National Aeronautics and
Space Administration

**KSC-DPV-0102**
**REVISION A**

# DATA PRESENTATION AND VISUALIZATION (DPV) INTERFACE CONTROL DOCUMENT

# Data Presentation and Visualization (DPV)
# Interface Control Document (ICD)

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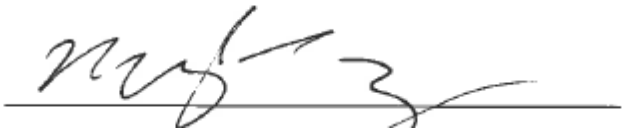

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## RECORD OF REVISIONS

| REV | DESCRIPTION | DATE |
|---|---|---|
| Basic | Document Baseline | March 23, 2009 |
| A | Updated to reflect DPV tool upgrades and document the MPC3 specification | March 9, 2015 |

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# 1. Introduction

## 1.1. Background

Data Presentation and Visualization (DPV) is a subset of the modeling and simulation (M&S) capabilities at Kennedy Space Center (KSC) that endeavors to address the challenges of how to present and share simulation output for analysts, stakeholders, decision makers, and other interested parties. DPV activities focus on the development and provision of visualization tools to meet the objectives identified above, as well as providing supporting tools and capabilities required to make its visualization products available and accessible across NASA.

## 1.2. Purpose

The DPV Interface Control Document (ICD) outlines the formats and processes required to move simulation data from an authoritative source into a DPV tool. It is intended as a guide for external project developers who need to build DPV-compatible export functionality into their applications.

## 1.3. Scope

This document will provide a detailed explanation of the inputs required to recreate a simulation within a DPV visual environment. It is intended for developers of authoritative analysis tools to assist them in creating data export applications.

# 2. Terminology

A common set of terms is required to foster understanding among simulation providers, DPV teams, and DPV end users. With respect to all DPV products and processes, the following definitions should be applied.

**Data Presentation:** The display and distribution of data for review and discussion. Data presentation occurs to present the final results of a test, study or concept. Data cannot be added to, removed, modified or manipulated.

**Data Visualization:** The integration and visual representation of data. Data visualization occurs to develop a meaningful understanding of the data under evaluation during a test, study or concept. The data may be combined with other data sets and manipulated as needed.

**Mission:** All scene elements and telemetry files required to recreate the results of a specific simulation activity within a DPV environment.

**Model**: The geometric representation of an object. Specifically, it is a computer graphics file that can be loaded and processed by a software application. A model serves as the visual representation of a simulated element within a visualization environment.

**Scene:** A specific collection of models to be displayed in a visualization environment. A single scene may have multiple simulations associated with it.

**Simulation:** Time-dependent data to be visualized within a DPV environment.

**Simulation Activity:** The collective design, development and execution of work performed in an authoritative simulation tool for a specific concept development or analysis task. Results from simulation activities are provided to DPV teams for recreation within their visualization tools.

**Telemetry:** Data provided by an authoritative source to identify how the dynamic objects in a scene behave or how time-dependent parameters change as the simulation progresses.

# 3. Roles

The process to move data from an authoritative simulation environment into a DPV-provided tool requires the communication and sharing of data between several parties. Each party holds one or more of the roles identified below.

**Mission Builder:** The person or group who integrates one or more sets of simulation data with models and scene data to create an overall mission. Items such as cameras and lighting are integrated based on feedback from the simulation developers and users to properly convey desired data or issues.

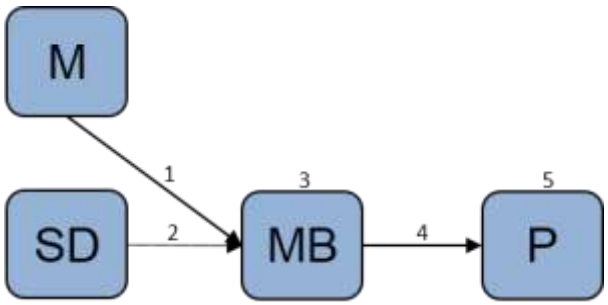
**Modeler:** The person or group who creates the individual graphics elements for inclusion in a graphics scene.

**Presenter:** The person or group responsible for obtaining the final data from the Mission Builder for presentation purposes.

**Simulation Developer:** The person or group who develops the simulation and generates telemetry for inclusion in a mission.

# 4. Generic Data Flow

The flow of data across the roles defined in Section 3 varies with the simulation activity requiring DPV support. In some instances the data exchanged between roles exists as physical files. In others the data exchanged is tool or interface information. The generic process for moving a simulation into or through DPV tools is provided in this section. Use cases illustrating specific applications of this data flow are provided in Appendix F.



