Air Vehicle/Mission System Architecture (AV/MSA) Interface Definition (ID)

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ABSTRACT

The US Government (USG) desires the ability to procure mission system capabilities separate from the procurement of the air vehicle for future acquisition projects. To achieve this goal, the USG acquired support from the Vertical Lift Consortium (VLC) to collaboratively develop an interface specification consistent with the tenets of a Modular Open Systems Approach (MOSA). The VLC collaboration team was formed to include a diverse group of companies and subject matter experts (SMEs) that span aircraft developers, systems integrators, suppliers, and academic institutions to obtain the broadest possible consensus on the end products.

This paper introduces the concept of the AV/MSA Interface Definition (ID). It describes the approach used to develop the Specifications using model-based systems engineering (MBSE) tools and processes, and presents the objectives and results of each AV/MSA ID Task and Sub-task. It discusses the application of the AV/MSA Interface Definition to aviation programs as part of a larger and longer term U.S. Army MOSA Transformation, positioned to support next-generation aircraft designs for the air vehicle (AV) and mission systems architecture (MSA) hosting aircraft avionics.

INTRODUCTION

Under the Aviation & Missile Technology Consortium® (AMTC) Other Transaction Agreement (OTA), fourteen (14) companies collaborated with the USG to produce an interface specification, named "Air Vehicle/Mission System Architecture (AV/MSA) Interface Definition". The AV/MSA ID was an iterative, multi-year effort begun in 2018 as part of the Joint Multi-Role (JMR) Technology Demonstrator (TD) with the last iteration ending in December 2020. The boundary between the AV and its mission systems represents a key system interface, as the AV and mission systems represent distinctly different capabilities that evolve at different rates, and possess different interoperability needs. In order to define this interface, the USG has collaborated with industry partners to develop the approach, methodology, and information required to define an interface separating the AV from its mission systems, and formally constrain how that boundary is described.

A major tenet of a modular open system approach (MOSA) in the development of a weapon system is a modular design that makes use of major system interfaces (*i.e.*, Key Interfaces) between a platform and its major system components. Modular design allows system components to be severable, allowing components to be incrementally added, removed, or replaced throughout the life cycle to afford opportunities for enhanced competition and innovation, while yielding significant cost savings or cost avoidance; schedule reduction; opportunities for technical upgrades; and increased interoperability including system-of-systems interoperability and mission integration. The USG desires to procure future updates to the AV and mission systems independently through well-defined and well-understood interfaces, to increase system capability while improving competitive opportunities. The AV/MSA ID is intended to facilitate this desire.

This AV/MSA ID (see figure 1) identifies three elements: the air vehicle (AV), the mission system architecture (MSA), and the interface between them. The AV and MSA encapsulate functions and exhibit behaviors, which inform the interface consisting of mechanical connections and electrical and digital signal exchanges. These interfaces are described using textual descriptions and model-based specifications.

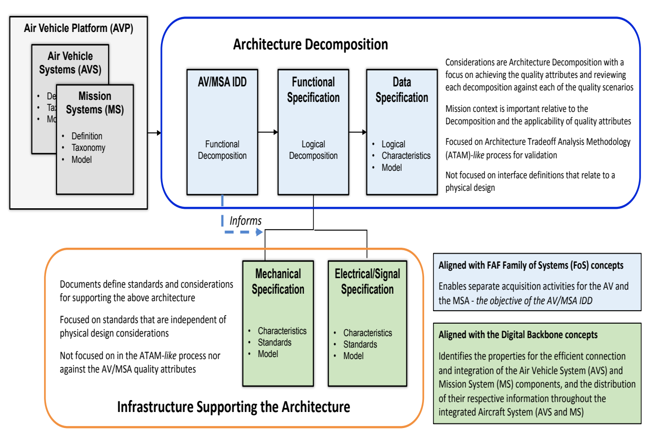

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Figure 1. U.S. Army's Air Vehicle / Mission System Interface Definition Organization.

