

Draft Recommendation for  
Space Data System Practices

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| Mission Operations  Mission Planning & Scheduling INFORMATION MODEL |

Draft Recommended PRACTICE

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FOREWORD

Through the process of normal evolution, it is expected that expansion, deletion, or modification of this document may occur. This Recommended Practice is therefore subject to CCSDS document management and change control procedures, which are defined in the *Organization and Processes for the Consultative Committee for Space Data Systems* (CCSDS A02.1-Y-4). Current versions of CCSDS documents are maintained at the CCSDS Web site:

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PREFACE

This document is a draft CCSDS Recommended Practice. Its ‘White Book’ status indicates that its contents are not stable, and several iterations resulting in substantial technical changes are likely to occur before it is considered to be sufficiently mature to be released for review by the CCSDS Agencies.

Implementers are cautioned **not** to fabricate any final equipment in accordance with this document’s technical content.

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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# Introduction

## General

Mission planning is an activity that often requires interaction between multiple entities. This may be to support distributed planning, where the responsibility for different aspects of mission operations planning is spread over multiple entities, including the space segment. It may also be to facilitate collaboration between missions, or to allow the planning of payloads by multiple end-users or the planning of multiple payloads from different agencies hosted on the same spacecraft. Other missions, such as observatories, may make payloads available to a wider user community. Some planning responsibility may be delegated to the spacecraft itself and the corresponding capabilities hosted onboard. Historically, these interoperable interfaces have typically been defined on a per-mission or per-agency basis.

This recommended practice has the objective of specifying the information model for generic, interoperable mission planning and scheduling interfaces, for all typical space mission use cases, including the ones identified above. These use cases are elaborated in the associated informational report (green book) [B2] *Mission Planning and Scheduling*.

Mission planning and scheduling are integral parts of Mission Operations (MO) and closely related to the other aspects of the overall monitoring and control of space missions. This close relationship is recognized in the context of the CCSDS Mission Operations and Information Management (MOIMS) Area by the fact that the MPS services have been identified and included from the start among the envisaged MO services described in reference [B1], *Mission Operations Services Concept*. This recommended practice defines the information model for Mission Operations (MO) Mission Planning and Scheduling (MPS) services in conformance with the CCSDS Mission Operations service framework described therein.

The envisioned MPS services based on this information model are a set of services that support: interaction with a mission planning system and its users at the level of planning requests, distribution of the plans generated, and control of the execution of those plans. It is expected, but not required, that these are used in conjunction with other mission operations services, such as Monitoring & Control [B4] and Automation, as identified in reference [B1]**.**.

The MPS information model are defined in terms of the Message Abstraction Layer (MAL) (see reference [2], *Mission Operations Message Abstraction Layer*), that is the core of the MO service framework. In this regard, the information model is defined in terms of the base set of MAL attribute types and data classes (composite, enumeration and MO object) that it defines.

The same MPS information model can also be applied to the definition of standard echangeable file formats for use where a service level interface is not required. In this context a specified encoding of the MAL attribute types can be applied, removing any specific dependency on the MAL.

## Purpose and Scope

This recommended practice defines, in an abstract manner, the MPS information model that describes the structure of MPS data, including planning requests, plans and supporting information objects that are referenced by the MPS services.

Not all aspects of this information model may need to be applied to support a conformant interface in the context of a specific MPS service or deployed system. Some aspects of the MPS information model are optional. A summary of the optional elements of the standard is provided in section 2.4.8.

This recommended practice does not specify:

1. individual implementations or products;
2. the implementation of entities or interfaces within real systems;
3. the encoding of the specified information data classes;
4. the expression language used for representation of conditions and calculations embedded within MPS data.

## Applicability

This recommended practice is applicable to any mission operations component that provides mission planning functionality or executes mission plans (schedules) and exposes mission planning and scheduling interfaces. This includes interfaces between:

* Mission users and the Mission Planning system;
* Hierarchical or distributed components of a Mission Planning system;
* Mission Planning and Plan Execution (Scheduler) components;
* Plan Execution and Mission Control.

Further detail is given in the associated informational report (green book) [B2].

This standard is intended to apply to interfaces wherever they may occur in a space system:

* between ground-based components across a terrestrial link;
* between ground-based and on-board components across a space link;
* and potentially between on-board components across an on-board interface.

## Rationale

The primary goal is to increase the level of interoperability for mission planning among agencies and space system users at the level of exchanged planning requests and plans. The MPS information model can also be used between systems within an agency and to promote the development of re-usable infrastructure for space systems and interoperability between missions.

Various use case scenarios applicable to the mission planning and scheduling standardization process have been identified by performing a survey of a number of representative space missions of various CCSDS member agencies. The missions subject to the survey have been categorized into mission types, in an attempt to identify commonalities in the mission planning processes, e.g. in the areas of planning cycles, execution feedback, navigation services, planning requests, resources and constraints, and output of the planning phase. The full results of this survey, including the identified mission types, are described in the MPS green book [B2].

The use of the underlying MO framework enables abstract services based on this MPS information model to be specified and implemented using appropriate encoding and information transfer technologies (file and/or message based) for the deployment context. An extensible set of MAL technology bindings exist to support:

* encoding of data structures within the context service messages;
* binding of the service operations to a specific messaging technology.

Note that security considerations are genera handled by the MPS service specifications based on this information model, by the MO framework layer or below.

## Document Structure

This recommended practice is organized in the following sections:

1. **Introduction**: provides purpose and scope, applicability, and rationale of this  
   recommended practice and lists the definitions, conventions, and references used  
   throughout the document;
2. **Overview**: describes the mission planning & scheduling concept and how this relates to MO services, as well as giving a high-level overview of both the MPS information model and the envisioned set of MPS services.
3. **MPS Information Model**: describes the MPS data items and their constituent information objects that can be referenced by MPS services.

## Definitions

For the purposes of this document, the following definitions apply.

NOTES

1. Abbreviations are to be found in annex A.
2. The terms plan and planning are used throughout this specification, but that this also encompasses schedule and scheduling respectively.
3. The prefix “planning” is used to disambiguate terms used in this specification from other more general uses of a term. This applies to planning activities, constraints, events, requests and resources.

|  |
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|  |
| action: A single executable task of an MO M&C service provider. A telecommand is an example of an action. |
| activity definition: The definition element of a planning activity. It forms part of the planning configuration data. |
| activity details: The information required to create an activity instance from an activity definition. It may be contained within a planning request to request inclusion of a planning activity, or within an activity definition (to specify child activities). |
| activity instance: The instance element of a planning activity. Activity instances are contained within plans. |
| area: A group of related MO services with an associated identifier and number. This Recommended Standard forms part of the MPS area, with the area number 5. |
| argument: A run-time parameter provided to various control items on invocation. For example, arguments apply to planning requests, planning activities and planning events. |
| constraint: (See planning constraint.) |
| custom function: An ancillary MPS data item that allows access to built-in Boolean functions of a planning system, for example in the context of planning constraints (specifically a function constraint). The custom function must be pre-defined to be referenceable and the MPS custom function definition holds the declaration of an available function. |
| definition: The statically declared information associated with an information object. This may, for example, include a description, set of defined arguments or any other information that applies to all occurrences of the information object. There may be multiple definitions [versions] over the mission lifetime associated with the same identity [definitionID]. |
| details: A data structure used to specify the information needed to create an instance from a definition for an information object that has multiple occurrences. |
| direction: An MPS data type that is used to represent a pointing direction or attitude of a spacecraft, payload instrument, or other object. |
| domain: A namespace that partitions separately addressable entities (e.g., planning activities, planning events or planning resources) in the mission. The mission is decomposed into a hierarchy of domains within which entity identifiers are unique. |
| effect: A type of planning constraint that is used in the context of modelling planning resources. It specifies the impact that executing a planning activity will have on a planning resource. |
| event definition: The definition element of a planning event. It forms part of the planning configuration data. |
| event instance: The instance element of a planning event. Event instances are contained within plans. |
| expression: A calculation to be performed at run time that supplies a value of a defined data type. Expressions are specified as text strings, together with the identification of the expression language used. No standard expression language is specified in this document. |
| full plan: A plan that contains the full details of a plan. Used to distinguish from a patch plan. |
| identity: A unique identity associated with an MO object, which comprises:   * The domain of the object; * The area of the object; * The type of the object; * A key (identifier) for the object, unique within domain, area and type; * The version of the object [optional]. |
| information object: The set of information about a real-world entity that is exchanged across an interface. This may include static definitions, dynamic status and metadata.  NOTE – Mission planning information objects include: planning requests, plans, planning activities, planning events and planning resources. |
| instance: A dynamically created object representing each new occurrence of an information object. This includes a unique instanceID of the occurrence and any unchanging data associated with it as a set of static attributes. It also includes the current status of the object as a set of dynamic attributes. An instance has a reference to its definition. |
| key: Part of the identity of an MO object, the key is a unique identifier for the object within the scope of the domain, area and object type. |
| MO dynamic item: A pattern of MO objects for an information object that has separate definition and instance objects, the latter representing an individual occurrence of the object with an evolving status. Updates reference the instance object. Instances reference the definition object. |
| MO object: An entity defined within the information model of an MO compliant service specification that has a unique identity enabling it to be referenced by other MO objects and in the body of MO service messages. Information objects may comprise multiple MO objects, adhering to one of the following object patterns: MO static item, MO state and MO dynamic item. |
| MO state: A pattern of MO objects for an information object that has a single element comprising both statically declared information and dynamically evolving status. Updates reference the definition object directly. |
| MO static item: A pattern of MO objects for an information object that has a single element comprising statically declared information with no evolving status. Static items comprise only a definition object, with no corresponding updates. |
| patch plan: A plan that only contains the delta (changes) from a precursor plan. A patch plan must be merged with its precursor plan to generate the target plan. |
| plan: The output of the planning process. It contains a set of selected planning activities associated with time, position, or planning event. A plan may contain additional related information.  NOTE – In the context of the mission planning and scheduling standardization activity, there is no distinction between the terms ‘plan’ and ‘schedule’ and only the term plan is used. |
| plan execution: The process of executing plans on-board or on the ground. |
| planning: The process of creating one or more plans (output) from planning requests (input).  NOTE – In the context of the mission planning and scheduling standardization activity, there is no distinction between the terms ‘planning’ and ‘scheduling’ and only the term planning is used. |
| planning activity: A meaningful unit of what can be planned. The granularity of a planning activity depends on the use case, it may be hierarchical. In other words planning activities are the building block for planning. |
| planning configuration data: The set of configuration data required by MPS service providers and consumers. It includes activity definitions, event definitions, resource definitions, request definitions, and MPS system configuration parameters. |
| planning constraint: Something that limits or restricts the planning of planning activities. Different types of constraint exist, including: temporal constraints, sequential constraints between planning activities and/or planning events, resource constraints, and geometric constraints (position and pointing). |
| planning event: The meeting of a condition. Planning activities can be associated with a planning event and specify their start or end relative to the event time. |
| planning request: An input to the planning process, which requests one or more planning activities. Each planning request contains all the information that the requester can provide. |
| planning resource: An abstraction of a real-world resource, physical or virtual, that is represented as a quantity. The level of fidelity in the modelling of a resource only needs to be sufficient to support planning decisions. A planning resource may constrain the execution of planned activities, which may in turn have an effect on the value of the resource. |
| planning user: Any entity that is responsible for submitting planning requests to a planning function and potentially receiving feedback on the status of planning requests and generated plans. For example, this could be an external Principal Investigator (PI) or a mission operations system or role. |
| position: An MPS data type that is used to represent the physical location of a spacecraft, or other object. |
| potential event: A type of planning event that is not predictable, but may still have a defined response within a plan. |
| precursor plan: A plan from which the current plan represents an evolution through replanning or an iterative planning cycle. The current plan contains the specification of the changes from the precursor plan as a set of plan revisions. |
| predicted event: A type of planning event that is expected to occur at a particular time or position that can be predicted as an input to planning and contained within a plan. Orbital events are an example of predicted events. |
| procedure: In the context of MPS: an executable process that is invoked to fulfil the execution of a planned activity. Automated operations procedures, on-board control procedures, and procedures supported by an MO Automation service provider (see reference **[B1]**) are examples of a procedure. |
| repetition: A data structure used in the context of a planning request to request the repeated execution of planning activities. Various sub-types of repetition are defined to support the specification of repeat cycles by different criteria, such as time, position, or pointing. |
| request definition: The optional definition element of a planning request that contains the specification of a re-usable planning request template. It forms part of the planning configuration data. |
| request instance: The instance element of a planning request. This may change over time if the request is updated by the user, each comprising a separate version of the request. |
| resource definition: The definition element of a planning resource. This may omit dynamic attributes of the resource (its value) and forms part of the planning configuration data. |
| resource profile: Provision for the evolution of the value of a planning resource over time. |
| slider: A relative position with respect to an MPS object, such as a planning activity, where 0 represents the start and 1 the end of the activity. The slider is a real number that can represent a specific point between these two extremes. |
| target plan: A full plan that is the result of applying a patch plan to its precursor plan. |
| trigger: A construct that allows specification of the specific condition that marks the start or end of something. It is used in the context of both planning activities and plans to specify when an activity should start or end. Triggers may be defined in terms of time, position, pointing, or a planning event. |
| update: A data structure used to report the changing value of dynamic attributes and arguments of an MO object (including its status) at a specific point in time. |
| version: Part of the identity of an MO object, typically of a definition object, that represents a defined set of values for its static attributes. When a definition is updated, the version is incremented, but other elements of the object’s identity, including its key remain unchanged. |

## Nomenclature

### Normative Text

The following conventions apply for the normative specifications in this recommended standard:

1. the words ‘shall’ and ‘must’ imply a binding and verifiable specification;
2. the word ‘should’ implies an optional, but desirable, specification;
3. the word ‘may’ implies an optional specification;
4. the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

NOTE – These conventions do not imply constraints on diction in text that is clearly informative in nature.

### Informative Text

In the normative sections of this document, informative text is set off from the normative specifications either in notes or under one of the following subsection headings:

* Overview;
* Background;
* Rationale;
* Discussion.

## Conventions

### Diagrams

Unified Modelling Language (UML) notation (reference [3]) is used for diagrams representing the MPS information model in section 3.

This section does not seek to provide a full description of the standard UML diagram types used, but defines the specific conventions applied in this document.

Class Diagrams



Figure 1‑1: Example Class Diagram

In the MPS information model, UML class diagrams are used to illustrate data structures and their relationships. The above example diagram highlights specific colour coding and other conventions used in this document.

Classes are used to represent MPS data structures or types and nominally have a tan background. Where they are greyed out this indicates that the data structure is an optional element of the MPS information model. Data structure names begin with an upper case letter and are shown in bold type. Abstract data types have their names italicized.

Where a data structure corresponds to an MO object (see 3.4.2), this is shown by the application of the <<MO object>> stereotype and a thick purple border.

The attributes of a data structure define its content as a series of data fields. Ultimately these are composed of fields of a valid MAL::Attribute type, but they can also be any of the composite MPS data structures defined in this document, which ultimately extend the MAL::Composite type. An attribute may be optional, or correspond to a list of items. This is indicated by a multiplicity qualifier [0..1] (optional: zero or one item) or [0..\*] (list: zero to many items). In the corresponding table entry, the attribute will be marked as nullable. Note that a non-nullable list has the multiplicity qualifier [1..\*]. The attributes of a data structure may or may not be shown in a given diagram, in the interest of conciseness (they will appear in another diagram focused on that data structure).

In the specific case of MO objects, distinction is drawn between those attributes that are static (their value does not change over time) and those that are dynamic (their value can change over time). Static attributes of MO objects are shown underlined. The identity of an MO object is an inherited attribute of the MO object class, and is not shown in the diagrams.

Data structures imported or referenced from outside the MPS information model are highlighted in other colours as indicated in the legend in the bottom left of the example diagram. These include MO MAL [2] and M&C Services [B4], and other CCSDS standards including the Navigation Event Message [B5] and Cross Support Services simple schedule [B7].

Relationships between data structures are shown by the connecting lines in the diagrams. The following UML class relationships are used:

* Association : shows a relationship between MO objects or data structures. References to an MO object are shown in this way, where the source object will have an attribute of type MAL::ObjectRef (or MAL::Identifier) pointing to another object.
* Generalization or Inheritance : shows that a data structure is derived from a parent class (which may be *abstract*), inheriting its attributes and extending or modifying them with its own.
* Composition : shows that a data structure is contained within a parent class. Aggregation (with an unfilled diamond) is similar, but the parent only contains references to the child structures.

Enumerations are identified by the stereotype <<enumeration>> and have a green background. The set of allowed statuses/enumerations is listed as attributes, together with their corresponding integer values. By convention the name of an enumeration ends with “Enum”, and the names of the statuses/enumerations are all in upper case.

An ∞ symbol on a class indicates that more detail is to be found on this class in another diagram.

State Machine Diagrams

UML state machine diagrams are used in the MPS information model to represent allowed states and state transitions for MPS information objects. This is done for planning requests, plans, planning activities and planning events, and applies to the status attribute of the corresponding instance object.



Figure 1‑2: Example State Machine Diagram

The blue boundary frames indicate which function is responsible for initially asserting these states (planning or plan execution). State transitions that occur as a result of an MPS service operation are marked with an \*, other transitions occur automatically as a result of planning or plan execution processes.

### Tables

The formal normative definitions of data structures, services and service operations are presented in an abstract tabular format in this document. This is consistent with that specified in the MO MAL standard [2], but has a more compact layout. The table formats used are summarised here to aid in understanding their presentation in this document. A full description can be found in reference [2].

Purple cells (dark grey when printed on a monochrome printer) contain table headings, light  
grey cells contain fields that are fixed for a pattern, and white cells contain values that   
are specific to the operation or structure.

Where types are required from other MO specifications, the following notation  
is used to denote the area in which the referenced definition resides:

<area>::<type name>

Note that all tables described below constitute a normative part of the standard, including the data structure tables that are contained within section 3.

Data Structures

Each data structure (or type) definition contained in the MPS information model (section 3) contains a table following the standard structure outlined below.

Table 1‑1: Example Data Structure Table

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **<Data Structure name>** | **Extends** | <Parent name> | **SFP** | <#> |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| ­<name> | <data type> | Yes¦No | <Description> |
| ­<name> | <data type> | Yes¦No | <Description> |
| … | … | … | … |

The first row of the table specifies the name of the MPS data structure (in bold), and that of the structure it extends, which may either be a MAL data type (typically MAL::Composite) or another MPS data type. The Short Form Part (SFP) gives the number used by the MAL to identify this structure within the area.

This is followed by a list of attributes or data fields that constitute the data structure. Inherited attributes may optionally be shown with a grey background. In this document this is only used for data structures of type MO Object to highlight the inherited identity attribute.

Attribute data types may either be a MAL::Attribute type, or another MPS data structure. In the case of the MAL::ObjectRef attribute type, two forms are supported:

MAL::ObjectRef[[1]](#footnote-1) Reference is to an explicit object type (encoded within the reference) to an MO object of any type, subject to restrictions defined in the description field.

MAL::ObjectRef<T> Reference is to an implicit object type (not encoded within the reference) and is restricted to the named concrete type T.

The same format is used for the MPS Expression type to indicated the type of the evaluation result of the expression, for example:

Expression<MAL::Duration>

The nullable column indicates whether the attribute is allowed to contain a null value. A nullable field does not need to be provided by the consumer, but must be supported by the provider unless it is an optional element of the standard.

A default value may be specified in the description for a non-nullable attribute. This means that a value must be supplied in any service message “on the wire”, to avoid the need for a provider implementation to have knowledge of the default, but that in the context of a user (or web-based) interface, the default value may be initially populated to avoid the need for the user to specify anything in the general case.

Attributes may also be a list of elements, represented as List<<element>>, where <element> can be of any MAL::Attribute or MPS data type. MAL lists are implicitly unbounded, ordered and may have zero elements and/or be nullable. A nullable list can be empty [0..\*], otherwise it must contain at least one entry [1..\*].

By convention data structure names start with an upper case letter. If the data structure is abstract (only used to define an inheritance hierarchy) then its name is italicized and the word “abstract” is substituted in the SFP. Attribute names start with a lower case letter. In the context of MPS MO objects (definitions and instances), static and dynamic attributes are differentiated by underlining the name of the static attributes.

Enumerations

Enumerations are also contained in the MPS information model (section 3) and defined using tables of the following format.

Table 1‑2: Example Enumeration Table

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **<Enumeration name>** | **SFP** | <#> |

| Status | Value | Description |
| --- | --- | --- |
| <STATE NAME> | <#> | <Description> |
| … | … | … |

The set of allowed statuses/enumerations is listed together with their corresponding integer values and a description.

By convention the name of an enumeration ends with “Enum”, and the names of the statuses/enumerations are all in upper case.

## References

The following publications contain provisions which, through reference in this text, constitute provisions of this document. At the time of publication, the editions indicated were valid. All publications are subject to revision, and users of this recommended standard are encouraged to investigate the possibility of applying the most recent editions of the publications indicated below. The CCSDS secretariat maintains a register of currently valid CCSDS publications.

[1] *Mission Operations Reference Model*. Issue 1. Recommendation for Space Data System Practices (Magenta Book), CCSDS 520.1-M-1. Washington, D.C.: CCSDS, July 2010.

[2] *Mission Operations Message Abstraction Layer*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 521.0-B-2. Washington, D.C.: CCSDS, March 2013.

[3] *Unified Modelling Language.* Issue 2.5.1. Object Management Group (OMG), formal/2017-12-05, December 2017.

[4] T. Berners-Lee, R. Fielding, and L. Masinter. Uniform Resource Identifier (URI): Generic Syntax. STD 66. Reston, Virginia: ISOC, January 2005

[5] H. Thompson and C. Lilley. XML Media Types. RFC 7303. Reston, Virginia: ISOC, July 2014.

[6] *Space Assigned Numbers Authority (SANA) - Role, Responsibilities, Policies and Procedures*. Issue 3. CCSDS Record (Yellow Book), CCSDS 313.0-Y-3. Washington, D.C.: CCSDS, October 2020.

[7] *Reference Architecture for Space Data Systems*. Issue 1. Recommendation for Space Data System Practices (Magenta Book), CCSDS 311.0-M-1. Washington, D.C.: CCSDS, Septenber 2008.

NOTE – Informative references are listed in ANNEX B.

# Overview

## General

This chapter introduces the concepts behind the MPS services. It has the following main sections:

* Mission Planning & Scheduling Concept
* Relationship to Mission Operations Services
* MPS Information Model Overview
* Optional Elements of the Standard

## Mission Planning & Scheduling Concept

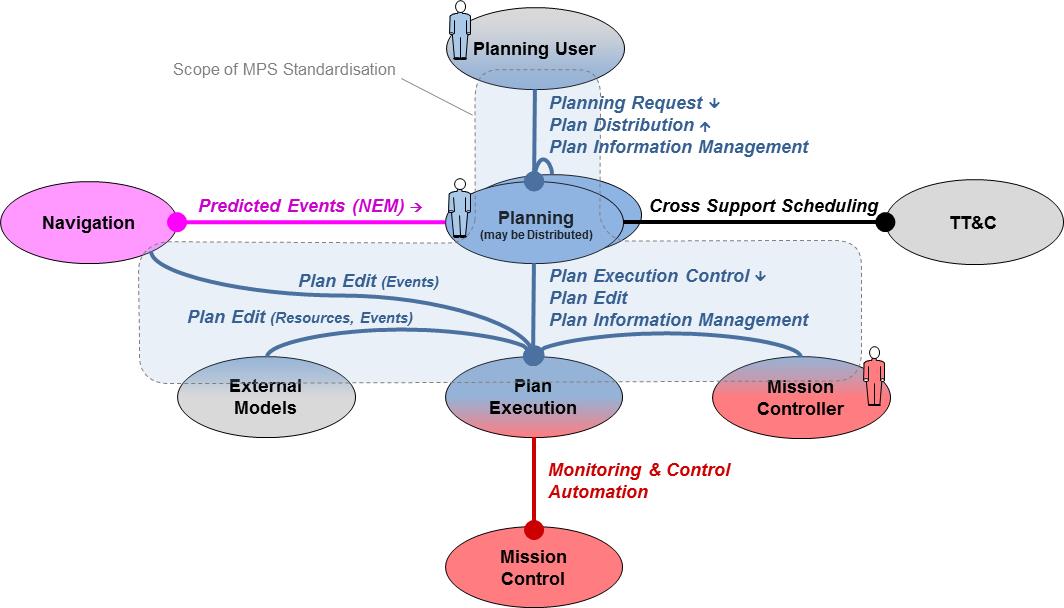


Figure 2‑1: Functions involved in Mission Planning

Mission planning & scheduling encompasses application level functions of a space mission system that may be distributed across multiple organizations and physical nodes, both in the space and ground segments. Standardization in this area concerns only the interaction between functions at the application level, and not the mission planning functions themselves.

The scope of standardization includes both the format/model of data exchanged, as well as the semantics of the interactions for their exchange, captured by the associated service level interfaces. A generalized view of the functions involved in mission planning and their interactions with other functions is given in Figure 2‑1. The entities shown in blue are in the functional area of mission planning. The entities shown in different colors belong to other functional areas of mission operations, such as monitoring and control, navigation and the ground station and communication network.

The following mission planning functions are identified:

* **Planning User**: a generic function that is responsible for submitting requests to the planning function. It may also receive feedback on the status of planning requests and the generated plans. It is not a planning function itself, but is a user of planning data and services. A deployment in an actual space mission may contain multiple types of planning user function, some of which correspond to other mission operations functions within the space mission system.
* **Planning**: the function responsible for performing mission planning. Internally it may be hierarchically organized and/or distributed. Planning requests are received from multiple Planning users (or other mission planning functions) and feedback on their status is provided. The output of the planning function is plans, which may be retrieved by planning users and submitted to plan execution functions. Planning may also control the execution of plans via the plan execution functions. Planning is itself a user of the navigation function and may receive predicted planning events, as a Navigation Event Message (NEM) [B5], that are related to orbital information, attitude or slew times; and negotiates the scheduling of ground station support via Cross Support Services (CSS) services [B7].
* **Plan Execution**: the function responsible for executing a plan (or part of it). There may be multiple plan execution functions distributed between space and ground segments. It is not a planning function itself, but it does support a common model of the plan in its interface with planning. It receives or retrieves distributed plans; allows external control of the plan execution process; and provides feedback on execution status of the plan. Plan execution may use underlying mission control services to effect the execution of planned activities. Mission controllers may interact with plan execution functions to control the plan execution process and to edit plans. External functions may also edit plans, for example to update planning events or resources.

It should be noted that in an actual deployment, there may be multiple copies of all the functions identified in Figure 2‑1.

The identified functions may be distributed over a number of distinct entities (organizations and systems) within a given space mission system. There is not a fixed set of such entities, but typical examples include:

* User Community / PIs;
* Science/Payload Operations Centre;
* Payload Processing Centre;
* Mission Operations Centre;
* Flight Dynamics / Navigation;
* Ground Tracking Network;
* Unmanned Spacecraft;
* Surface Lander / Rover;
* Manned Space Vehicle.

