Presented to:

19th Annual NDIA Systems Engineering Conference

Leveraging Modeling and Simulation to Impact Army Aviation Acquisition

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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

Date: 26 October 2016

Army Aviation

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Mission

Deliver responsive airworthiness solutions throughout the system lifecycle. Sustain the leadership and engineering expertise necessary to provide valued products to our aviation customers.

Airworthiness: The property of an air system configuration to safely attain, sustain, and complete flight in accordance with approved usage limits.

- Required by law (49 USC 106)
  - Under 14 CFR, FAA does for civil aviation
- Governed by Army Regulation 70-62
- Airworthiness Authority = CG AMCOM

What this means to the Aviation Units…

- It is Safe to Operate and will Perform the Mission when Delivered
- It will Continue to Safely Perform the Mission if Operated and Maintained per the Manuals
- Parts and Overhaul work must be per approved sources and standards to Maintain Airworthiness

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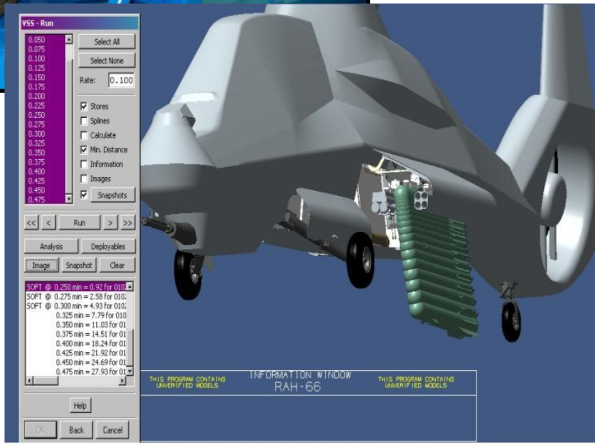
Lifecycle Acquisition Support

AMRDEC

- Contractor development test
- Formal inspection, design review, and safety assessment
- Component qualification test of performance under specified conditions and duration
- Formal contractor demonstrations
- Government testing
- Engineering analysis, modeling, and simulation (M&S)



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CREATE* Program

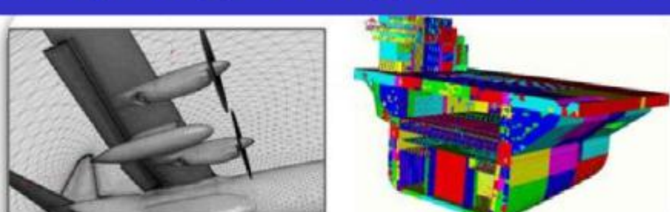
- **CREATE is a DoD program to develop and deploy multiphysics-based software for engineering design and analysis of:**
- **Air Vehicles (AV)**
  - Aerodynamics, structures, propulsion, control, concept design…
- **Ships**
  - Shock vulnerability, hydrodynamics, concept design
- **Radio Frequency (RF) Antennas**
  - RF Antenna electromagnetics and integration with platforms
- **Mesh and Geometry (MG) Generation**
  - Rapid generation of mesh and geometry representations

CREATE tools support all stages of acquisition from rapid early stage design to full life-cycle sustainment


Design concept


Seakeeping and resistance


Shock vulnerability


Aircraft and aircraft carrier meshes


Military platforms with antennas

*** Computational Research and Engineering Acquisition Tools and Environments**

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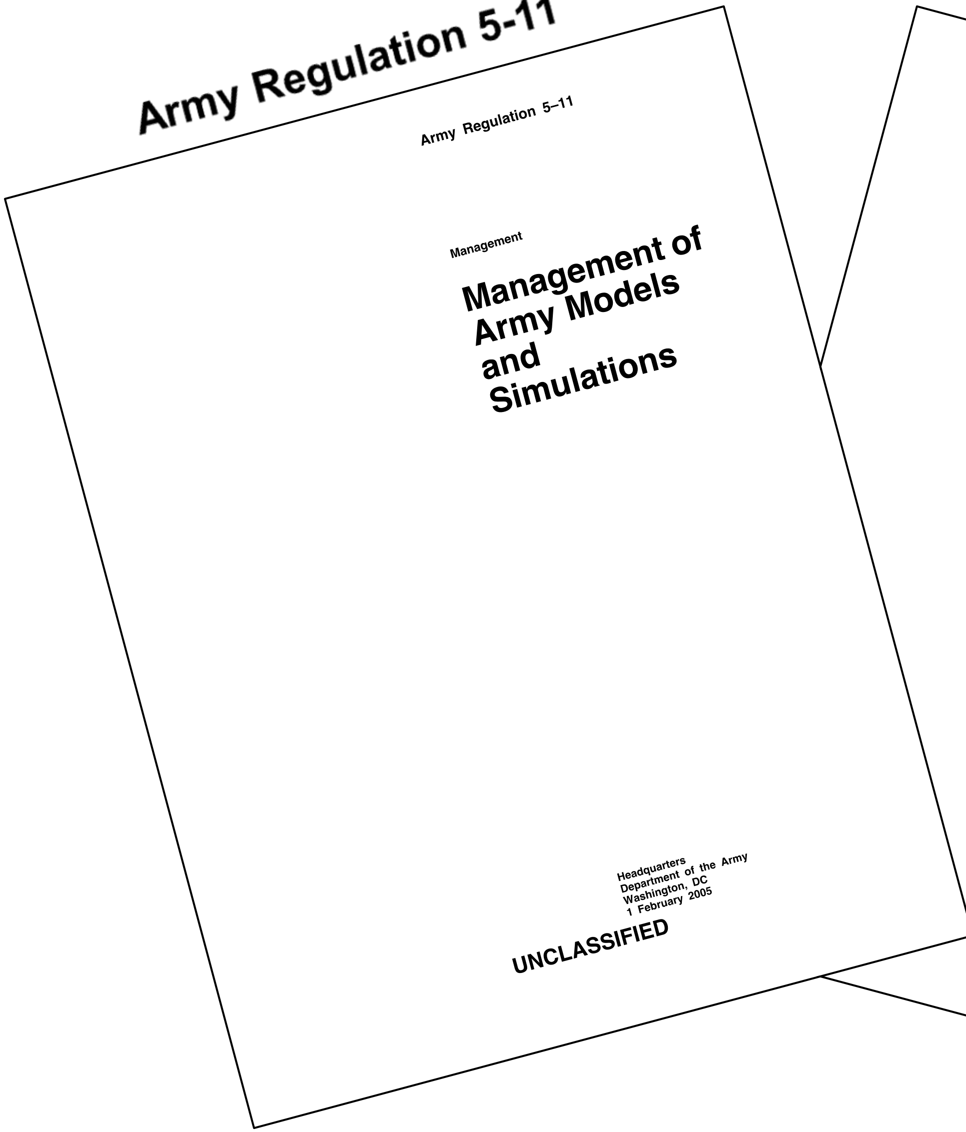
Verification, Validation, and Accreditation (VV&A)