This paper presents a summary of the results of the AV/MSA ID efforts. It also describes how the AV/MSA ID was developed by a diverse collaboration of fourteen (14) participating organizations, namely: BAE Systems, Bell, Collins Aerospace (CAS), Boeing, GE Aviation, Honeywell, Lockheed Martin/Sikorsky (LM/SAC), Northrop Grumman (NGC), Piasecki Aircraft Corporation (PiAC), Raytheon (RTX), SAIC, Skayl, Tucson Embedded Systems (TES), and the University of Alabama Huntsville (UAH). This paper describes how this interface definition supports the Army's MOSA Transformation through the Future Vertical Lift (FVL) Architecture Framework (FAF) by enabling the specification and development of modular, open systems. It includes next step efforts to support follow-on Army's MOSA Transformation efforts.

RESULTS

The initial AV/MSA ID products were delivered to the USG in March 2019 under the Vertical Lift Consortium (VLC) OTA and included an interface definition that identified the mechanical, electrical, signal/data, and functional interfaces between an AV and its MSA to include flight control and mechanical protocols independent of any particular AV or MSA (common to all aircraft variants/variations). This body of work was incorporated into the Army's FAF as part of a larger MOSA pertaining to the FVL program. The products informed numerous aspects within the FAF such as the Digital Backbone, functional libraries, and component specification pattern. The subsequent iteration began in January 2020 and was focused on refinements and additional definition to the original set of products based on recommendations from "the Team" at the end of the initial iteration.

The AV/MSA Team, referred to subsequently as "the Team", leveraged accepted and evolving open standards, and formed consensus on terms, definitions, and allocations of functions and capabilities for use with next-generation aircraft design. The AV/MSA ID was developed and refined with significant industry involvement and leadership based on substantial analysis and systems engineering.

Initial Iteration

Tasks during the initial iteration focused on analysis, interface development and validation of the interface products. The AV/MSA ID is intended to support a larger MOSA and is not intended to reflect a specific instantiation of an interface. As such, definition activities were kept at a conceptual level identifying necessary allocations, properties and characteristics, and data that would allow later application to standardize future interface definition. As part of the analysis, the team performed tasks focused on terminology, quality attributes (QAs), functions, standards, and variability associated with the key interface. Also performed was an assessment of tooling and compatibility between tooling necessary to support required modeling activities. These efforts led to products identifying an allocation of functions to either the AV or mission system, and the specification of mechanical, electrical, and data/signal aspects of the interface. The respective specifications included both textual (document), and model outputs. Specifications heavily leveraged applicable standards and identified numerous properties appropriate to the respective specification.

Functional allocation to either the AV side or MSA side (or partition) of the aircraft was an important consideration for this task. The Team decided AV functions were those that dealt with "aviate" functions of the integrated weapon system such as propulsion and vehicle subsystems. The MSA functions were those that supported the systems necessary to provide the "navigate", "communicate", and "operate" functions such as mission computing, displays, mission sensing, mission effectors, etc. The allocation of functions to either side of the interface was a lengthy and highly collaborative activity based on the application of the Army's Joint Common Architecture (JCA) product as well as the structure described by MIL-STD-881. The Team produced two variations of the allocation, as there was initially insufficient consensus on where Flight Director functions should be allocated. The larger team believed that Flight Director functions should be allocated to the AV due to the close coupling of flight control functions. A sizeable minority believed that guidance functions as part of the Flight Director can, and should be, separated as a larger part of navigation. Reconciling this difference of opinion was relegated to future iterations as were a set of functions that the Team believed required further decomposition before an adequate allocation could be made.

Also produced was a Strategies Report highlighting different considerations involved in the application of the interface definition and conformance and validation plans intended to assess the completeness of the overall definition. Due to the abstract nature of the interface definition, validation activities were primarily focused on participant reviews of internal products to assess completeness of the specifications and identify gaps or inconsistencies in products as compared to the identified quality attributes (QAs). The initial definition tasking completed by identifying several recommended refinements and additions to the resulting AV/MSA ID products. Suggested refinements focused on additional synchronization between strategy, QAs, and the specifications, decomposition and allocation of identified functions, alignment of the specifications to the USG's Digital Backbone concept and FAF, as well as consideration of cyber concerns across the various interfaced definition products. Those recommendations were the subject of a follow-on set of tasking using the AMTC OTA.

