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NATO STANDARD

AEP-4818 Vol. II

**ROBOTICS AND AUTONOMOUS
SYSTEMS – GROUND (RAS-G)
INTEROPERABILITY PROFILE (IOP):
JAUS PROFILING RULES**

Edition A Version 1
FEBRUARY 2023



NORTH ATLANTIC TREATY ORGANIZATION

ALLIED ENGINEERING PUBLICATION

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CHAPTER 1 SCOPE

This document is a normative attachment to the RAS-G Interoperability Profile (IOP) Overarching Profile and provides specific rules and requirements associated with the profiling of the SAE JAUS message set to achieve system level and platform level interoperability. SAE ARP6012, JAUS Compliance and Interoperability Policy, prescribes guidance and considerations for the profiling of the JAUS message set in order to achieve interoperability at various levels within a JAUS System. Specific recommendations include the specification of interoperability templates, specifying a common set of standards as well as interoperability profiles that specify additional constraints necessary to create interoperable systems. These constraints may be specified as options unique to each individual selected standard, such as service definitions, timing requirements, quality of service, communications protocols, etc.

This document identifies these additional profiling constraints with respect to the SAE JAUS messaging standards to meet the IOP defined levels of interoperability. As depicted in Figure 1: JAUS Profiling/IOP Relationship below, the JAUS profiling rules forms a direct relationship with the IOPs as well as the SAE JAUS standards.

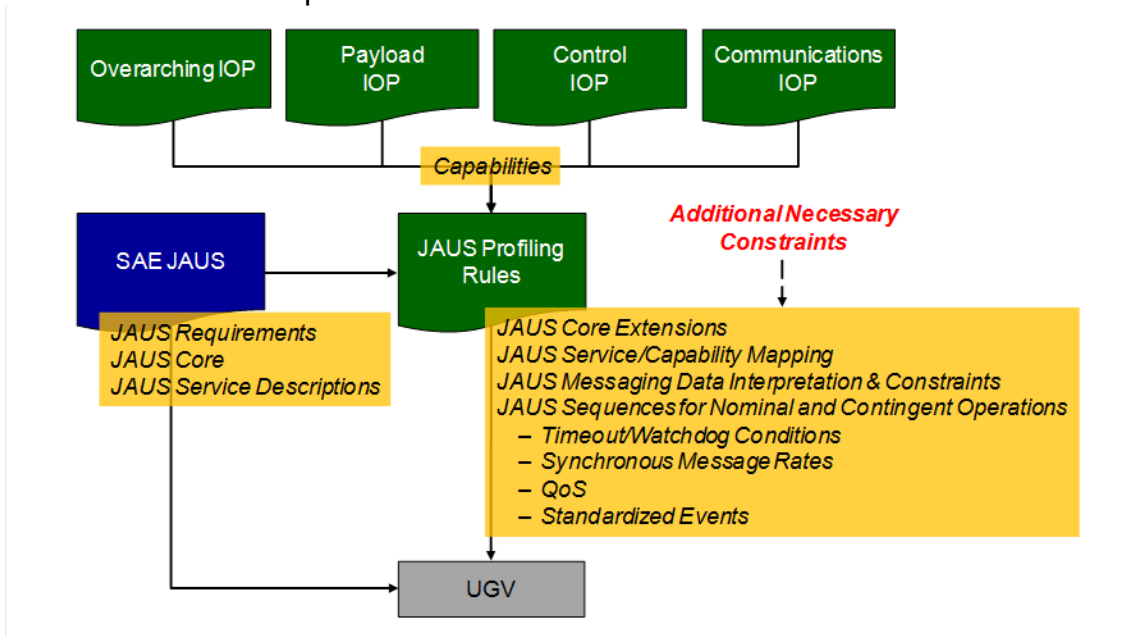


Figure 1: JAUS Profiling/IOP Relationship

IOP requirements and capabilities (functionality sets) are defined within the other IOP documents. This JAUS Profiling Rules document then specifies additional information, as required to affect an interoperability contract between controller(s) and UGV(s). Additional information (profiling constraints) addressed to meet IOP interoperability includes, but is not limited to:

1. Clarification of data consistency, as required, for specified messages (e.g., interpretation, constraints, precision, accuracy).
2. Specification of contracts for service/capability mapping (e.g., primitive, vector, velocity state, waypoint drivers).
3. Specification of watchdog/timeout conditions and contingencies; especially for safety critical functions (e.g., Heartbeats, Teleop, Video, Comms, Weapons Control, SL/V).
4. Specification of synchronous message rates.

CHAPTER 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

ID	Version	Document
TR8350.2	1	Department of Defense World Geodetic System 1984, Its Definition and Relationships with Local Geodetic Systems
EXT-AEODRS-10-1785-JAUS	1.4	Advanced Explosive Ordinance Disposal Robotic System (AEODRS) JAUS Extension Services and Experimental Messages
ADD-AEODRS-10-0802-CA	1.4	Advanced Explosive Ordinance Disposal Robotic System (AEODRS) Architecture Description Document

Table1: Government Documents

2.2 NON GOVERNMENT DOCUMENTS

ID	Version	Document
AIR5665A	Rev A	AE Aerospace Information Report, Architecture Framework for Unmanned Systems (AFUS)
ARP6012	1.0	SAE Aerospace Recommended Practice, JAUS Compliance and Interoperability Policy
AS5669A	Rev A	SAE Aerospace Standard, JAUS/SDP Transport Specification
AS5684B	Rev B	SAE Aerospace Standard, JAUS Service Interface Definition Language
AS5710A	Rev A	SAE Aerospace Standard, JAUS Core Service Set
AS6009	1.0	SAE Aerospace Standard, JAUS Mobility Service Set
AS6057A	Rev A	SAE Aerospace Standard, JAUS Manipulator Service Set
AS6060	1.0	SAE Aerospace Standard, JAUS Environment Sensing Service Set
AS6062	Rev A	SAE Aerospace Standard, JAUS Mission Spooling Service Set
AS6091	1.0	SAE Aerospace Standard, JAUS UGV Service Set
AS8024	1.0	SAE Aerospace Standard, JAUS Autonomous Behaviors Service Set

Table2: Non Government Documents

CHAPTER 3 KEY CONCEPTS AND INFORMATION

This section provides information on key document concepts, how to use this document to describe interoperability requirements, definitions, and other information.

3.1 DEFINITIONS

Table 3: Definitions

Term	Definition
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. In this document, a Capability is generally associated one to one with an Interoperability Attribute.
Complex Payload	A complex payload is a payload that aggregates multiple capabilities. The definition of logical payload in this document extends from the Payload IOP document to define a complex payload as either a physical or logical aggregation. A complex payload shall always be represented by a JAUS node.
IP Address Assignment List	The IP Address Assignment List is a list of IP addresses with associated JAUS IDs that are located at those IP addresses. For example, an IP Address Assignment List might have three IP addresses, with one JAUS ID associated with IP address #1, 2 JAUS IDs associated with IP address #2, and 1 JAUS ID associated with IP address #3. The IP Address Assignment List is used by Transport Layer Routing elements to properly route messages and other communications to the correct transport layer endpoint given a logical JAUS ID.
JAUS Component	A JAUS component is a logical grouping of JAUS Services. Each component aggregates services to provide an operationally relevant capability. The component offers a service interface to other consuming components to use. For example, teleoperation could be a component that aggregates a primitive driver service and some sensor services to provide teleoperation capabilities to a robotic controller.
JAUS Node	A JAUS Node is logical grouping of JAUS Components within a JAUS Subsystem. Within this IOP, 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 node) or physical (i.e. a manipulator payload with two cameras and a sensor on it are considered a node).

J AUS Service	J AUS services represent the lowest level of the topology. For the purposes of this IOP, services provide an abstraction to hardware or software algorithms that reside on the platform. Services may be internalized within a component or may be provided via an interface that is consumed by components.
J AUS Subsystem	A J AUS subsystem is an independent and distinct unit within a system. Subsystems include robotic controllers, robotic platforms, and video terminals connected and communicating via a specified set of interoperability attributes. A subsystem contains one or more J AUS Nodes.
J AUS System	A J AUS system is the top level element within the topology and can encompass all interoperable elements (robotic controllers and robotic platforms). The system contains multiple subsystems.
Transport Layer Routing Element	A Transport Layer Routing element is an element responsible for routing J AUS messages to the proper endpoint(s) on the transport layer, given a logical J AUS ID. Historically, the term "Node Manager" has often been used for the element providing this capability.

3.2 KEY CONCEPTS AND RULES

3.2.1 Interoperability Attributes

Interoperability Attributes are the primary organizational structure of this document. An Interoperability Attribute is a single operationally relevant function - for example, teleoperation would be a capability that provides the function of driving a vehicle non-line of sight using a camera. Interoperability Attributes may have one or more groups of related capabilities, called attribute reference groups. Each group of referenced attributes has a selection modifier that specifies whether all, any, or exactly one attribute from that group must be selected when the original Interoperability Attribute is included in an instantiation.

An attribute reference group will have one of three selection types associated with it: all, any, or one. These selection types, along with an indication of whether the attribute reference group is optional or not, inform which of the referenced attributes must be selected. Interpretations for the different selection type combinations are:

Table 4: Attribute Reference Group Selection Types

Optional	Selection Type	Description
True	All	Either all attributes or no attributes from the attribute reference group MUST be selected. These attributes are linked together.
False	All	All attributes from the attribute reference group MUST be selected. These are mandatory attributes.

True	Any	As many of the attributes as desired (including none) from the attribute reference group may be selected. These are optional attributes.
False	Any	At least one of the attributes from the attribute reference group MUST be selected. These attributes are each optional, so long as one is selected.
True	One	No more than one attribute from the attribute reference group can be selected. These are mutually exclusive, though not required, attributes.
False	One	One and ONLY one attribute from the attribute reference group MUST be selected. These are mutually exclusive attributes where a choice is required.

3.2.2 Requirements

Most attributes will have one or more requirements (the primary exception is attributes that group other attributes together). A Requirement provides specific details of what must be done to successfully implement an Interoperability Attribute. In this document, there are two types of requirements - a JAUS requirement, and an identified requirement. A JAUS requirement is only found in this document and defines required JAUS services, messages interpretations, and other JAUS-specific items. The other type of requirement is an identified requirement, which contains a single "shall" statement that specifies what must be done to comply with an Interoperability Attribute.

3.2.3 Parameters

Parameters are items found under Interoperability Attributes or Requirements that must have a value assigned to them. Typically, default or recommended values will be provided. Parameters are intended to be used to add additional detail required by certain Interoperability Attributes and Requirements, such as specifying how long before a drive timeout occurs. When referenced in text descriptions, parameters are marked in this document by a preceding "[Parameter]" statement, followed by the parameter name. For example, "[Parameter] Drive Timeout" defines a parameter called Drive Timeout. All Interoperability Attributes and Requirements that have parameters will have a sub-section that lists all parameters, their default value, and a description of the parameter.

3.2.4 Grouping Together Interoperability Attributes - the Node

One or more Interoperability Attributes may be grouped together using the concept of a Node. A Node defines a group of one or more related Interoperability Attributes. The relation may be physical (i.e. a payload that physically groups together multiple cameras, sensors, and a manipulator) or logical (i.e. a grouping of all functionality related to platform mobility). A Node requires only a unique name and the Interoperability Attributes that define it, but other information like a unique JAUS Node ID could also be specified.

By default, there are two Nodes (possibly located in a single JAUS Node) that shall be defined whenever this document is used to define UGV requirements:

1. **Platform Node** - Groups all platform components together, such as basic platform management, platform lights, and any other platform specific capabilities. In this document, a component target of "platform_manager" indicates a component on the Platform Node. The JAUS Node ID of the Platform Node is typically 1.
2. **Mobility Node** - Groups all mobility components together, including the Core Mobility Component, which provides low-level access to a platform's mobility capabilities. Any capabilities specifically related to the mobility of the platform should be added to the "Mobility" Node.

3.2.5 Periodicity Requirements

Many JAUS Requirements will list periodicity requirements. These are usually a minimum rate at which a command must be sent or at which a report must be provided. Periodicity requirements also include what messages for a given service must be published (periodic and on-change events). Any message (i.e. reporting global pose) for which a periodic event is required will provide a required or suggested rate, and any message that has periodic event specified (rate is in Hz) shall also support on-change events.

3.2.6 JAUS Hierarchy Rules

The rules for defining a JAUS Hierarchy using this document are defined in the mandatory JAUS Hierarchy Rules attribute.

3.2.6.1 JAUS Hierarchy Rules Attribute

Parent Attribute: Core Software and Logical Attribute

A JAUS hierarchy consists of four levels – JAUS Subsystems, JAUS Nodes, JAUS Components, and JAUS Services. These levels are defined in the definitions table at the beginning of this section. There are three simple rules that provide the only JAUS hierarchy requirements of this document – all other details are left to the requirements derived using this document, or to the implementation.

3.2.6.1.1 JAUS Hierarchy Rules Requirement

- V2.JAUS-1 *A JAUS Subsystem shall be defined for any grouping of Nodes. This JAUS Subsystem is typically a robotic system or OCU.*
- V2.JAUS-2 *For every Node defined (i.e. a payload), there shall be a single associated JAUS Node.*

3.2.7 Component Targets

Component targets show up in the "Component" column of the tables found under Component and Service Requirements. Component targets define where a specific service is expected to be found. There are 5 component targets: any, all, unique, if_inherited, and named.

When using the JAUS Profiling Rules to develop requirements, you may want to provide more specific component targets for certain services (even going as far as specifying the component IDs), but you should never relax the requirements provided in this document (i.e. changing a target of "all" to "any" or ignoring the "platform_manager" target).

3.2.7.1 any

The "any" component target indicates that a service could appear on any JAUS Component, but it is required to occur on AT LEAST one JAUS Component. The "any" target is the default target if the "Component" column is left blank. An example of an "any" target service would be GlobalPoseSensor, which could occur anywhere but would be expected somewhere if global pose is a requirement.

3.2.7.2 all

The "all" component target indicates that a service MUST be found on all JAUS Components. If the service is not found (or fails a test) on a single component, then the attribute requirements has not been met and compliance to that attribute is not achieved.

3.2.7.3 unique

The "unique" component target indicates that a service MUST occur on one and only one JAUS Component. This designation is often used for services that would cause issues if they occurred more than once, like Digital Resource Discovery.

3.2.7.4 if_inherited

The "if_inherited" target indicates that a service must be on a JAUS Component if some other service on that component inherits it. These target is typically used with core services like Access Control and Management.

3.2.7.5 Named Target

A named target is a specific name (also referred to as an alias) like "platform_manager" that specifies the component or components on which a service is expected to reside. There are two rules regarding named component targets:

1. The name may apply to one or more JAUS Components on the same JAUS Node. For example, the "platform_manager" target may apply to multiple JAUS Components on the Platform Node. A future revision of this document may add a way to specify an alias can apply to more than one node.

2. A JAUS Service that has a named component target is expected to occur on one and only one of the JAUS Components to which the alias specified by the component target applies. A future revision of this document may add a way to specify other types of multiplicity.

CHAPTER 4 CORE SECTION

This section contains core attributes for the JAUS Profiling Rules IOP.

4.1 CORE SOFTWARE AND LOGICAL ATTRIBUTE

Parent Attribute: IOP Usage

The Core Software and Logical Attributes are attributes that represent broad categories of system capabilities.

The following attributes are mandatory.

Attribute	Description
Core JAUS Attribute	Mandatory attribute that must be selected for every system that defines requirements using Interoperability Attributes.
JAUS Hierarchy Rules Attribute	Defines the rules for translating attribute requirements from this IOP into a JAUS Subsystem, Node, Component hierarchy.

Table 5: - Mandatory Select = all

Any number of the following attributes can be chosen.

Attribute	Description
Global Attribute	Global Interoperability Attributes do not tightly fit into a single attribute group or are likely to be used in conjunction with many different Interoperability Attributes
Platform Attribute	Platform-centric attributes that provide platform level capabilities such as discovery, engine status information, health information, etc.
Mobility Attribute	The Mobility Interoperability Attribute defines attributes related to platform mobility, such as driving.
Sensor Attribute	UGVs have payloads which can collect data from the surrounding environment. In addition UGVs have sensors that collect data from the robot in order to report back to the operator health and other status information.
Emitter Attribute	UGVs have payloads which can affect their surrounding environment at a distance. These include Lights, Speakers, Laser Target Designators, and Weapons.
Actuator Attribute	Actuator payloads provide mechanical means of manipulation.

Table 6: - Optional Select = any

4.2 CORE JAUS ATTRIBUTE

Parent Attribute: Core Software and Logical Attribute

The Core JAUS Attributes are mandatory attributes that must be specified for every system that defines requirements using Interoperability Attributes. Core JAUS Attributes are unique in that they are the only attributes that do not define a single specific capability, but instead define required capabilities that apply to all other Interoperability Attributes.

The following attributes are mandatory.

Attribute	Description
Access Control Attribute	Specifies how authority is used to control access to services that accept commands, like mobility and manipulator services.
Management Attribute	Capability to protect a system from taking certain actions if a system is in an emergency, failure, or other state that precludes the use of that functionality. Instructive uses of this capability are E-Stop and managing a dead man switch.
Component Liveness Attribute	Specifies that a Liveness service shall be provided by each component (allows liveness/connectivity checks to be performed).
ID Assignment and Propagation Attribute	Defines basic concepts used in assignment of JAUS Subsystems (Platform / OCU) and Nodes (payloads). Parent of all Subsystem and Node ID Assignment and Propagation attributes.
Transport Attribute	Specifies the type of transport layer(s) used to transport JAUS messages.

Table 7: - Mandatory Select = all

4.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:core:Transport, 1.1	if_inherited	AS5710A JAUS Core Service Set
urn:jaus:jss:core:Events, 1.1	if_inherited	AS5710A JAUS Core Service Set
urn:jaus:jss:core:AccessControl, 1.1	if_inherited	AS5710A JAUS Core Service Set
urn:jaus:jss:core:Management, 1.1	if_inherited	AS5710A JAUS Core Service Set
urn:jaus:jss:core>ListManager, 1.1	if_inherited	AS5710A JAUS Core Service Set

Table 8: - Component and Service Requirements for Core JAUS Attribute

4.2.2 Core Services Basic Requirements

Core services shall be provided by every JAUS Component. Based on the inheritance defined in the appropriate SAE JAUS document for every service on that JAUS Component, at least one and as many as all of the core service profiled in this requirement will be provided. The commonly required core services that are profiled here or separately are:

- Transport - The Transport service must be implemented by every JAUS component. It defines the interface between the JAUS Component and the transport layer that is responsible for getting messages to and from that JAUS Component.

- Events - The Events service provides a mechanism to create and manage events on a JAUS component. Events include periodic notifications (i.e. a regular global pose update) and on-change events (i.e. notification only when a specific value changes). JAUS Events approximates a publish-subscribe mechanism for exchanging information.
- Access Control - The Access Control service manages who has permission to access the command interface (i.e. moving a vehicle using a wrench effort) of a JAUS Component. Access Control requirements are detailed in Access Control Interoperability Attribute.
- Management - The Management service manages the lifecycle of a JAUS Component. It is primarily used to ensure that JAUS services that impact movement of something and have safety implications (i.e. mobility and manipulator drivers) will only respond to commands when in the ready management state.
- List Manager - The List Manager service provides the ability to create, modify, and use lists for dependent JAUS services that need lists, such as the Global Waypoint List Driver service.

4.2.2.1 Notes and Interpretations

4.2.2.1.1 Events

4.2.2.1.2 Supported Events

A CreateEvent message is sent to the Events service on a JAUS component when attempting to create a periodic or on-change event. There are three possible responses the Events service will provide: the event request was accepted at the requested rate, the event request was accepted but at a different rate, or the event request was rejected. One should not assume that any particular event for a particular JAUS message will be supported by a particular JAUS component implementation unless an event is explicitly required by the Periodicity section of a given Interoperability Attribute. Requirements for events that must be supported and the rates at which they must be supported, other than those explicitly defined within this document, must be defined separate from the requirements of this document.

4.3 ACCESS CONTROL ATTRIBUTE

Parent Attribute: Core JAUS Attribute

The Access Control Interoperability Attribute profiles the way to manage access to JAUS Components using the JAUS urn:jaus:jss:core:AccessControl service.

Any number of the following attributes can be chosen.

Attribute	Description
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Unsolicited Broadcast Control Available Attribute	Provides the capability to alert potential clients within the system that control has been made available.
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Table 9: - Optional Select = any

4.3.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:core:AccessControl, 1.1	if_inherited	AS5710A JAUS Core Service Set

Table 10: - Component and Service Requirements for Access Control Attribute

4.3.2 Authority Code Organization Requirement

Although JAUS defines a range of authority codes, there are no recommended practices for using them. The following table defines authority code ranges and their roles and description.

Table 11: Authority Code Roles and Descriptions

Role	Authority Code Range	Description
OWNER	255	"root" user concept, analogous to the root user of an OS.
SAFETY_CRITICAL	240-254	A role reserved for safety critical components that cannot have their control usurped. Will often be an on-board process like stability control of self-collision avoidance, but could also be an off-board client, even the OCU.
PRIMARY_OPERATOR	205-239	Only client role with mobility control. Can control/monitor any Component on the platform. A PRIMARY_OPERATOR is defined as any client that is not on-board the robotic platform itself, and will typically be something like the Operator Control Unit (OCU) that an operator is using.
ONBOARD_MOBILITY_DEVICE	155-204	Only onboard controller role with mobility control. Can control/monitor any Component on the platform. An onboard controller is defined as any process or capability on-board a platform (as opposed to an OCU that is typically off-board). An example is an autonomy process taking control of lower level services to do more advanced navigation.
OPERATOR	75-124	Client role that can control/monitor any Component on the platform except those contained under the Mobility Node.

ONBOARD_DEVICE	25-74	Onboard controller role that can control/monitor any Component on the platform except those defined under the Mobility Node.
MONITOR	0	Can only monitor Components.

Authority codes in a higher authority code range can pre-empt those in a lower authority code range. Clients with authority of 0 cannot take control of a component because the minimum default authority is 1.

Figure 2: Owner Pre-emption Use Case below shows a sequence diagram that illustrates the owner pre-emption use cases.

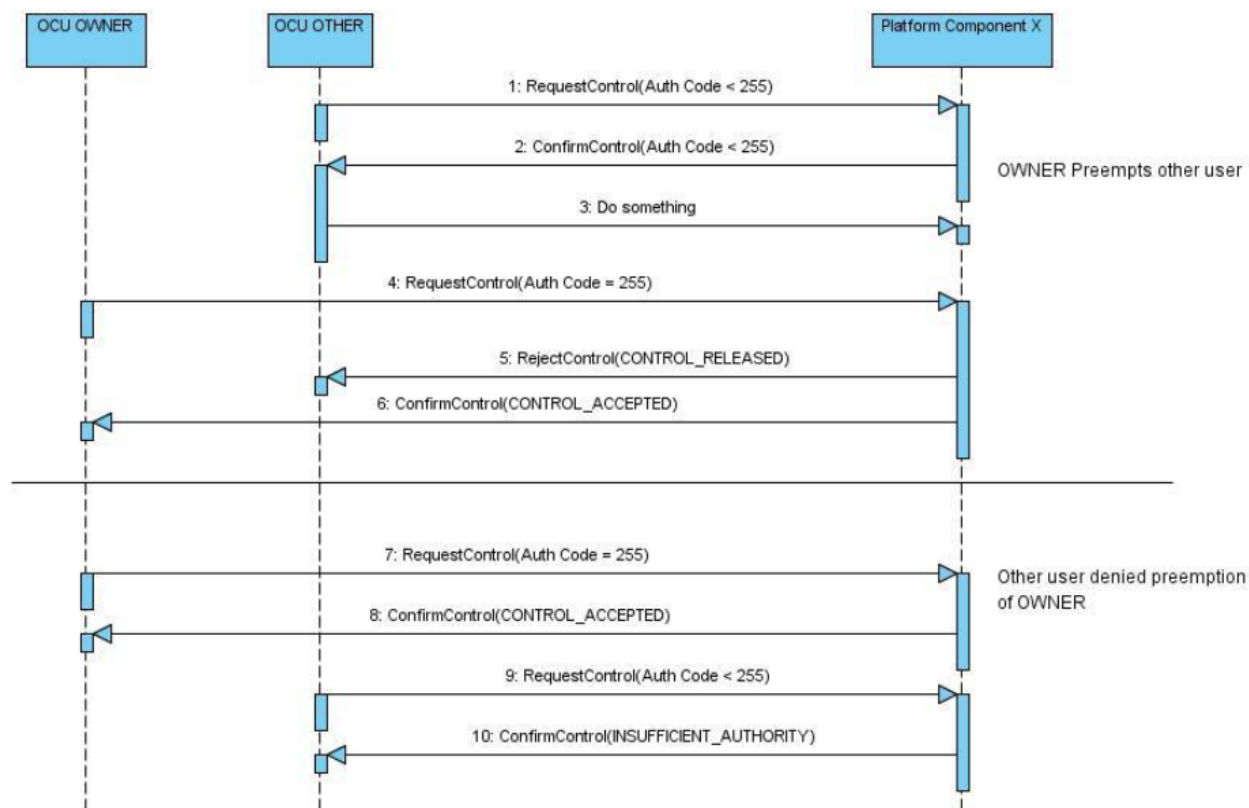


Figure 2: Owner Pre-emption Use Case

4.3.3 Default Authority Requirement

Default authority is the default authority assigned to a JAUS Component for the purposes of taking control of it using Access Control. The authority level of a client requesting control of an Access Controlled JAUS Component must be greater than or equal to the default authority in order for the requesting client to get control of the JAUS Component, regardless of the authority level of the current controller.

The following rules apply to the default authority level of JAUS Components within this IOP:

- The default authority of any Access Controlled JAUS Component on the Mobility Node shall be at least 125. This allows the ONBOARD_MOBILITY_DEVICE role and above to take control of platform mobility, while preventing roles with lesser authority from doing so.
- The default authority of any Safety Critical JAUS Component shall be at least 240. This prevents any clients that do not have the SAFETY_CRITICAL role from taking control.
- The default authority of any Access Controlled JAUS Component besides those on the Mobility Node shall be at least 1. This prevents the MONITOR role from controlling any device, while allowing the higher roles to take control.

V1.JAUS-3 The default authority of any Access Controlled JAUS Component on the Mobility Node shall be at least 125.

V1.JAUS-4 The default authority of any Access Controlled JAUS Component besides those on the Mobility Node shall be at least 1. This means that a client with authority of 0 shall not be able to take control of any component.

4.3.4 Access Control Timeout Requirement

The access control timeout feature of the urn:jaus:jss:core:AccessControl service as defined in AS5710A JAUS Core Service Set is used for maintaining liveness of control. This liveness differs from the connection liveness offered by the Liveness service and instead provides a way for the server to detect the presence of the client. As stated in the description of the access control service, a timeout is set that corresponds to the rate at which a controlling client component must periodically request control of a server component, releasing control if the timeout is exceeded. The access control timeout is specified using the parameter Access Control Timeout.

4.3.4.1 Parameter Listing

Parameter Name	Default Value	Allowed Values	Description
Access Control Timeout Parameter	5 seconds	<Range> 0..65535 seconds	The rate in Seconds at which a controlling client component must periodically request control.

Table 12: - Parameter Listing for Access Control Attribute

4.3.5 Mutually Exclusive Access Control Requirement

This document currently defines Interoperability Attributes for several different JAUS Components where each JAUS Components' services may want control of low level hardware controllers (i.e. platform motor drivers, manipulator joint motors, etc). A platform that has multiple JAUS components accessing low level hardware could have one of two things happen: either a single client could send messages to more than one JAUS Component, or two clients could send messages to two separate JAUS Components. In

either case, how the platform responds is unknown. This problem is solved by the following requirement:

There shall be a single ("singleton") JAUS Component that contains all possible services for controlling the low level hardware functionality of a device. This shall be the only JAUS Component whose services access the low level functionality of the device. This singleton JAUS Component is composed by specifying which Interoperability Attributes are used for control of the device - any duplicated services shall be presented as a single service. For example, when doing mobility control of a platform, if a singleton Core Mobility Component is composed of the RC and Teleop, it will look like Figure 3: Example of Singleton Core Mobility Component with the RC and Teleop attribute specified below.

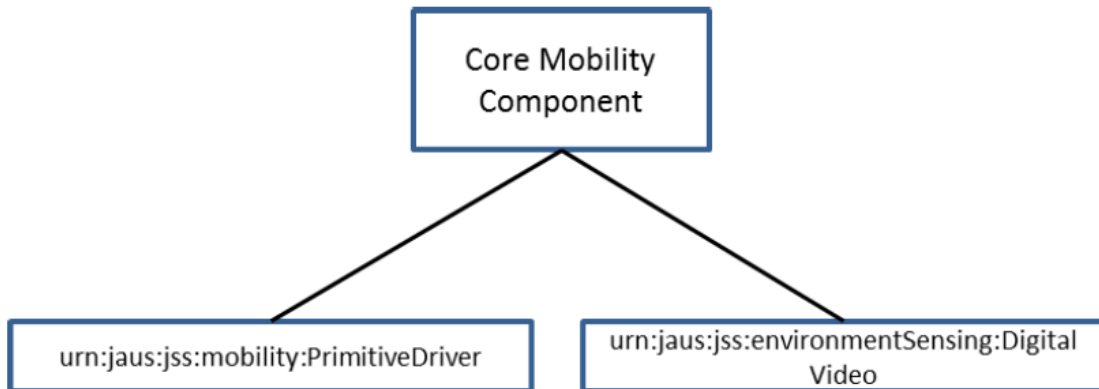


Figure 3: Example of Singleton Core Mobility Component with the RC and Teleop attribute specified

V1.JAUS-
5 *There shall be a single ("singleton") JAUS Component that contains all possible services for controlling the low level hardware functionality of a device. This shall be the only JAUS Component whose services access the low level functionality of the device.*

4.4 UNSOLICITED BROADCAST CONTROL AVAILABLE ATTRIBUTE

Parent Attribute: Access Control Attribute

The Unsolicited Broadcast Control Available attributes provides a means of alerting potential clients within the system that control has been made available to a component within the system. System designers should be aware that this broadcast can occur at the same time as other behaviors within the system and should be dealt with appropriately. For example, if the mobility component broadcasts that it is available to control, it may do so after a loss of communications from the controlling client. In this case, if a lost communications policy is in effect (i.e. an attempt to re-establish communications with the original controlling client) it may not be advisable for any other available client to request control of the component, but rather allow the lost communications behavior to continue.

In such cases, any clients within range should be able to query information related to the overall state of the system and determine if it is advisable to request control or not.

4.4.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:UnsolicitedBroadcastControlAvailable, 2.0		Custom Services, Messages and Transports

Table 3: - Component and Service Requirements for Unsolicited Broadcast Control Available Attribute

4.4.2 Unsolicited Broadcast Control Available Requirement

V1.JAUS-6 When the Unsolicited Broadcast Control Available Attribute is specified for a JAUS component, that JAUS component shall provide a Unsolicited Broadcast Control Available service that broadcasts availability of control when no control over the component is being maintained.