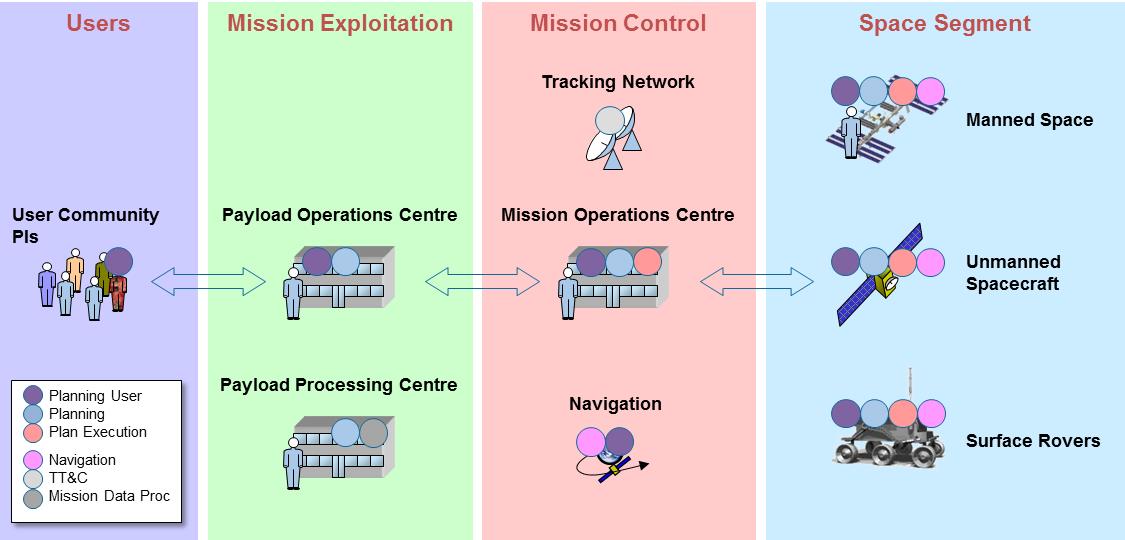


Figure 2‑2: Entities and Functions Involved in Mission Planning

As an example, Figure 2‑2 illustrates potential deployment of each of the functions identified in Figure 2‑1 to the entities listed above. The circles indicate where each of the functions are typically deployed in existing systems, or where they could potentially be deployed in the future. The arrows indicate the interactions in a typical current deployment, but the potential distribution of functions indicated by the circles shows that all the functional interfaces shown in Figure 2‑1 can be exposed to the boundaries between entities. It is where the interactions between the functions are exposed across one or more boundaries between entities that there is a need for standardization within CCSDS as a potentially interoperable interface between agencies.

The interactions within the scope of mission planning and scheduling standardization can be grouped into five services:

* **Planning Request**: submission of planning requests to a planning function, associated responses and their subsequent management and status feedback.
* **Plan Distribution**: distribution and access to plans generated by the planning function.
* **Plan Execution Control**: submission of plans to a plan execution function, management of the execution process and status feedback.
* **Plan Information Management**: access to planning data definitions.
* **Plan Edit**: direct manipulation of plans outside the planning process, either to update planning events and resources with the latest information or for emergency intervention.

Figure 2‑1 shows these MPS services as blue lines. Interactions supported by other CCSDS standards are shown in other colors. The circle at one end indicates which function is the service provider: Planning is the service provider for Planning Request and Plan Distribution services. Plan execution is the service provider for Plan Execution Control and Plan Edit services. Both functions can provide the Plan Information Management service. These services are not defined in this recommended practice, but are the subject of a separate CCSDS recommended standard (Blue Book).

A common MPS information model applies to the planning requests and plans transferred or Referenced by these services and also to the common configuration data required by service providers and consumers to interpret the planning requests and plans. This information model is introduced in section 2.4 below and formally defined in chapter 3.

For those organizations that do not wish to standardize the service level interaction, but only to standardize the data format used for the exchange of planning requests and plans, standard XML-based file formats may be defined using the same MPS information model, with an explicit encoding of the MAL attribute types, effectively removing any dependency on the MAL.

## Relationship To Mission Operations Services

The CCSDS Mission Operations (MO) Services Concept provides a standard framework for the specification of end-to-end services between mission operations applications (reference [B1]). MO services are defined in terms of a Message Abstraction Layer (MAL) (reference [2]), which provides a means of specifying data and service interfaces in an implementation, encoding and communication agnostic manner.

The following figure is taken from the CCSDS Application and Support Layer Architecture (reference [B11]) and shows the generic protocol stack for the MPS services.

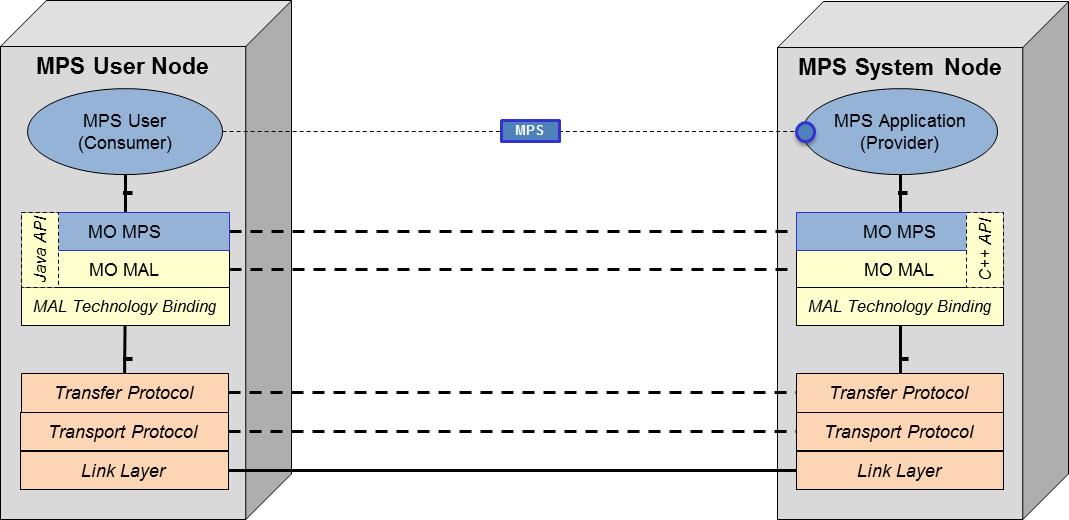


Figure 2‑3: MO MPS Services Generic Protocol Stack

The MO MAL defines:

* A set of MAL Attribute data types that can be used to represent the individual data fields of message structures;
* A set of MAL Interaction patterns that correspond to the message exchange behavior of individual service operations.

The abstract specification of the service interfaces and data can be mapped to a concrete implementation through:

1. a technology binding that defines how the abstract messages (composed of a sequence of MAL attributes) are encoded in a concrete format (e.g. binary, XML or ASCII);
2. a technology binding that defines how the resulting messages are carried over a concrete message transport protocol by mapping the standard MAL interaction patterns to that protocol;
3. a language binding that transforms the abstract service interface into a concrete API for a given programming language (e.g. Java, C++ or Python).

Figure 2‑3 illustrates a generic deployment of MPS services using the MO service framework with service consumer and provider functions hosted on different deployment nodes. MPS specific functions and protocol layers are shown in blue; elements of the “vanilla” MO framework in yellow; and underlying communications infrastructure layers in tan (light orange). The application level MPS service interaction is shown by the direct interface between service provider and consumer functions, carrying MPS service messages defined in terms of data structures specified in the MPS information model.

The MAL technology binding used in a specific deployment ensures on-the-wire interoperability at communications protocol level. Transfer protocol equates to the messaging or file transfer service used over the underlying transport and physical link layers. The diagram illustrates how different language bindings can be used by provider and consumer for the service API, as this does not affect the wire level protocol.

It is noted that while the MAL may be implemented as a specific software layer for reasons of maintainability and reusability, it is not a requirement to do so. The MAL may simply be used as an abstract specification that enables transformation of the service specification by the applied technology bindings into a concrete implementation of that service with no distinct MAL layer. The MO MPS, MO MAL and MAL technology binding layers in the diagram are effectively combined into a single software component. This is an important distinction for deployment contexts where the implementation is required to be both compact and efficient, such as on-board a spacecraft.

An MO object (see §3.4 for more detail) is an entity defined within the information model of an MO compliant service specification that has a unique identity enabling it to be referenced by other MO objects and in the body of MO service messages. The identity of an MO object is defined by its type and unique key, scoped by its area, domain and optionally by a version. The specification of a service-specific MO object class includes a custom set of references to other MO objects that capture the relationships between those objects. In the context of the MPS services, MO objects are defined to represent planning requests, plans and the planning activities, planning events, and resources that they reference.

An MO application-level service specification comprises a set of operations that the service consumer may invoke on the service provider. Each operation is mapped to a standard interaction pattern defined by the MAL and provides the service-specific body of the constituent messages.

In addition to the MAL and technology bindings, the MO service framework includes a set of Common Services [B3] that can be used in conjunction with any MO application level service. These include a Directory, Login and Configuration services.

## MPS Information Model Overview

### General

The information exchanged across the interfaces supported by MPS services is complex. Requests for activities to be planned require the specification of the activities to be performed and any constraints on their execution. Plans express not only the planned activities they contain, but also what triggers their execution relative to time, position or planning events.

The MPS information model describes the information objects that are transferred or operated on by service operations and the relationships between them. It addresses both the content of the messages that constitute service operations and also the configuration data that both consumer and provider must have access to to interpret those messages.

This document contains the specification of data structures derived from the MPS information model that are used in the body of service messages or referenced by them. These data structure definitions are a normative part of the Recommended Standard and are expressed in the tabular format described in 1.8.2.



Figure 2‑4 : MPS Data Items

A high-level overview of the MPS information model is given in figure 2‑4. This shows the principal MPS data items and their interrelationships using standard UML notation.

The rectangles in the diagram correspond to standard data items. The lines between them define the relationships between those data items. Data items are color-coded in Figure 2‑4 by functional area:

◼ Mission Planning data items defined in this document are shown in blue.

◼ Mission Control data items (red) correspond to CCSDS MO Monitoring & Control and the proposed MO Automation standards.

◼ Navigation data item (magenta) correspond to the CCSDS Navigation Event Message Recommended Standard.

◼ Cross Support Services data items (grey) correspond to CCSDS Cross Support Service Management Recommended Standards.

Relationships shown in black are within the scope of mission planning standardization, others are color-coded by their respective area.

The following principal MPS data items are shown in the diagram:

* Planning Requests;
* Plans;
* Planning Activities;
* Planning Events;
* Planning Resources.

These are introduced in the subsections below. Each of these data items comprises a set of MO objects with its own object identity, following one of the typical MO object patterns defined in §3.4.3

The status of planning requests, plans, planning activities, and planning events can evolve over time and is reported through the defined MPS services. State models are associated with each of these data items in the full information model, but only the minimum set of states has been defined to work with the defined services: missions may effectively extend these with additional states using additional information fields.

Planning requests and plans are both container objects, whose content relates to a set of planning data items: planning events, planning activities, and planning resources. For each of these three types (or classes) of planning data, there is a defined set of items that can be referenced or instantiated within planning requests and plans. Together these definitions comprise the planning configuration data.

Planning constraints are not self-standing data items, but can be attached to planning requests and planning activities. They are defined in 3.3.6. Subsection 3.3 also includes the definition of other MPS supporting data types, including:

* MPS Position and Direction data types;
* Expressions;
* Arguments;
* Triggers;
* Repetitions.

Some aspects of the MPS information model are optional. These aspects are not required to be supported by a compliant MO MPS service provider, although this may limit the set of service capabilities and associated operations that can be supported. Optional aspects of the model include:

* Planning Resources;
* Functions;
* Planning Constraints, other than representation as a text expression using any defined expression syntax supported by the service provider;
* Position and Direction data types;
* Repetitions (the representation of repetitive occurrences of planning activities).

### MO Objects

Figure 2‑5 shows how each of the MPS Data Items comprises multiple MO objects following a 1, 2, or 3 element MO object pattern. MO objects are shown with a bold purple border.

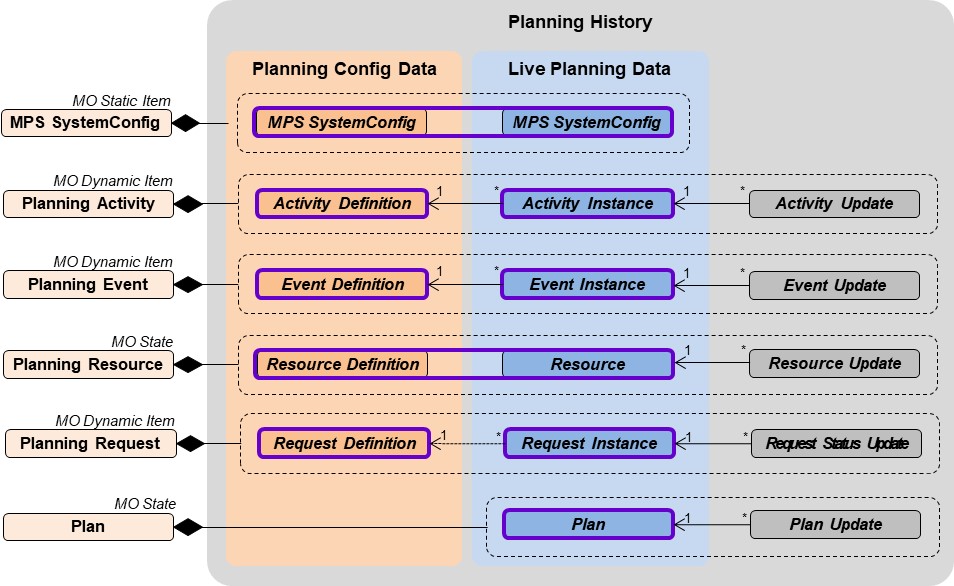


Figure 2‑5 : MPS Data Items and their Constituent MO Objects

Each MO object has a unique object identity, which includes an unchanging key (Identifier) and optionally a version. When a definition object is updated, it retains the same key, but its version is updated to uniquely identify a specific version of the definition. Planning request instances and plans also have an associated version.

The definition objects associated with planning activities, planning events, planning resources and planning requests all form part of the planning configuration data that must be available to both communicating parties that exchange planning requests and plans. Planning configuration data also includes a single MPS SystemConfig object that defines overall configuration parameters for the entire MPS system. Definition objects comprise only static attributes. The MPS services defined in this Recommended Standard do not address the bulk transfer of MPS configuration data between communicating parties, but individual definitions can be accessed using the Plan Information Management Service.

The instance objects associated with all MPS data items, are the live planning data created by and exchanged between communicating parties during planning and plan execution. Instance objects may comprise both static and dynamic attributes. For planning resources and MPS SystemConfig, the live instance has the same object identity as the associated definition, the only distinction being that the live instance may include dynamically updating attributes, such as the value of a planning resource.

Changes in state of the dynamic attributes of live planning data instance objects may be notified through an update structure exchanged through MPS service messages and optionally stored in planning history. These updates are not themselves MO objects, but reference the corresponding instance and the timestamp of the update as well as the value of dynamic attributes.

Planning requests may reference planning activities, planning events, and planning resources but do not contain instances of planning activities or planning events. Instead they specify the activity details for the requested planning activities.

Plans contain instances of planned activities, and optionally of planning events. They may also optionally contain planning resource profiles that express their planned evolution over time.

### Planning Request

Planning requests are the main input to the planning function. A planning request is a container for the information needed to be exchanged between the requester and the planner. It supports the specification of a request to plan one or more planning activities. Alternatively, it can support a request to use an existing plan (already containing a number of planning activities) as an input to the planning process. It can constitute a one-off planning request, or request the repetitive planning of activities as a ‘standing order’.

The main characteristic of the planning request is that, being a container, it needs to hold references to, or instances of, the constituent information items that are required by the planner and agreed by the interacting parties for exchange at interface level. It has one or more planning activities as the basis of the request. In addition, the request may optionally reference planning events. Information about planning constraints on when a requested activity can or shall be planned may be exchanged as part of the planning request, by referencing constraints on the timing or position of planning activities, both absolute and relative to planning events or other planning activities, and on the state of planning resources.

### Plan

The plan is the output of a planning process. The plan is basically a container of one or more selected planning activities, optionally associated with planning events. In addition, the usage of planning resources may be contained in the plan. The plan may contain specific information from the planning process, which applies to the plan as a whole. In the hierarchical and distributed planning concepts, the output of one planning function could be the input of another one. As such, a planning request could refer to an entire plan.

Plans may be iterative, and therefore overlap with the previous plan. This introduces the notion that a plan may have an identified predecessor or precursor plan, and also that if a planning data item is contained in multiple iterations of the plan, then it should have the same unique identity, except for an updated version) in each successive iteration of the plan to avoid ambiguity and duplication.

Plans comprise the following main elements:

* Plan Information: header data relating to the plan as a whole;
* Planned Items: the set of contained planning activities and planning events;
* Plan Revisions [optional]: summaries of the changes between this version of the plan and another specified version of a plan, usually its precursor plan;
* Plan Resources [optional]: value profiles covering the period of the plan for a set of planning resources.

### Planning Activity

A planning activity is the basic building block for the planning: a meaningful unit of what can be planned. As such, it has to be understood by the planning function. It could eventually be translated to something that can be executed by a plan execution function; this includes CCSDS MO M&C actions (reference [B4]) (that may represent telecommands) and CCSDS MO Automation procedures (reference [B1]) (that may represent any automated telecommand sequence, operational procedure, on-board control procedure, or function).

Planning activities support hierarchy: a planning activity may be composed of one or more subordinate planning activities. A planning activity may define arguments (parameters), which could be used to instantiate a specific planning activity in a plan, based on its generic definitions. Arguments of a planning request or planning event can be passed through to the arguments of planning activities resulting from these. Arguments can then similarly cascade down through a hierarchy of planning activities. A plan execution function may then flow down these arguments to any action or automated procedure initiated.

Planning constraints can also be associated with a planning activity, either generic constraints applicable to all occurrences (or instances) of the planning activity that are contained within its definition, or specific constraints associated with a particular instance that are defined in the context of the planning request. These planning constraints can be expressed in terms of the timing or position of a planning activity, both absolute and relative to planning events or other planning activities, and on the state of planning resources.

### Planning Event

A planning event marks when a condition is being met, expressed in terms of time or position. They may be used to represent predicted or planned events, such as predicted orbital events or planned periods of contact with a spacecraft, that are typically received as an input by the mission planning function, from an external function, such as navigation.

Planning events may be grouped hierarchically to represent a compound event, such as the start and end of a satellite pass over a ground station (AOS/LOS), or a satellite passing through eclipse (penumbra entry, umbra entry, umbra exit, penumbra exit). A planning event may define arguments (parameters) to convey additional information relevant to the planning process.

Planning activities may be linked to a related planning event. The start or end of the planning activity can be relative to the planning event, and the arguments of the event can be flowed down to the planning activity. Planning requests may also reference planning events, associating them with requested planning activities.

Planning events may be classified as predicted events or potential events:

* Predicted events are those that are expected to occur at a particular time or position that is known at the time of planning and can be contained within a plan. Uncertainty in the timing of predicted events may be refined closer to their time of occurrence. This can either be handled by re-planning, or by updating the events within an executing plan.
* Potential events are not predictable, but may still have a defined response within a plan: virtual observatory Target Of Opportunity (TOO) events are an example. Such events can be inserted into an executing plan.

### Planning Resource

A planning resource is an abstract status modelling the state of the system being planned. It may be necessary to model some aspects of system state in order to:

* trigger the execution of a planning activity;
* constrain the execution of a planning activity;
* define the effect that the execution of a planning activity has on the planning resource.

A planning resource is in effect a value of defined type that can evolve over time. A resource profile can be used to capture and communicate that evolution over time in the context of a plan.

If an event or constraint on a planning activity needs to be expressed in terms of the state of the system (rather than just time or position) then this corresponds to the state of planning resources. This is considered not internal to the planning function, if it forms part of the planning request or plan.

A planning resource could in principle be considered as information that is internal to the planning system. However, some resources may be shared across multiple planning entities. As such, information regarding a resource may need to be communicated between entities, and therefore has to be referenced as part of a planning request or of the plan, in terms of requested or consumed resources respectively. This may include the initialization or synchronization of planning resource values at specific points in the plan.

Planning resources are an optional element of the MPS information model. There is no requirement for a compliant MPS system to support them.

### Optional Elements of the Information Model

Compliance of an individual mission planning system deployment to MPS service specifications does not imply that the full MPS information model has to be supported.

The level of compliance of a specific deployment to an MPS service specification can be selected as follows:

1. The set of MPS services supported
2. The capability sets supported within each MPS service
3. The optional elements of the MPS information model supported

The supported capabilities of a service provider can be made available to consumers via the MO Common Directory Service [B3]. An entry in the directory is made for each MPS service supported by each MPS service provider, which lists the supported capability sets for that service and the MPS information model element sets supported.

Table 2‑1: Mandatory and Optional Elements of the Information Model

| # | Information Model Element Set | MO Objects | MPS Data Types | Constraints |
| --- | --- | --- | --- | --- |
| 1 | Core Features (Mandatory) | Planning Requests Plans Planning Activities Planning Events MPSSystemConfig | Base Data Types (excl. Position & Direction) Expressions Additional MPS Data Types Arguments Time & Event Triggers Time & Event Repetitions | Constraint Expression |
| 2 | Basic Constraints |  |  | Temporal Constraints Sequential Constraint Exclusion Constraint |
| 3 | Plan Revisions | Patch Plans | Plan Revisions |  |
| 4 | Resources | Resources | Resource Profiles Plan Resources |  |
| 5 | Resource Constraints (requires Resources) |  | Resource Constraints Argument Constraint Effects |
| 6 | Position & Direction |  | Position & Direction Types Location, Pointing and Angle Triggers Location, Pointing and Angle Repetitions |  |
| 7 | Geometric Constraints (requires Pos. & Dir.) |  | Geometric Constraints |
| 8 | Functions | Functions |  | Function Constraint |

The elements of the MPS information model are grouped into element sets detailed in Table 2‑1 above. Of these, only the Core Features are mandatory, subject to the further caveat that only those MPS information model elements exposed by supported capability sets of MPS services need to be implemented. Optional element sets are shown with a grey background.

At the interface level, a deployment must support all data structures that may appear within the messages of supported service operations. However, the deployment is not required to generate any data structure from an element set it does not support. If the deployment receives a message containing a data structure from an optional element set it does not support, it can either ignore it or reject the service operation with an UNSUPPORTED error.

Note that support for Resource Constraints is dependent on support for Resources, and that support for Geometric Constraints is dependent on support for Position & Direction types.

The optional element sets of the MPS information model are orthogonal to the capability sets of the MPS services.

# MPS Information Model

### General

This chapter defines the information model applicable to the Mission Planning and Scheduling standard, introducing and defining major data elements in line with the terminology used throughout this document. An overview of the MPS information model has been given in section 2.4 above.

The MPS information model has been defined in terms of the CCSDS Mission Operations [MO] framework, specifically the MO Message Abstraction Layer [MAL] and the associated set of MAL Attribute types. This is to enable the specification of MO compliant data formats and services that reference elements of the information model.

The structure of MPS MO objects is fully defined within this document, together with their relationships, usually represented as attributes of type ObjectRef.

It describes both the data actively exchanged by MPS Services and that required as common configuration data by service providers and users.

The information model diagrams contained in this section are expressed in UML and are informative, while the associated tables that define MPS data structures are consistent with the MO framework and normative. The diagrams and tables follow the conventions introduced in §1.7.1.

As previously introduced in §2.4, some elements of the MPS information model are optional. This is the case for individual data elements where:

* They may not be required by the supported capability sets of supported services.
* They form an optional element of a required data structure.

Where this is the case, this is indicated in the description of each element in the body of this chapter.

The chapter is organized into the following main sections:

1. This Introduction
2. MPS Data Items
3. MPS Data Types
4. MO Framework and Object Patterns

The principle MPS Data Items defined are those introduced in §2.4 that correspond to a set of MO objects that can be directly referenced in the context of the MPS services:

* Planning Requests
* Plans
* Planning Activities
* Planning Events
* Planning Resources [Optional]
* Planning Configuration Data
* Custom Functions [Optional]

MPS Data Types are supporting data structures used in the context of MPS Data Items and MPS service messages:

* MPS Base Data Types
* MPS Position and Direction Types [Optional]
* Expressions
* Additional MPS Data Types
* Arguments
* Constraints
* Triggers
* Repetitions

Section 3.4 gives an overview of how the MO Framework is applicable to the MPS standard and introduces the concept of a generic MO object and a set of common MO object patterns to which MPS data items conform. Three such MO object patterns are identified:

* MO Static Item: a singleton object containing static definitions only.
* MO State: a singleton object containing both static definitions and dynamic state.
* MO dynamic item: a definition object containing static definitions from which a set of dynamically instantiated objects may be derived. The associated instance objects contain static information specific to the instance and dynamic state.

### MO Object Numbers

The identity of MO objects requires the specification of the area and object type. In an efficient encoding this may be represented by a number, which is the same as the Short Form Part for the corresponding data structure (see §3.1.3) . The following (normative) table specifies the number codes assigned for efficient encoding of the defined MO object types:

Table 3‑1: MO Object Numbers

| Area | Area # | MO Object Type | Type # |
| --- | --- | --- | --- |
| MPS | 5 | ActivityDefinition | 101 |
| ActivityInstance | 102 |
| EventDefinition | 201 |
| EventInstance | 202 |
| Resource | 301 |
| RequestDefinition | 401 |
| RequestInstance | 402 |
| Plan | 501 |
| PlanningUser | 601 |
| MPSSystemConfig | 701 |

### Short Form Parts

As required by the MO MAL, each concrete MPS data type is defined with a numerical Short Form Part (SFP) that is expected to be used by efficient encodings when required to hold type information. Short Form Numbers (SFN) are scoped by Area [MPS], and are formed by combining Area number (as a UShort), and the Short Form Part (SFP) taken from the type definition (as an Integer). A convention has been adopted for the numbers used to ensure that all data types associated with a given MPS data item are contiguous, with scope for future extensions.

MPS Data Types defined in §3.3 are allocated SFPs at MPS Area level (5-SFP) within the range 1-100. Data structures associated with the MPS Data Items defined in §0 are allocated SFPs at MPS Area level (5-SFP) within the following range:

* Planning Activities are defined with SFPs in the range 101-200
* Planning Events are defined with SFPs in the range 201-300
* Planning Resources are defined with SFPs in the range 301-400
* Planning Requests are defined with SFPs in the range 401-500
* Plans are defined with SFPs in the range 501-600
* Planning Users are defined with the SFP 601
* MPS SysConfig is defined with the SFP 701
* Functions are defined with SFPs in the range 801-900

### Time Systems

Time system references allow specification the time system used for time attributes within an MPS system. This may be specified in the context of a planning request, a plan or as a system-wide default within the MPSSystemConfig object.

The set of allowed time system values is not defined by this standard, but specified in the SANA registry for time systems:

<https://sanaregistry.org/r/time_systems/>

To allow for evolution, both of the set of time systems defined within this registry and through mission specific extension, time systems are not defined as an enumeration but represented as a MAL::String.

### Lists and Nullability

Whether a field (attribute) of a data structure or service operation message can be null or not, is indicated in the ‘nullable’ column of the corresponding definition table.

Where a nullable field (attribute) is a List, then this gives rise to two possible representations where there are no entries in the List:

* A Null List—there is no List in the encoded message;
* An Empty List—there is a List with no entries in the encoded message.

In most cases these are equivalent. However, where the List represents an optional filter for a subscription or query operation, there may be a distinction in their interpretation. A null list shall always represent the absence of a filter and implies that any value in the filtered field passes the filter. The interpretation of an empty list is implementation dependent, but could be one of the following:

* no filter (equivalent to a null list);
* a filter for which there is no value that passes the filter, which would be of little use in practice;
* a filter for which only a null or empty value passes the filter. This may be of used for an attribute that is itself a list of values, for example, the ‘tags’ attribute of an ActivityInstance, where only those items that have no ‘tags’ would pass the filter.

