Department of the Air Force

Integrity - Service - Excellence

A Systematic Approach to Digital Transformation

Cliff Louden

Modular Open Systems Approach Program Element Monitor

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BLUF: A systematic approach to digital transformation

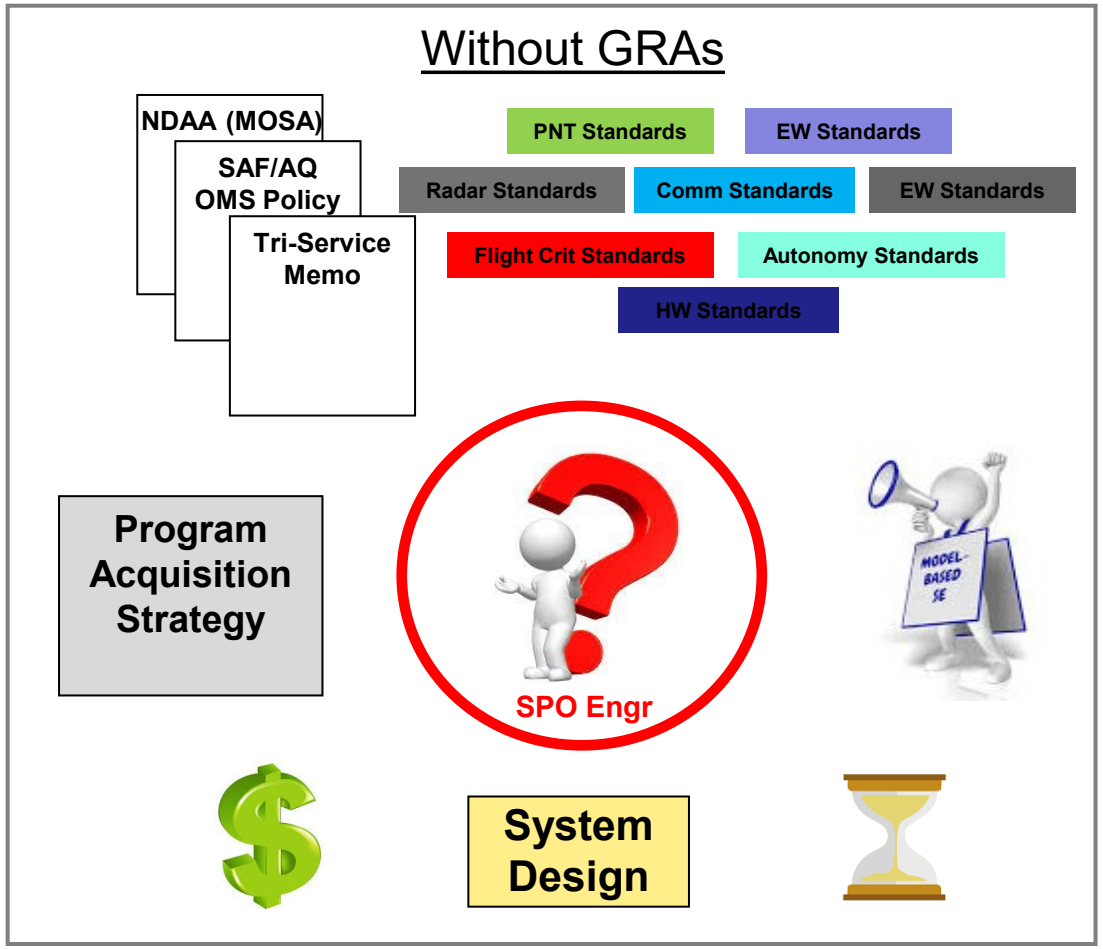
Open Architectures, Digital Material Management, and Digital Standardization lay the foundation of modern Systems Engineering

- Digital Materiel Management synchronizes activities across multiple program offices, functional leaders, and lifecycle activities
- Open Architecture Management synchronizes standards and reference architectures for legacy platforms and future systems
- The Digital Industry Association Consortium enables coordination among Government, industry, federally funded activities, and executing program offices
- The Digital Guide, and the Digital Innovation & Integration Center of Excellence (DIICE) enable lessons learned from any one discipline or program to be applied across others
- We are applying a systems approach to digital transformation to synchronize DMM, MOSA, Standards, Workforce, Specialty Engineering, Policy and Guidance activities

Many Standards, Many Applications

- **Previous DAF approach to implementing open architectures**
  - **20+ years of effort with dozens of open standards**
  - **Multiple System Program Offices (SPOs) and industry consortiums operating with minimal crosstalk to develop these standards**
  - **Significant tax-payer dollars invested**
  - **Multiple service and DoD memos and NDAA guidance but implementation challenges remain**

- **Moving Forward DAF will apply Government Reference Architectures (GRAs) as an integrated architecture approach**



Lots of OA Momentum BUT Lacking a Cohesive Implementation Plan

Architecture Concepts

- **Reference Architecture**
  - Provides authoritative MOSA requirements
  - Defines touchpoints between standards according to MOSA policy
  - Guides creation of more specific objective architectures

- **Objective Architecture**
  - Defines common, standard-compliant template architectures
  - Provides requirements traceability to standards
  - Can be further tailored by System Program Office (SPO) for their legacy aircraft

- **Solution Architecture**
  - Created by Vendors to meet SPO Objective Architecture requirements

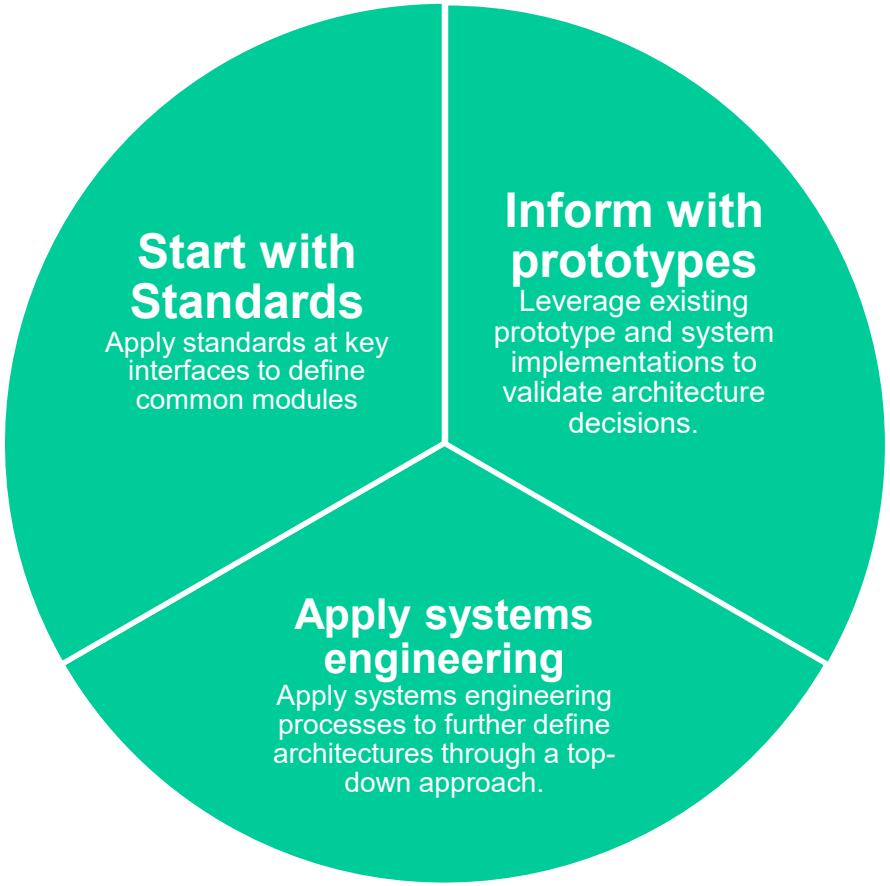


Figure: Architecture Definition Tenets

Business & Acquisition Use Cases

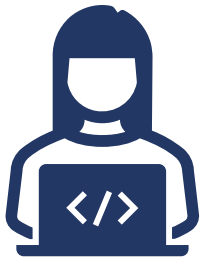
- **Reference Architecture**
  - Provides authoritative MOSA requirements
  - Defines touchpoints between standards according to MOSA policy
  - Guides creation of more specific objective architectures

