Challenges We Face for a Future Vertical Lift Vision

By
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JMR/FVL Program Director
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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

PROGRAM EXECUTIVE OFFICE

AVIATION

JMR – Joint Multi-Role
FVL – Future Vertical Lift
Why Do We Need a Future Vertical Lift Vision?

6 Elements of the FVL Strategy

1. Decision Point-Based Plan of Execution
2. S&T Plan that Aligns Technology Development with Milestone Decision Options
3. Early Joint Requirements Development
4. Multi-Role Family of Aircraft
5. Common Systems and Open Architecture
6. Industry Partnership/Interaction (thru the VLC)

* OEF 1 to 4/10/2013
Future Vertical Lift (FVL) &
Joint Multi-Role Technology Demo (JMR TD)

6 Elements of the FVL Strategy
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- Considers the vertical lift needs across the DoD
- Addresses the capability gaps identified in the Army Aviation Operations CBA, and the OSD-sponsored Future Vertical Lift CBA

**JMR TD Program**

**CT&A**

**MS T&A**

**JCA Dev**

**JCA Demo**

**Mission System Architecture Demo**

**Air Vehicle Demo**

**Mission Package**

**Common Capability Groups**
- Situational Awareness
- Survivability
- Safety & mishap Prevention
- Reliability
- Sustainability
- Architecture
- Networked C2

**Apply to All Classes**

**Common Mission Groups**
- Reconnaissance
- Attack
- Assault
- Sustainment

**Classes**
- Multi Role
  - (Light)
  - (Medium)
  - (Heavy)
  - (Ultra)

**FVL Spec Evolution**

**Common Aircraft Group (Family)**

**FVL Program**

**JCA Demo**

**Mission System Architecture Demo**

"The Congressional Rotorcraft Caucus is concerned about the lack of a strategic plan for improving the state of vertical lift aircraft in the United States."
The Challenges

- Solving tactical gaps require complex systems
- Integrated systems/platforms require more commonality and reuse
- Rising costs (development, procurement and operations/sustainment)
  - Historical development programs (stigma, overrun trends)
- Reduced budget with on-going legacy fleet modernization
**Historical Acquisition Timelines & Costs**

<table>
<thead>
<tr>
<th>Program</th>
<th>MS A to MS B (yrs)</th>
<th>MS B to MS C (yrs)</th>
<th>Total time (yrs)</th>
<th>Total RDTE Cost ($M)</th>
<th>Total RDTE Cost (FY25 $M)</th>
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<tr>
<td>UH-60A</td>
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<td>9*</td>
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<td>AH-64A</td>
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<td>6</td>
<td>6</td>
<td>12</td>
<td>6,903 (BY2014)</td>
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</table>

*Note – does not include the six year analysis period, three year engine development, or vendor efforts prior to MS A.

**Note – estimate at time of program cancellation.

***Note - estimated; not yet complete.

****Note - program initiated at MS B.

Data derived from System Acquisition Reports and normalization to FY25 executed thru an ACT-IT model.

Must Change the Historical Paradigm of Increasing Costs and Longer Schedules!
Agenda - Highlighting Some Efforts

• Develop
• Qualify
• Produce
• Sustain
• Document the Plan

• Joint Common Architecture (JCA)
• Model Based Development
  ➢ AADL → AVSI (SAVI) & AVCIP
  ➢ AME (NCDMM) → DMDII
• IMPACT Workshops
• FVL Business Case Analysis (BCA-1)
Efficient Development
System Architecture Virtual Integration (SAVI)

- Launched in 2008 to address the problem of growth in complexity of systems leading to cost and schedule overruns.
- The objective is to develop a standards-based Virtual Integration Process (VIP) that allows multiple parties to virtually integrate and analyze systems throughout development life cycle.
- The result is earlier detection and correction of errors leading to cost savings.
- Highly focused on integration – defining the state of the art in system integration consistency checking.

One Measure of Complexity

Late Discovery of System-Level Problems

Sources:
- G. Gabe, Software Quality Assurance – From Theory to Implementation, Pearson/Addison-Wesley (1994)
- SAVI Report 9/24/12

INCOSE 2010

The estimated nominal cost for fault removal

Safety
Security
Code Development

Where faults are introduced

Where faults are found

3x6
5x
20
20-100x
16x
10%
50.5%
16x
20%
16%
2x
20-100x
10%
5%
5x
100-1000x
9%
4%
100-1000x
70% 3.5%
70%
80% late error discovery at high repair cost
20.5% 110x
70% requirements and system interaction errors
This is expected to be more problematic as future systems become more complex if not adequately addressed. A $10k architecture phase correction saves $3M.