## MPS Data Items

### General

MPS data items are the principal elements of the MPS information model that are represented as MO objects, following one of the MO object patterns described in §3.4.3. These have been introduced in section §2.4 and shown in Figure 2‑4. The following data items are defined in the MPS information model:

MPS Core Objects

* Planning Activities
* Planning Events
* Planning Resources [Optional]

MPS Container Objects

* Planning Requests
* Plans
* Planning Configuration Data

MPS Ancillary Items

* Custom Functions [Optional]

Each of these is described in turn in the following subsections.

The MPS Core Objects are those which are referenced in the context of planning requests and plans, and for which there must be a set of definitions shared between communicating mission planning functions for those planning requests and plans to be interpreted.

The MPS Container Objects are those that contain a set of references to the Core Objects. Planning requests and plans are dynamically created as part of the planning process and exchanged between communicating mission planning functions. The Planning Configuration Data corresponds to the set of definitions shared between those functions to enable interpretation of the planning requests and plans.

Functions are an MPS Ancillary Item that enable references to externally defined functions.

The following subsections contain the definition of each MPS Data Item and are structured as follows:

1. MO Objects defined for the Data Item
2. State Model for the Data Item (if relevant)
3. Subordinate Data Types defined for the Data Item (if relevant)
4. Service-specific Data Types defined for the Data Item (these may be used in the context of MPS service messages).

#### Updates to Multiple Object Types

*PlanDetailUpdate*

Specifically in the case of reporting the detailed execution status of a plan, updates may be reported for multiple object types: planning activities, planning events and planning resources. To support this an abstract type of PlanDetailUpdate is defined as follows.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***PlanDetailUpdate*** | **Extends** | MAL::Composite | **SFP** | Abstract |



Figure 3‑1: MPS Plan Detail Updates

### Planning Activities

#### Activity Objects



Figure 3‑2: Planning Activities

Planning activities follow the MO dynamic item object pattern, comprising definition and instance classes of MO object.

Activity definitions define the set of activities that may be planned and form part of the planning configuration data for a mission planning system. The definition includes the specification of any arguments associated with the activity, as well as any constraints that apply to all occurrences of the activity.

Activity instances are created to represent a specific occurrence of the activity within a plan and include dynamic attributes that represent the changing status of the activity instance over time, including the value of any arguments and the current status of the activity. Plans contain activity instances to represent the current status of the activity within the plan.

Planning activities may be hierarchical, with parent activities containing multiple child activities. The activity definition contains activity details (in an activityNode) to specify each child activity. Each ActivityDetails points to the ActivityDefinition for the specified child activity. The activity instance maintains a set of pointers to its child ActivityInstances.

Activity details hold the information required to create an activity instance and may be contained within another object, such as a planning request or a parent activity definition. This is further defined in §3.2.2.3 below.

ActivityDefinition

An ActivityDefinition is an MO object that contains static configuration data relating to multiple occurrences of a planning activity. Its identity is defined by a definitionID, which includes a constant key and an evolving version that is updated each time the definition is revised. ActivityDefinitions form part of the planning configuration data.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ActivityDefinition** | **Extends** | MAL::Object | **SFP** | 101 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| identity | MAL::ObjectIdentity | No | Identity of the ActivityDefinition, including version. |
| description | MAL::String | No | Description of the Activity. |
| argDefs | List <ArgDef> | Yes | List of Argument Definitions. |
| constraints | ConstraintNode | Yes | Set of Constraints applicable to all instances of the Activity. |
| executionDefinition | MAL::Identifier | Yes | Reference to the definition of an executable body for the Activity (procedure, action sequence, etc.) [external to the MPS Information Model]. |
| durationSpec | Expression <MAL::Duration> | Yes | Supports calculation of an estimated duration of an Activity Instance. |
| children | ActivityNode | Yes | Set of Activity Details specifying child activities, optionally with repetition. |
| activityType | MAL::String | Yes | Enables a planning system to customize behavior for activities, such as their presentation in displays, based on the specified value. |
| defaultTags | List <MAL::String> | Yes | Default set of Tags that may be used to associate the Activity with others, grouping activities by operational responsibility (controller/group/system) or other criteria. |

ActivityInstance

An ActivityInstance is an MO object that contains the identity of a specific occurrence of a planning activity, together with both static and dynamic information associated with that occurrence. It supports relationships to its definition, source, a related planning event and any child activities.

ActivityInstances may be contained within a Plan.

NOTE – The start and end attributes specify the trigger conditions (including time) that specify when the ActivityInstance starts and/or ends in the context of a Plan. The duration is an estimate of the time taken to execute the ActivityInstance rather than an offset, which may for example be used in the visualization of a Plan. Duration may be used in conjunction with a specified end trigger to determine the planned start time of an ActivityInstance.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ActivityInstance** | **Extends** | MAL::Object | **SFP** | 102 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| identity | MAL::ObjectIdentity | No | Identity of the ActivityInstance |
| definition | MAL::ObjectRef <ActivityDefinition> | No | Reference to the ActivityDefinition |
| source | MAL::ObjectRef | No | Object Type: RequestInstance | ActivityInstance | PlanningUser  Reference to the source of the ActivityInstance, which is either its parent ActivityInstance, a RequestInstance if it is a root Activity, or a PlanningUser if directly inserted. |
| relatedEvent | MAL::ObjectRef <EventInstance> | Yes | Optional reference to an EventInstance that is specifically associated with this instance of the Activity. Typically the Activity is placed in response to the Event. |
| children | List <MAL::ObjectRef <ActivityInstance>> | Yes | References to any child ActivityInstances. |
| comments | MAL::String | Yes | Any notes associated with this instance of the Activity. |
| constraints | ConstraintNode | Yes | Set of Constraints applicable to this instance of the Activity. |
| arguments | List <Argument> | Yes | Argument values for each Argument defined in the Activity Definition. |
| start | Trigger | Yes | Optionally specifies the trigger that initiates the Activity: may be Time, Position or Event based. |
| end | Trigger | Yes | Optionally specifies the trigger that ends the Activity |
| duration | MAL::Duration | Yes | Optional duration of the Activity (estimated until execution, actual post execution). |
| subPlan | MAL::Identifier | Yes | Optional association of the Activity with a defined sub-plan. |
| tags | List <MAL::String> | Yes | Set of Tags that may be used to associate the Activity with others, grouping activities by operational responsibility (controller/group/system) or other criteria. |
| status | ActivityStatusEnum | No | Current Status of the Activity Instance (see Activity State Model in §3.2.2.2) |
| executionInstance | MAL::Identifier | Yes | Reference to the instance of an executable body for the Activity (procedure, action sequence, etc.) [external to the MPS Information Model]. |
| returnData | List<MAL::NamedValue> | Yes | Optional return data from the planning process, provided as a list of ID-Value pairs. This can be used to provide additional information required by the User to interpret the planned activity. |
| statusInfo | MAL::String | Yes | StatusInfo provides the reason for entering the Terminated State and is customizable, but if the following conditions exist then the specified text shall be used:  - Completed (nominal)  - Expired (prior to Activation or during plan Suspension)  - Deleted  - Failed (see ErrorCode/ErrorInfo) |
| errorCode | MAL::Integer | Yes | Error Code optional in the case of a failure status for the planning activity (for example Terminated state with statusInfo Failed). The codes are implementation specific. |
| errorInfo | MAL::String | Yes | Supplementary Error Information |

#### Activity State Model



Figure 3‑3: Activity State Model

The blue boundary frames indicate which of planning or plan execution functions is responsible for asserting these states. State transitions that occur as a result of an MPS service operation are marked with an \*, other transitions occur automatically as a result of planning or plan execution processes.

ActivityStatusEnum

The following states are defined for **ActivityStatus**:

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **ActivityStatusEnum** | **SFP** | 103 |

| Status | Value | Description |
| --- | --- | --- |
| PLANNED | 1 | The Activity Instance has been included in the Plan |
| ACTIVATED | 2 | The Plan including the Activity Instance has been Activated within the plan execution function. |
| EXECUTING | 3 | Execution of the Activity Instance has been initiated |
| SUSPENDED | 4 | Execution of the Activity Instance has been suspended |
| TERMINATED | 5 | Execution of the Activity Instance has been terminated (further information is provided in statusInfo) |

When an ActivityInstance is created within the context of a Plan by the planning function, it has the initial status of Planned.

Plans may be submitted to a plan execution function, but before they will execute they must be activated. Once a Plan has been activated, all contained ActivityInstances will also become Activated.

When an ActivityInstance reaches its execution time or other trigger and is initiated by the plan execution function, then its status is changed to Executing.

During execution, an ActivityInstance may be Suspended. If resumed, its status returns to Executing.

The status of the ActivityInstance is set to Terminated once execution has ended, or it will no longer be executed. StatusInfo provides the reason for termination and is customisable. If the following termination conditions exist, then the following statusInfo text shall be used:

* Completed (nominal)
* Expired (the trigger condition passed before the Plan was activated or while the Activity was suspended)
* Deleted
* Failed (see ErrorCode/ErrorInfo)

If an ActivityInstance that failed to execute is subsequently re-planned, its status may be returned to Planned. It is implementation dependent whether a re-planned Activity re-uses the same object identity or is assigned a new one.

#### Activity Details and Nodes



Figure 3‑4: Activity Details and Nodes

ActivityDetails is a structure that holds the information required to create an activity instance and may be contained within another object, such as a planning request or a parent activity definition.

There are three concrete sub-classes of ActivityDetails:

* **ActivityNode**: that allows details for multiple activities to be specified, as well as for those activities to be instantiated repeatedly through an optionally contained Repetition (see §3.3.8) that specifies the number and separation of the repeat instances.
* **SimpleActivityDetails**: that provides the details required to instantiate a single ActivityInstance.
* **InsertedActivityDetails**: a version of SimpleActivityDetails that is used only in the context of the insertActivity operation of the Plan Edit Service

As ActivityNodes can be nested, it is possible to specify complex repetitive sequences of activities.

*ActivityDetails*

Contains the information required to create one or more ActivityInstances, including the specification of argument values and constraints.

It should be noted that the activityRef and activityOffset attributes are only relevant in the case that a Repetition has been specified in a parent ActivityNode. Temporal and sequential constraints associated with the ActivityInstance can be specified as constraints attached to a concrete SimpleActivityDetails structure.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***ActivityDetails*** | **Extends** | MAL::Composite | **SFP** | Abstract |

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute | Type | Nullable | Description |
| activityRef | Slider | Yes | Specifies how the ActivityInstance is placed with respect to any defined Repetition (0=Start; 1=End). Default is Start. |
| activityOffset | Expression <MAL::Duration> | Yes | Specifies an offset in time for the ActivityInstance from any defined Repetition. Default is no offset. |
| relatedEvent | Expression  <MAL::ObjectRef> | Yes | Object Type: EventInstance.  Specifies a related Event (or Event Group) for the ActivityInstance. Argument specifications and constraints may reference arguments and attributes of the RelatedEvent. |
| comments | MAL::String | Yes | Any notes associated with the ActivityDetails. |

ActivityNode

A concrete sub-type of ActivityDetails, an ActivityNode is a container node for a set of ActivityDetails together with an optional Repetition specification. An ActivityNode is used as the root node of any ActivityDetails specification within a planning request or parent activity definition.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ActivityNode** | **Extends** | *ActivityDetails* | **SFP** | 104 |

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute | Type | Nullable | Description |
| repetition | Repetition | Yes | Optional Repetition specification. |
| activities | List <ActivityDetails> | Yes | Set of ActivityDetails. |

SimpleActivityDetails

A concrete sub-type of ActivityDetails, a SimpleActivityDetails provides the information required to instantiate a single ActivityInstance.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **SimpleActivityDetails** | **Extends** | *ActivityDetails* | **SFP** | 105 |

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute | Type | Nullable | Description |
| activityDefinition | MAL::ObjectRef <ActivityDefinition> | No | Reference to the ActivityDefinition. |
| argSpecs | List <ArgSpec> | Yes | Set of argument specifications for each argument definition contained in the referenced activity definition. These supply a value for each argument, or an expression to enable the value to be derived. |
| constraints | ConstraintNode | Yes | Set of Constraints specific to the ActivityInstance to be created. |
| subPlan | MAL::Identifier | Yes | Optional association of the ActivityInstance with a defined sub-plan. |
| tags | List <MAL::String> | Yes | Set of tags that may be used to associate the Activity with an identified subset of the Plan, grouping activities by operational responsibility (controller/group/system) or other criteria. |

#### Activity Service Structures



Figure 3‑5: Activity Service Structures

This section defines data structures specific to planning activities that are used in the context of MPS service operations and their associated messages.

ActivityUpdate

ActivityUpdate is a data structure that is used to report the dynamic status of an ActivityInstance in the context of the MPS Plan Execution Control service monitorPlanExecutionDetail and getActivityStatus operations.

ActivityUpdates may be distributed to subscribing applications, including status displays, to inform them of the latest status of the activity. This may be particularly relevant in conjunction with a plan execution function. ActivityUpdates may be stored in activity history to provide a complete record of evolving status over time.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ActivityUpdate** | **Extends** | *PlanDetailUpdate* | **SFP** | 106 |

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute | Type | Nullable | Description |
| activityInstance | MAL::ObjectRef <ActivityInstance> | No | Reference to the ActivityInstance to which the status update relates. |
| timestamp | MAL::Time | Yes | Time of status update.  Only nullable in the context of an updateActivity operation: the timestamp must be provided when reporting ActivityInstance status. |
| plan | MAL::ObjectRef <Plan> | Yes | Optional reference to the Plan containing the ActivityInstance to which this update pertains. |
| arguments | List <Argument> | Yes | Argument values. |
| start | Trigger | Yes | Optionally specifies the trigger that initiates the ActivityInstance: may be time, position, or event based. |
| end | Trigger | Yes | Optionally specifies the trigger that ends the ActivityInstance |
| duration | MAL::Duration | Yes | Optional duration of the ActivityInstance (estimated until execution, actual post execution). |
| subPlan | MAL::Identifier | Yes | Optional association of the ActivityInstance with a defined sub-plan. |
| tags | List <MAL::String> | Yes | Set of tags that may be used to associate the ActivityInstance with an identified subset of the Plan, grouping activities by operational responsibility (controller/group/system) or other criteria. |
| status | ActivityStatusEnum | No | Current status of the ActivityInstance |
| executionInstance | MAL::Identifier | Yes | Reference to the instance of an executable body for the ActivityInstance (procedure, action sequence, etc.) [external to the MPS information model]. |
| returnData | List<MAL::NamedValue> | Yes | Optional return data from the planning process, provided as a list of ID-Value pairs. This can be used to provide additional information required by the User to interpret the planned activity. |
| statusInfo | MAL::String | Yes | StatusInfo provides the reason for entering the Terminated State and is customizable, but if the following conditions exist then the specified text shall be used:  - Completed (nominal)  - Expired (prior to Activation or during plan Suspension)  - Deleted  - Failed (see ErrorCode/ErrorInfo) |
| errorCode | MAL::Integer | Yes | Error Code optional in the case of a failure status for the planning activity (for example Terminated state with statusInfo Failed). The codes are implementation specific. |
| errorInfo | MAL::String | Yes | Supplementary error information |

InsertedActivityDetails

A concrete sub-type of ActivityDetails (see 3.2.2.3) that is a variation of SimpleActivityDetails providing additional details for a single ActivityInstance to be inserted into a Plan using the MPS Plan Edit service.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **InsertedActivityDetails** | **Extends** | ActivityDetails | **SFP** | 107 |

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute | Type | Nullable | Description |
| plan | MAL::ObjectRef <Plan> | No | Reference to the Plan into which the ActivityInstance is to be inserted. |
| start | Trigger | Yes | Optionally specifies the trigger that initiates the ActivityInstance: may be time, position, or event based. |
| end | Trigger | Yes | Optionally specifies the trigger that ends the ActivityInstance |
| activityDefinition | MAL::ObjectRef <ActivityDefinition> | No | Reference to the ActivityDefinition. |
| argSpecs | List <ArgSpec> | Yes | Set of argument specifications for each argument definition contained in the referenced activity definition. These supply a value for each argument, or an expression to enable the value to be derived. |
| constraints | ConstraintNode | Yes | Set of Constraints specific to the ActivityInstance to be created. |
| subPlan | MAL::Identifier | Yes | Optional association of the ActivityInstance with a defined sub-plan. |
| tags | List <MAL::String> | Yes | Set of tags that may be used to associate the Activity with a subset of the Plan, grouping activities by operational responsibility (controller/group/system) or other criteria. |

ActivitySuspensionStatus

A data structure that returns the status and supplementary suspension information for an ActivityInstance affected by an MPS Plan Execution Control service SuspendActivity or ResumeActivity operation.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ActivitySuspensionStatus** | **Extends** | MAL::Composite | **SFP** | 108 |

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute | Type | Nullable | Description |
| activityInstance | MAL::ObjectRef <ActivityInstance> | No | Reference to an ActivityInstance. |
| plan | MAL::ObjectRef <Plan> | Yes | Optional reference to the Plan containing the ActivityInstance. |
| status | ActivityStatusEnum | No | Current Status of the ActivityInstance |
| suspensionInfo | MAL::String | Yes | Supplementary information on the suspension/resumption status of the ActivityInstance.  This may detail the point of suspension, which may be specific to the suspension mode; or a reason why resumption was not possible. |

### Planning Events

#### Event Objects



Figure 3‑6: Planning Events

Planning events follow the MO dynamic item object pattern, comprising definition and instance classes of MO object.

Event definitions define the set of planning events that may be referenced in planning requests and plans and form part of the planning configuration data for a mission planning system. The definition includes the specification of any arguments associated with the event.

Event instances are created to represent a specific occurrence of the event within a plan and include dynamic attributes that represent the changing status of the event instance over time, including the value of any arguments and the current status of the event. Plans include event instances to represent the current status of the event within the plan.

Planning events may correspond to either a single event, or an event group. Event groups provide a means to reference a set of related events together. An example might be Acquisition and Loss of Signal (AOS and LOS) for the same contact period between a spacecraft and ground station. There is no sub-typing of event definitions and event instances to differentiate single events and event groups; an event group is simply an event that has an associated set of child event definitions.

EventDefinition

An EventDefinition is an MO object that contains static configuration data relating to multiple occurrences of a planning event. Its identity is defined by a definitionID, which includes a constant key and an evolving version, which is updated each time the definition is revised. Event definitions form part of the planning configuration data.

Events may be either Predicted or Potential. Events that are predictable either by time or position can have specific instances included in a Plan . Potential events are those that may occur during the execution of a Plan , but the specific time or position is not predicted.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **EventDefinition** | **Extends** | MAL::Object | **SFP** | 201 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| identity | MAL::ObjectIdentity | No | Identity of the EventDefinition, including version. |
| description | MAL::String | No | Description of the event. |
| predictability | PredictabilityEnum | No | Enumeration: one of {Predicted, Potential} indicating whether the event occurrence is known in advance or can occur at any time. |
| eventType | MAL::String | Yes | Enables a planning system to customise behavior for events, such as their presentation in displays, based on the specified value. |
| argDefs | List <ArgDef> | Yes | List of argument definitions. |
| eventDefinitions | List <MAL::ObjectRef <EventDefinition>> | Yes | List of child event definitions. For a single event, this list shall be empty; for a group event, the list shall be populated. |

EventInstance

An EventInstance is an MO object that contains the identity of a specific occurrence of a planning event, together with both static and dynamic information associated with that occurrence. It supports relationships to its definition and source.

The source of an EventInstance may be an external event, corresponding to a NAV Predicted Event or a CSS Contact Event.

EventInstances may be contained within a Plan.

EventInstances may be referenced as a related event by an ActivityInstance, so that the ActivityInstance can reference the timing and arguments of the related EventInstance.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **EventInstance** | **Extends** | MAL::Object | **SFP** | 202 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| identity | MAL::ObjectIdentity | No | Identity of the EventInstance |
| definition | MAL::ObjectRef <EventDefinition> | No | Reference to the EventDefinition |
| sourceEvent | MAL::Identifier | Yes | Reference to an external source event (e.g. NAV predicted event, or CSS contact event) |
| events | List <MAL::ObjectRef <EventInstance>> | Yes | List of references to child EventInstances. For a single event, this list is empty; for a group event, the list will be populated. |
| eventTime | MAL::FineTime | Yes | Predicted or actual time of the event. EventTime is nullable: it can be predicted without an eventTime (e.g. if position based) |
| arguments | List <Argument> | Yes | Argument values for each argument defined in the EventDefinition. |
| eventStatus | EventStatusEnum | No | Current status of the event instance (see event state model in §3.2.3.2) |
| statusInfo | MAL::String | Yes | StatusInfo provides the reason for entering the terminated state and is customisable, but if the following conditions exist then the specified text shall be used:  - Occurred (Event has been triggered)  - Did Not Occur (Event expired or did not occur within validity period)  - Deleted (Event was deleted) |

PredictabilityEnum

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **PredictabilityEnum** | **SFP** | 203 |

| Enumeration | Value | Description |
| --- | --- | --- |
| PREDICTED | 1 | Events that are predictable either by time or position can have specific instances included in a Plan . |
| POTENTIAL | 2 | Potential events are those that may occur during the execution of a Plan , but the specific time or position is not predicted. |

#### Event State Model



Figure 3‑7: Event State Model

The blue boundary frames indicate which of planning or plan execution functions is responsible for asserting these states. State transitions that occur as a result of an MPS service operation are marked with an \*, other transitions occur automatically as a result of planning or plan execution processes.

EventStatusEnum

The following states are defined for **EventStatus**:

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **EventStatusEnum** | **SFP** | 204 |

| Status | Value | Description |
| --- | --- | --- |
| GROUP | 1 | The EventInstance is a group event |
| PLANNED | 2 | The EventInstance has been included in the Plan |
| ACTIVATED | 3 | The Plan including the EventInstance has been Activated within the plan execution function. |
| TERMINATED | 4 | The EventInstance has reached a terminal status (further information is provided in statusInfo) |

When an EventInstance is created within the context of a Plan by the planning function, it has the initial status of Planned if it is a single event, or Group if it is an event group.

Plans may be submitted to a plan execution function, but before they will execute they must be activated. Once a Plan has been activated, all contained events that are single events will also become Activated.

The status of the event is set to Terminated once it has occurred, or it will no longer occur. StatusInfo provides the reason for termination and is customisable. If the following termination conditions exist, then the following statusInfo text shall be used:

* Occurred (Event has been triggered)
* Did Not Occur (Event expired or did not occur within validity period)
* Deleted (Event was deleted)

#### Event Service Structures



Figure 3‑8: Event Service Structures

This section defines data structures specific to planning events that are used in the context of MPS service operations and their associated messages.

EventUpdate

EventUpdate is a data structure that is used to report the dynamic status of an EventInstance in the context of the MPS Plan Execution Control service monitorPlanExecutionDetail operation.

EventUpdates may be distributed to subscribing applications, including status displays, to inform them of the latest status of the event. This may be particularly relevant in conjunction with a plan execution function. EventUpdates may be stored in event history to provide a complete record of evolving status over time.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **EventUpdate** | **Extends** | *PlanDetailUpdate* | **SFP** | 205 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| eventInstance | MAL::ObjectRef <EventInstance> | No | Reference to the EventInstance to which the status update relates. |
| timestamp | MAL::Time | No | Time of status update. |
| eventTime | MAL::FineTime | No | Predicted or actual time of the event. EventTime is nullable: it can be predicted without an EventTime (e.g. if position based) |
| arguments | List <Argument> | Yes | Argument values. |
| eventStatus | EventStatusEnum | No | Current status of the EventInstance. |
| statusInfo | MAL::String | Yes | StatusInfo provides the reason for entering the Terminated state and is customisable, but if the following conditions exist then the specified text shall be used::  - Occurred (Event has been triggered)  - Did Not Occur (Event expired or did not occur within validity period)  - Deleted (Event was deleted) |

InsertedEventDetails

A data structure that provides the information required to create the EventInstance to be inserted into a Plan using the MPS Plan Edit service.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **InsertedEventDetails** | **Extends** | MAL::Composite | **SFP** | 206 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| plan | MAL::ObjectRef <Plan> | No | Reference to the Plan into which the Event is to be inserted. |
| eventDefinition | MAL::ObjectRef <EventDefinition> | No | Reference to the EventDefinition |
| eventTime | MAL::FineTime | No | Specifies the predicted or actual time of the event. For an inserted event this must be present. |
| arguments | List <Argument> | Yes | Argument values. |

### Planning Resources [Optional]

Planning resources are an optional element of the MPS information model. Support for planning resources is not a requirement for compliance of an MPS system with the MPS service interfaces.

#### Resource Objects



Figure 3‑9: Planning Resources

Planning resources follow the MO State object pattern, comprising a single class of MO object. The resource definitions form part of the planning configuration data for a mission planning system, but the same object identity is used to reference the value of the resource in a mission planning system.

Planning resources can be of any MAL Attribute data type. The value of the resource does not inherently require sub-types, as all data types can be represented by an attribute of type MAL::Attribute.

It is a requirement that the key field of the identity of resources is unique across all sub-data types of resource.

The attributes required to support data validation are type-specific, and to support this an optional validationData field has the abstract MPS data type *ValidationDetails,* whichis also used to support data validation of Arguments (see 3.3.5). Three concrete types are defined there to support:

* NumericRange: applicable for any numeric data type where a min-max range is defined for the resource (including Durations).
* StringPattern: applicable for resources of type String.
* StatusValues: applicable for enumerated status resources (of type Integer, but with interpreted status text strings).

An additional concrete type is defined here, specifically to support the definition of Resources:

* NumericProfile: applicable for any numeric data type where the min-max change varies over time.

The “x-axis” of a resource is always time: in other words it records the evolution of the value of the resource over time, and not other dimensions (such as position).

Resource

A resource is an MO object that contains both the static attributes that define a planning resource and a dynamic attribute that holds its current value. Its identity is defined by a constant key and evolving version, which is updated each time the definition is revised. Resource definitions form part of the planning configuration data and in practice the value attribute may be omitted in this context, although it may also be used to provide an initial or default value.

Depending on the resource data type, the resource definition may require additional type specific attributes to support data validation. Sub-types are defined for Numeric, String and enumerated Status type resources. The base Resource MO object type can be used where no data validation is applicable. The following attributes are applicable to the base type and all sub-types.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **Resource** | **Extends** | MAL::Object | **SFP** | 301 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| identity | MAL::ObjectIdentity | No | Identity of the Resource, including version of the Resource definition. |
| description | MAL::String | No | Description of the Resource. |
| dataType | MAL::AttributeType | No | Specifies the data type of the Resource, which must be a supported MAL Attribute type. |
| units | MAL::String | Yes | Optional. Specifies the units the value of the Resource is expressed in, as defined in reference [B6] annex D. |
| validationData | ValidationDetails | Yes | Optional. Specifies the allowed range of values for the Resource, with concrete subtypes specific to the data type of the Resource. |
| value | MAL::Attribute | Yes | Value of the resource. MAL Attribute type must match the dataType of the Resource definition.  The value is only nullable in the context of a Resource definition (planning configuration data). |

NumericProfile

An additional concrete sub-type of ValidationDetails applicable only to Resources of any numeric type, including Duration, that provides additional attributes for the specification of numeric data validation.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **NumericResource** | **Extends** | *ValidationDetails* | **SFP** | 302 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| minimum | ResourceProfile | No | Defines the permitted minimum value over time. |
| maximum | ResourceProfile | No | Defines the permitted maximum value over time. |

#### Resource Profiles



Figure 3‑10: Resource Profiles

Resource profiles provide the evolution of a value over time as a set of points.

They are used in both resource definitions where they can represent time-variant minimum and maximum values for the Resource; and in plans where they represent the predicted evolution of a Resource value over the duration of the Plan.

The profile comprises a series of profile segments, each of which identifies the time range covered, the interpolation method to be used between points, whether the start and end time are included in the segment, and a set of profile entries, each of which corresponds to a time-value pair.