Coordinate and align enterprise MOSA efforts

Organizational Leader

- **Objective Architecture**
  - Defines common, standard-compliant template architectures
  - Provides requirements traceability to standards
  - Can be further tailored by System Program Office (SPO) for their legacy aircraft

Tailor and compete candidate solution architectures



SPO Engineer

- **Solution Architecture**
  - Created by Vendors to meet SPO Objective Architecture requirements

Propose solution architectures to build systems

Industry

GRA Coordination

Legacy Aircraft

Flight/Safety Critical Processing

1553 data bus

Existing Mission Computer

1553 data bus | Or Ethernet

Existing Mission Capability

Govt Avionics Ref Arch (GARA)

Isolator

Existing Flight Safety

OMS Platform

"Sidecar"

OMS Abstract Service Bus

EW Capability (Big Iron)

PNT Capability (R-EGI)

Open Mission Systems (OMS) Mission Package

Attributes:
- Federated
- Adaptable
- Scales to need
- Common/Open
- Operational
- Lower risk
- Existing ecosystem

Complementary

Future Aircraft

Modular & Open Approach

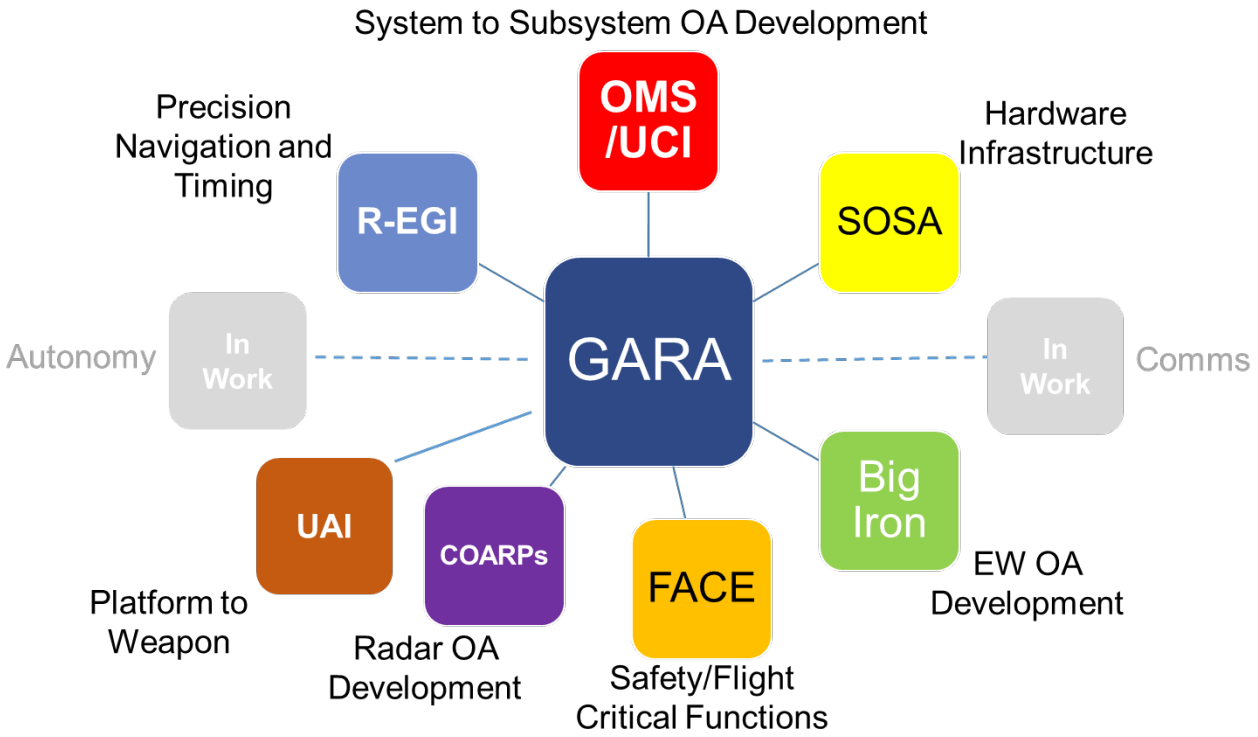
Platforms that will Remain "Custom" (Not-Open)

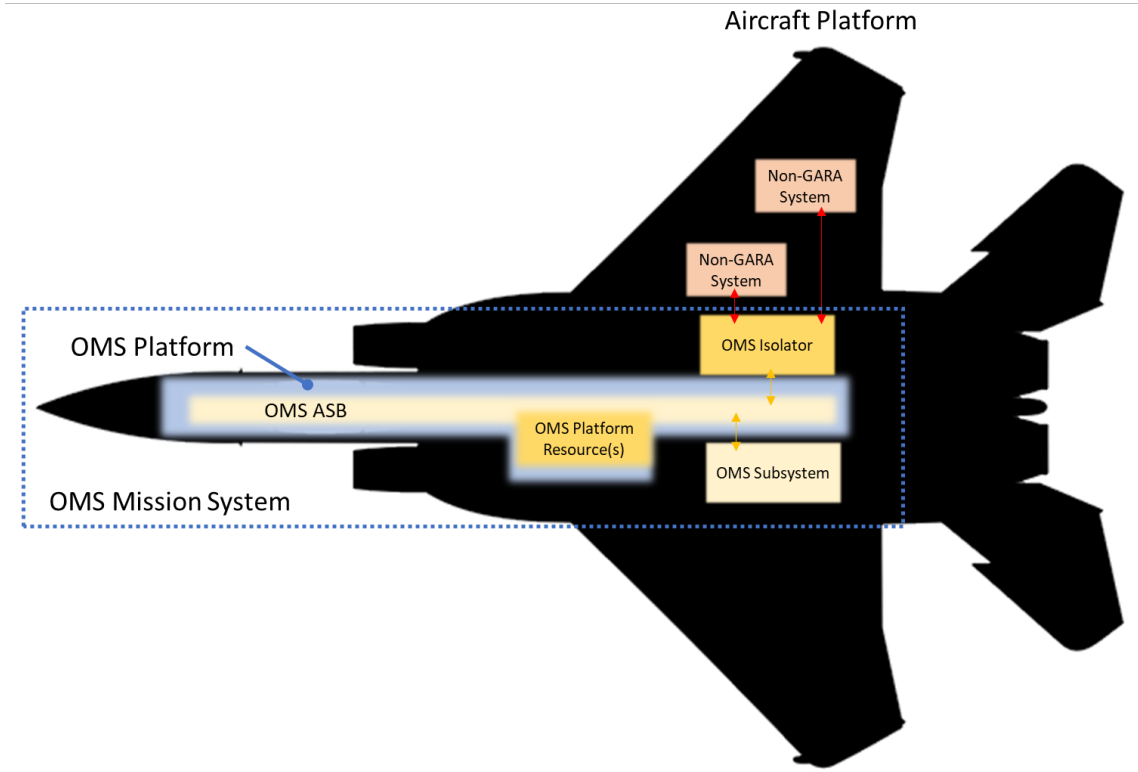
Key Legacy Platforms that will Modernize to become "Open"

Two Architecture Strategy to Drive MOSA Implementation

Future Platforms that will be Born "Open"