Organization of the Follow-on AV/MSA Interface Definition

Based on the recommendations of the initial Team, refinement Tasks were organized around three main efforts:

- Task 1 – Guidance
- Task 2 – Interface Specification Updates (with models)
- Task 3 – Cyber, crosscutting to support both Tasks 1 & Tasks 2

Due to the success of the initial effort, and commitment of the initial participants, the Team assembled for the refinement task was largely the same to include many of the initial participants despite the change in agreement vehicle, and lapsed time between the initial and refinement tasking. For the refinement tasking, the Team grew in both the number of involved organizations and participants. This level of coordination and collaboration between industry organizations is noteworthy and provides a template for future efforts requiring broad industry participation and definition.

Task 1 - Guidance

The AV/MSA ID Task 1 Guidance Sub-Tasks included:

- Task 1.1 – Quality Attributes.
- Task 1.2 – AV/MSA Strategy.
- Task 1.3 – Governance, Configuration Management, and Conformance, and
- Task 1.4 – Validation Plan.

The ***Quality Attributes*** sub-task**,** co-led by Raytheon and Lockheed Martin (LM)/Sikorsky Aircraft Company (SAC), refined the results of the initial 2019 Task 4 activities, and informed subsequent AV/MSA ID efforts. Additionally, this product was purposely positioned and aligned to inform other USG Science & Technology (S&T) and acquisition activities such as Integrated Mission Equipment (IME), and FVL.

Prior to the AV/MSA Interface Definition functional analysis sub-task activities (*i.e.*, Sub-task 2.1), the QAs were critical in assisting in the evaluation of the architecture, along with the corresponding use cases, growth and stressing scenarios, which were, generated from four primary QAs: Adaptability, Robustness, Survivability, and Usability. Collectively they assisted in the evaluation of the utility of the AV/MSA ID. The goals of the QA sub-task were to:

- Generate the prioritized Quality Attribute Utility Tree.
- Develop a set of scenarios further highlighting the Quality Attributes, and
- Assess the implications for, and impact on, the AV/MSA interface for each Quality Attribute.

Identifying, prioritizing, and generating scenarios for the QAs was a collaborative process that resulted in a QA tree, and a supplemental set of scenarios prepared for use as test cases for evaluating the AV/MSA ID products. The QAs and associated scenarios provided guidance and a framework for architecture trades such as allocation of functionality and definition of interfaces. The QA team felt that prioritizing QAs (rank-ordering) was crucial because many trades may favor one QA over another, and having a well-established prioritization scheme enables informed decision-making.

The ***AV/MSA Strategy*** sub-task, co-led by General Electric (GE) Aviation with Raytheon and Collins Aerospace (CAS), included a Model Style Guide, and an Architecture Strategy report.

The AV/MSA ID Model Style Guide documented the guidance for model developers to ensure consistency, readability, and maintainability across the multiple participating organizations developing the AV/MSA ID specifications. The document includes guidance on modeling elements, stereotypes, properties, and naming conventions, as well as modeling styles that support model domain aggregation and guidance to ensure interoperability across the different formats used to develop the AV/MSA ID models.

The Style Guide also governs the style of the model elements created during the course of the effort and describes the values for expected model element outputs. All other model styles conformed to standard UML, SysML, UPDM, the FACE™ data model architecture, or BPMN if not otherwise specified.

The Mechanical and Electrical domain models were developed to be *aggregable* into a common model using Cameo Enterprise Architecture or MagicDraw software. This means the models do not have redundant elements and instead utilize a common library or traceability between the models. Relationships to external models are also not redundant, such as traceability to the FAF. Additionally, projects referenced by the sub-domain models were implemented as Project Usages by the aggregate model.

The AV/MSA ID Architecture Strategies Report outlined the considerations and strategies shaping the AV/MSA ID to support Army Aviation's business objective of managing and procuring the AV separately from the MSA. The report identified four top level use cases that were used to support analysis and development of strategies to meet the high-level goals and objectives identified for Air Vehicle and Mission System procurement, development, integration, and qualification. These use cases were then assessed for types of variability, which a number of types of system variability that directly relate to the kinds of changes identified in the use cases. Finally, the report identified one or more potential strategies for dealing with the variability along with related QAs.

The ***Governance, Configuration Management, and Conformance*** sub-task, co– led by Tucson Embedded Systems (TES) and University of Alabama in Huntsville (UAH), documented the policy and procedures for use by the team and USG Stakeholders to maintain, and sustain the AV/MSA ID baseline products, announce updates, and manage changes.