The values in the profile entries are represented as MAL Attributes, the data type of which must match the defined dataType in the corresponding Resource definition.

It is noted that interpolation methods are only relevant for resources of Numeric type.

Resource profiles use absolute timestamps, but the derived relative resource profile uses relative timestamps of type Duration (indicating an offset from a reference time, such as the start time of an activity). Relative resource profiles are used in the context of a complex resource constraint.

ResourceProfile

A ResourceProfile provides the evolution of a value for a single planning resource over time as a set of ProfileSegments.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ResourceProfile** | **Extends** | MAL::Composite | **SFP** | 303 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| resource | MAL::ObjectRef <Resource> | No | Object Type: *Resource*  Reference to a Resource |
| profileSegments | List <ProfileSegment> | No | Set of Profile Segments |

ProfileSegment

A ProfileSegment defines the time range and interpolation method for a set of ProfileEntries.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ProfileSegment** | **Extends** | MAL::Composite | **SFP** | 304 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| interpolation | InterpolationTypeEnum | No | Interpolation method to be applied for values lying between points defined in the profile segment.  Default = Step. |
| start | Expression <MAL::Time> | No | Start of time range covered by the profile segment. |
| end | Expression <MAL::Time> | No | End of time range covered by the profile segment |
| startIncluded | MAL::Boolean | No | Indicates whether the start time is included in the profile segment.  Default = True. |
| endIncluded | MAL::Boolean | No | Indicates whether the end time is included in the profile segment. This allows the same time to be used as the end of one segment and the start of another.  Default = False. |
| profileEntries | List <ProfileEntry> | No | Set of profile entries (resource value points). |

InterpolationTypeEnum

The following InterpolationTypes are defined:

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **InterpolationTypeEnum** | **SFP** | 305 |

| Enumeration | Value | Description |
| --- | --- | --- |
| STEP | 1 | No interpolation: resource values remain unchanged between defined points. |
| LINEAR | 2 | Linear interpolation: resource values follow a straight line between defined points. |
| POLYNOMIAL | 3 | Polynomial interpolation: resource values follow a curve fitting the defined points. |

ProfileEntry

Defines the value [or minimum/maximum value] of a resource at a particular point in time.

The data type of the value can be any valid MAL Attribute type, but must match the defined dataType in the corresponding Resource definition.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ProfileEntry** | **Extends** | MAL::Composite | **SFP** | 306 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| time | Expression <MAL::Time> | No | Time of resource data point |
| value | MAL::Attribute | No | Value of resource data point |

RelativeResourceProfile

A variation on ResourceProfile, the RelativeResourceProfile uses relative timestamps of type Duration (indicating an offset from a reference time, such as the start time of an Activity). RelativeResourceProfiles are used in the context of a complex resource constraint.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **RelativeResourceProfile** | **Extends** | MAL::Composite | **SFP** | 307 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| resource | MAL::ObjectRef <Resource> | No | Object Type: *Resource*  Reference to a Resource |
| profileSegments | List <RelativeProfileSegment> | No | Set of RelativeProfileSegments |

RelativeProfileSegment

A RelativeResourceSegment defines the time range and interpolation method for a set of RelativeProfileEntries.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **RelativeProfileSegment** | **Extends** | MAL::Composite | **SFP** | 308 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| interpolation | InterpolationTypeEnum | No | Interpolation method to be applied for values lying between points defined in the relative profile segment.  Default = Step. |
| start | Expression <MAL::Duration> | No | Relative start of time range covered by the relative profile segment. |
| end | Expression <MAL::Duration> | No | Relative end of time range covered by the relative profile segment |
| startIncluded | MAL::Boolean | No | Indicates whether the start time is included in the relative profile segment.  Default = True. |
| endIncluded | MAL::Boolean | No | Indicates whether the end time is included in the relative profile segment. This allows the same time to be used as the end of one segment and the start of another.  Default = False. |
| profileEntries | List <RelativeProfileEntry> | No | Set of relative profile entries (resource value points). |

RelativeProfileEntry

Defines the value [or minimum/maximum value] of a resource at a relative point in time.

Specific sub-types exist for each allowed data type for a Resource. These replace the variant type value attribute with one of concrete data type.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **RelativeProfileEntry** | **Extends** | MAL::Composite | **SFP** | 309 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| time | Expression <MAL::Duration> | No | Relative time of resource data point |
| value | MAL::Attribute | No | Value of resource data point |

#### Resource Service Structures



Figure 3‑11: Resource Service Structures

This section defines data structures specific to planning resources that are used in the context of MPS service operations and their associated messages.

ResourceUpdate

ResourceUpdate is a data structure that is used to report the value of a Resource at a given point in time in the context of the MPS Plan Execution Control service monitorPlanExecutionDetail operation, or to supply an updated value for a Resource in the context of the MPS Plan Edit service.

Resource updates may be distributed to subscribing applications, including status displays, to inform them of the latest value of the Resource. This may be particularly relevant in conjunction with a plan execution function. Resource updates may be stored in resource history to provide a complete record of evolving value over time.

Resource updates are also effectively contained within a Plan to describe the predicted evolution of Resources over the duration of that Plan. However, in this context the ResourceProfile construct is used (see 3.2.4.2 above).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ResourceUpdate** | **Extends** | *PlanDetailUpdate* | **SFP** | 310 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| resource | MAL::ObjectRef <Resource> | No | Object Type: *Resource*  Reference to the Resource to which the value update relates. |
| timestamp | MAL::Time | No | Time of Resource value update. |
| value | MAL::Attribute | No | Value of the resource. MAL Attribute type must match the dataType of the resource definition. |

### Planning Requests

#### Planning Request Objects



Figure 3‑12: Planning Requests

Planning requests follow the MO dynamic item object pattern, comprising definition and instance classes of MO object, although in this case planning request instances can be created without reference to a planning request definition.

Request definitions provide a re-usable template for common planning requests from which specific request instances can be created and form part of the planning configuration data for a mission planning system. They include the details of a planning request that are generic to multiple invocations of the request, including the set of planning activities to be requested and any planning constraints specific to the request. Arguments may be specified to parameterise the planning request and referred to within the requested planning activities or specified constraints. They differ from activity and event definitions in two regards:

* RequestInstances can be created without reference to any RequestDefinition.
* Any aspect of a RequestInstance created from a RequestDefinition can be modified, including the set of requested planning activities and the constraints applicable. Once created a RequestInstance is independent from any initial RequestDefinition, although a reference is retained.

Request instances specify the details of a planning request, including the set of planning activities being requested and any planning constraints specific to the request. Arguments may be specified to parameterise the planning request and referred to within the requested planning activities or specified constraints.

The identity of the request instance is assigned by the planning function and returned to the requester as part of the MPS Planning Request service SubmitRequest operation. A user supplied reference may also be included in the body of the request. Where a planning request is updated by the user and resubmitted to a planning function, a new version of the RequestInstance is created, but retains the same key.

Planning requests may also reference or include an existing plan as the body of the request. In this case the referenced Plan corresponds to the output of one planning process, but is being requested as the input to another.

RequestDefinition

A RequestDefinition is an MO object that contains the specification of a re-usable planning request template.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **RequestDefinition** | **Extends** | MAL::Object | **SFP** | 401 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| identity | MAL::ObjectIdentity | No | Identity of the RequestDefinition, including version. |
| description | MAL::String | No | Description of the re-usable RequestDefinition. |
| argDefs | List <ArgDef> | Yes | List of argument definitions. Arguments may be referenced in ActivityDetails and constraints. |
| standingOrder | MAL::Boolean | No | A flag that indicates whether the planning request is for a repetitive standing order (unbounded other than by the validity period), or is a one-off request. If it is a standing order, then the ActivityNode must include specification of the repetition criteria. Note that a one-off request can still include repetition. |
| constraints | ConstraintNode | Yes | Set of Constraints applicable to the whole planning request. Note that constraints specific to a planning activity can be specified within the ActivityDetails for that activity within the ActivityNode. |
| activities | ActivityNode | No | Set of activity details specifying requested activities, optionally with repetition. |

RequestInstance

A RequestInstance is an MO object that contains the specification of a planning request. This may change over time if the request is updated by the user, each comprising a separate version of the request with the same object key.

In the context of a hierarchical or federated planning system, a RequestInstance can be used to submit a Plan (§3.2.6.1) to a planning function, either embedding the Plan in the RequestInstance or passing it by reference. If passed by reference, the Plan must be passed separately from the request. Patch plans are not permitted in this context.

Note: RequestInstances may be created from a RequestDefinition that has defined arguments (as ArgDefs) and will in this case have the associated Arguments. An ad-hoc RequestInstance is not anticipated to hold any Arguments. The values that can be parameterized through the arguments of a re-usable RequestDefinition can be directly entered in a RequestInstance, and there would be no corresponding ArgDef associated with any Arguments supplied.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **RequestInstance** | **Extends** | MAL::Object | **SFP** | 402 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| identity | MAL::ObjectIdentity | No | Identity of the RequestInstance, including version. |
| userReference | MAL::Identifier | Yes | Optional user supplied reference for the planning request. This is distinct from the instancetID of the RequestInstance that is assigned by the planning function. |
| creationDate | MAL::Time | No | Creation date-time of the RequestInstance version. |
| definition | MAL::ObjectRef <RequestDefinition> | Yes | Reference to the RequestDefinition from which the RequestInstance was created, if a planning request template was used. |
| planningPeriod | MAL::Identifier | No | Specifies which planning period the planning request applies to. Planning period IDs are mission specific, but can be used to indicate mission phase; planning cycle; or “semester” in observatory missions. |
| validityTimes | List <TimeWindow> | Yes | Validity period for the planning request, expressed as one or more time windows. The planning request must be satisfied within this period.  Only one of validityTime or validityEvent should be present in a planning request. |
| validityEvents | List <EventWindow> | Yes | Validity period for the planning request, expressed as one or more event windows. The planning request must be satisfied within this period.  Only one of validityTime or validityEvent should be present in a planning request. |
| timeSystem | MAL::String | Yes | Specifies the time system used for all time attributes within the planning request (see 3.1.4).  If null, the default time system is used (see 3.2.8). |
| user | MAL::ObjectRef <PlanningUser> | No | The User ID for the person or organisation raising the planning request. |
| description | MAL::String | No | Description of the request. |
| arguments | List <Argument> | Yes | List of named argument values. If created from a template planning request , this will include the arguments defined in the RequestDefinition. |
| standingOrder | MAL::Boolean | No | A flag that indicates whether the planning request is for a repetitive standing order (unbounded other than by the validity period), or is a one-off request. If it is a standing order, then the ActivityNode must include specification of the repetition criteria. Note that a one-off request can still include repetition. |
| constraints | ConstraintNode | Yes | Set of Constraints applicable to the whole planning request. Note that constraints specific to a planning activity can be specified within the ActivityDetails for that activity within the ActivityNode. |
| activities | ActivityNode | No | Set of activity details specifying requested activities, optionally with repetition. |
| inputPlanRef | MAL::ObjectRef <Plan> | Yes | Reference to an existing Plan (output of one planning function) submitted as a planning request to another planning function in the context of a distributed or hierarchical planning system.  Only one of inputPlanRef and inputPlan should be present within the planning request. |
| inputPlan | Plan | Yes | An existing Plan (output of one planning function) submitted as a planning request to another planning function in the context of a distributed or hierarchical planning system. The Plan is embedded within the planning request.  Only one of inputPlanRef and inputPlan should be present within the planning request. |
| comments | MAL::String | Yes | Free text for any additional user comments about the request. |
| status | RequestStatusEnum | No | Current status of the ActivityInstance (see planning request state model in §3.2.5.2) |
| outputPlanRef | List<MAL::ObjectRef<Plan>> | Yes | Reference to the output Plan(s) that contains the activities resulting from the planning request. Where multiple alternate plans have been generated, these may be listed here. |
| returnData | List<MAL::NamedValue> | Yes | Optional return data from the planning process, provided as a list of ID-Value pairs. This can be used to provide additional information required by the User to interpret the planned operations. |
| statusInfo | MAL::String | Yes | StatusInfo provides the reason for termination and is customisable, but if the following conditions exist then the specified text shall be used:  - Completed (all constituent activities completed successfully)  - Expired (constituent activities expired prior to execution)  - Failed (constituent activities failed during execution)  - Deleted (constituent activities were deleted)  - Partially Completed  It may also be used to provide the reason for rejection. |
| errorCode | MAL::Integer | Yes | Error Code optional in the case of a failure status for the planning request (for example Terminated state with statusInfo Failed). The codes are implementation specific. |
| errorInfo | MAL::String | Yes | Supplementary error information |

#### Planning Request State Model



Figure 3‑13: Planning Request State Model

All states are asserted by the planning function. The blue boundary frame indicates those states and transitions which require status feedback from the plan execution function.

RequestStatusEnum

The following states are defined for **RequestStatus**:

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **RequestStatusEnum** | **SFP** | 403 |

| Status | Value | Description |
| --- | --- | --- |
| REQUESTED | 1 | The planning request has been submitted to the planning function |
| ACCEPTED | 2 | The planning request has been accepted by the planning function |
| REJECTED | 3 | The planning request has been rejected by the planning function |
| CANCELLED | 4 | The planning request has been cancelled by the user |
| PLANNED | 5 | The planning request has been incorporated into a Plan (see outputPlanRef) |
| PROCESSING | 6 | The corresponding Plan has been activated within plan execution |
| PROCESSED | 7 | Execution of the all constituent activities of the planning request have terminated. Awaiting confirmation of the status of the planning request. |
| TERMINATED | 8 | The planning request has completed, either successfully or with a failure condition (further information is provided in statusInfo) |

When a planning request is first received by a planning function from a user (via an MPS Planning Request Service SubmitRequest operation) the RequestInstance is created with an initial state of Requested. The planning function may then accept or reject the request, setting its status to Accepted or Rejected accordingly.

Once the planning function has included the planning activities associated with the request in a Plan, the RequestInstance status is set to Planned.

An UpdateRequest service operation may be used to modify a planning request in the Accepted, Rejected or Planned state, in which case the RequestInstance version is updated and its status reverts to Requested.

A CancelRequest service operation may be used to cancel a planning request in the Accepted, Rejected or Planned state, in which case the RequestInstance status is set to Cancelled.

Once a Plan containing the requested planning activities has been submitted to a plan execution function, further status updates are dependent on feedback received by the planning function from plan execution. It is implementation dependent at what point the RequestInstance status is updated, but the following execution stages are defined:

* Processing once the containing Plan has been activated
* Processed once all constituent ActivityInstances have been terminated

It is dependent on the implementation of the planning function, and its defined planning rules, what happens once the Plan Execution function reports that all ActivityInstances have terminated and the status is set to Processed. The Processed state allows further assessment of whether the planning request has been satisfied, either automatically by the planning function or via user feedback.

The planning function may set the status of the RequestInstance directly to Terminated (in which case no further handling of the RequestInstance is possible.

Alternatively, an MPS system may support re-planning of failed (or incomplete) activities without requiring a new planning request. To support this, the transition of the RequestInstance from Processed to Accepted is permitted through one of the following mechanisms:

1. Through the application of an automated planning rule by the planning function
2. Through coordination with the User via a project-specific interface with the decision applied by the planning function
3. Applied directly by the User through an Update operation

StatusInfo provides more detailed information on reason for termination of the planning request and is customisable. If the following termination conditions exist, then the following statusInfo text shall be used:

* Completed (all constituent activities completed successfully)
* Expired (constituent activities expired prior to execution)
* Failed (constituent activities failed during execution)
* Deleted (constituent activities were deleted)
* Partially Complete

Similarly statusInfo may be used to report the reason for rejection of the planning request and is customizable, but includes:

* Budget (user has insufficient credit for requested operation)
* Policy (request does not meet current policy requirements)
* Resource (insufficient resources available to satisfy specified constraints)
* Expired (accepted request could not be planned within specified time constraints)

#### Planning Request Service Structures



Figure 3‑14: Planning Request Service Structures

RequestStatusUpdate

RequestStatusUpdate is a data structure that is used to report changes in status of the RequestInstance as it proceeds through both planning and plan execution functions. Reporting is the responsibility of the planning function.

Planning request status updates may be distributed to subscribing applications, including both Users and status displays, to inform them of the latest status of the planning request. This may be particularly relevant in conjunction with a plan execution function. Status updates may be stored in planning request history to provide a complete record of evolving status over time.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **RequestStatusUpdate** | **Extends** | MAL::Composite | **SFP** | 404 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| requestInstance | MAL::ObjectRef <RequestInstance> | No | Reference to the planning request instance to which the status update relates. |
| timestamp | MAL::Time | No | Time of status update. |
| status | RequestStatusEnum | No | Current status of the planning request. |
| outputPlanRef | MAL::ObjectRef <Plan> | Yes | Reference to the Plan that contains the planned activities resulting from the planning request. Note that this is only available once the planning request has been processed and successfully planned. The outputPlanRef may be updated following iterative planning cycles or re-planning. |
| returnData | List<MAL::NamedValue> | Yes | Optional return data from the planning process, provided as a list of ID-Value pairs. This can be used to provide additional information required by the User to interpret the planned operations. |
| statusInfo | MAL::String | Yes | StatusInfo provides the reason for termination and is customisable, but if the following conditions exist then the specified text shall be used:  - Completed (all constituent activities completed successfully)  - Expired (constituent activities expired prior to execution)  - Failed (constituent activities failed during execution)  - Deleted (constituent activities were deleted)  - PartiallyCompleted  It may also be used to provide the reason for rejection. |
| errorCode | MAL::Integer | Yes | Error Code optional in the case of a failure status for the planning request (for example Terminated state with statusInfo Failed). The codes are implementation specific. |
| errorInfo | MAL::String | Yes | Supplementary error information. |

PlanningRequestDetails

PlanningRequestDetails is a data structure used in the context of the MPS Planning Request service SubmitRequest and UpdateRequest operations, where the RequestInstance MO object cannot be used as the full identity of the resulting RequestInstance (key and version) is not yet known.

Its structure is equivalent to that of RequestInstance, but omitting the identity attributes and dynamic attributes used to report its status.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlanningRequestDetails** | **Extends** | MAL::Composite | **SFP** | 405 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| userReference | MAL::Identifier | No | User supplied reference for the planning request. This is distinct from the instancetID of the RequestInstance that is assigned by the planning function. |
| definition | MAL::ObjectRef <RequestDefinition> | Yes | Reference to the RequestDefinition from which the RequestInstance was created, if a planning request template was used. |
| planningPeriod | MAL::Identifier | No | Specifies which planning period the planning request applies to. Planning period IDs are mission specific, but can be used to indicate mission phase; planning cycle; or “semester” in observatory missions. |
| validityTimes | List <TimeWindow> | Yes | Validity period for the planning request, expressed as one or more time windows. The planning request must be satisfied within this period.  Only one of validityTime or validityEvent should be present in a planning request. |
| validityEvents | List <EventWindow> | Yes | Validity period for the planning request, expressed as one or more event windows. The planning request must be satisfied within this period.  Only one of validityTime or validityEvent should be present in a planning request. |
| timeSystem | MAL::String | Yes | Specifies the time system used for all time attributes within the planning request (see 3.1.4).  If null, the default time system for is used (see 3.2.8). |
| user | MAL::ObjectRef <PlanningUser> | No | The User ID for the person or organisation raising the planning request. |
| description | MAL::String | No | Description of the request. |
| arguments | List <Argument> | Yes | List of named argument values. If created from a template planning request , this will include the arguments defined in the RequestDefinition. |
| standingOrder | MAL::Boolean | No | A flag that indicates whether the planning request is for a repetitive standing order (unbounded other than by the validity period), or is a one-off request. If it is a standing order, then the ActivityNode must include specification of the repetition criteria. Note that a one-off request can still include repetition. |
| constraints | ConstraintNode | Yes | Set of Constraints applicable to the whole planning request. Note that constraints specific to a planning activity can be specified within the ActivityDetails for that activity within the ActivityNode. |
| activities | ActivityNode | No | Set of activity details specifying requested activities, optionally with repetition. |
| inputPlanRef | MAL::ObjectRef <Plan> | Yes | Reference to an existing Plan (output of one planning function) submitted as a planning request to another planning function in the context of a distributed or hierarchical planning system.  Only one of inputPlanRef and inputPlan should be present within the planning request. |
| inputPlan | Plan | Yes | An existing Plan (output of one planning function) submitted as a planning request to another planning function in the context of a distributed or hierarchical planning system. The Plan is embedded within the planning request.  Only one of inputPlanRef and inputPlan should be present within the planning request. |
| comments | MAL::String | Yes | Free text for any additional user comments about the request. |

PlanningRequestResponse

PlanningRequestResponse is a data structure used in the context of the MPS Planning Request service SubmitRequest and UpdateRequest operations, in response to the submitted PlanningRequestDetails defined above. It contains a reference to the created RequestInstance and the supplied userReference to allow the user to correlate the two.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlanningRequestResponse** | **Extends** | MAL::Composite | **SFP** | 406 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| instance | MAL::ObjectRef <RequestInstance> | No | Reference to the RequestInstance created in response to a SubmitRequest operation, or the updated version of the RequestInstance following an UpdateRequest operation. |
| userReference | MAL::Identifier | No | User supplied reference for the planning request. This is distinct from the instanceID of the RequestInstance that is assigned by the planning function. |

RequestSummaryStatus

RequestSummaryStatus is a data structure used in the context of the MPS Planning Request service getRequestSummaries operation, where a list of these structures is returned. It contains header fields of the planning request and its status, but not the request content (arguments, activities and constraints).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **RequestSummaryStatus** | **Extends** | MAL::Composite | **SFP** | 407 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| requestInstance | MAL::ObjectRef <RequestInstance> | No | Reference to the RequestInstance (key and version). |
| userReference | MAL::Identifier | Yes | Optional user supplied reference for the planning request. This is distinct from the instancetID of the RequestInstance that is assigned by the planning function. |
| creationDate | MAL::Time | No | Creation date-time of the RequestInstance version. |
| definition | MAL::ObjectRef <RequestDefinition> | Yes | Reference to the RequestDefinition from which the RequestInstance was created, if a planning request template was used. |
| planningPeriod | MAL::Identifier | No | Specifies which planning period the planning request applies to. Planning period IDs are mission specific, but can be used to indicate mission phase; planning cycle; or “semester” in observatory missions. |
| validityTime | List <TimeWindow> | Yes | Validity period for the planning request, expressed as one or more time windows. The planning request must be satisfied within this period.  Only one of validityTime or validityEvent should be present in a planning request. |
| validityEvent | List <EventWindow> | Yes | Validity period for the planning request, expressed as one or more event windows. The planning request must be satisfied within this period.  Only one of validityTime or validityEvent should be present in a planning request. |
| user | MAL::ObjectRef <PlanningUser> | No | The User ID for the person or organisation raising the planning request. |
| description | MAL::String | No | Description of the request. |
| standingOrder | MAL::Boolean | No | A flag that indicates whether the planning request is for a repetitive standing order (unbounded other than by the validity period), or is a one-off request. If it is a standing order, then the ActivityNode must include specification of the repetition criteria. Note that a one-off request can still include repetition. |
| comments | MAL::String | Yes | Free text for any additional user comments about the request. |
| status | RequestStatusEnum | No | Current status of the ActivityInstance (see planning request state model in §3.2.5.2) |
| outputPlanRef | List <MAL::ObjectRef <Plan>> | Yes | References to output Plans that contains the activities resulting from the planning request. |
| statusInfo | MAL::String | Yes | StatusInfo provides the reason for termination and is customisable, but includes:  - Completed (all constituent activities completed successfully)  - Expired (constituent activities expired prior to execution)  - Failed (constituent activities failed during execution)  - Deleted (constituent activities were deleted)  - PartiallyCompleted  It may also be used to provide the reason for rejection. |

RequestFilter

RequestFilter is a data structure used in the context of MPS Planning Request Service operations to specify a filtered set of planning requests. All filter criteria specified are applied (logical AND, not OR).

Note: all attributes are nullable and it is valid to specify a RequestFilter with no filter criteria – this corresponds to an open filter in which all available planning requests are returned.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **RequestFilter** | **Extends** | MAL::Composite | **SFP** | 408 |

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute | Type | Nullable | Description |
| domain | List<MAL::Identifier> | Yes | Domain of the RequestInstance. An ordered list representing a domain hierarchy, “\*” can be used to represent a wildcard at that level. |
| instanceID | MAL::ObjectRef <RequestInstance> | Yes | Identity (key and version) of the RequestInstance |
| creationDate | MAL::Time | Yes | Creation date-time of the RequestInstance version. |
| definitionID | MAL::ObjectRef <RequestDefinition> | Yes | Identity (key and version) of the RequestDefinition from which the RequestInstance was created. |
| userID | MAL::ObjectRef <PlanningUser> | Yes | userID of the User who initiated the RequestInstance |
| userReference | MAL::Identifier | Yes | Reference supplied by User when submitting the RequestInstance. |
| status | RequestStatusEnum | Yes | Current status (enum) of the RequestInstance |
| outputPlanRef | MAL::ObjectRef <Plan> | Yes | Reference to the output Plan generated in response to the RequestInstance |

### Plans

#### Plan Object



Figure 3‑15: Plans

Plans follow the MO state object pattern, comprising a single class of MO object. Plans are dynamically created and do not form part of the planning configuration data. They specify the details of a generated Plan that is the output of a planning function. Plans are versioned: the same planID can be used for successive iterations of a Plan, each differentiated by the version of the Plan.

The major part of a Plan is a static data structure that effectively comprises general header information followed by four sections, as shown in Figure 3‑16 below:

* Plan Information
* Planned Items (contains planned activities and events)
* Plan Revisions (details changes from a predecessor or precursor plan )
* Plan Resources (contains planning resource profiles)

Each of these sections is represented by its own data structure, defined in the following subsections. Both PlanRevisions and PlanResources are optional elements of the Plan. It is also optional whether planning events are included within the PlannedItems section.

The evolving status of a plan is represented by a set of dynamic attributes that can be updated during the lifetime of a version of a plan.

Plans can represent a full plan (contains all elements of the Plan ) or a patch plan (only contains the delta from a predecessor or precursor plan).

A full plan may have a precursor plan with which it overlaps and specifies changes in the PlanRevisions. If there is no precursor, then it is a self-standing Plan. The specification of PlanRevisions in a full plan allows a plan execution function to merge the successor Plan into an already loaded precursor Plan by applying only the changes identified. Alternatively the already loaded Plan can be discarded and the entire Plan loaded from the full plan.

A patch plan must have a precursor plan to which it is the delta. It contains only the differences between the precursor plan and a target plan. Patch plans cannot be used in the context of a planning request. If the patch plan is a distributed output of a planning function, it must also have the reference to the target Plan. It is only possible for a plan execution function to merge a patch plan into an already loaded precursor Plan by applying the changes identified – it does not include the full specification of the Plan to be loaded from scratch.

Each plan has its own unique planID (specified as a MAL::ObjectIdentity) which is assigned by the planning function that generates it. If it has a predecessor or precursor plan, then this is referenced in the precursorPlan field of the Plan as a MAL::ObjectRef.

In the specific case of a patch plan, the planning function first generates the required new full plan (the target plan) as an evolution from a specified precursor plan. The patch plan is then generated as the delta between the precursor and target plans and is assigned its own planID, distinct from both precursor and target plans. The precursorPlan field of the patch plan contains a reference to the precursor plan, while the targetPlan field of the patch plan contains a reference to the target plan.

When a plan execution function applies a patch plan to an already loaded precursor plan, the target plan is reconstituted and the identity of the resultant plan is that of the target plan, not the patch plan.



Figure 3‑16: Plan Details

The component parts are the same for full and patch plans.

For a patch plan, only PlannedItems that are new or modified with respect to the precursor Plan are included. Unchanged items should not be present, while a full plan will include any unchanged items.