Govt Avionics Reference Architecture: Common MOSA Strategy for Legacy Systems





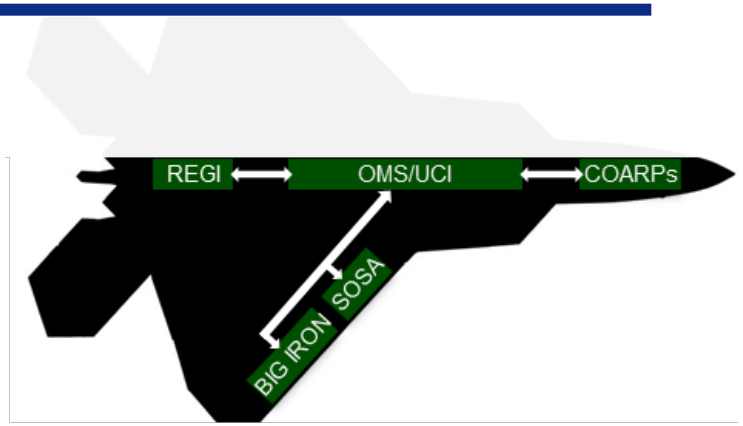
GARA "enables" the touch points between open standards; provides legacy weapon systems a common MOSA strategy

Enables Legacy Platforms to Implement a Modular Open Systems Approach Quickly

GARA <u>is not</u> another open standard, it leverages and integrates existing open standards and drives REUSE

GARA Roadmap

- **Minimum Viable Product (MVP)**
  - **OMS/UCI, SOSA HW, Big Iron**
  - **Informed by prototype and stakeholder engagement**
- **2024-25 Goals**
  - **Mature reference architecture (RA) and digital model**
  - **Scale the RA to include additional OAs of interest**



- **Future (2026+) Vision: Consortium of contractor SMEs similar to OMS/UCI but reduced scale**
  - **Support adopting programs (APs) with implementation and adaptation of GARA for their application**
  - **Ensure alignment and interoperability of legacy programs tasked with operating within the OSA of an NGAD and other System-of-Systems – SecAF OI #3[1]**
  - **Ensure DAF readiness of legacy and future platforms to compete with peer competitors through rapidly adaptable, open systems – SecAF OI #7[1]**

Accelerate Change OR LOSE with Proprietary, Closed Systems!

[1]Operational Imperatives. Department of Air Force. https://www.af.mil/Portals/1/documents/2023SAF/OPERATIONAL_IMPARITIVES_INFOGRAPHIC.pdf

GARA MVP (v0.5) Architecture Details

Reference Architecture

- Provides MOSA requirements from OMS, Big Iron, and SOSA
- Includes UCI Capability taxonomy
- Defines OMS as overarching mission system architecture standard
- Defines Big Iron internal to EW Subsystems
- Includes Open Hardware System definition informed by SOSA requirements

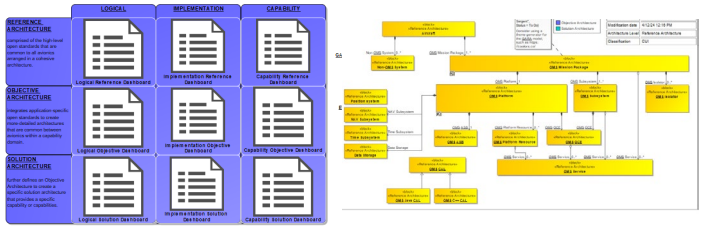
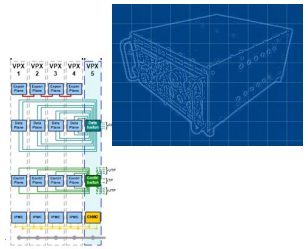


Figure: SysML Models and User Guide

Objective Architecture

- Defines a common EW OMS Subsystem and EW Capability Manager OMS Service
- Defines common EW-ES Big Iron Applications
- Defines a common EW open hardware chassis with selected Plug-in Cards



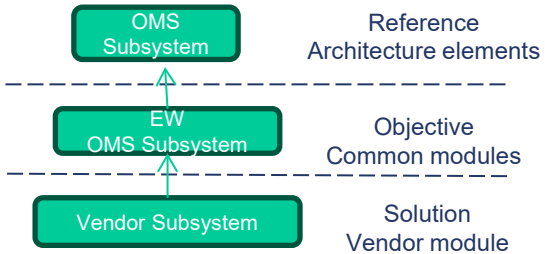
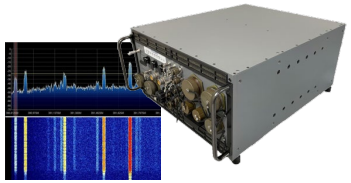


Figure: Traceability of architectural elements

Solution Architecture

- Provides an exemplar solution architecture with additional design detail



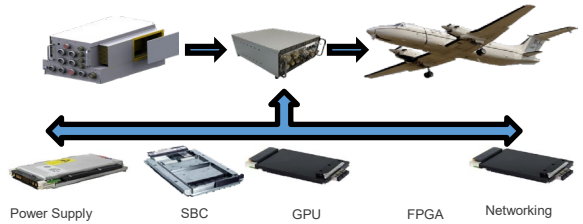
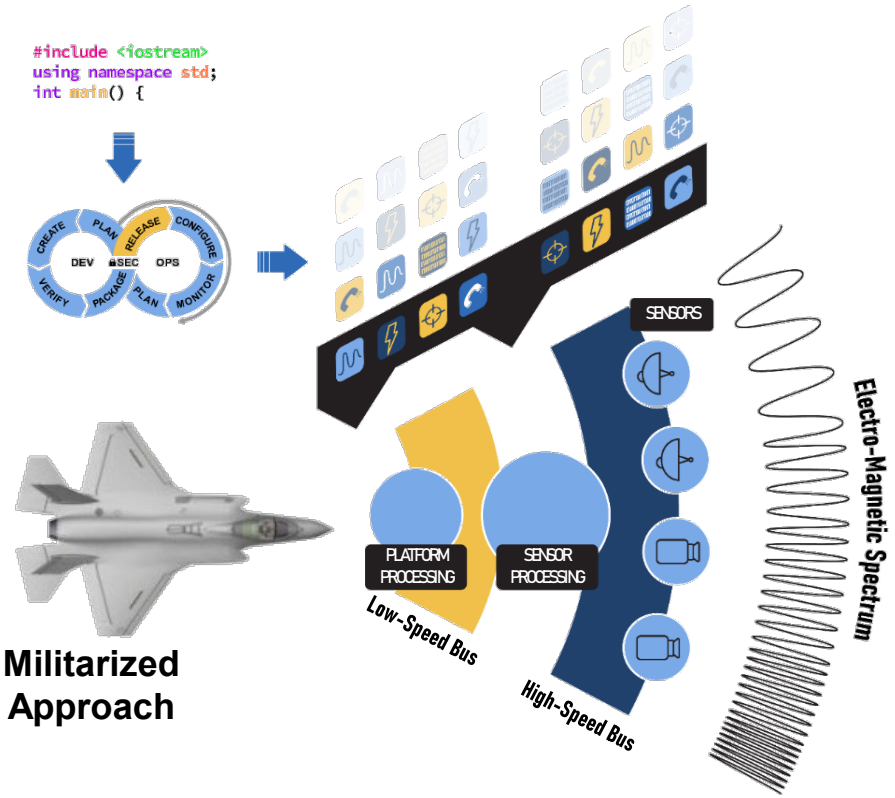


Figure: Exemplar Implementation Flight Demonstrated

Agile Mission Suite (AMS) Government Reference Architecture (GRA)