(1) The **Modeler (M)** provides geometric models to the **Mission Builder (MB)** for integration with telemetry data. It is critical that all reference frames and units are clearly understood and conveyed from the Modeler to the Mission Builder.

(2) The **Simulation Developer (SD)** provides simulation data to the **Mission Builder (MB)** for integration with geometric models and any other applicable mission telemetry. It is critical that all reference frames and units are clearly understood and conveyed from the Simulation Developer to the Mission Builder.

(3) The **Mission Builder (MB)** integrates models and telemetry from all required providers to create the overall Mission. The integrated Mission data could itself become a simulation source, generating additional data based on the data received.

(4) The **Mission Builder (MB)** exports data from the Mission and provides the files to the **Presenter (P)** for sharing with Mission stakeholders. The form of this data may include the MPC3 specification utilizing both the mission and data file formats for ingestion into an interactive data presentation system, or could include sets of animations and pictures for incorporation into static presentation. For the purposes of the DPV ICD, the presenter is an interactive system.

(5) The **Presenter (P)** imports the Mission data and provides stakeholder access to the interactive system.

# 5. Model Process Control Telemetry

To best support the variety of simulation tools within NASA and ensure their continued support as simulation and DPV tools evolve, DPV has chosen to define and standardize on a single telemetry format called Model Process Control (MPC). Data Presentation tools will be capable of receiving and processing telemetry in the MPC format. Data Visualization tools will be capable of receiving, processing and providing telemetry in the MPC format.

## 5.1. History

The original MPC telemetry format was a comma-delimited text file. Each line entry was associated with a unique object and point in time, and contained 14 fields defining object position, orientation, scale, visibility, and any commands to be executed by the visualization environment. Each object in the simulation had to be represented at each time step and all 14 fields were required to form a valid line of telemetry.

The second version of the MPC file format, MPC2, began utilizing XML to enable better readability, usability, and expandability. It retained the same data for each object (position, orientation, scale and visibility) but dropped the command section, and adopted a state change philosophy so that objects not moving or changing from one time step to the next did not need to be included for that given time step. MPC2 also introduced new telemetry concepts of metadata and parenting. Metadata, declared in a new initialization section, allowed the user to capture “extra” time dependent data that was pertinent to the mission but not generally used for visualizing the motion of objects.

Parenting allowed the data stream to dynamically alter the parent object of another object as a function of time.

MPC3 is the latest generation of the XML-based format created to transfer dynamic simulation information. It contains several changes to improve the usability of the format by software developers, improve the definition of data, and expand the data incorporated in the format. As a result of this effort, MPC3 is now comprised of two files: a mission setup file for defining the objects within the simulation, and a data file that contains the dynamic data for a given simulation/visualization.

## 5.2. MPC Specification

The following sections provide a general syntax for each file and a detailed description for each element found within the specification. For each element the following is provided: a general description is given to explain what the data stored within the element represents, the specific XML format for the element, a breakdown for each attribute available for the element, and a listing of any child elements that can be provided. For each attribute the following is provided: a description of the attribute is provided to explain the data associated with the attribute, the occurrence requirement for the attribute, the type of the value, the valid values, and the default value if not found. For each child element, the number of instances of that child is provided, ranging from “0” for not required, to “1” if it can occur only once, and “N” if the child can be provided any number of times.