4.5 MANAGEMENT ATTRIBUTE

Parent Attribute: Core JAUS Attribute

The core Management service provides an additional check on certain actions like driving and moving actuators by ensuring that the system is ready and not in emergency, failure, or other state where it is not ready to perform those actions. The functionality associated with a dead man switch, namely that certain actions not occur when the switch isn't pressed, can be implemented using the Management service. This capability is also utilized to provide E-Stop functionality.

4.5.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:core:Management, 1.1	if_inherited	JAUS Core Service Set

Table 4: - Component and Service Requirements for Management Attribute

4.5.2 Emergency Stop Safety Requirement

The emergency stop safety requirement provides the capability to stop a platform in a safe manner (note that this does not necessarily mean just setting 0 velocity). Safe implies that the platform will no longer be moving and will not be in a position to move on its own (i.e. slide down a slope because a parking brake is not engaged).

4.5.2.1 Notes and Interpretations

4.5.2.1.1 Management

The Management service on the Core Mobility Component is used to set an emergency (safe) stop. A Management service will always be present on the Core Mobility JAUS component since all driver services inherit from it.

Message(s)	Concept	Interpretations
ID 0006: SetEmergency	Usage	The value SAFETY = 2 is added to the enumeration for emergency code. SAFETY implies a safe stop and does not necessarily mean just 0 motion.

Table 5: - Message Interpretations for Management

4.6 ID ASSIGNMENT AND PROPAGATION

4.6.1 ID Assignment and Propagation Attribute

Parent Attribute: Core JAUS Attribute

The following definitions apply for subsystem ID assignment and propagation:

Basic Platform Management Component

A JAUS Component that resides on the Platform Manager Node that is responsible for ID Assignment and Propagation.

Unassigned Endpoints

Unassigned Endpoints are JAUS components that have an unassigned Subsystem ID, Node ID, or both. These endpoints can be used on systems using dynamic ID assignment and propagation. Components with unassigned endpoints represent their unknown Subsystem and/or Node IDs using a wildcard value of 0. There are three types of unassigned endpoints:

Type 1

A Type 1 endpoint is a Component that does not yet have its subsystem ID assigned and has a statically assigned node ID. Only the Basic Platform Manager Component can have a Type 1 endpoint. It's address is represented by (0.[NodeID].[ComponentID]). For example, address 0.1.1 represents a Basic Platform Manager Component with Node ID 1 and Component ID 1 on a subsystem (robot platform) that has not yet been assigned its subsystem ID. A transport layer shall route any message directed to all subsystems (65535) to any matching Type 1 Endpoint. For example, broadcasts to 65535.255.255 and 65535.1.1 would be routed to the Type 1 Endpoint given by the address 0.1.1. Type 1 endpoints cannot also be Type 2 or Type 3 endpoints and are assigned their subsystem ID using the Centralized Subsystem Assignment Attribute.

Type 2

A Type 2 endpoint is any payload / node other than the Basic Platform Manager Component's node that does not have an assigned subsystem ID, and is also represented by the wildcard JAUS address 0.[NodeID].[ComponentID]. A single component on a Type 2 endpoint node should manage the ID assignment responsibility for all components on that node. A Type 2 Endpoint should only receive messages destined for the subsystem which the Type 2 Endpoint resides on, using the platform's multicast address that is not received by other subsystems. A Type 2 Endpoint shall receive any message sent to the address [SubsystemID].255.255, including for wildcard (0) values of SubsystemID. For example, a message sent from an unassigned Basic Platform Manager Component (Type 1 Endpoint) located at 0.1.1 to a Type 2 Endpoint 0.1.102 is sent using a destination of 0.255.255 on the platform's multicast address. A Type 2 endpoint can also be a Type 3 endpoint but cannot also be a Type 1 endpoint. Type 2 endpoints are assigned their subsystem ID using the Subsystem ID Propagation Attribute.

Type 3

A Type 3 endpoint is any payload / node with an unassigned Node ID, and is represented by the address [SubsystemID].0.[ComponentID]. A Type 3 Endpoint shall receive any message sent to the address [SubsystemID].255.255, where SubsystemID is the ID of the subsystem on which the Type 3 endpoint resides. A Type 3 endpoint may also be a Type 2 Endpoint, in which case the Type 2 endpoint definition for message routing also applies. For example, a Type 3 endpoint with unknown subsystem and node IDs and component ID 102 (0.0.102) would receive messages sent on the platform multicast address using the destination 0.255.255), and a Type 3 endpoint with known subsystem ID 100 and component ID 102 (100.0.102) would receive messages with destination 100.255.255. A Type 3 endpoint cannot also be a Type 1 endpoint. Type 3 endpoints are assigned their node ID using the Dynamic Node ID Propagation Attribute.

Table 16: Endpoint Type Summary

Type 1	Type 2	Type 3	Component Description
Yes	Not Allowed	Not Allowed	Basic Platform Manager Component
No	Yes	No	Component (not Basic Platform Manager) that does not have a Subsystem ID assigned, but has a statically assigned Node ID
No	No	Yes	Component (not Basic Platform Manager) that does not have a Node ID assigned, but has a statically assigned Subsystem ID
No	Yes	Yes	Component (not Basic Platform Manager) that does not have a Subsystem ID or Node ID assigned

The following attributes are mandatory.

Attribute	Description
Subsystem ID Assignment Attribute	Specifies how JAUS Subsystems within a JAUS system are assigned a subsystem ID.
Node ID Assignment Attribute	Specifies how JAUS Nodes within a JAUS subsystem are assigned a node ID.

Table 6: - Mandatory Select = all

4.6.2 Subsystem ID Assignment

4.6.2.1 Subsystem ID Assignment Attribute

Parent Attribute: ID Assignment and Propagation Attribute

The Subsystem ID Assignment Interoperability Attribute specifies attributes that define methods for assigning unique JAUS IDs to JAUS subsystems. JAUS messages are routed from source to destination by a JAUS ID embedded in the JAUS message header. The JAUS ID is composed of three ID fields: The Subsystem ID field, the Node ID field, and the Component ID field.

The following attributes are mutually exclusive, exactly one must be chosen.

Attribute	Description
Static Subsystem Assignment Attribute	Defines static assignment of JAUS Subsystem IDs. Static assignment implies a predetermined set of JAUS Subsystem IDs are assigned for each JAUS Subsystem.
Centralized Subsystem Assignment Attribute	Defines a centralized approach to acquiring JAUS Subsystem IDs. In this approach, a central server provides unique IDs to all JAUS Subsystems that submit a request for an ID.

Table 7: - Mandatory Select = one

4.6.2.2 Static Subsystem Assignment Attribute

Parent Attribute: Subsystem ID Assignment Attribute

If the Static Subsystem ID Attribute is specified, the assignment of unique JAUS subsystem identifiers shall be done at set-up / configuration time. The exact way in which this is done is not specified by this IOP document, but typical methods include through a configuration file or other field-modifiable approach. If the Static Subsystem ID Assignment Attribute is selected, a method for ensuring the assignment and maintenance of unique JAUS identifiers must be used.

4.6.2.2.1 Static Subsystem ID Assignment Requirement

V1.JAUS-7 If the Static Subsystem ID Attribute is specified, the assignment of unique JAUS subsystem identifiers shall be done at set-up / configuration time.

4.6.2.3 Centralized Subsystem Assignment Attribute

Parent Attribute: Subsystem ID Assignment Attribute

If the Centralized Subsystem ID Assignment Attribute is specified, the assignment of unique JAUS subsystem identifiers shall be done using a run-time centralized approach for ID assignment. The Centralized Subsystem ID Assignment Attribute for JAUS Subsystem ID assignment is only valid if the Platform Management Interoperability Attribute is specified, and the JUDP Attribute child of the Transport Interoperability Attribute is selected (even if only selected for this purpose). This centralized approach is described below:

4.6.2.3.1 Procedure

4.6.2.3.1.1 How the Subsystem Acquires its JAUS Subsystem ID

1. A single Subsystem ID Server shall be provided on the network that contains the SubsystemIDAllocator JAUS Service and responds to RequestSubsystemID messages. Any implementation of this attribute must have a way to guarantee that there is only one SubsystemIDAllocator service (defined in the Custom Services, Messages, and Transports IOP Document) that will respond to RequestSubsystemID messages, or that there is a way to coordinate between multiple SubsystemIDAllocator services such that uniquely assigned JAUS Subsystem IDs are guaranteed. This document does not specify how this is accomplished.
2. Upon startup, a JAUS Subsystem (i.e. a robot or OCU) broadcasts to all subsystems (**65535.255.255**), through the Basic Platform Manager JAUS Component, a RequestSubsystemID message containing a unique identifier for the platform (MAC Address). The Basic Platform Manager JAUS Component shall register as a Type 1 Endpoint with the Transport Layer Routing Element, indicating it wants to receive all broadcasted messages. For UDP multicast, the internal (on the robot) multicast address shall be tried before sending over the external multicast address (sent to all subsystems).
3. Upon receiving the RequestSubsystemID message, the SubsystemIDAllocator Service responds via broadcast (**65535.255.255**) with a unique Subsystem ID associated with the unique identifier provided in the RequestSubsystemID message. Node ID and Component ID are the values for the source of the RequestSubsystemID message.
4. The Basic Platform Manager JAUS Component that sent the original RequestSubsystemID message receives the GrantSubsystemID message, verifies that the unique identifier in the message matches the unique identifier that it sent, and then sets its JAUS Subsystem ID to the ID provided in the GrantSubsystemID message.
5. Broadcasts performed to 0.255.255 are limited to the bounds of the platform (i.e. there is only one possible Discovery service that will respond). The specific details of this broadcast at the Transport Layer level are left to the implementation.

6. Once the Basic Platform Manager JAUS Component obtains the JAUS Subsystem ID for the platform, it shall begin broadcasting an unsolicited Report Heartbeat Pulse message (JAUS message ID 0x4202) to all JAUS Components on the platform using the [Subsystem ID].255.255 broadcast address. The unsolicited Report Heartbeat Pulse message shall NOT be broadcasted until the Basic Platform Manager JAUS Component has a JAUS Subsystem ID.

The following attributes are mandatory.

Attribute	Description
Subsystem ID Propagation Attribute	Defines a dynamic method for propagating the Subsystem ID from a Platform to its payloads and other attached JAUS Nodes. This attribute is mandatory when centralized subsystem ID assignment is performed because the JAUS Subsystem ID is not known a-priori.

Table 8: - Mandatory Select = all

4.6.2.3.2 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:exp:aeodrs:SubsystemIDAllocator, 1.4	unique	Custom Services, Messages, and Transports
urn:jaus:jss:iop:UnsolicitedHeartbeat, 1.1	platform_manager	Custom Services, Messages, and Transports

Table 20: - Component and Service Requirements for Centralized Subsystem Assignment Attribute

4.6.2.3.3 Centralized Subsystem ID Assignment Requirement

- V1.JAUS-8 *There shall be a server component somewhere within the JAUS system that guarantees unique JAUS Subsystem ID assignment. This does not necessarily need to reside on the robotic system, and will often run on something like an OCU.*
- V1.JAUS-9 *The Basic Platform Manager JAUS Component shall act as a client to the SubsystemIDAllocator Service, and shall execute the procedure specified in "How the Subsystem Acquires its JAUS Subsystem ID" procedure to obtain its Subsystem ID.*
- V1.JAUS-10 *The Basic Platform Manager JAUS Component shall broadcast an unsolicited ReportHeartbeAEPulse message to all JAUS Nodes and Components on the platform using the broadcast address [SubsystemID].255.255 ONLY AFTER it has obtained a Subsystem ID. If the platform Subsystem ID is reset to an unassigned value for any reason at any point, the Basic Platform Manager JAUS Component shall STOP broadcasting the message. The unsolicited heartbeat pulse is implemented in accordance with the urn:jaus:jss:iop:UnsolicitedHeartbeat service specified in Custom Services, Messages, and Transports.*

V1.JAUS-11 *ONLY the component specified by the "platform_manager" target (the Basic Platform Manager JAUS Component) shall implement the urn:jaus:jss:iop:UnsolicitedHeartbeat service. No other component on the JAUS Subsystem, including payloads that may be plugged into a JAUS Subsystem, shall broadcast an unsolicited heartbeat pulse message.*

4.6.2.3.3.1 Notes and Interpretations

4.6.2.3.3.1.1 Subsystem ID Allocator

Message(s)	Concept	Interpretations
ID DB01: RequestSubsystemID	MACaddr field	The MACaddr field specifies the MAC address of the requestor - this may be any MAC address unique to the requesting platform.
ID FB01: GrantSubsystemID		

Table 29: - Message Interpretations for Subsystem ID Allocator

4.6.2.3.3.1.2 Unsolicited Heartbeat

The Unsolicited Heartbeat service does not send its unsolicited Report Heartbeat Pulse message unless it has a fully known JAUS ID, including the Subsystem ID and Node ID.

4.6.2.3.4 Parameter Listing

Parameter Name	Default Value	Valid Values	Description
Unsolicited Heartbeat Pulse Rate	1 Hertz	<Range> 0..65535 Hertz	Rate in Hz at which the Basic Platform Manager Component broadcasts its unsolicited ReportHeartbeAEPulse message. To prevent systems that use this message as an indicator for lost connectivity, this rate should be significantly faster than the rate defined by 1 / Platform Manager Timeout defined in this document. Choosing this rate should consider variance caused by CPU loads, network traffic and latency, and other factors.

Table 22: - Parameter Listing for Centralized Subsystem Assignment Attribute

4.6.3 Subsystem ID Propagation

4.6.3.1 Subsystem ID Propagation Attribute

Parent Attribute: ID Assignment and Propagation Attribute

If the Subsystem ID Propagation Attribute is selected, the JAUS Subsystem ID of a platform is propagated dynamically to the payloads connected to that platform. Dynamic JAUS Subsystem ID propagation is required when a payload does not know the Subsystem ID of the platform it is being plugged into a-priori. There are two methods a payload can use to obtain its JAUS Subsystem ID – using the unsolicited ReportHeartbeAEPulse message from the Basic Platform Manager Component (recommended) or broadcasting a JAUS Subsystem level message (like QueryIdentification) that the Platform Manager will respond to with a JAUS Subsystem level broadcast of its own.

4.6.3.1.1 Procedure

There are two methods that an individual JAUS Components on a JAUS Subsystem may use to dynamically obtain its Subsystem ID. The first is to look for the unsolicited ReportHeartbeAEPulse message from the Basic Platform Manager Component, and use the source JAUS Subsystem ID from the ReportHeartbeAEPulse message (recommended), or the individual JAUS Components may logically broadcast, at the JAUS Subsystem level, a message to which the Basic Platform Manager Component will respond, like QueryIdentification.

4.6.3.1.1.1 Method 1: Using the Unsolicited Report Heartbeat Pulse Message to Obtain a JAUS Subsystem ID

Note: This is the recommended method to use as there is a requirement that only the Basic Platform Manager component may send the unsolicited ReportHeartbeAEPulse message. Using the second method could theoretically yield more than one response, even if unlikely. A single JAUS Component on a JAUS Node may be used to set the Subsystem ID for all components on that node.

1. A newly attached component (i.e. on a payload node, etc.) that does not yet have a JAUS Subsystem ID registers with its Transport Layer Routing Element as a Type 2 Endpoint.
2. The newly attached component looks for a ReportHeartbeAEPulse message broadcast at the Subsystem level ([SubsystemID].255.255) using the JAUS Subsystem multicast address.
3. The newly attached component uses the JAUS Subsystem ID provided in the source of the ReportHeartbeAEPulse message as its JAUS Subsystem ID, so long as that Subsystem ID is not 0 or 65535 (wildcard). If a wildcard Subsystem ID is received, the component shall continue steps 2-3 until a non-wildcard Subsystem ID is received.

4.6.3.1.1.2 Method 2: Using a Response from the Basic Platform Manager Component to a Message Sent by the Newly Attached JAUS Component

1. A newly attached component (i.e. on a payload node, etc.) that does not yet have a JAUS Subsystem ID registers with its Transport Layer Routing Element as a Type 2 Endpoint.
2. The newly attached component looks for a Discovery Service to register with by broadcasting a QueryIdentification message to the JAUS Subsystem using 0.255.255.
3. The Discovery service found on the Basic Platform Manager JAUS Component responds via broadcast with a ReportIdentification message.
4. The newly attached component receives the broadcast of the ReportIdentification message and uses the JAUS Subsystem ID provided in the source of the ReportIdentification messages as its JAUS Subsystem ID if that JAUS Subsystem ID is not 0 or 65535 (wildcard). If a wildcard Subsystem ID is received, the component shall continue steps 2-4 until a non-wildcard Subsystem ID is received.

4.6.3.1.2 Subsystem ID Propagation Requirement

- V1.JAUS-12 *If the Dynamic Subsystem ID Propagation attribute is selected, the JAUS Subsystem ID of a platform shall be propagated to its payloads and other attached JAUS nodes using the procedure found in the Subsystem ID Propagation Attribute.*
- V1.JAUS-13 *A message sent using a destination JAUS Subsystem ID of 0 shall be logically broadcast at the JAUS Subsystem level, using the Platform multicast address that does not get sent to other Subsystems. A Subsystem ID of 0 shall match any other Subsystem ID for purposes of determining if a message is intended for a particular destination.*
- V1.JAUS-14 *A payload or other attached JAUS Node shall monitor connectivity to its Basic Platform Manager, using any method (i.e. detecting that the unsolicited ReportHeartbeAEPulse message is no longer received). If connectivity is lost for more than the duration specified by the Parameter "Platform Manager Timeout", the payload or other attached JAUS Node shall reset its JAUS Subsystem ID to 0 and follow the procedure to re-acquire a Subsystem ID.*

4.6.3.1.3 Parameter Listing

Parameter Name	Default Value	Valid Values	Description
Platform Manager Timeout	5 seconds	<Range> 1..65535 seconds	Time in seconds after which connectivity to the platform manager is considered lost.

Table 23: - Parameter Listing for Subsystem ID Propagation Attribute

4.6.4 Node ID Assignment

4.6.4.1 Node ID Assignment Attribute

Parent Attribute: ID Assignment and Propagation Attribute

The Node ID Assignment Interoperability Attribute specifies attributes that define methods for assigning unique JAUS IDs to JAUS nodes. JAUS messages are routed from source to destination by a JAUS ID embedded in the JAUS message header. The JAUS ID is composed of three ID fields: The Subsystem ID field, the Node ID field, and the Component ID field.

The following attributes are mutually exclusive, exactly one must be chosen.

Attribute	Description
Static Node ID Assignment Attribute	Defines static assignment of JAUS Node IDs, done at setup / configuration time.
Dynamic Node ID Assignment Attribute	Defines dynamic assignment of JAUS Node IDs, done at run-time.

Table 10: - Mandatory Select = one

4.6.4.2 Static Node ID Assignment Attribute

Parent Attribute: Node ID Assignment Attribute

If the Static Node ID Assignment Attribute is specified, the assignment of unique JAUS node identifiers shall be done at set-up / configuration time. The exact way in which this is done is not specified by this IOP document, but typical methods include through a configuration file or other field-modifiable approach. If the Static attribute Value is selected, a method for ensuring the assignment and maintenance of unique JAUS identifiers must be used.

4.6.4.2.1 Static Node ID Assignment Requirement

V1.JAUS-15 If the Static Node ID Assignment attribute is specified, the assignment of unique JAUS node identifiers shall be done at set-up / configuration time.

4.6.4.3 Dynamic Node ID Assignment Attribute

Parent Attribute: Node ID Assignment Attribute

If the Dynamic Node ID Assignment Attribute is specified, the assignment of unique JAUS node identifiers shall be done using a run-time approach for ID assignment that combines a centralized JAUS Node ID allocator with a look-up table method based on the type of JAUS Node and a location code.

4.6.4.3.1 Procedure

There are two value ranges that apply to Node IDs assigned under the Dynamic Node ID Assignment Attribute of the Node ID Assignment Interoperability Attribute: a the look-up table range and a dynamic range.

The look-up table range is a range of values that can only be assigned using the method specified in ADD-AEODRS-10-0802-CA AEODRS Architecture Description Document, v1.3.1 (Feb 2013). In this range, JAUS Node IDs are assigned based on a starting value and some offset from that starting value. For each range, there is also an end value that defines the maximum offset from the starting value.

The dynamic range is the range of values that can be assigned by a NodeIDAllocator service. In order to prevent conflict with the pseudo-static range of JAUS Node IDs, the NodeIDAllocator service shall not assign any values outside of the Dynamically Assigned range specified in Table 25: Table of Node ID Assignment Ranges below.

Table 25: Table of Node ID Assignment Ranges

Node Type	Range Start	Range End	Max Instances	Comments
Platform / Master CM	0x01	0x01	1	Singleton. This node value represents the node where the platform management services are located (i.e. Discovery).
Power Management / Power System CM	0x02	0x02	1	Singleton. This node value represents the power management node. Currently IOP defines no separate power management node, so this ID is primarily associated with AEODRS.
Mobility / Mobility CM	0x03	0x03	1	Singleton. This node value represents the node where mobility services are present.
Reserved	0x04	0x0F	12	This range is reserved for additional singleton values.
Manipulator / Manipulator CM	0x10	0x1F	16	This range is for nodes that provide manipulator capabilities.
End-Effector / End-Effector CM	0x20	0x2F	16	This range is for nodes that provide end-effector capabilities.
Visual Sensors / Visual Sensors CM	0x30	0x3F	16	This range is for nodes that provide visual sensor (camera) capabilities.
Autonomous Behaviors / Autonomous Behaviors CM	0x40	0x4F	16	This range is for nodes that provide autonomy / behavior capabilities.
Communications	0x50	0x5F	16	This range is for nodes that provide communications capabilities.

Reserved	0x60	0xAF	80	This range is reserved for future node type ranges, using the pseudo-static method of JAUS Node ID Assignment.
Dynamically Assigned	0xB0	0xFE	79	This range is the range of NodeIDs that a NodeIDAllocator can grant, if present.

4.6.4.3.1.1 How the Component Acquires its Node ID

1. Upon startup, at least one JAUS Component on a newly attached JAUS Node that does not yet have a JAUS Node ID registers with its Transport Layer Routing Element as a Type 3 Endpoint. The newly attached JAUS Component then broadcasts a RequestNodeID message to its JAUS Subsystem ([Subsystem ID].255.255). The subsystem ID may be 0 (unassigned) at this point as well, in which case the JAUS component is also a Type 2 Endpoint.
2. If a NodeIDAllocator service is present, the JAUS Component uses the procedure in 4.6.4.3.1.2 Procedure to Acquire Node ID from NodeIDAllocator service, otherwise it falls back on the procedure specified in 4.6.4.3.1.3 Procedure to Acquire Node ID using Look-up Table method. The minimum time a JAUS Component shall attempt to get a response from the NodeIDAllocator is the time defined by the Platform Manager Timeout parameter. The rate at which RequestNodeID messages are sent is implementation specific, but a rate determined according to the description for the Unsolicited Heartbeat Pulse Rate parameter is recommended.

4.6.4.3.1.2 Procedure to Acquire Node ID from NodeIDAllocator service

1. Upon receiving the RequestNodeID message, the NodeIDAllocator Service responds via JAUS Subsystem level broadcast ([SubsystemID].255.[ComponentID]) with a unique Node ID associated with the unique identifier provided in the RequestNodeID message.
2. The newly attached JAUS Component that sent the original RequestNode message receives the GrantNodeID message, verifies that the unique identifiers in the message matches the unique identifiers that it sent, and then sets its JAUS Node ID to the ID provided in the GrantNodeID message.

Other JAUS Components on the newly attached JAUS Node may follow the above procedure, or there may be another implementation specific way to distribute the Node ID to all the other JAUS Components on the newly attached JAUS Node.

4.6.4.3.1.3 Procedure to Acquire Node ID using Look-up Table method

1. The Node retrieves its starting value based on the type of node it is. The JAUS Node ID is determined by adding a location code value as specified in the Payloads IOP to the starting value specified in Table of Node ID Assignment Ranges. If no location code value is available, the default location code value of 0x0F (15) shall be used.

4.6.4.3.2 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:NodeIDAllocator, 1.1	Basic Platform Manager Component (on the Platform Node)	Custom Services, Messages, and Transports

Table 11: - Component and Service Requirements for Dynamic Node ID Assignment Attribute

4.6.4.3.3 Dynamic Node ID Assignment Requirement

- V1.JAUS-16 *The Basic Platform Manager JAUS Component shall guarantee unique JAUS Node ID assignment using the NodeIDAllocator service. If the Basic Platform Manager Component is reset, but comes back online with a valid Subsystem ID before the time specified by "Platform Manager Timeout", it must ensure that it does not assign already in use addresses, either by waiting to send out any messages until the timeout occurs, or assessing what dynamic addresses are already in use.*

- V1.JAUS-17 *All JAUS Components added to a JAUS Subsystem shall act as clients to the NodeIDAllocator service, either directly or through a proxy component on the same node.*

- V1.JAUS-18 *A payload or other attached JAUS Node shall monitor connectivity to its Basic Platform Manager, using any method (i.e. detecting that the unsolicited ReportHeartbeAEPulse message is no longer received). If connectivity is lost for more than the duration specified by the Parameter "Platform Manager Timeout", the payload or other attached JAUS Node shall reset its JAUS Node ID to 0 and follow the procedure to re-acquire a Node ID.*

- V1.JAUS-19 *The minimum time a JAUS Component shall attempt to reach the NodeIDAllocator is the time defined by the Platform Manager Timeout parameter. The rate at which RequestNodeID messages are sent is implementation specific, but a rate determined according to the description for the Unsolicited Heartbeat Pulse Rate parameter is recommended.*

4.6.4.3.3.1 Notes and Interpretations

4.6.4.3.3.1.1 Node ID Allocator

The process of acquiring a JAUS Node ID can be used as an alternative method of propagating the JAUS Subsystem ID as described in 4.6.2.1 Subsystem ID Assignment Attribute.

Message(s)	Concept	Interpretations
ID DB02: RequestNodeID ID FB02: GrantNodeID	Usage of the IP Address and Instance Fields	The IP Address field is used to provide a unique value to associate a RequestNodeID message with. This may either be an IPv4 or Ipv6 value, as described in the Custom Services, Messages, and Transports document. The instance field is used to guarantee a unique ID even if two logical JAUS Nodes are contained on the same IP Address. For example, if two JAUS nodes are on the IP Address 192.168.1.100, then both would use the IP Address as part of the unique identifier, but each would have to use a different value for the Instance field. The way this value is made unique is up to the implementation.
ID FB02: GrantNodeID	Allowable JAUS Node IDs	The JAUS Node IDs granted by the NodeIDAllocator service shall not be outside the range specified in Table 25: Table of Node ID Assignment Ranges.

Table 12: - Message Interpretations for Node ID Allocator

4.7 TRANSPORT SECTION

4.7.1 Transport Attribute

Parent Attribute: Core JAUS Attribute

The Transport Interoperability Attribute specifies multiple options that can be used to define the transport layer or layers that are used for transporting IOP specified JAUS messages between two IOP systems. The transport layer sits between the application layer (i.e. OCU or robot software) and the communications medium (i.e. Internet Protocol, Serial). Three possible values may be selected for the Transport Interoperability Attribute - JUDP, JTCP, and Custom, each of which is defined below. If multiple values are selected, assure that the usage for each is specified (i.e. JUDP is used for command and control messages, JTCP is used for authentication).

At least one of the following attributes must be chosen.

Attribute	Description
JUDP Attribute	Specifies that messages shall be transported using the JAUS over UDP as defined in AS5669A JAUS/SDP Transport Specification. JUDP defines JAUS over User Datagram Protocol, which is a simple connectionless protocol with lower latency than TCP but without guaranteed delivery.

JTCP Attribute	Specifies that messages shall be transported using the JAUS over TCP as defined in AS5669A JAUS/SDP Transport Specification. JTCP defines JAUS over Transmission Control Protocol, which is a connection oriented protocol that provides reliable delivery, but with higher latency than UDP.
Custom Transport Attribute	Specifies that a custom transport defined in the Custom Services, Messages, and Transports IOP document shall be used.

Table 13: - Mandatory Select = any

Any number of the following attributes can be chosen.

Attribute	Description
Off-Board Communications Attribute	The Off-Board Communications Interoperability Attributes define capabilities to deal with communications off-board the platform.

Table 29: - Optional Select = any

4.7.2 JUDP Attribute

Parent Attribute: Transport Attribute

If the JUDP Attribute is selected, the JAUS over UDP (JUDP) transport as defined in AS5669A JAUS/SDP Transport Specification shall be used for transport of messages. If selected, the type of broadcast used must be specified using the Broadcast Type Parameter. The valid values for Broadcast Type are Multicast (using UDP Multicast to perform a JAUS broadcast) or Broadcast (using UDP Broadcast to perform a JAUS broadcast). If the Multicast value for the Broadcast Type Parameter is used, then another parameter, Multicast Address (default = as specified in AS5669A JAUS/SDP Transport Specification), must provide a valid Multicast address that will be used as the default broadcast address for JAUS messages. Additional multicast addresses may be used to better scope logical JAUS broadcasts, but those are not defined in this document.

An IP Address Assignment List Method Parameter shall also be defined when using the JUDP Value. The IP Address Assignment List Method specifies how the IP Address Assignment List is made available between Transport Layer Routing elements (see Key Concepts and Information: Definitions). One IP address may be associated with multiple JAUS IDs (i.e. two components on one node associated with one IP address). The two valid methods for providing the IP Address Assignment List Method include the Static and Dynamic parameter values. When using the Static parameter value, every Transport Layer Routing element shall have access to a pre-configured listing of JAUS address to IP address mappings - this can be done in any way desired such as from a file or database. When using the Dynamic parameter value, every Transport Layer Routing element shall dynamically build the list of JAUS Address to IP Address mappings. This shall be done by broadcasting messages for JAUS addresses not yet known, and adding to the list for any responses from previously unknown JAUS addresses.

4.7.2.1 JUDP Transport Requirement

- V1.JAUS-20 *If the JUDP Attribute is selected, the JAUS over UDP (JUDP) transport as defined in AS5669A JAUS/SDP Transport Specification shall be used for transport of messages.*

- V1.JAUS-21 *If selected, the type of broadcast used shall be specified using the [parameter] BroadcastType (Default = multicast).*

- V1.JAUS-22 *If the Multicast value for the BroadcastType parameter is used, then another [parameter] MulticastAddress (default = as specified in AS5669A JAUS/SDP Transport Specification) shall provide a valid Multicast address that will be used the default logical broadcast address. Logical broadcast to all subsystem, nodes, and components must be supported on this address.*

- V1.JAUS-23 *The port 3794 shall be used for all broadcast messages and all JAUS Components should expect to receive messages on this port.*

- V1.JAUS-24 *A [parameter] IP Address Assignment List Method (default = dynamic) shall also be defined when using the JUDP Value.*

- V1.JAUS-25 *When using the Dynamic parameter value of the [parameter] IP Address Assignment List Method, every Transport Layer Routing element shall dynamically build the list of JAUS Address to IP Address mappings. This shall be done by broadcasting messages for JAUS addresses not yet known, and adding to the list for any responses from previously unknown JAUS addresses.*

4.7.2.1.1 Parameter Listing

Parameter Name	Default Value	Allowed Values	Description
Broadcast Type	Multicast	<Enumeration>	Specifies how a logical JAUS broadcast shall be implemented.
		Multicast	Uses UDP Multicast to perform a logical JAUS broadcast.
		Broadcast	Uses UDP Broadcast to perform a logical JAUS broadcast.
Multicast Address	239.255.0.1	239.255.0.1	Specifies the default multicast address used to implement JUDP broadcast semantics.