The objectives of this activity were to:

- Describe the process for Governing the sustainment of the AV/MSA ID.
- Describe how the Products are Managed through Change using a Control Board, Change Process, and Configuration Management, and
- Describe the Conformance Procedures capable of assessing whether an implementation of the AV/MSA ID satisfies the requirements of the AV/MSA ID and is in conformance with the guidance outlined in the AV/MSA ID Model Style Guide.

The *Validation Plan & Efforts* sub-task, co-led by UAH and TES, documented the process and methods by which the Team worked both internally and with USG Stakeholders to validate the initial prototype of the AV/MSA ID.

During the initial validation efforts, individual specification models (*i.e.,* Electrical, Mechanical, and Functional specifications) were developed by the separate sub-task groups. These models were aggregated into a single integrated AV/MSA ID Description Specification model, delivered in Cameo's native format, .mdzip, which facilitated the integration into a single model. Using the Validation Plan, the aggregated model was analyzed by the specification groups to validate their information was properly aggregated.

Aligning to the previous Validation Plan, the Team member organizations validated the completeness and correctness of the Mechanical and Electrical Specifications against specifications of existing avionics components of member organizations.

Each team member organization was tasked to select and compare an internal avionics component(s) against these specifications, identify alignments, and report any gaps. At the conclusion of the review, the team determined that the initial interface definition aligned well to a diverse set of real-world Original Equipment Manufacturer (OEM) avionics components. Identified gaps were corrected and the specifications revised as appropriate.

Whereas the initial effort of the Validation Plan outlined and executed a process to ensure completeness of the interface definitions, the refinement effort was oriented around ensuring the longer-term applicability of the specification models for use on future programs. The objectives of the refined Validation Plan were to:

- Describe a process to validate the integrated model for conformance with the Model Style Guide, to ensure completeness, and identify and remove any redundancies across modeling efforts.
- Ensure that the Mechanical and Electrical Interface Specifications are aligned with ISO 42010 required views; these define relationships between the Specifications and the high-level project goals, as well as the Digital Backbone concepts of Nodal Points and Points of Presence within the FAF.
- Describe the Interface Elaboration Process (with a framework that connects interface designs) to the Mechanical, Electrical, and Functional/Data Interface Specifications, and
- Refine the definition of "Conformance", and establish the initial procedures for Conformance determining alignment with the Interface Specifications (*i.e.*, Mechanical, Electrical, and Signal/Data); and to develop steps to propose future automation of these Validation efforts.

To enable these objectives, the specifications and any proposed changes to the specifications had to align with guidance established in the AV/MSA ID Model Style Guide, which provides context and a common semantic framework for the Interface Specification models. The guidelines in the AV/MSA ID Model Style Guide, in conjunction with the execution of the Validation Plan, were intended to ensure the specification models were developed correctly.

Task 2 – Interface Specification (with models)

A series of Specification products were produced corresponding to the AV/MSA ID illustrated in Figure 1. The Task 2 efforts included:

- Task 2.1 – AV/MSA Interface Definitions.
- Task 2.2 – Mechanical Interface Specification.
- Task 2.3 – Electrical/Signal Interface Specification, and
- Task 2.4 – Functional/Data Interface Specification.

The ***AV/MSA Interface Definitions*** sub-task, co-led by LM/SAC and Northrop Grumman Corporation (NGC) & Raytheon & Boeing, established the set of definitions and functions that compose the AV and MSA.

Sub-task 2.1 established the MSA and AV definitions, as shown in the top of Figure 1. These definitions include a set of terms and the list of functions that make up the MSA and the list of functions that make up the AV. These lists provided the basis for identifying the interfaces between functions on the AV and MSA, thus detailing the different interface specifications (*i.e.*, Mechanical, Electrical, and Functional/Data). The Definitions Report provides a description of used terminology and augments the initial report in several important ways.

