Generic System-of-Systems Description (GSoSD)

The Arrowhead Core Systems

**Abstract**

This document outlines the 5th generation of the Arrowhead Core systems, which offer functionality expected to be needed for the majority of use cases where Arrowhead is applied. It contains a high-level architectural description of what problems the Core systems solve and how they interact.

The primary purpose of the document is to present the functionality offered by the Arrowhead Core systems. Its architectural aspects are defined in the abstract, by which we mean that no specific implementations or technologies endorsed by it.

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1. Overview

The Eclipse Arrowhead project exists to produce solutions and specifications that support industrial automation systems that can adapt quickly and automatically to changing circumstances and business requirements. This adaptability is enabled through *Service-Oriented Architecture* (SOA), which entails dividing automation systems into smaller independent *systems* that communicate by sending messages to, or *consuming*, the *services* offered by the other systems. Each system is expected to be designed around the principles of

1. **loose coupling**, which means that services have narrow, well-defined application areas and depend internally on as few other services as possible to fulfil their functions,
2. **late binding**, which entails providing as much functionality as possible given what needed services, configuration data and other details are currently available, as well as
3. **lookup**, which means that systems, when possible, look up needed data by consuming services instead of relying on the data being in given configuration files.

These principles help facilitate the design of automation systems that are cheap and easy to implement, upgrade, extend and reuse, are highly resilient to failures and attacks, and are highly transparent about their constituents and activities.

While designing industrial automation systems around these principles has the advantages we mention, it also introduces the complexity inherent to all distributed applications. The Core systems of Eclipse Arrowhead exist to help manage this complexity by facilitating

1. **discovery**, or helping systems independently find the services they need,
2. **authorisation**, or regulating how systems are allowed to consume what services, as well as
3. **orchestration,** or centrally managing what systems consume what services.

Diagram

Description automatically generatedEach of these concerns is addressed by its own service, provided by its own system, as outlined in the following component diagram:

Each box in the diagram represents a system. Every system, except for the generic consumer, provides one service represented by an attached circle. Service consumption is denoted by forks extending from the consuming systems to the circles. Some forks are merged to improve clarity. A deployment of systems interrelated in this manner makes up a *system-of-systems*. When a system-of-systems can fulfil its functions without Internet access, we refer to it as a *local cloud*.

In the next section, Section 2, we consider what these services and systems do in more detail. In Section 3, we describe various use cases in which some or all of them are used. In Section 4, we discuss how the Core systems make up the *control plane* of a distributed application and why that matters. In Section 5, we outline important differences between versions 4 and 5 of Arrowhead. In Section 6, we present key non-functional requirements. In Section 7 we consider what parts of this document, which is still not officially released, are currently subject to discussion. Finally, in Sections 8 and 9 we list document references and versions.

1. Systems

The Core systems of the Eclipse Arrowhead project are meant to address concerns expected to be typical to most settings where SOA is applied. We describe them here in the abstract. The implementations of these systems are meant to be described in separate, non-generic documents referred to as *System-of-Systems Descriptions* (SoSDs).

|  |  |
| --- | --- |
| System | Service |
| Service Registry | Service Discovery |
|  | Service Registry Management |
| Authorisation System | Authorisation |
|  | Authorisation Management |
| Orchestration System | Orchestration Management |
|  | Orchestration Pull |
|  | Orchestration Push |

The Core systems, and the services they provide, are as follows:

The purposes of the respective Core systems are presented in the following subsection. In the subsection after that, we consider how local clouds end up in a working state when subject to a cold start. We then present a matrix of both core and support systems provided, or planned to be provided, by the Eclipse Arrowhead project.

Note that in addition to the Core systems, several *support* systems are described in the document *GSoSD Arrowhead Support Systems 5.0*. We expect also these support systems to be common in many Arrowhead deployments. Since they, however, are not as essential as the systems listed here, we keep them in a separate document to reduce the length and improve the clarity of this document.

# System Descriptions

We now proceed to informally state the purposes and services of the Core systems. More detailed abstract descriptions of the services they provide are available in separate documents we refer to as *Service Descriptions* (SDs).

## Service Registry

One of the main principles of SOA is *lookup*, which means that whenever possible, data required for whatever reason should be looked up by consuming a service. One kind of data that is virtually always required to facilitate a system-of-systems is the network information, such as IP addresses and port numbers, needed by systems to be able to communicate with each other.