- Built on the foundation of previous Open Architecture developments but decomposes previous “black boxes” into software-defined modules
- Government-owned Sensor-to-Glass interfaces
- Strong isolation between safety/flight-critical and mission-critical components to enable adopting platforms to field rapid software updates
- Well-defined, high-speed mission-systems interfaces allowing adopting platforms to leverage best-of-breed capabilities

Commercial Approach

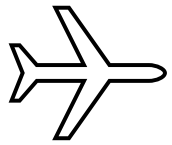


Militarized Approach

AMS GRA ensures adopting platforms respond to dynamic threat environment at the speed of software (vs. hardware)

Notional Use Cases

Platforms



Some investments will be entirely federated or entirely within vendor locked systems

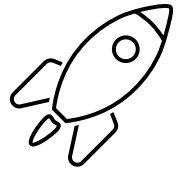
Sub-Systems

Other capabilities will be open architecture subsystems integrated within a vendor-locked OFP

Control

Programs may utilize a hybrid approach, with a narrow open architecture enclave within a legacy vendor-locked system

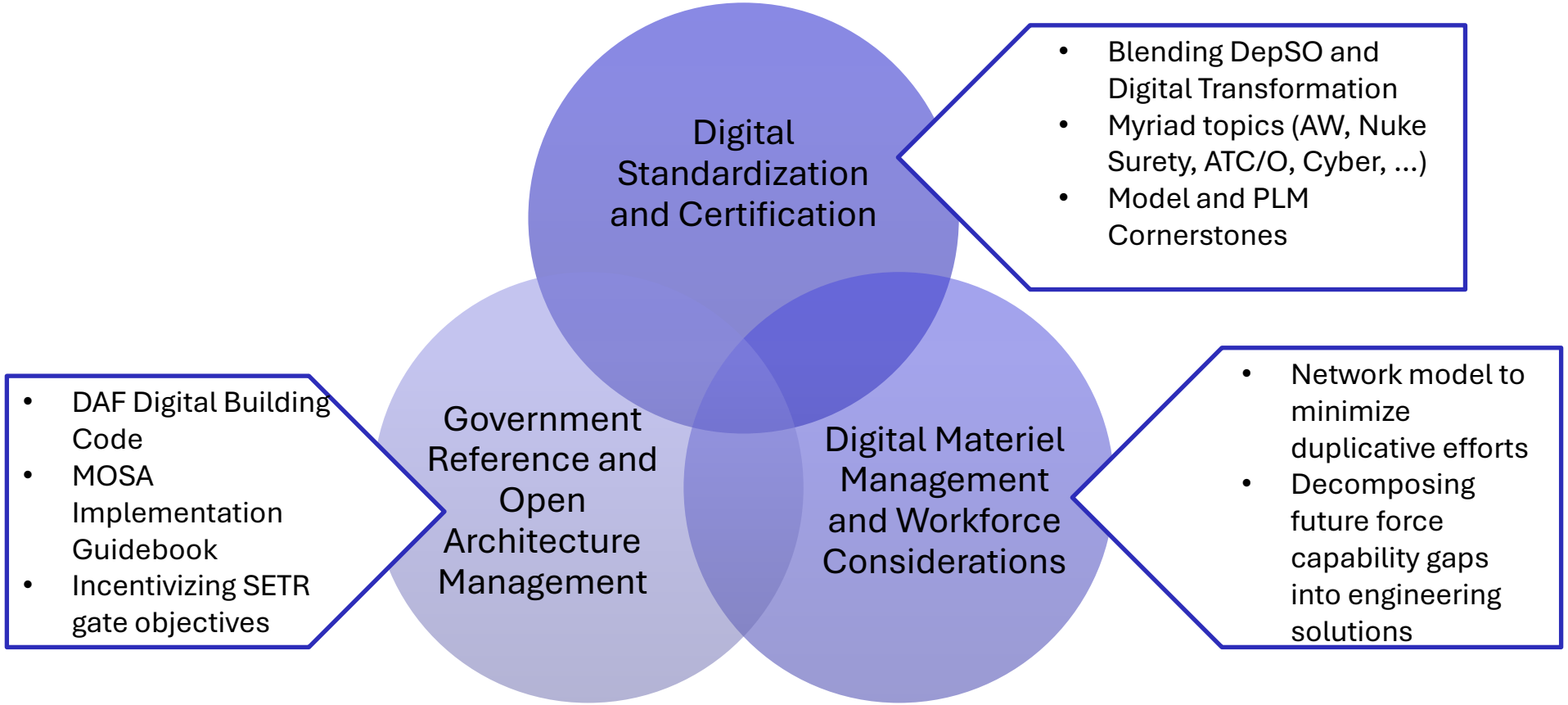
Future Program



Future programs may integrate open subsystems into an open Government Reference Architecture

A Range of Implementation Options Needed According to Lifecycle ROI Analysis

DAF Capabilities



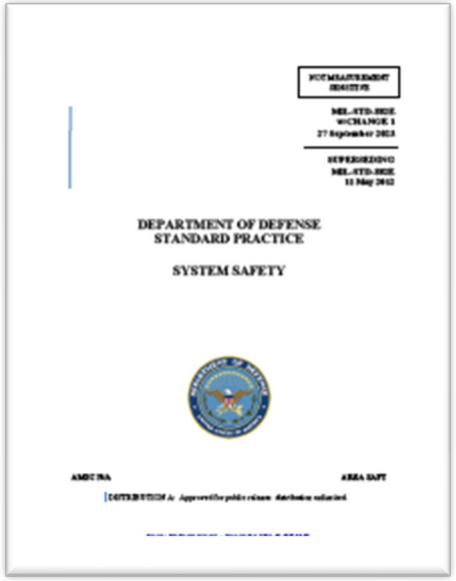
Co-Maturation of Digital Efforts Means Becoming Less Ad Hoc and More Intentional

Policy Standardization

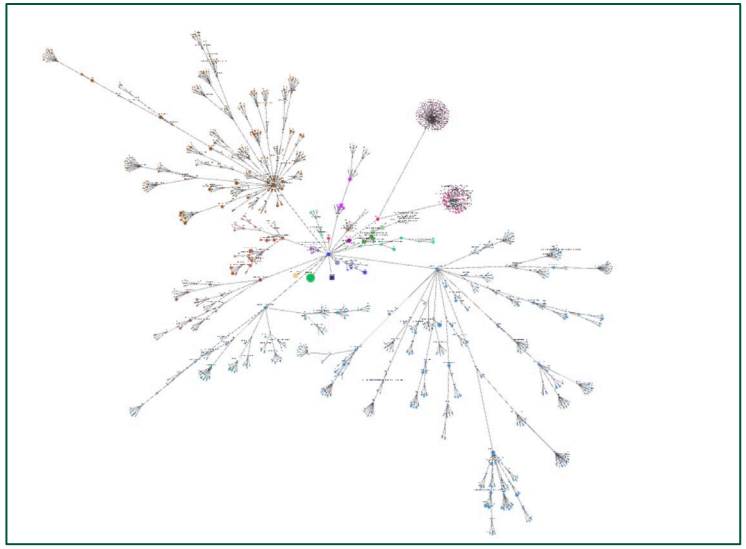
- The DAF is in its digital transformation journey to fully embrace a complete digital ecosystem of DoD standards, handbooks, specs, artifacts, etc.
  - Envision a complete digital acquisition ecosystem
- The DAF will require the capability to ingest PDFs and documents into models; i.e.
  - Certification artifacts
  - Program Protection Plans
- The digital approach can evolve the capability to perform policy traces to understand how document-based policies are dependent upon each other

DIICE

- Asked Digital Innovation & Integration Center of Excellence (DIICE) to model MIL-STD-882
  - Scripts written for ASSIST and EPUBS to extract policy document references
  - MeTRA API and Large Language Model (LLM) used to generate models showing document relationships & content
  - 100+ policy document models generated – on order of 30 min each
  - Models are searchable and filterable


