Unmanned Ground Vehicle (UGV) Interoperability Profile (IOP)
Overarching Profile
Version 0

Robotic Systems, Joint Project Office (RS JPO)
SFAE-GCS-UGV MS 266
6501 East 11 Mile Road
Warren, MI 48397

21 December 2011

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **21 DEC 2011**	2. REPORT TYPE	3. DATES COVERED **00-00-2011 to 00-00-2011**
4. TITLE AND SUBTITLE **Unmanned Ground Vehicle (UGV) Interoperability Profile (IOP) Overarching Profile, Version 0**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Robotic Systems, Joint Project Office (RS JPO),SFAE-GCS-UGV MS 266,6501 East 11 Mile Road,Warren,MI,48397**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**40**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Table of Contents

1 Scope

1.1 Purpose

The Robotics Systems Joint Project Office (RS JPO) has launched an initiative to identify and define interoperability standards to be organized and maintained within an Unmanned Ground Vehicle (UGV) Interoperability Profile (IOP). This IOP will be employed by UGV acquisition managers in the acquisition of future Programs of Record, the upgrade of fielded systems, and the evaluation/acquisition of Commercial-Off-The-Shelf (COTS) products.

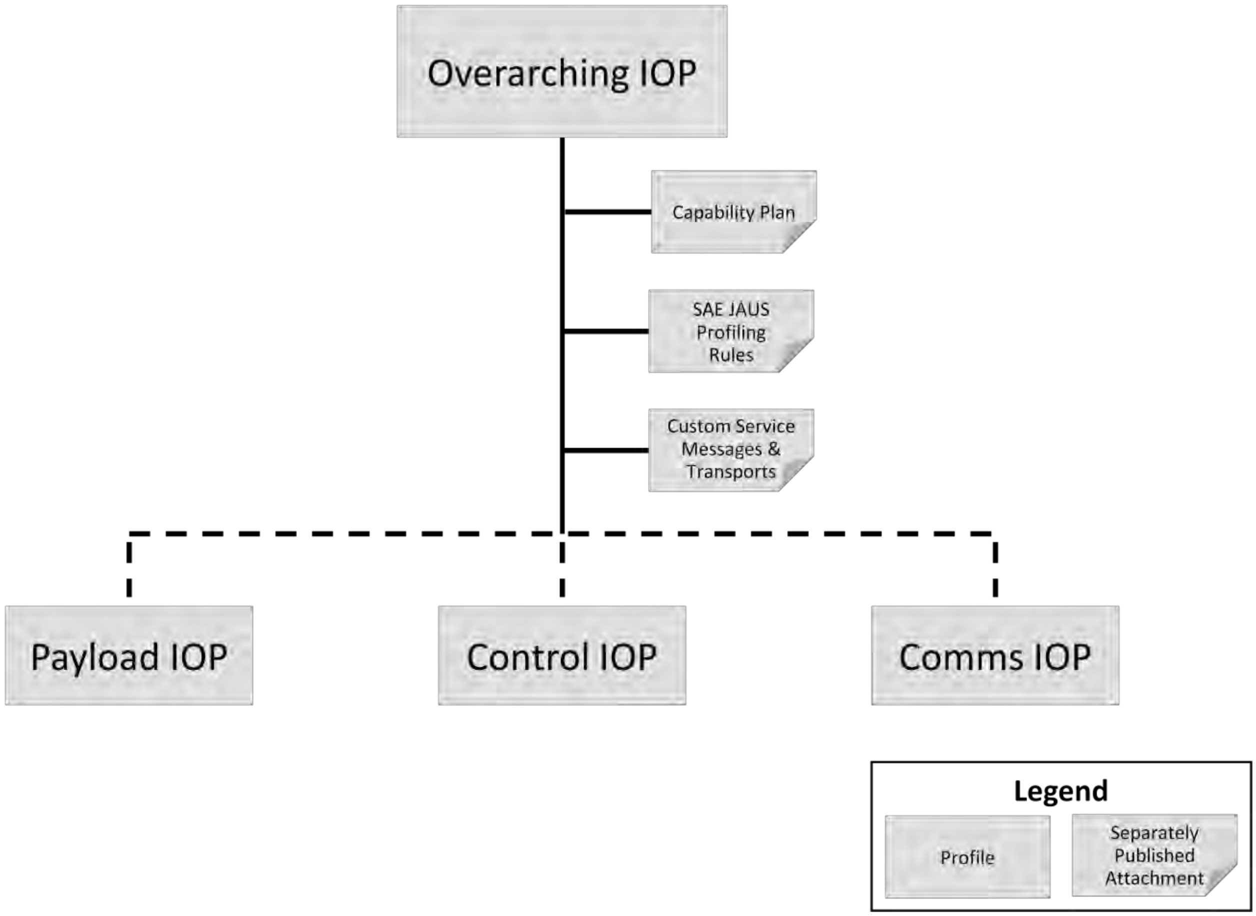
A primary goal of this initiative is to leverage existing and emerging standards within the Unmanned Vehicle (UxV) community such as the Society of Automotive Engineers (SAE) AS-4 Joint Architecture for Unmanned Systems (JAUS) standard, the Advanced Explosive Ordnance Disposal Robotic System (AEODRS) Architecture Description Documents Version 1.0, and the Army Unmanned Aircraft Systems (UAS) Project Office IOPs with an end goal of:

- Facilitating interoperability among new UGV initiatives and legacy systems;
- Facilitating interoperability between controllers and UxV robotic system(s);
- Facilitating collaboration between UGV and UAS systems;
- Providing a path forward to standardized interoperable technology solutions
- Promoting payload and on-board subsystem modularity and commonality across the portfolio of UGV systems.

IOP Version 0 (V0) has been developed using a government/industry Working Integrated Product Team (WIPT) structure, and defines the interoperable interfaces and protocols necessary to enable interoperability and modularity to be introduced to the capabilities that have already been widely fielded. The exact set of capabilities addressed in IOP V0 is described in the UGV IOP V0 Capabilities Plan. The RS JPO intends to publish annual revisions to the IOP in order to expand and evolve its scope as necessary, based on the evolution of Warfighter capability requirements and technological advances.

1.2 Document Structure & Overview

This document provides the base concepts, architecture, requirements, and overview for the UGV IOP; and specifically addresses platform, payload, mobility, on-vehicle network, communication, and messaging requirements. Additionally, this document introduces and presents the conformance and validation approach to be employed within the IOP. The complete set of documents that comprise the UGV IOP and their intended usage is presented below.



UGV IOP – Overarching Profile

In addition to the topics specified above, this document also provides three separately published attachments that comprise the Overarching IOP V0. These attachments are described below:

- ***UGV IOP V0 – Capabilities Plan***
  Defines capability requirements related to the employment and usage of UGVs to perform current and relevant near-term robotic missions, in turn scoping and bounding the content of the UGV IOP. This Capabilities Plan is based on a mission analysis that reviewed the usage of currently fielded UGVs and the capability requirements of a number of existing and emerging Programs of Record.
- ***UGV IOP – SAE JAUS Profiling Rules***
  Specifies the manner in which the SAE AS-4 JAUS standards have been profiled, to include clarification or additional content to define interoperability between controllers and UGVs as well as intra-UGV (platform/subsystem) interoperability.

- ***UGV IOP – Custom Services, Messages and Transports***
  Specifies additional SAE AS-4 JAUS messages and transport protocols required to support the scope of the UGV IOP. Although titled "custom", these messages are published and standardized within the UGV IOP community with the end goal of transitioning to the SAE AS-4 JAUS standard(s) for official adoption.

UGV IOP – Control Profile
This document specifies the Operator Control Unit (OCU) logical architecture, standards, Human-Machine Interface (HMI) requirements, and conformance approach to include host application user interface requirements, such as mission planning and command and control. Although OCU concepts and high level architecture are touched upon in the Overarching Profile, the Control Profile provides the more detailed requirements to specify how interoperability is to be achieved for conformant controllers.

UGV IOP – Payloads Profile
This document specifies the payload classification, standards, requirements, and conformance approach. Although these concepts are touched upon in the Overarching Profile, the Payloads Profile provides the more detailed requirements to specify the interoperability requirements for payloads with respect to the UGV platform.

UGV IOP – Communications Profile
This document specifies the communications standards, requirements, and conformance approach. Although these concepts are touched upon in the Overarching Profile, the Communications Profile provides the more detailed requirements to specify interoperability requirements for communications between and among controllers and UGVs.

1.3 Discussion of Technical Topics

1.3.1 Interoperability Attributes

The UGV IOP has been designed to support interoperability on a variety of missions and objectives, vehicle classes/types, controller classes/types, payload classes/types, physical/software architectures, and interaction with external systems (e.g., networks, C2). Since every interoperability requirement will not be applicable to every system, the IOP provides a mechanism to independently specify these requirements in a composable manner, using Interoperability Attributes. In this way, Interoperability Attributes applicable to the specification and design of a system can be identified and subsequently utilized to filter applicable requirements from the UGV IOP, supporting system design, development, conformance and validation testing, initial operational test and evaluation, and fielding.

Throughout the UGV IOP, the term "Interoperability Attributes" has been designated to identify these composable attributes, which may be specified as options in the application of the UGV IOP to a system acquisition activity. This concept is depicted below in Figure 1-1.

Interoperability Attribute	Selectable Values	Associated Requirements
Transport	JUDP	Robotic systems (controllers and/or vehicles) with a designated "JUDP" transport Interoperability Attribute shall implement the transport in compliance with the JUDP transport specified in SAE JAUS AS5669A.
	JTCP	Robotic systems (controllers and/or vehicles) with a designated "JTCP" transport Interoperability Attribute shall implement the transport in compliance with the JTCP transport specified in SAE JAUS AS5669A.
	Custom	Robotic systems (controllers and/or vehicles) with a designated "Custom" transport Interoperability Attribute shall implement the transport in compliance with the designated Custom transport specified in *UGV IOP Custom Service Messages and Transports*.