The Service Registry holds a table that maps the identifiers of individual services to the information generally required to communicate with their providers. Individual systems may elect to register, update or deregister their own services in a Service Registry, and so make it possible for other systems to look them up. Alternatively, the Service Registry can be manually populated with entries representing the services that should be available.

When using a Service Registry, the only network address systems are required to know is that of the Service Registry. With that, the systems can look up the network addresses of the systems they need to consume—given that they know their type names or identifiers.

Entries in the Service Registry are not limited to holding only network address details. They may also include other metadata that may be relevant when selecting what specific service instances to consume. For example, it may be relevant to denote the physical locations of services that provide temperature and humidity measurements, or to indicate at what conveyer belts some welding service is provided.

Registering, updating, deregistering and querying the Service Registry is performed through its *Service Discovery* service. In addition, the system provides the *Service Registry Management* service, which allows for services to be registered, updated or deregistered in bulk. The latter service is meant to be useful primarily for administration.

## Authorisation System

When a system-of-systems applies any kind of access control, it becomes relevant for every service provider to know what systems are allowed to consume its services—and with what limitations. The Authorisation System holds a table that maps the identifier of each system to the identifiers of the individual services that system is permitted to consume, as well as additional details regarding any limits or tokens related to that consumption. Each entry in this table can be referred to as an *access control rule*. Whenever a system attempts to consume a service, the provider of that service may consult the Authorisation System to make sure that the consumer is permitted to do so.

Using an Authorisation System means that individual service providers do not need to know in advance what other systems are allowed to consume them.

To reduce the number of times a given system has to consult the Authorisation System, a *caching strategy* may be employed, as discussed further in Section 6.1.

Checking whether an attempted service consumption is allowed is performed through the *Authorisation* service of the Authorisation System. In addition, the system also provides the *Authorisation Management* service, which allows for access control rules to be added, updated, removed and queried. The latter service is meant to be useful primarily for administrative purposes.

## Orchestration System

Using only the Service Registry means that network information does not have to be manually supplied to the individual systems of a given local cloud. However, each system must still be manually configured, or use its own search procedure, to determine what exact service instances to consume. This becomes an issue when the same type of service is provided by many systems at the same time, but there are other differences to each provided service. If, for example, a given service instance reports the air quality for a specific location, what service instance is consumed affects what data is received by the consumer.

The main task of the Orchestration System is to help the consumers to decide which service instances they should use. An orchestration request can result a list of providers that offers different services (to satisfy all the consumer’s needs); or a list of providers that offers the same service (viable alternatives); or just one provider.

There are multiple approaches how an Orchestration System can fulfil this task. All of them have different advantages and disadvantages.

The first approach (atomic service) holds a table that maps each relevant system to the specific service instances it *should* consume. The orchestration request returns service instance identifiers. The consumer can use these identifiers to acquire access information from the Service Registry. The advantages of this approach that is very simple, easy to implement, uses very few computing resources and the Orchestration System can work independently from other systems. The main disadvantage here is that this approach delegates most of the tasks to the consumer’s side. Also, the synchronization between the Service Registry’s data and the Orchestration mappings can be a challenge (for the local cloud administrator or a support system).

The second approach (advanced service) is more complex and offers a lot of features. It provides other types of orchestration besides the static orchestration rules: dynamic orchestration and a more flexible rule orchestration where rules are not peer-to-peer mappings but templates specified by system and service instance metadata. This solution requires the continuous assistance of the Service Registry and the Orchestration System cannot provide any useful information without it. If the local cloud contains other Core or Support systems, the Orchestration Core System can offer much more:

* Authorization: if the consumer is not authorized the orchestration service removes the appropriate provider from the response ;
* Authorization: orchestration service automatically adds every necessary tokens (if the related provider requires it);
* Gatekeeper: inter-cloud orchestration is possible;
* Gateway (besides the Gatekeeper): inter-cloud orchestration is possible even between two closed local clouds and the necessary communication tunnel will be built during the orchestration process;
* QoS Support: during orchestration Quality-of-Service requirements can be considered;

The advantage of this approach that is more feature rich, more convenient for the consumers (the orchestration response return everything what is needed for the consumer to perform a service consumption). The disadvantages here are that this approach is more difficult to implement, uses more computing resources and the system have dependencies to other systems (at least to the Service Registry).

There are use cases when the first approach are the preferable and there are use cases when the second one. So the Arrowhead framework should contain both orchestration systems with a shared interface and the operator of the local cloud should decide which kind of orchestration their local cloud should use.