DEPARTMENT OF DEFENSE
STANDARD PRACTICE

SYSTEM SAFETY

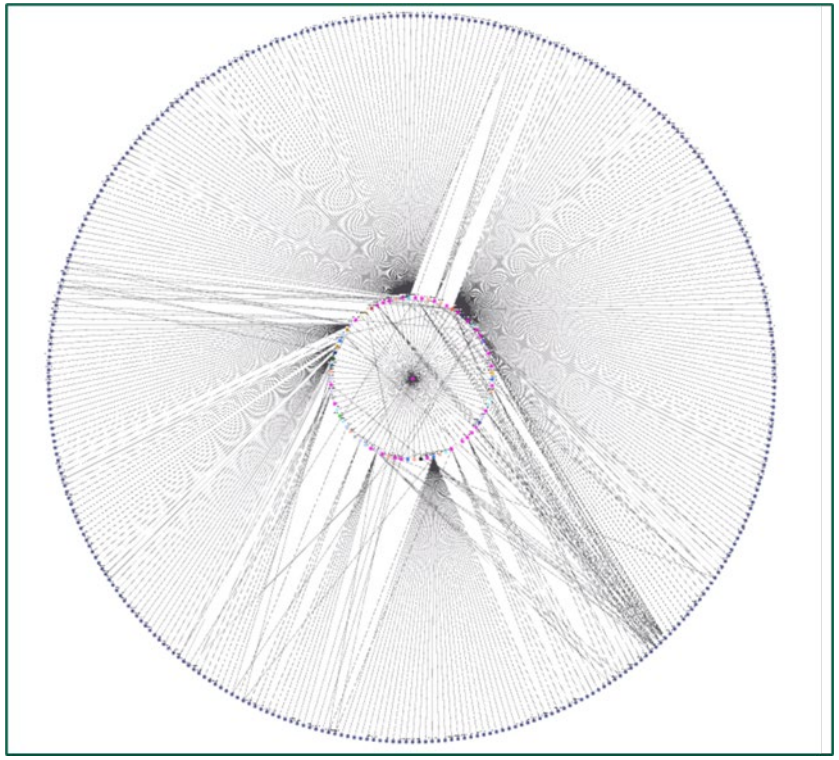


MIL-STD-882 Model

Knowledge Graphs Visualize Policy Relationships Effectively while LLMs Reduce Required Reading

Policy Maker Implementation

- When making a change to policy, visualize the downstream effects to other policy documents
- Enables real-time analysis of policy changes and effects to resolve gaps on tight turn-arounds in a war-gaming environment



Model showing direct and secondary references to MIL-STD-882

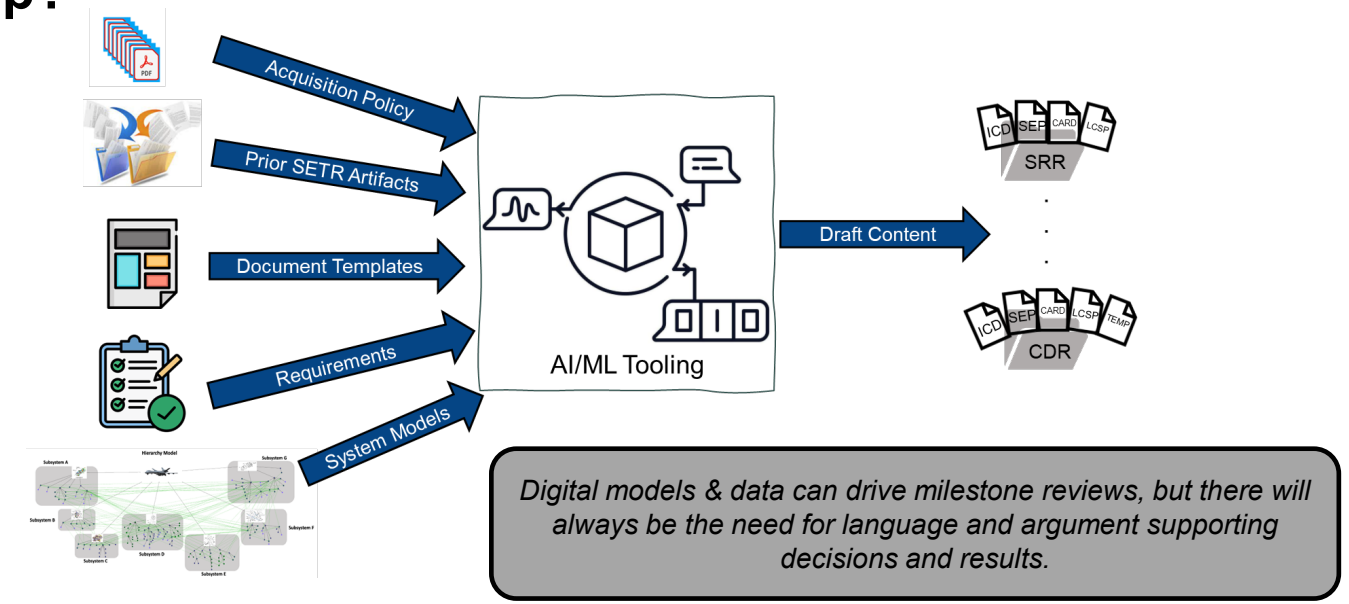
Conclusion

- The DAF continues to drive innovation in the digital domain
- Standards provide the guiderails drive the department into the same direction
- Lessons learned are used recursively to improve our training, tools, and policy
- Through use of policy, GRAs, guidebooks, etc. our teams are enabled to develop the products needed to win
- Co-maturation of DAF capabilities in the digital domain comes down to harmonizing people, processes and products