## 5.3. Mission File

The MPC mission setup file contains the data needed to construct the visualization. This data includes the object hierarchy, lighting, and any cameras for viewing the scene. Also included in the mission file is a list of valid telemetry data sets for use with the scene. The general syntax is shown below, followed by descriptions of the elements and attributes.

```
<mpcMission version="3.0" epoch=" YYYY-MM-DDTHH:mm:ss.ssZ " author="string" baseFilePath="dir/”>
    <note>Mission description</note>
        <scene name="string" baseFilePath="dir/">
            <note>Scene description</note>
            <units time="unit" distance="unit" angle="unit" force="unit"/>
            <environment type="type" up="0 0 1" forward="1 0 0">
                <!-- Background options -->
                <backgroundColor color="r g b"/>
                <backgroundTexture tiling="1 1" offset="0 0" filePath="filepath"/>
                <skybox>
                    <front tiling="1 1" offset="0 0" filePath="front.tif"/>
                    <back tiling="1 1" offset="0 0" filePath="back.tif"/>
                    <top tiling="1 1" offset="0 0" filePath="top.tif"/>
                    <bottom tiling="1 1" offset="0 0" filePath= “bottom.tif"/>
                    <left tiling="1 1" offset="0 0" filePath="left.tif"/>
                    <right tiling="1 1" offset="0 0" filePath="right.tif"/>
```

```
</skybox>
<light type="type" parent="ID" color="r g b" unitDistance="unit" pos="x y
z" forward="x y z" intensity="value" unitAngle="unit" spotCutoff="value"
range="value"/>
<camera name="name" unitAngle="unit" fov="value" unitDistance="unit"
 pos="x y z" up="x y z" forward="x y z" parent="ID"  track="ID2"/>
</environment>
<objects baseFilePath="dir/">
<terrain id="ID" name ="name">
    <note>Description of terrain</note>
    <offset unitDistance="unit" pos="x y z" quat="x y z w"/>
    <geometry>
      <model type="type" unitDistance="unit" pos="x y z" quat="x y z w"
      scale="1" unitModel="unit" filePath="dir1/base.tif" tiling="1 1"
      offset="0 0" textureFilePath="dir2/base.png"/>
    </geometry>
</terrain>
<object id="ID" isStatic="1" name="name">
    <note>Description of object</note>
    <offset unitDistance="unit" pos="x y z" quat="x y z w"/>
    <geometry>
      <model unitDistance="unit" pos="x y z" quat="x y z w" scale="1"
      unitModel="unit" filePath="dir1/base.tif"/>
    </geometry>
    <object id="ID2" isStatic="1" name="name">
        …
    </object>
    <joint id="ID3" type="type" name="name">
        <note> Description of Joint</note>
        <pin unitDistance="unit" pos="x y z" quat="x y z w"/>
        <geometry>
           <model unitDistance="unit" pos="x y z" quat="x y z w"
           scale="1" unitModel="unit" filePath="dir1/base.tif"/>
        </geometry>
        <object id="ID4" isStatic ="1" name="name">
                …
        </object>
    </joint>
    <thruster id="ID5" name="name">
        <note> Description of Thruster</note>
        <offset unitDistance="unit" pos="x y z" quat="x y z w"/>
        <geometry>
            <model unitDistance="unit" pos="x y z" quat="x y z w"
            scale="1" unitModel="unit" filePath="dir1/base.tif"/>
        </geometry>
    </thruster>
</object>
```

```
            </objects>
        </scene>
    <telemetries baseFilePath="dir/">
        <telemetry name="string" type="type" format="format" epoch="YYYY-MM-
        DDTHH:mm:ss.ssZ" source="location">
            <note>Telemetry description</note>
        </telemetry>
    </telemetries>
</mpcMission>
```

### 5.3.1. Mission Level Element Definitions

**<mpcMission>**

**Description** The primary element of the mission file. This element encompasses all other elements of the file.

**Format**

```
<mpcMission version="3.0" epoch="YYYY-MM-
DDTHH:mm:ss.ssZ" author="string" baseFilePath="dir/"> …
</mpcMission>
```

**Attributes**

*version*

| | |
|---|---|
| Description: | Defines the version of the MPC file. |
| Occurrence: | Required |
| Type: | String |
| Values: | 3.0 |
| Default: | None |

*epoch*

| | |
|---|---|
| Description: | Used to specify a Gregorian date/time value in UTC that should map to time "zero" of the simulation data, i.e. the double precision time value 0.0. This value is used when the data is being integrated with other data, including celestial body data. |
| Occurrence: | Optional |
| Type: | String, following ISO 8601 standard YYYY-MM-DDTHH:mm:ss.ssZ |
| Values: | User Defined |
| Default: | Application defined |

*author*

| | |
|---|---|
| Description: | Name of the mission developer |
| Occurrence: | Optional |
| Type: | String |
| Values: | User Defined |
| Default: | Empty String |

*baseFilePath*

Description: Provides a default path location where all future filePaths within the mission may be relative to
Occurrence: Optional
Type: String
Values: User defined
Default: Mission file directory

**Subelements** **note (0..1)**
**scene (1..1)**
*telemetries (0..1)*

**<note>**

**Description** A note is an optional element used to provide descriptions or additional information that may be of interest regarding the overall mission file. Only one note is expected in any given section that provides the ability to store a note. The data contained within the note is not designed to be used by software reading MPC, other than for display purposes, but should be maintained with the MPC file if the file is imported and exported.

**Format** <note>string</note>

**Attributes** None
**Subelements** None

## 5.3.2. Scene Section Element Definitions

**<scene>**

**Description** Scene is the main element tag for the section, enclosing all scene elements. Only one scene section is allowed within the mission file and is required.