A patch plan must have a PlanRevision, and only one PlanRevision can be present - relative to the precursor Plan. Updated ResourceProfiles may also be included. This is unlikely to be relevant for a patch plan that is a request.

Several plans may share the same precursor, representing alternative options. Plans may be released as Operational or Alternate plans. An Operational plan is the default to be applied, while Alternate plans may be provided to allow for a last-minute operational choice or to handle predicted contingency situations. Whether a Plan is Operational or Alternate can be modified after it has been generated and this status is therefore a dynamic attribute.

Plan

A Plan is an MO object that contains both the static attributes that define a version of a plan and dynamic attributes that hold its current state. Its identity is defined by a constant key and an evolving version, which is updated each time the Plan is revised.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **Plan** | **Extends** | MAL::Object | **SFP** | 501 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| identity | MAL::ObjectIdentity | No | Identity of the Plan, including version. |
| isPatchPlan | MAL::Boolean | No | Flag indicating if the Plan is a patch plan that only contains details of the changes from the precursor Plan. A patch plan must have a precursor. It must also include a single PlanRevision relative to the precursor Plan. |
| precursorPlan | MAL::ObjectRef <Plan> | Yes | Reference to a precursor (or predecessor) Plan from which the changes are detailed in the Plan. This may be used if there is an iterative re-planning cycle in which successive plans overlap, or where a previous Plan has been updated through re-planning. If there is no precursor, then the Plan must be a self-standing full plan.  If the Plan is a Patch Plan, then a precursor plan must be specified. |
| targetPlan | MAL::ObjectRef  <Plan> | Yes | Applicable only for patch plans, this is a reference to the target Plan. This target Plan is the result of applying the patch plan to the precursor Plan and is distinct from the identity of the patch plan itself. Patch plans are not permitted in the context of a planning request. |
| information | PlanInformation | No | Contains header information relating to the Plan, including its originator and validity period. |
| items | PlannedItems | No | Contains the planned activities and events that constitute the Plan . |
| revisions | PlanRevisions | Yes | Details the changes between this Plan and other Plans (or other versions of the same Plan), usually the precursor Plan. Optional, but must be present in a patch plan. |
| resources | PlanResources | Yes | Optional. Contains resource profiles for planning resources covering the period of the Plan . |
| isAlternate | MAL::Boolean | No | Flag indicating if the Plan has currently been released as an Operational or Alternate plan. |
| status | PlanStatusEnum | No | Current status of the Plan. |
| statusInfo | MAL::String | Yes | Supplementary information for a Plan in the Terminated state. This is customisable, but if the following conditions exist then the specified text shall be used:  - Completed (nominal)  - Superseded (by a successor Plan)  - Revoked  - Cancelled (deactivated after start of execution)  - Expired |

##### Plan Information

PlanInformation

The PlanInformation section of a plan contains administrative and validity details associated with the plan as a whole.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlanInformation** | **Extends** | MAL::Composite | **SFP** | 502 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| originator | MAL::Identifier | No | Identity of the entity or system responsible for the production of the plan. |
| productionDate | MAL::Time | No | Date and time of production of the plan. |
| description | MAL::String | No | Description of the plan. |
| comments | MAL::String | Yes | Field for additional comments or notes to the operations team regarding the plan . |
| validityStart | MAL::Time | No | Start of validity period for the plan.  The validity period defines when the plan is available for operational use. It cannot be used outside its validity period. |
| validityEnd | MAL::Time | No | End of validity period for the plan. |
| planPeriodStart | Trigger | No | Start of the plan period.  The plan period defines the start and end points of the plan. Planned items (planning activities and events) contained within the plan must at least partially overlap the plan period. The use of the trigger structure allows this to be specified in terms of time, position, pointing or planning events. Examples are:  - a specified period of time  - an orbital repeat cycle  - a period between two events |
| planPeriodEnd | Trigger | No | End of the plan period. |
| timeSystem | MAL::String | Yes | Specifies the time system used for all time attributes within the Plan (see 3.1.4).  If Null, the default time system is used (see 3.2.8). |

##### Planned Items

The PlannedItems section of the Plan specifies the set of planning activities and planning events contained within the Plan. It comprises two lists of contained MO objects: one of EventInstances and one of ActivityInstances. Both lists can be empty.

If the Plan is a full plan, then there must be an entry in the list for all planned items contained within the plan , whether changed or not. If the plan is a patch plan, then there is only an entry in the list for those planned items that have changed (new or modified).

PlannedItems

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlannedItems** | **Extends** | MAL::Composite | **SFP** | 503 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| plannedEvents | List <EventInstance> | Yes | List of planned events contained within the Plan. |
| plannedActivities | List <ActivityInstance> | Yes | List of planned activities contained within the Plan. |

##### Plan Revisions [Optional]

The optional PlanRevisions section details the changes between this Plan and another Plan. PlanRevisions comprise a collection of PlanRevision structures, each of which details the changes with respect to one version of a Plan (the revised Plan ).

In the typical case, there is only one PlanRevision corresponding to the changes between the Plan and its predecessor (the precursor plan). However, it is possible to include multiple PlanRevision structures documenting the differences with any other version of a Plan. This can be used to provide a change history for successive versions of the same Plan, or to document the differences between alternate Plans.

In the case of a patch plan, the Plan must include a single PlanRevision relative to the precursor Plan.

Each PlanRevision comprises an ordered set of ItemRevisions that document the change to individual planned items (planning events and activities). The order should be from earliest to latest modification within the plan period, to allow for the earliest and most critical changes to be applied first to a currently executing plan. Each ItemRevision references an individual EventInstance or ActivityInstance and indicates whether the planned item is new, modified or deleted in the current Plan. New or modified items must also exist within the PlannedItems section of the Plan, but deleted items are not contained within the current Plan. Note that unmodified items do not appear in the PlanRevision.

PlanRevisions

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlanRevisions** | **Extends** | MAL::Composite | **SFP** | 504 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| planRevisions | List <PlanRevision> | No | Set of PlanRevision structures, each detailing the change with respect to an identified Plan. |

PlanRevision

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlanRevision** | **Extends** | MAL::Composite | **SFP** | 505 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| revisedPlan | MAL::ObjectRef <Plan> | No | Reference to the Plan (key and version) with respect to which the plan revisions are detailed. Typically this is the precursor Plan , but any other Plan can be used. |
| revisionStart | MAL::Time | No | Start time of the earliest revision. |
| revisionEnd | MAL::Time | No | End time of the latest revision. |
| itemRevisions | List <ItemRevision> | Yes | Ordered list (earliest to latest) of revisions to planned items (activity and event instances). |

ItemRevision

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ItemRevision** | **Extends** | MAL::Composite | **SFP** | 506 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| itemRef | MAL::ObjectRef | No | Object Type: ActivityInstance | EventInstance  Reference to a planned ActivityInstance or EventInstance that is new or modified in the current Plan, or has been deleted with respect to the referenced revisedPlan. |
| revisionStatus | RevisionStatusEnum | No | Revision status of the referenced item. May be one of New, Modified or Deleted. Default = Undefined. |

RevisionStatusEnum

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **RevisionStatusEnum** | **SFP** | 507 |

| Status | Value | Description |
| --- | --- | --- |
| NEW | 1 | The item is new in this revision of the Plan. |
| MODIFIED | 2 | The item has been modified in this revision of the Plan. |
| DELETED | 3 | The item has been deleted in this revision of the Plan. |
| UNDEFINED | 4 | The item is unchanged in this revision of the Plan, or its revision status is undefined. |

##### Plan Resources [Optional]

The optional PlanResources section allows the projected values of planning resources to be communicated between distributed planning and plan execution functions as part of a plan.

This is provided as a set of ResourceProfiles (see §3.2.4.2), one per planning resource included. Resource profiles can provide the projected evolution of the value of a planning resource over the period of the Plan. Alternatively it can provide a single value at the start of the Plan to enable synchronisation between planning systems. It is a deployment choice which approach is used.

PlanResources

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlanResources** | **Extends** | MAL::Composite | **SFP** | 508 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| resourceProfiles | List <ResourceProfile> | No | Set of resource profiles, one per planning resource, containing the initial value of the resource and optionally the projected evolution of the resource value over the period of the Plan . |

#### SubPlans and Tags

Two mechanisms are provided to enable service operations to reference and act upon a subset of the Plan: SubPlans and Tags. Both apply to the ActivityInstances (see §3.2.2.1) contained within the Plan.

SubPlans

While Plans divide the timeline of mission operations into successive potentially overlapping periods of time, SubPlans divide it orthogonally grouping operations according to another criteria. The operations grouped by a SubPlan should be internally coherent such that they can be controlled together, and relatively loosely coupled to operations in other SubPlans. The grouping criteria of SubPlans is mission and deployment specific, but could include:

* Domain representing a spacecraft or subsystem;
* The type of operation (payload, attitude & orbit control, etc.);
* The area of operational responsibility;
* A group of related operations in an on-board mission timeline.

SubPlans are pre-defined and represented by an Identifier. ActivityInstances can be associated with one and only one SubPlan. The SubPlan is not specific to a Plan, but applies to all activated Plans. The Plan Execution Control Service allows for co-ordinated control over the execution of all ActivityInstances associated with the SubPlan, through the following operations:

* activateSubPlan
* deactivateSubPlan
* getSubPlanStatus

Whether the SubPlan is initially Activated or Deactivated is implementation specific. ActivityInstances are only initiated if the status of an associated SubPlan is Activated.

Tags

Tags are text strings that can be associated with individual ActivityInstances. Multiple tags can be associated with each ActivityInstance. They do not have to be pre-defined, although detault tags can be associated with an ActivityDefinition.

Tags allow arbitrary groups of ActivityInstances to be referenced and operated on together. Tags may be used as a filter criteria in the context of the following service operations:

* Plan Distribution Service
  + getPartialPlan
* Plan Execution Control Service
  + monitorPlanExecutionDetail
  + suspendActivity
  + resumeActivity
  + getActivityStatus
* Plan Information Management Service
  + listActivityDefs

#### Plan State Model



Figure 3‑17: Plan State Model

The blue boundary frames indicate which of planning or plan execution functions is responsible for asserting these states. State transitions that occur as a result of an MPS service operation are marked with an \*, other transitions occur automatically as a result of planning or plan execution processes.

PlanStatusEnum

The following states are defined for **PlanStatus**:

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **PlanStatusEnum** | **SFP** | 509 |

| Status | Value | Description |
| --- | --- | --- |
| DRAFT | 1 | The Plan has been saved by the planning function |
| RELEASED | 2 | The Plan has been released for operational use by the planning function |
| SUBMITTED | 3 | The Plan has been submitted to the plan execution function and is available for use, but will not execute until activated. |
| ACTIVATED | 4 | The Plan has been activated by the plan execution function |
| TERMINATED | 5 | The Plan has reached a terminal state, as detailed in the statusInfo. This includes the following cases:  - Completed (nominal)  - Superseded by a successor Plan  - Revoked by a User  - Cancelled (deactivated after start of execution)  - Expired (reached the end of its validity period without being activated) |

Draft and Released states are asserted by the planning function with the transition normally being under user control.

Submitted, Activated and Terminated states are asserted by the plan execution function.

A Plan may be submitted to a plan execution function using the MPS Plan Execution Control service submitPlan operation, upon which it enters the Submitted state. The Plan and its contained activities will not execute until the Plan has been activated using the activatePlan operation, when its state becomes Activated. The Plan enters the Terminated state when its execution has been completed, or it has been superseded by the activation of a successor Plan.

A Plan in the Activated state may be deactivated using the deactivatePlan operation, but remains available for re-activation if its start time is still in the future. If a Plan is deactivated after execution has started, then its state becomes Terminated.

A Plan in the Submitted or Activated states may be made permanently unavailable for execution using the RevokePlan operation, in which case it is placed in the Terminated state. A Plan may also move to the Terminated state if it has passed its start time without being activated or its validity period has expired.

#### Plan Service Structures



Figure 3‑18: Plan Service Structures

This section defines data structures specific to Plans that are used in the context of MPS service operations and their associated messages.

PlanUpdate

PlanUpdate is a data structure that is used to report changes in status of the Plan as it proceeds through both planning and plan execution functions. It is returned in the context of the MPS Plan Distribution service GetPlanStatus and MonitorPlanStatus operations, and also the MPS Plan Execution Control service MonitorPlanExecution and GetPlanStatus operations.

PlanUpdates may be distributed to subscribing applications, including status displays, to inform them of the latest status of a Plan. PlanUpdates may be stored in plan history to provide a complete record of evolving status over time.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlanUpdate** | **Extends** | MAL::Composite | **SFP** | 510 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| plan | MAL::ObjectRef <Plan> | No | Reference to the Plan (key and version) to which the status update relates. |
| timestamp | MAL::Time | No | Time of status update. |
| isAlternate | MAL::Boolean | No | Flag indicating if the Plan has currently been released as an Operational or Alternate plan. |
| status | PlanStatusEnum | No | Current status of the Plan. |
| statusInfo | MAL::String | Yes | Supplementary information for a Plan in the Terminated state. This is customisable, but if the following conditions exist then the specified text shall be used:  - Completed (nominal)  - Superseded by a successor Plan  - Revoked by a User  - Cancelled (deactivated after start of execution)  - Expired (reached the end of its validity period without being activated) |

PlanSummaryStatus

PlanSummaryStatus is a data structure that provides an summary view of a Plan that includes the PlanInformation section and current status, but not the full details of the Plan. It is returned in the context of the MPS Plan Distribution service GetPlanSummaries operation.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlanSummaryStatus** | **Extends** | MAL::Composite | **SFP** | 511 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| plan | MAL::ObjectRef <Plan> | No | Reference to the Plan (key and version) to which the summary status relates. |
| isPatchPlan | MAL::Boolean | No | Flag indicating if the Plan is a patch plan that only contains details of the changes from the precursor Plan. A patch plan must have a precursor. It must also include a single PlanRevision relative to the precursor Plan. |
| precursorPlan | MAL::ObjectRef <Plan> | Yes | Reference to a precursor (or predecessor) Plan from which the changes are detailed in the Plan. This may be used if there is an iterative re-planning cycle in which successive plans overlap, or where a previous Plan has been updated through re-planning. If there is no precursor, then the Plan must be a self-standing full plan.  If the Plan is a Patch Plan, then a precursor plan must be specified. |
| targetPlan | MAL::ObjectRef <Plan> | Yes | Applicable only for patch plans, this is a reference to the target Plan. This target Plan is the result of applying the patch plan to the precursor Plan and is distinct from the identity of the patch plan itself. Patch plans are not permitted in the context of a planning request. |
| information | PlanInformation | No | Contains header information relating to the Plan, including its originator and validity period. |
| isAlternate | MAL::Boolean | No | Flag indicating if the Plan has currently been released as an Operational or Alternate plan. |
| status | PlanStatusEnum | No | Current status of the Plan. |
| statusInfo | MAL::String | Yes | Supplementary information for a Plan in the Terminated state. |

PlanActivationStatus

PlanActivationStatus is a data structure that returns the activation status of a Plan in the context of the MPS Plan Execution Control service ActivatePlan and DeactivatePlan operations.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlanActivationStatus** | **Extends** | MAL::Composite | **SFP** | 512 |

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute | Type | Nullable | Description |
| plan | MAL::ObjectRef <Plan> | No | Reference to the Plan (key and version) to which the status relates. |
| status | PlanStatusEnum | No | Current status of the Plan. |
| activationInfo | MAL::String | No | ActivationInfo provides customisable detailed information on the result of the activation/deactivation request for the referenced Plan. |

SubPlanUpdate

SubPlanUpdate is a data structure that is used to report changes in status of a sub-plan during plan execution. It is returned in the context of the MPS Plan Execution Control service MonitorSubPlanExecution and GetSubPlanStatus operations.

Sub-plans are not defined as objects within the MPS model. Individual activities within a Plan may be associated with a single sub-plan via its Identifier. The plan execution function is responsible for managing and reporting sub-plan status associated with relevant Plan Execution Control service operations, if supported.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **SubPlanUpdate** | **Extends** | MAL::Composite | **SFP** | 513 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| subPlan | MAL::Identifier | No | Identifier of the sub-plan to which the update relates. |
| timestamp | MAL::Time | No | Time of status update. |
| status | SubPlanStatusEnum | No | Current status of the sub-plan, which may be Activated or Deactivated.. |

SubPlanStatusEnum

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **SubPlanStatusEnum** | **SFP** | 514 |

| Status | Value | Description |
| --- | --- | --- |
| ACTIVATED | 1 | The sub-plan is active. |
| DEACTIVATED | 2 | The sub-plan is not active. |

SubPlanActivationStatus

SubPlanActivationStatus is a data structure that returns the activation status of a sub-plan in the context of the MPS Plan Execution Control service ActivateSubPlan and DeactivateSubPlan operations.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **SubPlanActivationStatus** | **Extends** | MAL::Composite | **SFP** | 515 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| plan | MAL::Identifier | No | Identifier of the sub-plan to which the status relates. |
| status | SubPlanStatusEnum | No | Current status of the sub-plan, which may be Activated or Deactivated. |
| activationInfo | MAL::String | No | ActivationInfo provides customisable detailed information on the result of the activation/deactivation request for the referenced sub-plan. |

PlanQuery

PlanQuery is a data structure used in the context of queryPlan operation of the MPS Plan Distribution Service. It is used to specify search criteria for querying the available set of Plans. All fields are nullable, in which case they do not apply as a search criteria.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlanQuery** | **Extends** | MAL::Composite | **SFP** | 516 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| planID | MAL::ObjectRef <Plan> | Yes | Query for Plans with the specified PlanID. |
| hasPrecursor | MAL::Boolean | Yes | Query for Plans with or without a precursor. |
| isPatchPlan | MAL::Boolean | Yes | Query for Plans that are or are not patch plans |
| precursorPlan | MAL::ObjectRef <Plan> | Yes | Query for Plans with the specified precursor Plan. |
| targetPlan | MAL::ObjectRef <Plan> | Yes | Applicable only for patch plans. Query for patch plans that have the specified target Plan. |
| originator | MAL::Identifier | Yes | Query for Plans with the specified originator. |
| productionDate | TimeWindow | Yes | Query for Plans with a production date in the specified range. |
| validityPeriod | TimeWindow | Yes | Query for Plans with a validity period within (overlapping with) the specified range. |
| isAlternate | MAL::Boolean | Yes | Query for Plans that are or are not Alternate plans. |
| status | List <PlanStatusEnum> | Yes | Query for Plans that have a current status matching one of the specified list of Plan statuses. |
| containedEvents | List <MAL::ObjectRef <EventDefinition>> | Yes | Query for Plans that contain EventInstances whose definition matches one of the specified list of EventDefinitions. |
| containedActivities | List <MAL::ObjectRef <ActivityDefinition>> | Yes | Query for Plans that contain ActivityInstances whose definition matches one of the specified list of ActivityDefinitions. |

PartialPlan

A PartialPlan is a data structure returned from the getPartialPlan operation of the Plan Distribution Service that contains a reference to the source Plan, the criteria used to select the partial plan, and the partial plan itself. The partial plan uses the same structure as a normal Plan, with header fields matching those of the source Plan, but only containing the subset of ActivityInstances that matches the selection criteria. Whether EventInstances and Resources are included is implementation specific, but it might be assumed that any events and resources related to the selected ActivityInstances would be included in the returned partial plan.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PartialPlan** | **Extends** | MAL::Composite | **SFP** | 517 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| sourcePlan | MAL::ObjectRef <Plan> | No | Reference to the Plan of which the partial plan is a selected subset. |
| domain | List<MAL::Identifier> | Yes | Selection criterion based on the domain of contained ActivityInstances.  An ordered list representing a domain hierarchy, “\*” can be used to represent a wildcard at that level. |
| subPlan | MAL::Identifier | Yes | Selection criterion based on the subPlan of contained ActivityInstances. |
| tags | List <MAL::String> | Yes | Selection criterion based on tags associated with contained ActivityInstances |
| partialPlanStart | Trigger | Yes | Selection criterion indicating the start of a range of time, position or events associated with contained ActivityInstances. |
| partialPlanEnd | Trigger | Yes | Selection criterion indicating the end of a range of time, position or events associated with contained ActivityInstances. |
| partialPlan | Plan | No | The returned partial plan. |

PlanFilter

PlanFilter is a data structure used in the context of MPS Plan Distribution Service operations to specify a filtered set of Plans. All filter criteria specified are applied (logical AND, not OR).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlanFilter** | **Extends** | MAL::Composite | **SFP** | 518 |

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute | Type | Nullable | Description |
| domain | List<MAL::Identifier> | Yes | Domain of the Plan  An ordered list representing a domain hierarchy, “\*” can be used to represent a wildcard at that level. |
| planID | MAL::ObjectRef <Plan> | Yes | Identity (key and version) of the Plan |
| precursorPlan | MAL::ObjectRef <Plan> | Yes | Identity (key and version) of the precursor Plan |
| status | PlanStatusEnum | Yes | Current status (enum) of the Plan |
| originator | MAL::Identifier | Yes | Originator of the Plan |
| validityPeriod | TimeWindow | Yes | Period of time with which the validity period of the Plan overlaps. |

PartialPlanFilter

PartialPlanFilter is a data structure input to the getPartialPlan operation of the Plan Distribution Service that contains a reference to the source Plan, and specifies the criteria used to select the partial plan.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PartialPlanFilter** | **Extends** | MAL::Composite | **SFP** | 519 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| sourcePlan | MAL::ObjectRef <Plan> | No | Reference to the Plan of which the partial plan is a selected subset. |
| domain | List<MAL::Identifier> | Yes | Selection criterion based on the domain of contained ActivityInstances.  An ordered list representing a domain hierarchy, “\*” can be used to represent a wildcard at that level. |
| subPlan | MAL::Identifier | Yes | Selection criterion based on the subPlan of contained ActivityInstances. |
| tags | List <MAL::String> | Yes | Selection criterion based on tags associated with contained ActivityInstances |
| partialPlanStart | Trigger | Yes | Selection criterion indicating the start of a range of time, position or events associated with contained ActivityInstances. |
| partialPlanEnd | Trigger | Yes | Selection criterion indicating the end of a range of time, position or events associated with contained ActivityInstances. |

### Planning Users



Figure 3‑19: Planning Users

PlanningUser

The source of a planning request is the user that raises it, and this is identified in the user field of a RequestInstance as a reference to a PlanningUser object.

The information held on planning users is outside the scope of this standard. The only requirement on the PlanningUser object is that it is formulated as an MO object, with an associated object identity. Any additional content [attributes] of the PlanningUser object are system specific. As the PlanningUser object is not transferred in any message of the MPS services, there is no requirement to fully define the data structure within this standard, but it is referenced in other MPS objects and data structures using an attribute of type MAL::ObjectRef.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PlanningUser** | **Extends** | MAL::Object | **SFP** | 601 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| identity | MAL::ObjectIdentity | No | Identity of the PlanningUser, including version. |

The set of PlanningUser definitions may be considered part of the MPS Configuration Data.

### Planning Configuration Data



Figure 3‑20: Planning Configuration Data

Planning configuration data is the set of definition objects that together define the set of available data items that can be referenced in planning requests and plans. This configuration data must be available to both communicating parties that exchange planning requests and plans. This includes the definitions for:

* Planning Activities
* Planning Events
* Planning Resources
* Planning Requests
* Planning Users
* Custom Functions

In addition to the above, the planning configuration data includes MPS system wide configuration parameters, defined in a singleton MPSSystemConfig MO object.

MPSSystemConfigDetails

The referenced timeSystem allows specification the time system used for time attributes within an MPS system. This may be specified in the context of a planning request, a plan or as a system-wide default here within the MPSSystemConfig object.

Other configuration parameters specific to the MPS system can be defined using the customConfig attribute as a list of name-value pairs.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **MPSSystemConfigDetails** | **Extends** | MAL::Object | **SFP** | 701 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| identity | MAL::ObjectIdentity | No | Identity of MPS system config, including version. |
| timeSystem | MAL::String | No | Specifies the default time system used by the MPS system (see 3.1.4). |
| customConfig | List <MAL::NamedValue> | Yes | Optional set of custom configuration parameters defined as a set of named values. |

### Custom Functions [Optional]



Figure 3‑21: Custom Functions

Custom functions are an MPS ancillary data item that allow access to built-in Boolean functions of a planning system, for example in the context of planning constraints (see §3.3.6.1.6 Function Constraint). The function must be pre-defined to be referenced and the FunctionDefinition holds the declaration of an available function.

FunctionDefinitions include a set of ArgDefs that define the set of input arguments for the function.

Similar to ActivityDetails, the FunctionDetails data type can be embedded in other items, such as a function constraint, that specify the invocation of a defined function. This references a FunctionDefinition and provides a set of ArgSpecs that specify the input value for each defined argument.

FunctionDefinitionDetails

FunctionDefinition is a data structure that contains static configuration data relating to custom functions: built-in Boolean functions of an MPS system, each of which has a specified Identifier and optional set of argument definitions. This may change over time, each comprising a separate version of the definition. FunctionDefinitionDetails form part of the planning configuration data.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **FunctionDefinitionDetails** | **Extends** | MAL::Composite | **SFP** | 801 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| functionID | MAL::Identifier | No | ID of the function |
| version | MAL::UInteger | No | Version of the FunctionDefinition. |
| description | MAL::String | No | Description of the function. |
| argDefs | List <ArgDef> | Yes | List of argument definitions. |

FunctionDetails

Contains the information required to invoke a defined function, including the specification of argument values.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **FunctionDetails** | **Extends** | MAL::Composite | **SFP** | 802 |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| function | MAL::Identifier | No | ID of a specific FunctionDefinition. |
| argSpecs | List <ArgSpec> | Yes | Set of argument specifications for each argument definition contained in the referenced function definition. These supply a value for each argument, or an expression to enable the value to be derived. |

## MPS Data Types

MPS Data Types are supporting data structures used in the context of MPS Data Items and MPS service messages:

* MPS Base Data Types;
* MPS Position and Direction Types [Optional];
* Expressions;
* Additional MPS Data Types;
* Arguments;
* Constraints;
* Triggers;
* Repetitions.

### MPS Base Data Types



Figure 3‑22: MPS Base Data Types

The MPS information model is defined in terms of a set of base data types. As MPS services are defined as abstract services in terms of the MO service framework, these data types must also be compatible with the attribute types defined in the MO Message Abstraction Layer (MAL). The MAL attribute types (shown in Figure 3‑22 above in purple) are as follows:

* Boolean
* Float *32-bit floating point number*
* Double *64-bit floating point number*
* Octet *8-bit signed integer*
* UOctet *8-bit unsigned integer*
* Short *16-bit signed integer*
* UShort *16-bit unsigned integer*
* Integer *32-bit signed integer*
* UInteger *32-bit unsigned integer*
* Long *64-bit signed integer*
* ULong *64-bit unsigned integer*
* Duration *Length of time in seconds (may include a fractional component)*
* Time *Absolute date and time to millisecond resolution*
* FineTime *Absolute date and time to picosend resolution*
* String *Text as a variable-length, unbounded, Unicode string*
* Blob *Stores binary objects, it is a variable-length, unbounded, octet array*
* Identifier *Stores Identifiers, a variable-length, unbounded, Unicode string*
* URI *Stores URI addresses, a variable-length, unbounded, Unicode string*
* ObjectRef[[2]](#footnote-2) *Reference to an MO object*

MAL::Object2 is defined as an abstract extension of MAL::Composite that contains a representation of the data structure of an MO object. It has one attribute, that is the identity of the MO object, represented as a MAL::ObjectIdentity composite data structure.

MAL::ObjectIdentity2 is defined as an extension of MAL::Composite that contains the identity of an MO object, including its domain, key and version. The area and type of the MO object are implied by the derived concrete type of the object.