Army Regulation 5-11


Army Regulation 5–11

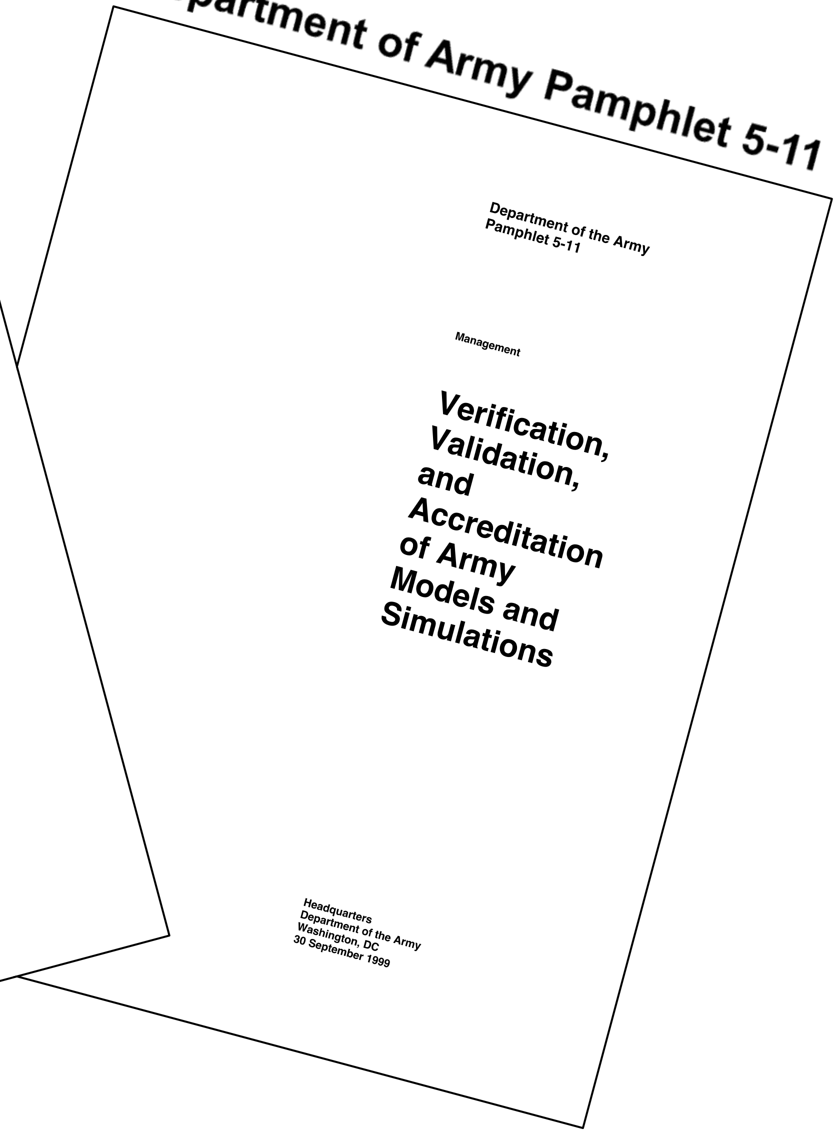
Management

Management of Army Models and Simulations

Headquarters
Department of the Army
Washington, DC
1 February 2005

UNCLASSIFIED

Department of Army Pamphlet 5-11


Department of the Army
Pamphlet 5-11

Management

Verification, Validation, and Accreditation of Army Models and Simulations

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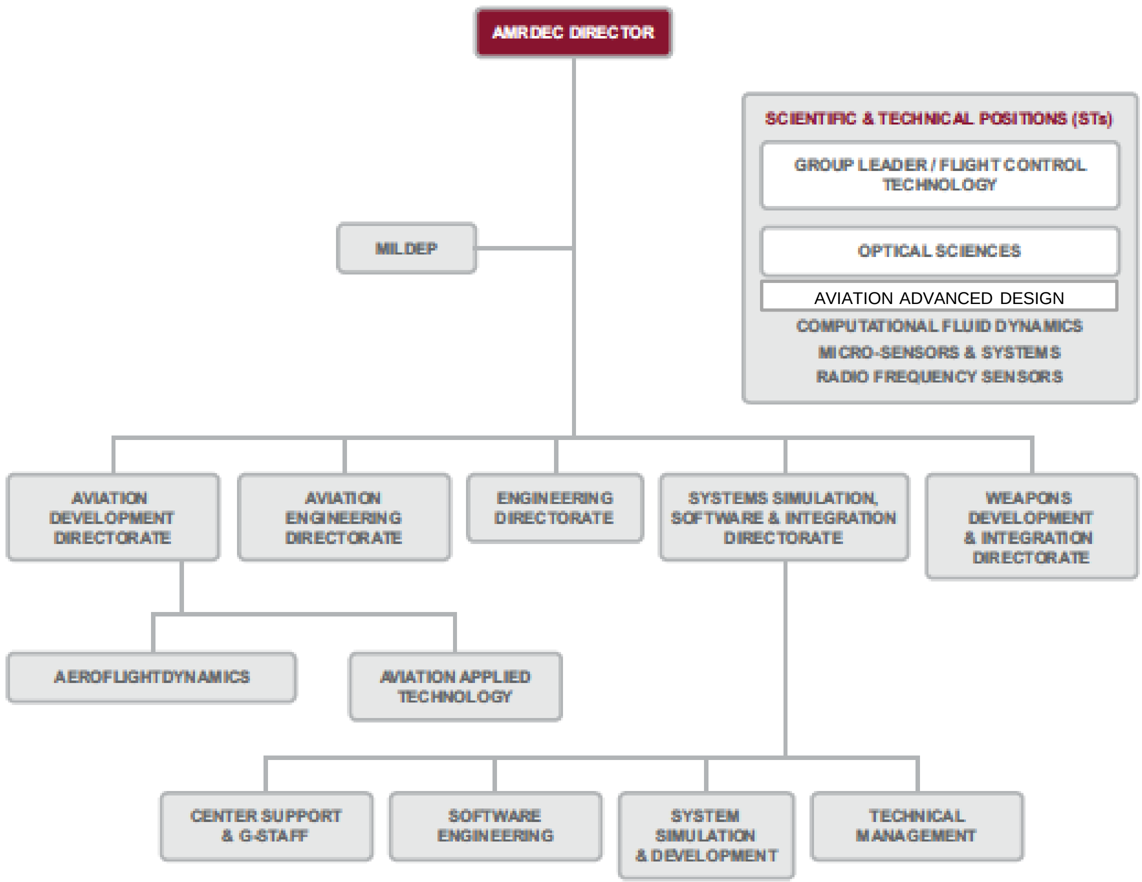
Washington, DC
30 September 1999