Figure 1-1 Interoperability Attribute Concept Example

System requirements specified in the UGV IOP are tagged, accordingly, with Interoperability Attribute designations. The manner in which the attribute is to be interpreted is also specified within the UGV IOP. It is acknowledged that UGV requirements will vary based upon capability, mission, and other acquisition requirements. For this reason, the capabilities defined within this IOP have been subset via Interoperability Attributes that specify the robotic system capabilities in a granular fashion, from the most simple to the most complex. The Interoperability Attributes are utilized to determine what capability is required along with what requirements are applicable to each capability (to include test and validation). In some cases, Interoperability Attributes specify choices which may be mutually exclusive, while in other cases, multiple options of the same Interoperability Attribute may be allowable.

The figure also depicts a "conceptual" interoperability template that can be utilized by various stakeholders to include the acquisition developer, the prime system developer, and the conformance and validation tester. The RS JPO has the responsibility for identifying the Interoperability Attributes applicable to each acquisition program. The prime systems developer has the responsibility for implementing the UGV IOP in accordance with the specified Interoperability Attributes, and the conformance and validation tester has the responsibility for developing and executing conformance tests, based on those Interoperability Attributes.

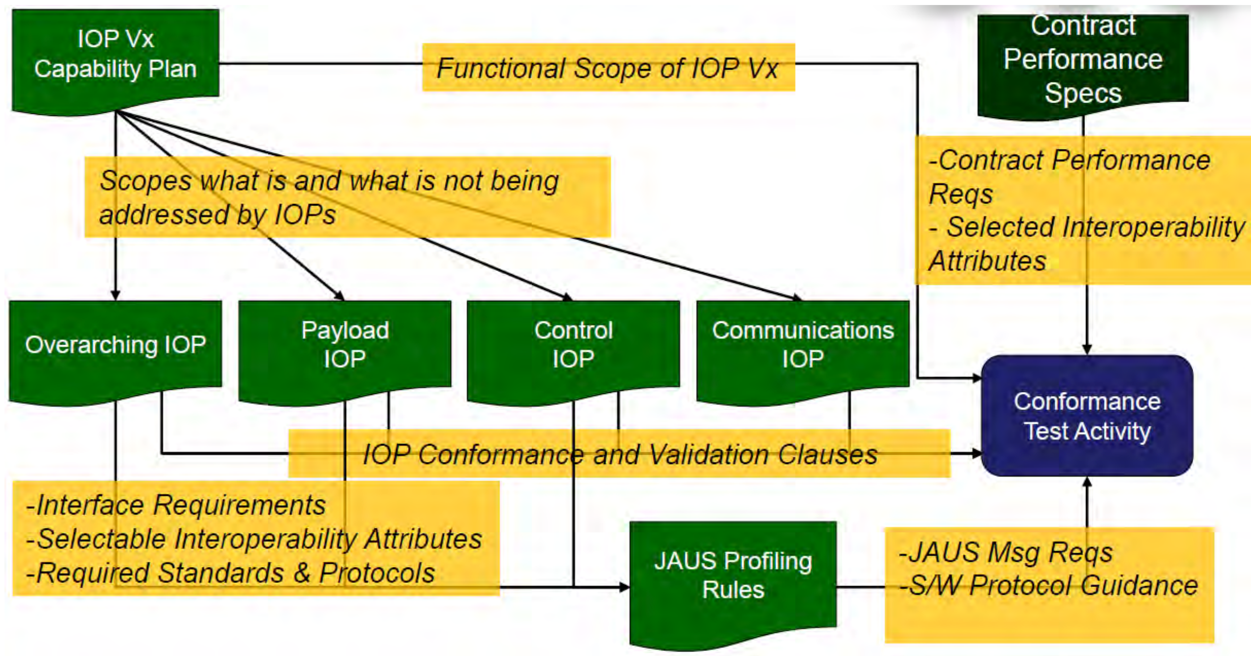


Figure 1-2 Mission/UGV IOP Flowdown

As shown in Figure 1-2, the *UGV Vx Capability Plan* document identifies specific capabilities and functionality that are within scope of the current Version level of the IOP effort. These requirements flow directly or indirectly to individual IOPs where additional level of detail is derived to support the IOP objective These are then further decomposed within the *JAUS Profiling Rules* document to define specific interface requirements (e.g., synchronous message rates) and behavior required to implement the defined Capability Plan requirement(s). Requirements from all of these levels, in addition to requirements cited within the contract performance specification, are flowed to the conformance and test activity to support a given system/subsystem test and validation activity. For each individual acquisition program, the Project Manager (PM) representatives will review the IOP package and select which Interoperability Attribute values will apply, based on system requirements. The requirements associated with those Interoperability Attributes will then become part of the contractual requirements for that program.

1.3.2 UGV Classes of Vehicles

The UGV IOP is targeted toward a limited set of UGV classes. These class definitions have been defined by the Joint Ground Robotics Integration Team (JGRIT). In the future, the JGRIT plans to define additional categories (e.g., small, micro, nano), with each category having multiple variants with roles defined by modular mission payloads mounted on a common platform. The current classification is as follows:

UGV Class of Vehicles (CoV). Army UGV CoV are categorized according to transportability within the four following classes:

- **Warfighter Transportable CoV** is the UGV class small enough for Warfighters to carry for extended periods. Within this class are the Single Warfighter and Crew Served Robotic systems.
- **Vehicle Transportable CoV** is larger than Soldier Transportable CoV and must be transported by another system, such as in a truck, on a trailer, or towed to its mission location.
- **Self Transportable CoV** is the UGV class large enough to transport itself and required payloads for extended periods.
- **Appliqué System** is an add-on standard robotics conversion appliqué kit, that will enable a manned vehicle to operated unmanned at the commander’s discretion. The appliqué system equipped vehicle is a scalable UGV with controls from manual operation to fully autonomous while maintaining its transportability as an unmanned vehicle the same as it did as a manned vehicle.

Given that UGV classes will impact the usage and application of the UGV IOP, “UGV Class” has been adopted as an Interoperability Attribute. The applicability of this attribute will be defined within relevant sections of the UGV IOP as it is employed. Currently there are no specific requirements for any one CoV.

1.3.3 Implementation of Standards

The UGV IOP defines standards as well as guidance with respect to implementation in order to promote interoperability as required by the acquisition program managers. Standards requirements are identified in a variety of areas, including electrical, mechanical, video, audio, communications, and messaging. However, due to the broad scope and expected operational usage of UGVs, not all standards will be applicable to every system.

Acquisition programs requiring conformance to this IOP will specify their interoperability requirements such that system developers can identify and conform to the applicable sections of the IOP.

System developers shall adhere to the standards and guidance as mandated within their procurement contracts relating to this IOP. Robotic system end items shall be tested and validated in accordance with the conformance and validation clauses contained within this overarching profile, as well as those contained in applicable companion IOP documents.

1.3.4 Control and Status Messages & JAUS Profiling

To the degree possible, the UGV IOP utilizes the SAE AS-4 JAUS standards to define the interfaces between the OCU and the UGV as well as among on-board UGV subsystems. The *UGV IOP SAE AS-4 JAUS Profiling Rules* document provides guidance with respect to the profiling of the JAUS standard, in order to define the manner in which interfaces are applied/interpreted as a means of limiting ambiguity and maximizing interoperability among disparate vendors.

1.3.5 Custom Services, Messages, and Transports

A set of "custom" UGV IOP services has been defined to provide mission capabilities scoped within the UGV IOP domain that are either not currently available in the SAE JAUS standards or require SAE JAUS extension by the SAE AS-4 Committee. These messages are documented in the *UGV IOP Custom Services, Messages, and Transports* document. To the extent possible, Custom Services, Messages, and Transports will be avoided, and when deemed necessary will be taken to the SAE JAUS committee for consideration of inclusion in a future public release. If/when Custom Services, Messages, and Transports have been accepted and published within the applicable SAE AS-4 JAUS standards, they will be removed from the *UGV IOP Custom Services, Messages, and Transports* document.

1.3.6 Latency

Latency requirements govern the overall system performance and can be defined at various levels. For example, the control of a UGV manipulator can be measured from input on the OCU to the commanded movement of the manipulator or at various points along the thread to include OCU to comms link transmission, comms link transmission to comms link reception, comms link reception to manipulator. In general latency will be a factor of the operational mission/mission parameters and will not necessarily be applicable to every UGV system in the same regard. For this reason, latency requirements will be identified within specific Program of Record (POR) acquisition documentation. The ability to test and validate latency will be shown through a set of use cases as defined in the test & validation documentation developed in support of IOP V0 but not supplied with it.

2 Source Documents

The following documents are referenced within this IOP and shall be used to implement the requirements contained within the IOP.

2.1 Government Documents

1011-I-2.0	NIST Special Publication, Autonomy Levels for Unmanned Systems (ALFUS) Framework Volume I: Terminology, Version 2.0, October 2008.

2.2 Non-Government Documents

AIR5665A	SAE Aerospace Information Report, Architecture Framework for Unmanned Systems (AFUS), April 2009.
ARP 6012	SAE Aerospace Recommended Practice, JAUS Compliance and Interoperability Policy, April 2009.
AS5669A	SAE Aerospace Standard, JAUS/SDP Transport Specification, February 2009.
AS5684	SAE Aerospace Standard, JAUS Service Interface Definition Language, December 2008.
AS5710	SAE Aerospace Standard, JAUS Core Service Set, December 2008.
AS6009	SAE Aerospace Standard, JAUS Mobility Service Set, April 2009.
AS6057	SAE Aerospace Standard (draft 0.5a), JAUS Manipulator Service Set.
AS6040	SAE Aerospace Standard (draft 0.3), JAUS HMI Service Set.
AS6060	SAE Aerospace Standard (draft 0.9), JAUS Environment Sensing Service Set.
IEEE 802.3-2008	Standards for Ethernet based LANs

3 Architecture

3.1 System Context

From a system perspective, the UGV IOP is defined to address interoperability at multiple levels within varying systems configurations. The context diagram, presented in Figure 3-1, depicts this concept by showing the UGV and a controller interfacing to external UxV and external command & control (C2)/battle command systems. This concept can be instantiated in a number of ways from a basic OCU/UGV configuration to more complex configurations (i.e., an OCU controlling multiple UGVs with UAV feeds and/or a communication relay/extension). Interoperability can be applied to various aspects of these configurations as required by the system product manager, to include:

- OCU/UxV(s) – radio/data interfaces
- Intra-OCU – between and among OCU hardware and software elements
- Intra-UGV – between and among UGV subsystems/payloads and platform
- OCU/UGV to External C2 Systems – exchange of command and control, battlespace, and audio/video information.