IP Address Assignment List Method	Dynamic	<i><Enumeration></i>	Specifies how the IP Address Assignment List is made available between Transport Layer Routing elements.
		Dynamic	When using the Dynamic parameter value, every Transport Layer Routing element shall dynamically build the list of JAUS Address to IP Address mappings. This shall be done by broadcasting messages for JAUS addresses not yet known, and adding to the list for any responses from previously unknown JAUS addresses.
		Static	When using the Static parameter value, every Transport Layer Routing element shall have access to a pre-configured listing of JAUS address to IP address mappings - this can be done in any way desired such as from a file or database.

Table 30: - Parameter Listing for JUDP Attribute

4.7.3 JTCP Attribute

Parent Attribute: Transport Attribute

If the JTCP Attribute is selected, then JAUS over TCP (JTCP) transport as defined in AS5669A JAUS/SDP Transport Specification shall be used for transport of messages.

The port 3794 shall be used as the TCP/IP well known port and all JAUS Components should expect to receive messages on this port. Note that JAUS traffic is not limited to this port. As per SAE AS-5669A, JAUS components may send messages from any port, so long as they can also receive on the same port. This allows a component to negotiate a private port during discovery.

The Static value for the IP Address Assignment List Method (default = none) shall be used when using the JTCP Value, as specified in 4.7.2 JUDP Attribute.

4.7.3.1 JTCP Transport Requirement

V1.JAUS-26 If the JTCP Value is selected, then JAUS over TCP (JTCP) transport as defined in AS5669A JAUS/SDP Transport Specification shall be used for transport of messages.

V1.JAUS-27 *The port 3794 shall be used as the TCP/IP well known port and all JAUS Components should expect to receive messages on this port.*

V1.JAUS-28 *The Static value for the [parameter] IP Address Assignment List Method (default = none) shall be used when using the JTCP transport.*

4.7.4 Custom Transport Attribute

Parent Attribute: Transport Attribute

If the Custom Transport Attribute is selected, a custom transport as defined in the Custom Services, Messages, and Transports IOP document shall be used. The specific transport being used defined in the Custom Services, Messages, and Transports IOP document may be specified.

4.7.5 Off-Board Communications Attribute

Parent Attribute: Transport Attribute

The Off-Board Communications Interoperability Attributes define capabilities to deal with communications off-board the platform. This is typically through a communications link such as a radio, but may include other forms of communications. The following communications Interoperability Attributes are defined:

The following attributes are mandatory.

Attribute	Description
Communicator Attribute	Defines a capability to interact with a communications device, such as a radio, including configuring it.

Table 31: - Mandatory Select = all

4.7.6 Communicator Attribute

Parent Attribute: Off-Board Communications Attribute

If selected, the Communicator Interoperability Attribute provides a mechanism for run-time configuration and monitoring of a communication link, usually a radio, through a Communicator service. Multiple instances of the Communicator attribute may be specified, with each instance corresponding to a single communication link.

4.7.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:Communicator, 1.2		Custom Services, Messages, and Transports

Table 32: - Component and Service Requirements for Communicator Attribute

4.7.6.2 Communicator Requirement

4.7.6.2.1 Notes and Interpretations

Note that in some implementations, determining the signal quality between nodes in a mesh network may require active testing between the radios. This may cause a delay in the signal quality information being available, and may negatively impact communications performance. In these cases, clients are encouraged to limit the rate of health updates to balance performance needs.

4.8 COMPONENT LIVENESS ATTRIBUTE

Parent Attribute: Core JAUS Attribute

The Component Liveness Interoperability Attribute defines how the urn:jaus:jss:core:liveness JAUS service is used to maintain connection liveness between a JAUS component and a client. The Liveness service shall be the default way that a client maintains connectivity to a server component (a component that provides services for use). If specifically defined by another Interoperability Attribute, receiving regular, periodic messages from another service other than Liveness may be used to maintain connectivity to a server component.

4.8.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:core:Liveness, 1.1	all	AS5710A JAUS Core Service Set

Table 33: - Component and Service Requirements for Component Liveness Attribute

4.8.2 Liveness Requirement

All JAUS components that act as server components are required to provide the urn:jaus:jss:core:Liveness service.

V1.JAUS-29 The Liveness service shall be the default way that a client maintains connectivity to a server component (a component that provides services for use). If specifically defined by another Interoperability Attribute, receiving regular, periodic messages from another service other than Liveness may be used to maintain connectivity to a server component.

V1.JAUS-30 The Platform Manager JAUS component's Liveness service shall be used to maintain liveness from client subsystems (such as an OCU).

V1.JAUS-31 *Every JAUS component providing component liveness through the Liveness service shall support periodic event for the ReportHeartbeAEPulse message based on the rate specified by the Heartbeat Rate parameter.*

4.8.2.1 Periodicity

4.8.2.1.1 Liveness

Every JAUS component providing component liveness through the Liveness service shall support periodic event for the ReportHeartbeAEPulse message based on the rate specified in Heartbeat Rate Parameter. A value of 0 provided for the HeartbeatRate parameter indicates that periodic events do not need to be supported (i.e. polling for ReportHeartbeAEPulse by sending periodic QueryHeartbeAEPulse messages from a client).

4.8.2.2 Parameter Listing

Parameter Name	Default Value	Allowed Values	Description
Heartbeat Rate	1 Hertz	<Range> 0..65535 Hertz	Specifies the minimum rate a periodic event for requesting a ReportHeartbeAEPulse messages shall be supported at, in Hz. A value of 0 provided for the HeartbeatRate parameter indicates that periodic events do not need to be supported.

Table 34: - Parameter Listing for Component Liveness Attribute

CHAPTER 5 GLOBAL ATTRIBUTE SECTION

Global Interoperability Attributes are attributes that do not fall into any other specific category.

5.1 GLOBAL ATTRIBUTE

Parent Attribute: Core Software and Logical Attribute

Global Interoperability Attributes do not tightly fit into a single attribute group or are likely to be used in conjunction with many different Interoperability Attributes.

Global Interoperability Attributes can be applied across more than one attribute category. For example, a Global Pose Sensor might be added to a JAUS component on the Platform JAUS node for an IMU integrated on the platform, or could be added to a JAUS component of a complex payload to represent an IMU that comes with an autonomy package.

Any number of the following attributes can be chosen.

Attribute	Description
Pose And Attitude Attribute	Adds ability to view/ report the pose and attitude of a platform. Many other capabilities are built upon this information.
Power Plant Management Attribute	Provides the ability to get information from and manage a power plant, which may be batteries, a gasoline engine, a diesel engine, or a hydraulic/pneumatic system.
Preset Pose Attribute	Provides the ability to get information on available preset poses that a platform or payload has, and to command that platform or payload to go to one of those preset poses (i.e. a "Stow" pose for storing a system).
Render Useless Attribute	Defines the capability to render a platform, payload, or other device useless.
Tamper Detection Attribute	Defines the capability to report on when tampering has occurred.
Odometry Attribute	Defines on distance travelled and provides the ability to set trip meters.
Health Attribute	Provides for summary reports and detailed reports of JAUS subsystem, node, and component health, providing reporting to the level of service health to the level of sensors and actuators.
Obstacle Reporting Attribute	Provides a way to report obstacles and hazardous terrain using an overhead 2D cost map.
Physical Specification Attribute	Provides a mechanism for describing the physical characteristics of a node, and any associated mounting sites for child nodes.

Data Logging Attribute	Provides the ability to control and receive feedback from one or more loggers.
Software Version Reporting Attribute	Provides the ability for a JAUS component to describe the software packages, shared libraries, scripts, etc. installed on it.
Uninterrupted Power Supply Attribute	In cases of sudden loss of power, the UPS capability affords the system the ability to shut down without loss of data, or causing damage to any part of the system.

Table 14: - Optional Select = any

5.2 POSE AND ATTITUDE ATTRIBUTES

The Pose and Attitude attributes include basic and advanced pose reporting attributes.

5.2.1 Pose And Attitude Attribute

Parent Attribute: Global Attribute

The Pose And Attitude Attribute provides the capability to view/ report the pose and attitude of a platform. Many other capabilities are built upon this information.

At least one of the following attributes must be chosen.

Attribute	Description
Basic Global Position and Attitude Attribute	Defines the capability to report Basic Global Position and Attitude.
Basic Local Position and Attitude Attribute	Defines the capability to report Basic Local Position and Attitude.
Path Reporting Attribute	Defines the capability to access the historical (previous) local and global positions of the platform.

Table 15: - Mandatory Select = any

5.2.2 Basic Global Position and Attitude Attribute

Parent Attribute: Pose And Attitude Attribute

The Basic Global Position and Attitude Interoperability Attribute allows the addition of a global positioning sensing capability to an Interoperability Attribute. This global position is typically obtained from a Global Positioning Sensor (GPS), but may also be a combination of multiple sensor modalities that lead to a global pose referenced using WGS 84.

5.2.2.1 Component and Service Requirements

Service	Component	Reference
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urn:jaus:jss:mobility:GlobalPoseSensor, 1.1	AS6009 JAUS Mobility Service Set
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Table 16: - Component and Service Requirements for Basic Global Position and Attitude Attribute

5.2.2.2 Basic Global Position and Attitude Requirement

5.2.2.2.1 Periodicity

5.2.2.2.1.1 Global Pose Sensor

ID 4402: ReportGlobalPose – **[Parameter] Global Pose Report Rate**(Default = 1 Hz) – The Global Pose Report Rate parameter defines the minimum rate at which the Global Pose Sensor must be able to send Report Global Pose messages, either through a periodic Event (urn:jaus:jss:core:events) or by responding to regularly sent QueryGlobalPose messages. This parameter should be defined to allow for safe operation of the platform.

5.2.2.3 Parameter Listing

Parameter Name	Default Value	Valid Values	Description
Global Pose Report Rate	1 Hertz	<Range> 0..65535 Hertz	The Global Pose Report Rate parameter defines the minimum rate (Hz) at which the Global Pose Sensor must be able to send Report Global Pose messages, either through a periodic Event (urn:jaus:jss:core:events) or by responding to regularly sent QueryGlobalPose messages. This parameter should be defined to allow for safe operation of the platform. A value of 0 indicates there is no defined rate.

Table 38: - Parameter Listing for Basic Global Position and Attitude Attribute

5.2.3 Basic Local Position and Attitude Attribute

Parent Attribute: Pose And Attitude Attribute

The Basic Local Position and Attitude Interoperability Attribute allows the addition of a local positioning sensing capability to an Interoperability Attribute. This local position is usually referenced to a (0, 0) starting point of the platform, and updated utilizing sensor such as wheel encoders, IMUs, etc.

5.2.3.1 Component and Service Requirements

Service	Component	Reference
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urn:jaus:jss:mobility:LocalPoseSensor, 1.1	AS6009 JAUS Mobility Service Set
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Table 17: - Component and Service Requirements for Basic Local Position and Attitude Attribute

5.2.3.2 Basic Local Position and Attitude Requirement

5.2.3.2.1 Periodicity

5.2.3.2.1.1 Local Pose Sensor

ID 4403: ReportLocalPose – **[Parameter] Local Pose Report Rate**(Default = 1 Hz) – The Local Pose Report Rate parameter defines the minimum rate at which the Local Pose Sensor must be able to send Report Local Pose messages, either through a periodic Event (urn:jaus:jss:core:events) or by responding to regularly sent QueryLocalPose messages. This parameter should be defined to allow for safe operation of the platform.

5.2.3.3 Parameter Listing

Parameter Name	Default Value	Valid Values	Description
Local Pose Report Rate	1 Hertz	<Range> 0..65535 Hertz	The Local Pose Report Rate parameter defines the minimum rate at which the Local Pose Sensor must be able to send Report Local Pose messages, either through a periodic Event (urn:jaus:jss:core:events) or by responding to regularly sent QueryLocalPose messages. This parameter should be defined to allow for safe operation of the platform.

Table 40: - Parameter Listing for Basic Local Position and Attitude Attribute

5.2.4 Path Reporting Attribute

Parent Attribute: Pose And Attitude Attribute

At least one of the following attributes must be chosen.

Attribute	Description
Local Path Reporting Attribute	Defines the capability to access the historical (previous) local positions of the platform.
Global Path Reporting Attribute	Defines the capability to access the historical (previous) global positions of the platform.

Table 41: - Mandatory Select = any

5.2.5 Local Path Reporting Attribute

Parent Attribute: Path Reporting Attribute

The Local Path Reporting Attribute augments the basic local position support to also allow access to the historical (previous) positions of the platform.

5.2.5.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:behaviors:PathReporter, 1.1		AS8024 JAUS Autonomous Behaviors Service Set

Table 42: - Component and Service Requirements for Local Path Reporting Attribute

5.2.5.2 Local Path Reporting Requirement

V1.JAUS- 32 *The Path Reporter implementation shall support, at a minimum, PathType::HistoricalLocalPath.*

5.2.6 Global Path Reporting Attribute

Parent Attribute: Path Reporting Attribute

The Global Path Reporting Attribute augments the basic Global position support to also allow access to the historical (previous) positions of the platform.

5.2.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:behaviors:PathReporter, 1.1		AS8024 JAUS Autonomous Behaviors Service Set

Table 43: - Component and Service Requirements for Global Path Reporting Attribute

5.2.6.2 Global Path Reporting Requirement

V1.JAUS- 33 *The Path Reporter implementation shall support, at a minimum, PathType::HistoricalGlobalPath.*

5.3 POWER PLANT MANAGEMENT ATTRIBUTE

Parent Attribute: Global Attribute

The Power Plant Management Interoperability Attribute provides a way to query status of and control power plants. Four types of power plants are supported: batteries, diesel engines, gasoline engines, and hydraulic/pneumatic systems. For each of these four types, the capabilities can be reported and the configuration (how the power plant is currently configured) can be reported and changed.

5.3.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:ugv:PowerPlantManager, 1.0	any	AS6091 JAUS UGV Service Set

Table 44: - Component and Service Requirements for Power Plant Management Attribute

5.3.2 Power Plant Management Requirement

5.3.2.1 Notes and Interpretations

5.3.2.1.1 Power Plant Manager

Message(s)	Concept	Interpretations
ID 4508: ReportPowerPlantStatus	Reporting Types	Only the record or records that apply to the power plant capabilities of the vehicle shall be used when sending a ReportPowerPlantStatus message. For example, if a vehicle with a diesel engine and battery is reporting information, it shall provide the battery status and dieselEngineStatus records, and not the gasolineEngineStatus record. Hydraulic state and fuelCellState have been added for power plants that support those specific types.
ID 4506: ReportPowerPlantConfiguration	Reporting Types	For reporting engine RPM, the record corresponding to the type of engine (either gasEngineState for a gasoline engine or dieselEngineState for a diesel engine) shall be used. Hydraulic state and fuelCellState have been added for power plants that support those specific types.
ID 0506: SetPowerPlantConfiguration ID 2506: QueryPowerPlantConfiguration ID 2507: QueryPowerPlantCapabilities ID 2508: QueryPowerPlantStatus ID 4506: ReportPowerPlantConfiguration ID 4507: ReportPowerPlantCapabilities ID 4508: ReportPowerPlantStatus	Usage	For pneumatic (air) based power plants, the implementation should use the hydraulic variant in all messages. However, the description field in ReportPowerPlantCapabilities must specify that the system is actually pneumatic.

Table 45: - Message Interpretations for Power Plant Manager

5.3.2.2 Periodicity

5.3.2.2.1 Power Plant Manager

Message(s)	Rate
ID 2506: QueryPowerPlantConfiguration	5.0 Hz (Recommended)
ID 2508: QueryPowerPlantStatus	5.0 Hz (Recommended)

Table 18: - Periodicity Information for Power Plant Manager

5.4 PRESET POSE ATTRIBUTE

Parent Attribute: Global Attribute

The Preset Pose Interoperability Attribute provides a way to command preset poses and get information on the preset poses that a platform supports. Preset poses are defined as a known configuration of platform actuators and manipulators (to included flippers) that represent a single logical pose i.e. a Stow pose might have all platform manipulators hugging the platform to reduce its volumetric footprint to the greatest extent possible for stowage.

5.4.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:PresetPose, 1.2	any	RAS-G IOP Custom Services, Messages, and Transports

Table 19: - Component and Service Requirements for Preset Pose Attribute

5.4.2 Preset Pose Requirement

V1.JAUS-34 Manipulator poses shall be referenced in accordance with section 3.5 Manipulator Linkage Notation of AS6057A JAUS Manipulator Service Set.

V1.JAUS-35 Flipper poses shall be referenced in accordance with AS6091 JAUS UGV Service set.

5.4.2.1 Notes and Interpretations

The Preset Pose service is used to set and query/report preset poses for a platform, where a pose refers to a particular orientation and position of various actuators, flippers, and manipulators. Preset Pose has been updated for this version of the IOP to add more advanced capabilities, which are documented in the following table and the Custom Services Messages, and Transports IOP document.

5.4.2.1.1 Preset Pose

Message(s)	Concept	Interpretations
ID F004: SetCurrentPose	Usage	Sending a SetCurrentPose message does not guarantee success - one must wait for a ReportTransitionCompleted message to get information on the status of the transition to a new current pose.
ID F001: QueryPresetPoseCapabilities ID F004: SetCurrentPose ID F0F1: ReportPresetPoseCapabilities	Usage	The reported preset poses are the only ones the platform shall support transition to. Pose change requests to poses that the platform does not support shall be responded to with a negative acknowledgement.
ID F0F4: ReportTransitionCompleted ID F004: SetCurrentPose	Handling of Transitions	ReportTransitionCompleted is the only message that is not directly solicited by a query message - it is sent when a transition on the side that received a SetCurrentPose message is completed, either succeeding, failing, or timing out. The server receiving a SetCurrentPose message is responsible for handling transition timeouts since it knows how long the transition should take - the server shall send a ReportTransitionCompleted with status of TRANSITION_TIMED_OUT.

Table 20: - Message Interpretations for Preset Pose

5.4.2.2 Periodicity

5.4.2.2.1 Preset Pose

Message(s)	Rate
ID FF02: QueryCurrentPose	5.0 Hz (Recommended)

Table 49: - Periodicity Information for Preset Pose

5.5 RENDER USELESS ATTRIBUTE

Parent Attribute: Global Attribute

Rendering a sub-system (i.e. platform/other) useless is a final state for the sub-system. In other words, the sub-system is non-recoverable without physically retrieving it. Along these lines, the acquisition program should mandate the policies on how the render useless mechanism is engaged. For instance, one program may mandate multiple user authentications in order to engage the render useless mechanism. Additionally, the acquisition program should also dictate what mechanisms (i.e. software, hardware, or a combination thereof) are being engaged by the render useless controls provided by the Controller.

An acquisition program may optionally specify the location of an authentication server to establish the authorization of a client to engage render useless functionality.

Since rendering a sub-system useless is essentially a final state of the platform, status information back to the controller is not guaranteed without correct systems design, and any signals sent to the sub-system or received from the sub-system are not guaranteed to work as predicted.

5.5.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:RenderUseless, 1.2		Custom Services, Messages, and Transports

Table 50: - Component and Service Requirements for Render Useless Attribute

5.5.2 Render Useless Requirement

5.5.2.1 Notes and Interpretations

Render useless provides a mechanism to destroy, disable, or in some way make a component, node, or subsystem less valuable if it were to be captured by an adversary. The specific mechanism is left to the implementation, but may include electronic overload, explosives, or erasing computer storage devices. Also depending on implementation, the component may or may not be usable following a render useless command.

5.6 TAMPER DETECTION ATTRIBUTE

Parent Attribute: Global Attribute

Tamper Detection can be provided for by a number of means utilizing a combination of hardware and software. Adding this capability will provide a mechanism for reporting on when tampering has occurred.

5.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:TamperDetection, 1.1		Custom Services, Messages, and Transports

Table 21: - Component and Service Requirements for Tamper Detection Attribute

5.6.2 Tamper Detection Requirement

V1.JAUS-36 *All sub-systems shall incorporate an authentication means for verifying that a trusted device has been attached.*

5.6.2.1 Notes and Interpretations

Tamper detection provides only the messages required to report on tampering in an interoperable way – the method of detecting when tampering has occurred is up to the implementation.

5.7 ODOMETRY ATTRIBUTE

Parent Attribute: Global Attribute

Provides a way to report and configure platform odometry. Platform odometry provides high level odometry information such as distance travelled overall and allows for the configuration of trip meters that provide distance travelled since the beginning of a trip. This attribute is most logically associated with the Platform or Mobility capabilities of a platform, but could also be measured by something like a payload.

5.7.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:ugv:OdometryService, 1.0		AS6091 JAUS UGV Service Set

Table 52: - Component and Service Requirements for Odometry Attribute

5.7.2 Odometry Requirement

5.7.2.1 Notes and Interpretations

5.7.2.1.1 Odometry

Message(s)	Concept	Interpretations
ID 0515: QueryOdometry	Usage	A value of PLATFORM for the OdometryType shall be used to request the distance traveled by the platform since it began service. A value of TRIP_A shall be used to query the distance traveled on the current trip. The current trip starts whenever an external entity, such as an OCU, issues a ResetOdometry message with a value of TRIP_A.
ID 4516: ResetOdometry	Usage	This message shall be used with a value of TRIP_A to start a new trip.

Table 53: - Message Interpretations for Odometry

5.8 HEALTH ATTRIBUTE

Parent Attribute: Global Attribute

The Health Interoperability Attributes provide for summary reports and detailed reports of JAUS subsystem, node, and component health, providing reporting to the level of service health to the level of sensors and actuators.

Any number of the following attributes can be chosen.

Attribute	Description
Health Reporter Attribute	Adds low level health reporting capabilities, tied into built in tests (BIT).

Table 522: - Optional Select = any

5.9 HEALTH REPORTER ATTRIBUTE

Parent Attribute: Health Attribute

The Health Reporter Interoperability Attribute defines a Health Reporter service that is used to perform built-in test (BIT) operations at Power-On and subsets of built-in-test in the background during runtime (RBIT) and when requested via command message (CBIT). The Health Reporter service maintains a record of the most current BIT results, and provides the most current BIT results when requested by a client or configured event. When the Health Reporter Attribute is specified for a JAUS component, that JAUS component shall provide a Health Reporter service that collects and reports on component health information.

5.9.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:exp:aeodrs:HealthReporter, 1.4		Custom Services, Messages, and Transports

Table 23: - Component and Service Requirements for Health Reporter Attribute

5.9.2 Health Reporter Requirement

5.9.2.1 Notes and Interpretations

There is typically one Health Reporter per JAUS Node (i.e. a payload). If using more than one Health Reporter service on a Node, care must be taken to make sure that two Health Reporter services do not report for the same components.

5.9.2.1.1 Service Functionality

The Health Reporter service implementation initiates built-in test (BIT) operations at Power-On (PBIT), and subsets of built-in-test in the background during runtime (RBIT) and when requested via command message (CBIT). The Health Reporter implementation should maintain the most current BIT results, and provide reports of BIT results. The two reports that should be provided are a detailed report providing a status record for each Service provided by each JAUS Component within the JAUS Node, and a summary report providing the status of each JAUS Component. The Health Reporter should provide maintenance reminder timers as well, with support for up to 16 maintenance timers per Health Reporter instance.

5.9.2.1.2 Built-in-Test

The Health Reporter service reports the results of three types of built-in test, and initiates performance of the Commanded Built-In Test. The three types of test are:

1. Power-On Built-In Test (PBIT)
2. Runtime Built-In Test (RBIT)
3. Commanded Built-In Test (CBIT)

General descriptions of these three types of built-in test (BIT) and their general requirements are provided in the paragraphs below.

5.9.2.1.2.1 Power-On Built-In Test (PBIT)

The Power-On Built-In Test (PBIT) takes place during a node's power-on sequence. The PBIT suite consists of tests of program storage, RAM, processor, and interface peripherals, similar to those performed by the Power-On Self-Test (POST) suite included in most embedded PC BIOS implementations. Typical interface peripheral testing includes internal loopback testing of data communications peripherals. In addition, the PBIT suite includes testing of peripherals, interfaces, and dedicated sensors and actuators specific to each node. PBIT tests may be data-destructive. This is distinct from RBIT tests, which must preserve data and assure uninterrupted operation of the system without noticeable impact on system performance, and CBIT tests, which may impact system performance but must preserve data.

5.9.2.1.2.2 Runtime Built-In-Test (RBIT)

Runtime Built-In-Test (RBIT) is conducted periodically as a background activity during normal operation of the system. RBIT testing must preserve data and assure uninterrupted system operation with no noticeable impact on system performance. RBIT testing typically consists of an incrementally-executed data-preserving subset of PBIT testing. RBIT testing conceptually includes operational health reporting for sensors and actuators, although sensor and actuator health reporting is generally embedded in normal runtime sensor/actuator control code.

5.9.2.1.2.3 Commanded Built-In-Test (CBIT)

Commanded Built-In-Test (CBIT) is conducted only on operator command, and is not intended to be run during normal operation of the system. CBIT testing must preserve data, but may briefly interrupt system operation, and cannot be initiated until the system has entered a safe (non-moving, effectors-denied) state. CBIT is intended for troubleshooting and maintenance purposes, and is not intended to be used or available for use when the UGV is downrange.

5.9.2.1.2.4 Maintenance Reminders

The Health Reporter implementation service supports the use of multiple maintenance reminder timers. Service intervals are defined as power-on (operation) time since last service. Note that this requires that needed maintenance reminders be defined and named, and their service intervals defined.

5.10 MESSAGE FILTER ATTRIBUTE

Parent Attribute: Global Attribute

The Message Filter Interoperability Attribute provides a way to filter a message through an intermediary component before it is passed onto its final endpoint component. This filter component can choose to modify the contents of the message before it is sent to the final destination, or may pass it through unchanged. Examples of using this capability include filtering motion causing messages to perform behaviors like self-collision avoidance.

5.10.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:PassthroughMessage, 1.0		Custom Services, Messages, and Transports

Table 24: - Component and Service Requirements for Message Filter Attribute

5.10.2 Message Filter Requirement

V1.JAUS-37 If a specific target and message pair is not supported by a filtering component, the filtering component shall NOT pass that message onto the specified destination.

V1.JAUS-38 Any component implementing the PassthroughMessage service shall report all mapped components (components for which it filters). Reporting of mapped components shall be done using notes and interpretations guidance for the ReportPassthroughMessageProperties message.

V1.JAUS-39 The Management state (for the urn:jaus:jss:core:Management service) of a filtering component shall attempt to propagate Management state changes through to its mapped components.

5.10.2.1 Notes and Interpretations

5.10.2.1.1 Definition of Filtering and Mapped Components

1. A **filtering component** is a JAUS Component that hosts a PassthroughMessage service. The filtering component takes in desired commands destined for another component using the SetPassthroughMessage, and then sends the encapsulated command onto its final destination after possibly applying filtering.
2. A **mapped component** is a JAUS Component that receives filtered messages from a filtering component. A mapped component will receive command from a filtering component that may be modified based on higher level behaviors such as self-collision avoidance.

The figure below shows a simple example of the use of filtering and mapped components for centralized self-collision avoidance. In this example, there are two manipulators nodes on the platform, node IDs 64 and 222. These nodes each contain a JAUS component that provide primitive manipulator and manipulator joint position sensor services, but do not provide their own self-collision avoidance behavior. JAUS Node 3 (the "Self-Collision Avoidance" node) resides on the platform, and contains a JAU Component (ID = 1) providing the PassthroughMessage service that is responsible for using feedback from each manipulator payload to make sure the manipulators do not collide with each other or the platform. Using a QueryPassthroughProperties message, the issuing OCU is able to identify component 100.3.1 as a filtering component which filters for the purpose of self-collision avoidance, and supports filtering to the mapped components 100.64.2 and 100.222.2. The OCU is then able to send encapsulated manipulator control messages (SetManipulatorJointEffort) to each manipulator using a SetPassthroughMessage sent to the PassthroughMessage service on the filtering component 100.3.1.

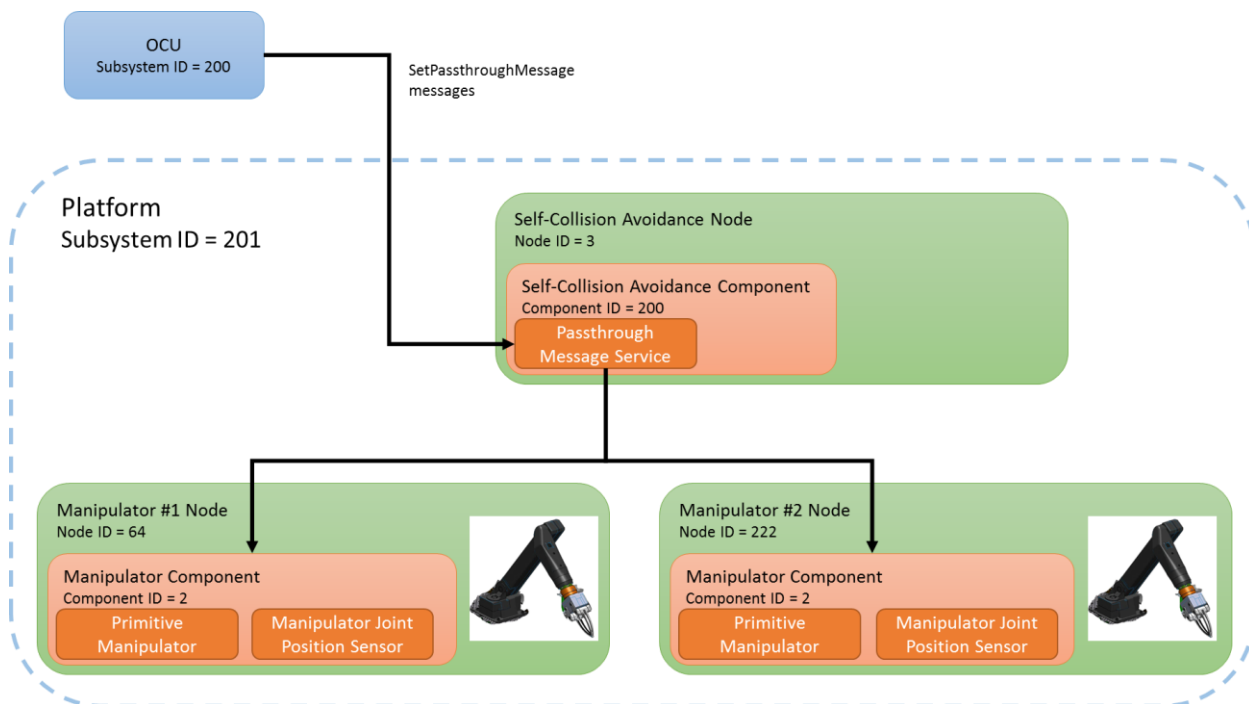


Figure 4: Example of Filtering and Mapped Components

5.10.2.1.2 Access Control and Control of Mapped Components

Filtering components must take control of their mapped components and put them into the Management::Ready state in order to properly filter commands coming from a client like an OCU (and to actually properly use the mapped components). The exact implementation of access control policies with regards to filtering capabilities is not mandated by the IOP, but the following guidelines are recommended when implementing a specific policy:

1. If you want to guarantee a filtering capability cannot be turned off by a client (i.e. an operator connecting with an OCU that is in the highest valid authority range defined by the PRIMARY_OPERATOR role), you should set the authority of the filtering components to be in authority code range defined by the SAFETY_CRITICAL role (see 4.3.2 Authority Code Organization Requirement). If you ONLY want filtering components to control a specific mapped component, then the default authority of any mapped components should be set to the lowest value in the SAFETY_CRITICAL authority code range to ensure that clients with authority less than SAFETY_CRITICAL are not able to directly take control.
2. If the filtering capability is set to do nothing, but the filtering components still have control of the mapped components, the filtering components should pass on any command they receive to the mapped components unchanged.
3. Whenever a filtering component is actively filtering actions/messages, that filtering component should have control of its mapped components.