The Team developed a set of definitions to guide the work, and used definitions from MIL-STD-881D (referred to hereon as "881D") as well as from the USG provided FAF to support the AV/MSA ID tasks. Key terminology from 881D is referenced below:

- Air Vehicle – The complete flying aircraft including the Airframe, Propulsion, Vehicle Subsystems and Avionics.
- Avionics – "aviation electronics" includes the aviation equipment on board the air vehicle, which is primarily electronic in nature. Includes the automatic flight control, mission computer, communications, sensors, navigation aids, *etc*., and
- Crew Station – Provisioning for crew and passengers including electronic equipment (*e.g*., crew displays) Medical Evacuation (medevac) equipment, environmental control, seats, *etc*.

881D does not explicitly define a Mission System (MS), other than in the context of removable payloads, which are not permanently installed equipment. The working definition of mission system the team used to include permanently installed equipment consistent with 881D is the following subsets of the Avionics and Crew Station:

- Avionics Mission Computer, including Mission Computer software, and
- Components under the control of the Mission Computer.

Similarly, the USG provided the following division and definition as part of the FAF:

- Air Vehicle Systems are the avionics that support the "Aviate" functions of the AV (*e.g*., flight computers, aviate sensors, primary flight displays, sub-system monitoring and control, backup instrumentation, *etc*.), and
- Mission Systems are the avionics that support the "Navigate", "Communicate", and "Operate" functions of the AV (*e.g.,* mission computers, mission displays, mission sensors, mission effectors, *etc*.).

Based on these references, the Team agreed to use the following definitions for AV and MSA:

- AV – The complete flying aircraft including the Airframe, Propulsion, Vehicle Subsystems and Avionics, inclusive of the MS and AVS, and
- MSA architecture for the MS that support the systems necessary to provide the "Navigate", "Communicate", and "Operate" functions of the MS (*e.g*., mission computers, multi-function displays, mission sensors, mission effectors, *etc*.).

From these definitions, the Team derived the following AV/MSA IDs:

- AV-MSA functional and data interfaces are between the MS and the AVS.
- AV-MSA mechanical interface: between the MS and the AV (*e.g*., AV Airframe), and
- AV-MSA electrical interface: between the MS and the AV (*e.g.,* AV Power subsystem).

Since the MSA is defined to be a part of the AV, the relation between the MSA and the AV is the relation of a part to a whole. Functions that are allocated to the MSA part are designated as MSA functions. The remaining functions that are not part of the MSA are designated as AV functions.

The Team noted that modern technology advances enable physical implementations that combine computing elements and sensors that support multiple functions. For example, it is possible that future aircraft may not have physically separate chassis to provide the "mission computer" and "flight computer" functions. Terms such as "Computer" or "System" are to be understood to be functional descriptions and not intended to restrict physical implementation. For example, the term "Mission Computer" is understood to refer to a mission computing function that could be satisfied with at least three possible implementations:

1. Mission computer chassis separate from an AVS computer chassis.
2. Mission computer board located within a chassis shared with the AVS computing function, and
3. Software partition with processing resources provisioned by another processing function either on one board or instantiated across multiple boards.

Similarly, other physical components such as sensors may be able to support multiple functions such as surveillance, fire control, communications, or flight control. Sensor technology advances may allow a shift in what sensor functions are implemented as separate components versus what sensor functions may be embedded in a shared processing function. The identification of a sensing or processing function is not intended to restrict innovative designs that combine functions, *e.g.,* to reduce weight.

The Team also noted that the USG FAF model, uses a slightly different definition of "Air Vehicle" than is used in this report and 881D. FAF introduces the term "Air Vehicle Platform" to refer to the entire flying aircraft including the Air Vehicle (AV), AVS and MS.

Following agreement on the terms and definitions, the Team developed a set of functions covering the full system with the AV and MSA combined, and then performed the allocation to either AV or MSA. The AV-MSA Function List was developed from three primary sources: 881D, the Joint Common Architecture (JCA), and the Objective Mission System Definition (OMSD).

- 881D Appendix A - 881D provided the most inclusive listing of air vehicle functions (breadth), but generally stayed at a high-level and does not provide the same level of detail found in the other two sources for mission system functionality. The initial working set of 881D considered additional functions that were determined to either be higher level groupings, or are work breakdown structure (WBS) items such as "Integration, Assembly, Test, and Checkout." These functions were identified by the team as "Not Applicable" and not included in the functions that were allocated.
- JCA - The JCA functions are focused on potential mission system software functionality intended to operate in the Portable Component Segment of the Future Airborne Computing Environment (FACE™) and does not generally provide descriptions of other air vehicle or avionics equipment functions, and
- OMSD –The OMSD function listing included many functions addressed by 881D and JCA. The Team review identified six OMSD functions to be considered during the allocation process.