For the purposes of IOP V0, only the circled portion of this architecture is within scope. This includes the hardware and software interfaces to define interoperability and modularity between a platform and a single OCU, between a platform and its payloads, and between a radio and a platform or OCU, and between an OCU and its human operator.

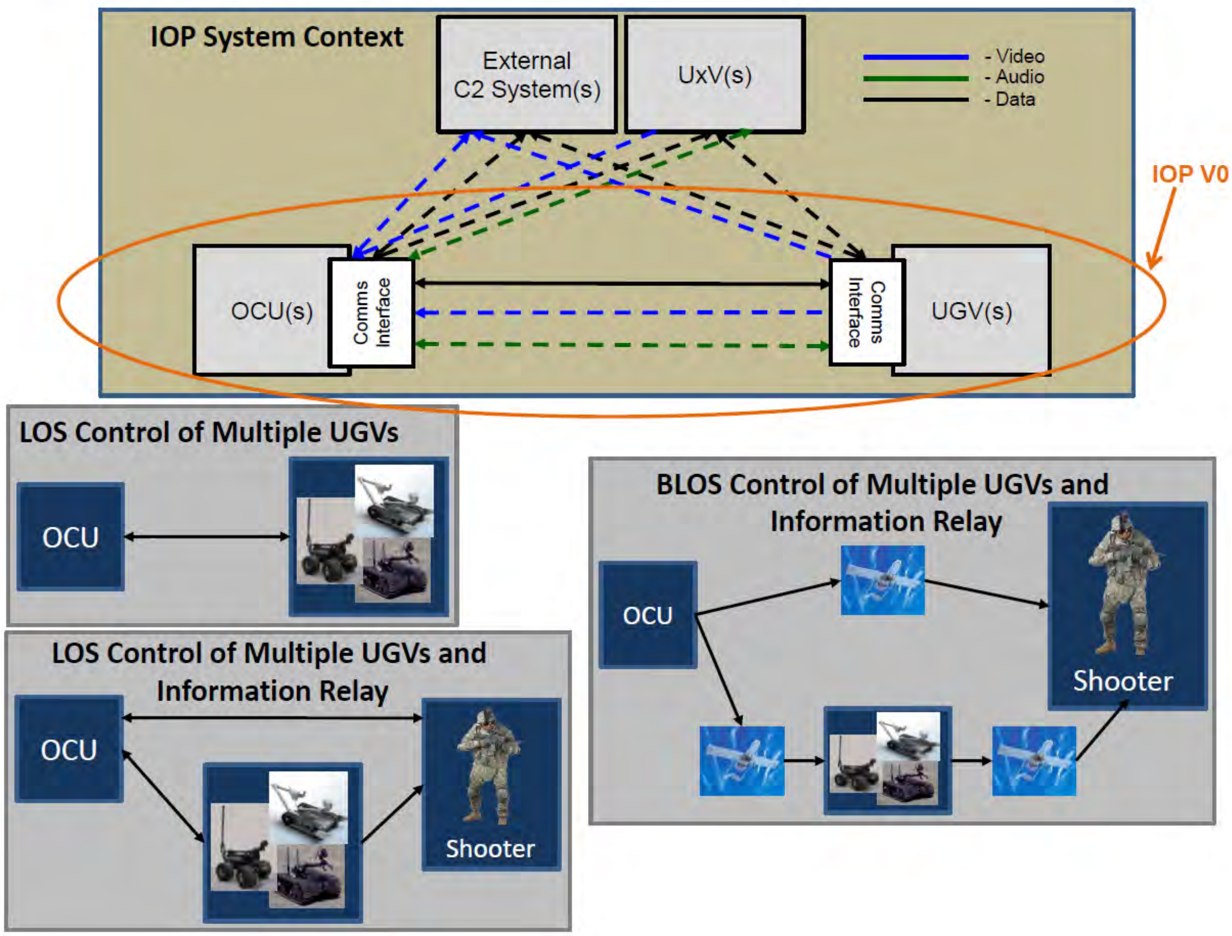


Figure 3-1 UGV IOP Context

3.2 Reference Architecture

The architecture presented in

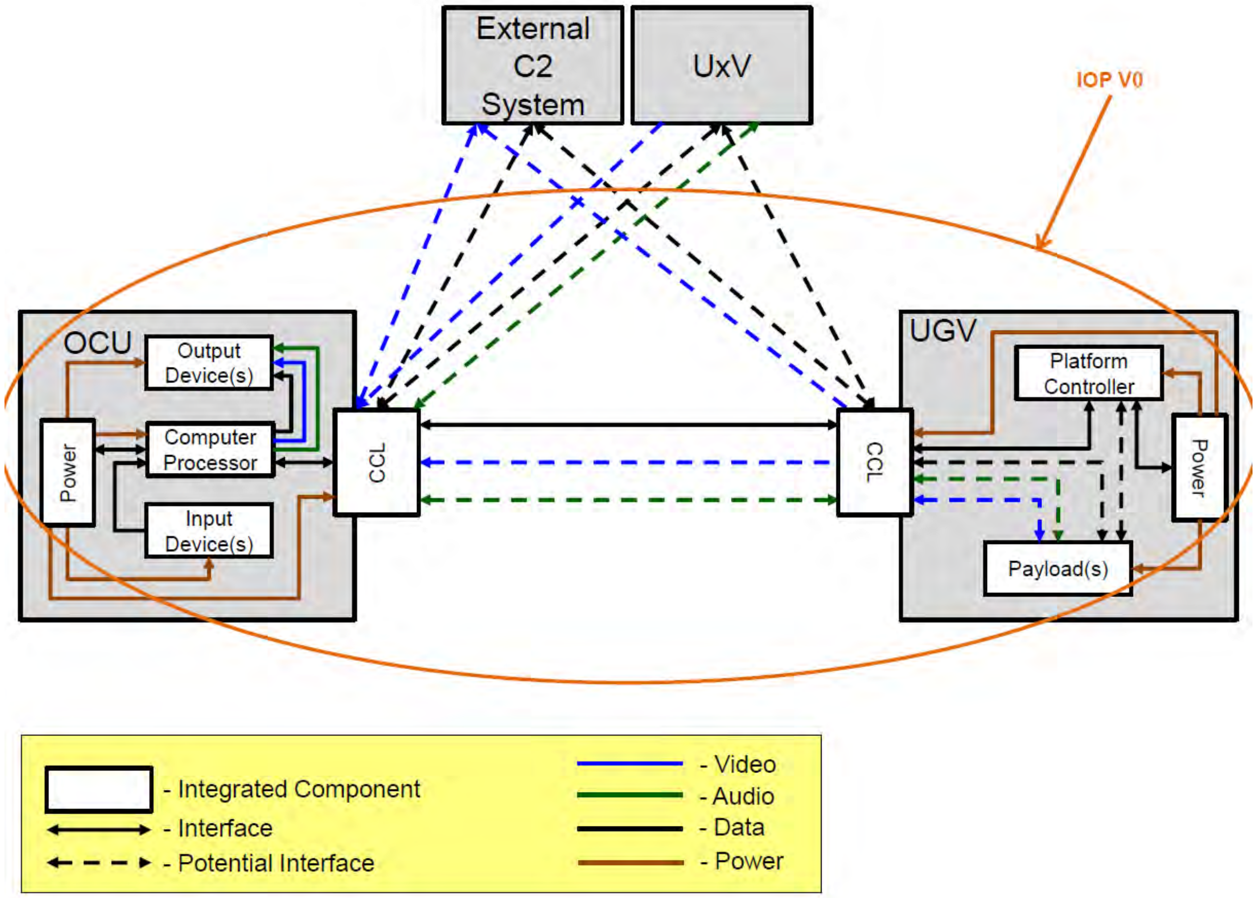


Figure 3-2 builds upon the system context and defines key integrated elements of the UGV and OCU along with internal and external interfaces. These elements are defined in this IOP in a generic (abstract) manner and may be realized within a system in a variety of ways. For example, although all UGVs will have a conceptual platform controller to provide platform and mobility processing, the platform controller may be realized as a single computer, a single line replaceable unit (LRU) with multiple computers or a set of LRUs with distributed processing and internal interfaces. The terms defined and presented in the architecture diagram are defined to provide a consistent terminology and point of reference for utilization throughout this IOP.