Service consumers get lists of service instances to consume, by using the *Orchestration Pull* service of the Orchestration System. Consumers may also use the *Orchestration Push* service to be notified of any changes to their orchestration. In addition, the Orchestration System also provides the *Orchestration Management* service, which allows for orchestration rules to be added, updated, removed and queried. The latter service is meant to be useful for administrative purposes.

# Local Cloud Bootstrapping

When a local cloud starts up, none of its constituent systems will have the network addresses, credentials or other details necessary to consume the services it needs. For that data to become available for the systems to look up, the Core systems must first become ready to provide their services. We refer to the process of the Core systems becoming ready as *bootstrapping*. What is required for the bootstrapping of a particular local cloud to be successful depends on which of the Core systems are being used. However, one requirement is constant: *each system and every service must have a unique identifier prior to the bootstrapping process*.

If only the Service Registry is used, each system must be preconfigured with the network address of the Service Registry—or be able to determine it through some other well-defined mechanism. Every system must know how to decide what specific service instances to consume, something we consider more in Section 3.1.

If also the Authorisation System is used, all other systems must also be preregistered in its table, which maps system identifiers to the identifiers of the services each respective system is permitted to consume.

If also the Orchestration System is used, the need for having each system be able to independently determine what service instances to consume goes away. However, what systems are to consume what services must instead be registered in the table of the Orchestration System.

# The System-Service Matrix

En bild som visar bord

Automatiskt genererad beskrivningIn order to keep track of what services are produced and consumed by different systems, we present a system-service matrix below. This matrix outlines the Core systems in terms of what services they provide and consume.

The matrix is meant to eventually contain references to both the abstract definition of all systems, as well as to the available implementations of those systems. The abstract definitions are provided in documents we refer to as Service Descriptions (SDs), while the interfacing details of their implementations are documented in Interface Design Descriptions (IDDs). The full matrix can be found in Appendix 1.

1. Use-cases

To make it more apparent how the Arrowhead Core systems can be used in practical scenarios, we here present four use case descriptions. Each description centres around a sequence diagram illustrating how systems consume each other’s services.

# Service Discovery

Diagram

Description automatically generatedThe first, and most basic, of our use cases shows how some system **B** can consume the service **a**, provided by **A**, by looking up its address in a Service Registry instance. No security mechanisms are in place. The only precondition is that **A** and **B** both know of the network address of the Service Registry instance. The use case is depicted below.

The use case consists of three message exchanges, which are as follows:

1. **A** registers its service **a** with the Service Registry, which accepts the registration.
2. Later, **B** attempts to lookup the service **a** via the Service registry, which responds with the network address, and other details, of **a**.
3. **B** then proceeds to consume **a** by sending a request to **A**, which responds with some status and payload of relevance to the service.

As we assumed that only one instance of the **a** service was registered in the Service Registry, the response in exchange 2 only contained one address. If, however, more than once such service instance would have been registered, **B** would have received the network addresses of all of them. **B** would then have been forced to determine by itself which instance would be most appropriate to consume, perhaps by looking at other details also present in the received registrations.

Alternatively, **B** could have provided the instance identifier of a particular service instead of a service type name in its query request to the Service Registry. Since those identifiers must be unique, the query result could then only contain at most one result. It would, however, also mean that relevant service instance identifiers must be known in advance, and that the specific instance is online when **B** needs to consume it.

Another approach is to centralise decisions about service consumption using an Orchestration System, as shown later in Section 3.3.

# Authorisation

Diagram

Description automatically generatedIn this, our second, use case, we add access control by introducing an Authorisation System. Whenever an attempt is made to consume a service, its providing system validates the request by consulting the Authorisation System before responding to it. We assume that all services were registered in the Service Registry before the use case begins. We also assume that the Authorisation System has already been provided with an appropriate set of access control rules. The use case is depicted below:

The use case consists of the following message exchanges:

1. **A** looks up **b** via the Service Registry, which responds with the network address of **b**.
   1. However, to make sure A is authorised to discover services, the Service Registry consults the Authorisation System before responding, which gives its approval.
2. **A** attempts to consume **b** by sending a request to **B**, which later responds.
   1. Before responding, however, **B** must ascertain that **A** is permitted to consume its **b**. Since **B** does not yet know the network address of the Authorisation System, it queries it and subsequently receives the address.
      1. In turn, the Service Registry checks if B is permitted to consume its Service Discovery service, which it proves to be.
   2. **B** then proceeds to check with the Authorisation System if **A** is permitted to consume its instance of **b**, which reports that it is.