5.10.2.1.3 Setup

1. A-priori knowledge of payload JAUS addresses (for example if static addresses are used) may be used to configure the PassthroughMessage service.
2. A system may also dynamically create filtering links and fill out the underlying information for the PassthroughMessage service based on discovered moving payloads (nodes that contain components with management services) and any data provided by supporting services.

5.10.2.1.4 Management of Filtering and Mapped Components

A filtering component must be in the Management Ready state before it will pass a filtered message through to the destination mapped component. In order to maintain consistency between the filtering and mapped component, the filtering component must change the management state of a mapped component it controls whenever the management state of the filtering component is changed. For example, if a client, which already has control of the filtering component, changes the filtering component from the STANDBY state to the READY state, the filtering component should send a Resume message to the mapped component, and ensure that the mapped component successfully transitioned to the READY state.

5.10.2.1.5 Passthrough Message

Message(s)	Concept	Interpretations
ID D703: ReportPassthroughMessageProperties	Mapped Component List	All components for which filtering is supported shall be included in the MappedComponentList. Components not in this list are not valid targets of the filtering component.

ID D703: ReportPassthroughMessageProperties	Reporting mapped components	For any component providing the PassthroughMessage service, it reports all components for which it supports passing through messages using the ReportPassthroughMessageProperties message. This message contains a list called MappedComponentList which contains an entry for the JAUS address of every mapped component. For any component not reported as a mapped component, filtered messages sent through the PassthroughMessageService will not be passed on.
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Table 57: - Message Interpretations for Passthrough Message

5.10.2.2 Periodicity

5.10.2.2.1 Passthrough Message

When passing through messages to mapped components, a component implementing the PassthroughMessage service should try to match the rate of receive SetPassthroughMessages received as closely as possible. This is to maintain the periodicity requirements for any services and messages that are mapped. This statement may not apply in cases where the component implementing the passthrough message is designed to take corrective actions like receiving an inconsistent message rate from an OCU and ensuring a consistent rate to the filtered component.

5.11 OBSTACLE REPORTING ATTRIBUTE

Parent Attribute: Global Attribute

The Obstacle Reporting Interoperability Attribute provides a way to report obstacles and hazardous terrain using an overhead 2D cost map.

5.11.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:behaviors:CostMap2D, 1.1		AS8024 JAUS Autonomous Behaviors Service Set

Table 58: - Component and Service Requirements for Obstacle Reporting Attribute

5.11.2 Obstacle Reporting Requirement

5.11.2.1 Notes and Interpretations

An IOP instantiation may elect to specify which Cost Variant is used for reporting the cost map data.

5.12 PHYSICAL SPECIFICATION ATTRIBUTE

Parent Attribute: Global Attribute

The Physical Specification Interoperability Attribute provides a mechanism for describing the physical and power characteristics of a node.

5.12.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:exp:aeodrs:ComponentPhysicalProperties, 1.1		Custom Services, Messages, and Transports
urn:jaus:jss:exp:aeodrs:MountSiteProperties, 1.1		Custom Services, Messages, and Transports

[Table 59: - Component and Service Requirements for Physical Specification Attribute](#)

5.13 DATA LOGGING ATTRIBUTE

Parent Attribute: Global Attribute

The Data Logging attribute provides the ability to control and receive feedback from one or more loggers that have been implemented within a component.

5.13.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:DataLogging, 2.0		Custom Services, Messages, and Transports

[Table 60: - Component and Service Requirements for Data Logging Attribute](#)

5.13.2 Data Logging Requirement

V1.JAUS-40 When the Data Logging Attribute is specified for a JAUS component, that JAUS component shall provide a Data Logging service that interfaces to the data logging implementation(s) on that component.

5.13.2.1 Notes and Interpretations

5.13.2.1.1 Data Logging

Logging Level

- UNKNOWN: Message that should always be logged but may not fit within the other log categories.
- CRITICAL: Condition leading to an irrecoverable failure within the system, i.e. will most likely cause the system to crash.
- ERROR: Condition leading to a failure within the system. The failure is one that can be recovered from.
- WARNING: Indicates anything that could cause a potential problem. For example, a configuration setting that is not set and therefore defaults to some predefined value.
- INFORMATION: Useful information about the system. E.g. configuration information which may be used for debugging or just as status information.
- DEBUG: Information that is diagnostically helpful to system designers

5.14 SOFTWARE VERSION REPORTING ATTRIBUTE

Parent Attribute: Global Attribute

The Software Version Reporting Interoperability Attribute provides the ability for a JAUS component to describe the software packages, shared libraries, scripts, etc. installed on it.

5.14.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:SoftwareVersionReporting, 1.1		Custom Services, Messages, and Transports

Table 61: - Component and Service Requirements for Software Version Reporting Attribute

5.15 UNINTERRUPTED POWER SUPPLY ATTRIBUTE

Parent Attribute: Global Attribute

The Uninterrupted Power Supply Attribute add the capability to accommodate systems that contain a UPS system. A UPS system’s main purpose is to allow controlled vehicle shutdown in the event of dissipation or failure of main system power. It is here treated as a Payload, but the system could be tightly integrated with or inseparable from the platform and maintain a logical IOP interface only.

5.15.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:UninterruptedPowerSupply, 1.1	any	Custom Services, Messages, and Transports

Table 62: - Component and Service Requirements for Uninterrupted Power Supply Attribute

CHAPTER 6 PLATFORM ATTRIBUTES

Platform Interoperability Attributes are platform-centric attributes that provide platform level capabilities such as discovery, engine status information, health information, etc.

6.1 PLATFORM ATTRIBUTE

Parent Attribute: Core Software and Logical Attribute

The following attributes are mutually exclusive, exactly one must be chosen.

Attribute	Description
Platform Management Attribute	The system provides platform management functionality.
No Platform Manager Attribute	Implies that there is no Platform Manager JAUS node or component and that discovery is not provided.

Table 63- Mandatory Select = one

Any number of the following attributes can be chosen.

Attribute	Description
Enhanced Access Control Attribute	Adds enhanced access control capability to all components that provide the standard access control. Enhanced access control gives the ability to perform graceful handoff of control from a current controller to one with equal or less authority.
Stability Control Attribute	Provides a way to discover and activate driver-assist capabilities of the vehicle.
Terrain Limits Attribute	Provides a capability to detect when the platform has encountered impassable terrain.
Loading Specifications Attribute	Describes the physical characteristics of a load (such as a trailer) attached to a platform.

Table 64: - Optional Select = any

The following attributes are mutually exclusive, exactly one must be chosen.

Attribute	Description
No Automated Behaviors Attribute	Specifies that the platform offers no dedicated services for automated behaviors, and leaves that support to the OCU.
Basic Automated Behaviors Attribute	Adds support for accomplishing automated behaviors by issuing predefined sequences of JAUS messages.
Advanced Automated Behaviors Attribute	Placeholder for future enhanced automated behaviors that extend the basic capabilities.

Table 65: - Mandatory Select = one

6.2 PLATFORM MANAGEMENT SECTION

6.2.1 No Platform Manager Attribute

Parent Attribute: Platform Attribute

The No Platform Management Interoperability Attribute implies that there is no Platform Manager JAUS node or component, that discovery is not provided, and that locations of JAUS nodes, components, and services must be known apriori. An example of a subsystem using no Platform Manager is a legacy system converted to use IOP standards, but with static and known JAUS addresses that messages are always sent to.

6.2.2 Platform Management Attribute

Parent Attribute: Platform Attribute

The Platform Management Interoperability Attribute defines the platform management services that are required on the platform_manager component. If Platform Management is selected, a Platform Manager JAUS component shall be provided under the Platform JAUS node.

Any number of the following attributes can be chosen.

Attribute	Description
Advanced Platform Management Attribute	The Advanced Platform Management Interoperability Attribute is reserved for providing future capabilities such as calibration, software updates, etc.
Platform Mode Attribute	Provides the capability to query and change the mode of a platform, for example, from operational to maintenance.
Platform State Attribute	Provide the capability query and change the state of a platform. The state is the overall platform state, and changing the state of the platform may change the state of various entities on that platform.

Table 66: - Optional Select = any

The following attributes are mandatory.

Attribute	Description
Digital Resource Discovery Attribute	Digital resource discovery attribute specifies how digital resources like digital video and audio streams are registered to be discovered by clients like an OCU.

Table 67: - Mandatory Select = all

6.2.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:core:Discovery, 1.1	platform_ma nager	AS5710A JAUS Core Service Set
urn:jaus:jss:core:Liveness, 1.1	platform_ma nager	AS5710A JAUS Core Service Set
urn:jaus:jss:exp:aeodrs:HealthMonitor, 1.4	platform_ma nager	RAS-G IOP Custom Services, Messages, and Transports
urn:jaus:jss:iop:UnsolicitedHeartbeat, 1.1	platform_ma nager	RAS-G IOP Custom Services, Messages, and Transports

Table 25: - Component and Service Requirements for Platform Management Attribute

6.2.2.2 Basic Platform Management Requirement

The Platform Management Attribute requires a Platform JAUS Node that contains all JAUS Components to which the alias "platform_manager" applies.

V1.JAUS-41 If the Platform Management Attribute is selected, one or more JAUS Components with the alias "platform_manager" shall be provided as part of the Platform JAUS node.

V1.JAUS-42 The Platform node shall have an always-known (not dynamically assigned) JAUS Node ID. The recommended value for this Node ID is 1.

V1.JAUS-43 One and only one JAUS Component with the "platform_manager" alias shall broadcast an unsolicited JAUS Subsystem level (broadcast address [Subsystem ID].255.255) ReportHeartbeAEPulse message at a rate of at least 1 HZ as specified by the urn:jaus:jss:iop:UnsolicitedHeartbeat service.

6.2.2.2.1 Notes and Interpretations

6.2.2.2.1.1 Discovery

There are two primary elements of discovery that must be implemented by a system that complies with the Platform Management Attribute - registration of services by the various payloads, modules, or other JAUS nodes 'plugged in' to a platform JAUS subsystem, and the discovery and use of services provided by a platform JAUS subsystem.

When a payload, module, or other JAUS node (node is used for short, and defined as having one or more JAUS Components) is attached to a platform (JAUS subsystem) or otherwise comes online, the following procedure shall be followed:

1. The JAUS Components on the JAUS Node logically broadcast a QueryIdentification message within the confines of its JAUS subsystem.
2. The Discovery service on the Basic Platform Manager Component replies with a ReportIdentification message - this gives the JAUS Components the location of the Discovery service it will publish its services to.
3. Knowing the location of the Discovery service, the JAUS Components form a RegisterServices message (from each JAUS Component provided by that node), and sends that to the Discovery Service, which publishes the services available.
4. The JAUS Component registering its service is responsible for verifying those services were registered properly. It does this by sending a QueryServiceList or QueryServices message for each JAUS component, and verifying that each JAUS Component's services were properly registered. If the corresponding ReportServiceList or ReportServices messages does not indicate all services were properly registered, the JAUS Component shall re-register service until they are correct.

An Operator Control Unit (OCU) or other client can use the Discovery service on a platform to determine the configuration of that platform and the services provided by the platform and all its payloads, modules, and other JAUS Nodes and JAUS Components. See Figure 26 in AS5710A JAUS Core Service Set for a visual depiction of the discovery process.

Message(s)	Concept	Interpretations
ID 2B00: QueryIdentification ID 4B00: ReportIdentification	Unique Platform identification	When a client requests a subsystem level identification (QueryType=2), the corresponding ReportIdentification message shall include a globally unique string ("call sign") in the Identification field. The exact information and format of the string is program-specific, but may be based on vehicle serial number, radio MAC address, or other unique identifiers. If a program requires information about the vehicle class or chassis, please consult the Platform Specification Interoperability Attribute.
ID 2B00: QueryIdentification ID 4B00: ReportIdentification ID 0B00: RegisterServices	Finding and Losing Subsystem Discovery Service	If at any time, communications with the Discovery Service are determined to not be possible, the Discovery service shall be considered lost. The method of determining if communications to the discovery service are lost is left to the implementation, but possible methods include utilizing the liveness service of the JAUS Component that the Discovery Service is on, or periodically broadcasting a QueryIdentification message and looking for a ReportIdentification. When a Discovery

		<p>service is found after being considered lost, the RegisterServices message shall be sent to the Discovery service containing information on all services the component provides, including the core services.</p>
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Table 26: - Message Interpretations for Discovery

6.2.2.2.1.2 Liveness

The liveness service provided by the Basic Platform Manager JAUS component shall be used by an OCU or other client to maintain liveness to the Platform Manager.

6.2.2.2.1.3 Health Monitor

The Health Monitor service, defined in the Custom Service, Messages, and Transports IOP obtains health status information for an entire JAUS subsystem by querying all Health Reporter services on that JAUS subsystem for their ReportHealthSummary message. The Health Monitor service retains that information, refreshing it on receipt of UpdateUGVSummary and periodically at a rate specified by the Health Monitor Refresh Rate parameter. The Health Monitor service constructs a ReportHealthSummary message using its retained health information. The Health Monitor service should use information from any Health Reporter services registered with the Discovery service to form its health summaries and reports. If no Health Reporter services are provided, the health monitor shall base its status information on information from JAUS component Management and Liveness services as stated in the Message Interpretations for Health Monitor Service.

Message(s)	Concept	Interpretations
<p>ID FD10: ReportHealthSummary</p>	<p>Emergency and Failure Management States</p>	<p>If any JAUS Component that provides a Management service is in Emergency state, the indicated severity for the JAUS node it resides on shall be 3 (ERR). If any JAUS Component that provides a Management service is in Failure state, the indicated severity for the JAUS node it resides on shall be 4 (FAIL).</p>
<p>ID FD10: ReportHealthSummary</p>	<p>Communications Lost State</p>	<p>If liveness to a JAUS component registered with the Discovery service is lost (urn:jaus:jss:core:Liveness service), indicated severity for the JAUS node it resides on shall be 3 (ERR).</p>

Table 70: - Message Interpretations for Health Monitor

6.2.2.2.1.4 Unsolicited Heartbeat

The Unsolicited Heartbeat service does not send its unsolicited Report Heartbeat Pulse message unless it has a fully known JAUS ID, including the Subsystem ID and Node ID. The unsolicited Report Heartbeat Pulse message is sent a rate specified by the Unsolicited Heartbeat Rate parameter.

6.2.2.2.2 Periodicity

6.2.2.2.2.1 Discovery

- Every JAUS Component on the JAUS Subsystem shall determine if it has lost connection to the Discovery Service at least every 30 seconds. A JAUS Component must attempt to re-acquire and re-register its services with a lost Discovery Service at least every 30 seconds while the Discovery Service is considered lost.

6.2.2.2.2.2 Health Monitor

- The Health Monitor shall check for connectivity to each JAUS component on the subsystem at a rate of at least once per 60 seconds for every component on the subsystem, and at least once per second for the Core Mobility Component.
- Health Summary Update - The health summary for the platform must be updated at a rate specified by the [parameter] HealthMonitorRefreshRate. The way in which the health summary is updated is implementation specific. An UpdateHealthSummary message may be used to force an update if the specified update rate is not sufficient for certain requirements.

6.2.2.2.3 Parameter Listing

Parameter Name	Default Value	Allowed Values	Description
Health Monitor Refresh Rate	0.2 Hertz	<Range> 0.0..65535.0 Hertz	Specifies the minimum rate (Hz) at which health information as reported by the Health Monitor service shall be updated.
Unsolicited Heartbeat Rate	1 Hertz	<Range> 1..65535 Hertz	Specifies the rate at which the unsolicited Report Heartbeat Pulse message is sent by the urn:jaus:jss:iop:UnsolicitedHeartbeat service, in Hertz.

Table 71: - Parameter Listing for Platform Management Attribute

6.2.3 Advanced Platform Management Attribute

Parent Attribute: Platform Management Attribute

The Advanced Platform Management Attribute of the Platform Management Interoperability Attribute is reserved for providing future capabilities such as calibration, software updates, etc.

6.2.4 Digital Resource Discovery Attribute

Parent Attribute: Platform Attribute

The Digital Resource Discovery Attribute specifies how digital resources like digital video and audio streams are registered to be discovered by clients like an OCU.

6.2.4.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:DigitalResourceDiscovery, 1.1	platform_ma nager	Custom Services, Messages, and Transports

Table 72: - Component and Service Requirements for Digital Resource Discovery Attribute

6.2.5 Platform Mode Attribute

Parent Attribute: Platform Management Attribute

This attribute defines the capability to specify and query platform modes. There are three defined modes (Standard Operating, Training, and Maintenance) with defined meanings, and also mode IDs that can be used for program specific requirements.

6.2.5.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:PlatformMode, 1.1	platform_ma nager	RAS-G IOP Custom Services, Messages, and Transports

Table 73: - Component and Service Requirements for Platform Mode Attribute

6.2.5.2 Platform Mode Requirement

6.2.5.2.1 Notes and Interpretations

6.2.5.2.1.1 Platform Mode

A platform mode referred to interchangeably as a mode of operation is a characterization of specific, well-understood categories of platform operation that have distinctive sets of behavior associated with them. There are three explicitly enumerated platform modes:

- Standard Operating - the default mode of a platform and indicates that there are no mode-related, special restrictions on a platform's operation.
- Training - prepared for use in operator training. A platform in training mode will often have various limits placed on the full functionality of the vehicle to ensure safe training. Training mode may also imply a distinct set of running services or simulated data being provided to the operator. The exact restrictions and limitations imposed in Training mode are not defined by the service, and must be specified by acquisition requirements.
- Maintenance - prepared to undergo service or repair. A platform in maintenance mode would typically have its systems on, but secured in such a way as to ensure the safety of an operator performing maintenance on the platform. Note that the exact restrictions and limitations imposed in Maintenance mode are not defined by the service, and must be specified by acquisition requirements.

There is a reserved range on enumerated values for program-specific platform modes. When a component or service has different behavior or initialization/ exit routines for the platform modes, it may implement a client of the Platform Mode Service or expose through its native interfaces (e.g. mobility or manipulator limits) a means to configure/ notify it when the platform's mode of operation changes. In certain modes of operation, a platform may need to completely lock out a component that the acquisition program deems too dangerous to be allowed to operate. This can be accomplished with a core JAUS Management SetEmergency message (and a corresponding ClearEmergency message when the component can resume operation).

6.2.6 Platform State Attribute

Parent Attribute: Platform Management Attribute

This attribute defines the capability to query and manage platform states. The platform state is global to the whole platform, and not just a single component.

6.2.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:PlatformState, 1.1	platform_ma nager	RAS-G IOP Custom Services, Messages, and Transports

Table 74: - Component and Service Requirements for Platform State Attribute

6.2.6.2 Platform State Requirement

6.2.6.2.1 Notes and Interpretations

6.2.6.2.1.1 Platform State

The state of the platform is one of five fundamental, well-defined statuses, each of which has implication for a platform's underlying components and sub-systems. Each of these states represents some important information about the current capabilities of the platform, e.g. the presence of a critical system failure. These states should not be confused with the software life-cycle management provided by JAUS to individual components, nor the states contained within a JAUS service's protocol behavior. The two concepts are interlinked, however (e.g. transitioning to a Shutdown state indicates that all JAUS components on the platform have been commanded to undergo their shutdown sequence).

- Initialize - the state of a system that has just been powered on or reset and has various subsystems and software running initialization routines and coming online. The platform is not ready to undergo any commanded action. The transition from Initialize to Operational is expected to occur automatically when all mission-critical components that support the JAUS Management interface have transitions out of the Init state.
- Shutdown - state of a system that has received a request for a system wide shutdown of all of its hardware and software components/ systems. Once a platform enters Shutdown state it should end operations and stop responding to messages until the platform is physically restarted.
- Operational - indicates that all systems can be in an actively controlled state and the full functionality of the platform is available to the operator. The transition into Operational is a largely transparent result of systems coming online or removing special or emergency constraints on vehicle operation.
- System Abort - indicates that a dead-lining failure has occurred resulting in a non-mission capable status for the system. These types of failures are also known as Non-Operator Correctable Essential Function Failures(EFFNOC). Transitions to a Systems Abort state are automatic when a mission-critical component fails and may require direct physical operator intervention or maintenance to resolve. Failures that are operator correctable (i.e. through a reset of the particular sub-

system or component) or involved non-critical systems will not cause a transition to this state.

- Emergency - every component on a platform enters its own Emergency (halted and safe) state while some important malfunction is recovered from. The operator can, at his discretion, transition into Emergency state when needed and out of Emergency when the problem is resolved. A platform's components should not accept any commands until it is transitioned from Emergency state.

6.3 ENHANCED ACCESS CONTROL ATTRIBUTE

Parent Attribute: Platform Attribute

If selected, the Enhanced Access Control Interoperability Attribute requires that all JAUS Components on the Platform and Mobility JAUS Nodes that provide an Access Control service will provide the Enhanced Access Control service in addition to standard Access Control.

The Enhanced Access Control service provides the capability to do graceful handoff of control between controllers of different authority levels, and for controllers of equal authority to request a control handoff where with normal access control an attempt would be automatically rejected. Since the Enhanced Access Control service extends the basic Access Control service, all the same capabilities of nominal JAUS Access Control are still available to controllers that are not able to utilize enhanced access control.

6.3.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:EnhancedAccessControl, 2.0	all	RAS-G IOP Custom Services, Messages, and Transports
urn:jaus:jss:iop:HandoffController, 2.0		RAS-G IOP Custom Services, Messages, and Transports

Table 75: - Component and Service Requirements for Enhanced Access Control Attribute

6.3.2 Enhanced Access Control Requirement

The Enhanced Access Control Interoperability Attribute shall compliment the urn:jaus:jss:core:AccessControl, v1.1 service on any JAUS Component that requires access control.

V1.JAUS-44 *If selected, the Enhanced Access Control Interoperability Attribute requires that all JAUS Components on the Platform and Mobility JAUS Nodes that provide an Access Control service will provide the Enhanced Access Control service in addition to standard Access Control.*

6.3.2.1 Notes and Interpretations

Selecting the Enhanced Access Control Interoperability Attribute does not guarantee graceful handoff is supported. The current controller of the platform and the entity requesting control must also support handoff with this attribute in order to be able to use the Enhanced Access Control service, otherwise, only the Access Control service portions will be available for use. Handoff support for a controller must be provided with a Handoff Controller Service, urn:jaus:jss:iop:HandoffController, v2.0.

6.3.2.2 Parameter Listing

Parameter Name	Default Value	Allowed Values	Description
Handoff Decision Timeout	60 seconds	<Range> 0.. seconds	The Handoff Decision Timeout parameter specifies the amount of time that must pass between the Enhanced Access Control service requesting a handoff from the current controlling client and the service receiving a ConfirmReleaseControl message in response before that handoff request is considered failed due to a timeout. A value of zero indicates this feature is disabled.
Handoff Request Timeout	5 seconds	<Range> 0.. seconds	The Handoff Request Timeout parameter specifies the maximum amount of time between a client reasserting its desire for a handoff before that request for a handoff is considered timed out. A value of zero indicates this feature is disabled.

Table 27: - Parameter Listing for Enhanced Access Control Attribute

6.4 STABILITY CONTROL ATTRIBUTE

Parent Attribute: Platform Attribute

The Stability Control Interoperability Attribute provides a way to discover and activate driver-assist capabilities of the vehicle. These capabilities include Traction Control (to limit tire slip during acceleration), Anti-Lock Brake Systems (to limit tire slip during braking), Electronic Stability Control (brakes applied to counter over/under steer), and Active Rollover/Pitchover Control. Note that the precise implementation of each of these capabilities is platform-specific and not limited by this service.

6.4.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:IntelligentVehiclePolicyManager, 1.2		Custom Services, Messages, and Transports

Table 28: - Component and Service Requirements for Stability Control Attribute

6.4.2 Stability Control Requirement

6.4.2.1 Notes and Interpretations

Programs may define additional capabilities by specifying the use of the reserved user-defined range.

6.5 TERRAIN LIMITS ATTRIBUTE

Parent Attribute: Platform Attribute

The Terrain Limits Attribute provides a capability to detect when the platform has encountered impassable terrain.

If selected, the Terrain Limits Interoperability Attribute provides the capability to detect when the platform is not able to traverse a region in the environment. At a minimum, the platform must support the ability to know when it is stuck, e.g. not able to make forward progress either due to slip or other terrain limits.

However, for more advanced systems that may detect and recognize impassable terrain before becoming stuck, said terrain can be treated as an obstacle. In that case, the Obstacle Avoidance and Obstacle Reporting Attributes should also be considered.

Any number of the following attributes can be chosen.

Attribute	Description
Obstacle Avoidance Attribute	Provides a capability to stop or deviate around obstacles encountered when the platform is moving.
Obstacle Reporting Attribute	Provides a way to report obstacles and hazardous terrain using an overhead 2D cost map.

Table 29: - Optional Select = any

6.5.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:IntelligentVehiclePolicyManager, 1.2	any	Custom Services, Messages, and Transports

Table 30: - Component and Service Requirements for Terrain Limits Attribute

6.5.2 Terrain Limits Requirement

6.5.2.1 Notes and Interpretations

When the Terrain Limits Interoperability Attribute is selected, the implementation of the Intelligent Vehicle Policy Manager (version 1.2 or later) shall support "stuck detection", at a minimum.

6.6 LOADING SPECIFICATIONS ATTRIBUTE

Parent Attribute: Platform Attribute

The Loading Specifications Attribute provides the capability to describe the height, width, length, center of gravity and weight of a load (such as a trailer) attached to a platform.

6.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop>LoadingSpecificationsService, 2.0		Custom Services, Messages, and Transports

Table 80: - Component and Service Requirements for Loading Specifications Attribute

6.6.2 Loading Specifications Requirement

V1.JAUS-45 When the Loading Specifications Attribute is specified for a JAUS component, that JAUS component shall provide a Loading Specifications service.

6.7 AUTOMATED BEHAVIORS

6.7.1 No Automated Behaviors Attribute

Parent Attribute: Platform Attribute

The No Automated Behaviors Attribute implies that the platform offers no dedicated services for automated behaviors. However, this does not prevent a client, such as an Operator Control Unit (OCU), from supporting automated behaviors via a purely client-side implementation. This would require nearly constant contact between the OCU and the platform, with sequencing, monitoring, and spooling performed by the client.

6.7.2 Basic Automated Behaviors Attribute

Parent Attribute: Platform Attribute

The Basic Automated Behaviors Attribute adds support for accomplishing automated behaviors by issuing predefined sequences of tasks.

The SAE JAUS Mission Spooler Service is responsible for executing these predefined sequences of tasks, each task comprised of a JAUS message and parameters related to its use. The Mission Spooler can send messages to multiple destination components and will use the authority code of its client for messages that require Access Control. Mission Spooler supports both tasks that must execute to completion before the next begins (blocking) and those that do not need to finish before the following task begins (non-blocking).

6.7.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:missionSpooler:MissionSpooler, 2.0	unique	SAE AS6062 Rev A: JAUS Mission Spooling Service Set

Table 81: - Component and Service Requirements for Basic Automated Behaviors Attribute

6.7.2.2 Basic Automated Behaviors Requirement

V1.JAUS-46 Systems selecting the Basic Automated Behaviors Attribute shall implement the Mission Spooler Service (version 2.0 or compatible).

6.7.2.2.1 Notes and Interpretations

The Mission Spooler represents a mission pool as one or more tasks.

- The mission spooler assumes the access control authority of its client when requesting control.
- All messages associated with tasks are sent using the Mission Spooler as the source as opposed to the client.
- Tasks with the blocking flag set to true must be performed strictly sequentially and contain a command message from a service that inherits from Events version 1.1 or compatible.

6.7.3 Advanced Automated Behaviors Attribute

Parent Attribute: Basic Automated Behaviors Attribute

The Advanced Automated Behaviors Attribute is not supported in this version. This is a place-holder for future work to allow for more complex mission plans and behaviors.

CHAPTER 7 MOBILITY SECTION

7.1 MOBILITY ATTRIBUTE

Parent Attribute: Core Software and Logical Attribute

The Mobility Interoperability Attribute defines attributes related to platform mobility, such as driving.

Multiple Mobility Interoperability Attributes may be selected that require the same service be added to the Core Mobility Component - in this case, only a single instance of that service is added that fulfills the requirements for both Attributes that require it. Mobility Interoperability Attributes are grouped under the "Mobility" Requirements Node.

Any number of the following attributes can be chosen.

Attribute	Description
Platform Specification Attribute	Report the Platform Specification inherent to the platform such as limits for speed and acceleration (not based on the mobility type).
Gear Attribute	Provides the ability to control the gears of a platform.
Parking Brake Driver Attribute	Provides the ability to control the parking brake on a platform.
Stabilizer Attribute	Provides the ability to control a platform stabilizer (i.e. flippers).
Remote Control Attribute	Provides services for performing basic, open loop, line of sight remote control of a vehicle.
Teleoperation Attribute	Provides the services for performing teleoperation control of a platform. Teleoperation is the non-line of sight equivalent to remote control, and requires the addition of a drive video source.
Autonomy and Behaviors Attribute	Provide higher level navigation capabilities and support for other behaviors that take place absent complete operator control.