AMRDEC Org Chart



AMRDEC ORGANIZATION CHART

AMRDEC is part of the U.S. Army Research, Development and Engineering Command (RDECOM), which has the mission to develop technology and engineering solutions for America's Soldiers. RDECOM is a major subordinate command of the U.S. Army Materiel Command (AMC). AMC is the Army's premier provider of materiel readiness – technology, acquisition support, materiel development, logistics power projection, and sustainment – to the total force, across the spectrum of joint military operations. If a Soldier shoots it, drives it, flies it, wears it, eats it or communicates with it, AMC provides it.

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Projects Impacting Acquisition

AMRDEC

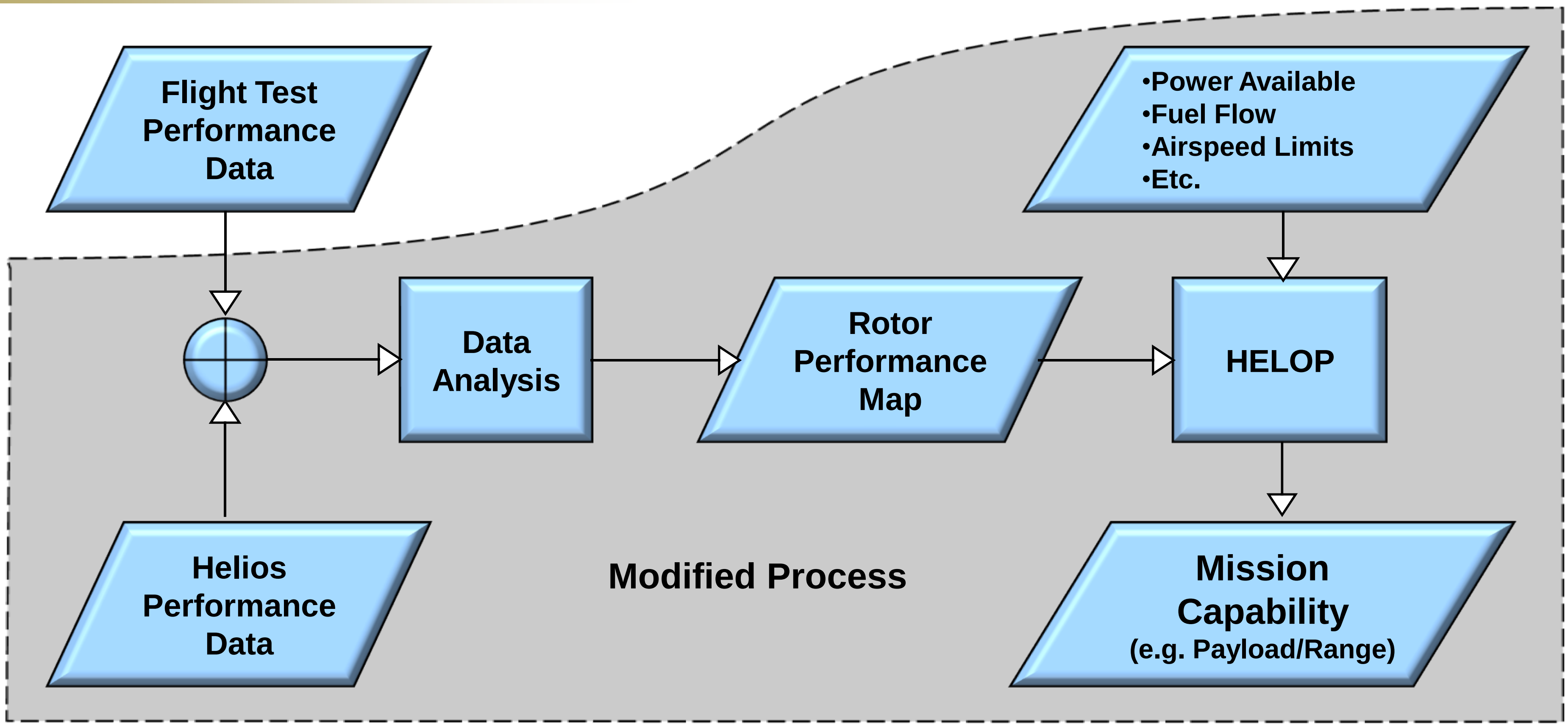
- *Modeling and Simulation Effort to Support the CH-47 Block II Program – ACRB Flight Performance (2014-15)*

- *CH-47 Steady State Flight Envelope (2016)*

- Engineering Analysis for Engine/Airframe Integration of the Improved Turbine Engine (ITE) Program (2015)

- Gray Eagle Flight Performance (2016)

CH-47 Mission Analysis
Mission Capability Process



Benefits

– Basis for predicting impact of future modifications
– Supports Data Analysis
– Optimized flight test matrix

CH-47 Mission Analysis

Objective

Demonstrate accuracy in predicting mission capability for the Legacy CH-47 helicopter using Helios Engineering Model based rotor map.