Highly focused on integration - defining the state of the art in system integration consistency checking.

The result is earlier detection and correction of errors leading to cost savings throughout development life cycle process (VIP) that integrates and analyzes systems from multiple parties to virtually simulate and analyze systems leading to cost and schedule savings.

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Late Discovery of System-Level Problems

INCOSE 2010

80% late error discovery at high repair cost

70% requirements and system interaction errors
Full Members
- Airbus
- Boeing
- DoD
- EADS
- Embraer
- GE Aviation
- Goodrich (now UTC)
- Honeywell
- Rockwell Collins
- Rolls Royce
- Saab
- United Technologies

Associate Members
- BAE Systems
- Bombardier
- Gulfstream
- Lockheed Martin

Liaison Members
- FAA
- NASA
- Aerospace Valley
- Honeywell
SAVI Objective and Themes

• Reduce costs/development time through early and continuous model-based virtual integration
  - *Shift to new paradigm*
    • Systems engineering in cross-domain context
    • Models provide basis for improvements
    • Models promote consistency – “absence of contradictions”
  - *Architecture-centric approach* — *start with models*
    • Meld with requirements for traceability
    • Facilitate trade studies
  - *Virtual Integration* — *early and continuous integrated analysis*
    • Proof-based (consistency checked)
    • Component-based (hierarchical models)
    • Model-based (annotated models)

“Integrate, analyze ... then build”
SAVI Objective and Themes

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"Integrate, analyze ... then build"

The DoD version of this effort is called Architecture Centric Virtual Integration Process (ACVIP).
Joint Common Architecture

**Purpose:**
Develop a common avionics architecture that is open and can be used across the next generation of Joint Future Vertical Lift family of aircraft

**Results/Products:**
- Verified avionics systems architecture developed and published via a Government / Industry Standards Body
- Approved tool suite for JCA product development, integration and conformance testing
- Guidance Documentation

**Payoff/Benefits:**
- Enables, enhances, and accelerates capabilities to the Warfighter
- Strategic Avionics System Reuse
- Reduces cost of integration
- Establishes reusable software capabilities
- Establishes a business model that is beneficial to both Government and Industry
- Fosters innovation and competition
Air Vehicle Demonstration (AVD)
Mission Systems Architecture Demo (MSAD)

Joint Common Architecture (JCA)

- Incremental efforts designed to investigate specific concepts / technologies
- Demonstrate benefits of Model Based Approach & Open Systems Architecture
- Later efforts will be adjusted based on results of earlier efforts

JCA Demo
ACVIP Shadow

Architecture Implementation Process Demos

Trades and Analyses
- Architectures
- Communications
- Sensors and Sensor Fusion
- Cockpit HMI Technologies
- Survivability
- Weapons

- Verify JCA Standard 0.X
- Utilize JCA / FACE Ecosystem
- Exercise Partial System Architecture Virtual Integration (SAVI) Process
- Demonstrate Software Portability and Interoperability

Air Vehicle Demonstration (AVD)

- BAA Award
- IDRR CDR
- 1st flight

Scope: Design, fabricate and test 2 vehicles
- Performance demonstration and verification
- Technology characterization
- Test predictions and correlation
- Value and readiness assessments

Model Performance Specification

Vehicle Config Trades

Scope
- Trade space description
- Prioritize critical attributes/capabilities
- Establish success metrics
- Assess value and affordability

Fort Rucker/FVL Study
Phase I Phase II

JMR TD Schedule
## Bringing it Together for FVL

<table>
<thead>
<tr>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
<th>FY20</th>
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<td>JMR TD MSA Demo</td>
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### Tool Capabilities
- **Requirements**
- **Mdl Consistency**
- **Optimize**
- **User Interface**
- **Func Interop**
- **Timing**
- **Safety/Reliability**
- **Info/CyberSecurity**
- **System integr**
- **Certif. assurance**
- **PO ACVIP Lab**
- **Tech Transition**

<table>
<thead>
<tr>
<th>Acquire &amp; develop,</th>
<th>Internal shadow,</th>
<th>Demo maturity,</th>
<th>FVL Ready</th>
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</thead>
<tbody>
<tr>
<td>In testing</td>
<td>Limited capability</td>
<td>Limited capability</td>
<td></td>
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</tbody>
</table>

**Capability sets** are subdivided into multiple specific subtasks and tools.

Individual subtasks and deliverables have different milestones.
Efficient Qualification
IMPACT Workshops

IMPACT: Innovations and Modernization Projects Affecting Capabilities and Technologies

IMPACT workshops are cross-domain and cross organizational interchanges where the total impact on the material and operational enterprises of developing and fielding a future capability are discussed.

