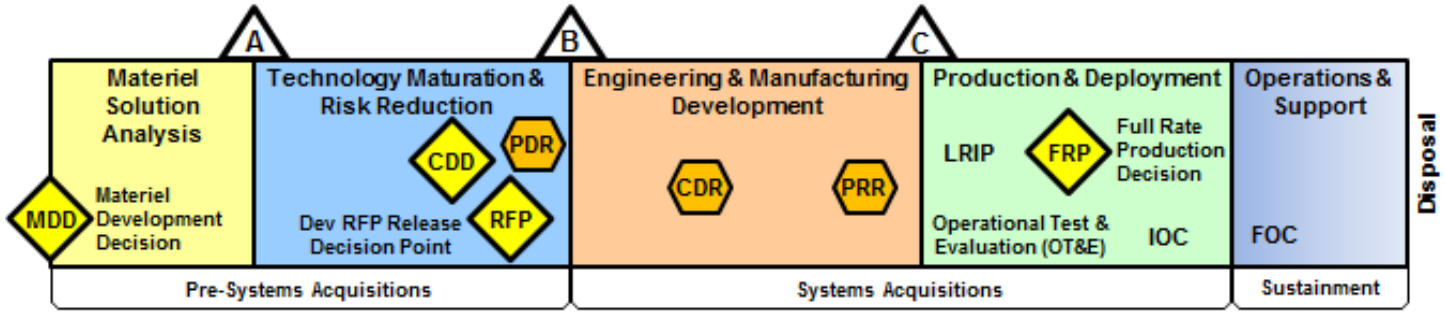
PEO Chief Engineers Forum (Technical Chiefs from each PM)

- 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

- *Future Vertical Lift Project Office* (5 September 2017)
  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
- *Unmanned Aircraft Systems (UAS) Project Office* (21 November 2017)
  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.

Summary



- 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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