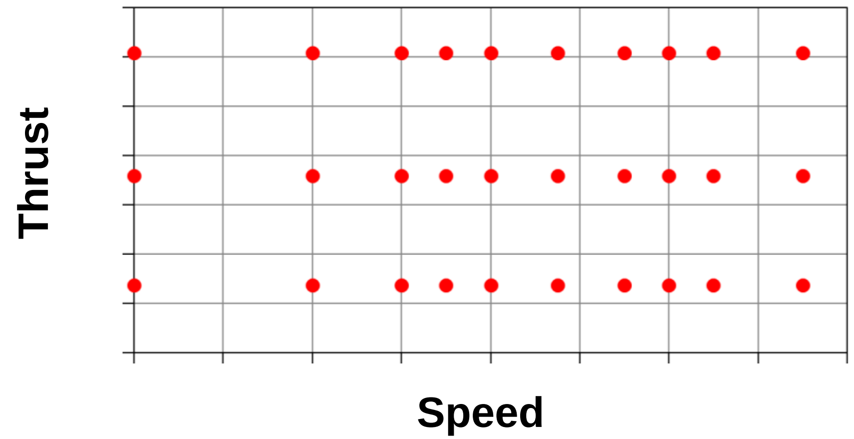
Software Basis

Helios v4.0

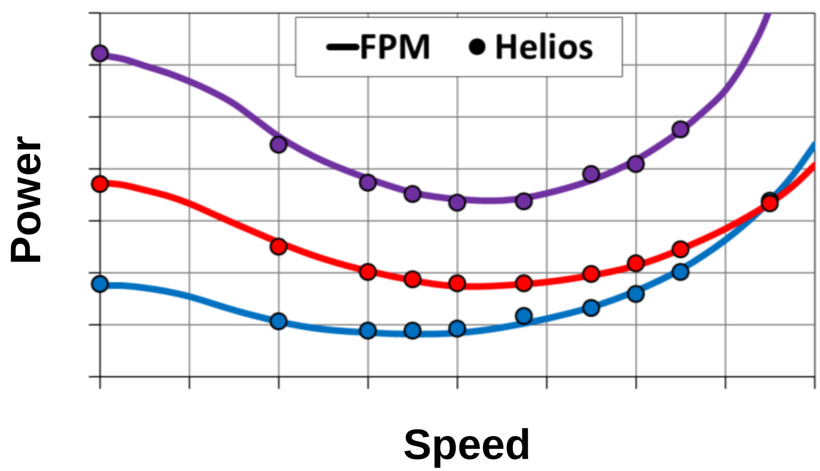
Evaluation Data

Legacy CH-47 Flight Performance Model (FPM)

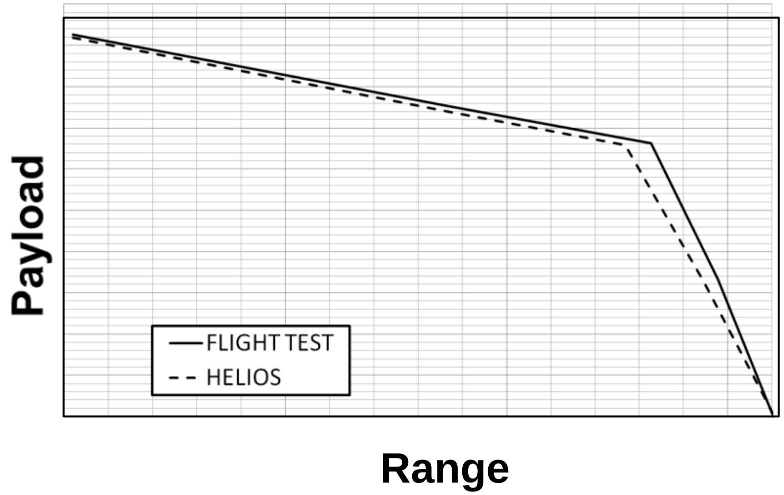
Run Matrix



Performance Data



Sample Mission



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CH-47 w/ACRB Blades Mission Analysis Prediction

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Objective

Predict mission performance for the CH-47 helicopter w/ACRB blades using Helios Engineering Model based rotor map.

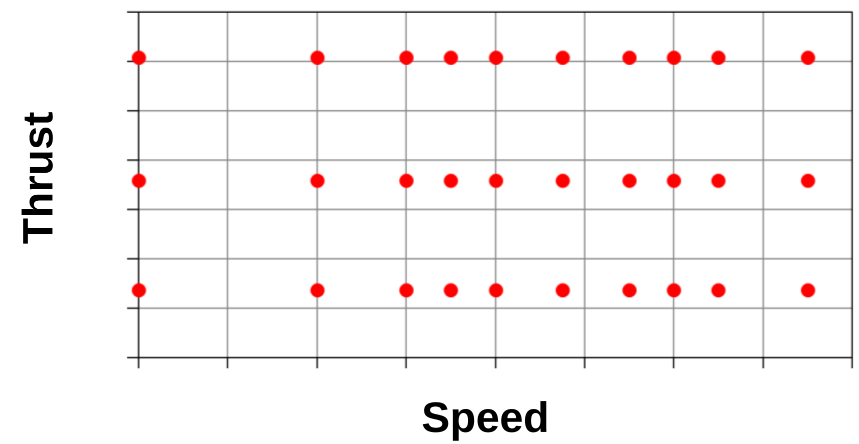
Software Basis

Helios v4.0

Evaluation Data

Will compare with flight test data when available.

Run Matrix



Schedule

Task ID	Task Name	Q1 14	Q2 14	Q3 14	Q4 14	Q1 15	Q2 15
		J F M	A M J	J A S	O N D	J F M	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						

Summary of Predictions

- Initial 2012 ACRB prediction based on SME experience (not a repeatable process)
- Current 2015 ACRB prediction based on modeling and simulation (repeatable process)
- 2015 ACRB prediction is slightly more conservative at higher thrusts compared to 2012.