Table 82: - Optional Select = any

7.1.1 Drive Timeout Requirement

There shall be a drive timeout set of values specified for the use of the platform Core Mobility Component. These values shall specify the maximum amount of time between mobility messages to the platform's Core Mobility Component before the platform specific mobility driver is told to stop for safety reasons. These values are based on the speed of the vehicle, dynamics of the vehicle, and other internal and external factors. Once a drive timeout has occurred, the vehicle shall stay in a stopped state until mobility messages are received again for a specified amount of time at a specified minimum rate. The time and rate are also determined by the particulars of the vehicle and the environment it is expected to operate in. To meet the drive timeout attribute requirements, values must be specified for the Drive Timeout Time and Drive Recovery Time parameters (see Figure below for explanation of states):

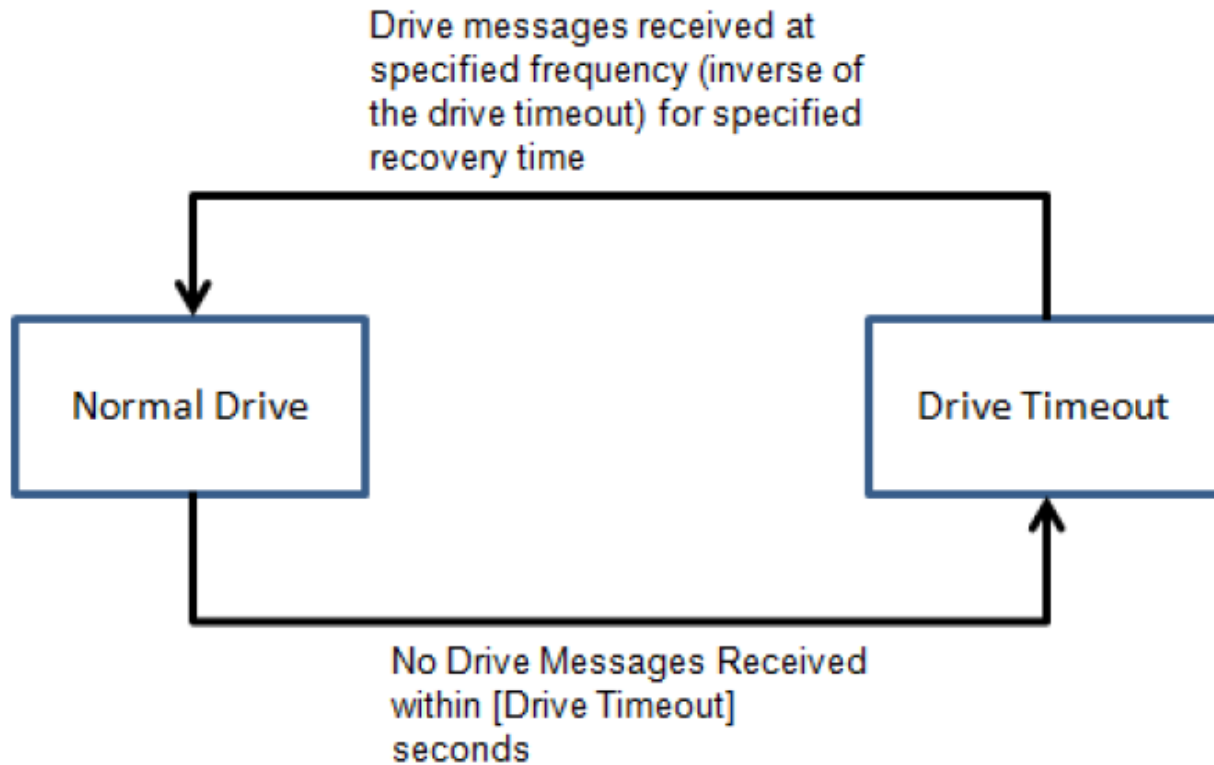


Figure 5: Drive Timeout

V1.JAUS-47 *There shall be a drive timeout set of values specified for the use of the platform Core Mobility JAUS component. These values shall specify the maximum amount of time between mobility messages to the platform's Core Mobility JAUS component before the platform specific mobility driver is told to stop for safety reasons.*

V1.JAUS-48 *Once a drive timeout has occurred, the vehicle shall stay in a stopped state until mobility messages are received again for a specified amount of time at a specified minimum rate.*

7.1.1.1 Parameter Listing

Parameter Name	Default Value	Allowed Values	Description
Drive Timeout Time	1 seconds	<Range> 0..65535 seconds	The time (in Seconds) after receiving the last drive message (i.e. a SetWrenchEffort or SetVelocityState message) at which a Drive Timeout is considered to occur. A 0 value indicates no drive timeout.

Drive Recovery Time	1 seconds	<Range> 0..65535 seconds	The amount of time (in Seconds) over which drive messages must be received at the specified Drive Frequency before transitioning out of a Drive Timeout state to a Normal Drive state. A 0 value indicates no drive timeout.
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Table 83: - Parameter Listing for Mobility Attribute

7.1.2 Core Mobility Component

Any subsystem that provides mobility services, such as a primitive driver or velocity state driver, shall provide a Core Mobility JAUS component under the Mobility JAUS node. All subsystem mobility services that control core mobility shall be placed under the Core Mobility Component to allow for mutually exclusive access control to low level drive services as specified in 4.3.5 Mutually Exclusive Access Control Requirement.

V1.JAUS-49 Any subsystem that provides mobility services, such as a primitive driver or velocity state driver, shall provide a Core Mobility JAUS component (the Core Mobility Component) under the Mobility JAUS node.

V1.JAUS-50 All subsystem mobility services that control core mobility shall be placed under the Core Mobility Component

7.2 PLATFORM SPECIFICATION ATTRIBUTE

Parent Attribute: Mobility Attribute

If selected, the Platform Specification Interoperability Attribute provides the capability to query the physical characteristics and mobility limits inherent to (not associated with a particular type of driver) the platform, including limits for maximum speed and acceleration.

7.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:ugv:PlatformSpecifications, 1.0		JAUS UGV Service Set

Table 84: - Component and Service Requirements for Platform Specification Attribute

7.2.2 Platform Specification Requirement

7.2.2.1 Notes and Interpretations

7.2.2.1.1 Platform Specifications

Message(s)	Concept	Interpretations
ID 2502: QueryPlatformSpecifications	Usage	The PlatformInertialSpecificationsRec shall be used to return the speed and acceleration/deceleration limits of the

ID 4502: ReportPlatformSpecifications		platform. Forward implies positive X direction and negative implies negative X direction
ID 4502: ReportPlatformSpecifications	Mobility chassis classification	The information and syntax of the MobilityPlatformName string shall be program specific. The expectation is that this string will be standardized by individual programs and used to describe a vehicle's classification. This might include manufacturer and model number, mission-specific configuration details, etc. It is expected that all platforms of the same type/configuration would report the same data in the MobilityPlatformName string. For globally unique identification between platforms, see the Basic Platform Management Attribute message interpretations.

Table 85: - Message Interpretations for Platform Specifications

7.3 TELEOPERATION ATTRIBUTE

Parent Attribute: Mobility Attribute

If selected, the Teleoperation Interoperability Attribute provides the capability to teleoperate a platform (non-line of sight, with video feed).

The following attributes are mandatory.

Attribute	Description
Remote Control Attribute	Provides services for performing basic, open loop, line of sight remote control of a vehicle.
Video Attribute	Provides a method for interacting with a video source, such as a digital or analog camera or video from another source.

Table 86: - Mandatory Select = all

7.4 GEAR ATTRIBUTE

Parent Attribute: Mobility Attribute

The Gear Interoperability Attribute defines the way in which the gears of a vehicle are controlled.

The IOP defines interfaces that support a variety of drive train types, including those for drive configurations such as two-wheel drive, four-wheel drive, all-wheel drive, as well as non-traditional user-defined configurations. Refer to the RAS-G IOP SAE JAUS Profiling Rules for logical interfaces for drive trains.

7.4.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:ugv:DriveTrainDriver, 1.0		AS6091 JAUS UGV Service Set

Table 87: - Component and Service Requirements for Gear Attribute

7.4.2 Gear Requirement

7.4.2.1 Notes and Interpretations

In order to confirm successful transition into a different gear, a client requesting a change in gear should set up an event to get notified of any changes in transmission state. Currently, if transition to a new gear does not occur, there is no way to report back the reason why the client should wait for an update on the current gear and try to set the gear again if it does not change.

The Transfer Case messages may be used to switch between common drive configurations, such as two-wheel, four-wheel, and all-wheel drive. In addition, programs may individually specify the use of the user-defined range allowed by the TransferCaseState enum in range 201-255. If one or more user-defined enumerations are specified by a program, such an implementation shall also set the user-defined bit in the ReportTransmissionCapabilities::transferCaseBF to support dynamic discovery of these capabilities. Note that use of the user-defined range can also support more complex drive/steering configurations; for instance, crab steer (in which both the front and rear axles are pivoted in the same direction) could be supported by combining a user-defined TransferCaseState with an Ackermann Steering Interoperability Attribute.

7.5 PARKING BRAKE DRIVER ATTRIBUTE

Parent Attribute: Mobility Attribute

The Parking Brake Driver Interoperability Attribute provides the ability to control the parking brake on a platform. A parking brake is as a latching brake intended to keep the vehicle from moving.

7.5.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:ugv:ParkingBrakeDriver, 1.0		AS6091 JAUS UGV Service Set

Table 88: - Component and Service Requirements for Parking Brake Driver Attribute

7.6 STABILIZER ATTRIBUTE

Parent Attribute: End Effector Attribute

The Stabilizer Interoperability Attribute provides a way to add support for stabilizers (typically flippers) to a Mobility component.

7.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:ugv:StabilizerDriver, 1.0		AS6091 JAUS UGV Service Set

Table 89: - Component and Service Requirements for Stabilizer Attribute

7.6.2 Stabilizer Requirement

7.6.2.1 Periodicity

7.6.2.1.1 Stabilizer Driver

Message(s)	Rate
ID 2504: QueryStabilizerPosition	1.0 Hz (Recommended)

Table 90: - Periodicity Information for Stabilizer Driver

7.7 REMOTE CONTROL SECTION

7.7.1 Remote Control Attribute

Parent Attribute: Mobility Attribute

The Remote Control 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].

Any number of the following attributes can be chosen.

Attribute	Description
Effort Driving Attribute	Provides the ability to engage in open-loop, effort-based driving.
Velocity State Driver Attribute	Provides the ability to control the vehicle using closed loop velocity commands.

Vector Driver Attribute	Provides the ability to perform closed loop control of the desired heading, altitude, and speed of a mobile platform.
Ackermann Steering Attribute	Provides the ability to control Ackermann steered vehicles.
Skid Steer Attribute	Provides the ability to control skid steer vehicles.

Table 91: - Optional Select = any

7.7.2 Effort Driving Attribute

Parent Attribute: Remote Control Attribute

The Effort Driving Attribute adds the capability to drive a platform using open-loop effort-based control. A platform implementing this attribute may not necessarily have the ability to sense its velocity.

7.7.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:mobility:PrimitiveDriver, 1.1		AS6009 JAUS Mobility Service Set

Table 92: - Component and Service Requirements for Effort Driving Attribute

7.7.2.2 Effort Driving Requirement

7.7.2.2.1 Notes and Interpretations

The platform orientation referenced in Message Interpretations is further detailed in AS6009 Mobility Service Set.

7.7.2.2.1.1 PrimitiveDriver

The following message interpretations apply for the Primitive Driver service.

Message(s)	Concept	Interpretations
ID 0405: SetWrenchEffort ID 2405: QueryWrenchEffort ID 4405: ReportWrenchEffort	Platform Acceleration	- Propulsive Linear Effort X: positive values indicate the percent of maximum forward effort. Negative values indicate the percent of maximum reverse effort. - Vehicle with gear select: By default, there is no message set for selecting gears - a positive value of Propulsive Linear Effort X will indicate throttle level to be used while in drive, and a negative value will automatically cause the platform to shift into an appropriate gear for travelling in reverse. If the gear Attribute is selected, gears shall be selected as defined in 7.4 GEAR ATTRIBUTE.

ID 0405: SetWrenchEffort ID 2405: QueryWrenchEffort ID 4405: ReportWrenchEffort	Platform Deceleration	<ul style="list-style-type: none"> - Some platforms will decelerate with decrease in Propulsive Linear Effort X due to resistive force inherent in the drive motor when power is decreased or not applied. - Resistive Linear Effort X: The value will be translated to braking force against platform movement in forward or reverse direction on platforms that support braking.
ID 0405: SetWrenchEffort ID 2405: QueryWrenchEffort ID 4405: ReportWrenchEffort	Platform Steering	<ul style="list-style-type: none"> - Propulsive Rotational Effort Z: Positive values indicate steering to the right, negative values indicate steering to the left, as a percentage of maximum rotational effort. - Skid steer vehicles: If platform velocity is non zero (or above some minimum threshold value), value of 100 will indicate maximum propulsive effort on left traction component and minimum on the right. A value of -100 will indicate maximum propulsive effort on right traction component and minimum on the left If platform velocity is zero, positive values indicate pivot clockwise (as seen from above the platform), and negative values indicate pivot counter clockwise. - Multiple axis steering vehicles are not covered in this version.
ID 0405: SetWrenchEffort ID 2405: QueryWrenchEffort ID 4405: ReportWrenchEffort	Speed/Effort Reporting	The reported wrench effort may not correspond exactly with the actual speed of the vehicle, and should not be used for performing any closed loop control.

Table 93: - Message Interpretations for PrimitiveDriver

7.7.2.2.2 Periodicity

7.7.2.2.2.1 PrimitiveDriver

ID 0405: Set Wrench Effort - The set wrench effort command is a periodic command that must be sent at a rate sufficient for the safe operation of the vehicle at a given speed. This rate is determined by the speed rating as well as the intended use of the platform. Safe operations must be considered to set the minimum rate required for a given speed. The actions taken if this message is not received at a given rate or within a given amount of time are specified in 7.1.1 Drive Timeout Requirement.

7.7.3 Velocity State Driver Attribute

Parent Attribute: Remote Control Attribute

If used, the Velocity State Driver Attribute adds the capability to drive a platform using closed loop velocity based control. This Attribute implies that the platform has the ability to sense its velocity.

7.7.3.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:mobility:VelocityStateDriver, 1.1		AS6009 JAUS Mobility Service Set

Table 94: - Component and Service Requirements for Velocity State Driver Attribute

7.7.3.2 Velocity State Driver Requirement

7.7.3.2.1 Notes and Interpretations

7.7.3.2.1.1 Velocity State Driver

Message(s)	Concept	Interpretations
ID 0415: SetVelocityCommand ID 0416: SetAccelerationLimit ID 2415: QueryVelocityCommand ID 2416: QueryAccelerationLimit ID 4415: ReportVelocityCommand ID 4416: ReportVelocityLimit	Maximum Velocity	Optionally, the first SetVelocityCommand message issued to the platform shall set the maximum velocities that the platform is allowed to perform by specifying a command type of 1 (Set maximum allowed values). If maximum values are not set or are set above the inherent platform Platform Specification, the inherent platform Platform Specification shall be used. A QueryVelocityCommand message shall be used to confirm the limits are set.
ID 0415: SetVelocityCommand ID 0416: SetAccelerationLimit ID 2415: QueryVelocityCommand ID 2416: QueryAccelerationLimit ID 4415: ReportVelocityCommand ID 4416: ReportVelocityLimit	Platform Acceleration (increase in velocity)	- To achieve a particular velocity, the platform shall not exceed the acceleration limits set using the SetAccelerationLimit message. - Positive velocity is movement in the positive X (forward) direction.
ID 0415: SetVelocityCommand ID 0416: SetAccelerationLimit ID 2415: QueryVelocityCommand ID 2416: QueryAccelerationLimit	Platform Deceleration (decrease in velocity)	- To achieve a particular velocity, the platform shall not exceed the acceleration limits set using the SetAccelerationLimit message.

ID 4415: ReportVelocityCommand ID 4416: ReportVelocityLimit		- Negative velocity is movement in the negative X (reverse) direction
ID 0415: SetVelocityCommand ID 0416: SetAccelerationLimit ID 2415: QueryVelocityCommand ID 2416: QueryAccelerationLimit ID 4415: ReportVelocityCommand ID 4416: ReportVelocityLimit	Vehicles with Gear Select	- A positive velocity in the X (forward) direction shall utilize a forward (drive) gear. - A negative velocity in the X (backward) direction shall utilize a reverse gear.
ID 0415: SetVelocityCommand ID 0416: SetAccelerationLimit ID 2415: QueryVelocityCommand ID 2416: QueryAccelerationLimit ID 4415: ReportVelocityCommand ID 4416: ReportVelocityLimit	Platform Steering	- Yaw Rate: Positive values indicate steering to the right, negative values indicate steering to the left. - Skid Steer Vehicles: If platform velocity is non- zero (or above some minimum threshold value), a positive value shall pivot the vehicle around the right traction component, and a negative value shall pivot the vehicle around the left traction component, at the rate specified. If platform velocity is zero, positive values indicate pivot clockwise (as seen from above the platform), and negative values indicate pivot counter clockwise. - Multi-axle steering vehicles are not supported.
ID 0415: SetVelocityCommand ID 0416: SetAccelerationLimit ID 2415: QueryVelocityCommand ID 2416: QueryAccelerationLimit ID 4415: ReportVelocityCommand ID 4416: ReportVelocityLimit	Acceleration Limit	A SetAcceleration limit message may be sent to the Velocity State Driver service to limit the acceleration used to accomplish the velocity desired. If acceleration limits are not set or are set above those reported by Platform Specification Attribute, the values reported by Platform Specification shall be used. A QueryAccelerationLimit message shall be used to confirm the limits are set. Note that acceleration limits may be changed by the controller to drive mobility performance. For example, a "dash" speed may have a higher acceleration limit than a traditional "fast" speed option.

Table 95: - Message Interpretations for Velocity State Driver

7.7.3.2.2 Periodicity

7.7.3.2.2.1 Velocity State Driver

ID 0415: Set Velocity Command - This command is a periodic command that must be sent at a rate sufficient for the safe operation of the vehicle at a given speed. This rate is determined by the speed as well as the intended use of the platform. Safe operations must be considered to set the minimum rate required for a given speed. The actions taken if this message is not received at a given rate or within a given amount of time are specified in 7.1.1 Drive Timeout Requirement.

7.7.4 Ackermann Steering Attribute

Parent Attribute: Remote Control Attribute

If selected, the Ackermann Steering Interoperability Attribute provides the ability to control Ackermann steered vehicles. An Ackermann vehicle uses steering linkages in which the inside and outside wheels are turned at different angles to compensate for the different radii each wheel traces through a turn.

7.7.4.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:ugv:AckermannDriver, 1.0		AS6091 JAUS UGV Service Set

Table 96: - Component and Service Requirements for Ackermann Steering Attribute

7.7.4.2 Ackermann Steering Requirement

7.7.4.2.1 Periodicity

7.7.4.2.1.1 Ackermann Driver

ID 0500: Set Ackermann Parameters - This command is a periodic command that must be sent at a rate sufficient for the safe operation of the vehicle at a given speed. This rate is determined by the speed as well as the intended use of the platform. Safe operations must be considered to set the minimum rate required for a given speed. The actions taken if this message is not received at a given rate or within a given amount of time are specified in the Drive Timeout Interoperability Attribute .

7.7.5 Vector Driver Attribute

Parent Attribute: Remote Control Attribute

If selected, the Vector Driver Interoperability Attribute provides the ability to perform closed loop control of the desired heading, altitude, and speed of a mobile platform.

At least one of the following attributes must be chosen.

Attribute	Description
Local Vector Driver Attribute	Provides the ability to perform closed loop control of the desired local heading, altitude, and speed of a mobile platform using local (non-GPS) coordinates.
Global Vector Driver Attribute	Provides the ability to perform closed loop control of the desired global heading, altitude, and speed of a mobile platform using global (GPS) coordinates.

Table 97: - Mandatory Select = any

7.7.6 Local Vector Driver Attribute

Parent Attribute: Vector Driver Attribute

If selected, the Vector Driver Interoperability Attribute provides the ability to perform closed loop control of the desired heading, altitude, and speed of a mobile platform. The Local Vector Driver Attribute specifies the use of vectors in the Local coordinate frame. The Local coordinate frame is defined in AS6009 JAUS Mobility Service Set.

7.7.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:mobility:LocalVectorDriver, 1.1		AS6009 JAUS Mobility Service Set

Table 98: - Component and Service Requirements for Local Vector Driver Attribute

7.7.7 Global Vector Driver Attribute

Parent Attribute: Vector Driver Attribute

If selected, the Vector Driver Interoperability Attribute provides the ability to perform closed loop control of the desired heading, altitude, and speed of a mobile platform. The Global Vector Driver Attribute specifies the use of vectors in the global coordinate frame. The global coordinate frame is globally referenced using WGS84 and is typically going to be obtained from a Global Positioning System (GPS) device.

7.7.7.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:mobility:GlobalVectorDriver, 1.1		AS6009 JAUS Mobility Service Set

Table 99: - Component and Service Requirements for Global Vector Driver Attribute

7.7.8 Skid Steer Attribute

Parent Attribute: Remote Control Attribute

If selected, the Skid Steer Interoperability Attribute provides the ability to control skid steer vehicles. A skid steer vehicle is defined as generating differential velocity by independently engaging wheels or tracks on opposite sides of the vehicle.

7.7.8.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:ugv:SkidSteerDriver, 1.0		AS6091 JAUS UGV Service Set

Table 100: - Component and Service Requirements for Skid Steer Attribute

7.7.8.2 Skid Steer Requirement

7.7.8.2.1 Periodicity

7.7.8.2.1.1 Skid Steer Driver

ID 0501: Set Skid Steer Effort - This command is a periodic command that must be sent at a rate sufficient for the safe operation of the vehicle at a given speed. This rate is determined by the speed as well as the intended use of the platform. Safe operations must be considered to set the minimum rate required for a given speed. The actions taken if this message is not received at a given rate or within a given amount of time are specified in 7.1.1 Drive Timeout Requirement.

CHAPTER 8 AUTONOMY AND BEHAVIORS ATTRIBUTES

8.1 AUTONOMY AND BEHAVIORS ATTRIBUTE

Parent Attribute: Mobility Attribute

Autonomy and Behaviors Interoperability Attributes provide higher level navigation capabilities and support for other behaviors that take place absent complete operator control.

Any number of the following attributes can be chosen.

Attribute	Description
Waypoint Navigation Attribute	Provides the capability for navigation using waypoint path following.
Leader/Follower Attribute	Provides the capability for navigation using a leader/follower configuration, such as in a convoy.
Retrotraverse Attribute	Provides the capability to perform retrotraverse actions. A retrotraverse action causes a vehicle to move back along a path that it previously has travelled.
Guarded Teleop Attribute	Provides the capability to define a guarded teleoperation policy that will be used for a platform.
Obstacle Avoidance Attribute	Provides a capability to stop or deviate around obstacles encountered when the platform is moving.
Driver Assist Attribute	Provides the capability to enable common driver assist/driver warning functionality.
Lost Comms Management Attribute	Provides the capability to define a policy for when communications are lost between the platform and its controller.
Path Segment Driver Attribute	Provides the ability to perform closed loop control of position and velocity along a path
Self-Righting Attribute	Provides a mechanism for controlling and obtaining status of a self-righting behavior.

Table 101: - Optional Select = any

8.2 BASIC NAVIGATION

8.2.1 Waypoint Navigation Attribute

Parent Attribute: Autonomy and Behaviors Attribute

This capability is intended to provide a simple navigation mechanism. The waypoint is intended to represent a geo-location and may define some simple level of tolerance with respect to signifying the capture of the waypoint itself and desired speed between path segments.

Actions at waypoints, waypoint time constraints (e.g., arrival and departure), plan volatility, plan validation, multi-plan definition/selection, and waypoint corridors are deferred to subsequent versions.

At least one of the following attributes must be chosen.

Attribute	Description
Global Basic Navigation Attribute	Defines the capability for navigation using waypoint path following with globally referenced waypoints.
Local Basic Navigation Attribute	Defines the capability for navigation using waypoint path following with locally referenced waypoints.

Table 102: - Mandatory Select = any

Any number of the following attributes can be chosen.

Attribute	Description
Enhanced Waypoint Navigation Attribute	Augments Waypoint Navigation by adding more detailed waypoint information and execution status.

Table 103: - Optional Select = any

8.2.2 Global Basic Navigation Attribute

Parent Attribute: Waypoint Navigation Attribute

The Waypoint Navigation Attribute provides the ability to move/drive the platform via a defined set of points specified by an external source. The Global Basic Navigation attribute specifies the use of global waypoints. Global waypoints are globally referenced using WGS84 and are typically going to be obtained from a Global Positioning System (GPS) device.

8.2.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:mobility:GlobalWaypointDriver, 1.1		AS6009 JAUS Mobility Service Set
urn:jaus:jss:mobility:GlobalWaypointListDriver, 1.1		AS6009 JAUS Mobility Service Set
urn:jaus:jss:behaviors:PathReporter, 1.1		AS8024 JAUS Autonomous Behaviors Service Set

Table 104: - Component and Service Requirements for Global Basic Navigation Attribute

8.2.3 Local Basic Navigation Attribute

Parent Attribute: Waypoint Navigation Attribute

The Waypoint Navigation Attribute provides the ability to move/drive the platform via a defined set of points specified by an external source. The Local Basic Navigation attribute specifies the use of local waypoints. Local waypoints are locally referenced, often to the platform, using a variety of techniques. For additional control over the local frame of reference, the 5.2.3 Basic Local Position and Attitude Attribute can be added to this component.

8.2.3.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:mobility:LocalWaypointDriver, 1.1		AS6009 JAUS Mobility Service Set
urn:jaus:jss:mobility:LocalWaypointListDriver, 1.1		AS6009 JAUS Mobility Service Set
urn:jaus:jss:behaviors:PathReporter, 1.1		AS8024 JAUS Autonomous Behaviors Service Set

Table 31: - Component and Service Requirements for Local Basic Navigation Attribute

8.2.4 Enhanced Waypoint Navigation Attribute

Parent Attribute: Waypoint Navigation Attribute

The Enhanced Waypoint Navigation Attribute augments the Waypoint Navigation Attribute by adding more detailed waypoint information and waypoint execution status.

At least one of the following attributes must be chosen.

Attribute	Description
Global Enhanced Navigation Attribute	Augments the Global Waypoint Navigation Attribute by adding more detailed waypoint information and waypoint execution status.
Local Enhanced Navigation Attribute	Augments the Local Waypoint Navigation Attribute by adding more detailed waypoint information and waypoint execution status.

Table 106: - Mandatory Select = any

8.2.5 Global Enhanced Navigation Attribute

Parent Attribute: Enhanced Waypoint Navigation Attribute

The Global Enhanced Navigation Attribute augments the Global Basic Navigation Attribute by adding more detailed waypoint information and waypoint execution status.

8.2.5.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:EnhancedGlobalWaypointList Driver, 1.1		Custom Services, Messages, and Transports

Table 107: - Component and Service Requirements for Global Enhanced Navigation Attribute

8.2.6 Local Enhanced Navigation Attribute

Parent Attribute: Enhanced Waypoint Navigation Attribute

The Local Enhanced Navigation Attribute augments the Local Basic Navigation Attribute by adding more detailed waypoint information and waypoint execution status.

8.2.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:EnhancedLocalWaypointListDriver, 1.1		Custom Services, Messages, and Transports

Table 108: - Component and Service Requirements for Local Enhanced Navigation Attribute

8.3 LEADER FOLLOWER

8.3.1 Leader/Follower Attribute

Parent Attribute: Autonomy and Behaviors Attribute

If selected, the Leader/Follower (LF) Interoperability Attribute provides the ability to specify the robotic platform leader/follower mode within a leader/follower configuration. For this basic capability, the robotic platform will be designated as a "Leader", "Follower" or both. The intent of the leader capability requirement is to provide a simple position designation to a set of external followers. The intent of the follower capability is to monitor a simple position report from a designated leader and follow the position in accordance with a defined set of values.

At least one of the following attributes must be chosen.

Attribute	Description
Leader Attribute	Provides the capability to perform the leader portion of leader follow navigation, such as in a convoy.
Follower Attribute	Provides the capability to perform the follower portion of leader follow navigation, such as in a convoy.

Table 109: - Mandatory Select = any

8.3.2 Leader Attribute

Parent Attribute: Leader/Follower Attribute

If selected, the Leader Interoperability Attribute provides the ability to specify the robotic platform leader mode within a leader/follower configuration. For this basic capability, the robotic platform will be designated as a "Leader". The intent of the leader capability requirement is to provide a simple position designation to a set of external followers.

8.3.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:LeaderManagement, 1.1		Custom Services, Messages, and Transports

Table 32: - Component and Service Requirements for Leader Attribute

8.3.2.2 Leader Requirement

8.3.2.2.1 Notes and Interpretations

1. **Convoy Mode:** The existing leader and follower services support different vehicle types.
2. **Configuration of Multiple Followers:** The existing leader and follower services allow for the configuration of multiple followers, including chains in which a vehicle is both a leader and a follower.
3. **Designation of a leader other than self and other than robotic platform:** Any entity that has a Global Pose Sensor service (i.e. can provide a global pose) and a JAUS ID can be identified as a leader. For designation of leader in GPS denied (no global position available) environments, see the next bullet point.
4. **Leader follower in GPS denied environments (no Global Pose Sensor service information available from leader and/or follower):** The current Leader Follower services requires a Global Pose Sensor service to report an absolute position of a leader and does not specify a particular localization approach. As long as a global position of leader and follower can be determined, using any method, this approach is valid.

5. **Historical Path Reporting:** While not required, platforms hosting the Leader Attribute are recommended to also include the Global Path Reporting Attribute. This allows follower vehicles to query the previous path of the leader.

8.3.3 Follower Attribute

Parent Attribute: Leader/Follower Attribute

If selected, the Follower Interoperability Attribute provides the ability to specify the robotic platform follower mode within a leader/follower configuration. For this basic capability, the robotic platform will be designated as a "Follower". The intent of the follower capability is to monitor a simple position report from a designated follower and follow the position in accordance with a defined set of values.

8.3.3.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:LeaderFollowerDriver, 2.0		Custom Services, Messages, and Transports

Table 111: - Component and Service Requirements for Follower Attribute

8.3.3.2 Follower Requirement

8.3.3.2.1 Notes and Interpretations

1. **Convoy Mode:** The existing leader and follower services support different vehicle types.
2. **Configuration of Multiple Followers:** The existing leader and follower services allow for the configuration of multiple followers, including chains in which a vehicle is both a leader and a follower.
3. **Designation of a leader other than self and other than robotic platform:** Any entity that has a Global Pose Sensor service (i.e. can provide a global pose) and a JAUS ID can be identified as a leader. However, for improved error handling capabilities, vehicles acting as leaders are recommended to also include the Leader Attribute. For designation of leader in GPS denied (no global position available) environments, see the next bullet point.
4. **Leader follower in GPS denied environments (no Global Pose Sensor service information available from leader and/or follower):** The current Leader Follower services requires a Global Pose Sensor service to report an absolute position of a leader and does not specify a particular localization approach. As long as a global position of leader and follower can be determined, using any method, this approach is valid.

5. **Formations:** The current leader and follower services use a six degree of freedom offset, which can be used to configure any number of formations. The one significant limitation of the current services is that the formation must be based on a global position of one or more of the vehicles within the formation. Future versions of this document will address formations that are not dependent on global positions of entities within the formation.
6. **Platform Specification:** While not required, platforms hosting the Follower Attribute are recommended to also include the Platform Specification Attribute. This allows leader vehicles to query the capabilities of the follower(s) and adjust performance accordingly.

8.4 RETROTRAVERSE ATTRIBUTE

Parent Attribute: Autonomy and Behaviors Attribute

If selected, the Retrotraverse Interoperability Attribute provides the capability to tell a platform to re-travel a certain distance on its path.