BACK-UP

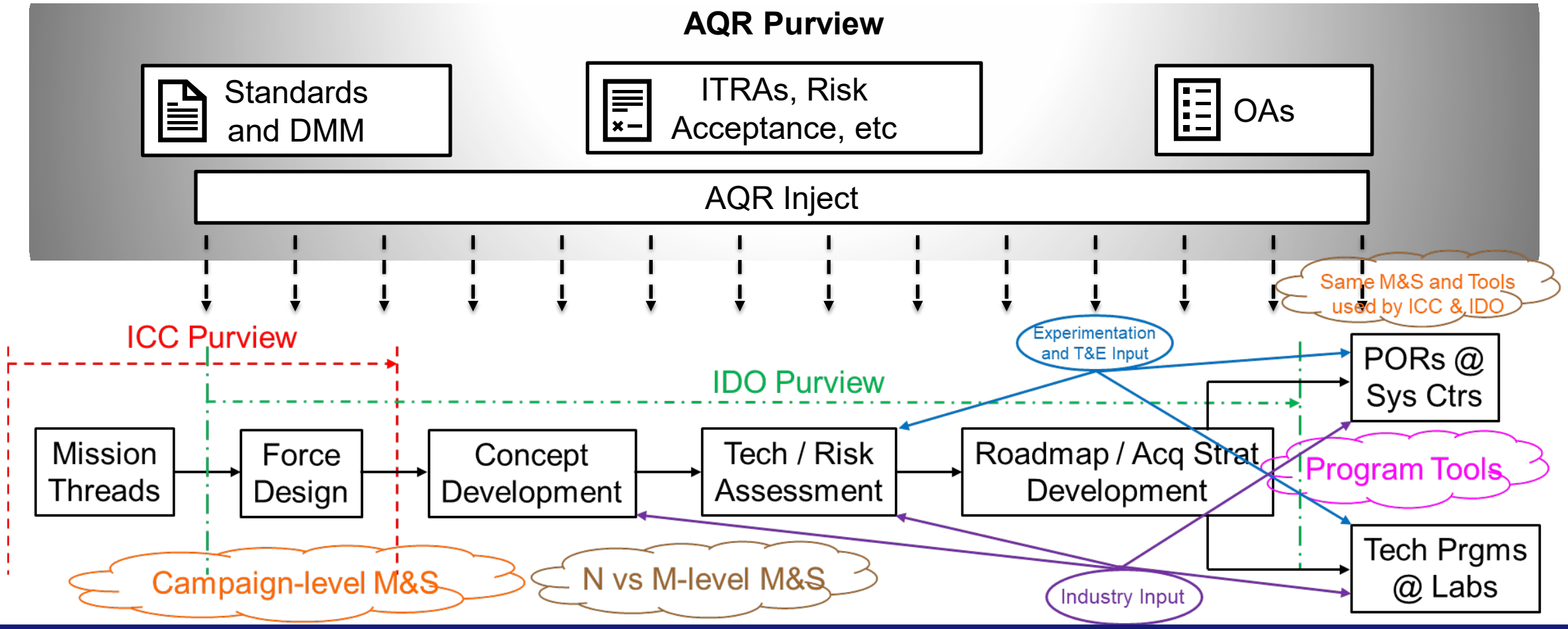
Other Use Cases

- AI/ML agent can rapidly create draft content for human review, prioritizing time for strategic thought & decision making
- Milestone reviews based on “point in time” documentation aligned to requirements, showing compliance, and building an argument around current state of program – why not use tools to help?



Digital models & data can drive milestone reviews, but there will always be the need for language and argument supporting decisions and results.

Cross-Stakeholder Development



We Are Maturing our DMM, OAMO and Standards in a Consistent, Integrated Fashion Across Stakeholder Community

Open Architecture Management Office (OAMO)

OMS/UCI Consortium

USG

OAMO

AIR FORCE LCMC

78th SOFTWARE ENGINEERING GROUP

AIR FORCE RESEARCH LABORATORY

Open Group

Anduril
Boeing
Collins Aerospace
General Dynamics Mission Systems
Lockheed Martin Aeronautics Company
Northrop Grumman Aeronautics Systems
Raytheon Technologies

Candidate GRA
AMS-GRA – Agile Gov't Ref Arch
GARA – OMS-based Gov't Ref Arch
W-GRA – Weapons Gov't Ref Arch
A-GRA – Autonomy Gov't Ref Arch
Candidate Standards
OMS – Open Mission Systems
UCI – Univ C2 Interface
UAI – Univ Armament Interface
CFWI – Common Flex Wpn Interface
WOSA – Weapons Open Sys Arch
Big Iron – EW open architecture
R-EGI – PNT open architecture
COARPS – radar open architecture
SOSA – Sensors Open Sys Arch
SSCI – NATO CM interface
SCARS – simulator open architecture
Others – FACE, CBM+, ground sys

Program Office Needs Relevant to System-of-Interest

Use of the GARA digital model will ease program office ability to effectively and efficiently:

- Identify the specific parts of open standards relevant to the avionics system-of-interest
- Provide traceability and evidence that their system-of-interest architecture is GARA compliant
- Provide guidance for data and language supporting acquisition requirements and artifacts required from vendors for GARA compliance

Example System of Interest tech refresh or modernization needs:

- Major block upgrades
- Specific avionics system or LRU modernization
- Infrastructure or mission processor refresh
- Software rework

"Each program must consider the available standards during their MOSA strategy development and apply their unique capability requirements in determining the appropriate strategy".

[AFLCMC/EN-EZ, MOSA Strategy for Avionics and Mission Systems memo, Nov 2023]

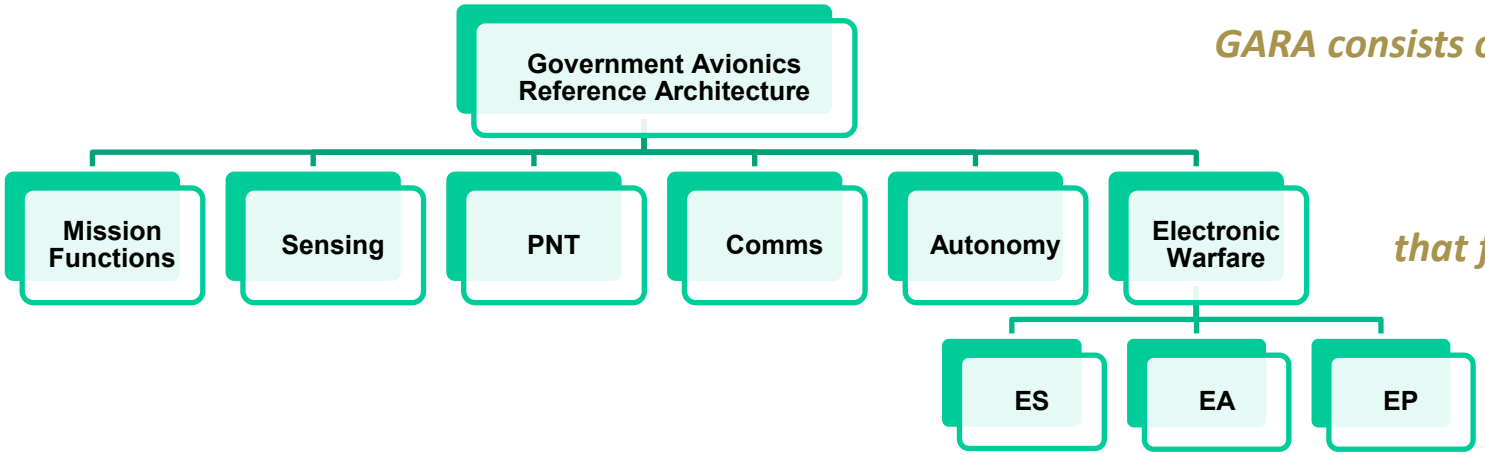
Platform-associated constraints and trades across vendor solutions specific for a given platform or mission need impact decisions

Government Avionics Reference Architecture

GARA will guide programs in application of multiple open standards in support of USAF vision and direction

Current focus is on legacy platform (5th gen and older) application – modernization and tech refresh

Will refine and constrain use of applicable open architecture standards associated with avionics end-item design and acquisition



GARA consists of overarching guidance common to all avionics systems

that flows-down to partitioned capability domains (e.g., EW)

and their subordinates (e.g., ES) as necessary

This will refine the guidance and add specificity most relevant to a given capability

GARA Program Strategy

Why

GARA Strategy

Informed by Air Force and DoD enterprise strategy, policy, and law.