Projects Impacting Acquisition

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

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- Gray Eagle Flight Performance (2016)

Performed by Army AED using HPCMP CREATE™

DOD HPC MODERNIZATION PROGRAM

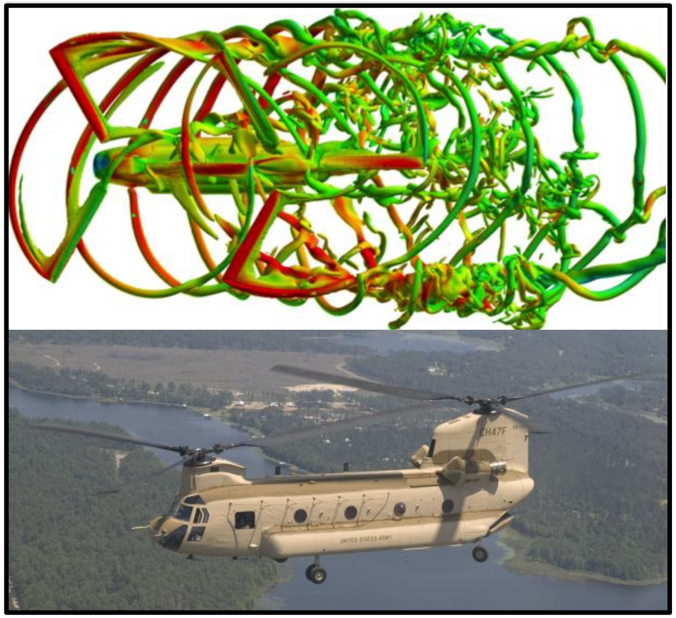
CH-47 Steady State Flight Envelope

Context: This project targets the Army's Aviation Engineering Directorate (AED) and the CH-47 PMO. AED is the lead for all structural assessments that lead to airworthiness releases (AWRs) for all Army aircraft. The CH-47 PM is developing a new rotor blade (ACRB), which has the potential to negatively impact dynamic component fatigue loads due to the planned increase in performance.

Project Objectives: Utilize HPCMP CREATE™ -AV tool Helios to develop and validate analytical predictions of dynamic component loads for rotor steady state operating conditions. Extend the validated baseline model to predict steady state dynamic component loads for the new ACRB rotor.

Project Impacts:

- Increased throughput of structural airworthiness assessments (interpretation of flight test data augmented with simulation capabilities)
- Flight Test Matrix Optimization through virtual test capacity
- Inform risk-reduction trade studies assessing the impact of blade design parameters on fatigue critical loads prior to an ACRB Milestone B decision



CH-47 Helicopter in steady state level flight; Helios main rotor wake contribution to dynamic component loads calculation

The validated Helios model provides AED with a supplemental tool to augment the current process of structural airworthiness assessment. This process supports the CH-47 PMO through risk reduction analytical studies and flight test matrix optimization.

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Engineering Analysis for Engine/Airframe Integration of ITEP

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- Black Hawk Tail Rotor: Recently a Helios tail rotor model (in-plane rotor with blades spaced by 90 degrees) was developed for the Black Hawk helicopter. This model will be leveraged to evaluate a new rigging procedure proposed by the PM to take advantage of increased engine power available. Current/future flight test data will be available for this effort.

- Apache Tail Rotor: Boeing's Apache attack helicopter is equipped with a teetering, stacked, scissored (i.e. the blades are not spaced by 90 degrees) tail rotor configuration. Recently, Boeing has re-designed the tail rotor blade to increase reliability. In collaboration with Boeing, this effort will use Helios to validate the re-design and provide a high fidelity tail rotor model for integration into Boeing's existing full-configuration aircraft model.

- Engine Modeling: Evaluate ITEP turboshaft engine/airframe integration, to include representative drive system dynamics and a core engine model, to emulate system torsional stability, rotor droop and overshoot for the AH-64 and UH-60 platforms. Existing flight test data will be available for this effort.

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Tail Rotor Effectiveness

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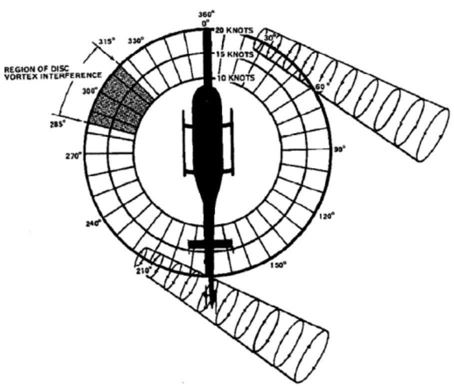
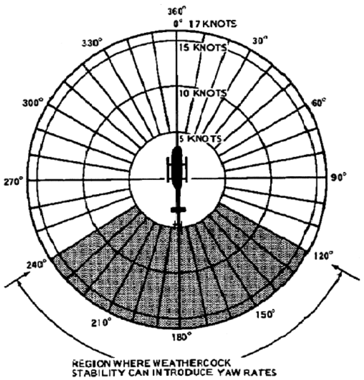
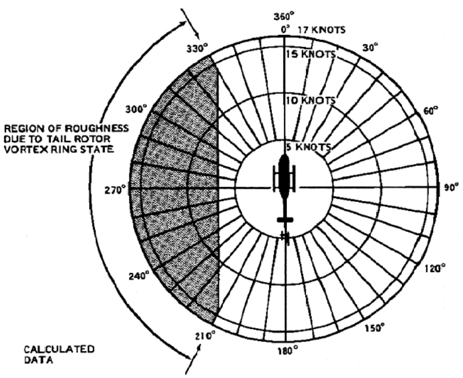
- The ability of the tail rotor (TR) to produce the thrust needed to balance the main rotor (MR) torque/power.
- As main rotor power increases, the tail rotor is pushed closer to the limits of its effectiveness.
- Hover and Low Speeds
- Heavy helicopter - max gross weight
- High / Hot atmospheric conditions
- Other factors influencing tail rotor effectiveness (FAA CA-90-95)



Tail rotor interacts with main rotor vortex wake.



Tail wind introduces an un-commanded yaw rate.



Tail rotor experiences vortex ring state.

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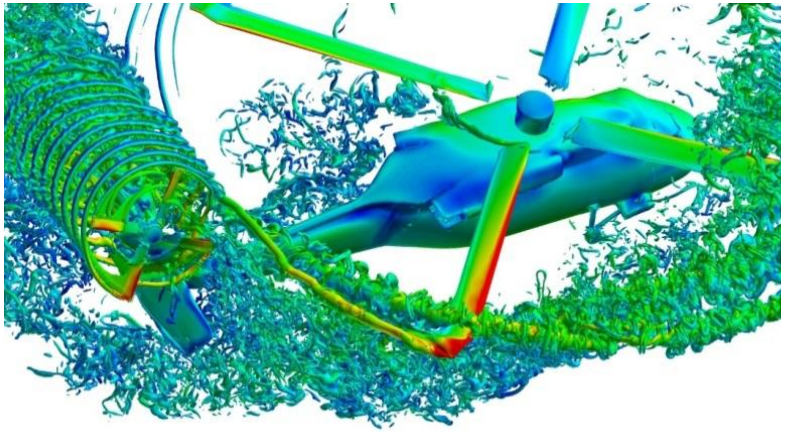
ITE Program Impact Chart

Performed by Army AED using HPCMP CREATE™

Improved Turbine Engine Program (ITEP)

Context: The Improved Turbine Engine Program (ITEP) is developing an engine that will produce significantly more power than the engine currently utilized by the Army's medium-sized helicopter fleet which includes the Black Hawk and Apache. This increase in power available will enhance mission performance. However, some operations may be limited due to the anti-torque available from current tail rotor designs.