**Format** <scene name="string" baseFilePath="dir/">…</scene>

**Attributes**
*name*

Description: Informative name can be provided for the scene
Occurrence: Optional
Type: String
Values: User Defined
Default: Empty String

*baseFilePath*

Description: Provides a default path location where all future filePaths within the Scene element may be relative to
Occurrence: Optional

Type: String
Values: User defined
Default: Mission Base File Path

**Subelements** note (0..1)
units (0..1)
environment (1)
objects (1)

**<units>**

**Description** The units element is used to set the units for each of the supported types throughout the scene and for each type not specified by telemetry.

**Format** <units time="unit" distance="unit" angle="unit" force="unit"/>

**Attributes**

*time*

Description: Unit of time to be used in the absence of specification.
Occurrence: Optional
Type: String
Values: millisecond, second, minute, hour, day
Default: second

*distance*

Description: Unit of distance to be used in the absence of specification.
Occurrence: Optional
Type: String
Values: millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile
Default: meter

*angle*

Description: Unit of angle to be used in the absence of specification.
Occurrence: Optional
Type: String
Values: degree, radian
Default: degree

*force*

Description: Unit of force to be used in the absence of specification.
Occurrence: Optional
Type: String

Values: newton, pound
Default: newton

**Subelements** None

**<environment>**

**Description** The environment element encompasses the properties used for setting up the general environment aspects of the scene.

**Format** <environment type=”string” up=” x y z” forward=” x y z” baseFilePath=”dir/”>…</environment>

**Attributes**

*type*

Description: Determines the default tool specific background of the scene
Occurrence: Optional
Type: String
Values: Earth, Moon, Mars, Space, Custom
Default: Custom

*up*

Description: Specifies the default “up” direction of the scene
Occurrence: Optional
Type: Set of three doubles
Values: User defined unit vector orthogonal to “forward” direction
Default: 0 0 1

*forward*

Description: Specifies the default “forward” direction of the scene
Occurrence: Optional
Type: Set of three doubles
Values: User defined unit vector orthogonal to “up” direction
Default: 1 0 0

*baseFilePath*

Description: Provides a default path location where all future filePaths within Environment element may be relative to
Occurrence: Optional
Type: String
Values: User defined
Default: Scene Base File Path

**Subelements**

backgroundColor (0..1)
backgroundTexture (0..1)
skybox (0..1)
light (0..N)
camera (0..N)

**<backgroundColor>**

**Description** The backgroundColor element specifies the color to use for a scene backdrop if no backgroundTexture element or skybox element is specified or supported.

**Format** <backgroundColor color=”r g b”/>

**Attributes**

*color*

| | |
|---|---|
| Description: | The color to use for the background |
| Occurrence: | Required |
| Type: | r g b |
| Values: | User defined set of three doubles clamped at 0 and 1 |
| Default: | None |

**Subelements** None

**<backgroundTexture>**

**Description** The backgroundTexture element specifies the texture for a scene backdrop if no skybox element is specified or supported. The specified texture is warped to the inner surface of the bounding volume of the scene. A backgroundTexture element overrides any specified backgroundColor element.

**Format** <backgroundTexture tiling=”x y” offset=”x y” filePath=”string”/>

**Attributes**

*tiling*

| | |
|---|---|
| Description: | The number of repetitions of the texture to use in the width and height directions |
| Occurrence: | Optional |
| Type: | Set of two integers |
| Values: | User defined set of two non-negative non-zero integers |
| Default: | 1 1 |

*offset*

Description: The offset of the top left corner of the texture from the top left corner of the planar surface of the bounding volume of the scene
Occurrence: Optional
Type: Set of two integers
Values: User defined set of two non-negative integers
Default: 0 0

*filePath*

Description: Path to a texture file
Occurrence: Required
Type: String
Values: User defined file path, either absolute, or relative to Environment Base File Path
Default: None

**Subelements** None

**<skybox>**

**Description** The skybox element encompasses the specification of a set of six textures for a scene backdrop. The specified textures are applied to each of the 6 primary directions.