The initial analysis identified three functions pertaining to crew station, flight and mission augmentation, and remote management that were too complex to be simply allocated to one side or the other. The follow-on effort decomposed those initial three functions into 13 new functions and allocated each to either AV or MSA. The initial report also identified non-consensus on how to handle differences in Flight Control and Flight Direction in terms of allocation, which impacted 26 functions. The majority position allocated most of those 26 functions to the AV. The follow-on task conducted additional analysis to resolve the non-consensus using the QA assessment process described earlier. Using this approach, three functions were determined to contain both AV and MSA components, so they were decomposed to yield three AV functions and three MS functions. After this decomposition, there was a total of 26 functions considered. The QA analysis was then conducted to compare whether having those functions allocated to the AV or the MSA would better support the Quality Attributes. The result of the analysis confirmed the original allocation of the remaining functions to the AV.

The function count varied over the initial and follow on tasks as the analysis progressed and some functions were decomposed into multiple functions. In all 258 functions were allocated to the MSA, and 158 functions allocated to the AV (84 functions allocated to both the AV and MSA).

The **Mechanical Interface Specification** sub-task, co–led by UAH, Boeing, and CAS defined the physical accommodations that the AV provides to the on-board air vehicle and mission system components and specified common standards to be used by the AV/MSA ID, as well as documented gaps requiring new or modified standards. The Mechanical Interface Specification considered the versatility and configurability necessary to improve the mission flexibility of the platform while minimizing the recertification aspects required for changes in mission equipment from a mechanical installation point of view. Since no physical configuration is defined for the MSA or Air Vehicle AV, the specification was generalized in terms of the data that needs to be described and in what format.

During the initial effort, a list of mechanical characteristics was developed that captured relevant characteristics needed to describe an installation of mission equipment. Each characteristic included considerations that detail needed information that either the air vehicle or mission equipment will need to know from the other side. AV Considerations include the information that the AV supplier must know of the Mission System to adequately characterize the interface and accommodate the installation. MSA Considerations include the information that the MSA supplier must know of the AV interface to adequately design and/or install their equipment to specification. The refinement task was primarily focused on reviewing and updating the mechanical characteristics considering the FAF and USG concept of the Digital Backbone including the impacts of nodal points and points of presence.

Each of these considerations associated with the mechanical characteristics were addressed using existing standards that are widely supported and consensus-based (*e.g.*, ARINC, MIL-STD, SAE, *etc.*) as well as other emerging standards such as Hardware Open Systems Technologies (HOST), Open Mission Systems (OMS), and/or Sensor Open Systems Architecture (SOSA) where applicable.

The **Electrical/Signal Interface Specification** sub-task, co-led by NGC, GE Avn., Collins, and UAH documented a rubric of electrical characteristics needed to describe each of a particular platform's AV/MSA interfaces. During the initial effort, the Team identified four main categories of electrical interface: power, electro-magnetic interference (EMI), signal protocol, and signal physical connection as well as sub-categories that further refined types of each of the four categories. Similar to the Mechanical Interface Specification, each of the sub-categories were described in terms of MSA and AV Considerations, identified applicable existing standards that are widely supported and consensus-based (*e.g.*, ARINC, MIL-STD, SAE, *etc.*).

The primary objective of the refinement activities was to update the Electrical Interface Specification to be consistent with the Digital Backbone concept described in the FAF. While reviewing the FAF characteristics, the Team found that the breakdown of "Required" and "Rating" characteristics should be adopted as they align with the allocation of characteristics to the concepts of the Digital Backbone. As an example, a power point of presence type will have a characteristic of Maximum Power Consumption Required and a system component would have Maximum Power Consumption Rating. The two characteristics can be tied together using parametric views to verify the point of presence requirement is met based on the rating of the component. Once the team developed a comprehensive set of characteristics by combining the characteristics from the FAF and the initial release of the Electrical Interface Specification, and adopted the “Required” and “Rating” characteristics, each characteristic was allocated to the concepts of the Digital Backbone, categorized, and assigned a measurement unit or marked for further decomposition. The categorization provides a method to separate the characteristics into groups that apply to more specific usages of the Digital Backbone concepts. This led to the definition of specific types of points of presence and system components that carry unique electrical characteristics.