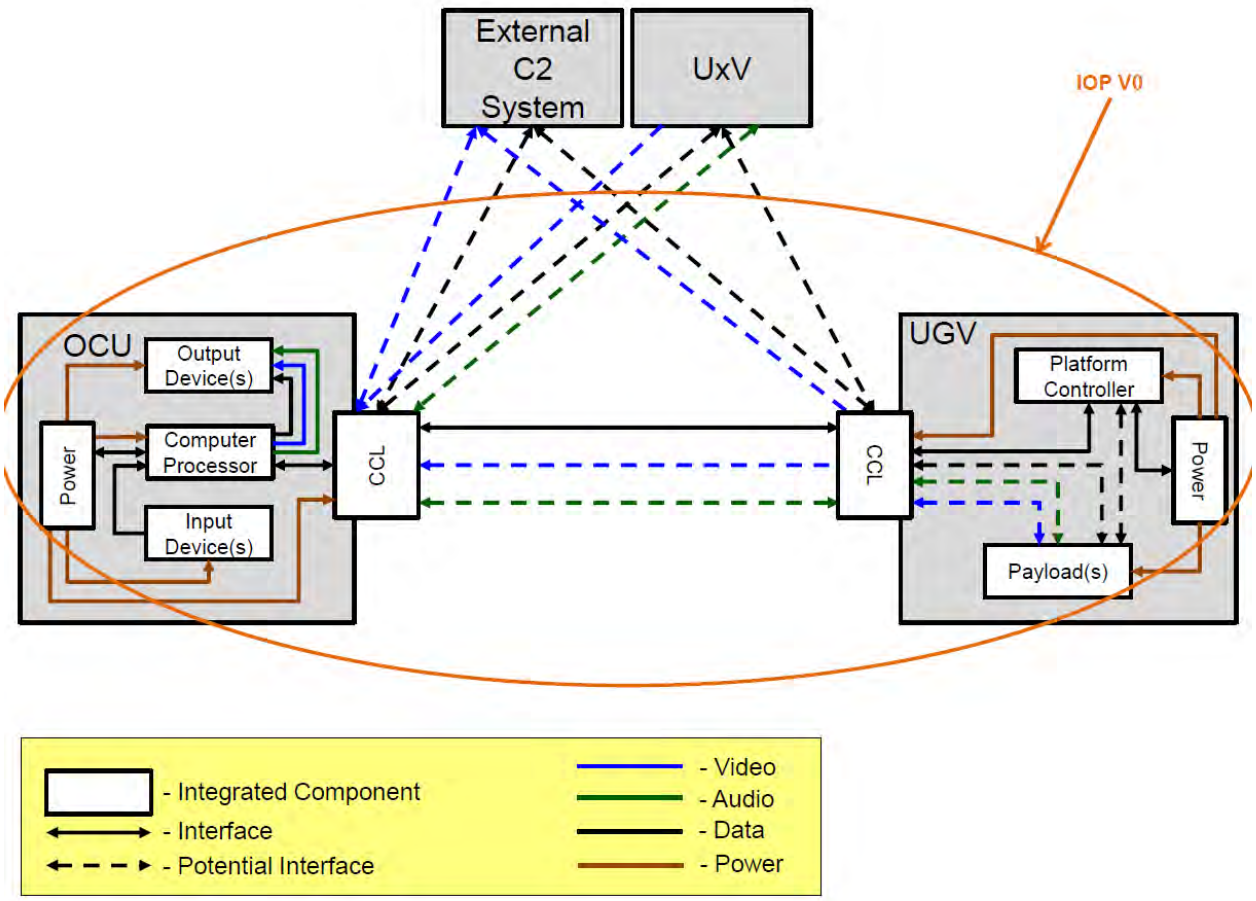


Figure 3-2 UGV IOP Reference Architecture

As depicted in the figure, systems within the reference architecture are comprised of integrated elements, interfaces, and potential interfaces. An integrated element is an element that will exist (at least conceptually) within the specified system; an interface defines an inter or intra system linkage between integrated elements; and a potential interface is an interface that may or may not exist depending upon the required functionality as specified by a system's Interoperability Attributes.

3.2.1 Operator Control Unity (OCU)

The OCU system of the reference architecture provides the human operator a capability to issue commands to and receive input back from one or more UGVs. Specific OCU-level requirements are included within the *Control IOP*.

The Input and Output Device element(s) are generic and could be adapted to describe a traditional controller implemented with joysticks, keyboard, mechanical switches, and a display, or other types of controllers such as those implemented with a glove, video game controller, monocle, voice, smart phone, or tactile belt.

3.2.2 Common Communications Link (CCL)

The Common Communications Link (CCL) element is an abstraction of the networking and/or point-to-point communications solution required for command and control of UGVs. It provides the OCU with the ability to transmit and receive data to/from a UGV, external C2 System, and/or another UxV.

While it is not within the scope of IOP V0 to define all CCL requirements, it does represent the first “core” set of requirements defining necessary interoperable behaviors for near-term UGV radios. A future Version of the IOP will include full definition of how the CCL must operate in the long term.

3.2.3 Unmanned Ground Vehicle (UGV)

The UGV system of the reference architecture consists of a Platform Controller element integrated with zero or more Payload elements, and interfaced externally to an OCU and/or UxV and External C2 Systems via a CCL element. The Platform Controller element is conceptually responsible for providing platform management (e.g., system diagnostic monitoring, system safety, BIT/FIT) and mobility. The Platform Controller element receives data and provides status through the CCL element. The Payload element(s), if present, may be communicated with external consumers via an external connection through the CCL or may be integrated directly to the Platform Controller element. An example of a Payload element with a direct connection to the CCL might be an SAE AS-4 JAUS compliant payload that can be discovered and communicated to directly by an OCU. An example of a Payload element with a connection to the Platform Controller element might be a payload with an SAE AS-4 JAUS interface resident on the Platform Controller where commands to the SAE AS-4 JAUS interface are translated to the payload in a non-SAE AS-4 JAUS format. In addition, an SAE AS-4 JAUS compliant payload capable of interfacing directly to an OCU may still have an interface to the Platform Controller in order to provide subsystem status and to register for platform data (e.g., navigation, state/mode). The Power element provides power to all UGV integrated components.

3.2.4 External Command & Control (C2)

While outside the scope of IOP V0, the External C2 system of the reference architecture provides for the interfacing of an OCU and/or UGV with an external system, such as a battle command system. Sharing of payload data into external ground or air based systems or networks will be addressed in a future version of this IOP. .

3.2.5 Other Unmanned Vehicles (UxVs)

While also outside the scope of IOP V0, the UxV system of the reference architecture provides for the coordinated interaction of a UxV system with the OCU and/or UGV. UxV in this context represents a generic unmanned system to include another UGV, a UAV, or an unattended sensor. Interface requirements for communicating with UxVs outside of the ground domain with be addressed in a future version of this IOP..

3.3 UGV Logical Architecture

In addition to the reference and system architecture, the UGV IOP applies to logical architectures for both the OCU and the UGV, specifying the general hardware and software interfaces relevant to interoperability within the OCU and UGV systems. The term logical refers to the fact that these elements may be implemented in varying physical configurations and that the physical configuration is not specifically relevant to . An

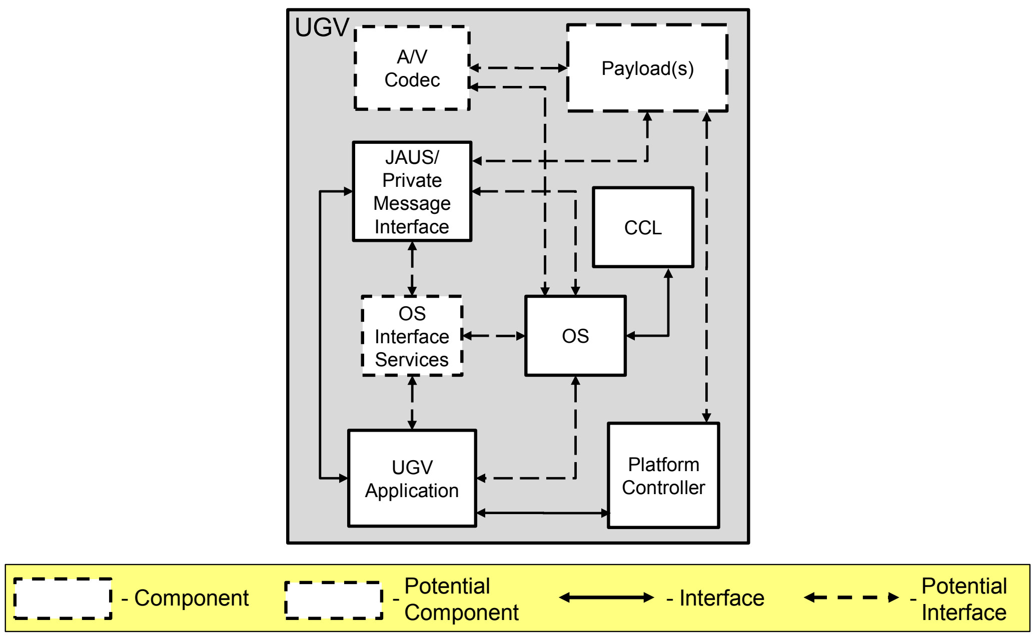


Figure 3-3 Example UGV Logical Architecture

The solid elements depicted in the figure represent elements that are always present within the UGV system. The dashed elements represent potential elements that may be present within the UGV system. Similarly the solid lines between elements represent defined element interfaces while dashed lines represent potential element interfaces. Within the UGV IOP, potential element/interface requirements are subset via Interoperability Attributes to provide for the specification of a basic UGV configuration that can be augmented to accommodate specific interoperability requirements related to the interface with external system(s). A brief description of the controller elements is presented in the following paragraphs.

OS (Element) – The OS represents the controller operating system. In general, requirements related to the operating system will not be addressed within this IOP and will instead be defined via acquisition requirements or design decisions.

OS Interface Services (Potential Element) – The OS interface services specify inter-process communication (IPC) mechanisms required to implement interoperability interfaces between software (application) elements. This could be an interface between the controller application and an external system(s), the controller application and a vendor plug-in, and/or an interface utilized by the JAUS system to provide an underlying transport.

A/V Codec (Potential Element) – The A/V Codec represents the element within the system that decodes/encodes digital audio and video data streams. The codec formats required within the system will largely be dependent upon the requirements associated with specific payloads and/or the communications data link.

JAUS/Private Message Interface (Element) – The JAUS/Private message interface represents the element responsible for interfacing with the application to encode, marshal, transmit and receive, unmarshal, and decode JAUS messages between the controller and the robotic system(s). This element may be incorporated with or separate from the application software component.

UGV Application (Element) – The UGV application specifies the element responsible for the logical execution of the UGV system. In general requirements related to the application will not be addressed within this IOP and will instead be defined via acquisition requirements or design decisions

Platform Controller (Element) – The platform controller specifies the element responsible for hosting and execution of the UGV application. This element may be realized in a variety of ways from a small micro-controller up to a multi-LRU configuration in accordance with the platform size and mission capabilities/requirement(s). In general internal requirements related to the platform controller will not be addressed within this IOP and will instead be defined via acquisition requirements or design decisions. External and interfacing requirements associated with the platform controller will be defined and presented within this IOP.

CCL (Element) – The CCL represents the communications data link between the controller and the robotic system. The requirements governing this interface are specified within the *UGV IOP Communications Profile*.

Payload(s) (Potential Element) – The Payload element specifies the element responsible for conducting mission specific functions/capabilities alone or in concert with other payloads and/or the UGV platform. This element may be realized in a variety of ways and configurations in accordance with the platform size and mission capabilities/requirement(s). Internal requirements related payloads will not be addressed within this IOP and will instead be defined via acquisition requirements or design decisions. Payload interfaces to/from the platform (e.g., electrical, mechanical), as well as interfaces between the payload and external systems (e.g., data formats, message protocols) are defined within the *UGV IOP Payload Profile*.