The MAL::ObjectRef attribute type has a similar conceptual structure, but includes the area and type of the referenced object and its encoding is dependent the MAL binding used. MAL::ObjectRef can be used in two ways:

ObjectRef without a defined object type, in which case the area and type of the referenced MO object are explicitly encoded within the reference.

ObjectRef<T> with a defined object type <T>, in which case the area and type of the referenced MO object are implicit and not encoded within the reference.

The latter allows for more compact encoding of the reference and should be used where the context only permits a single type of object to be referenced. If the reference can point to objects of multiple types or to an abstract type that has multiple concrete sub-types, then an untyped ObjectRef should be used.

The MAL also defines NamedValue as an extension of MAL::Composite that allows the specification of a name-value pair.

The MPS information model optionally extends the set of MAL attribute types with the following additional MAL composite data types:

* Position *Coordinates defining a physical location.*
* Direction *Coordinates defining a target pointing angle.*

ArgTypeEnum

ArgTypeEnum is an MPS extension of the MAL::AttributeType enumeration that also allows specification of the data type as Position or Direction.

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **ArgTypeEnum** | **SFP** |  |

| Status | Value | Description |
| --- | --- | --- |
| BLOB | 1 | Binary object |
| BOOLEAN | 2 | Boolean value (True or False) |
| DURATION | 3 | Length of time in seconds |
| FLOAT | 4 | Floating point number (32 bits) |
| DOUBLE | 5 | Double precision floating point number (64 bits) |
| IDENTIFIER | 6 | The Identifier structure is used to store an identifier and can be used for indexing. It is a variable-length, unbounded, Unicode string. |
| OCTET | 7 | Signed 8 bit Integer |
| UOCTET | 8 | Unsigned 8 bit Integer |
| SHORT | 9 | Signed 16 bit Integer |
| USHORT | 10 | Unsigned 16 bit Integer |
| INTEGER | 11 | Signed 32 bit Integer |
| UINTEGER | 12 | Unsigned 32 bit Integer |
| LONG | 13 | Signed 64 bit Integer |
| ULONG | 14 | Unsigned 64 bit Integer |
| STRING | 15 | Text. It is a variable length, unbounded, Unicode string. |
| TIME | 16 | Absolute date-time to millisecond resolution. |
| FINETIME | 17 | Absolute date-time to picosecond resolution. |
| URI | 18 | Uniform Resource Identifier (address). It is a variable-length, unbounded Unicode string. |
| OBJECTREF | 19 | Object Reference |
| DIRECTION | 129 | MPS Direction |
| POSITION | 130 | MPS Position |

### MPS Position and Direction Data Types [Optional]

#### Introduction

This section defines MPS Position and Direction data types and support types required in the definition of pointing constraints. These are consistent with those used within CCSDS Navigation data format standards, and specifically the Pointing Request Message (PRM) (reference [B6]), but for MPS, to enable use of the MO Framework, they are defined explicitly in terms of MAL Attributes.

MPS Position and Direction data types are only required in the context of the following MPS data structures:

* Geometric Constraints (see §3.3.6.1.7)
* Triggers of type PositionTrigger and DirectionTrigger (see §3.3.7)
* Repetitions of type PositionRepetition and PointingRepetition (see 3.3.8)

As all of these are considered optional elements of the MPS information model, MPS Position and Direction data types are themselves optional.

Coordinate System

Some sub-types of MPS Position and Direction require the specification of the coordinate reference frame used. The set of allowed coordinate system values is specified in the PRM (reference [B6]) annex B2 or in the SANA registry as per reference [B6] annex E2, or a mission specific frame.

To allow for evolution, both of the set of standard coordinate systems defined within this registry and through mission specific extension, coordinate systems are not defined as an enumeration but represented as a MAL::String.

#### Position Data Type



Figure 3‑23: Position Data Type

The abstract Position data type is used to specify a physical location.

The Position type corresponds to the “Orbit Entity” type defined in [PRM] §3.3.2.11. Only the ephemeris object and orbit file representations are supported in PRM template parameters and as such in pointing constraint attributes.

For MPS it is possible to define a Position using one of the following coordinate types, each of which is defined as a concrete sub-type of Position:

* **Cartesian**: a set of explicitly provided x,y and z coordinates.
* **Spherical**: a pair of coordinates corresponding to longitude and latitude.
* **OrbitFile**: a reference to a file containing a CCSDS Orbit Data Message [ODM] defining the orbital ephemeris.
* **Orbital**: a set of explicitly provided coordinates based on orbit number and angle.
* **Object**: a reference to a named target object.
* **Reference**: a reference to a reusable position definition.

*Position*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***Position*** | **Extends** | MAL::Composite | **SFP** | Abstract |

CartesianPosition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **CartesianPosition** | **Extends** | *Position* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| x | MAL::Double | No | Cartesian x coordinate defined in the given frame and with values of the given unit. |
| y | MAL::Double | No | Cartesian y coordinate defined in the given frame and with values of the given unit. |
| z | MAL::Double | No | Cartesian z coordinate defined in the given frame and with values of the given unit. |
| frame | MAL::String | No | One of the coordinate reference frames as defined in reference [B6] annex B2, or in the SANA registry as per reference [B6] annex E2 or a mission specific frame. |
| units | MAL::String | Yes | The distance unit name, as defined in [PRM] annex D.  Default = “km”. |

SurfacePosition

The unit may be defined here. Typically used to specify a coordinate on the surface of a celestial body. Optionally, the altitude above the surface (as defined by a reference ellipsoid) can also be specified.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **SurfacePosition** | **Extends** | *Position* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| longitude | MAL::Double | No | Angular coordinate. May also represent azimuth. |
| latitude | MAL::Double | No | Angular coordinate. May also represent elevation. |
| frame | MAL::String | No | One of the coordinate reference frames as defined in reference [B6] annex B2, or in the SANA registry as per reference [B6] annex E2 or a mission specific frame. |
| units | MAL::String | Yes | To be one of the Angle units as defined in reference [B6] annex D.  Default = “deg”. |
| altitude | MAL::Double | Yes | Altitude above a reference ellipsoid (negative values allowed).  Default = 0 |
| altitudeUnits | MAL::String | Yes | The distance unit name, as defined in reference [B6] annex D.  Default = “m”. |

OrbitFilePosition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **OrbitFilePosition** | **Extends** | *Position* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| orbitFile | MAL::String | No | Name of or reference to a file containing an ODM (reference [D12]). |

OrbitalPosition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **OrbitalPosition** | **Extends** | *Position* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| orbitNumber | MAL::Integer | No | Orbit number. Depending on the relativeOrbit flag, the orbit number may be absolute (since start of mission) or relative (to the orbital repeat cycle). |
| relativeOrbit | MAL::Boolean | No | Flag indicating if the orbit number is absolute or relative to the orbital repeat cycle. |
| orbitAngle | MAL::Double | No | Angle within orbit. |
| units | MAL::String | Yes | The units used for orbitAngle, as defined in reference [B6] annex D. |

ObjectPosition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ObjectPosition** | **Extends** | *Position* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| object | MAL::String | No | Name or identifier of a celestial body as per reference [B6] annex E2, or a mission specific object. |

PositionReference

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PositionReference** | **Extends** | *Position* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| reference | MAL::String | No | Name of a mission specifc position definition. |

#### Direction Data Type



Figure 3‑24: Direction Data Type

The abstract Direction data type is used to specify a pointing direction or attitude.

The Direction type corresponds to that defined in [PRM] §3.3.2.9. Only the coordinates representation is supported in PRM template parameters and as such in pointing constraint attributes.

A direction is either defined in the base frame (e.g. an inertial frame) and any sub-frame of the base frame, or in a secondary frame (i.e. the pointing frame, e.g. a spacecraft frame) or any sub-frame of the secondary frame (e.g. an instrument boresight).

For MPS it is possible to define a Direction using one of the following coordinate types, each of which is defined as a concrete sub-type of Direction:

* **Cartesian**: a set of explicitly provided x,y and z coordinates.
* **Spherical**: a pair of coordinates corresponding to azimuth and elevation.
* **RADec**: a pair of coordinates typically used for astronomical observations corresponding to right ascension and declination.
* **NamedTarget**: a reference to a named target object.
* **Reference**: a reference to a reusable direction definition.

*Direction*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***Direction*** | **Extends** | MAL::Composite | **SFP** | Abstract |

CartesianDirection

Dimensionless unit vector. Either a direction in the base frame or in a secondary frame may be defined.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **CartesianDirection** | **Extends** | *Direction* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| x | MAL::Double | No | Cartesian x coordinate defined in the given frame. |
| y | MAL::Double | No | Cartesian y coordinate defined in the given frame. |
| z | MAL::Double | No | Cartesian z coordinate defined in the given frame. |
| frame | MAL::String | No | One of the coordinate reference frames as defined in reference [B6] annex B2, or in the SANA registry as per reference [B6] annex E2 or a mission specific frame. |

SphericalDirection

Based on azimuth and elevation, the unit may be defined here. Typically used to define a direction in a secondary frame. When used to specify a surface coordinate, this actually represents a {longitude, latitude} pair.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **SphericalDirection** | **Extends** | *Direction* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| azimuth | MAL::Double | No | Angular coordinate. May also represent longitude. |
| elevation | MAL::Double | No | Angular coordinate. May also represent latitude. |
| frame | MAL::String | No | One of the coordinate reference frames as defined in reference [B6] annex B2, or in the SANA registry as per reference [B6] annex E2 or a mission specific frame. |
| units | MAL::String | Yes | To be one of the Angle units as defined in reference [B6] annex D.  Default = ‘deg’. |

RADecDirection

Based on celestial angular coordinates of right ascenscion and declination, the unit may be defined here.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **RADecDirection** | **Extends** | *Direction* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| ra | MAL::Double | No | Right Ascension: Celestial angular coordinate, measured eastward along the celestial equator. |
| dec | MAL::Double | No | Declination: Celestial angular coordinate, north or south of the celestial equator. |
| frame | MAL::String | No | One of the coordinate reference frames as defined in reference [B6] annex B2, or in the SANA registry as per reference [B6] annex E2 or a mission specific frame. |
| units | MAL::String | Yes | To be one of the Angle units as defined in reference [B6] annex D.  Default = ‘deg’. |

RevolutionDirection

Based on fixed rotation about an axis, the direction is defined by an angle within a single revolution.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **RevolutionDirection** | **Extends** | *Direction* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| revolutionAngle | MAL::Double | No | Angle within a revolution. |
| units | MAL::String | Yes | To be one of the Angle units as defined in reference [B6] annex D.  Default = “deg”. |

NamedTargetDirection

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **NamedTargetDirection** | **Extends** | *Direction* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| namedTarget | MAL::String | No | Name or identifier of a catalogued celestial object or a mission specific object. |

DirectionReference

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **DirectionReference** | **Extends** | *Direction* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| reference | MAL::String | No | Name of a mission specific direction definition. |

#### Physical Value Data Types



Figure 3‑25: Physical Value Data Types

Physical Value

PhysicalValue is an abstract base type for the specific value types defined below. Only specific value types are used in the pointing constraint definitions below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***PhysicalValue*** | **Extends** | MAL::Composite | **SFP** | Abstract |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| value | MAL::Double | No | Physical value. |
| units | MAL::String | Yes | Optional unit. The unit type depends on the specific value type, as defined in reference [B6] annex D. |

For MPS, three specific physical value types (as defined in reference [B6] annex D) are used in the context of geometric constraints on position or pointing:

Angle

Has units of type Angle.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **Angle** | **Extends** | *PhysicalValue* | **SFP** |  |

AngularVelocity

Has units of type AngularVelocity.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **AngularVelocity** | **Extends** | *PhysicalValue* | **SFP** |  |

Distance

Has units of type Distance.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **Distance** | **Extends** | *PhysicalValue* | **SFP** |  |

### Expressions



Figure 3‑26: Example Sub-Types of MPS Expression

Expression

When entering MPS data, it is often not possible to provide an absolute value for a required attribute. Instead, it is necessary to provide a calculation to be performed at run time that supplies the value. These calculations are defined as expressions of a specified data type. The data type can be any defined ArgType [see §3.3.1], which may be any MAL Attribute type, Position or Direction.

In Figure 3‑26 and other information model diagrams, derived sub-types of Expression are used to illustrate how the result of an expression may be constrained to be of a specific data type. These are shown in grey. However, as the value of an expression is itself a MAL::Attribute, this polymorphism is handled at the MAL layer. Formally, there is only one concrete class for Expression in terms of the XML specification of the MPS standard and MAL encoding.

In this specification, where an attribute of a data type is defined as Expression, then the form Expression<T> is used to indicate that the result is constrained to be of type T. This is equivalent to the representation of attributes of type MAL::ObjectRef.

The expressions are themselves text strings which comprise a sequence of operands and operators. Operands may be literals or references to objects and their attributes or arguments, as defined within the MPS information model.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **Expression** | **Extends** | MAL::Composite | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| type | ArgTypeEnum | No | Enumeration specifying the data type of the result of the expression. |
| value | MAL::Attribute | No | Providing the ArgType is a MAL Attribute type, this field may be used to hold a simple literal value or the evaluated result of the expression. |
| expressionLanguage | MAL::String | No | Defines the expression language used to specify the expression. |
| expression | MAL::String | No | The text of the expression. |

The value that the expression provides may be specified in three ways:

* As a literal value of the appropriate type (in the value field)
* As a simple reference to an argument or attribute of an MO object, or to an MO object itself, of the appropriate data type (in the expression field). The referenced item contains the value at run-time.
* As an Expression comprising multiple operands (specified as literals or references as above) together with appropriate arithmetic, logical or other operators (in the expression field). Evaluation of the expression at run-time delivers a value result of the appropriate data type.

If the value of the expression is provided in the value field, then the expressionLanguage and expression strings should be left empty. If a non-empty string is provided for the expression, then any value provided in the value field is subject to being overwritten at run-time following evaluation of the expression.

As there is no equivalent MAL::Attribute type for Position or Direction, values of these types are represented as a MAL::String containing a literal in the defined expression format for these types. In this case, the expressionLanguage should be specified, even if a literal value is provided in the value field, to enable interpretation. A default literal format for Position and Direction values is provided in ANNEX C.

References and Expressions are provided as a text string in the expression attribute. The expression language itself is not specified as part of the standard. However, there are specific requirements which must be fulfilled in the following areas:

* Formats for the representation of literal values of all data types
* Object References
* Time and Duration Expressions

If there is no native language for the specification of expressions in the target deployment, then it is suggested that one could be defined based on the XPath syntax [B9]**.**. A simple syntax for the representation of literal values, including for object references, positions and directions, is provided in ANNEX C.

The expressionLanguage attribute is used to specify which syntax is used in the expression attribute. It is itself a string rather than an enum to allow extensibility and the use of user defined expression languages. There must be a service agreement between service provider and service user on the language(s) to be used.

#### Object References

The syntax for object references must support the following:

* References to planning events, planning activities, planning requests and planning resources
* References to any attribute of planning events, planning activities, planning requests and planning resources
* References to any argument (by name) of planning events, planning activities and planning requests

References may be via:

* Name (the key field of the object identity)
* The current object (by context) "Me"
* An object referenced in an argument or attribute of another object
* A child object of another object by name
* A sibling object (another child of the parent [source] object) by name

Note that child and sibling relationships apply only to planning events and planning activities.

Note that name identifies a planning resource explicitly, but only the definition class of planning activities and planning events. These references must be resolvable at run time to a specific instance, based on context.

#### Time and Duration Expressions

The syntax for Time (T) and Duration (D) expressions must support the following constructs, which may include a numeric (N) value or reference:

T = Ta±D add or subtract a Duration to/from a Time to give another Time.

D = Ta-Tb subtract two Times to give a Duration

D = Da±Db add or subtract two Durations to give another Duration

D = Da\*/N multiply or divide a Duration by a numeric factor to give another Duration. Note this may substitute for a simple duration in the previous cases, for example T = Ta±D\*/N.

### Additional MPS Data Types



Figure 3‑27: MPS Additional Data Types

These correspond to structures used repeatedly within the MPS information model.

Slider

Used to indicate a relative position with respect to an MPS object, such as a planning activity where 0 represents the start and 1 the end of the activity. The slider is a real number that can represent any point between these two extremes.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **Slider** | **Extends** | MAL::Composite | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| position | MAL::Float | No | Relative point between the start and end of an MPS object, where 0 represents the start and 1 represents the end. |

A slider **s** is a floating point value. It converts the startTime and endTime of an ActivityInstance into a referenceTime:

*referenceTime* = *startTime* + **s** \* (*endTime* - *startTime*)

Sliders are often associated with an offset. An offset **o** is a Duration. It converts a referenceTime into an applicableTime:

*applicableTime* = *referenceTime* + **o**

StateDef

Status values may be represented as enumerated Integers, but the enumeration is not defined by the standard, but in the context of planning configuration data. StateDefs hold the definitions of the text labels associated with specific status values.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **StateDef** | **Extends** | MAL::Composite | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| value | MAL::Integer | No | Enumerated value of the Status |
| state | MAL::String | No | Text label associated with the enumerated value. |

TimeWindow

Represents a specific period of time, specified as two Expressions of type Time defining the start and end of the TimeWindow.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **TimeWindow** | **Extends** | MAL::Composite | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| start | Expression <MAL::Time> | No | Start time of the time window. |
| end | Expression  <MAL::Time> | No | End time of the time window. |

EventWindow

Represents a specific period relative to two events that mark the start and end of the EventWindow.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **EventWindow** | **Extends** | MAL::Composite | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| startEvent | Expression <MAL::ObjectRef> | No | Object Type: EventInstance.  The start of the event window is relative to the referenced startEvent. |
| startOffset | Expression <MAL::Duration> | No | The start of the event window is offset by the defined time period from the startEvent. |
| endEvent | Expression <MAL::ObjectRef> | No | Object Type: EventInstance.  The end of the event window is relative to the referenced endEvent. |
| endOffset | Expression <MAL::Duration> | No | The end of the event window is offset by the defined time period from the endEvent. |

DefListEntry

Used in the context of the MPS Plan Information Management service, this holds a list of definitions for a specified type of MPS data item, together with their definitions.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **DefListEntry** | **Extends** | MAL::Composite | **SFP** |  |

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute | Type | Nullable | Description |
| definitionID | MAL::ObjectRef | No | Object Type: ActivityDefinition | EventDefinition | *Resource* | RequestDefinition  Item Definition (key and version) |
| description | MAL::String | No | Description of the item |

### Arguments



Figure 3‑28: Arguments

Arguments are a common feature for MPS data items that follow the MO dynamic item object pattern described in §3.4.3.3 below. This includes planning events, planning activities and planning requests that have both definitions and instances.

A mission-specific set of arguments may be associated with each defined planning event, planning activity or planning request. These hold additional information specific to the defined data item and can be used to parameterise the data item. Each argument has an identifying ArgName and an associated value of any defined ArgType (see §3.3.1) and may correspond to an array of values.

Arguments are not themselves MO objects, but are contained within them, and follow a similar pattern to the MO Instance object, comprising definitions, instances and details.

ArgDef

The definition of an argument is an ArgDef, a set of which may be contained within the definition MO object of a planning event, planning activity or planning request. This defines the name and data type of the argument. Depending on the data type, the ArgDef may require additional type specific attributes to support data validation.  SubTypes are identified for Numeric, String and Status arguments.

Note that if the argument is an array, then all values of the array are of the same type, as defined in argType.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ArgDef** | **Extends** | MAL::Composite | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| argName | MAL::Identifier | No | Name of the argument |
| description | MAL::String | No | Extended description of the argument |
| argType | ArgTypeEnum | No | Enumeration specifying the data type of the argument. |
| argUnits | MAL::String | Yes | Units that the argument value is expressed in, as defined in reference [B6] annex D. |
| isArray | MAL::Boolean | No | If True, indicates that the argument is an array of values of type ArgType. |
| validationData | ValidationDetails | Yes | Optional. Specifies the allowed range of values for the Argument, with concrete subtypes specific to the data type of the Argument. |

Argument

The instance of an argument is an Argument, a set of which may be contained within the instance MO object of a planning event or planning activity or within a planning request. This comprises the name and value of the argument, corresponding to the set of arguments defined in the ArgDef. Argument values are represented as a MAL Attribute of appropriate data type. As there is no equivalent MAL::Attribute type for Position or Direction, values of these types are represented as a MAL::String containing a literal in the defined expression format for these types.

Note that if the argument is an array (count > 1) then all values of the array are of the same type, as defined by the argType of the associated ArgDef.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **Argument** | **Extends** | MAL::Composite | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| argName | MAL::Identifier | No | Name of the argument |
| count | MAL::Integer | Yes | If argument is an array, count of the number of elements in the array. |
| argValues | List <MAL::Attribute> | No | Argument value (or values if it is an array). MAL Attribute type must match the ArgType of the ArgDef. Position and Direction values are represented as a MAL::String. |

ArgSpec

In the case of the planning activity, there is also an ArgSpec, a set of which may be contained within the ActivityDetails structure embedded within a planning request or parent planning activity definition. The ArgSpec defines how to derive the value of an Argument when instantiating it at run-time. The ArgSpec attribute is an Expression, the result of which must be a value matching the defined ArgType.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ArgSpec** | **Extends** | MAL::Composite | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| argName | MAL::Identifier | No | Name of the argument |
| count | MAL::Integer | Yes | If argument is an array, count of the number of elements in the array. |
| argSpecs | List <Expression> | No | Expression that can be evaluated at run-time to provide argument value(s) of appropriate data type. |

#### Validation Details



Figure 3‑29: Validation Details

The attributes required for the validation of Argument values are type-specific, and to support this an optional validationData field is included in the ArgDef that has the abstract data type *ValidationDetails*. Three concrete types are defined to support:

* NumericRange: applicable for any numeric data type where a min-max range is defined for the resource (including Durations).
* StringPattern: applicable for resources of type String.
* StatusValues: applicable for enumerated status resources (of type Integer, but with interpreted status text strings).

Note: *ValidationDetails* are also used to support the definition of Resources (see 3.2.4).

ValidationDetails

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***ValidationDetails*** | **Extends** | MAL::Composite | **SFP** | Abstract |

NumericRange

Concrete sub-type of *ValidationDetails* that provides additional attributes to support data validation for numeric data types.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **NumericRange** | **Extends** | *ValidationDetails* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| min | MAL::Double | No | Minimum value of the argument |
| max | MAL::Double | No | Maximum value of the argument |
| precision | MAL::Short | No | Precision of the argument. |

StringPatterm

Concrete sub-type of *ValidationDetails* that provides additional attributes to support data validation for the string data type.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **StringPattern** | **Extends** | *ValidationDetails* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| maxLength | MAL::Integer | No | Maximum length of the string (characters). |
| regex | MAL::String | No | A “regular expression” or sequence of characters defining a character pattern that the string value must match. |

StatusValues

Concrete sub-type of *ValidationDetails* that provides additional attributes to support data validation and interpretation for integer type arguments that are effectively enumerated Statuses.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **StatusValues** | **Extends** | *ValidationDetails* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| allowedValues | List <StateDef> | No | Set of allowed State definitions (see §3.3.4), comprising the enumerated value and an associated text label. |

### Constraints



Figure 3‑30: Planning Constraints

Planning constraints describe the relationships between planning activities and other entities represented in the MPS information model, including:

* Time, Position and pointing Direction
* Planning events
* Planning resources
* Other planning activities

Planning constraints are not free-standing MO objects within the model, but are attached to either planning requests or planning activities.

There are two main sub-types of planning constraint: ConditionalConstraints and Effects.

Conditional constraints specify conditions that must be satisfied when placing a planning activity within a plan.

Effects specify the impact that executing a planning activity will have on planning resources. These may be used to predict the evolution of the values of planning resources over the period of a plan. This in turn enables the verification that sufficient resource is available for execution of the plan and that all explicit resource constraints are satisfied. As for Resources, Effects are an optional element of the MPS information model.

Conditional constraints and Effects are detailed in the following subsections.

Most, but not all, sub-classes of *Constraint* include the attribute activityRef that identifies the planning activity that is constrained. This includes Temporal, Resource, Argument, Function and Geometric constraints as well as Effects. This attribute is nullable depending on context of the constraint. If it is associated with a planning activity, then will normally be omitted. If it is directly associated with a planning request (and not with a requested activity) then it must be specified.

If omitted in the context of a planning activity, then the constrained activity is by default assumed to be the activity which contains that constraint. In the case of an ActivityDef this will be all ActivityInstances created from that definition; while in the case of an ActivityInstance it will be that specific instance that is constrained.

*Constraint*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***Constraint*** | **Extends** | MAL::Composite | **SFP** | Abstract |

ConstraintNode

Multiple planning constraints can be combined using a ConstraintNode. The ConstraintNode specifies the logical operation (AND or OR) to be used when combining a set of constraints together. As the ConstraintNode is itself defined as a sub-type of Constraint, it is possible to construct a tree of ConstraintNodes using different logical operators.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ConstraintNode** | **Extends** | *Constraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| operator | LogicOpEnum | No | Enumeration specifying the logic for combining multiple Boolean conditions together. One of {AND, OR}.  Default = AND |
| negate | MAL::Boolean | No | Specifies whether the result of combining the Constraints is to be inverted (NOT function).  Default = False |
| constraints | List <Constraint> | No | The set of Constraints to be combined. |

LogicOpEnum

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **LogicOpEnum** | **SFP** |  |

| Enumeration | Value | Description |
| --- | --- | --- |
| AND | 1 | Logical AND |
| OR | 2 | Logical OR |

#### Conditional Constraints



Figure 3‑31: Conditional Constraints

A wide range of conditional constraint sub-types are defined to support different classes of condition. These are shown in Figure 3‑31 above, except for geometric constraints which are shown in Figure 3‑32.

Each of the following sub-types of conditional constraint is described in a separate sub-section below:

* Constraint Expression (a Boolean expression that evaluates to True if the constraint is met)
* Temporal Constraints (when a planning activity can be planned)
* Sequential Constraints (which order planning activities must be executed in)
* Exclusion Constraints (identifying planning activities that cannot be executed concurrently)
* Resource Constraints (restrictions based on the value of planning resources)
* Argument Constraints (restrictions based on the value of an argument)
* Function Constraints (restrictions based on the result of a function)
* Geometric Constraints (restrictions based on position or pointing direction).

Of these, only the ConstraintExpression is required to be supported for compliance of an MPS system to the MPS services standard. All other conditional constraint types are optional.

Where a constraint is associated with a planning activity, this may be by reference to an ActivityDefinition, in which case it applies to all instances of that definition, or to a specific ActivityInstance, in which case it only applies to that instance.

*Conditional Constraint*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***ConditionalConstraint*** | **Extends** | *Constraint* | **SFP** | Abstract |

##### Constraint Expression

All types of constraint can be considered conditions that are either met or not met when a planning activity is placed in a Plan. They can therefore be specified as a potentially complex Boolean expression that combines references to the arguments and attributes of objects in the MPS information model using operators of various types (arithmetic, comparative, logical, string, temporal and geometric). The expression must evaluate to TRUE for the constraint to be met.