The intent is use a team of Government, Industry and academia to define the problem, identify related metrics and understand and develop potential solution sets and scope necessary actions across the enterprise to enable the future capability for the Warfighter.

Three current topics
1) Manned Unmanned Teaming
2) Zero Maintenance Aircraft
3) Airworthiness of Complex Systems

Finding ways to deal with tough, overarching, multi-organizational problems
Airworthiness IMPACT Workshop

- Airworthiness process is becoming expensive and schedule intensive as systems become more complex
  - What can we learn from Other Governmental Agencies (OGAs), industry, academia in terms of developing and qualifying these complex/learning/adaptive systems that improve current airworthiness processes?
  - How does industry develop and qualify civilian applications of complex systems that may be adaptable to the airworthiness processes, standards or methods of compliance?
  - What regulatory and statutory differences between various OGAs influence their approval or certification of these complex systems?
  - What standards and methods of compliance are used by other activities for these type systems that aviation can leverage?
  - What types of complex systems may aviation have to deal with in the future that may be emerging in other industries, OGAs and/or academia?
- 14-15 Oct Final Study Results from Industry and OGA Teams Brief, Huntsville
Efficient Production
Where We are in Manufacturing Will Not Work for FVL!

- Linear process through design, make, and deliver
- Limited application of composites; heavy use of fasteners
- Large parts count and significant number of assembly steps
- Process intensive fabrication and cumbersome material processing
- Minimal automation and high levels of touch labor, increasing labor costs globally, and skills gap
- Outsourcing: separation of designers and makers has stunted innovation
- Barriers for Sharing Data and Information: technology, skills, security, trust, IP, standards

TODAY

FUTURE

- Additive Manufacturing (AM)
  - America Makes – National Additive Manufacturing Innovation Institute
  - Materials Development
  - Process Improvements

- Advanced Composites
  - New Institute focused on Advanced Composites
  - Alternative bonding technologies to remove fasteners
  - Light weighting, high strength
  - High temperature (CMCs)
  - Material structure and design
  - Out of Autoclave
  - Thermoplastics

- Assembly enhancement
  - In-situ inspection
  - Repeatability
  - Robotics (application specific)
  - Paperless assembly

Shorten Timelines and Reduce Costs
Change the Design to Manufacture Paradigm

Current State
- Isolated Expertise
- Separate Tool & Data Repositories
- Manual Workflow & Data Movement
- Task Centric

Future State
- Integrated Knowledge
- Unified & Searchable
- Automated Workflow & Data Movement
- Project/Process Centric

Enable Rapid Multi-Disciplinary Optimization and Risk Assessment
What is Digital Manufacturing?

Digital manufacturing and design is the aggregation and application of digital data across the lifecycle of a manufactured product.
Rethinking Industrial R&D

**Old**
Design dictates materials and manufacturing selection

- Mostly sequential process
- Few interactions
- Limits design options

**New**
Manufacturing and materials differentiate product design

- Non-sequential process
- Creates interactions
- New degrees of freedom

Need More Integration
Efficient Sustainment
Zero Maintenance Objectives

- Seek a significant reduction in the sustainment costs, time and activities required to operate the fleet.
- A balance of high reliability and easy maintenance, accompanied by an effective support system, will provide an affordable and effective fleet for the Army.
  - System Engineering approach
  - Design system to common useful life in realistic environments
  - Harmonization of reliability criteria
  - Significantly reduce inspections/inspection time - Automate
  - Near-zero false faults and removal
  - Simplify and minimize preventive maintenance
  - Simplify other maintenance
  - Zero-maintenance during longer phase intervals (Maintenance Free Operating Period (MFOP)) coordinated with projected block technology insertion/upgrades
Zero Maintenance IMPACT Workshops

• **Purpose:** To lay the foundation for developing the requirements, concepts, technologies, and *RELATIONSHIPS* to move forward from the current legacy fleet sustainment and CBM paradigms towards a vision for ultra-reliability and zero-maintenance to meet the needs for the Future Vertical Lift fleet and beyond.