8.4.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:behaviors:Retrotraverse, 1.1		AS8024 JAUS Autonomous Behaviors Service Set

[Table 112: - Component and Service Requirements for Retrotraverse Attribute](#)

8.4.2 Retrotraverse Requirement

8.4.2.1 Notes and Interpretations

See the section on the Retrotraverse service in AS8024 JAUS Autonomous Behaviors Service Set for further explanation of the types of retrotraverse.

8.5 GUARDED TELEOP ATTRIBUTE

Parent Attribute: Autonomy and Behaviors Attribute

If selected, the Guarded Teleop Interoperability Attribute provides the capability to utilize guarded teleoperation. Guarded teleoperation is normal teleoperation enhanced by obstacle detection and avoidance sensors (i.e. LADARs, cameras) where the commanded motion is altered based on the guarded teleoperation policy.

8.5.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:IntelligentVehiclePolicyManager, 1.2		Custom Services, Messages, and Transports

[Table 113: - Component and Service Requirements for Guarded Teleop Attribute](#)

8.5.2 Guarded Teleop Requirement

V1.JAUS-51 *When the Guarded Teleop Interoperability Attribute is selected, the implementation of the Intelligent Vehicle Policy Manager version 1.2 shall support STOP or DEVIATE for the 'Teleoperation' Motion Type, at a minimum.*

8.5.2.1 Notes and Interpretations

When the guarded teleop capability is set to anything other than "do nothing" using the EnabledBehaviors field of the SetIntelligentVehicleConfiguration message, any available obstacle information shall be used to modify the commanded motion of the vehicle prior to that command being sent to the low level motor drivers of the vehicle. Any service on the Core Mobility component that uses open-loop effort based control or closed loop velocity based control must alter any accepted commands in accordance with the guarded teleoperation policy prior to sending them to the low level mobility drivers of the platform.

When the Guarded Teleop Interoperability Attribute is selected, it is assumed that there are sensors on the platform that provide obstacle detection and avoidance information, but no specific requirement is placed on the types or configurations of sensors.

When the Guarded Teleop Interoperability Attribute is selected, the implementation of the Intelligent Vehicle Policy Manager version 1.2 shall support STOP or DEVIATE for the 'Teleoperation' Motion Type, at a minimum.

8.6 OBSTACLE AVOIDANCE ATTRIBUTE

Parent Attribute: Autonomy and Behaviors Attribute

The Obstacle Avoidance Attribute provides a capability to stop or deviate around obstacles encountered when the platform is moving.

If selected, the Obstacle Avoidance Interoperability Attribute provides the capability to autonomously avoid obstacles encountered when the platform is moving. Note that obstacle avoidance may be supported with some motion types, such as waypoints and retrotraverse, but not in others depending on the implementation. The Query/Report Capabilities Ext message allows a client to discover which motion types support obstacle avoidance.

8.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:IntelligentVehiclePolicyManager, 1.2	any	Custom Services, Messages, and Transports

Table33: - Component and Service Requirements for Obstacle Avoidance Attribute

8.7 DRIVER ASSIST ATTRIBUTE

Parent Attribute: Autonomy and Behaviors Attribute

If selected, the Driver Assist Attribute provides a mechanism for discovering automated driver assist behaviors supported by the platform, controlling their state, and determining current status. Examples of Driver Assist functions include Lane Departure Warning Systems, Adaptive Cruise Control, and Parking Assist functions. Note that it is not expected that all vehicles will support all behaviors supported by the service; rather the Query/Report Capability pair should be used to determine which functions are available on a particular implementation.

8.7.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop: IntelligentVehiclePolicyManager, 1.2		Custom Services, Messages, and Transports

Table 115: - Component and Service Requirements for Driver Assist Attribute

8.8 LOST COMMS MANAGEMENT ATTRIBUTE

Parent Attribute: Autonomy and Behaviors Attribute

If selected, the Lost Comms Management Interoperability Attribute provides the capability to detect when communications are lost between a platform and its current controller, and specifies what shall be done when those communications are lost.

8.8.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:behaviors:CommsLostPolicyManager, 1.1		AS8024 JAUS Autonomous Behaviors Service Set

Table 34: - Component and Service Requirements for Lost Comms Management Attribute

8.8.2 Lost Comms Policy Management Requirement

8.8.2.1 Notes and Interpretations

The policy for lost communications is set using the ID 0C01: SetCommsLostPolicy message. One and only one comms lost policy shall be set using the CommsLostPolicyVar variant field of the SetCommsLostPolicy message. The interpretation of the variant values is as follows:

1. StopMotionVar – if stop motion is specified, then the motion of the vehicle shall be stopped when communications are lost.
2. ContinueMissionVar – if continue mission is specified, no change shall be made to the vehicle when communications are lost. This is appropriate for when an autonomous mission is being performed (i.e. following a waypoint path through an area where it is known that communications will be lost).
3. MoveToGlobalPosSeq – if move to global position is specified, then the platform shall move to the specified global position when communications are lost.
4. MoveToLocalPosSeq – if move to local position is specified, then the platform shall move to the specified local position when communications are lost.
5. Retrotraverse – if retrotraverse is specified, then the platform shall retrotraverse its path according to the Retrotraverse service. If this attribute is specified, then the Retrotraverse Interoperability Attribute must be selected.
6. RunSpoolRec – if run spool is specified, then the platform shall execute the predefined mission spool using the Mission Spooler service.

8.9 PATH SEGMENT DRIVER ATTRIBUTE

Parent Attribute: Autonomy and Behaviors Attribute

If selected, the Path Segment Driver Interoperability Attribute provides the ability to perform closed loop control of position and velocity along a path where the path is defined in a generic manner.

At least one of the following attributes must be chosen.

Attribute	Description
Local Path Segment Driver Attribute	Provides the ability to perform closed loop control of position and velocity along a path where the path is defined in a generic manner, using local (non-GPS) coordinates.
Global Path Segment Driver Attribute	Provides the ability to perform closed loop control of position and velocity along a path where the path is defined in a generic manner, using global (GPS) coordinates.

Table 35: - Mandatory Select = any

8.10 GLOBAL PATH SEGMENT DRIVER ATTRIBUTE

Parent Attribute: Path Segment Driver Attribute

If selected, the Path Segment Driver Interoperability Attribute provides the ability to perform closed loop control of position and velocity along a path where the path is defined in a generic manner. The Global Path Segment Driver Attribute specifies the use of Path Segments in the global coordinate frame. The global coordinate frame is globally referenced using WGS84 and is typically going to be obtained from a Global Positioning System (GPS) device.

8.10.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:mobility:GlobalPathSegmentDriver, 1.1		AS6009 JAUS Mobility Service Set

Table 36: - Component and Service Requirements for Global Path Segment Driver Attribute

8.11 LOCAL PATH SEGMENT DRIVER ATTRIBUTE

Parent Attribute: Path Segment Driver Attribute

If selected, the Path Segment Driver Interoperability Attribute provides the ability to perform closed loop control of position and velocity along a path where the path is defined in a generic manner. The Local Path Segment Driver Attribute specifies the use of Path Segments in the Local coordinate frame. The Local coordinate frame is defined in AS6009 JAUS Mobility Service Set.

8.11.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:mobility:LocalPathSegmentDriver, 1.1		AS6009 JAUS Mobility Service Set

Table 37: - Component and Service Requirements for Local Path Segment Driver Attribute

8.12 SELF-RIGHTING ATTRIBUTE

Parent Attribute: Autonomy and Behaviors Attribute

The Self-Righting Attribute provides a mechanism for controlling and obtaining status of a self-righting behavior.

The associated custom service is designed to support a wide variety of implementations, as the method used to self-right is intentionally not specified and may include intelligent reasoning, automated scripts, or any other means.

8.12.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:behaviors:SelfRighting, 1.1	any	AS8024 JAUS Autonomous Behaviors Service Set

Table 120: - Component and Service Requirements for Self-Righting Attribute

CHAPTER 9 PAYLOAD SECTION

9.1 SENSOR SECTION

9.1.1 Sensor Attribute

Parent Attribute: Core Software and Logical Attribute

The Sensor Interoperability Attribute provides capabilities to sense aspects inherent to a platform or the environment.

Any number of the following attributes can be chosen.

Attribute	Description
Video Attribute	Provides a method for interacting with a video source, such as a digital or analog camera or video from another source.
Still Image Attribute	Provides the capability to configure and retrieve information from a still image source.
Range Sensor Attribute	Provides the capability for getting information back from a range sensor. This may be either a simple range finder (one range, like a ranging laser) or a more complex range finder (like a LIDAR unit with many returns per second over a large azimuth).
Microphone Attribute	Provides the capability to receive audio from a microphone device. It is assumed that the audio will be sent in a digital format. Multiple microphones may be represented using this attribute.
Chemical, Biological, Radiological, & Nuclear Sensor Attribute	The Chemical, Biological, Radiological, & Nuclear Sensor Attribute provides a method for interacting with a Chemical, Biological, Radiological, & Nuclear (CBRN) sensor source.
Tire Pressure System Attribute	Provides the capability to communicate, control and receive status from a tire pressure system.
Acceleration State Sensor Attribute	Defines the capability to report acceleration state information.
Velocity State Sensor Attribute	Defines the capability to report velocity state information.
Force/Torque Sensor Attribute	Provides a way to get force or torque information from one or more devices.
Acoustic Sensor Attribute	Provides a mechanism for controlling and obtaining data from an acoustic sensor.
Engagement Detection Attribute	The Engagement Detection Attribute provides a capability to identify and locate small weapons fire. The capability itself is agnostic of the underlying detection mechanism and specific sensor(s) used.

Magnetic Sensor Attribute	Provides a mechanism for controlling and obtaining data from an magnetic sensor.
Seismic Sensor Attribute	Provides a mechanism for controlling and obtaining data from a seismic sensor.
Global Contact Tracking Attribute	Provides a capability to identify and track objects moving in the environment. These objects may be limited to humans, vehicles, pedestrians, etc. based on the specific needs of the program. The actual method of detection and tracking, e.g. vision versus lidar or some combination, is left to the implementation

Table38: - Optional Select = any

9.1.2 Video Attribute

Parent Attribute: Sensor Attribute

Video based sensors come in various forms. Some video data present information in color and others present information in monochrome. Others convey different meanings with hue, saturation, and value (e.g. infrared vs. LADAR) of each pixel. Some cameras can only turn when the vehicle is commanded to turn while others can be controlled independently from the UGV chassis.

At least one of the following attributes must be chosen.

Attribute	Description
Digital Video Attribute	The Digital Video Interoperability Attribute provides a method for interacting with a digital video source, such as a digital camera or digital video from another digital source.
Analog Video Attribute	Provides a method for interacting with an analog video source, such as an analog camera.

Table 122: - Mandatory Select = any

Any number of the following attributes can be chosen.

Attribute	Description
Pan Tilt Video Sensor Attribute	Provides the capability to configure, control, and find/connect to a video device (analog or digital) that has pan tilt capabilities (i.e. a PTZ camera).

Table 123: - Optional Select = any

9.1.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:environmentSensing:VisualSensor, 1.0		AS6060 JAUS Environment Sensing Service Set

Table 124: - Component and Service Requirements for Video Attribute

9.1.2.2 Video Requirement

V1.JAUS-52 *An IOP defined thermal imaging sensor shall use the added value enumerations and value ranges specified in the Visual Sensor service Notes and Interpretations section for reporting and setting thermal imaging sensor specific modes (color palettes).*

V1.JAUS-53 *An IOP defined thermal imaging sensor shall use the added subfield specified in the Visual Sensor service Notes and Interpretations section for reporting thermal imaging sensor mode capabilities (supported color palettes).*

9.1.2.2.1 Notes and Interpretations

9.1.2.2.1.1 Visual Sensor

Thermal Imaging sensors are a special type of visual sensor that display thermal variations in the environment to a user. Thermal imaging cameras present data to a user by applying a color palette to represent the different temperatures. Common palettes include White Hot (hotter temperatures are shown using white pixels), Black Hot (hotter pixels are shown using Black Hot), and Rainbow Hot/Cold (a spectrum of colors is used to show temperature variations, like using red for hottest and blue for coldest). The default JAUS Visual Sensor service does not support setting or reporting on these thermal sensor imaging modes. IOP modifies the SAE JAUS Visual Sensor service by adding enumerations, ranges, and sub fields to extend the existing Report Visual Sensor Configuration, Set Visual Sensor Configuration, and Report Visual Sensor Capabilities message to support thermal imaging modes.

For the current SetVisualSensorConfiguration and ReportVisualSensorConfiguration messages, the ImagingMode field contains 4 enumerated values:

12	<fixed_field> ImagingMode	unsigned byte	one	true	value_enum 0 = Color (default) 1 = Greyscale 2 = Infrared 3 = Lowlight
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Table 125: Imaging Mode Enumeration Values

The extended IOP interpretation adds the following enumerations and value ranges:

value_enum

4 = Thermal White Hot

5 = Thermal Black Hot

6 = Thermal Rainbow Hot Cold

value_range [7-11]: Reserved for additional common thermal imaging palettes

value_range [12-19]: Sensor specific palettes

For the current ReportVisualSensorCapabilities message, the ImagingModes field current defines the following 4 supported imaging modes:

8	<bit_field> ImagingModes	unsigned byte	one	true	List of supported imaging modes (0: unsupported, 1: supported) Bit 0 = Color Bit 1 = Greyscale Bit 2 = Infrared Bit 3 = Lowlight
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Table 126: Imaging Mode Bit Field Values

The extended IOP interpretation adds the following sub-fields:

- List of supported imaging modes
- Bit 4 = Thermal White Hot
- Bit 5 = Thermal Back Hot
- Bit 6 = Thermal Rainbow Hot Cold
- Bit 7 = Additional Thermal Imaging Modes

Message(s)	Concept	Interpretations
ID 2806: QueryVisualSensorCapabilities ID 2807: QueryVisualSensorConfiguration ID 2805: QuerySensorGeometricProperties ID 0803: SetVisualSensorConfiguration ID 4806: ReportVisualSensorCapabilities ID 4807: ReportVisualSensorConfiguration ID 4805: ReportSensorGeometricProperties ID 0801: ConfirmSensorConfiguration	Use of Sensor ID Field	The values 1000 - 1032 are reserved SensorID values for drive cameras. Any Video Sensor with a SensorID of between 1000 and 1032, inclusive, indicates that it is a video feed suitable for driving a platform. It is recommended, but not required, that any camera suitable for driving falls in the range 1000 - 1032 inclusive.
ID 4805: ReportSensorGeometricProperties	Reporting of Manipulator Attachment Points	Any video sensor that is attached to a known point on a manipulator, including a pan tilt manipulator, shall report the JAUS ID and joint number that the analog video sensor is attached to.

<p>ID 4807: ReportVisualSensorConfiguration ID 0803: SetVisualSensorConfiguration</p>	<p>Additional value enumerations and ranges for Thermal Imaging modes.</p>	<p>The following value enumerations and value ranges are added to the ImagingModeEnum fixed field as seen on page 73 of AS6060 JAUS Environmental Sensing Service Set:</p> <pre> <value_enum enum_index="4" enum_const="Thermal White Hot" /> <value_enum enum_index="5" enum_const="Thermal Black Hot" /> <value_enum enum_index="6" enum_const="Thermal Rainbow Hot Cold" /> <value_range lower_limit="7" lower_limit_type="inclusive" upper_limit="11" upper_limit_type="inclusive" interpretation="Reserved for Additional Common Thermal Imaging Palettes" /> <value_range lower_limit="12" lower_limit_type="inclusive" upper_limit="19" upper_limit_type="inclusive" interpretation="Sensor Specific Palettes" /> </pre>
<p>ID 4806: ReportVisualSensorCapabilities</p>	<p>Additional supported imaging modes bit values.</p>	<p>The following subfields are added to the "ImagingModes" bit field as seen on page 104 of AS6060 JAUS Environment Sensing Service Set:</p> <pre> <sub_field name="Thermal White Hot"> <bit_range from_index="4" to_index="4" /> <value_set offset_to_lower_limit="false" /> </pre>

		<pre><value_enum enum_const="Unsupported" enum_index="0" /> <value_enum enum_const="Supported" enum_index="1" /> </value_set> </sub_field> <sub_field name="Thermal Black Hot"> <bit_range from_index="5" to_index="5" /> <value_set offset_to_lower_limit="false" /> <value_enum enum_const="Unsupported" enum_index="0" /> <value_enum enum_const="Supported" enum_index="1" /> </value_set> </sub_field> <sub_field name="Thermal Rainbow Hot Cold"> <bit_range from_index="6" to_index="6" /> <value_set offset_to_lower_limit="false" /> <value_enum enum_const="Unsupported" enum_index="0" /> <value_enum enum_const="Supported" enum_index="1" /> </value_set> </sub_field> <sub_field name="Additional Thermal Imaging Modes"> <bit_range from_index="7" to_index="7" /></pre>
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		<pre> <value_set offset_to_lower_limit="false" /> <value_enum enum_const="Unsupported" enum_index="0" /> <value_enum enum_const="Supported" enum_index="1" /> </value_set> </sub_field> </pre>
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Table 39: - Message Interpretations for Visual Sensor

9.1.3 Digital Video Attribute

Parent Attribute: Video Attribute

The Digital Video Interoperability Attribute provides a method for interacting with a digital video source, such as a digital camera or digital video from another digital source. There are two possible configurations that can be selected: 'Pull' and 'Push'.

Video sources may be categorized as a drive camera (non-drive cameras are considered general purpose cameras). This is reflected by assigning the JAUS SensorID in the 1000-1032 range. Generally, the drive cameras are permanent, platform-mounted forward or rear facing cameras, although the IOP does not explicitly define or limit what might be considered a drive camera. Drive cameras do not perform or behave in any way differently than general purpose cameras, but having the additional information available at the controller may allow the operator to rapidly differentiate between multiple video streams to perform a particular function. For swappable payloads that include video sources, implementations should consider run-time configurable approaches to setting the SensorID so that the decision to assign a video source as a drive camera can be made in the field. Ultimately, it is the responsibility of the program or requirements writer to determine which video source(s), if any, should be categorized as a drive camera and how SensorID assignments for video payloads should be addressed.

In the simplest configuration, each camera is associated one-to-one with a digital video stream. In some systems, however, multiple cameras may feed into one digitizing board resulting in a many-to-one relationship between cameras and video streams. Further, the cameras may be multiplexed such that a single video stream contains feeds from multiple cameras. In this scenario, the IOP allows that all cameras and all supported multiplexed feeds be treated as unique video SensorIDs. As a result, the number of SensorIDs may exceed the number of registered digital video streams. In this case, some additional requirements are placed on the assignment and use of SensorIDs:

1. When multiple cameras (or multiplexed cameras) are associated with a single video stream, the SensorIDs assigned to each camera must be contiguous.
2. When a stream is associated with multiple cameras, the stream must register using the lowest SensorID.
3. A client can select which camera is active for a video stream using the State field of the SetVisualSensorConfiguration message. When a particular SensorID is made active, it is assumed that all other cameras associated with that video stream are inactive.
4. Each reported sensor may optionally use the SensorName field of the ReportVisualSensorCapabilities message to provide additional information about the relationship between cameras and streams.

As an example, consider a case where 4 cameras are connected to a digitization board capable of producing 2 independent video streams. The board also supports multiplexing such that all four cameras can be combined into a single "quad view" video stream. In this scenario, the video provider would have a total of 10 SensorIDs, according to the following table:

Sensor ID	Physical Interpretation
1	Camera 1 on Stream 1
2	Camera 2 on Stream 1
3	Camera 3 on Stream 1
4	Camera 4 on Stream 1
5	Quad View (multiplexed) on Stream 1
6	Camera 1 on Stream 2
7	Camera 2 on Stream 2
8	Camera 3 on Stream 2
9	Camera 4 on Stream 2
10	Quad View (multiplexed) on Stream 2

Table 128: Sensor IDs

When using the Digital Video "Pull" attribute, two video streams would register with the Digital Resource Discovery Service, with one stream referencing SensorID of 1, and the second stream referencing SensorID of 6.

The following attributes are mutually exclusive, exactly one must be chosen.

Attribute	Description
Digital Video Pull Attribute	Provides a method for interacting with an digital video source using the 'Pull' configuration.
Digital Video Push Attribute	Provides a method for interacting with an digital video source using the 'Push' configuration.

Table 40: - Mandatory Select = one

The following attributes are mandatory.

Attribute	Description
H264 Video Encoding Attribute	If H264 video encoding is used, specifies services and requirements to support H.264 video encoding.

Table 41: - Mandatory Select = all

9.1.3.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:environmentSensing:DigitalVideo, 1.0		AS6060 JAUS Environment Sensing Service Set

Table 421: - Component and Service Requirements for Digital Video Attribute

9.1.3.2 Digital Video Requirement

9.1.3.2.1 Notes and Interpretations

9.1.3.2.1.1 Digital Video

Message(s)	Concept	Interpretations
ID 0805: ControlDigitalVideoSensorStream	Use of Message	The ControlDigitalVideoSensorStream message may be sent, but a video source may ignore the message if that video source is controlled using another method like RTSP. For any attribute that defines a method alternate to the ControlDigitalVideoSensorStream message for doing stream control, you

		should not use the ControlDigitalVideoStream message.
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Table 43: - Message Interpretations for Digital Video

9.1.4 Digital Video Pull Attribute

Parent Attribute: Digital Video Attribute

If the pull configuration is selected, then digital video shall be done using RTSP and RTP as specified in the Payloads IOP. RTSP serves as the protocol for establishing a video session, and RTP is the transport layer over which the video is actually sent.

9.1.4.1 Digital Video Registration Requirement

If the Platform Management Attribute is specified, a video source is responsible for registering its stream(s) with the Digital Resource Discovery service.

V1.JAUS-54 *If the Platform Management Attribute is specified, a digital video source implemented using the Digital Video Pull Attribute shall register itself with the Digital Resource Discovery service using the RegisterDigitalVideoEndpoint message.*

V1.JAUS-55 *If the Platform Management Attribute is specified, a digital video source implemented using the Digital Video Pull Attribute shall periodically check for the Digital Resource Discovery service until it is able to register its endpoints. The digital video endpoint is responsible for ensuring it was properly registered with the Digital Resource Discovery service, and shall attempt to re-register if registration attempts fail.*

9.1.5 Digital Video Push Attribute

Parent Attribute: Digital Video Attribute

If the Digital Video Push Attribute is selected, then digital video shall be done as follows:

1. Client determines the imaging capabilities of the sensor.
2. Client configures the sensor's imaging modes and parameters.
3. Client determines the sensor's video format options and streaming capabilities.
4. Client selects format option and streaming format.
5. Client supplies its own IP address and desired RTP port to which it desires the video stream to be sent.
6. Client commands the sensor to initiate the video stream.

9.1.5.1 Component and Service Requirements

Service	Component	Reference
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urn:jaus:jss:exp:aeodrs:AEODRSDigitalVideo, 1.4		Custom Services, Messages, and Transports
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Table 44: - Component and Service Requirements for Digital Video Push Attribute

9.1.6 H264 Video Encoding Attribute

Parent Attribute: Digital Video Attribute

If H.264 is selected as the encoding for the digital video stream, the requirements defined by this attribute must be implemented. This attribute is expected to be included in support of one of the Digital Video attributes, and not independently.

9.1.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:H264VideoEncoding, 1.0		Custom Services, Messages, and Transports

Table 45: - Component and Service Requirements for H264 Video Encoding Attribute

9.1.6.2 H264 Video Encoding Requirement

V1.JAUS-56 If the digital video implementation does not use H.264, the services identified by the H264 Video Encoding Attribute shall be considered optional.

9.1.7 Analog Video Attribute

Parent Attribute: Video Attribute

The Analog Video Interoperability Attribute provides a method for interacting with an analog video source, such as an analog camera. Multiple related analog video sensors (such as multiple analog cameras on a single payload) may be represented using this capability.

Video sources may be categorized as a drive camera (non-drive cameras are considered general purpose cameras). This is reflected by assigning the JAUS SensorID in the 1000-1032 range. Generally, the drive cameras are permanent, platform-mounted forward or rear facing cameras, although the IOP does not explicitly define or limit what might be considered a drive camera. Drive cameras do not perform or behave in any way differently than general purpose cameras, but having the additional information available at the controller may allow the operator to rapidly differentiate between multiple video streams to perform a particular function. For swappable payloads that include video sources, implementations should consider run-time configurable approaches to setting

the SensorID so that the decision to assign a video source as a drive camera can be made in the field. Ultimately, it is the responsibility of the program or requirements writer to determine which video source(s), if any, should be categorized as a drive camera and how SensorID assignments for video payloads should be addressed.

9.1.7.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:environmentSensing:AnalogVideo, 1.0		AS6060 JAUS Environment Sensing Service Set

Table 46: - Component and Service Requirements for Analog Video Attribute

9.1.8 Pan Tilt Video Sensor Attribute

Parent Attribute: Video Attribute

The Pan Tilt Video Sensor Interoperability Attribute provides the capability to configure, control, and find/connect to a video device (analog or digital) that has pan tilt capabilities (i.e. a PTZ camera). The Pan Tilt Video Sensor is a specific instance of a Basic Pan Tilt Manipulator Interoperability Attribute that applies a Digital Video Sensor Attribute or Analog Video Sensor Attribute. The Pan Tilt Video Sensor is provided as its own Interoperability Attribute because of its common use as a sensor.

The following attributes are mandatory.

Attribute	Description
Pan Tilt Manipulator Attribute	Defines requirements common to all pan-tilt manipulator related services.

Table 47: - Mandatory Select = all

9.1.8.1 Pan Tilt Video Sensor Requirement

V1.JAUS-57 The video sensor on the pan tilt unit must report the JAUS ID of the component it is attached to regardless of where the Digital Video or Analog Video service is located.

9.1.9 Still Image Attribute

Parent Attribute: Sensor Attribute

The Still Image Interoperability Attribute defines the capability to configure and retrieve information from a still image source. Multiple related still image sources (such as multiple cameras that all take still images on a single payload) may be represented.

9.1.9.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:environmentSensing:StillImage, 1.0		AS6060 JAUS Environment Sensing Service Set

Table 48: - Component and Service Requirements for Still Image Attribute

9.1.10 Range Sensor Attribute

Parent Attribute: Sensor Attribute

Successful UGV navigation requires detailed knowledge of the surrounding area. Static and dynamic obstacles and other terrain features can impede UGV mobility if not detected. Laser range finder sensors can help in this regard by providing distance information. These distance vectors can also aid in aiming weapons.

The Range Sensor Interoperability Attribute provides the capability for getting information back from a range sensor. This may be either a simple range finder (one range, like a ranging laser) or a more complex range finder (like a LIDAR, RADAR, or Ground-Penetrating RADAR unit with many returns per second over a large azimuth). Multiple related range sensors (such as multiple LIDARs on a single payload) may be represented using this attribute.

9.1.10.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:environmentSensing:RangeSensor, 1.0		AS6060 JAUS Environment Sensing Service Set

Table 49: - Component and Service Requirements for Range Sensor Attribute

9.1.10.2 Range Sensor Requirement

9.1.10.2.1 Notes and Interpretations

9.1.10.2.1.1 Range Sensor

Message(s)	Concept	Interpretations
ID 4801: ReportRangeSensorCapabilities	Use of the CoordinateTransformationS supported field.	The value for support of coordinate transformations in a range sensor shall be 0 unless the CoordinateTransformationS

		upported field is provided with a value of 1.
ID 4801: ReportRangeSensorCap abilities	Use of the RangeSensorDataPointRec	For a single point range sensor (i.e. a single distance ranging laser), the PointID field shall not be included. Bearing and inclination shall be set to 0 and 0 respectively unless the range sensor does not get distance straight ahead with regard to its reference frame.

Table 50: - Message Interpretations for Range Sensor

9.1.11 Microphone Attribute

Parent Attribute: Sensor Attribute

The Microphone Interoperability Attribute provides the capability to receive audio from a microphone device. It is assumed that the audio will be sent in a digital format. Multiple microphones may be represented using this attribute.

At least one of the following attributes must be chosen.

Attribute	Description
Microphone Pull Attribute	Provides the capability to receive audio from a microphone device. It is assumed that the audio will be sent in a digital format. The pull method uses an RTSP endpoint to serve up a digital stream over RTP, making the client pull the stream from a registered audio endpoint.
Microphone Push Attribute	Provides the capability to receive audio from a microphone device. It is assumed that the audio will be sent in a digital format. The push method tells the digital audio source what endpoint it should send audio to using RTP.

Table 51: - Mandatory Select = any

9.1.12 Microphone Pull Attribute

Parent Attribute: Microphone Attribute

If the Pull configuration is selected, then digital audio shall be done using RTSP and RTP as specified in the Payloads IOP. RTSP serves as the protocol for establishing an audio

session, and RTP is the transport layer over which the video is actually sent. A component containing a microphone shall register with the DigitalResourceDiscovery service in the same way that a video source registers.

9.1.12.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:DigitalAudio, 1.1		Custom Services, Messages, and Transports

Table 52: - Component and Service Requirements for Microphone Pull Attribute

9.1.12.2 Microphone Pull Requirement

If the Platform Management Attribute is specified, an audio source is responsible for registering its stream(s) with the Digital Resource Discovery service.

V1.JAUS-58 If the Platform Management Attribute is specified, a microphone (audio source) implemented using the Microphone Pull Attribute shall register itself with the Digital Resource Discovery service using the RegisterDigitalResourceEndpoint message.

V1.JAUS-59 If the Platform Management Attribute is specified, a microphone (audio source) implemented using the Microphone Pull Attribute shall periodically check for the Digital Resource Discovery service until it is able to register its endpoints. The digital audio endpoint is responsible for ensuring it was properly registered with the Digital Resource Discovery service, and shall attempt to re-register if registration attempts fail.

9.1.12.2.1 Notes and Interpretations

9.1.12.2.1.1 Digital Audio

Message(s)	Concept	Interpretations
ID DAAE: SetDigitalAudioConfiguration ID DABE: QueryDigitalAudioCapabilities ID DACE: QueryDigitalAudioConfiguration ID DAEE: ReportDigitalAudioCapabilities	Sensor ID Field	The primary SensorID (microphone) on a platform shall be assigned the lowest SensorID out of all the microphones. The primary microphone is not explicitly defined, but will likely be a microphone used to communicate for platform-human interactions.

ID DAFE: ReportDigitalAudioConfiguration		
ID DAAE: SetDigitalAudioConfiguration ID DAFE: ReportDigitalAudioConfiguration	Sensitivity Field	For a microphone, the sensitivity field indicates the ratio of sound that gets recorded/transmitted to the power of the input sound received by the microphone. A value of 0% indicates that nothings is recorded/transmitted, while a value of 100% indicates that maximum amplification is applied to the input sound.

Table 532: - Message Interpretations for Digital Audio

9.1.13 Microphone Push Attribute

Parent Attribute: Microphone Attribute

If the push configuration is selected, then digital audio from a microphone shall be done as follows:

1. Client determines the capabilities of the sensor.
2. Client configures the sensor's modes and parameters.
3. Client determines the sensor's format options and streaming capabilities.
4. Client selects format option and streaming format.
5. Client supplies its own IP address and desired RTP port to which it desires the audio stream to be sent.
6. Client commands the sensor to initiate the audio stream.