4 IOP Usage Guide

4.1 Overview of IOP Usage Process

This set of IOPs will be used by both the Project Manager (PM) community and the vendor community. For convenience, individuals within the Materiel Developer (the PM) will be referred to as “MATDEV”. Private industry (or academia) developers of systems, payloads, radios, technologies, or systems engineering/integration expertise will be referred to as “vendors”.

For a given UGV acquisition program, the process begins with the MATDEV reviewing the operational requirements as articulated by the User community. These will typically be articulated in the form of a Capabilities Development Document (CDD) or Capabilities Production Document (CPD), and written by a Combat Developer, such as the Army’s Training & Doctrine Command (TRADOC), or the USMC’s Marine Corps Combat Development Command (MCCDC).

The MATDEV will then use systems engineering processes to transform these operational requirements into performance requirements. During this process, the MATDEV will conduct a formal review of the IOP documentation and select Values for each of the Interoperability Attributes defined within the set of IOPs. Each Interoperability Attribute Value has an associated requirement, which will be inserted into the PM’s contractual requirements for the program’s Request for Proposal (RFP). Selection of the appropriate Value of a given Interoperability Attribute will often require the MATDEV to conduct formal trade studies to inform the decision. There are also a number of Mandatory Interoperability Attributes, who’s requirements will be imposed on all systems. These Mandatory Interoperability Attributes are described within the *JAUS Profiling Rules IOP*.

The vendors within the competition space will then implement the requirements that have been selected based on the Interoperability Attributes, in accordance with the IOPs, and particularly in accordance with the *JAUS Profiling Rules IOP* and the *Custom Services, Messages & Transports* document.

An example of this process would be that the MATDEV receives a new requirement for a system that has Leader / Follower capabilities, as well as requirements for sensing Chemical, Biological, Radiological, Nuclear (CBRN) threats. In this case, the MATDEV will know that in addition to specifying the Mandatory Mobility Interoperability Attributes of “Core Mobility”, “Drive Timeout”, and “Safety Requirements”, they will also know that they must select, at a minimum, the “Leader Follower (LF)” Value (likely in addition to most of the other selectable values). Similarly, the MATDEV will also know that in must also specify the CBRN Sensor Attribute Option, in addition to other common payload requirements. The requirements associated with each of these Values would then become requirements imposed on the vendor to be compliant with the performance and/or product specifications.

4.2 Applicability of IOP to Stakeholders

For the MATDEV, the IOPs will be used as part of the requirements decomposition & allocation process prior to release of RFPs. It should be noted that the interface requirements in the IOPs represent a “product level specification”, as opposed to the typical “performance level specification” that PMs are typically responsible for. This has been done intentionally in order to provide sustained interoperability and modularity of systems throughout their full lifecycles. MATDEVs will build program-specific interoperability requirements into their RFPs prior to being released, based on this IOP. For the MATDEV, the *Overarching IOP*, *Payloads IOP*, *Communications IOP*, and *Control IOP* are of primary interest, since those contain definitions of the Interoperability Attributes, and the applicable requirements for each of the selected Values.

For vendors who are marketing products, this IOP should be used as a guide for what to expect in future RFPs. This package of documents describes the hardware and software interfaces that the RS JPO would like to see in products that vendors may be developing. For vendors who are awarded RFPs in future programs, these documents represent the technical requirements that will be imposed to promote interoperability. For industry, the *JAUS Profiling Rules* document is of primary interest, as it contains the product level specifications that can be implemented to build interoperable systems.

4.3 Usage of Overarching IOP

The Overarching IOP will be used by the MATDEV and industry to serve as a description of the intent of the full IOP package, to describe its usage, to define overarching requirements for all systems, to point to applicable sections in the other IOPs, and to define Interoperability Attributes that may be selected by the MATDEV to impose interoperability requirements into acquisition contracts.

4.4 Usage of Communications IOP

The Communications IOP will be used by the MATDEV and industry to define communications and radio related requirements for a CCL, to point to applicable sections in the other IOPs, and to define communications related Interoperability Attributes that may be selected by the MATDEV to impose interoperability requirements into acquisition contracts.

4.5 Usage of Payloads IOP

The *Payloads IOP* will be used by the MATDEV and industry to define payload related requirements for both payloads themselves and UGV platforms, to point to applicable sections in the other IOPs, and to define payload related Interoperability Attributes that may be selected by the MATDEV to impose interoperability requirements into acquisition contracts.

4.6 Usage of Control IOP

The Control IOP will be used by the MATDEV and industry to define desired common qualities of controllers. It is acknowledged that there are a variety of types of controllers that make sense for different missions, and the technology related to controllers is evolving rapidly, particularly based on advancements being made in the mobile/smart-phone and gaming markets. The current Control IOP V0 contains desired guidelines for user interfaces for conventional controllers, but does not mandate explicit requirements. Controllers must be capable of communicating JAUS-based messages as defined in this IOP package, and must interface with the CCL as defined in the *Communications IOP*. The primary intent of the Control IOP is to promote an interoperable Human Machine Interface (HMI), which means that the relationship between the controller and the human operator must be modular based on minimized training for operation among different systems. If controllers can support the JAUS-based messages described in this IOP package, then interoperable messages will become the interface between the controller and the UGV platform.

For example, if a controller operator presses a keypad arrow to turn right, then an interpretable message command will be received and understood by the UGV platform. If another controller utilizes a joystick to turn right, then the UGV platform should receive an identical message as that sent from the first controller. Similarly, user input to turn right on a smartphone type accelerometer device, a speech-based device, a motion-recognition device, or other innovative controller technology should all result in an identical, interpretable JAUS-based message being received by the UGV platform.

4.7 Usage of JAUS Profiling Rules IOP

The *JAUS Profiling Rules IOP* will be used primarily by industry as implementation guidance for complying with the requirements defined within all of the other IOPs. It provides the product-level JAUS-based message implementation guidance, and reference to the appropriate SAE AS-4 JAUS documents. Additionally, the JAUS *Profiling Rules IOP* will be used by the MATDEV in developing System Integration Labs (SILs) for verifying that the IOPs achieve the desired outcomes, as well as assessing the compliance of vendor products to the IOPs.

4.8 Usage of Custom Services, Messages & Transports

The *Custom Services, Messages & Transports* document will be used to define JAUS-based services that are not currently defined in any existing SAE AS-4 JAUS approved document. Currently in V0 the *Custom Services, Messages & Transports* document contains JAUS-based guidance for the following Custom Services: Leader Management, Leader Follower Driver, Communicator, Platform Mode, Health Monitor, Health Reporter, Digital Stream Discovery, and Preset Pose. Currently there are no defined custom messages or custom transports in this document.

It is the intent of the RS JPO for each of the custom services, messages, and transports defined in this package to be recommended for adoption by the SAE AS-4 JAUS Committee, and published in an approved SAE document. Once the services, messages, or transports are approved in a published SAE document, this IOP package will be modified to reference the new published document instead of the *Custom Services, Messages & Transports* document (and they will be removed from the subject document as well).

Additionally, proprietary services, messages, or transport protocols will not be accepted into this document.

5 UGV System Requirements

This section specifies interoperability requirements for the UGV to include the robotic platform and payload interface. These requirements are organized in accordance with the reference architecture specified in Section 3 and are further derived in accordance with a taxonomy based upon the Architecture Framework for Unmanned Systems (AFUS), defined in *SAE AIR5665A*. The taxonomy has been employed to identify composable capabilities, such that they can be specified via Interoperability Attributes to define robotic system/controller interoperability performance specifications, to be used in acquisition contracts.

The UGV IOP Taxonomy shown in Figure 5-1 depicts the AFUS branches and highlights sections of the AFUS that have been extended or are currently not in use. In addition, the figure depicts the section of the UGV IOP that addresses the requirements relevant to each branch/capability.

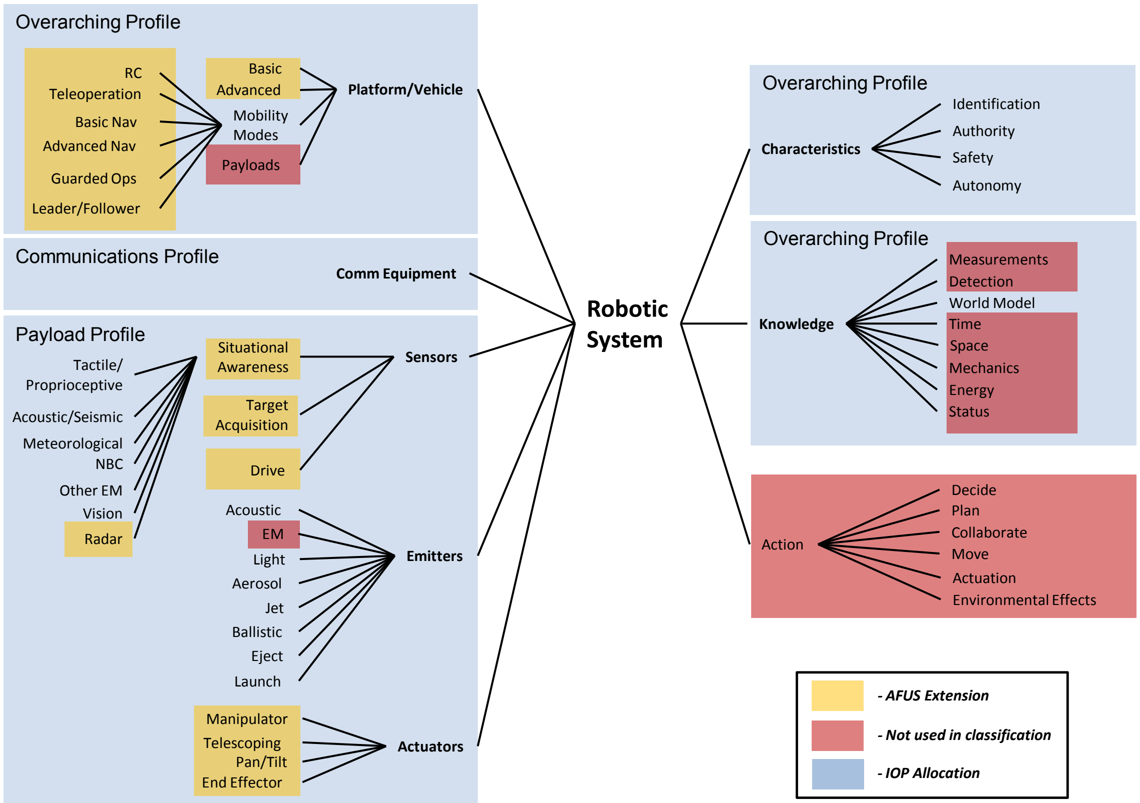


Figure 5-1 IOP Composability Taxonomy

The Requirements enumerated below specify both hardware and software requirements

ical
ctor
-2.