As introduced in §3.3.3, this standard does not define a full expression language capable of supporting such complex Boolean expressions. It does, however, support the use of externally defined expression languages. The ConstraintExpression type allows for the use of such an expression language to define any type of constraint, providing communicating entities all have the capability to evaluate that expression language.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ConstraintExpression** | **Extends** | *ConditionalConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| constraint | Expression <MAL::Boolean> | No | Potentially complex conditional expression that must evaluate to TRUE for the constraint to be met. |

##### Temporal Constraints [Optional]

*TemporalConstraint*

Temporal constraints impose a restriction on when a planning activity can appear in a plan. The abstract type *TemporalConstraint* identifies the planning activity that is subject to the constraint, while concrete sub-types allow the specification of three different types of temporal constraint:

* TimeConstraint: the time at which the planning activity is to be planned
* TimeWindowConstraint: a time window within which the planning activity is to be planned
* DurationConstraint: a restriction on the duration of the planning activity in the plan

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***TemporalConstraint*** | **Extends** | *ConditionalConstraint* | **SFP** | Abstract |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| activityRef | Expression <MAL::ObjectRef> | Yes | Object Type: ActivityInstance.  Identifies the constrained planning activity. If omitted the activity containing the constraint is assumed. |

TimeConstraint

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **TimeConstraint** | **Extends** | *TemporalConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| time | Expression <MAL::Time> | No | The time at which the planning activity must be planned. |
| timeRef | Slider | No | The point in the duration of the planning activity that is time constrained.  0: the start of the planning activity  1: the end of the planning activity |

The use of a time Expression allows the time constraint to be specified in terms of a planning event or an argument of a planning request or planning activity.

The Slider construct (see §3.3.4) may be used to express any point in the duration of the planning activity between its start (0) and end (1) that is constrained to the specified time.

TimeWindowConstraint

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **TimeWindowConstraint** | **Extends** | *TemporalConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| startRef | Slider | No | The point in the duration of the activity that is constrained to be after the start time of the time window. Although typically the start of the activity (0), this can be any point up to the end of the activity (1). |
| endRef | Slider | No | The point in the duration of the activity that is constrained to be before the end time of the time window. Although typically the end of the activity (1), this can be any point up to the start of the activity (0). |
| timeWindows | List <TimeWindow> | No | The [set of] TimeWindows within which the activity must be placed on the Plan. |

The use of the Sliders to specify the start and end time references for the planning activity with respect to the specified TimeWindow[s] allows a range of overlap conditions to be expressed, for example:

* startRef = start[0] and endRef = end[1] means that the planning activity must be fully contained within the specified TimeWindow.
* startRef = start[0] and endRef = start[0] means that the planning activity must start within the specified TimeWindow, but can continue beyond the end of the TimeWindow.
* startRef = end[1] and endRef = start[0] means that the planning activity can overlap both the start and end of the TimeWindow.

Multiple TimeWindows can be specified. This indicates that the planning activity may be placed within any of the specified TimeWindows, not that it should be placed multiple times.

DurationConstraint

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **DurationConstraint** | **Extends** | *TemporalConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| minDuration | Expression <MAL::Duration> | No | Specifies the minimum duration of the planning activity |
| maxDuration | Expression <MAL::Duration> | No | Specifies the maximum duration of the planning activity |

##### Sequential Constraint [Optional]

Sequential Constraint

Sequential constraints impose a restriction on the order of planning activities in a Plan with respect to both other planning activities and planning events.

Two objects are identified: the predecessor which must be followed in the Plan by the successor. While either the predecessor or successor may be a planning event, it is not possible to specify a sequential constraint between two planning events: one or both must be a planning activity.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **SequentialConstraint** | **Extends** | *ConditionalConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| predecessor | Expression <MAL::ObjectRef> | No | Object Type: ActivityInstance | EventInstance  Identifies the planning activity or planning event that must occur first on the Plan . |
| successor | Expression <MAL::ObjectRef> | No | Object Type: ActivityInstance | EventInstance  Identifies the planning activity or planning event that must follow the predecessor on the Plan . |
| predecessorRef | Slider | No | Point on the predecessor that must be followed by the successor |
| successorRef | Slider | No | Point on the successor that must follow the predecessor |
| minOffset | Expression <MAL::Duration> | No | Minimum period between the specified points on the predecessor and successor. |
| maxOffset | Expression <MAL::Duration> | No | Maximum period between the specified points on the predecessor and successor. |

As with the time window constraint, the Slider construct is used to specify the point on the duration of the predecessor object that the specified point on the successor object is constrained to follow. This allows various overlap conditions to be expressed. For example, if the start of the successor must follow the end of the predecessor, then the predecessorRef is end[1] and the successorRef is start[0].

The constraint may also specify an offset, or interval, between the predecessor and successor objects. This is expressed as a minimum and maximum duration between the specified points on the predecessor and successor objects.

##### Exclusion Constraint [Optional]

Exclusion Constraint

An exclusion constraint specifies a set of 2 or more planning activities or planning events that cannot occur concurrently in a Plan. As only planning activities can be excluded, at least one of the set must be a planning activity. Excluded objects are specified by definition [class] rather than instance, the exclusion applying to all instances of the class. Exclusion implies no overlap between the excluded items.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ExclusionConstraint** | **Extends** | *ConditionalConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| classRefs | List <MAL::ObjectRef> | No | Object Type: ActivityDefinition | EventDefinition  Specifies the definition (class) of excluded planning activities and planning events. |

##### Resource and Argument Constraints [Optional]

Resource and argument constraints allow the value of a Resource or an Argument (of any MAL::Attribute type) to be compared against a specified value.

Note that all MAL Attribute data types can be supported by a single subtype that has the value attribute of type MAL Attribute. Argument constraints cannot be used for Arguments of type Position or Direction as the values are not MAL::Attributes.

ArgumentConstraint

An argument constraint may be associated with a planning activity to restrict when it can be planned, based on the value of an argument of the planning activity itself or a related planning event.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ArgumentConstraint** | **Extends** | *ConditionalConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| activityRef | Expression <MAL::ObjectRef> | Yes | Object Type: ActivityInstance.  Identifies the planning activity for which the argument constraint applies. If omitted the activity containing the constraint is assumed. |
| objectRef | Expression <MAL::ObjectRef> | Yes | Object Type: ActivityInstance | EventInstance  Identifies the Object (planning activity or planning event) whose argument is to be referenced. If omitted the activity containing the constraint is assumed. |
| argName | MAL::Identifier | No | Identifies the specific argument of the referenced Object whose value is to be compared |
| comparator | ExpressionOperatorEnum | No | Comparisson operator, which may be one of:  =, !=, >, >=, <, <=, contains, icontains  The contains operator only applies to strings and may be case sensitive or insensitive. |
| value | MAL::Attribute | No | Value (of same type as the referenced Argument) to be compared against. |

ExpressionOperatorEnum

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **ExpressionOperatorEnum** | **SFP** |  |

| Enumeration | Value | Description |
| --- | --- | --- |
| EQUAL | 1 | = |
| DIFFER | 2 | != |
| GREATER | 3 | > |
| GREATER\_OR\_EQUAL | 4 | >= |
| LESS | 5 | < |
| LESS\_OR\_EQUAL | 6 | <= |
| CONTAINS | 7 | Case sensitive containment (Strings only) |
| ICONTAINS | 8 | Case insensitive containment (Strings only) |

*ResourceConstraint*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***ResourceConstraint*** | **Extends** | *ConditionalConstraint* | **SFP** | Abstract |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| activityRef | Expression <MAL::ObjectRef> | Yes | Object Type: ActivityInstance.  Identifies the planning activity for which the resource constraint applies. If omitted the activity containing the constraint is assumed. |
| resourceRef | MAL::ObjectRef | No | Object Type: *Resource*  Identifies the planning resource that is constrained for the duration of the planning activity. |
| comparator | ExpressionOperatorEnum | No | COM comparisson operator, which may be one of:  =, !=, >, >=, <, <=, contains, icontains  The contains operator only applies to strings and may be case sensitive or insensitive. |

These attributes are common to all sub-types.

SimpleResourceConstraint

The simple resource constraint must be satisfied for the duration of the referenced planning activity.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **SimpleResourceConstraint** | **Extends** | *ResourceConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| value | MAL::Attribute | No | Value (of same type as the referenced Resource) to be compared against. |

ComplexResourceConstraint

In the [simple] resource constraint, the value of the referenced planning resource is constrained against a single value for the entire duration of the referenced planning activity.

With the complex resource constraint, the period over which the constraint applies can be customised relative to the referenced planning activity; and the value against which the referenced planning resource is constrained can be specified as a relative resource profile which evolves over time.

The attributes of the complex resource constraint extend or modify those of the [simple] resource constraint as follows:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ComplexResourceConstraint** | **Extends** | ResourceConstraint | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| startRef | Slider | No | Identifies the point in the duration of the referenced planning activity to which the start of the constraint period relates. |
| endRef | Slider | No | Identifies the point in the duration of the referenced planning activity to which the end of the constraint period relates. |
| startOffset | Expression <MAL::Duration> | No | Offset from startRef that specifies the start of the constraint period. |
| endOffset | Expression <MAL::Duration> | No | Offset from endRef that specifies the end of the constraint period. |
| valueProfile | RelativeResourceProfile | No | ResourceProfile specifying an evolving value over time against which the value of the planning resource is to be compared.  See §3.2.4.2 |

The period over which the resource constraint applies is specified as startRef+startOffset to endRef+endOffset.

##### Function Constraint [Optional]

Function Constraint

Function constraints make use of an external custom function to determine whether or not a constraint is satisfied. Available functions must be pre-defined (see §3.2.9) to allow them to be referenced in a function constraint.

As for complex resource constraints, the period over which the function constraint applies is specified relative to the referenced planning activity.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **FunctionConstraint** | **Extends** | *ConditionalConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| activityRef | Expression <MAL::ObjectRef> | Yes | Object Type: ActivityInstance.  Identifies the planning activity for which the function constraint applies. If omitted the activity containing the constraint is assumed. |
| startRef | Slider | No | Identifies the point in the duration of the referenced planning activity to which the start of the constraint period relates. |
| endRef | Slider | No | Identifies the point in the duration of the referenced planning activity to which the end of the constraint period relates. |
| startOffset | Expression <MAL::Duration> | No | Offset from startRef that specifies the start of the constraint period. |
| endOffset | Expression <MAL::Duration> | No | Offset from endRef that specifies the end of the constraint period. |
| function | FunctionDetails | No | Specifies the Function to be applied and its set of input arguments. |

##### Geometric Constraints [Optional]



Figure 3‑32: Geometric Constraints

Geometric constraints impose a restriction on a planning activity appearing in a Plan , based on the position or pointing direction of a physical object, such as a spacecraft or instrument.

The abstract type *GeometricConstraint* identifies the planning activity that is subject to the constraint, and the period over which the constraint is applicable, relative to the start and end of that planning activity. Concrete sub-types allow the specification of different types of geometric constraint:

* PositionConstraint: expressed in terms of a specified Position and a tolerance. Different sub-types support the specification of Position using different coordinate systems.
* PointingConstraint: expressed in terms of the pointing templates defined for use within CCSDS Navigation data format standards.
* RevolutionConstraint: expressed in terms of revolution angle and a tolerance.
* DistanceConstraint: expressed in terms of the distance between observer and target objects.
* AngleConstraint: expressed in terms of the angle subtended by three objects.

*GeometricConstraint*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***GeometricConstraint*** | **Extends** | *ConditionalConstraint* | **SFP** | Abstract |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| activityRef | Expression <MAL::ObjectRef> | Yes | Object Type: ActivityInstance.  Identifies the planning activity for which the geometric constraint applies. If omitted the activity containing the constraint is assumed. |
| startRef | Slider | No | Identifies the point in the duration of the referenced planning activity to which the start of the constraint period relates. |
| endRef | Slider | No | Identifies the point in the duration of the referenced planning activity to which the end of the constraint period relates. |
| startOffset | Expression <MAL::Duration> | No | Offset from startRef that specifies the start of the constraint period. |
| endOffset | Expression <MAL::Duration> | No | Offset from endRef that specifies the end of the constraint period. |

These attributes are common to all sub-types of geometric constraint (including pointing constraints).

The period over which the geometric constraint applies is specified relative to the referenced planning activity as startRef+startOffset to endRef+endOffset.

PositionConstraint

Sub-type of geometric constraint expressed in terms of a specified Position and a tolerance. The tolerance is defined as a sphere around the specified position, expressed as a distance or angle. Note that the position itself can be expressed using any of the concrete position sub-types, including orbital and surface positions. The use of a constraint expressed by OrbitalPosition is particularly relevant for earth observation satellites with a repetitive ground track and on-board position based scheduler. The position can also specified as an expression.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PositionConstraint** | **Extends** | *GeometricConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| position | Expression <Position> | No | Specifies the required position expressed using any concrete position type. |
| tolerance | Expression <MAL::Double> | No | Specifies the maximum distance or angle from the required position that satisfies the constraint, effectively defining a sphere around the required position. |
| units | MAL::String | Yes | Optional. The tolerance unit name, as defined in reference [B6] annex D.  Default = ‘km’, but ‘deg’ is more relevant for an OrbitalPosition. |

PointingConstraint

Pointing constraints impose a restriction on a planning activity appearing in a Plan , based on the pointing direction of a physical object, such as a spacecraft or instrument.

As with the Direction data types [see §3.3.2.3], pointing constraints are consistent with the pointing templates defined for use within CCSDS Navigation data format standards, and specifically the Pointing Request Message (PRM) [B6]. PointingConstraint is a concrete sub-type of *GeometricConstraint* that includes attributes common to all pointing templates. The pointing template itself is then identified as an attribute and any additional arguments applicable to the template are provided as a list of name-value pairs.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PointingConstraint** | **Extends** | *GeometricConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| pointingFrame | MAL::String | Yes | Optional. Frame to which the pointing constraint applies. One of the spacecraft body frames defined in reference [B6] annex B2, or in the SANA registry as per reference [B6] annex E2, section 1.7 reference [19] or a mission specific frame. Default frame is the spacecraft frame or any other mission specific default frame. |
| boresight | Direction | No | Direction in any spacecraft frame. |
| boresightMargin | Angle | Yes | Defines an optional cone region around the boresight, allowing a margin for application of the pointing constraint.  Default = 0.0 |
| phaseAngleMargin | Angle | Yes | Defines an optional rotation around the boresight, w.r.t. the default phase angle, allowing a margin for application of the pointing constraint.  Default = 0.0 |
| unconstrainedPhaseAngle | MAL::Boolean | Yes | If TRUE no constraint will apply to the phaseAngle. The phaseAngleMargin attribute will be ignored in this case.  Default = FALSE |
| pointingTemplate | MAL::String | No | One of the pointing templates defined in the PRM with the XML available in the SANA registry reference [B6] annex E2, or a mission specific pointing template. |
| pointingArguments | List <MAL::NamedValue> | Yes | The argument list is consistent with the referenced template by name. Physical values are represented as a pair of arguments containing the value and units respectively. Position and Direction type arguments are represented as strings containing the literal value. |

The following table summarises currently defined pointing templates and their additional arguments. Not all templates require additional arguments.

| Pointing Template | Argument | Type |
| --- | --- | --- |
| Inertial Pointing | target  phaseAngle  offsetAngle  angularRate | Direction  Angle  Angle  AngularVelocity |
| Sun Pointing | phaseAngle  offsetAngle  angularRate | Angle  Angle  AngularVelocity |
| Track with Inertial Direction Yaw Steering | targetBody  phaseAngle | Position  Angle |
| Track with Power Optimized Yaw Steering | targetBody | Position |
| Nadir with Power Optimized Yaw Steering |  |  |
| Nadir with Ground Track Aligned Yaw Steering |  |  |
| Nadir with Orbital Pole Aligned Yaw Steering |  |  |
| Limb Pointing with Power Optimized Yaw Steering | surface  dirVector  height | MAL::String  Direction  Distance |
| Limb Pointing with Inertial Direction Yaw Steering | surface  dirVector  height  phaseAngle | MAL::String  Direction  Distance  Angle |
| Velocity Pointing with Orbital Pole Yaw Steering | phaseAngle | Angle |

RevolutionConstraint

Specifies a range of revolution angles for a rotating spacecraft.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **RevolutionConstraint** | **Extends** | *GeometricConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| revolutionAngle | Expression <MAL::Double> | No | Angle of revolution |
| tolerance | Expression <MAL::Double> | No | Tolerance in the angle of revolution |
| units | MAL::String | Yes | Optional. The angular unit name, as defined in reference [B6] annex D.  Default = ‘deg’. |

DistanceConstraint

Specifies a range of distances between two physical objects (the observer and the target).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **DistanceConstraint** | **Extends** | *GeometricConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| observer | Expression <Position> | No | Position of the observer [Object1] |
| target | Expression <Position> | No | Position of the target [Object2] |
| minDistance | Expression <MAL::Double> | No | Minimum distance between observer and target |
| maxDistance | Expression <MAL::Double> | No | Maximum distance between observer and target |
| units | MAL::String | Yes | Optional. The distance unit name, as defined in reference [B6] annex D.  Default = ‘km’. |

AngleConstraint

Specifies a range of values for the angle subtended between three physical objects. The constrained angle is that subtended at the central object by target objects 1 and 2.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **AngleConstraint** | **Extends** | *GeometricConstraint* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| centreObject | Expression <Position> | No | Position of the central object. |
| targetObject1 | Expression <Position> | No | Position of target object 1. |
| targetObject2 | Expression <Position> | No | Position of target object 2. |
| minAngle | Expression <MAL::Double> | No | Minimum angle subtended at the central object by target objects 1 and 2.. |
| maxAngle | Expression <MAL::Double> | No | Maximum angle subtended at the central object by target objects 1 and 2. |
| units | MAL::String | Yes | Optional. The angular unit name, as defined in reference [B6] annex D.  Default = ‘deg’. |

#### Effects [Optional]



Figure 3‑33: Effects

Effects are an optional element of the MPS information model that may be used in conjunction with planning resources. They specify the impact that executing a planning activity will have on planning resources. These may be used to predict the evolution of the values of planning resources over the period of a plan. This in turn enables the verification that sufficient resource is available for execution of the Plan and that all explicit resource constraints are satisfied.

The abstract type Effectidentifies the planning activity that causes the effect and the planning resource to which the effect is applied. The planning activity may be identified by ActivityDefinition, in which case it applies to all instances of that definition, or by a specific ActivityInstance. There are two concrete sub-types:

* Simple Effect
* Complex Effect

*Effect*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***Effect*** | **Extends** | *Constraint* | **SFP** | Abstract |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| activityRef | Expression <MAL::ObjectRef> | Yes | Object Type: ActivityInstance | ActivityDefinition.  Identifies the planning activity for which the resource effect applies. May be either an ActivityDefinition or an ActivityInstance. If omitted the activity containing the effect is assumed. |
| resourceRef | MAL::ObjectRef | No | Object Type: *Resource*  Identifies the planning resource that is constrained for the duration of the planning activity. |

These attributes are common to both sub-types.

Simple Effect

A simple effect applies the defined operation on the specified planning resource at the time relative to the planning activity defined by timeRef+timeOffset.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **SimpleEffect** | **Extends** | *Effect* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| timeRef | Slider | No | The point in the duration of the planning activity to which the time of the Effect is relative.  0: the start of the planning activity  1: the end of the planning activity |
| timeOffset | Expression <MAL::Duration> | No | Offset from timeRef that specifies the time at which the Effect is to be applied. |
| operator | EffectOperationEnum | No | Operation to be performed on the planning resource. One of: SET, INCREMENT, DECREMENT.  Increment and decrement are only applicable to numeric data types. |
| value | MAL::Attribute | No | The value that the planning resource is to be set to if the Effect operator is SET; or to be incremented/decremented by if it is INCREMENT or DECREMENT. |

EffectOperationEnum

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **EffectOperationEnum** | **SFP** |  |

| Status | Value | Description |
| --- | --- | --- |
| SET | 1 | Set to specified value |
| INCREMENT | 2 | Increment by specified value |
| DECREMENT | 3 | Decrement by specified value |

ComplexEffect

In the simple effect, the value of the impacted planning resource is set to the specified value at a single point in time.

With the complex effect, the value of the impacted planning resource can be evolved over a specified time period in accordance with a defined RelativeResourceProfile.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **ComplexEffect** | **Extends** | *Effect* | **SFP** |  |

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute | Type | Nullable | Description |
| startRef | Slider | No | Identifies the point in the duration of the referenced planning activity to which the start of the effect period relates. |
| endRef | Slider | No | Identifies the point in the duration of the referenced planning activity to which the end of the effect period relates. |
| startOffset | Expression <MAL::Duration> | No | Offset from startRef that specifies the start of the effect period. |
| endOffset | Expression <MAL::Duration> | No | Offset from endRef that specifies the end of the effect period. |
| operator | EffectOperationEnum | No | Operation to be performed on the planning resource. One of: SET, INCREMENT, DECREMENT.  Increment and decrement are only applicable to numeric data types. |
| Value | RelativeResourceProfile | No | Resource profile specifying an evolving value to which the value of the planning resource is to be set.  See §3.2.4.2 |

### Triggers



Figure 3‑34: Triggers

A trigger is a construct that allows specification of the specific condition or event that marks the start or end of something. It is used in the context of both planning activities and plans to specify when an activity should start.

The following sub-types of Trigger are supported:

* TimeTrigger: the trigger event is defined by time.
* PositionTrigger: the trigger event is defined by position.
* PointingTrigger: the trigger event is defined by pointing
* EventTrigger: the trigger event is defined in terms of a planning event.

Position and pointing triggers are optional elements of the MPS information model.

*Trigger*

All sub-classes of Trigger include the time at which they are predicted to occur (in advance of execution); and, where applicable, the time at which they actually occurred (post execution).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***Trigger*** | **Extends** | MAL::Composite | **SFP** | Abstract |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| time | MAL::Time | No | Predicted or actual time of Trigger. The predicted time may evolve during the planning process up to the time of execution. The actual time is only available post execution, and hence can only be provided by a plan execution function. |

#### Temporal Triggers

TimeTrigger

Sub-type of Trigger based on time. The trigger time is the specified constraint, and will usually match the predicted time on the base class during the planning process, but the actual time could still be slightly different post-execution.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **TimeTrigger** | **Extends** | *Trigger* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| triggerTime | MAL::Time | No | Planned time of Trigger. |

#### Position Triggers [Optional]

PositionTrigger

Sub-type of Trigger based on position. Depending on the coordinate type of position used, a margin may be specified in terms of distance from the specified position. This is not relevant for an OrbitalPosition, as an orbiting spacecraft would pass through the specified angle.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PositionTrigger** | **Extends** | *Trigger* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| triggerPosition | Position | No | Planned position of Trigger. |
| distanceMargin | Distance | Yes | Defines a sphere around the trigger position within which a position is considered to meet the trigger condition. |

#### Direction Triggers [Optional]

DirectionTrigger

Sub-type of Trigger based on pointing. Depending on the coordinate type of direction used, a margin may be specified in terms of angle from the specified direction. This is not relevant for a RevolutionDirection, as a rotating spacecraft or instrument would pass through the specified angle.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **DirectionTrigger** | **Extends** | *Trigger* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| triggerDirection | Direction | No | Planned direction of Trigger. |
| angleMargin | Angle | Yes | Defines a circle around the trigger direction within which a direction is considered to meet the trigger condition. |

#### Angle Trigger [Optional]

Angle Trigger

Sub-type of Trigger based on the angle subtended between three physical objects. The trigger angle is that subtended at the central object by target objects 1 and 2.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **AngleTrigger** | **Extends** | *Trigger* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| centreObject | Expression <Position> | No | Position of the central object. The trigger angle is that subtended at the central object by target objects 1 and 2. |
| targetObject1 | Expression <Position> | No | Position of target object 1. |
| targetObject2 | Expression <Position> | No | Position of target object 2. |
| angleMargin | Angle | No | The trigger occurs if the angle is within ± angleMargin of the trigger angle. |

#### Event Triggers

Event Trigger

Sub-type of Trigger based on planning event.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **EventTrigger** | **Extends** | *Trigger* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| triggerEvent | MAL::ObjectRef <EventInstance> | No | Reference to an EventInstance |
| timeOffset | MAL::Duration | No | Time offset from the EventInstance |

### Repetitions



Figure 3‑35: Repetitions

*Repetition*

A repetition is used to specify the repeated instantiation of a [set of] planning activities. Multiple sub-types of Repetition are defined to support the specification of repeat cycles by different criteria. It can be used in the context of a planning request to specify a standing order for repeated execution of the [set of] planning activities.

In the context of an ActivityNode embedded within a planning request (see 3.2.2.3), it is possible to nest one Repetition inside another, enabling the specification of complex repetitive sequences of activities.

All sub-types have the following attributes:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***Repetition*** | **Extends** | MAL::Composite | **SFP** | Abstract |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| count | MAL::Integer | Yes | Maximum number of repeat cycles/instances [optional].  If not specified there is no limit to the number of repetitions. |
| timeWindow | TimeWindow | Yes | Time period over which the repetition is applicable [optional].  If not specified repetition continues indefinitely. |
| separationType | SeparationTypeEnum | No | Specifies whether the repetition interval is **Relative** to the previous occurrence, or **Absolute** for all occurrences. |

For Repetitions, the interval between occurrences [the cadence] is expressed as a separation±tolerance.

If the separationType is Relative, then this defines the required interval between successive occurrences: Tn+1 = Tn+separation±tolerance. Consequently, the average interval over multiple occurrences may deviate from the specified separation.

If the separationType is Absolute, then the tolerance relates to a multiple of separation from the initial occurrence, and is not directly related to the interval between successive occurrences: Tn = T0+n\*separation±tolerance.

SeparationTypeEnum

|  |  |  |  |
| --- | --- | --- | --- |
| Name | **SeparationTypeEnum** | **SFP** |  |

| Enumeration | Value | Description |
| --- | --- | --- |
| RELATIVE | 1 | Tolerance on separation is only considered between any two occurrences |
| ABSOLUTE | 2 | Tolerance on separation applies to a multiple of the separation from the initial occurrence. |

#### Temporal Repetition

TemporalRepetition

A sub-type of Repetition based on time.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **TemporalRepetition** | **Extends** | *Repetition* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| initialTime | Expression <MAL::Time> | No | Nominal time of first occurrence. |
| separation | Expression <MAL::Duration> | No | The required time interval between occurrences. |
| tolerance | Expression <MAL::Duration> | No | The allowed tolerance (+/-) in the required time between occurrences, the interpretation of which is dependent on the separationType. |

#### Location Repetition [Optional]

*LocationRepetition*

A sub-type of Repetition based on Position. Separate concrete sub-types provide for repetitions based on generic position and orbital position.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***LocationRepetition*** | **Extends** | *Repetition* | **SFP** | Abstract |

PositionRepetition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **PositionRepetition** | **Extends** | *LocationRepetition* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| initialPosition | Expression <Position> | No | Nominal position of first occurrence. |
| repetitionDirection | Expression <Direction> | No | Direction of repetition. |
| separation | Expression <MAL::Double> | No | The required Distance between occurrences. |
| tolerance | Expression <MAL::Double> | No | The allowed tolerance (+/-) in the required distance between occurrences, the interpretation of which is dependent on the separationType. |
| units | MAL::String | Yes | The units used for separation and tolerance, as defined in reference [B6] annex D. |

OrbitRepetition

A sub-type of Repetition based on the orbital cycle.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **OrbitRepetition** | **Extends** | *LocationRepetition* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| orbitNumber | Expression <MAL::Long> | No | Orbit number for the first occurrence. Depending on the relativeOrbit flag, the orbit number may be absolute (since start of mission) or relative (to the orbital repeat cycle). |
| relativeOrbit | MAL::Boolean | No | Flag indicating if the orbit number is absolute or relative to the orbital repeat cycle. |
| orbitSeparation | Expression <MAL::Long> | No | The required number of orbits separation between occurrences. If orbitNumber is Relative and the required repetition is once per repeat cycle, this is the number of orbits in the repeat cycle, but the value 0 may also be used. |
| angleSeparation | Expression <MAL::Double> | No | The required angular separation between occurrences. This allows for multiple repetitions within an orbit. The value 0 indicates only one occurrence within the orbit. |
| orbitAngle | Expression <MAL::Double> | No | The required position of the first occurrence within the orbit expressed as an angle. |
| tolerance | Expression <MAL::Double> | No | The allowed tolerance (+/-) in the required orbital angle. |
| units | MAL::String | Yes | The units used for orbitAngle, angularSeparation, and tolerance, as defined in reference [B6] annex D. |

Note that the separationType is irrelevant in this case.