- Drive adoption of open standards to align with future systems and break vendor lock
- Increase speed to field and manage increasing system complexity
- Guarantee dynamic edge and economy of scale

What

Goal 1: Synergistic Open Architecture Definition

Clear and consistent definition of architecture that supports the synergistic integration and alignment of MOSA-enabling efforts for avionics mission systems

Goal 2: Effective Digital Engineering for MOSA Implementation

Application of Model-Based Systems Engineering to support MOSA business, technical, and mission use cases for AF weapon systems through an integrated digital engineering approach

Goal 3: Efficient Agile Governance, Coordination and Collaboration

Agile workflows that support efficient governance, close collaboration between contributors, and coordination between stakeholders, including industry, AF leadership, and adopting programs

How

Objective 1.1 …
…
Objective 1.N …

Objective 2.1 …
…
Objective 2.N …

Objective 3.1 …
…
Objective 3.N …

BLUF: People – Processes – Products

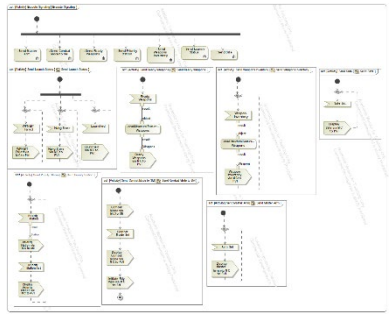
Open Architectures, Digital Material Management, and Digital Standardization lay the foundation of modern Systems Engineering

- We are maturing our DMM, GRAs (via OAMO), Standards and Specialty Engineering* in a consistent, integrated fashion
- *Specialty engineering is what we broadly call all the unique engineering functions we do such as HSI, AM, DMSMS, corrosion, etc.
- We are applying a digital approach to our Systems Engineering role which synchronizes our DMM, Standards, Workforce, Specialty Engineering, Policy and Guidance activities
- Lessons learned in any one discipline are recursively applied to the other disciplines
- This continuous improvement requires coordination between industry, policy makers and executing program office
- In the end, it comes down to people in order to execute on goals

SME Model Development Tasks

SMEs

- ✓ Provide Model Requirements
- ✓ Oversee Model Development
- ✓ Participate in Domain Focused Training



- Vet Developed Model
- Suggest Model Usage Intent
- Assume Model Ownership

Standards

DMM

OAs

Acquisition Artifact

The relationship between OAs, DMM, and DS are Distinct, Layered, and Inter-Dependent

MOSA Technical Strategy

DEPARTMENT OF THE AIR FORCE
AIR FORCE LIFE CYCLE MANAGEMENT CENTER
WRIGHT-PATTERSON AIR FORCE BASE OHIO

16 November 2023

MEMORANDUM FOR AFLCMC/EZ (DOEs)
AFRL Chief Scientists and Senior Scientists
SSC/ZA
MAJCOM/A5

FROM: AFLCMC/EN-EZ
2145 Monahan Way, Building
Wright-Patterson AFB 45433

SUBJECT: Modular Open Systems A
Avionics and Mission Systems

1. In December 2021, AFLCMC/EN-E
memo mentions the 2021 National Def
acquisitions programs and legacy syste
than ever, we are faced with advancing
systems. Because of this, we want to re
element to enabling rapid delivery of w
Operational Imperatives and AFMC/C

2. As each air and space program deve
Open Architecture (OA) Standards ava
requirements and technology insertion
and mature OA Standards to leverage t
technical complexity for your Chief En
MOSA strategy for your weapon syste
which standards are vital to the AFLC
modernizing our legacy fleet of aircraft
elements (critical interfaces, data requi
broader acquisition strategy and capabi
need to use existing mature OA standar
paragraphs outline key imperatives eac
strategy.

3. **"Define a MOSA Strategy that is**
program's development or moderniza
system components should be modular
sustainment strategy to determine the i
there are hardware and/or software com
address the rapidly changing threat env

Moreover, if you anticipate competing a replacement system in the future, then having an open architecture design along with a supporting acquisition strategy will provide the greatest flexibility for the system in the future. An excellent reference for your teams is the AFMC Guidebook for Implementing MOSA In Weapon Systems (Version 2.0). For assistance consult the Open Architecture Management Office (OAMO) for help and guidance.

4. **"Adopt mature open architecture standards." and "Adapt the existing OA standards leveraging existing Change Processes rather than building additional standards."** Once you have the modular systems identified in your avionics design, adopt mature open architecture standards to standardize the Modular System Interfaces. Because there are mature and proven OA standards and interfaces that may be leveraged, each program should start with these first. There are reference architectures and architectural standards supported heavily by the Department of Defense and Defense Industry that should be used as starting points. These prominent OA standards and reference architectures have change processes that enables adaptation. Most OA standards are developed to address a specific goal in development of an avionics mission system. However, it should be clear a singular OA standard cannot be applied to all programs in all circumstances. Use of a critical few can result in more commonality and interoperability throughout our weapon systems. This commonality allows for re-use and reduces time and effort in weapon systems development and modernization. The six OA standards and reference architectures identified below are meant to provide implementation guidance and reduce overall complexity when selecting the appropriate OA standards in the development of a MOSA strategy:

a. Open Mission Systems (OMS) for the subsystem to platform interface;

b. Resilient – Embedded GPS and Inertial Navigation System (R-EGI) for the navigation subsystem modules and interfaces;

c. Big Iron to support Electronic Warfare capabilities;

d. Sensor Open Systems Architecture (SOSA) for the avionics hardware infrastructure;

e. Future Airborne Capability Environment (FACE) considerations for Safety Critical software (as needed/if needed);

f. Common OA Radar Programs (COARPs) for radar applicati
areas.

5. **"Support the Government Avionics Reference Architecture**
As we continue to refine and mature our GARA, having you particip
the peer review during its development phase will pay huge dividen
that meets our needs now into the future. The OAMO began deve
2021 and is nearing the completion of the minimum viable product.
and help legacy programs apply multiple open standards in an avion
is defined using the baseline standards stated above. In addition, the
align the various OA standards to be more compatible with each oth
and costs as you leverage these open architecture standards. As the

is imperative the Research and Development (R&D) and Acquisition communities support this development. The key to success for GARA will be its adoption. Potential adopting programs are the stakeholders and should work with OAMO to properly align and communicate programs needs into the development goals.

6. The AFLCMC points of contact for this matter are the OAMO's Mr. Wayne Artuso and Mr. Steve Brooks at aflcmc.xz.oamo@us.af.mil.

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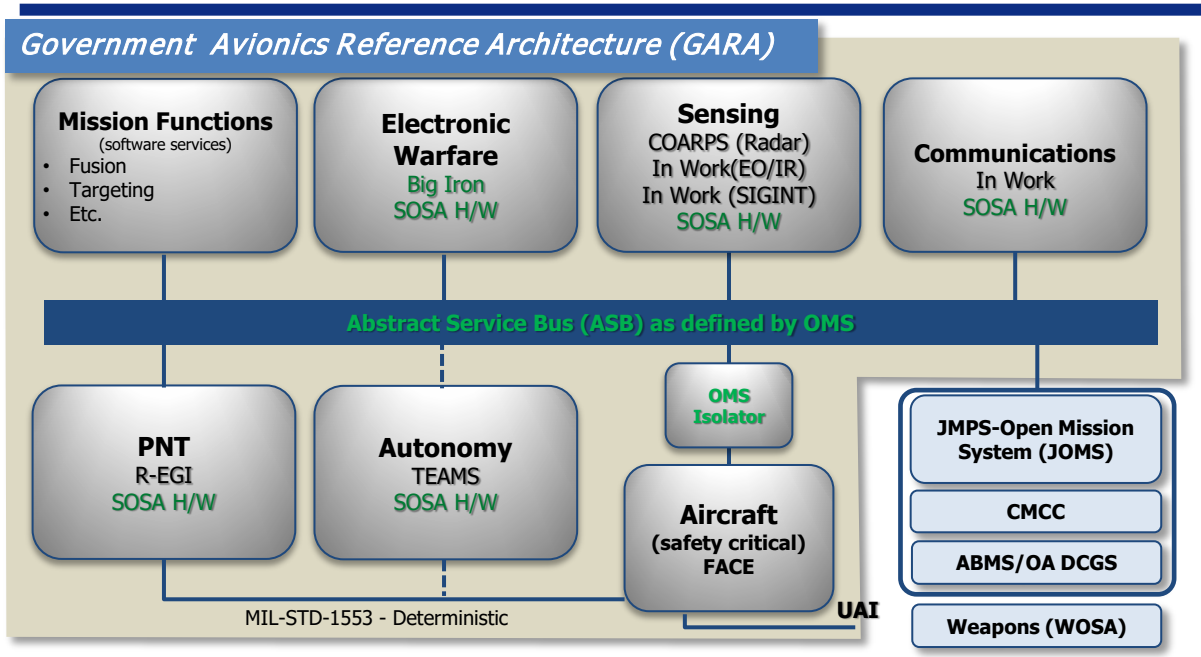
- **Define a MOSA Strategy that is part of your Acquisition Strategy**
  - **Address tech insertion needs and threat response**
- **Adopt and adapt existing mature open architecture standards**
  - **OMS for subsystem to platform**
  - **R-EGI for inertial navigation subsystems**
  - **Big Iron for electronic warfare subsystems**
  - **SOSA for avionics hardware infrastructure**
  - **FACE for safety critical interfaces (as needed)**
  - **COARPs for ISR radar subsystems**
- **Support GARA development and adoption**