Using authorisation in this manner means that a list of access control rules must be prepared and provided to an Authorisation System in advance. As such rules must contain the unique identifiers associated with the various systems and services in the given local cloud, also those identifiers must be known in advance. To be able to guarantee that every system is associated with the expected set of identifiers, it must be preconfigured with its own set of identifiers. It is possible to avoid this need for preconfiguration by using a separate system that dynamically creates access control rules according to given strategies. Such a system is, however, beyond the scope of this document.

# Orchestration

As we mentioned towards the end of the first use case in Section 3.1, using only a Service Registry means that we must either rely on (1) systems being able to choose what specific service instances to consume, or (2) being able to preconfigure each system with the identifiers of those specific service instances. If we, on the other hand, introduce an Orchestration system, we can avoid either by having the individual systems lookup what services we *want* them to consume.

Chart, box and whisker chart

Description automatically generatedWe assume that all services were registered in the Service Registry before the use case begins, as well as that the Orchestration System has been provided with an appropriate set of orchestration rules, which describe what systems should consume what services. We also assume no security mechanisms are in place. The use case is depicted below:

The use case consists of the following message exchanges:

1. **A** looks up the network address of the Orchestration Pull service by consuming the Service Discovery service of the Service Registry, which responds with the requested address.
2. **A** queries the Orchestration System for the network addresses of the services it should consume, which responds with the network address of **b**, provided by **B**.
   1. Since the Orchestration System does not hold any actual network addresses, it consults the Service Registry for the network address of **b**, which it also gets.
3. **A** consumes **b** of **B** by sending some request, which **B** responds to.

In this particular use case, orchestration information was *pulled* by **A**, by which we mean that A requested the information from the Orchestration System on its own accord. The Orchestration System also supports *pushing* orchestration rules, however, which means that rather than requesting it directly, **A** could have subscribed to changes to the orchestration rules relevant to itself. Pushing orchestration rules in this manner means that changes to the rules are more likely to end up at their respective systems. They are also likely going to get the information quicker than if they had been requesting their rules from the Orchestration System at regular intervals.

# Authorisation and Orchestration

While we already covered authorisation and orchestration separately in Sections 3.2 and 3.3, we have one important reason to consider them being used at the same time. The Orchestration system can create and distribute access tokens, which can be used to increase security by having the credentials actually passed between systems expire faster.

Diagram

Description automatically generatedWe assume that all services were registered in the Service Registry before the use case begins. We also assume that **A** has already looked up the network address of the Orchestration System, as well as that the Orchestration System has been provided with an appropriate set of orchestration rules. We also assume that the Authorisation System has already been provided with an appropriate set of access control rules. The use case is depicted below:

The use case consists of the following message exchanges:

1. **A** requests its set of orchestration rules from the Orchestration System, which later responds with the network address of **b** and the access token **A** needs to consume **b**.
   1. First, however, the Orchestration System checks if **A** is authorised to request its orchestration rules, which it proves to be.
   2. Then the Orchestration System determines the network address of **b** by consulting the Service Discovery service of the Service Registry.
      1. The Service Registry checks if the Orchestration System is allowed to consume the Service Discovery service, which it is.
   3. Before responding A, the Orchestration System also requests the Authorisation System to create an access token for A, which it does.
2. **A** consumes **b** and includes the access token it received in the request. **B** responds.
   1. Before responding, **B** uses the access token to check if **A** is authorised to consume **b**, which it proves to be.
3. Control and Data Planes

None of Core and Support systems provided by the Eclipse Arrowhead project are designed to directly fulfil the business objectives of any given local cloud. What they are designed to do, however, is to help create the situation in which these business objectives can be fulfilled. They do this, generally, by controlling and distributing information *about* the local cloud and its resources.

Traditionally, computer networks are reasoned about in *planes*, where each plane presents the same network in terms of a different perspective with its own aims and conditions. The term *control plane* is used when considering how networking equipment, such as firewalls, switches and routers, are setup to allow for information to flow in certain ways. The term *data plane*, on the other hand, is used when considering the contents of those information flows—without regard to how they were set up. This separation into planes increases the number of things that must be considered, but it also reduces the complexity of each of those things.