• **Approach:** Series of IMPACT Workshops to bring together the Government’, Industry and Academia SME’s on relevant Aviation sustainment requirements and technologies to:
  
  – Define Zero-Maintenance
  – Identify key sustainment requirements of FVL and beyond to 2048
  – Identify enabling technologies and concepts
  – Identify opportunities to cooperate and collaborate
    - Develop a plan to strive towards the vision
    - Plan and budget in the next POM cycle and EPP to execute the vision

• **ZMA Workshop 4:** early December 2014, Huntsville/Redstone Arsenal
  
  – AMRDEC/ADD & ARL/VTD co-host
  – In conjunction with Fatigue-Free Workshop II
  – Industry & Academia invited to participate
Document the Plan
Initial Business Case Analysis (BCA-1)

• Detailed consideration of candidates for relative affordability to inform acquisition leadership leading to a Materiel Development Decision and provide guidance for Analysis of Alternatives (AoA).
• Alternative COAs for fleet: 1) As-Is, 2) Upgrade, 3) Major Upgrade, and 4) FVL.
• Four Study Groups established: Product Support, Commonality, Reliability, Producibility
• First Joint BCA-1 Workshop held 16-17 July
  – Teams established Affordability Candidates for investigation under BCA-1

<table>
<thead>
<tr>
<th>Product Support</th>
<th>Commonality</th>
<th>Reliability</th>
<th>Producibility</th>
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<tbody>
<tr>
<td>Technical Data Strategies</td>
<td>Common Software &amp; Re-Use</td>
<td>Engine Reliability</td>
<td>Digital Thread</td>
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<tr>
<td>Optimize Maintenance</td>
<td>Common Training Systems</td>
<td>Advanced Health Monitoring</td>
<td>Composites</td>
</tr>
<tr>
<td>Optimize Sustainment Capabilities</td>
<td>Common Mission Systems</td>
<td>Advanced Materials</td>
<td>Additive Manufacturing</td>
</tr>
</tbody>
</table>
Vision for the Future: Desired Capabilities

**Communication**
- LOS Voice and Data
- BLOS Voice and Data
- Integrated Tactical Networks (SRW, WNW, JTRS, etc)
- Advanced Antennas (Conformal, Multi-band, etc.)
- Interoperability with DHS
- Backwards compatibility

**Avionics Architecture**
- Advanced Mission Processing
- High Speed Backplanes
- Data Concentrators
- Solid State Recording Devices
- High Speed Interconnects
- Open Systems Standards (JCA / FACE)
- Information Assurance
- Multi-level Security

**Crew Station**
- Fully Integrated Advanced Cockpit
- HMI Designed-In
- Advanced Controls and Displays
  - Multi-Function
  - Helmet Mounted
  - Heads up
  - Effective Cueing
- EDM (Electronic Data Manager)

**Navigation/Pilotage**
- Integrated GPS
- Transponders
- Integrated IFF
- Decision Aiding/OPV
- Integrated DVE/CA/OA

**Engagement & Effects**
- Scalable effect warheads & weapons
  - Non-Lethal Weapons
  - Directed Energy
  - Counter-UAS and Air-to-Air
  - Hostile Fire Detection
- Next Gen Integrated Targeting, SA, DVE sensor suite
  - Decision Aiding for optimal, synchronized use of on- and off-board effects
  - Maritime search, track, and identification of surface and subsurface targets
  - IED Detection
  - CBR Detection

**Situation Awareness**
- Real-time information (threat, weather, a/c state, BC, etc.)
- 360 Spherical Sensing
- Information Mgmt
- Data Fusion, Decision Aiding
- COP (GIG, BFT, etc.)

**Survivability**
- Signature Management / Suppression
- Survivability SA and Planning
- Advanced Countermeasures
- Tunable Pyrotechnics
- Hostile Fire Indication
- IASE
- Advanced Warning Receivers
- EMP Hardening

**Flexibility**
- Mission reconfigurable
- Upgradable
- Land based and maritime operations
- Tactical and peace-time operations

**MUM-T**
- LOI 4 / LOI 2
- Decision Aiding
- Wingman/Over-watch

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- Scalable effect warheads & weapons
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Mission systems must be affordable across the life cycle In addition to being effective.

UNCLASSIFIED