MOSA: Modular Open Systems Approach
OMS: Open Mission Systems
R-EGI: Resilient Embedded GPS/INS
SOSA: Sensor Open Systems Architecture
FACE: Future Airborne Capability Environment
COARPs: Common Open Architecture Radar Programs
GARA: Govt Avionics Reference Architecture

GARA Approach (MVP)



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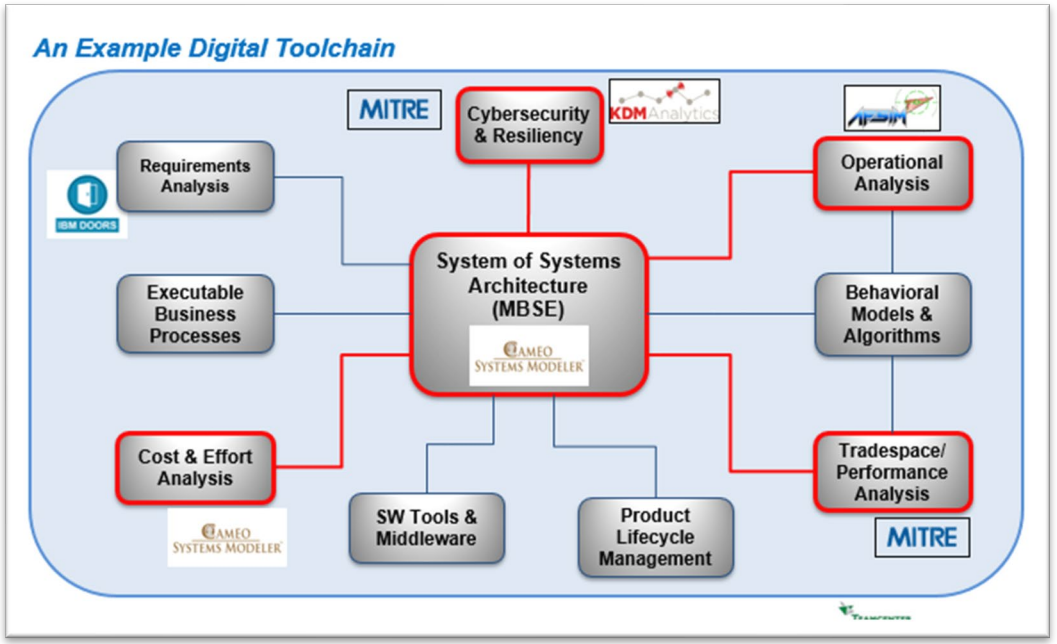


Business Drivers

- Drive adoption of open standards
- Increase fielding speed
- Manage and mitigate OA use risks
- Speed and cultivate innovation
- Manage/guarantee dynamic technical edge

Architectural Drivers

- Customizable: guide design choices
- Applicable: guarantee appropriate OA choice w/decision support tools
- Identifiable: trace reqts to design
- Modifiable: enable change to OA Stds
- Justifiable: automated compliance validation

- Arch Tools
- Standards
- Govt Ref Arch
- Ecosystem
- Automation

→ *Go Fast!!!*

Enable Legacy Platforms to Implement a Modular Open Systems Approach Quickly

MBSE Path Forward for GARA (post MVP)

Update model framework and methodology to follow industry best practices (e.g. MagicGrid & OOSEM).

Maximize model reuse through project usages

Scale model ecosystem to additional domains and tackle additional work in parallel

Coordinate MBSE interoperability with other efforts (e.g. OMS NSG, BI Consortium, SOSA).

Update and optimize end user implementation process for ease of use

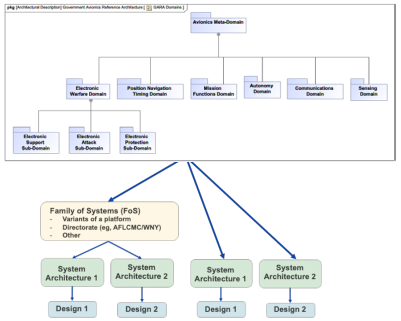
	REQUIREMENTS	BEHAVIOR	SYSTEM CONTEXT	STRUCTURE	DATA & OTHER	VALIDATION	PROJECT USAGES
REFERENCE ARCHITECTURE	GARA Requirements	GARA Behaviors	GARA System Domains BDD GARA System ASB IBD	SW Structure BDD - OMS Hardware Structure BDD - SOSA			OMS Standard SOSA Standard Model
OBJECTIVE ARCHITECTURE EW-ES System	EW-ES System Requirements	EW-ES System Objective Architecture Behaviors	EW-ES System BDD	Big Iron BDD Big Iron BDD			Big Iron Standard
OBJECTIVE ARCHITECTURE Whatever other domain							
OBJECTIVE ARCHITECTURE Whatever other domain							

SOLUTION TEMPLATE GRID

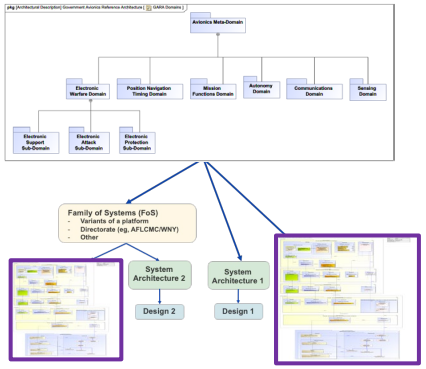
	REQUIREMENTS	BEHAVIOR	SYSTEM CONTEXT	STRUCTURE	DATA & OTHER	VALIDATION	PROJECT USAGES
SOLUTION ARCHITECTURE							GARA Framework Model △

Digital Transformation via GARA: As-Is and Future Vision

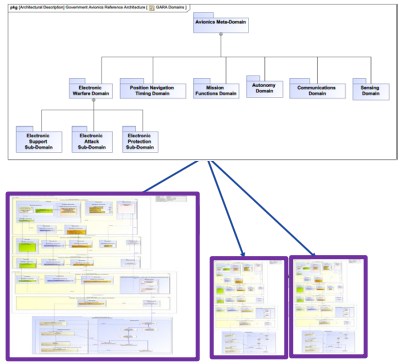
- **Model-Based GARA to capture and relate Modularity and Open Standards guidance data**
- **Lower the barrier to entry. Meet program offices where they are now with simple touch-points for GARA – UAF/ SysML not required**



- **Model-Based GARA extends to capture more information and increase DE capabilities**
- **Mature use. Support programs to use model-based artifacts in technical design and acquisitions activities**



- **Model-Based GARA continues maturation of DE capabilities, extensibility to models of open standards where available**
- **Increase community use of model-based artifacts in technical design and acquisitions activities**



MBSE process will promote future extensibility and will mature use to provide a digitally integrated and traceable means of MOSA evaluation

Benefits of a model-based approach to MOSA guidance and verification:

- Configuration management
- Automated checking of compliance to open standards
- Higher likelihood of exposing aspects of architecture relationships, gaps, and/or conflicts through linked data