9.1.13.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:exp:aeodrs:DigitalAudioSensor, 1.4		Custom Services, Messages, and Transports

Table 54: - Component and Service Requirements for Microphone Push Attribute

9.1.13.2 Microphone Push Requirement

9.1.13.2.1 Notes and Interpretations

9.1.13.2.1.1 Digital Audio Sensor

Message(s)	Concept	Interpretations
ID EE01: QueryDigitalAudioSensorCapabilities	Sensor ID Field	The primary SensorID (microphone) on a platform shall be assigned the lowest

ID EE02: QueryDigitalAudioSensorConfiguration ID DE02: SetDigitalAudioSensorConfiguration ID DE03: SetDigitalAudioSensorStreamEndpoint ID FE02: ReportDigitalAudioSensorConfiguration ID FE03: ReportDigitalAudioSensorStreamEndpoint	SensorID out of all the microphones. The primary microphone is not explicitly defined, but will likely be a microphone used to communicate for platform-human interactions.
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Table 55: - Message Interpretations for Digital Audio Sensor

9.1.14 Chemical, Biological, Radiological, & Nuclear Sensor Attribute

Parent Attribute: Sensor Attribute

The Chemical, Biological, Radiological, & Nuclear Sensor Attribute provides a method for interacting with a Chemical, Biological, Radiological, & Nuclear (CBRN) sensor source.

9.1.14.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:CBRNSensorService, 1.1		Custom Services, Messages, and Transports

Table 145: - Component and Service Requirements for CBRN Sensor Attribute

9.1.15 Tire Pressure System Attribute

Parent Attribute: Sensor Attribute

The Tire Pressure Interoperability Attribute provides a way to report and potentially control the air pressure in one or more tires for the platform.

9.1.15.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:TirePressureService, 1.1		Custom Services, Messages, and Transports

Table 56: - Component and Service Requirements for Tire Pressure System Attribute

9.1.16 Acceleration State Sensor Attribute

Parent Attribute: Sensor Attribute

The Acceleration State Sensor Interoperability Attribute specifies an acceleration state sensing capability. This acceleration state may come from a sensor such as an Inertial Measurement Unit (IMU).

9.1.16.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:mobility:AccelerationStateSensor, 1.1		AS6009 JAUS Mobility Service Set

Table 57: - Component and Service Requirements for Acceleration State Sensor Attribute

9.1.17 Velocity State Sensor Attribute

Parent Attribute: Sensor Attribute

The Velocity State Sensor Interoperability Attribute specifies a velocity state sensing capability.

9.1.17.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:mobility:VelocityStateSensor, 1.1		AS6009 JAUS Mobility Service Set

Table 58: - Component and Service Requirements for Velocity State Sensor Attribute

9.1.18 Force/Torque Sensor Attribute

Parent Attribute: Sensor Attribute

The Force Torque Sensor Interoperability Attribute provides a way to get force or torque information from one or more devices.

9.1.18.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:ForceTorqueSensor, 1.1		Custom Services, Messages, and Transports

Table 59: - Component and Service Requirements for Force/Torque Sensor Attribute

9.1.19 Acoustic Sensor Attribute

Parent Attribute: Sensor Attribute

The Acoustic Sensor Attribute provides a mechanism for controlling and obtaining data from an acoustic sensor.

9.1.19.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:AcousticSensor, 2.0	any	Custom Services, Messages, and Transports

Table 60: - Component and Service Requirements for Acoustic Sensor Attribute

9.1.19.2 Acoustic Sensor Requirement

The custom service is designed to support a wide variety of underlying hardware, so a Query/Report Capabilities pair allows a client to determine the capabilities of a particular implementation.

9.1.20 Engagement Detection Attribute

Parent Attribute: Sensor Attribute

The Engagement Detection Attribute provides a capability to identify and locate small weapons fire. The capability itself is agnostic of the underlying detection mechanism and specific sensor(s) used.

The Engagement Detection Attribute provides a mechanism for controlling and obtaining data from a system capable of detecting, locating, and possibly classifying small arms fire. The associated custom service is designed to support a wide variety of underlying hardware, and is agnostic to the sensor(s) and algorithms used.

9.1.20.1 Component and Service Requirements

Service	Component	Reference
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urn:jaus:jss:iop:EngagementDetection, 1.1	any	Custom Services, Messages, and Transports
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Table 61: - Component and Service Requirements for Engagement Detection Attribute

9.1.21 Magnetic Sensor Attribute

Parent Attribute: Sensor Attribute

The Magnetic Sensor Attribute provides a mechanism for controlling and obtaining data from a magnetic sensor.

9.1.21.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:MagneticSensor, 1.1	any	Custom Services, Messages, and Transports

Table 62: - Component and Service Requirements for Magnetic Sensor Attribute

9.1.21.2 Magnetic Sensor Requirement

The custom service is designed to support a wide variety of underlying hardware, so a Query/Report Capabilities pair allows a client to determine the capabilities of a particular implementation.

9.1.22 Seismic Sensor Attribute

Parent Attribute: Sensor Attribute

The Seismic Sensor Attribute provides a mechanism for controlling and obtaining data from a seismic sensor.

9.1.22.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:SeismicSensor, 1.1	any	Custom Services, Messages, and Transports

Table 633: - Component and Service Requirements for Seismic Sensor Attribute

9.1.22.2 Seismic Sensor Requirement

The custom service is designed to support a wide variety of underlying hardware, so a Query/Report Capabilities pair allows a client to determine the capabilities of a particular

implementation. While the service is flexible enough to support a number of use cases, the expected application is intruder detection.

9.1.23 Global Contact Tracking Attribute

Parent Attribute: Sensor Attribute

The Global Contact Tracking Attribute provides a capability to identify and track objects moving in the environment. The service itself is agnostic of the underlying detection mechanism and specific sensor(s) used.

The Global Contact Tracking Attribute provides a mechanism for obtaining data from a system capable of detecting, locating, tracking, and possibly classifying moving objects. The associated custom service is designed to support a wide variety of underlying hardware, and is agnostic to the sensor(s) and algorithms used.

9.1.23.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:GlobalContactTracking, 1.1	any	Custom Services, Messages, and Transports

Table 64: - Component and Service Requirements for Global Contact Tracking Attribute

9.2 EMITTERS SECTION

9.2.1 Emitter Attribute

Parent Attribute: Core Software and Logical Attribute

The following attributes describe each of these emitters.

Any number of the following attributes can be chosen.

Attribute	Description
Illumination Attribute	Provides the capability to interact with lights.
Camera Lights Attribute	Provides a method for interacting with lights associated with one or more cameras.
Speaker Attribute	Provides the capability to send audio that gets annunciated over a speaker. Multiple speakers may be represented using this attribute.

Debris Blower Attribute	Provides the capability to blow debris.
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Table 65: - Optional Select = any

9.2.2 Illumination Attribute

Parent Attribute: Emitter Attribute

If selected, the Illumination Interoperability Attribute provides the capability to interact with lights.

Note that this is intended for platform centric lights and not camera lights – the Camera Lights Interoperability Attribute defines methods more appropriate for interacting with camera lights.

Any number of the following attributes can be chosen.

Attribute	Description
Military Illumination Attribute	Provides the capability to engage military style lighting such as blackout lamps (i.e. markers, head lights, tail lights, etc.).

Table 66: - Optional Select = any

9.2.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:ugv:IlluminationService, 1.0		AS6091 JAUS UGV Service Set

Table 67: - Component and Service Requirements for Illumination Attribute

9.2.2.2 Illumination Requirement

9.2.2.2.1 Notes and Interpretations

9.2.2.2.1.1 Illumination

Message(s)	Concept	Interpretations
ID 0513: SetIlluminationState ID 4513: ReportIlluminationState ID 4514: ReportIlluminationConfiguration	IlluminationState bit_field	1. - Headlights – the headlights field will be used to turn on and off vehicle headlights. Headlights are defined as forward facing light or lights used to illuminate the driving path of a vehicle as it moves forward. For vehicles without

		<p>traditional headlights (i.e. on a smaller platform), this is defined as any non-variable lights associated with the vehicle forward drive camera.</p> <ol style="list-style-type: none">2. - Left Turn Signal – the left turn signal will be used to turn on and off a vehicle’s left turn signal. The left turn signal is defined as a visual signal presented to an observer behind the vehicle that indicates the vehicle is about to or is turning left. In the case of a vehicle that has no left turn signal, this field shall be set to 0 indicating off. On may indicate either a solid or blinking on state.3. - Right Turn Signal – the right turn signal will be used to turn on and off a vehicle’s right turn signal. The right turn signal is defined as a visual signal presented to an observer behind the vehicle that indicates the vehicle is about to or is turning right. In the case of a vehicle that has no right turn signal, this field shall be set to 0 indicating off. On may indicate either a solid or blinking on state.4. - Running Lights – the running lights field will be used to turn on and off vehicle running lights. Running lights are defined as all lights that are used while a vehicle is running for purposes other than signaling or driving (i.e. lighting for safety).
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		<p>5. - Brake Lights – the brake lights field will be used to turn on and off vehicle brake lights. Brake lights are defined as rear facing lights used to indicate that a vehicle is applying a resistive linear force in order to slow down. If a vehicle does not have brake lights, this field shall be set to 0 indicating off.</p> <p>6. - VariableLights – the variable light fields are used to turn on and off lights that have varying intensities, where 0 indicates off and 15 indicates maximum intensity. Values in between shall be mapped to the closest light level the variable light is capable of producing.</p> <p>7. - VisibleLightSource – the VisibleLightSource field shall not be used for the overall vehicle.</p> <p>8. - IRLightSource – the IRLightSource field will be used to turn on and off an IR light source associated with the currently controlled drive camera</p>
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Table 68: - Message Interpretations for Illumination

9.2.3 Military Illumination Attribute

Parent Attribute: Illumination Attribute

If selected, the Military Illumination Attribute provides the capability to engage military style lighting such as blackout lamps (i.e. markers, head lights, tail lights, etc.).

9.2.3.1 Component and Service Requirements

Service	Component	Reference
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urn:jaus:jss:ugv:MilitaryIlluminationService, 1.0		Custom Services, Messages, and Transports
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Table 69: - Component and Service Requirements for Military Illumination Attribute

9.2.3.2 Military Illumination Requirement

9.2.3.2.1 Notes and Interpretations

The Military Illumination Service inherits from the Illumination service meaning that selecting military illumination also selects regular illumination control.

9.2.4 Camera Lights Attribute

Parent Attribute: Emitter Attribute

If selected, the Camera Lights Interoperability Attribute provides the capability to interact with lights that are associated with a camera.

9.2.4.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:exp:aeodrs:AEODRSVideoIlluminator, 2.0		Custom Services, Messages, and Transports

Table 70: - Component and Service Requirements for Camera Lights Attribute

9.2.5 Speaker Attribute

Parent Attribute: Emitter Attribute

The Speaker Interoperability Attribute provides the capability to send audio that gets announced over a speaker. It is assumed that the audio will be sent in a digital format and converted to an analog signal if required by the speaker. Multiple speakers may be represented using this attribute.

At least one of the following attributes must be chosen.

Attribute	Description
Speaker Pull Attribute	Provides the capability to send audio to a speaker device. It is assumed that the audio will be sent in a digital format. The pull method uses an RTSP endpoint to serve up a digital stream over RTP, making the speaker component pull the audio that it will play from a specified stream.

Speaker Push Attribute	Provides the capability to send audio to a speaker device. It is assumed that the audio will be sent in a digital format. The push method tells the client (i.e. OCU) where it should push audio data over RTP to.
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Table 71: - Mandatory Select = any

9.2.6 Speaker Pull Attribute

Parent Attribute: Speaker Attribute

If the Pull configuration is selected, then digital audio shall be done using RTSP and RTP as specified in the Payloads IOP. RTSP serves as the protocol for establishing an audio session, and RTP is the transport layer over which the video is actually sent. The component containing the speaker service will be told the endpoint from which it can stream the audio the speaker will play.

9.2.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:DigitalAudioAnnunciator, 1.1		Custom Services, Messages, and Transports

Table 72: - Component and Service Requirements for Speaker Pull Attribute

9.2.6.2 Speaker Pull Requirement

If the Pull configuration is selected, then digital audio shall be done using RTSP and RTP as specified in the Payloads IOP. RTSP serves as the protocol for establishing an audio session, and RTP is the transport layer over which the video is actually sent. A component containing a microphone shall register with the DigitalResourceDiscovery service in the same way that a video source registers.

V1.JAUS-60 If the Platform Management Attribute is specified, the audio source for a speaker implemented using the Speaker Pull Attribute shall register itself with the Digital Resource Discovery service using the RegisterDigitalVideoEndpoint message.

V1.JAUS-61 If the Platform Management Attribute is specified, the audio source for a speaker implemented using the Speaker Pull Attribute shall periodically check for the Digital Resource Discovery service until it is able to register its endpoints. The digital audio endpoint is responsible for ensuring it was properly registered with the Digital Resource Discovery service, and shall attempt to re-register if registration attempts fail.

9.2.6.2.1 Notes and Interpretations

9.2.6.2.1.1 Digital Audio Annunciator

Message(s)	Concept	Interpretations
ID DA7E: SetDigitalAudioStreamSource ID DA8E: QueryDigitalAudioStreamSource ID DA9E: ReportDigitalAudioStreamSource	Sensor ID Field	The primary SensorID (speaker) on a platform shall be assigned the lowest SensorID of all speakers. The primary speaker is not explicitly defined, but will likely be a speaker used to communicate for platform-human interactions.
ID DA7E: SetDigitalAudioStreamSource	Usage	This message is used to tell the speaker where it can stream the audio it will play from. It will most likely be located on a client such as an Operator Control Unit.
ID DAAE: SetDigitalAudioConfiguration ID DAFE: ReportDigitalAudioConfiguration	Digital Audio Sensitivity Field	For a speaker, the sensitivity field indicates the gain applied to the input signal as a percent. A value of 0% indicates that no output signal is generated, while a value of 100% indicates that maximum amplification is applied to the input.

Table 73: - Message Interpretations for Digital Audio Annunciator

9.2.7 Speaker Push Attribute

Parent Attribute: Speaker Attribute

If the push configuration is selected, then digital audio from a speaker shall be done as follows:

1. Client determines the capabilities of the speaker.
2. Client configures the speaker's modes and parameters.
3. Client determines the speaker's format options and streaming capabilities.
4. Client selects format option and streaming format.
5. Client queries the IP address and desired RTP port to which it will send the audio stream to the speaker.
6. Client initiates the audio stream to the speaker.

9.2.7.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:exp:aeodrs:DigitalAudioAnnunicator, 1.4		Custom Services, Messages, and Transports

Table 744: - Component and Service Requirements for Speaker Push Attribute

9.2.8 Debris Blower Attribute

Parent Attribute: Emitter Attribute

The Debris Blower Interoperability Attribute provides a way to command and control a debris/leaf blower that may be attached or towed by a platform.

9.2.8.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:DebrisBlower, 1.1		Custom Services, Messages, and Transports

Table 75: - Component and Service Requirements for Debris Blower Attribute

9.3 ACTUATORS SECTION

9.3.1 Actuator Attribute

Parent Attribute: Core Software and Logical Attribute

Actuator Interoperability Attributes are related to actuators and manipulators, and typically deal with common robotics manipulators such as arms and pan tilt units. The following Actuator Interoperability Attributes are defined:

At least one of the following attributes must be chosen.

Attribute	Description
Robotic Arm Control Attribute	Provides the capability to communicate, control, and receive status from a robotic arm.
Pan Tilt Manipulator Attribute	Defines requirements common to all pan-tilt manipulator related services.
End Effector Attribute	Adds support for the capability to control and/or receive status from an end-effector

Table 76: - Mandatory Select = any

Any number of the following attributes can be chosen.

Attribute	Description
Self-Collision Avoidance Attribute	Provides the capability to communicate, control, and receive status from a self-collision avoidance system.

Table 77: - Optional Select = any

9.3.1.1 General Actuator Requirement

Actuators are defined as devices that have linkages that move around or translate about joints. All services that control the low level manipulator capabilities of one actuator/manipulator device (i.e. a single arm with one arm controller), as defined in the selectable Actuator Interoperability Attributes, shall be placed under a single JAUS component to allow for mutually exclusive access control to low level drive services as specified in the 4.3.5 Mutually Exclusive Access Control Requirement. If two or more completely independent actuator or manipulator devices are found on a platform, each

one will have its own single JAUS component on which all of its manipulator services are contained.

9.3.1.2 Actuator/Manipulator Drive Timeouts Requirement

All actuators and manipulators that use either effort based or velocity based control of joints and/or other parts of the manipulator shall define values for drive timeout parameters similar to those in 7.1.1 Drive Timeout Requirement. These values shall specify the maximum amount of time between manipulator drive messages (i.e. SetJointEffort) to the manipulator before the manipulator is stopped. These values should be based on the capabilities and characteristics of the manipulator or actuator. Once a drive timeout has occurred, the actuator/manipulator shall stay in a stopped state until manipulator drive messages are received again for a specified amount of time at a specified minimum rate. To meet the actuator/manipulator drive timeout requirements, values must be specified for the following parameters: Actuator Drive Timeout Time and Actuator Drive Recovery Time. Figure 5: Drive Timeout above applies, except the transitions are based on manipulator drive messages instead of platform drive messages.

9.3.1.2.1 Parameter Listing

Parameter Name	Default Value	Allowed Values	Description
Actuator Drive Timeout Time	1 seconds	<Range> 0..65535 seconds	The time after receiving the last drive message (i.e. SetJointEffort) at which a Drive Timeout is considered to occur.
Actuator Drive Recovery Time	1 seconds	<Range> 0..65535 seconds	The amount of time over which drive messages must be received at the specified Drive Frequency before transitioning out of a Drive Timeout state to a Normal Drive state.

Table 78: - Parameter Listing for Actuator Attribute

9.3.2 Robotic Arm Section

9.3.2.1 Robotic Arm Control Attribute

Parent Attribute: Actuator Attribute

Robotic Arm payloads provide a means to manipulate objects. Types include lower arms that extend underneath the UGV platform and upper arms that rest on top of a UGV chassis. The arm is often positioned via a commanded desired position of the end effectors (e.g. grasper) using inverse kinematics. For many UGVs however, the operator often controls robotic arm links/joints independently. In addition, torques/forces provided by the motors are limited and the robotic arm may not be able to lift certain heavy objects that, if attempted, may cause the UGV to rollover. Therefore, feedback to the operator is often essential.

Any number of the following attributes can be chosen.

Attribute	Description
Basic Manipulator Attribute	Defines a basic manipulator controlled using open loop control.
Mast Actuator Attribute	Provides the capability to communicate, control, and receive status from a mast actuator.
Manipulator Joint Velocity Control Attribute	Defines the capability to control manipulator joints using closed loop velocity control.
Manipulator Joint Position Control Attribute	Defines the capability to control manipulator joints using closed loop position control.
Manipulator Joint Force/Torque Driver Attribute	Provides the capability to add closed loop force (prismatic joint) or torque (revolute joint) control of a manipulator.
Fly-The-End-Effector Attribute	Defines the capability to control the location or velocity of an end-effector through commanding the manipulator arm on which it is attached.
Manipulator Joint Velocity Sensor Attribute	Defines the capability to get velocity information for manipulator joints.
Manipulator Joint Position Sensor Attribute	Defines the capability to get position information for manipulator joints.
Manipulator Joint Force/Torque Sensor Attribute	Provides the capability to report the values of instantaneous torques (for revolute joints) and forces (for prismatic) joints.
Manipulator End Effector Position Sensor Attribute	Defines the capability to get information on the position of the end effector.
Manipulator End Effector Velocity State Sensor Attribute	Defines the capability to get information on the velocity of the end effector.

Table 79: - Optional Select = any

9.3.2.1.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:ManipulatorSpecificationService, 2.0		AS6057A JAUS Manipulator Service Set
urn:jaus:jss:manipulator:ManipulatorJointMotionProfile, 2.0		AS6057A JAUS Manipulator Service Set

Table 80: - Component and Service Requirements for Robotic Arm Control Attribute

9.3.2.1.2 Robotic Arm Specifications Requirement

Robotic arms typically contain multiple actuators that have linkages that move around or translate about joints. SAE AS6057A Manipulator Service Set introduces new specifications services for manipulators that take the overlapping messages of multiple manipulator services and place them in a single specification service. The general capabilities for querying and reporting the type of manipulator are provided by using the QueryManipulatorSpecifications and ReportManipulatorSpecifications messages and using the record type (revolute or prismatic) to determine the type of manipulator. This applies to all manipulator attributes that specify these messages. The type of actuator is implied for the Mast Actuator Interoperability Attribute.

Further, for services that involve moving the actuators of a robotic arm, the QueryJointMotionProfile and ReportJointMotionProfile messages specify the maximum speeds, accelerations, and decelerations for joints based on specific safety requirements for their operation.

9.3.2.1.2.1 Notes and Interpretations

9.3.2.1.2.1.1 Manipulator Specification Service

Message(s)	Concept	Interpretations
ID 2600: QueryManipulatorSpecifications ID 4600: ReportManipulatorSpecifications	Usage	The ManipulatorCoordinateSystemRec shall be included unless the manipulator service handling Query Manipulator Specifications responses is not aware of the position of the manipulator base on the platform.
ID 2600: QueryManipulatorSpecifications ID 4600: ReportManipulatorSpecifications	Joint Types	Each revolute (rotation) and prismatic (translation) joint contained in the manipulator shall be included using the appropriate records according to AS6057 JAUS Manipulator Service Set. This includes maximum and minimum joint angles or offsets (Query/Report limits), the total number of joints (Query/Report degrees of freedom), and the types of joints (prismatic or revolute).

Table 81: - Message Interpretations for Manipulator Specification Service

9.3.2.1.2.1.2 Manipulator Joint Motion Profile

Message(s)	Concept	Interpretations
ID 0607: SetJointMotionProfile	Usage	The SetJointMotionProfile message should be used to set maximum speeds, accelerations, and

		decelerations for joints based on specific safety requirements for their operation.
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Table 82: - Message Interpretations for Manipulator Joint Motion Profile

9.3.2.2 Basic Manipulator Attribute

Parent Attribute: Robotic Arm Control Attribute

Basic manipulators are the most simplistic manipulators defined by the IOP that contain support for primitive actuation. Basic manipulators provide open loop control of manipulator joints. Addition Actuator attributes can provide closed loop velocity and position control, end-effector based control, and position and velocity sensing.

9.3.2.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:PrimitiveManipulator, 2.0		AS6057A JAUS Manipulator Service Set
urn:jaus:jss:iop:ExtendedPrimitiveManipulator, 1.1		Custom Services, Messages, and Transports

Table 83: - Component and Service Requirements for Basic Manipulator Attribute

9.3.2.2.2 Basic Manipulator Requirement

9.3.2.2.2.1 Notes and Interpretations

9.3.2.2.2.1.1 Extended Primitive Manipulator

Message(s)	Concept	Interpretations
ID F293: ReportHostManipulator	Usage	This message shall report the JAUS ID and joint number of the host, if this manipulator is mounted on another.

Table 84: - Message Interpretations for Extended Primitive Manipulator

9.3.2.2.2.2 Periodicity

9.3.2.2.2.2.1 Primitive Manipulator

ID 0601: SetJointEffort – Sending of the SetJointEffort message shall comply with the manipulator drive timeout requirements defined in 9.3.1.2 Actuator/Manipulator Drive Timeouts Requirement.

9.3.2.3 Mast Actuator Attribute

Parent Attribute: Robotic Arm Control Attribute

A Mast Actuator is a component that is a specific type of Basic Manipulator, but with certain restrictions on the specifications of its joints and capabilities.

9.3.2.3.1 Mast Actuator Requirement

V1.JAUS-62 *A Mast Actuator is a manipulator with a single prismatic joint and no other joints – the Mast Actuator goes back and forth along the Mast Actuator axis of motion, where a value of 0 indicates the Mast Actuator is fully retracted and there is some maximum value that corresponds to the limit that the Mast Actuator can extend to.*

V1.JAUS-63 *The Report Manipulator Specifications message shall always report a single Prismatic Joint with a Min value (in the PrismaticJointAngleRec) of 0 and a maximum value that is equivalent to the maximum extension of the Mast Actuator.*

9.3.2.4 Manipulator Joint Position Control Attribute

Parent Attribute: Robotic Arm Control Attribute

The Manipulator Joint Position Control Interoperability Attribute adds closed loop position control of manipulator.

9.3.2.4.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:ManipulatorJointPositionDriver, 2.0		AS6057A JAUS Manipulator Service Set

[Table 855: - Component and Service Requirements for Manipulator Joint Position Control Attribute](#)

9.3.2.4.2 Manipulator Joint Position Control Requirement

9.3.2.4.2.1 Notes and Interpretations

9.3.2.4.2.1.1 Manipulator Joint Position Driver

Message(s)	Concept	Interpretations
ID 2608: QueryCommandedJointPosition ID 4608: ReportCommandedJointPosition	Usage	<ul style="list-style-type: none"> The actual positions of the joints of the manipulator and the positions of the joints reported by this message pair are not guaranteed to be the same.

[Table 86: - Message Interpretations for Manipulator Joint Position Driver](#)

9.3.2.5 Manipulator Joint Velocity Control Attribute

Parent Attribute: Robotic Arm Control Attribute

The Manipulator Joint Velocity Control Interoperability Attribute adds closed loop velocity control of manipulator joints.

9.3.2.5.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:ManipulatorJointVelocityDriver, 2.0		AS6057A JAUS Manipulator Service Set

[Table 87: - Component and Service Requirements for Manipulator Joint Velocity Control Attribute](#)

9.3.2.5.2 Manipulator Joint Velocity Control Requirement

9.3.2.5.2.1 Notes and Interpretations

9.3.2.5.2.1.1 Manipulator Joint Velocity Driver

Message(s)	Concept	Interpretations
ID 2603: QueryCommandedJointVelocity ID 4603: ReportCommandedJointVelocity	Usage	<ul style="list-style-type: none"> The actual velocities of the joints of the manipulator and the velocities of the joints reported by this message pair are not guaranteed to be the same.

[Table 88: - Message Interpretations for Manipulator Joint Velocity Driver](#)

9.3.2.5.2.2 Periodicity

9.3.2.5.2.2.1 Manipulator Joint Velocity Driver

ID 0603: SetJointVelocity - Sending of the SetJointVelocity message shall comply with the manipulator drive timeout requirements defined in 9.3.1.2 Actuator/Manipulator Drive Timeouts Requirement.

9.3.2.6 Manipulator Joint Force/Torque Driver Attribute

Parent Attribute: Robotic Arm Control Attribute

The Manipulator Joint Force/Torque Driver Interoperability Attribute adds closed loop force (prismatic joint) or torque (revolute joint) control of a manipulator.

9.3.2.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:ManipulatorActuatorForceTorqueDriver, 2.0		AS6057A JAUS Manipulator Service Set

[Table 89: - Component and Service Requirements for Manipulator Joint Force/Torque Driver Attribute](#)

9.3.2.6.2 Manipulator Joint Force/Torque Driver Requirement

9.3.2.6.2.1 Notes and Interpretations

9.3.2.6.2.1.1 Manipulator Joint Force/Torque Driver

Message(s)	Concept	Interpretations
ID 2613: QueryCommandedActuatorForceTorque ID 4613: ReportCommandedActuatorForceTorque	Usage	The actual values of the force/torque and the force/torque reported by this message pair are not guaranteed to be the same.

Table 90: - Message Interpretations for Manipulator Joint Force/Torque Driver

9.3.2.6.2.2 Periodicity

9.3.2.6.2.2.1 Manipulator Joint Force/Torque Driver

ID 0613: SetActuatorForceTorque - Sending of the SetActuatorForceTorque message shall comply with the manipulator drive timeout requirements defined in 9.3.1.2 Actuator/Manipulator Drive Timeouts Requirement.

9.3.2.7 Fly-The-End-Effector Attribute

Parent Attribute: Robotic Arm Control Attribute

The Fly-The-End-Effector Interoperability Attribute allows for a manipulator arm to be commanded via a desired position or velocity of an attached end effector (e.g. grasper), generally using inverse kinematics.

The following attributes are mandatory.

Attribute	Description
End Effector Attribute	Adds support for the capability to control and/or receive status from an end-effector

Table 91: - Mandatory Select = all

At least one of the following attributes must be chosen.

Attribute	Description
Manipulator End Effector Position Control Attribute	Defines the capability to "fly the end effector" using closed loop position control of an end effector.
Manipulator End Effector Velocity Control Attribute	Defines the capability to "fly the end effector" using closed loop velocity commands.

Table 92: - Mandatory Select = any

Any number of the following attributes can be chosen.

Attribute	Description
Manipulator End Effector Frame of Reference Attribute	The Frame of Reference Attribute allows a client to change the coordinate frame for end effector based services. This allows for more user-friendly options for fly-the-end-effector functionality and coordination between two or more manipulators on the same platform.
Manipulator End Effector Position Sensor Attribute	Defines the capability to get information on the position of the end effector.
Manipulator End Effector Velocity State Sensor Attribute	Defines the capability to get information on the velocity of the end effector.

Table 93: - Optional Select = any

9.3.2.7.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:ManipulatorToolOffsetService, 2.0		AS6057A JAUS Manipulator Service Set

Table 94: - Component and Service Requirements for Fly-The-End-Effector Attribute

9.3.2.7.2 Fly-The-End-Effector Requirement

9.3.2.7.2.1 Notes and Interpretations

9.3.2.7.2.1.1 Manipulator Tool Offset

Message(s)	Concept	Interpretations
ID 0604: SetToolOffset	Usage	<ul style="list-style-type: none"> If there is no tool other than a simple gripper, this message shall have no meaning. Interpretation of this message for other end effectors (i.e. cutters, excavators, etc.) is reserved for later versions of this document.

Table 95: - Message Interpretations for Manipulator Tool Offset

9.3.2.8 Manipulator Joint Velocity Sensor Attribute

Parent Attribute: Robotic Arm Control Attribute

The Manipulator Joint Velocity Sensor Interoperability Attribute adds velocity sensing capability for manipulator.

9.3.2.8.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:ManipulatorJointVelocitySensor, 2.0		AS6057A JAUS Manipulator Service Set

Table 966: - Component and Service Requirements for Manipulator Joint Velocity Sensor Attribute

9.3.2.8.2 Manipulator Joint Velocity Sensor Requirement

9.3.2.8.2.1 Periodicity

9.3.2.8.2.1.1 Manipulator Joint Velocity Sensor

Message(s)	Rate
ID 2603: QueryJointVelocity	10.0 Hz (Recommended)

Table 97: - Periodicity Information for Manipulator Joint Velocity Sensor

9.3.2.9 Manipulator Joint Position Sensor Attribute

Parent Attribute: Robotic Arm Control Attribute

The Manipulator Joint Position Sensor Interoperability Attribute adds position sensing capability for manipulator joints.