In a similar manner, we use the *term control* plane when considering how systems are controlled to facilitate desired service consumption patterns. In a control plane component or sequence diagram, for example, interactions between Core, Support and application systems are illustrated, but communications between application systems are left out. The reverse is the case for *data plane* diagrams: interactions with and between Core and Support systems are generally omitted, while interactions between application systems are included.

In this document, we do not make a distinction between control and data plane diagrams. While we certainly do focus on our control plane, the data plane is included for the sake of clarity. To get a better understanding of what control and data plane diagrams could like, consider the sequence diagram in Section 3.4. Its message exchange denoted with  is exclusively concerned with the control plane. In it, the application system **A** gets the control plane details needed for it to consume the service **b**. Also, the *a* exchange of message sequence  belongs to the control plane, as it is between a Core system and an application system. A pure data plane version of the diagram would only include the message exchange between systems **A** and **B**, without any references to access tokens or other control plane details.

An important aspect of the control plane is that no data exchange is allowed to occur here. The core systems should not have to consider the requirements of the data transmissions in the Arrowhead cloud. Furthermore, once the system-of-systems have been established and no need for change is imminent, the control plane could even be removed or shut down. Keeping a separation of the control and data plane allow different performance and different scaling of respective plane.

When designing your local cloud, it is generally useful to split your design into a control and a data plane. The first of the two would be concerned with which Core and Support systems, as well as other complementary systems, are being used and under what conditions. The second of the two would be concerned with how your local cloud directly addresses its business objectives.

1. Release Notes

**Work in progress.**

This section describes the differences between current version and previous versions of the architecture. It will be written in full when the issues in Section 7 have been resolved.

1. Non-Functional Requirements

Setting up and operating an Arrowhead local cloud comes with the many caveats shared by all distributed systems. Managing these caveats typically means that you need to prioritise certain qualities when designing or choosing the systems for your local cloud. In this section, we outline such qualities promoted by the Eclipse Arrowhead project as a list of non-functional requirements, one in each of the following subsections.

# Accurate Enough Message Caching

Most modern computing devices, including embedded such, can call local functions in the order of microseconds or faster. In contrast, calling a function on another device by sending a message is typically completed in the order of milliseconds or slower. The relative expense, in time and capacity utilisation, of sending messages is often high enough to often make it worthwhile to spend quite some effort to reduce the number of messages that must be sent for the use case at hand to be possible to realise.

One important way to reduce messaging is to make it possible for systems to *cache* data they receive, by which we mean that the data is saved with the expectation that it may become useful in the future. When a system finds itself in need of some data of concern, it first consults its cache to see if it can find it there. If it can, it uses that data, and no message needs to be sent.

The trade-off inherent in using caches is, however, that the entries they contain become invalid as soon as the original data they are based on change. Unless the caching systems are notified about the event, they cannot be confident the original data has not changed unless they request it again, which requires sending the message we wanted to avoid in the first place. If notifying systems is not practical for a given use case, then there are many ways to have cache entries expire when too old or when other factors make it seem as if they may have become invalid. These ways are beyond the scope of this document, however.

The important thing to note here is that caching can indeed help reduce the need for sending messages, but using it requires carefully planning how to avoid systems acting on invalid cache entries. The Arrowhead Core and support systems must all be designed to make it easy to reason about and manage the caching of the data they hold.

# Relative System Independence

Systems tend to become more brittle the larger and more complicated they become, and local clouds are no exception. The more and the more complicated systems make up a local cloud, the larger the probability gets of any of those systems degrading or breaking. One way to mitigate this is by promoting systems with small scopes, which means fewer things can break in each system, as well as by making the systems able to independently work around these kinds of eventualities. However, making systems independent means that each of them needs to own enough resources and capabilities for this independence to be possible. Among other things, this entails systems owning their own data rather than storing it in external databases.

Designing a local cloud effectively means that its resilience to failures must be accounted for, and that its systems are given the capabilities required to work around any contingencies.