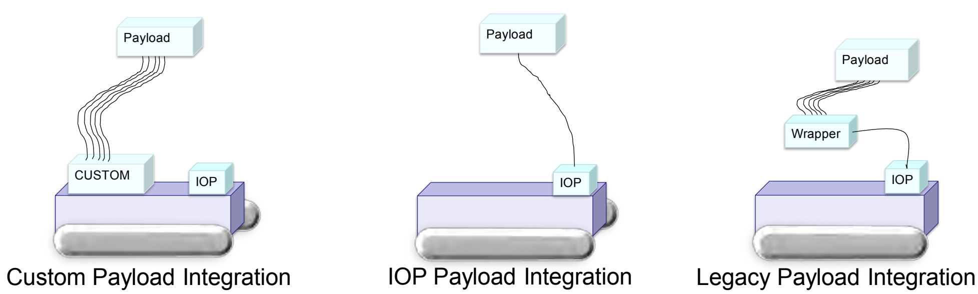


Figure 5-2 Payload Integration Techniques

The Custom Payload Integration technique presented in the figure depicts the employment of custom interfaces to access and interface to the payload subsystem.

This technique would be achieved by not mandating the capabilities/requirements documented within this section. This method would be considered non-compliant with the IOP. The IOP Payload Integration technique utilizes the mechanical and connector interfaces defined within this section to specify the manner in which payload(s) are integrated to the UGV platform. The Legacy Payload Integration technique is a hybrid of the previous two, providing the use of defined IOP interfaces to integrate the payload to the platform via a wrapper (translation subsystem) that communicates to the payload via a custom or legacy interface.

5.1.1 Platform Mounting

This section defines requirements associated with the physical mounting of payload(s) to the UGV platform. This is defined in the *UGV IOP Payloads Profile*.

5.1.2 Connectors

This section defines requirements associated with the physical/electrical connectors employed to integrate subsystems and payload(s) to the UGV platform. This is defined in the *UGV IOP Payloads Profile*.

5.2 Network Implementation Requirements

This section specifies requirements associated with the robotic system network as it pertains to both on-board and external networks. Some requirements defined within this section may have a direct mapping to capabilities defined within the *UGV IOP Communications Profile*, but be described at a higher level. For example, quality of service (QoS)/prioritization standards would be provided within this section of the IOP but standards that provide for the physical realization to perform QoS would be defined within the communications profile.

5.2.1 On-Platform Routing

This section defines requirements associated with the routing of data on-board the UGV platform. This is defined in the *UGV IOP Communications Profile*.

5.2.2 Platform Databus

This section defines the databus requirements associated with the interchange of data among defined IOP elements and subsystems integrated on the UGV platform. Due to the fact that not all robotic platforms require a databus, requirements within this section of the IOP are subset via a Platform Databus Interoperability Attribute. This Interoperability Attribute currently has the values of Ethernet and None, where the value “None” is used to indicate that a platform databus is not required.

[OVA 001] Robotic systems (vehicles) with a designated “Ethernet” Platform Databus Interoperability Attribute shall provide an on-board Gigabit Ethernet databus IAW IEEE 802.3-2008 for the integration of components and payload subsystems.

5.2.3 Internet Protocol

This section defines the internet protocol (IP) requirements associated with the interchange of data among defined IOP elements and subsystems integrated on the UGV platform. These requirements are defined in the *UGV IOP Communications Profile and the JAUS Profiling Rules IOP*.

5.2.4 Quality of Service

Quality of Service (QOS) requirements are not within the scope of IOP V0. These will be handled uniquely by each individual Acquisition Program.

5.2.5 Information Assurance

Information assurance requirements are defined with the *Communications IOP*.

5.3 Power Requirements

This section specifies requirements associated with the power generation and management subsystems provided on the UGV platform and is targeted, primarily, towards the integration of interoperable subsystems and payload devices.

[OVA 002] The UGV platform shall supply power to all base configuration payloads.

This is defined in further detail in the *UGV IOP Payloads Profile.* Additionally, each individual Acquisition Program will need to perform an analysis to determine what the base configuration is, as well as power management techniques to support a dynamic payload configuration.

5.4 Payload(s) Requirements

Requirements governing the interfacing with mission equipment payloads are defined within the *Payloads Profile* portion of the UGV IOP.

[OVA 003] Payloads shall be implemented in accordance with the *UGV IOP Payloads Profile* and any required (specified) Interoperability Attributes.

5.5 Communications Requirements

The communications interface is the interface between the robotic platform and a controller. The communications interface is realized via the CCL Communications Profile and is responsible for the transmission and receipt of digital data (to include video and audio).

[OVA 004] UGV platforms shall implement the communications data link interface in accordance with the *UGV IOP Communications Profile* and any required (specified) Interoperability Attributes.

5.6 Platform Controller Requirements

5.6.1 Implementation of SAE JAUS Message Set

SAE AS-4 JAUS messages provide the means for robotic controllers to connect to and control robotic systems to include robotic systems payloads. Conformant implementations of this IOP shall utilize the SAE AS-4 JAUS message set as specified within these IOP documents and in accordance with the specified profiling rules.

5.6.1.1 Command, Control, and Status Messages

Command, control, and status messages specify the set of messages used to control a robotic system to perform a mission function. These messages support control of a single robotic system from one controller as well as control of multiple robotic systems by a single controller, or shared control of a single robotic system by multiple controllers. This section provides the interoperability messaging requirements relevant to controllers, robotic systems, and robotic system payloads.

[OVA 005] Command, control and status messages shall be implemented using the SAE AS-4 JAUS standards as profiled by the *UGV IOP SAE JAUS Profiling Rules* and any required (specified) Interoperability Attributes.

5.6.1.2 Custom Messages

Custom (or “private) messages provide a mechanism to specify necessary command, control, and status messages that have not been defined within the specified SAE AS-4 JAUS standards. For the UGV IOP, all private messages approved for use are defined within the *UGV IOP Custom Services, Messages and Transports*. Custom messages are controlled within the UGV IOP activity and it is the intent of the RS JPO to seek standardization of these private messages within the applicable SAE AS-4 JAUS committees and seek wide adoption within the Army robotic ground vehicle community.

The UGV IOP will specify the use of SAE AS-4 JAUS messages to achieve interoperability and only employ private messages when no JAUS message will suffice.

Custom messages will be published and distributed to the stakeholder community without proprietary markings.

[OVA 006] Custom command, control and status messages shall be implemented in accordance with the *RS JPO, UGV IOP Custom Services, Messages and Transports*.

5.6.1.3 Transport

SAE JAUS AS5669A specifies software defined protocols to be employed in the dissemination of JAUS messages between robotic systems and robotic controllers. The transport protocol delineates the formats and protocols employed for the transport of messages between compliant entities for all supported link-layer protocols and media. There are currently three transports specified in AS5669A: JUDP (JAUS over UDP), JTCP (JAUS over TCP), and JSerial (JAUS over Serial).

The Transport Interoperability Attribute provides for the specification of a transport and includes the following as defined below (JUDP, JTCP, Custom). This attribute may be designated as a set of values, as applicable (e.g., a controller that controls multiple robotic systems utilizing different transports).

Transport control and status messages shall be implemented in accordance with the *RS JPO, UGV IOP JAUS Profiling Rules*.

5.6.1.3.1 JUDP

[OVA 007] Robotic systems (controllers and/or vehicles) with a designated "JUDP" Transport Interoperability Attribute Value shall implement the transport in compliance with the JUDP transport specified in SAE JAUS AS5669A.

5.6.1.3.2 JTCP

[OVA 008] Robotic systems (controllers and/or vehicles) with a designated "JTCP" Transport Interoperability Attribute Value shall implement the transport in compliance with the JTCP transport specified in SAE JAUS AS5669A.

5.6.1.3.3 Custom Transports

It is acknowledged that over time, custom transports may be developed that employ paradigms/technologies suitable for specific robotic command and control environments (e.g., Service Oriented Architecture and Deterministic Real Time). The custom transport specification is similar in concept to custom messages, in that it is an agreed upon, defined transport that is intended to fill a gap while undergoing standardization within the SAE AS-4 JAUS community.

Private transports will be pluggable with *SAE JAUS AS5669A* transports to the degree possible.

[OVA 009] Robotic systems (controllers and/or vehicles) with a designated "Custom" Transport Interoperability Attribute Value shall implement the transport in compliance with the designated Custom transport specified in *UGV IOP Custom Services, Messages and Transports*.

5.6.2 Platform Management

Capabilities defined within this section map to the platform/vehicle capabilities defined within the IOP composability taxonomy (Figure 5-1). For Version 0 of the IOP, the platform/vehicle branch has been subdivided into Basic and Advanced platform management capabilities. Basic platform management capabilities encompass the set of capabilities that are generally common to all robotic platforms, while advanced platform management capabilities typically relate to those capabilities that are found in advanced or larger UGV platforms (e.g., power management, fault isolation, autonomy). This section has been defined and subdivided in this manner to demonstrate the concept of defining capabilities, such that they can be specified for incorporation into a robotic system end item. It is envisioned that in future revisions of this IOP, these platform management capabilities will be expanded and further subdivided to provide necessary levels of granularity to support the set of systems within the UGV IOP domain.