Project Objectives: Utilize HPCMP CREATE™ -AV tools Helios and Kestrel to better understand issues related to ITEP engine integration. Targeted Platforms include Apache (with both the legacy tail rotor and Improved Tail Rotor Blade, ITRB) and Black Hawk (integrated effects of fuselage, main rotor, and engine).



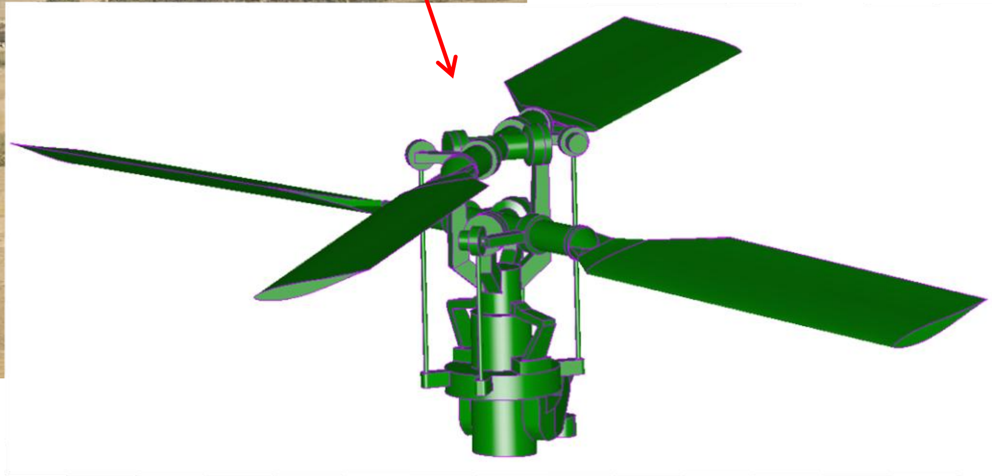
Black Hawk in low-speed flight demonstrating main rotor wake entrainment into the tail rotor.

Project Impacts:

- Apache: Delivered to the OEM a verified aircraft model that integrates the fuselage, main rotor and tail rotor. The OEM is using this verified model to assess tail rotor effectiveness and its impact on operational capability and support costs.
- Black Hawk: Developed a process that allows the Program Office access to OEM proprietary engine data that is critical for modeling and simulation to enable decisions on capability and cost early in the acquisition cycle.

The verified Helios model provides decision makers with quantifiable insight into the life-cycle cost impacts of ITE integration by allowing the Army and its industry partners the ability to assess effectiveness and influence conceptual aircraft design, such as Future Vertical Lift.

Apache Tail Rotor

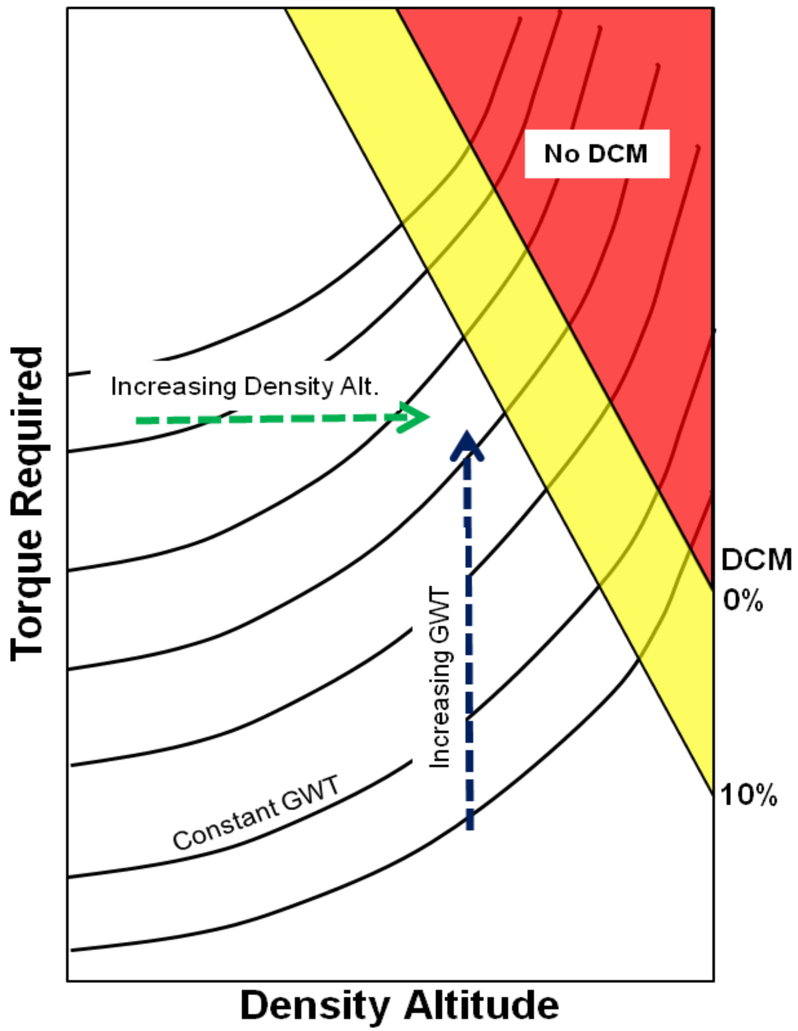


Apache attack helicopter is equipped with a teetering, stacked, scissored tailrotor configuration

Picture from Wikimedia Commons, the free media repository.