9.3.2.9.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:ManipulatorJointPositionSensor, 2.0		AS6057A JAUS Manipulator Service Set

Table 98: - Component and Service Requirements for Manipulator Joint Position Sensor Attribute

9.3.2.9.2 Manipulator Joint Position Sensor Requirement

9.3.2.9.2.1 Periodicity

9.3.2.9.2.1.1 Manipulator Joint Position Sensor

Message(s)	Rate
ID 2602: QueryJointPosition	10.0 Hz (Recommended)

Table 99: - Periodicity Information for Manipulator Joint Position Sensor

9.3.2.10 Manipulator Joint Force/Torque Sensor Attribute

Parent Attribute: Robotic Arm Control Attribute

The Manipulator Joint Force/Torque Interoperability Attribute adds the capability to report the values of instantaneous torques (for revolute joints) and forces (for prismatic) joints.

9.3.2.10.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:ManipulatorJointForceTorqueSensor, 2.0		AS6057A JAUS Manipulator Service Set

Table 100: - Component and Service Requirements for Manipulator Joint Force/Torque Sensor Attribute

9.3.2.10.2 Manipulator Joint Force/Torque Sensor Requirement

9.3.2.10.2.1 Periodicity

9.3.2.10.2.1.1 Manipulator Joint Force/Torque Sensor

Message(s)	Rate
ID 2605: QueryJointForceTorque	10.0 Hz (Recommended)

Table 101: - Periodicity Information for Manipulator Joint Force/Torque Sensor

9.3.3 Pan Tilt Manipulator Section

9.3.3.1 Pan Tilt Manipulator Attribute

Parent Attribute: Actuator Attribute

Pan tilt manipulators are a specific type of manipulator designed for panning and tilting, typically with a device attached such as a camera.

At least one of the following attributes must be chosen.

Attribute	Description
Basic Pan Tilt Attribute	Defines a basic, open-loop pan tilt manipulator capability.
Pan Tilt Manipulator Position Control Attribute	Defines the capability to control a pan tilt manipulator using closed loop position control.
Pan Tilt Manipulator Velocity Control Attribute	Defines the capability to control a pan tilt manipulator using closed loop velocity control.

Table 102: - Mandatory Select = any

Any number of the following attributes can be chosen.

Attribute	Description
Pan Tilt Manipulator Velocity Sensor Attribute	Defines the capability to get velocity information for a pan tilt manipulator.

Pan Tilt Manipulator Position Sensor Attribute	Defines the capability to get position information for a pan tilt manipulator.
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Table 103: - Optional Select = any

9.3.3.1.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:PanTiltSpecificationService, 2.0		AS6057A J AUS Manipulator Service Set
urn:jaus:jss:manipulator:PanTiltMotionProfileService, 2.0		AS6057A J AUS Manipulator Service Set

Table 104: - Component and Service Requirements for Pan Tilt Manipulator Attribute

9.3.3.2 Basic Pan Tilt Attribute

Parent Attribute: Pan Tilt Manipulator Attribute

The Basic Pan Tilt Interoperability Attribute defines the capability for interacting with a Pan Tilt manipulator in a simple open-loop fashion.

9.3.3.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:PrimitivePanTilt, 2.0		AS6057A J AUS Manipulator Service Set
urn:jaus:jss:iop:ExtendedPrimitivePanTilt, 1.1		Custom Services, Messages, and Transports

Table 105: - Component and Service Requirements for Basic Pan Tilt Attribute

9.3.3.2.2 Basic Pan Tilt Requirement

9.3.3.2.2.1 Notes and Interpretations

9.3.3.2.2.1.1 Primitive Pan Tilt

Message(s)	Concept	Interpretations
ID 0621: SetPanTiltJointEffort	Usage	Joint1Effort is the "pan" and Joint2Effort is the "tilt".

Table 106: - Message Interpretations for Primitive Pan Tilt

9.3.3.2.2.1.2 Extended Primitive Pan Tilt

Message(s)	Concept	Interpretations
ID F29B: ReportHostManipulator	Usage	This message shall report the J AUS ID and joint number of the host, if this pan/tilt unit is mounted on a manipulator.

Table 1077: - Message Interpretations for Extended Primitive Pan Tilt

9.3.3.2.2 Periodicity

9.3.3.2.2.1 Primitive Pan Tilt

ID 0621: SetPanTiltJointEffort - Sending of the SetPanTiltJointEffort message shall comply with the manipulator drive timeout requirements defined in 9.3.1.2 Actuator/Manipulator Drive Timeouts Requirement.

9.3.3.3 Pan Tilt Manipulator Position Control Attribute

Parent Attribute: Pan Tilt Manipulator Attribute

The Pan Tilt Manipulator Position Control Interoperability Attribute adds the capability to perform closed loop position based control to a Basic Pan Tilt Manipulator.

9.3.3.3.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:PanTiltJointPositionDriver, 2.0		AS6057A JAUS Manipulator Service Set

Table 108: - Component and Service Requirements for Pan Tilt Manipulator Position Control Attribute

9.3.3.3.2 Pan Tilt Manipulator Position Control Requirement

9.3.3.3.2.1 Notes and Interpretations

9.3.3.3.2.1.1 Pan Tilt Joint Position Driver

Message(s)	Concept	Interpretations
ID 4628: ReportCommandedPanTiltJointPosition	Usage	<ul style="list-style-type: none"> Joint1Position is the "pan" joint position, and Joint2Position is the "tilt" joint position. The commanded pan tilt joint position is not guaranteed to be the same as the actual pan tilt joint position.
ID 0622: SetPanTiltJointPosition	Usage	<ul style="list-style-type: none"> Joint1Position is the "pan" joint position, and Joint2Position is the "tilt" joint position.

Table 109: - Message Interpretations for Pan Tilt Joint Position Driver

9.3.3.4 Pan Tilt Manipulator Velocity Control Attribute

Parent Attribute: Pan Tilt Manipulator Attribute

The Pan Tilt Manipulator Velocity Control Interoperability Attribute adds the capability to perform closed loop velocity based control to a Basic Pan Tilt Manipulator.

9.3.3.4.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:PanTiltJointVelocityDriver, 2.0		AS6057A JAUS Manipulator Service Set

Table 200: - Component and Service Requirements for Pan Tilt Manipulator Velocity Control Attribute

9.3.3.4.2 Pan Tilt Manipulator Velocity Control Requirement

9.3.3.4.2.1 Notes and Interpretations

9.3.3.4.2.1.1 Pan Tilt Joint Velocity Driver

Message(s)	Concept	Interpretations
ID 4631: ReportCommandedPanTiltJointVelocity	Usage	<ul style="list-style-type: none"> Joint1Effort is the "pan" and Joint2Effort is the "tilt". The commanded pan tilt joint velocity is not guaranteed to be the same as the actual pan tilt joint velocity.
ID 0623: SetPanTiltJointVelocity	Usage	<ul style="list-style-type: none"> Joint1Effort is the "pan" and Joint2Effort is the "tilt".

Table 201: - Message Interpretations for Pan Tilt Joint Velocity Driver

9.3.3.4.2.2 Periodicity

9.3.3.4.2.2.1 Pan Tilt Joint Velocity Driver

ID 0623: SetPanTiltJointVelocity - Sending of the SetPanTiltJointVelocity message shall comply with the manipulator drive timeout requirements defined in 9.3.1.2 Actuator/Manipulator Drive Timeouts Requirement.

9.3.3.5 Pan Tilt Manipulator Velocity Sensor Attribute

Parent Attribute: Pan Tilt Manipulator Attribute

The Pan Tilt Manipulator Velocity Sensor Interoperability Attribute adds the capability to get pan tilt manipulator joint velocities from a Basic Pan Tilt Manipulator.

9.3.3.5.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:PanTiltJointVelocitySensor, 2.0		AS6057A JAUS Manipulator Service Set

Table 202: - Component and Service Requirements for Pan Tilt Manipulator Velocity Sensor Attribute

9.3.3.5.2 Pan Tilt Manipulator Velocity Sensor Requirement

9.3.3.5.2.1 Notes and Interpretations

9.3.3.5.2.1.1 Pan Tilt Joint Velocity Sensor

Message(s)	Concept	Interpretations
ID 4623: ReportPanTiltJointVelocity	Usage	<ul style="list-style-type: none"> Joint1Velocity is the "pan" joint velocity, and Joint2Velocity is the "tilt" joint velocity.

Table 203: - Message Interpretations for Pan Tilt Joint Velocity Sensor

9.3.3.5.2.2 Periodicity

9.3.3.5.2.2.1 Pan Tilt Joint Velocity Sensor

Message(s)	Rate
ID 2623: QueryPanTiltJointVelocity	10.0 Hz (Recommended)

Table 204: - Periodicity Information for Pan Tilt Joint Velocity Sensor

9.3.3.6 Pan Tilt Manipulator Position Sensor Attribute

Parent Attribute: Pan Tilt Manipulator Attribute

The Pan Tilt Manipulator Position Sensor Interoperability Attribute adds the capability to get pan tilt manipulator joint positions from a Basic Pan Tilt Manipulator.

9.3.3.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:PanTiltJointPositionSensor, 2.0		AS6057A JAUS Manipulator Service Set

Table 205: - Component and Service Requirements for Pan Tilt Manipulator Position Sensor Attribute

9.3.3.6.2 Pan Tilt Manipulator Position Sensor Requirement

9.3.3.6.2.1 Notes and Interpretations

9.3.3.6.2.1.1 Pan Tilt Joint Position Sensor

Message(s)	Concept	Interpretations
ID 4622: ReportPanTiltJointPosition	Usage	<ul style="list-style-type: none"> Joint1Position is the "pan" joint position, and Joint2Position is the "tilt" joint position.

Table 206: - Message Interpretations for Pan Tilt Joint Position Sensor

9.3.3.6.2.2 Periodicity

9.3.3.6.2.2.1 Pan Tilt Joint Position Sensor

Message(s)	Rate
ID 2622: QueryPanTiltJointPosition	10.0 Hz (Recommended)

Table 207: - Periodicity Information for Pan Tilt Joint Position Sensor

9.3.4 End Effectors Section

9.3.4.1 End Effector Attribute

Parent Attribute: Actuator Attribute

An end effector is a specialized tool attached either directly to a platform or to a joint (typically the last one) of an actuator system. An end effector generally manipulates the environment or platform in some way such as gripping an object, cleaning a sensor, or stabilizing a platform.

Any number of the following attributes can be chosen.

Attribute	Description
Basic End Effector Attribute	Provides the capability to communicate, control, and receive status from an end-effector.
Manipulator End Effector Frame of Reference Attribute	The Frame of Reference Attribute allows a client to change the coordinate frame for end effector based services. This allows for more user-friendly options for fly-the-end-effector functionality and coordination between two or more manipulators on the same platform.
Fly-The-End-Effector Attribute	Defines the capability to control the location or velocity of an end-effector through commanding the manipulator arm on which it is attached.
Manipulator End Effector Position Control Attribute	Defines the capability to "fly the end effector" using closed loop position control of an end effector.
Manipulator End Effector Position Sensor Attribute	Defines the capability to get information on the position of the end effector.

Manipulator End Effector Velocity Control Attribute	Defines the capability to "fly the end effector" using closed loop velocity commands.
Manipulator End Effector Velocity State Sensor Attribute	Defines the capability to get information on the velocity of the end effector.
Stabilizer Attribute	Provides the ability to control a platform stabilizer (i.e. flippers).
Complex End Effector Attribute	Provides the capability to define a complex end effector beyond a simple one degree of freedom.
Windshield Wiper Attribute	Provides the capability to communicate, control, and receive status from windshield wipers.
Door Lock System Attribute	Provides the capability to communicate, control, and receive status from the door locking system on the robot.
Manipulator End Effector Force/Torque Sensor Attribute	Provides a way to get force or torque information from a manipulator end effector.
Surrogate UAV Attribute	Provides a capability to identify, launch, and recover a surrogate UAV associated with the host platform.
Tether Spooler Attribute	Adds support for controlling and obtaining status from a tether's spooling mechanism

Table 110: - Optional Select = any

9.3.4.2 Basic End Effector Attribute

Parent Attribute: End Effector Attribute

The Basic End Effector Interoperability Attribute defines a simple one degree of freedom end effector. While traditional simple end-effectors such as a basic two fingered gripper are supported, this Attribute can be used to control any end-effectors types that are limited to a single degree of freedom. Examples include cutters, drills, digging tools (buckets), and welding torches. For end effectors with multiple joints and/or multiple degrees of freedom, the end effector can instead be modeled as one or more Basic Manipulators, as described in the 9.3.2.2 Basic Manipulator Attribute.

9.3.4.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:PrimitiveEndEffector, 2.0		AS6057A JAUS Manipulator Service Set

Table 111: - Component and Service Requirements for Basic End Effector Attribute

9.3.4.2.2 Primitive End Effector Requirement

9.3.4.2.2.1 Notes and Interpretations

9.3.4.2.2.1.1 Primitive End Effector

Message(s)	Concept	Interpretations
ID 2632: QueryEndEffectorSpecification ID 4632: ReportEndEffectorSpecification	Usage	ParentID shall be the JAUS identifier of the Basic Manipulator component that the end effector is attached to.
ID 0633: SetEndEffectorEffort	Gripper Type End Effector	When applied to a gripper type end effector, a positive value indicates the gripper is closing, and a negative value indicates the gripper is opening.
ID 0633: SetEndEffectorEffort	Other End Effector Types	The behaviors for extra end effector types will be provided in later versions of this document.

Table 112: - Message Interpretations for Primitive End Effector

9.3.4.2.2.2 Periodicity

9.3.4.2.2.2.1 Primitive End Effector

ID 0633: SetEndEffectorEffort - Sending of the SetEndEffectorEffort message shall comply with the manipulator drive timeout requirements defined in 9.3.1.2 Actuator/Manipulator Drive Timeouts Requirement.

9.3.4.3 Manipulator End Effector Frame of Reference Attribute

Parent Attribute: End Effector Attribute

The Frame of Reference Attribute provides a mechanism for setting and reporting the frame of reference for end effector based motions including fly-the-end-effector.

The associated custom service is expected to be co-located, i.e. hosted by the same JAUS component, with one or more Manipulator End Effector services. Consequently, implementations are encouraged to also select attributes such as Advanced Manipulator, Manipulator End Effector Velocity Control, and/or Manipulator End Effector Velocity State.

9.3.4.3.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:ugv:FrameOfReference, 1.1	any	Custom Services, Messages, and Transports

Table 113: - Component and Service Requirement for Manipulator End Effector Frame of Reference Attribute

9.3.4.4 Manipulator End Effector Position Control Attribute

Parent Attribute: Fly-The-End-Effector Attribute

The Manipulator End Effector Position Control Interoperability Attribute extends the capabilities of the Basic Manipulator attribute by adding support for control of the manipulator through specifying end effector pose.

9.3.4.4.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:ManipulatorEndEffectorPoseDriver, 2.0		AS6057A JAUS Manipulator Service Set
urn:jaus:jss:manipulator:ManipulatorEndEffectorPoseListDriver, 2.0		AS6057A JAUS Manipulator Service Set

Table 114: - Component and Service Requirements for Manipulator End Effector Position Control Attribute

9.3.4.4.2 Manipulator End Effector Position Control Requirement

9.3.4.4.2.1 Notes and Interpretations

9.3.4.4.2.1.1 Manipulator End Effector Pose Driver

Message(s)	Concept	Interpretations
ID 2610: QueryCommandedEndEffectorPose ID 4610: ReportCommandedEndEffectorPose	Usage	The actual pose of the manipulator and the pose reported by this message pair are not guaranteed to be the same.

Table 115: - Message Interpretations for Manipulator End Effector Pose Driver

9.3.4.4.2.1.2 Manipulator End Effector Pose List Driver

Message(s)	Concept	Interpretations
ID 0604: SetToolOffset	Usage	<ul style="list-style-type: none"> If there is no tool other than a simple gripper, this message shall have no meaning. Interpretation of this message for other end effectors (i.e. cutters, excavators, etc.) is reserved for later versions of this document.

Table 116: - Message Interpretations for Manipulator End Effector Pose List Driver

9.3.4.5 Manipulator End Effector Position Sensor Attribute

Parent Attribute: Robotic Arm Control Attribute

The Manipulator End Effector Position Sensor Interoperability Attribute adds end-effector position sensing capability.

9.3.4.5.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:ManipulatorEndEffectorPoseSensor, 2.0		AS6057A JAUS Manipulator Service Set
urn:jaus:jss:manipulator:ManipulatorToolOffsetService, 2.0		AS6057A JAUS Manipulator Service Set

Table 117: - Component and Service Requirements for Manipulator End Effector Position Sensor Attribute

9.3.4.5.2 Manipulator End Effector Position Sensor Requirement

9.3.4.5.2.1 Notes and Interpretations

9.3.4.5.2.1.1 Manipulator Tool Offset

Message(s)	Concept	Interpretations
ID 0604: SetToolOffset	Usage	<ul style="list-style-type: none"> If there is no tool other than a simple gripper, this message shall have no meaning. Interpretation of this message for other end effectors (i.e. cutters, excavators, etc.) is reserved for later versions of this document.

Table 118: - Message Interpretations for Manipulator Tool Offset

9.3.4.5.2.2 Periodicity

9.3.4.5.2.2.1 Manipulator End Effector Pose Sensor

Message(s)	Rate
ID 2615: QueryEndEffectorPose	10.0 Hz (Recommended)

Table 119: - Periodicity Information for Manipulator End Effector Pose Sensor

9.3.4.6 Manipulator End Effector Velocity Control Attribute

Parent Attribute: Fly-The-End-Effector Attribute

The Manipulator End Effector Velocity Control Interoperability Attribute adds closed loop velocity control of an end effector (fly-the-end-effector).

9.3.4.6.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:ManipulatorEndEffectorVelocityStateDriver, 2.0		AS6057A JAUS Manipulator Service Set

Table 120: - Component and Service Requirements for Manipulator End Effector Velocity Control Attribute

9.3.4.6.2 Manipulator End Effector Velocity Control Requirement

9.3.4.6.2.1 Notes and Interpretations

9.3.4.6.2.1.1 Manipulator End Effector Velocity State Driver

Message(s)	Concept	Interpretations
ID 2612: QueryCommandedEndEffectorVelocityState ID 4612: ReportCommandedEndEffectorVelocityState	Usage	<ul style="list-style-type: none"> The actual velocities of the end effector and the velocities of the end effector reported by this message pair are not guaranteed to be the same.

Table 121: - Message Interpretations for Manipulator End Effector Velocity State Driver

9.3.4.6.2.2 Periodicity

9.3.4.6.2.2.1 Manipulator End Effector Velocity State Driver

ID 0612: SetEndEffectorVelocityState - Sending of the SetEndEffectorVelocityState message shall comply with the manipulator drive timeout requirements defined in 9.3.1.2 Actuator/Manipulator Drive Timeouts Requirement.

9.3.4.7 Manipulator End Effector Velocity State Sensor Attribute

Parent Attribute: Robotic Arm Control Attribute

The Manipulator End Effector Velocity State Sensor Interoperability Attribute adds end-effector velocity sensing capability.

9.3.4.7.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:manipulator:ManipulatorEndEffectorVelocityStateSensor, 2.0		AS6057A JAUS Manipulator Service Set
urn:jaus:jss:manipulator:ManipulatorToolOffsetService, 2.0		AS6057A JAUS Manipulator Service Set

Table 1220: - Component and Service Requirements for Manipulator End Effector Velocity State Sensor Attribute

9.3.4.7.2 Manipulator End Effector Velocity State Sensor Requirement

9.3.4.7.2.1 Notes and Interpretations

9.3.4.7.2.1.1 Manipulator Tool Offset

Message(s)	Concept	Interpretations
ID 0604: SetToolOffset	Usage	<ul style="list-style-type: none"> If there is no tool other than a simple gripper, this message shall have no meaning. Interpretation of this message for other end effectors (i.e. cutters, excavators, etc.) is reserved for later versions of this document.

Table 123: - Message Interpretations for Manipulator Tool Offset

9.3.4.7.2.2 Periodicity

9.3.4.7.2.2.1 Manipulator End Effector Velocity State Sensor

Message(s)	Rate
ID 2616: QueryEndEffectorVelocityState	10.0 Hz (Recommended)

Table 124: - Periodicity Information for Manipulator End Effector Velocity State Sensor

9.3.4.8 Complex End Effector Attribute

Parent Attribute: End Effector Attribute

A complex end effector can be modelled as one or more Basic Manipulator Attributes, all residing on the same JAUS node with each additional manipulator added to the first attached to some position on the previously defined manipulator. This allows for arbitrarily complex end effectors.

The following attributes are mandatory.

Attribute	Description
Basic Manipulator Attribute	Defines a basic manipulator controlled using open loop control.

Table 125: - Mandatory Select = all

9.3.4.8.1 Complex End Effector JAUS Requirement

9.3.4.8.1.1 Notes and Interpretations

Representing a complex end effector as one or more manipulators, each with one or more joints, provides a generic method for command and control. In order to convey the functionality of each joint to a human operator, implementations are encouraged to use the description field in the Report Manipulator Specifications message to describe the actuator's behavior. In addition, programs may consider standardizing language within the description field in order to provide additional information.

For example, this may include a mapping of the complex end effector to a CAD model or similar imagery on the user interface.

Further, the generic approach uses positive and negative effort, as a percent from -100 to 100, to apply actuation. The actual interpretation of these values is left to the implementation, and will obviously vary based on the specific nature and behavior of the end effector. Where possible, programs are encouraged to use positive values to engage the tool. For example, positive effort might close the gripper, engage an air hammer, or trigger an emitter.

9.3.4.9 Windshield Wiper Attribute

Parent Attribute: End Effector Attribute

The Wiper/Cleaner Interoperability Attribute provides the ability to control surface cleaners like windshield wipers or wipers for a camera.

9.3.4.9.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:Wiper, 1.1		Custom Services, Messages, and Transports

[Table 126: - Component and Service Requirements for Windshield Wiper Attribute](#)

9.3.4.9.2 Windshield Wiper Requirement

9.3.4.9.2.1 Notes and Interpretations

The hardware underlying the Wiper Service is implied by other services co-located on the same component. If the Wiper Service is located on the Platform Component, the service shall control any windshield wipers. If multiple windshield wipers are present, such as a front and rear wiper, all wipers are assumed to be in the same setting at all times. If the Wiper Service is located on a component that hosts one or more video-related services, the service shall control a cleaning mechanism associated with any cameras hosted by that component. This may include wipers that offer a repeating or interval mode, or other cleaning mechanisms that operate on a per-request (one-shot) mode.

9.3.4.10 Door Lock System Attribute

Parent Attribute: End Effector Attribute

The Platform Doors Interoperability Attribute provides a way to lock and unlock vehicle doors, as well as determine the state of the doors.

9.3.4.10.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:PlatformDoorService, 1.1		Customer Services, Messages, and Transports

[Table 127: - Component and Service Requirements for Door Lock System Attribute](#)

9.3.4.11 Manipulator End Effector Force/Torque Sensor Attribute

Parent Attribute: End Effector Attribute

The Manipulator End Effector Force/Torque Sensor Interoperability Attribute provides a way to get force or torque information from manipulator end effector.

9.3.4.11.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:ManipulatorEndEffectorForceTorqueSensor, 1.1		Custom Services, Messages, and Transports

Table 128: - Component and Service Requirements for Manipulator End Effector Force/Torque Sensor Attribute

9.3.4.12 Surrogate UAV Attribute

Parent Attribute: End Effector Attribute

The Surrogate UAV Attribute provides a capability to identify, launch, and recover a surrogate UAV associated with the host platform. The UAV could be tethered or untethered. In the most basic configuration, the surrogate is expected to follow the host platform at a specified relative altitude. The means of following is left to the implementation; example approaches include active control or being pulled by a tether. However, surrogate UAVs can be associated with more advanced functionality through additional Attributes, allowing for behaviors like independent control, leader/follower, and loiter patterns.

The associated custom service is designed to support a wide variety of underlying hardware, providing only basic control for maintaining an altitude relative to the host platform. For more advanced functionality, system designers are encouraged to consider additional attributes for the UAV to enable independent teleoperation, leader/follower behavior, or waypoint following, for example. Further, tethered UAVs may host or be a client of a Tether Spooler Attribute.

9.3.4.12.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:SurrogateUAVDriver, 1.1	any	Custom Services, Messages, and Transports

Table 129: - Component and Service Requirements for Surrogate UAV Attribute

9.3.4.12.2 Surrogate UAV Driver Requirement

9.3.4.12.2.1 Notes and Interpretations

Note that launching a surrogate UAV may change the physical dimensions of the total platform, particularly when tethered. Subsequently, controlling a surrogate UAV may cause the values reported by the Platform Specification Attribute to change, which may have additional implications for obstacle detection and avoidance.

9.3.4.13 Tether Spooler Attribute

Parent Attribute: End Effector Attribute

A tether is a line that connects a UGV to an OCU or payload that can range from something simple like a chain or rope to a material capable of transmitting communications like an optical fiber or a wire. There are at least two use cases where an UGV may operate while connected to a tether:

- **Optical Fiber/ Wire Communications:** the UGV communicates over an optical fiber or wire which must be spooled in or out based on the movement of the mobility platform
- **Winch-based Recovery:** a winch mechanism is used to extricate an UGV that has become stuck in difficult terrain or recover another object/payload from the environment

The Tether Spooler Attribute supports these use cases by providing the capability to logically control a tether’s spooling mechanism with the custom Tether Spooler Driver service. The custom service can support manual control of the spooler and semi-autonomous spooling that either maintains a specified tension on the tether or feeds the tether based on the mobility of the platform. The goal of these semi-autonomous behaviors is to create just the right amount of slack in the line to prevent “tugs” while simultaneously optimizing the amount of tether used.

9.3.4.13.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:TetherSpoolerDriver, 1.1	any	Custom Services, Messages, and Transports

Table 130: - Component and Service Requirements for Tether Spooler Attribute

9.3.4.13.2 Tether Spooler Driver Requirement

The Tether Spooler Driver Service controls manual and automatic tether spooling behaviors.

9.3.4.13.2.1 Notes and Interpretations

9.3.4.13.2.1.1 Tether Spooler Driver

Message(s)	Concept	Interpretations
ID D013: ReportTetherSpoolerCapabilities	Modes of Operation	The Tether Spooler Driver may support multiple different modes of operation depending on the spooling system capabilities: <ul style="list-style-type: none"> • Manual – Operator directly controls the rate of tether being spooled • Tension – The system automatically tries to maintain an operator specified tension • Track Out – Tether is automatically fed outwards when the platform moves regardless of the direction of its motion • Track Motion – Tether is automatically fed outward as the platform moves forward/upward, and inward as the platform moves backward/downward • Reverse Track – Tether is automatically fed inward as the platform moves forward/upward, and outward as the platform moves backward/downward

Table 229: - Message Interpretations for Tether Spooler Driver

9.3.5 Self-Collision Avoidance Section

9.3.5.1 Self-Collision Avoidance Attribute

Parent Attribute: Actuator Attribute

The Self-Collision Avoidance Attribute specifies the capability to support self-collision avoidance.

The following attributes are mutually exclusive, exactly one must be chosen.

Attribute	Description
Centralized Self-Collision Avoidance Attribute	Provides the capability to have centralized self-collision avoidance on a system.
Distributed Self-Collision Avoidance Attribute	Provides the capability to have distributed self-collision avoidance on a system.

Table 230: - Mandatory Select = one

9.3.5.2 Centralized Self-Collision Avoidance Attribute

Parent Attribute: Self-Collision Avoidance Attribute

The Centralized Self-Collision Avoidance System Attribute specifies filtering that is used specifically to support centralized self-collision avoidance.

The following attributes are mandatory.

Attribute	Description
Message Filter Attribute	Provides a way to pass actions such as commands through a filter before they reach their final destination.

Table 231: - Mandatory Select = all

9.3.5.2.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:PassthroughMessage, 1.0	Self-Collision Avoidance Filter	Custom Services, Messages, and Transports
urn:jaus:jss:iop:SelfCollisionAvoidancePolicy Manager, 1.1	any	Custom Services, Messages, and Transports

Table 232: - Component and Service Requirements for Centralized Self-Collision Avoidance Attribute

9.3.5.2.2 Centralized Self-Collision Avoidance System Requirement

V1.JAUS-64 The Passthrough Message JAUS service shall reside on a component on a JAUS Node that is referred to henceforth as a Self-Collision Avoidance Node.

V1.JAUS-65 Any JAUS Component that acts as a filter component shall be known as a "Self-Collision Avoidance" component.

9.3.5.2.2.1 Notes and Interpretations

9.3.5.2.2.1.1 Use of Self Collision Avoidance Policy Manager Service

When using the Centralized Self-Collision Avoidance attribute, there are multiple approaches to using the Self Collision Avoidance Policy Manager Service, depending on system design. A system may be designed to do all filtering through a single component, to filter using multiple components on the same node, or to filter using multiple "filtering" nodes. Some example setups:

- A single filtering component on a self-collision avoidance node does all filtering for two manipulator payload nodes and one stabilizer node
- Three filtering components on a single self-collision avoidance node perform filtering for two manipulator payload nodes and one stabilizer node, with each filtering component responsible for filtering messages for a single payload node
- The filtering nodes with one or more filtering components each perform filtering for two manipulator payloads nodes and one stabilizer node, with each filtering node being associated with a "mirrored" mapped node

Any of the above examples are valid ways to organize self-collision avoidance, and any of the following approaches may be used when determining how many Self Collision Avoidance Policy Manager services are provided and how those services are used:

- There may be a single Self Collision Avoidance Policy Manager for the whole subsystem, where changing the policy affects all filtering components present
- There may be a single Self Collision Avoidance Policy Manager per node, where changing the policy for a single node only effects the filtering components on that node
- There may be a single Self Collision Avoidance Policy Manager per filtering component, where changing the policy effects only a single filtering component

These three valid approaches allow self-collision avoidance to be configured with varying degrees of granularity – from the whole subsystem (robot) level, to individually turning on and off self-collision avoidance for individual components.

9.3.5.2.2.1.2 Passthrough Message

Message(s)	Concept	Interpretations
ID D703: ReportPassthroughMessageProperties	FilterType	The FilterType field shall include a value of "1" in bit position 0 to indicate that SELF_COLLISION_AVOIDANCE is a supported type for this filter.

Table 233: - Message Interpretations for Passthrough Message

9.3.5.3 Distributed Self-Collision Avoidance Attribute

Parent Attribute: Self-Collision Avoidance Attribute

If selected, the Distributed Self-Collision Avoidance Attribute specifies that distributed self-collision avoidance is to be performed. Distributed self-collision avoidance does not depend on a having a centralized filtering node, but instead relies on individual components to make their own decisions on self-collision avoidance based on whatever information is available to them.

9.3.5.3.1 Component and Service Requirements

Service	Component	Reference
urn:jaus:jss:iop:SelfCollisionAvoidancePolicy Manager, 1.1	Self-Collision Avoidance	Custom Services, Messages, and Transports

Table 234: - Component and Service Requirements for Distributed Self-Collision Avoidance Attribute

9.3.5.3.2 Distributed Self-Collision Avoidance Requirement

V1.JAUS-66 *Any node supporting distributed self-collision avoidance (i.e. a manipulator, stabilizer, etc.) shall contain at least one component that provides a Self-Collision Avoidance Policy Manager service. Any component containing a Self-Collision Avoidance Policy Manager shall be referred to as a "Self-Collision Avoidance" component.*

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