#### Pointing Repetition [Optional]

*PointingRepetition*

A sub-type of Repetition based on Pointing. Concrete sub-types provide for repetition based on direction and revolutions.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | ***PointingRepetition*** | **Extends** | *Repetition* | **SFP** | Abstract |

DirectionRepetition

A sub-type of Repetition based on direction, which supports the specification of astronomical surveys

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **DirectionRepetition** | **Extends** | *PointingRepetition* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| initialDirection | Expression <Direction> | No | Nominal direction of first occurrence. |
| targetDirection | Expression <Direction> | No | Specifies the direction of repetition as line connecting the initial and target directions. |
| separation | Expression <MAL::Double> | No | The required angle between occurrences. |
| tolerance | Expression <MAL::Double> | No | The allowed tolerance (+/-) in the required angle between occurrences, the interpretation of which is dependent on the separationType. |
| units | MAL::String | Yes | The units used for separation and tolerance, as defined in reference [B6] annex D. |

RevolutionRepetition

A sub-type of Repetition based on the revolutions of a rotating spacecraft or instrument.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **RevolutionRepetition** | **Extends** | *PointingRepetition* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| revsSeparation | Expression <MAL::Long> | No | The required number of revolutions between occurrences. |
| revsTolerance | Expression <MAL::Long> | No | The allowed tolerance (+/-) in the required number of revolutions between occurrences, the interpretation of which is dependent on the separationType. |
| revAngle | Expression <MAL::Double> | Yes | Specifies the angle within a revolution. |
| units | MAL::String | Yes | The units used for revAngle, as defined in reference [B6] annex D. |

#### Angle Repetition [Optional]

AngleRepetition

A sub-type of Repetition based on the angle subtended between three physical objects. The repetition angle is that subtended at the central object by target objects 1 and 2.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **AngleRepetition** | **Extends** | *Repetition* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| centreObject | Expression <Position> | No | Position of the central object. |
| targetObject1 | Expression <Position> | No | Position of target object 1. |
| targetObject2 | Expression <Position> | No | Position of target object 2. |
| initialAngle | Expression <MAL::Double> | No | Initial angle subtended at the central object by target objects 1 and 2. |
| separation | Expression <MAL::Double> | No | The required angle between occurrences.  If this is zero, this implies that repetition is between multiple occurrences of the initialAngle. |
| tolerance | Expression <MAL::Double> | No | The allowed tolerance (+/-) in the required angle between occurrences, the interpretation of which is dependent on the separationType. |
| units | MAL::String | Yes | The units used for separation and tolerance, as defined in reference [B6] annex D. |

The count attribute inherited from the abstract *Repetition* class can be used to specify how many repetitions should be planned. If the separation angle is zero, then repetition is based on each occurrence of the specified initialAngle. If the separation angle is non-zero, then this is used to indicate repetition at different subtended angles. For example, for an initial angle of 20° and a count of 5:

* if the separation is 2° then the activity is planned when the initial angle of 20° occurs, and then with 4 further repetitions at 2° intervals up to 28°.
* if the separation is 0° then the activity is planned for the next 5 occurrences of the initial angle of 20°

Note that repetitions can be nested to allow repetition over both occurrences and offset angles.

#### Event Repetition

Event Repetition

A sub-type of Repetition based on planning events.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | **EventRepetition** | **Extends** | *Repetition* | **SFP** |  |

| Attribute | Type | Nullable | Description |
| --- | --- | --- | --- |
| eventRef | Expression <MAL::ObjectRef> | No | Object Type: EventDefinition.  Reference to an EventDefinition (type of event) |
| separation | Expression <MAL::Long> | No | Number of occurrences of the planning event required between occurrences of the planning activity. |
| tolerance | Expression <MAL::Long> | No | The allowed tolerance (+/-) in the number of occurrences of the planning event between occurrences of the planning activity, the interpretation of which is dependent on the separationType. |

## MO Framework

This section gives a brief introduction to elements of the MO framework relevant to the MPS information model, organised in the following subsections:

* Message Abstraction Layer (MAL)
* MO Objects
* MO Object Patterns

For a full description of the MAL, the reader is referred to the corresponding CCSDS standard document [2].

The MPS information model is defined in terms of MO objects consistent with the concept defined in the MAL. The structure of MPS Objects is fully defined within this document, together with their relationships.

### Message Abstraction Layer (MAL)

For information to be carried by an MO compliant service, it must be defined in terms of the data types specified by the Message Abstraction Layer (MAL) to enable encoding of MAL messages in accordance with multiple MO Technology Bindings.

The MAL Attribute is the simplest MAL element; it cannot be decomposed into smaller elements and is used to build more complex structures. There is a non-extensible set of MAL Attribute types defined by the MAL, corresponding to common data types. These types are detailed in §3.3.1 above and directly referenced in the MPS information model using the form MAL::<AttributeType>. The MAL also allows the use of the type MAL::Attribute as a generic for any supported MAL Attribute type, effectively supporting polymorphism at this level.

The MPS information model uses the following data types are directly supported by the MAL:

* ObjectIdentity (a MAL composite structure defining the identity of an MO object)
* ObjectRef (a MAL attribute type referencing another MO object).

MAL Composites are compound data structures comprising multiple MAL Attributes. The MAL can transport any fixed data structure defined as a MAL Composite. The MAL supports polymorphism to the extent that data structures can include fields of abstract type. Abstract types can extend other abstract types, but concrete types cannot be extended. At run-time all abstract fields must be substituted by a data structure of a derived concrete type to enable encoding.

### MO Objects



Figure 3‑36: MO Objects

An MO object is an entity defined within the information model of an MO compliant service specification that has a unique identity enabling it to be referenced by other MO objects and in the body of MO service messages.

A representation of an MO object may also be carried in an MO compliant service message. To enable this, the MAL identifies MAL::Object as an abstract derived type of MAL::Composite with a single attribute which represents its identity. The MO compliant service specification defines its MO objects as data structures derived from MAL::Object, with the first (inherited) field identity.

The identity of an MO object is defined by an attribute of type MAL::ObjectIdentity. This is a MAL::Composite data structure containing the following attributes:

* domain an ordered list of MAL::Identifiers
* key MAL::Identifier
* version MAL::UInteger

The object identity includes the domain of the object, which allows for the concept of hierarchical namespacing. Note that an empty domain list is valid, to allow for simple deployments that do not use the concept of hierarchical namespacing.

Each object is assigned a key (Identifier) that is unique within the scope of the domain, and for the object type (specified as area + type). The area and type of the object are implicit and specific to each defined class of MO object. For objects defined in this standard, see Table 3‑1.

MO objects may have both static attributes that do not change and dynamic attributes that can change over time. For some types of object, it may be occasionally required to change the value of the static attributes, while maintaining the same object key for continuity. In this case, the MO object should include an evolving version. The combination of object key and version provides a unique identity for a specific version of the object and its static attributes. This approach is typically used for definition objects that may be occasionally updated, but also applies to some instance objects that have updatable static attributes, such as planning requests.

For MO objects that do not have evolving versions, the version should be set to 1. This allows the value 0 to be used as a wild-card in searches and filters.

Relationships with other MO objects can be defined within an MO object by including attributes of type MAL::ObjectRef. An ObjectRef can be used to specify all the fields of the object identity, including its explicit area and type, although a wild-card value of 0 may be used for version.

Where the reference is restricted in the service specification to a particular type of MO object, then the form ObjectRef<T> can be used, which must be of type T. An efficient encoding of a typed object reference may omit the area and type of the reference.

Examples of types of relationships that can be defined include:

* **Definition**: MO objects that are dynamically instantiated based on an existing definition may reference the corresponding definition object. An example is the relationship between and ActivityInstance and the corresponding ActivityDefinition.
* **Source**: MO objects that are dynamically instantiated may reference another object responsible for its creation. An example is the relationship between an ActivityInstance and its source planning RequestInstance.
* **Parent/Child**: MO objects that are hierarchically organised may reference their parent or child objects. Examples include hierarchical ActivityInstances and EventInstances.
* **Other**: special relationships that are specific to a class of MO objects. Examples include the relationship of an ActivityInstance to an EventInstance that governs its timing and/or input arguments.

The MPS Information Model defines the following ten classes of MO object:

* ActivityDefinition
* ActivityInstance
* EventDefinition
* EventInstance
* Resource
* RequestDefinition
* RequestInstance
* Plan
* MPSSystemConfig
* PlanningUser

### MO Object Patterns

The information objects associated with MO compliant services are often implemented as a compound set of objects, each of which is derived from the MO object. These compound objects often follow one of a number of common object patterns.

Three such MO object patterns, relevant to MPS, are illustrated in Figure 3‑37:

* MO Static Item
* MO State
* MO Dynamic Item

These share the following common elements:

* A unique identity that may be used to reference all occurrences of the information object (compound object) throughout the mission lifetime. This is a combination of the domain and a unique key (name or identifier) within the domain. The identity forms part of the definition object below.
* A definition that comprises the statically declared information associated with the information object. This may, for example, include a description, set of defined arguments or any other information that applies to all occurrences of the information object. There may be multiple versions of the definition over the mission lifetime associated with the same identity. Definitions are typically contained in configuration databases that are maintained off-line under version control and deployed for use in the on-line environment.
* An instance that is dynamically created for each new occurrence of the information object. This includes the unique instance ID of the occurrence and any unchanging data associated with it as a set of static attributes. It also includes the current status of the object as a set of dynamic attributes.
* An instance has a reference to its definition.
* An update is a data structure used to report the changing status of the information object or a specific occurrence of it at a specific point in time. This may include a current value, current processing state, or a current set of values for defined arguments. Updates may be generated periodically, or only when there is a change of status. Updates may be used to disseminate changing status and to record the detailed status history of the information object.

An update has a reference to its instance.

**MO Static Item Object Pattern**



**MO State Object Pattern**



**MO Dynamic Item Object Pattern**



Figure 3‑37: MO Object Patterns

#### MO Static Item Object Pattern

An MO Static Item is a single element information object that only comprises statically declared information with no evolving status. An MPS example is the MPSSystemConfig object that contains configuration parameters for an MPS system.

Static Items comprise only the definition object described above, with no corresponding update data structure.

#### MO State Object Pattern

An MO State is a single element information object representing a status: it is a persistent object for which there is only one set of dynamic status values at any given time (although this may not be known). MPS examples are planning resources, and plans.

MO States comprise two of the elements described above: a definition object and update data structure. As it is persistent rather than instantiated, status updates relate directly to the definition object. Note that for plans the corresponding definition object is created dynamically as part of the planning process, and is not normally considered part of the planning configuration data.

#### MO Dynamic Item Object Pattern

An MO Dynamic Item is a dual element compound information object representing any type of operation that is repeatable and extends over a measurable period of time. MPS examples include planning requests, planning activities and planning events.

MO dynamic item comprises all three of the elements described above: definition and instance objects and update data structure. As an MO dynamic item may be invoked multiple times, there may be multiple instance objects created from the same definition object. Updates relate to a specific instance object.

A details data structure may also be required to specify the information needed to create an instance from a definition. For example, this may include how to derive any argument values, or any specific constraints to be applied. The details do not themselves form part of the information object to which they relate, but may be embedded within another information object, typically the parent or source object responsible for creation of the instance.

For MPS, only planning activities have a details data structure defined, which may be embedded within a planning request or the definition of a parent activity to specify its children.

1. Definition of Acronyms  
   (Informative)

| Acronym | Definition |
| --- | --- |
| AOS | Acquisition Of Signal |
| COM | Common Object Model |
| CSS | Cross Support Services |
| LOS | Loss of Signal |
| MAL | Message Abstraction Layer |
| MO | Mission Operations |
| MOIMS | Mission Operations and Information Management Systems [CCSDS Area] |
| MPS | Mission Planning and Scheduling |
| NAV | CCSDS Navigation Working Group |
| NEM | Navigation Event Message |
| ODM | Orbit Data Message |
| PDS | Plan Distribution Service |
| PECS | Plan Execution Control Service |
| PES | Plan Edit Service |
| PI | Principal Investigator |
| PICS | Protocol Implementation Conformance Statement |
| PIMS | Plan Information Management Service |
| PRL | (PICS) Requirements List |
| PRM | Pointing Request Message |
| PRS | Planning Request Service |
| SANA | CCSDS Space Assigned Numbers Authority |
| SFN | Short Form Number |
| SFP | Short Form Part |
| TOO | Target Of Opportunity |
| UML | Unified Modelling Language |
| URI | Uniform Resource Identifier |
| URL | Uniform Resource Locator |
| URN | Uniform Resource Name |
| XML | eXtensible Markup Language |

1. Informative References  
   (Informative)

[B1] *Mission Operations Services Concept*. Issue 3. Report Concerning Space Data System Standards (Green Book), CCSDS 520.0-G-3. Washington, D.C.: CCSDS, December 2010.

[B2] *Mission Planning and Scheduling*. Issue 1. Report Concerning Space Data System Standards (Green Book), CCSDS 529.0-G-1. Washington, D.C.: CCSDS, June 2018.

[B3] *Mission Operations—Common Services*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 522.0-B-1. Washington, D.C.: CCSDS, May 2020.

[B4] *Mission Operations Monitor & Control Services*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 522.1-B-1. Washington, D.C.: CCSDS, October 2017.

[B5] *Navigation Data Messages Overview*. Issue 3. Informational Report (Green Book), CCSDS 500.2-G-3. Washington, D.C.: CCSDS, March 2023.

[B6] *Pointing Request Message*. Issue 1. Recommendation for Space Data Systems Standards (Blue Book), CCSDS 509.0-B-1. Washington, D.C.: CCSDS, October 2023 (incorporating Technical Corrigenda 1 and 2).

[B7] *Cross Support Service Management—Simple Schedule Format Specification*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 902.1-B-1. Washington, D.C.: CCSDS, May 2018.

[B8] *Space Engineering—Telemetry and Telecommand Packet Utilization*. ECSS-E-ST-70-41C. Noordwijk, The Netherlands: ECSS Secretariat, 15 April 2016.

[B9] “XML Path Language (XPath) 3.1.” Version 3.1, 21 March 2017. W3C. https://www.w3.org/TR/xpath-31/.

[B10] *Mission Operations—Message Abstraction Layer Binding to HTTP Transport and XML Encoding*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 524.3-B-1. Washington, D.C.: CCSDS, June 2018.

[B11] *Application and Support Layer Architecture*. Issue 1. Report Concerning Space Data System Standards (Green Book), CCSDS 371.0-G-1. Washington, D.C.: CCSDS, November 2020.

[D12] *Orbit Data Messages*. Issue 3. Recommendation for Space Data Systems Standard (Blue Book), CCSDS 502.0-B-3. Washington, D.C.: CCSDS, April 2023

1. Literal Formats In Expressions  
   (Informative)
   1. Introduction

When entering MPS data, it is often not possible to provide an absolute value for a required attribute, but instead a dynamic value can be specified as an expression (see §3.3.3) for derivation at run time. The expression can be provided as:

* A literal value
* A reference to an attribute or argument of an MO object
* A calculated value including one or more references to attributes or arguments of MO objects

The language used to represent the expression does not form part of this standard – any expression language can be used within a particular deployment. This annex specifies an optional simple XSD-based syntax for the specification of literal values and references that can be used in the absence of a complete expression language.

If used in an MPS Expression, the expressionLanguage field should be set to “MPSliteral”.

MPS Expressions can be of any MAL::Attribute type plus the MPS position and direction types, as detailed in the following table.

Table C1: MPS Expression Types

| # | Type | Expression Subclass | XSD Type | Comment |
| --- | --- | --- | --- | --- |
| 1 | Blob | Binary | hexbinary |  |
| 2 | Boolean | Boolean | boolean |  |
| 3 | Duration | Duration | duration |  |
| 4 | Float | Real | float |  |
| 5 | Double | double |  |
| 6 | Identifier | String | string | Format restricted to that of a MAL Identifier. Cannot contain the characters :.()\* as these have special meaning in the literal representation of an ObjectRef |
| 7 | Octet | Integer | byte |  |
| 8 | UOctet | unsignedByte |  |
| 9 | Short | short |  |
| 10 | UShort | unsignedShort |  |
| 11 | Integer | int |  |
| 12 | UInteger | unsignedInt |  |
| 13 | Long | long |  |
| 14 | ULong | unsignedLong |  |
| 15 | String | String | string |  |
| 16 | Time | Time | dateTime | Format constrained to CCYY-MM-DDThh:mm:ss.sss |
| 17 | FineTime | dateTime | Format constrained to CCYY-MM-DDThh:mm:ss.sssssssss |
| 18 | URI | String | anyURI |  |
| 19 | ObjectRef | Object | mal:ObjectRef | Corresponds to an XSD complex type |
| 129 | Direction | Direction | mps:Direction |  |
| 130 | Position | Position | mps:Position |  |

The # and Type columns correspond to the possible values of the ArgTypeEnum that defines the data type of the expression. This specifies the type of the result value of the evaluated expression.

The Expression Subclass column groups these types based on the operations (expression operators and syntax) relevant to them.

The XSD Type column maps each data type to its representation in XML schema.

This is presented in the following subsections:

C2 Literals for Expression Types corresponding to XSD simple types

C3 Literals for Object References

C4 Literals for Position and Direction Types

Within the specification of the literals for ObjectRef, Position and Direction, the names of the attributes of the corresponding composite data types are shown in *italics*. These attributes can be represented by the literal form of the corresponding XSD simple type for the attribute.

* 1. Literals for Expression Types Corresponding to XSD simple Types

For those expression types that can be mapped directly to XSD data types, as shown in Table E1 above, literal values can be supplied according to the rules defined for XML Schema in <https://www.w3.org/TR/xmlschema-2/>.

This applies to all types with the exception of ObjectRef, Direction and Position, for which special rules are defined in the following sections.

A literal value for these data types can be supplied directly for the Expression.value field, or included within the expression string itself.

MAL Identifiers are essentially represented as XSD strings, but have additional constraints as follows:

* The following characters cannot be used within a MAL Identifier, as they are used as delimiters in the literal representation of ObjectRefs (colon, period or dot and parentheses) :.()
* The “\*” character cannot be used within a MAL Identifier, as this is used to indicate a wildcard domain.

Times and FineTimes are both represented as XSD dateTimes, but with restricted format rules as outlined in the table above.

* 1. Literals for Object References

A reference to an MO object comprises multiple elements, all of which may need to be expressed in its literal representation:

* domain an ordered list of MAL::Identifiers
* area MAL::Identifier
* type MAL::Identifier
* key MAL::Identifier
* version MAL::UInteger

The area and type can be omitted where a field is constrained to be a reference to an MO object of specific type. The domain may be omitted where it is defined by context. The version may also be omitted where the current or latest version is assumed. In its simplest form a literal objectRef consists only of the key field, which is a MAL::Identifier represented as an XSD string.

The following literal format is defined for an ObjectRef:

*objectref* = [*area*:*type*:][*domain*[.*domain*]\*.]*key*[(*version*)]

The above returns a value of type ObjectRef. MO object references may also be used to access the values of attributes or arguments of the object in expressions of any type. The value returned has the type of the corresponding attribute or argument. The literal format above is extended as follows:

*objectref = objectref*.*attribute*[\[*index*|*name*\]]| o*bjectref*@*argument*[[\[*index*\]]

where *attribute* and *argument* are the names of the attribute or argument of the object respectively.

If the attribute or argument is itself a set or array, then a specific item can be referenced using an integer *index* enclosed in square brackets. In the specific case that an attribute is itself a collection of objects, then the required object can be specified by name.

Note: the name (or *key*) used to reference a specific object in a collection is dependent on the type of object. For Resources it is the name of the Resource; but for instantiated objects such as ActivityInstance and EventInstance it is the name of the associated Definition.

Note that where the returned value is itself an object reference, attribute references can be used iteratively to follow a sequence of references to the required value. For example:

[myActivityInst.source]@argA  
returns the argument argA of the parent ActivityInstance of myActivityInst

[myActivityInst.source].children[myActivityDef]  
returns an ObjectRef pointing to the sibling activity of myActivityInst that has the name myActivityDef.

Note: square brackets may be used to enclose an object reference to aid readability.

The special keyword “Me” may be used to reference the current object in context. This gives a shorthand form of referencing the attributes and arguments of an object:

Me.*attribute*

Me@*argument*

* 1. Literals for Position and Direction Types

As positions and directions are not supported as MAL::Attribute types, it is not possible to supply a literal value directly to the value attribute of an MPS expression. The literal value must be provided within the expression string. The expression language used is implementation dependent, but the following provides an optional simple XSD-based representation for positions and directions.

The position and direction types are specific to MPS and defined as abstract data types with multiple concrete subtypes representing different types of coordinates.

The literal representation of all types begins with the @ symbol, followed by two discriminator characters that indicate which coordinate subtype is represented.

For Positions this is as follows:

@PC(*x,y,z*)[*units*]:*frame* CartesianPosition

@PS(*longitude,latitude*[*,altitude*])[*units*[,*altitudeUnits*]]:*frame* SurfacePosition

@PF(*orbitFile*) OrbitFilePosition

@PO(*orbitNumber*,R|A,*orbitAngle*)[*units*] OrbitalPosition

@PN(*object*) ObjectPosition

@PR(*reference*) PositionReference

For Directions this is as follows:

@DC(*x,y,z*):*frame* CartesianDirection

@DS(*azimuth,elevation*)[*units*]:*frame* SphericalDirection

@DA(*ra,dec*)[*units*]:*frame* RADecDirection

@DN(*namedTarget*) NamedTargetDirection

@DR(*reference*) PDirectionReference

Where the named attributes are represented as XSD literals for the corresponding data type, with the exception of the relativeOrbit boolean flag in OrbitalPosition, which is represented as R (True for relative orbit) or A (False for absolute orbit). The *frame* attribute is represented by one of the defined string values for the coordinate system.

1. Security, SANA, and Patent Considerations   
   (Informative)
   1. Security Considerations
      1. System Security Requirements

Security requirements are applicable to MPS service specifications rather than the MPS Information Model that is the subject of this recommended practice.

Security requirements are specific to the deployed mission system and can vary significantly between different mission systems. The MPS services or file formats support a limited subset of the interactions supported by a typical mission system, and as such must be capable of deployment in the context of a mission or organization specific security architecture that supports multiple services.

The mission security architecture shall address the following:

* Protection of the communications link between MPS service consumer and provider to ensure data integrity and confidentiality. This may or may not include the encryption of service messages, depending on mission specific requirements.
* Control of access to specific MPS services, service operations and service data through the management of access rights associated with registered service users.
* Authentication to ensure only genuine registered service users have access to MPS services and to ascertain their level of access rights.

For the MPS services, the security considerations of this specification are the same as those of the MAL in reference [2]. Specifically, authentication and authorization of a participating consumer or provider is provided by the MAL access control concept and is covered in subsections 3.6, 5.2, and 5.3 of the Reference Model (reference [1]).

Security of the communications link carrying the MPS services is delegated to the implementation of the underlying Transport Layer.

For MPS file formats, this specification only addresses the format of the files, not the method of transfer. All security considerations relating to the transfer of these files must therefore be addressed by the actual file transfer service and security architecture of the deployed mission system.

* + 1. Potential Threats

In many mission systems, mission planning is the principal or nominal way of controlling the mission. Unauthorized access to the MPS services can therefore be a means of sabotaging the mission:

* Dangerous planning requests could be injected into the system. This is mitigated by the Planning function itself, the implementation of which can be used to detect and flag potentially dangerous requests either for automatic rejection or to obtain authorization from the mission planner.
* Planning requests and plans may contain confidential information about submitted planning requests or planned activities.
* Unauthorized plans could be injected into the system.
  + 1. Access Control

The MPS services are closely tied to the Access Control aspect of the MAL where returned authentication identifiers are used in the MAL message header to authenticate and authorise messages via Access Control.

Registered users are assigned roles (access rights) that may limit their access to MPS services. The set of access control roles is specific to the service deployment. An implementation of the MPS service provider can than restrict access to services, service capability sets, and individual service operations based on the assigned roles. Similarly roles can be used to restrict access to a subset of service data, either by data class or domain.

Which access control roles are supported is specific to the mission deployment and depends on the access control requirements for the mission. Typical MPS roles include access to:

* Individual MPS Services.
* Restricted Capbility Sets or individual Operations of an MPS Service: more sensitive operations may require a special access control role.
* Data class or domain of contained information (for example to restrict access to a specific spacecraft, subsystem or payload in terms of available planning requests and planning activities)
* Information pertaining to other users: access for some users may be restricted to their own planning requests and planned activities.
* Submission of custom planning requests: access for some users may be restricted to predefined planning requests.

It is the responsibility of the implementation of the MPS service provider to enforce access control based on the assigned user roles.

* + 1. Data Integrity

As stated previously, the confidentiality and integrity of MPS service messages is delegated to the implementation of the underlying transport layer.

This is dependent on the technology used for the implementation of the transport layer and the corresponding MAL technology binding. It may include the encryption of the service messages,.

* + 1. Authentication

Authentication for the MPS Services, as for all MO Services, may be supported through the MO Common Login Service (reference [E3]).

The Login service allows a service user to provide authentication information to the system. It takes the user’s credentials and uses a deployment-specific mechanism to authenticate the user; the result of this is used by the MAL during access control.

The Login service and the access control provided by the MAL are fully dependent on a deployment-specific security architecture (for example, the authentication protocol Kerberos). Both layers (Common and MAL) provide access to, and use of, this security service; they do not implement it themselves.

* + 1. Confidentiality

For some missions, there may be commercial or security considerations that result in a need for confidentiality of planning requests and resultant planned activites.

Where this is the case, the MPS service provider may be required to implement an access control filter on the return of information to users. In particular:

* Visibility of planning requests may be restricted (based on a specific access control role) to those raised by the user currently accessing the service.
* Distributed plans may similarly be filtered to restrict visibility of the planned activites resulting from restricted planning requests. A partial plan would then be returned in place of the full unrestricted plan.

It is mission and deployment specific how this is implemented, but it is expected that this would make use of special access control roles assigned to users. This may typically restrict access to information based on a level of access rights:

1. All Information
2. User’s Own + Unrestricted Information
3. Only User’s Own Information
   * 1. Auditing

The MPS Services include the potential to access the evolving state of planning requests and plans (together with their contained planning activities, planning events and planning resources) through the delivery of status updates pertaining to the corresponding MPS data items.

The full set of updates provides a comprehensive audit trail on the execution of MPS service operations at the level of planning requests and plans.

While storage of and access to historical updates is not directly supported by the MPS Service specification, this provides the potential for a service provider to implement such an audit trail.

* + 1. Availability

Availability requirements are mission specific. The required availability of an MPS service provider implementation will impact its design, both in terms of the physical deployment architecture and its software implementation.

* 1. SANA Considerations

This recommended practice specifies an MPS information model with associated data structures. MPS service specifications that utilise this information model will require that SANA populate the registry specified in reference [2] with the derived XML specification, which will include the data structures described in this document, defined at MPS area level.

There is no product arising from this recommended practice that is required to be placed in the SANA registry.

* 1. Patent Considerations

The recommendations of this document have no patent issues.

1. Note: from an MO MAL perspective this formally corresponds to MAL::ObjectRef<MAL::Object>, where it is constrained to be any MO object. [↑](#footnote-ref-1)
2. Object, ObjectIdentity, and ObjectRef are proposed for inclusion in issue 3.0 of the MAL [↑](#footnote-ref-2)