This IOP defines a set of platform management modes for the purposes of providing a shared context among controllers and robotic systems and among robotic systems and integrated payloads that require a platform state/mode awareness for synchronization and use. Platform modes are defined to be extensible in order that they can amended/extended in future revisions of this IOP. The platform mode state diagram is illustrated below in Figure 5-3.

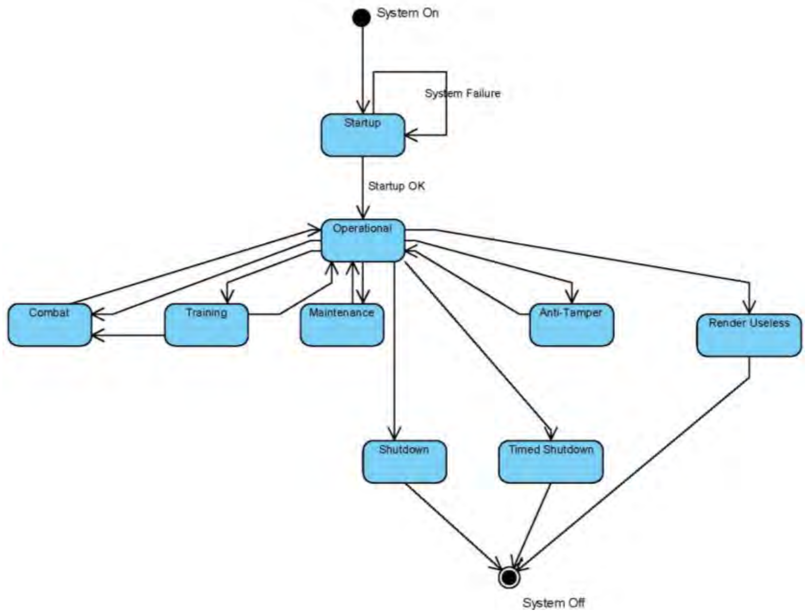


Figure 5-3 Platform Mode

The following paragraphs provide a brief description of the platform modes along with an indication as to whether or not the mode is defined within the basic or advanced platform/vehicle capability. Platform modes are incorporated into the platform management capability in accordance with the Platform Management Interoperability Attribute (defined below).

Startup (Basic Mode) – the startup platform mode is entered upon vehicle power on. The platform will transition from startup to operational mode when it has been determined that the system startup is ok and the system is operational. The specific meaning of “startup ok” is left to the implementer or further definition of acquisition requirements, but the general intent is that the system and its on-board subsystems are available for use.

Operational (Basic Mode) – the operational platform mode is entered upon successful startup. Once the system has achieved the operational mode, it will be available for use by a controller.

Shutdown (Basic Mode) – the shutdown mode is entered upon operator selection from the operational mode. Once the system has successfully transitioned into shutdown mode, it will gracefully shutdown on-board subsystems and transition to a power off state.

Combat (Advanced Mode) – While not within scope of IOP V0, the combat platform mode is entered upon operator selection from the operational or training mode. The specific requirements associated with combat mode are left to the implementer or further definition of acquisition requirements, but the general intent is that combat systems integrated onto the platform will be available for operator selection, arming, and use from within this mode.

Training (Advanced Mode) – While not within scope of IOP V0, the training platform mode is entered upon operator selection from the operational mode. The specific requirements associated with training mode are left to the implementer or further definition of acquisition requirements, but the general intent is that the platform will be placed into a mode to support instructional training of operators (e.g., inhibit of platform/payload response to commanded action and potential emulation or simulation of platform/payload output/status).

Maintenance (Advanced Mode) – While not within scope of IOP V0, the maintenance platform mode is entered upon operator selection from the operational mode. The specific requirements associated with maintenance mode are left to the implementer or further definition of acquisition requirements, but the general intent is that the platform will be placed into a mode to support the analysis or update of the system (e.g., reprogramming, detailed fault analysis, boresight). As with training mode, it is anticipated that certain operational aspects of the system would be inhibited while in maintenance mode.

Anti-Tamper (Advanced Mode) – While not within scope of IOP V0, the anti-tamper platform mode is entered upon operator selection from the operational mode. The specific requirements associated with anti-tamper mode are left to the implementer or further definition of acquisition requirements, but the general intent is that the platform will be placed into a mode where it initiates a self awareness of threats entering defined zone(s) and initiates defined (potentially progressive) action(s) against detected threats which may include operator authorization.

Render Useless (Advanced Mode) – While not within scope of IOP V0, the render useless platform mode is entered upon operator selection from the operational mode. The specific requirements associated with render useless mode are left to the implementer or further definition of acquisition requirements, but the general intent is that the platform will be placed into a state where it can no longer be operated and all on-board data will be destroyed.

Timed Shutdown (Advanced Mode) – While not within scope of IOP V0, the timed shutdown mode is entered upon operator selection from the operational mode. This mode is identical to the shutdown mode with the additional requirement to wait a specified amount of time for on-board subsystems and processes to perform a graceful shutdown. Specifying a timed shutdown with a time of zero would indicate an immediate shutdown of the platform.

The Platform Management Interoperability Attribute provides for the specification of a defined set of components/services that can be used as the basis of a contract between a controller and a vehicle; i.e., a controller that supports these option(s), will know what to expect and how to control a vehicle that implements the same option(s). The Platform Management Interoperability Attribute Values that can be selected are None, Basic, or Advanced; where the specified value relates to the capability to be implemented. These capabilities are further described in the following subsections.

5.6.2.1 None

A Platform Management Interoperability Attribute Value of "None" indicates that platform/vehicle capability is provided in a user defined manner in accordance with the services defined in the JAUS specifications and that the platform/vehicle capabilities defined herein do not apply.

[OVA 010] Robotic systems (controllers and/or vehicles) with a Platform Management Interoperability Attribute Value of "None" shall do so in accordance with the requirements specified in the *UGV IOP SAE JAUS Profiling Rules*.

5.6.2.2 Basic

A Platform Management Interoperability Attribute Value of "Basic" provides general platform control/status information to/from the robotic system to include battery status, platform gauges, position/attitude, preset pose, subsystem configuration, subsystem enable/disable, usage, and vehicle/subsystem health. In addition, the basic capability provides for the definition of a platform mode with a limited set of mode options (startup, shutdown, timed, shutdown, and operational).

[OVA 011] Robotic systems (controllers and/or vehicles) implementing the "Basic" Platform Management Interoperability Attribute shall do so by implementing the Platform Manager JAUS Node in accordance with the Basic Platform Management requirements specified in Section 4.2.1.1 of the *UGV IOP SAE JAUS Profiling Rules*.

5.6.2.3 Advanced

A Platform Management Interoperability Attribute Value of "Advanced" includes all of the basic platform capabilities and adds additional platform modes of operation (maintenance, render useless, anti-tamper, combat, and training), built in test (BIT), fault isolation and test (FIT), platform articulation (poses), calibration, and software update.

[OVA 012] Robotic systems (controllers and/or vehicles) implementing "Advanced" Platform Management Interoperability Attribute shall do so by implementing the Platform

Manager JAUS Node in accordance with the Advanced Platform Management requirements specified in the *UGV IOP SAE JAUS Profiling Rules*.

5.6.3 Mobility

Mobility capabilities provide for the mobilization of the platform in support of mission objectives (the manner in which a robotic system moves from place to place, under its own power and under any mode or method of control [ALFUS]). The mobility capability is subdivided into composable sets of capabilities commensurate with typical modes of operation found in robotic systems across the UGV IOP domain. These capabilities are organized in a simple level of autonomy hierarchy and are not necessarily mutually exclusive (i.e., some may be prerequisites to others). For example, Advanced Navigation presumes Basic Navigation and Teleoperation presumes Remote Control. Mobility has been subdivided in this manner to support increasing levels of complexity from UGVs controlled in view of the operator to UGVs capable of processing and executing complex mission plans supporting reconnaissance, patrol, security, and other operations. Mobility JAUS services will be made available from within the platform operational, combat, and training modes; where required, and are implemented via JAUS services specified within the *SAE JAUS Profiling Rules*.

The Mobility Interoperability Attribute provides for the specification of a defined set of elements/services that can be used as the basis of a contract between a controller and a vehicle with respect to mobility modes of operation (a controller that supports these options will know what to expect and how to control a vehicle that implements the same options). For IOP V0, the Mobility Interoperability Attribute can be selected as Values of Remote Control, Teleoperation, or Basic Navigation. Advanced Navigation will be added to the scope in future versions of the IOP. It is envisioned that these mobility capabilities will be further subset in future revisions to support requirements in relation to specific mission objectives.

5.6.3.1 Remote Control

The Value “Remote Control” of the Mobility Interoperability Attribute denotes a mobility capability (mode of operation) wherein the human operator controls the robotic system on a continuous basis, from a location off the robotic system via only her/his direct observation. In this mode, the robotic system takes no initiative and relies on continuous or nearly continuous input from the human operator [ALFUS].

[OVA 013] Robotic systems (controllers and/or vehicles) implementing the “Remote Control” Value of the Mobility Interoperability Attribute shall do so by implementing the appropriate JAUS services in accordance with the definition and rules specified in Section 4.3.4 of the *UGV IOP SAE JAUS Profiling Rules*.

5.6.3.2 Teleoperation

The Value “Teleoperation” of the Mobility Interoperability Attribute denotes a mobility capability (mode of operation) wherein the human operator, using sensory feedback, either directly controls the actuators or assigns incremental goals on a continuous basis, from a location off the robotic system [ALFUS].

[OVA 014] Robotic systems (controllers and/or vehicles) implementing the "Teleoperation" Value of the Mobility Interoperability Attribute shall do so by implementing the appropriate JAUS services in accordance with the definition and rules specified in Section 4.3.5 of the *UGV IOP SAE JAUS Profiling Rules*.

5.6.3.3 Basic Navigation

The Value "Basic Navigation" of the Mobility Interoperability Attribute defines a capability commensurate with robotic systems that provide simple autonomy via the definition of simple waypoint following or leader following plans. The manner in which the navigation is accomplished is not configurable (is not typically affected) by the operator/controller system. The Basic Navigation capabilities that are within the scope of IOP V0 are waypoint following and leader/follower. While waypoint following interoperability is achieved through the existing AS6009 JAUS Mobility Service Set, a new service for leader/follower has been defined in the *Custom Services, Messages & Transports* document.