1. Unresolved Issues

As far as is currently known, the following issues remain to be addressed before this document can be released as version 1.0.

|  |  |
| --- | --- |
| **1.** | **What security systems should be provided by Eclipse Arrowhead?**  As of Arrowhead version 4, security is managed by the Authorisation system, which is a simple store for access control rules that is also able to generate one specific kind of access control tokens. Certificates must be issued for all systems and are used directly in every established connection between systems, in addition to the tokens (when used). The Onboarding Controller can be used if wanting to limit the lifetimes of the certificates and have systems automatically renew them as they are about to expire. The Certificate Authority system can be used to issue and revoke certificates.  While this security setup works, *it does not provide a direct means of integrating with other identity frameworks*. How would you, for example, make it possible for a certain Active Directory user to consume services? One common approach to solving this in other contexts is to use something like *OpenID Connect* or *SAML 2.0*. These standards make it possible to setup rules that enable one system (like Active Directory) to create temporary identities in another system (like an Arrowhead local cloud). If using OpenID Connect jargon, the name of the system issuing the temporary identities in the “other system” would be *Identity Provider*. As an identity provider, essentially, accept credentials and returns temporary identities, it could also accept usernames and passwords, onboarding certificates, or One-Time Passwords.  The issues that need to be resolved are how a would-be Identity Provider system (or systems) relates to the Authorisation system, Onboarding Controller and Certificate Authority, as well as if the Identity Provider is a Core or Support system.  The current Authorisation system issues temporary identities in the form of single-service access tokens, while the Onboarding Controller issues temporary identities in the form of device and system certificates. It is possible to argue that moving all identity issuance to the Identity Provider would facilitate a better separation of concerns. Any system able to present an acceptable credential to the Identity Provider may acquire a temporary identity, in the form of certificates, tokens or otherwise, useful for providing and/or consuming services in a local cloud. But what would the role of the Onboarding Controller be then? Assuming that onboarded devices cannot access the Identity Provider, or that they cannot present credentials the Identity Provider can accept, the Onboarding Controller could mediate for such devices.  Would the Identity Provider use the Certificate Authority when issuing identities, or does the Identity Provider issue certificates by itself? Which depends on whether the Identity Provider also is concerned with revoking identities.  Is issuing identities sufficiently different from issuing tokens to divide the tasks between two systems, an Identity Provider and a Token Provider? Should integration with other identity systems be done by dedicated Identity Bridge systems? Should the Identity Provider push out identity revocations to concerned service providers? |
| **2.** | **How do we push orchestration rules to their intended receivers?**  Should the Orchestration system allow for other systems to *subscribe* to rule changes via a service provided by the Orchestration system? The alternative is to have every system that can and is willing to accept rule changes provide its own service through which its orchestration rules can be changed. This latter approach assumes that the Orchestration system can scan the Service Registry, or otherwise identify, all systems that provide this service.  The *subscription-approach* requires the receivers of the orchestration rules to decide from where they are received, as an Orchestration system must be contacted for the subscription to be initiated. The *own-service-approach* means that orchestration rules can come from any system permitted to consume the orchestration service (would *Orchestratable Service* be a good name for it?), which, arguably, makes orchestration pushing more robust, as no one system is required to maintain a list of subscribers that can be lost if a system goes down.  Note that there still is no accepted way of directly describing subscriptions in the documentation format used for Arrowhead up until this point. If the *subscription-approach* is chosen, the documentation format must be extended. |
| **3.** | **Systems/services or systems/services?**  The terms *systems* and *services*, as they have been used previously, are easy to confuse with similar terms used in many other contexts. The terms *systems* and *services* have been proposed as new names to avoid this confusion. The *micro-* prefix is meant to allude to how designing systems with loose coupling and smaller scopes is promoted by the Eclipse Arrowhead project.  A downside to the new names is that they are longer than the old ones, which makes it more inconvenient when including the terms in the names of systems and services. For example, the “Service Registry System” is, arguably, harder to read than “Service Registry System”. A remedy to this downside could be to promote a different way of naming services and systems in Arrowhead. For example, the “Service Registry System” could be renamed to the “Service Registrar”. |
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1. References

**Work in progress.**

1. Revision History

# Amendments

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No. | Date | Version | Subject of Amendments | Author |
| 1 | 2023-01-12 | 0.1 | Initial draft. | Per Olofsson |
| 2 | 2023-02-03 | 0.2 | Refined and extended Sections 1, 2 and 3. Removed unneeded sections. Cleaned up the other. | Emanuel Palm |
| 3 | 2023-02-07 | 0.3 | Update figures. Update Sections 1, 2. Write Sections 4, 6 and 7. | Emanuel Palm |
| 4 | 2023-02-24 | 0.4 | Added to Section 4. | Per Olofsson |

# Quality Assurance

|  |  |  |  |
| --- | --- | --- | --- |
| No. | Date | Version | Approved by |
| 1 | YYYY-MM-DD | 1.0 | Nnnnn Nnnnnnn |
| 2 |  |  |  |