The **Functional/Data Interface Specification** sub-task, co–led by CAS with Skayl, Science Applications International Corp (SAIC), NGC and TES documented the data, interfaces, operations, and characteristics associated with the functions that are expected to exchange data across the AV and the MSA boundary.

During the initial effort, the Team determined the majority of interfaces crossing between the AV and MSA could be identified by analyzing functions allocated to one partition, and selected the AV partition as the focus. This focus resulted in an initial assessment of 41 functions that defined:

- Data required and provided by AV and MSA functions.
- Interfaces between AV and MSA functions.
- Interface Operations (functional interface requirements).
- Input/Output Data Groups, and
- Data Attributes/Characteristics such as latency, functional criticality, potential variability, and existing standards.

During the refinement task, the Team focused on developing a repeatable process to analyze functional interfaces, further developed functional interfaces for 24 additional AV functions, and identified a number of interface characteristics pertaining to safety, security, latency, and resolution etc. The effort identified several observations that should be considered in continued definition. Notably, system context is key in developing and validating an appropriate functional interface. Given the nature of the AV/MSA ID, functions have been analyzed as stand-alone entities. Such context should not only aid in interface specification development but will also assist in identifying functions that are missing or incomplete.

Task 3 - Cyber, Crosscutting to support Tasks 1 & 2

Task 3 was co-led by Bell, SAIC, and Boeing, and it supplemented and informed the efforts and results of the other tasks. Its purpose was to review the larger effort in the context of safety and cyber, and to ensure the various products considered, and were appropriately informed by those aspects. In addition to the in-task contributions, the Team also provided several suggested next steps that included:

- Using the modeling efforts and the data flows identified for the AV/MSA functions, to identify potential attack surfaces associated with the functions.
- Using available framework and attack patterns, to identify and define Attack Trees for each attack surface documented, and
- Identifying, modeling, and mapping cyber controls to mitigate each of the identified attacks.

Next Step Suggestions

The Industry to USG out-briefs included suggested steps to enhance the AV/MSA ID specifications. Other enhancements involved investigating model format interoperability and tooling to ensure used modeling tools can exchange model data without loss (*e.g.*, round-trip data through: UML, SysML, .FACE, AADL, *etc.*); and USG-funded support the development of tools and processes for the development and sustainment of cross-organizational input using a Single-Source-of-Truth (SSoT). Also discussed was the ability to produce and deliver a model-based test harness along with the model specifications, so that vendor products could be evaluated against the specifications.

CONCLUSIONS

The boundary between the AV and its mission systems represents a major system interface as the AV and mission systems represent distinctly different capabilities that evolve at different rates and possess different interoperability needs. As part of a larger approach to open systems development, the USG and Industry collaborated over the course of three years on the development and refinement of an AV/MSA ID that sought to define terminology, identify strategies and guidance, develop governance and processes, and importantly, describe the mechanical, electrical and functional interfaces supporting the separation of an AV from its mission systems. The USG used both the VLC OTA, and the AMTC OTA as the means to obtain an impressive amount of collaboration from 14 industry and academia partners working together as a seamless team. The approach demonstrated the effectiveness and usefulness of an OTA to obtain coordinated, broad-based input and support from industry partners throughout a very large breadth of domain specific expertise.

The Army is using the resultant products of this effort to gain understanding, and support the development of a larger, transformational approach to Modular Open Systems applied to the larger Aviation Enterprise. The AV/MSA ID has been incorporated into the FVL Architecture Framework (FAF), which is used as the foundation for model-based USG furnished information (GFI). The FAF is currently the focus of the Architecture Collaboration Working Group (ACWG), which is a voluntary organization of 824 USG and Industry participants (as of this writing) collaborating to shape the future of Army aviation through architecture and modular open systems.

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Acknowledgment therefore truly includes each of these 14 contributing VLC Task 4 Companies from both Industry, and Academia, with contributions from each of the 75 Subject Matter Experts (SMEs). They effectively worked side-by-side with other Industry members and with the USG Stakeholders to accomplish this important contribution to the aviation community.

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