[OVA 015] Robotic systems (controllers and/or vehicles) implementing the "Basic Navigation" Value of the Mobility Interoperability Attribute shall do in accordance with Section 4.3.6 of the *UGV IOP SAE JAUS Profiling Rules*.

5.6.3.4 Advanced Navigation

While not within the scope of IOP V0, the future Mobility Interoperability Attribute of "Advanced Navigation" will define a capability commensurate with robotic systems that provide advanced autonomous navigation above and beyond basic navigation. Additional capabilities include the ability to specify planner(s), contingencies, coordination data in support of robot teaming, detection and reporting of obstacle data, and the ability to load/query/report geospatial data in a variety of formats.

5.6.4 Identification

Identification provides for the discovery and comprehension in relation to one or more robotic systems, to include subsystems, and their associated capabilities. Capabilities pertaining to identification are provided in accordance with SAE AS-4 JAUS core services, primarily discovery. Requirements related to the implementation of the JAUS core service set are defined within the *UGV IOP SAE JAUS Profiling Rules*.

5.6.5 Authority

Authority provides for the access and access control associated with a robotic system, to include its integrated subsystems. Capabilities pertaining to authority are provided in accordance with SAE AS-4 JAUS core services, primarily access control.

Requirements related to the implementation of the JAUS core service set are defined within the *UGV IOP SAE JAUS Profiling Rules*.

5.7 Safety, Environmental, and Other Requirements

While safety, environmental, and other requirements are important to any system, requirements for those areas will not be defined by this IOP. However, consideration of the impact on these areas was taken into account in the selection of the appropriate IOP requirements contained through the set of IOP documents.

6 Controller Requirements

Controller or Operator Control Unit (OCU) requirements define the set of capabilities necessary to interface to, control, and maintain the status of an unmanned system(s). This includes not only the functional capabilities to be effected by the controller but also the message protocol and transport requirements. Within the UGV IOP, controller capabilities are specifically addressed and defined within the *UGV IOP Control Profile*.

[OVA 016] Controller requirements shall be implemented in accordance with the *UGV IOP Control Profile*.

7 Interoperability Attributes

The following table specifies the set of Interoperability Attributes defined within this IOP. These attributes are used to specify required interoperable capabilities to be implemented within a robotic system controller. The specification of an Interoperability Attribute may imply additional requirements defined in other portions of the IOP.

Attribute	Paragraph	Title	Values
UGV Class	1.3.2	UGV Classes	Soldier Transportable, Vehicle Transportable, Self Transportable, Appliqué Package
Platform Databus	5.2.2	Databus	None, Ethernet
Transport	5.6.1.3	Transport	UDP, TCP, Custom
Platform Management	5.6.2	Platform Management & Platform Modes	None, Basic, Advanced
Mobility	5.6.3	Mobility	Remote Control, Teleoperation, Basic Navigation

8 Conformance and Validation Requirements

The table below specifies the conformance requirements associated with this IOP. This matrix maps product unique identifiers (PUIs) to applicable IOP requirements, paragraph numbers, titles/subtitles, and planned verification methods. System Developers, Conformance and Verification Testers, and Acquisition Managers can use this matrix to help validate conformant implementations to this IOP. The following verification methods are defined:

Analysis – Analysis is an element of verification that uses established technical or mathematical models or simulations, algorithms, charts, graphs, circuit diagrams, or other scientific principles and procedures to provide evidence that stated requirements were met.

Examination – Examination is an element of verification that is generally nondestructive and typically includes the use of sight, hearing, smell, touch, and taste; simple physical manipulation; and mechanical and electrical gauging and measurement.

Demonstration – Demonstration is an element of verification that involves the actual operation of an item to provide evidence that the required functions were accomplished under specific scenarios. The items may be instrumented and performance monitored.

Test – Test is an element of verification in which scientific principles and procedures are applied to determine the properties or functional capabilities of items.

PUI	Paragraph	(U)	Title	Verification Method				
				A	E	D	T	N/A
001	5.2.2	U	Platform Databus		E			
002	5.3	U	Power Requirements			D		
003	5.4	U	Payloads Requirements			D		
004	5.5	U	Communications Requirements			D		
005	5.6.1.1	U	Command, Control and Status Messages			D		
006	5.6.1.2	U	Custom Messages			D		
007	5.6.1.3.1	U	JUDP			D		
008	5.6.1.3.2	U	JTCP			D		
009	5.6.1.3.3	U	Custom Transports			D		
010	5.6.2.1	U	Platform Management (None)			D		
011	5.6.2.2	U	Platform Management (Basic)			D		
012	5.6.2.3	U	Platform Management (Advanced)			D		
013	5.6.3.1	U	Mobility - Remote Control			D		
014	5.6.3.2	U	Mobility - Teleoperation			D		
015	5.6.3.3	U	Mobility – Basic Navigation			D		
016	6.0	U	Controller Requirements			D		

9 Appendix A – Acronyms and Abbreviations

AEODRS	Advanced Explosive Ordnance Disposal Robotic System
AFUS	Architecture for Unmanned Systems
ALFUS	Architecture Levels for Unmanned Systems
BIT	Built in Test
CCL	Common Communications Link
DISR	DoD Information Technology Standards Registry
DoD	Department of Defense
FIT	Fault Isolation and Test
IA	Information Assurance
IP	Internet Protocol
JAUS	Joint Architecture for Unmanned Systems
JGRIT	Joint Ground Robotics Integration Team
LRU	Line Replaceable Unit
OCU	Operator Control Unit
QoS	Quality of Service
SA	Situational Awareness
SAE	Society of Automotive Engineers
SWB	Software Blocking
TCP	Transmission Control Protocol
UAS	Army Unmanned Aircraft Systems
UDP	User Datagram Protocol
UGV	Unmanned Ground Vehicle
UxV	Unmanned Vehicle

10 Appendix B – Definitions

Actuator: An actuator is a mechanical device that can change shape in response to a signal. An actuator can be a simple device that has linear movement (prismatic) or rotational movement (revolute), or it can be an articulated manipulator arm with many joints and links. The classic manipulator is an "arm" of a robotic system used to position an end-effector. Another common manipulator is a pan-tilt unit often used to position a directional sensor or emitter. At this time, all unpowered devices attached to a robot will also be classified as an actuator. (Examples include rakes, extensions, and bumpers.)

Analysis: Analysis is an element of verification that uses established technical or mathematical models or simulations, algorithms, charts, graphs, circuit diagrams, or other scientific principles and procedures to provide evidence that stated requirements were met.

Capability: A capability is a single operationally relevant function - for example, teleoperation would be a capability that provides the function of allowing a user to drive a vehicle non-line of sight using a camera.

Complex Payload: A complex payload is a payload that aggregates multiple capabilities either logically or physically. A complex payload shall always be represented by a JAUS node.

Demonstration: Demonstration is an element of verification that involves the actual operation of an item to provide evidence that the required functions were accomplished under specific scenarios. The items may be instrumented and performance monitored.

Emitter: An emitter is a device that can discharge a substance or energy into the environment. Examples include radio, RADAR, LASER, loudspeaker, liquid jet or disruptor or sprayer, ballistic weapons, and launchers for various self-propelled devices. An emitter can be a hardware device that generates some form of oscillating electromagnetic fields, which is intended to convey information (via modulation) to a receiver (i.e. radios). An emitter can be a device that creates acoustic pressure waves to convey audible information, or to incapacitate those in hearing range with very high energy acoustic waves. An emitter can also be a device that discharges a solid object on a ballistic trajectory; drops objects by way of gravity (special case of ballistics); shoots a jet or water or other liquid, a disruptor; etc. Most weapons fall into the class of emitters.

Examination: Examination is an element of verification that is generally nondestructive and typically includes the use of sight, hearing, smell, touch, and taste; simple physical manipulation; and mechanical and electrical gauging and measurement.

Interoperability Attribute: This concept is defined in Section 1.3.1.

JAUS Component: A JAUS component is a logical grouping of services. Each JAUS component aggregates services to provide a single operationally relevant capability. The JAUS component offers a service interface to other consuming components to use. For example, teleoperation could be a JAUS component that aggregates a primitive driver service and some sensor services to provide teleoperation capabilities to a robotic controller.

JAUS Node: JAUS nodes are a logical grouping of JAUS components within a JAUS subsystem. Within this IOP, JAUS nodes are specified to aggregate related capabilities. This aggregation may be either logical (i.e. any capability that affects platform motion is aggregated under the Mobility JAUS node) or physical (i.e. a manipulator payload with two cameras and a sensor on it are considered a JAUS node).

JAUS Service: JAUS services represent the lowest level of the JAUS topology. For the purposes of this IOP, JAUS services provide an abstraction to hardware or software algorithms that reside on the platform. JAUS services may by internalized within a JAUS component or may be provided via an interface that is consumed by other JAUS components.

JAUS Subsystem : A JAUS subsystem is an independent and distinct unit within a JAUS system. JAUS subsystems include robotic controllers, robotic platforms, and video terminals connected and communicating via a specified set of Interoperability Attributes. A JAUS subsystem contains one or more JAUS nodes.

JAUS System: The top level element within the JAUS topology and can encompass all interoperable elements (robotic controllers and robotic platforms). The JAUS system contains multiple JAUS subsystems.

Payload: A robot payload is a physical device that interfaces to the robot using interoperable physical, power, and / or data interfaces, and is replaceable (modular) based on mission needs. A payload can be similar in nature to other devices that are integrated on a robotic vehicle, but a payload is not required for native UGV capabilities.

Sensor: Sensors codify information from the environment and can be used to reason about the environment. Typical sensor types include, but are not limited to, tactile, proprioceptive, seismic, acoustic, meteorological, chemical, biological, radiological, nuclear, visual, and range finding. All sensors fall into two categories, either passive or active. Passive sensors perform their detection without effecting or altering the environment (i.e. thermometer). Active sensors use some form of emission to detect the reflection or other effect that emission has on the environment (i.e. radar).

Test: Test is an element of verification in which scientific principles and procedures are applied to determine the properties or functional capabilities of items.