Directional Control Margin (DCM)
Impact to Warfighter

Typical Hover Chart



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Projects Impacting Acquisition

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Gray Eagle Flight Performance

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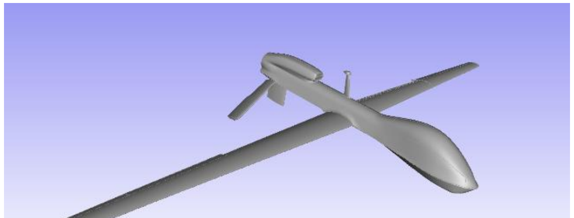
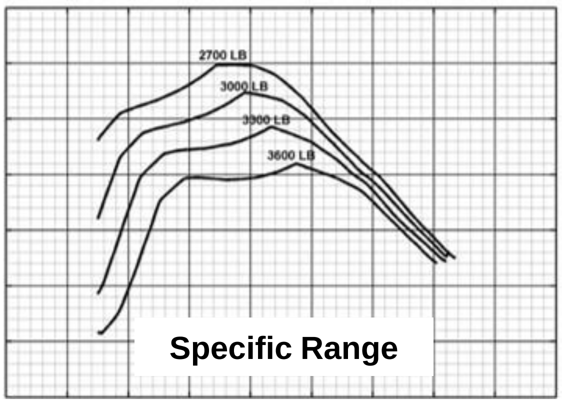


Scanned Model



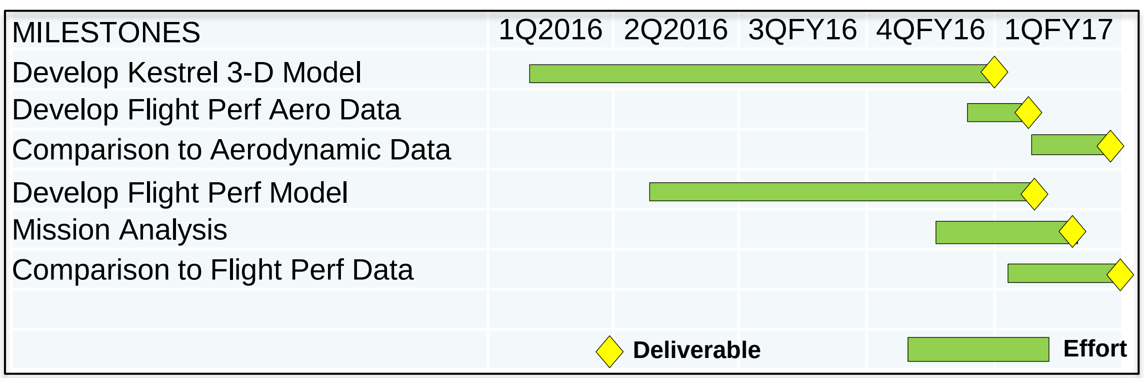
Specific Range

Purpose:

The Gray Eagle is an unmanned air vehicle used by the U.S. Army for a variety of missions. Maximizing time-on-station for these different missions is of utmost importance. Therefore, it is of interest to obtain flight performance (climb, cruise, descent) predictions for the Gray Eagle. Development of a validated computational model along with processes for predicting flight performance is a key goal for this effort. ***This will lead to future efforts that will investigate the effects of cross winds on takeoff and landing performance.***

Products:

- **Aerodynamic Database based on a Kestrel CFD Model of full scale aircraft with articulating control surfaces**
- **Flight Performance Model**
  - **Climb – Decent – Cruise**
  - **Specific Range**
  - **Time on Station vs. Mission Radius**



Payoff:

- **Provides PM UAS with an independent tool for evaluating flight performance for proposed modifications**
  - **OML changes (e.g., antenna, control surfaces)**
  - **Addition of store (e.g., pods, weapons)**
- **Independent evaluation of operator manuals**

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Gray Eagle – Common CAD

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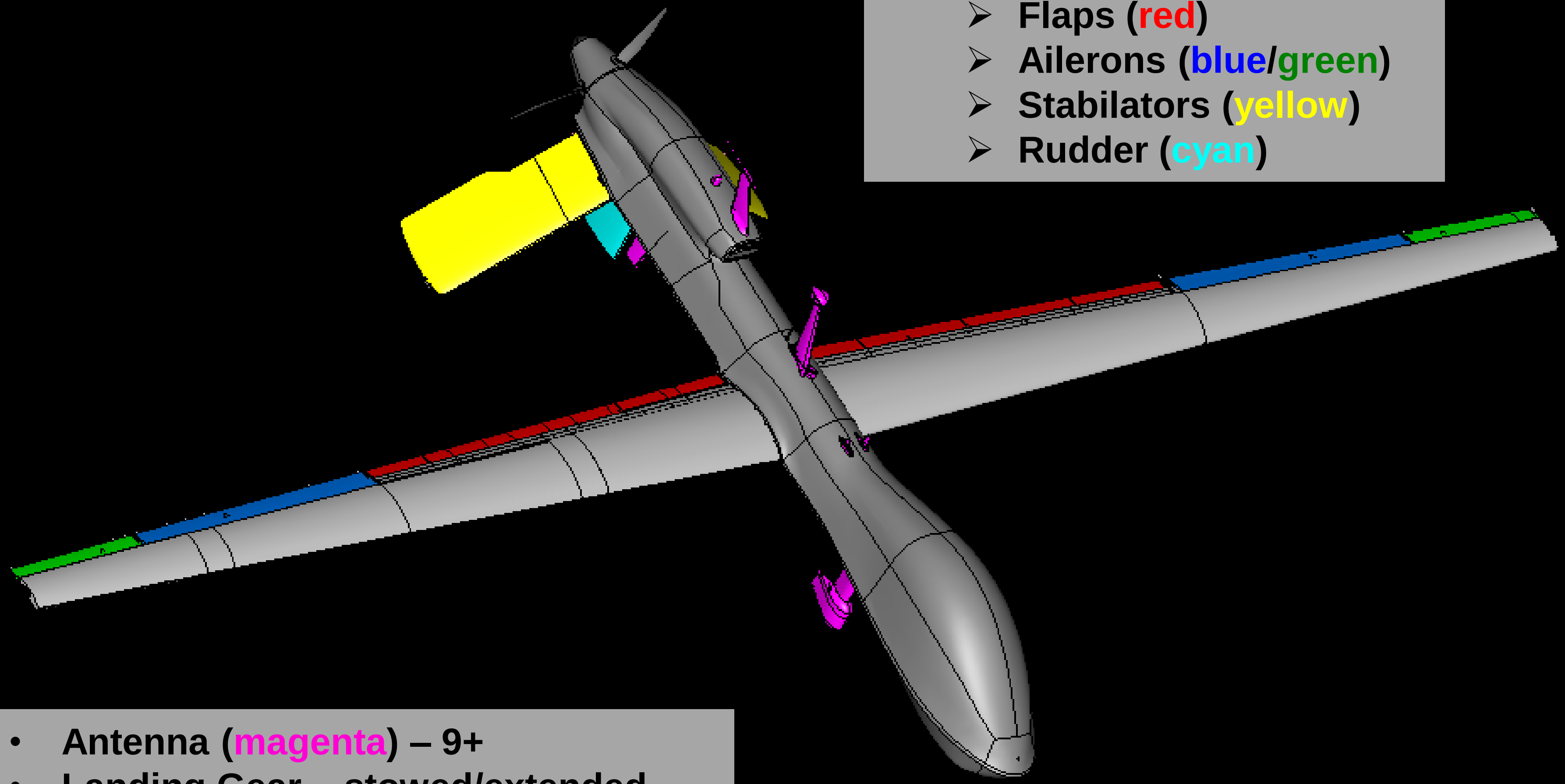
Control Surfaces:

- Flaps (red)
- Ailerons (blue/green)
- Stabilators (yellow)
- Rudder (cyan)



- Antenna (magenta) – 9+
- Landing Gear – stowed/extended

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Fixed Wing Aerodynamics

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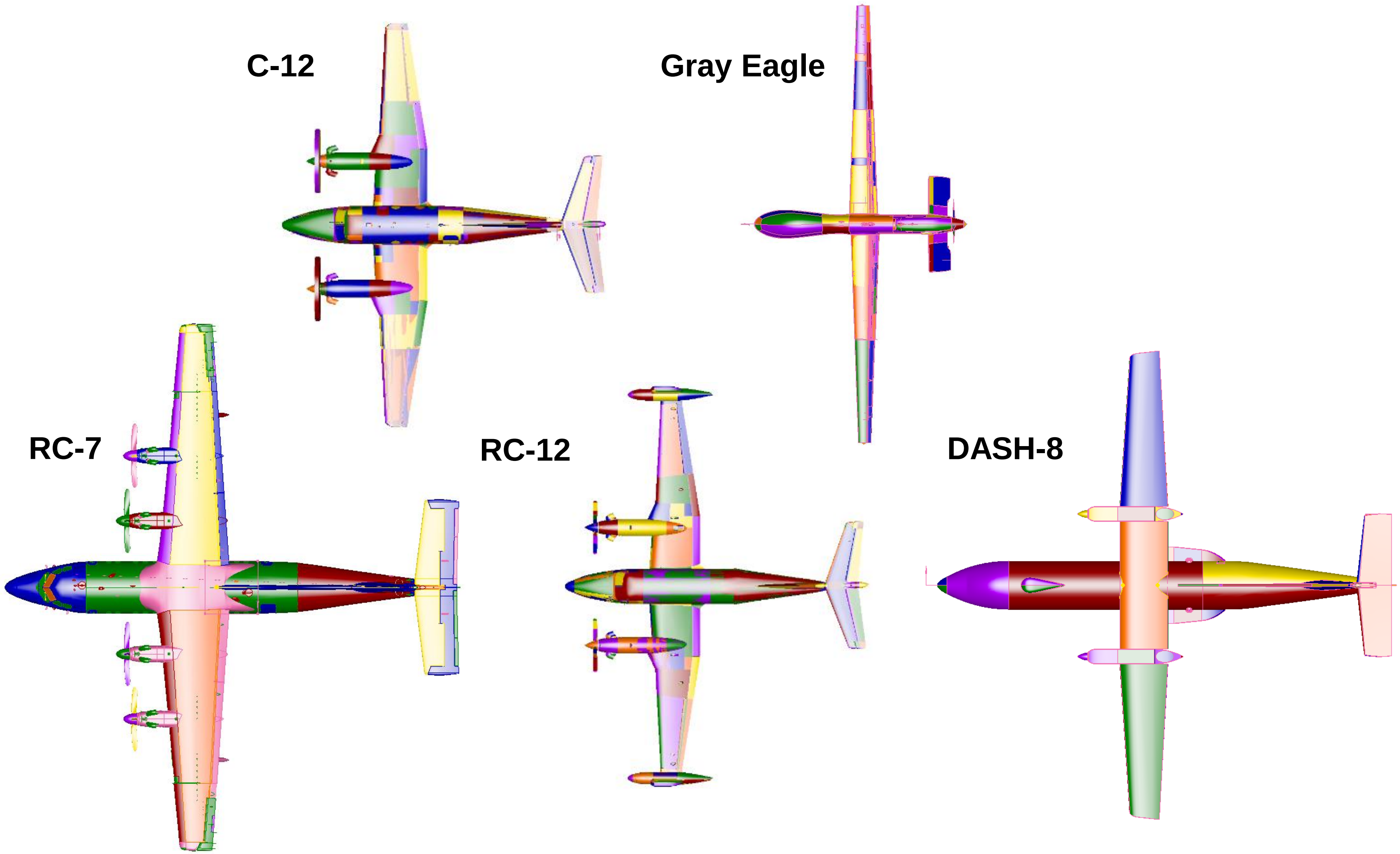
- Computational Fluid Dynamics (CFD) has been used for fixed-wing aerodynamics in support of Aviation Systems since 2003 in the following areas:
  - Flight Performance: Drag prediction and interference of external installed components, or any outer mold line (OML) changes
  - Handling Qualities: Provide static longitudinal and lateral characteristics comparison between OEM and modified aircraft
  - Source Selection: Provide drag increment between the OEM and proposed aircraft for performance evaluation.
- Fixed wing CAD inventory with various wingspan: RC-7 (93 ft), C-12 and RC-12 (54 ft), DASH-8 (84 ft), C-26 (46 ft), C-23 (75 ft), C-27J (94 ft), Gray Eagle (56 ft)

Scanned Fixed-Wing Aircraft
Procured by the Army



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Summary

- **<u>AED Mission:</u>** Deliver responsive airworthiness solutions throughout the system lifecycle. Sustain the leadership and engineering expertise necessary to provide valued products to our aviation customers.

- Credible lifecycle acquisition support that leverages modeling and simulation

Army Regulation 5-11. Management of Army Modeling and Simulation

4-1. General

a. VV&A establishes the credibility of M&S to effectively support Army decisions and processes.

b. 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 (V&V) throughout their lifecycles and be accredited for the intended use.

- Future Vertical Lift Support

JMR TD Configurations

Other Configurations

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