**Format** <skybox> … </skybox>

**Attributes** None

**Subelements** front (1..1)
back (1..1)
top (1..1)
bottom (1..1)
left (1..1)
right (1..1)

**<front>**

**Description** Defines the texture to be applied to the front wall of the skybox.

**Format** <front tiling=”x y” offset=”x y” filePath=”string”/>

**Attributes**

*tiling*

Description: The number of repetitions of the texture to use in the width and height directions
Occurrence: Optional
Type: Set of two integers

Values: User defined set of two non-negative non-zero integers
Default: 1 1

*offset*

Description: The offset of the top left corner of the texture from the top left corner of the front plane of the skybox
Occurrence: Optional
Type: Set of two integers
Values: User defined set of two non-negative integers
Default: 0 0

*filePath*

Description: Path to a texture file
Occurrence: Required
Type: String
Values: User defined file path, either absolute, or relative to Environment Base File Path
Default: None

**Subelements** **None**

**<back>**

**Description** Defines the texture to be applied to the back wall of the skybox.

**Format** <back tiling=”x y” offset=”x y” filePath=”string”/>

**Attributes**

*tiling*

Description: The number of repetitions of the texture to use in the width and height directions
Occurrence: Optional
Type: Set of two integers
Values: User defined set of two non-negative non-zero integers
Default: 1 1

*offset*

Description: The offset of the top left corner of the texture from the top left corner of the front plane of the skybox
Occurrence: Optional
Type: Set of two integers
Values: User defined set of two non-negative integers
Default: 0 0

*filePath*

Description: Path to a texture file

Occurrence: Required
Type: String
Values: User defined file path, either absolute, or relative to Environment Base File Path
Default: None

**Subelements** None

**<top>**

**Description** Defines the texture to be applied to the top wall of the skybox.

**Format** <top tiling=”x y” offset=”x y” filePath=”string”/>

**Attributes**

*tiling*

Description: The number of repetitions of the texture to use in the width and height directions
Occurrence: Optional
Type: Set of two integers
Values: User defined set of two non-negative non-zero integers
Default: 1 1

*offset*

Description: The offset of the top left corner of the texture from the top left corner of the front plane of the skybox
Occurrence: Optional
Type: Set of two integers
Values: User defined set of two non-negative integers
Default: 0 0

*filePath*

Description: Path to a texture file
Occurrence: Required
Type: String
Values: User defined file path, either absolute, or relative to Environment Base File Path
Default: None

**Subelements** **None**

**<bottom>**

**Description** Defines the texture to be applied to the bottom wall of the skybox.

**Format** <bottom tiling=”x y” offset=”x y” filePath=”string”/>

**Attributes**

*tiling*

| | |
|---|---|
| Description: | The number of repetitions of the texture to use in the width and height directions |
| Occurrence: | Optional |
| Type: | Set of two integers |
| Values: | User defined set of two non-negative non-zero integers |
| Default: | 1 1 |

*offset*

| | |
|---|---|
| Description: | The offset of the top left corner of the texture from the top left corner of the front plane of the skybox |
| Occurrence: | Optional |
| Type: | Set of two integers |
| Values: | User defined set of two non-negative integers |
| Default: | 0 0 |

*filePath*

| | |
|---|---|
| Description: | Path to a texture file |
| Occurrence: | Required |
| Type: | String |
| Values: | User defined file path, either absolute, or relative to Environment Base File Path |
| Default: | None |

**Subelements** None

**<left>**

**Description** Defines the texture to be applied to the left wall of the skybox.

**Format** <left tiling=”x y” offset=”x y” filePath=”string”/>

**Attributes**

*tiling*

| | |
|---|---|
| Description: | The number of repetitions of the texture to use in the width and height directions |
| Occurrence: | Optional |
| Type: | Set of two integers |
| Values: | User defined set of two non-negative non-zero integers |
| Default: | 1 1 |

*offset*

| | |
|---|---|
| Description: | The offset of the top left corner of the texture from the top left corner of the front plane of the skybox |
| Occurrence: | Optional |

Type: Set of two integers
Values: User defined set of two non-negative integers
Default: 0 0

*filePath*

Description: Path to a texture file
Occurrence: Required
Type: String
Values: User defined file path, either absolute, or relative to Environment Base File Path
Default: None

**Subelements** None

**<right>**

**Description** Defines the texture to be applied to the right wall of the skybox.

**Format** <right tiling=”x y” offset=”x y” filePath=”string”/>

**Attributes**

*tiling*

Description: The number of repetitions of the texture to use in the width and height directions
Occurrence: Optional
Type: Set of two integers
Values: User defined set of two non-negative non-zero integers
Default: 1 1

*offset*

Description: The offset of the top left corner of the texture from the top left corner of the front plane of the skybox
Occurrence: Optional
Type: Set of two integers
Values: User defined set of two non-negative integers
Default: 0 0

*filePath*

Description: Path to a texture file
Occurrence: Required
Type: String
Values: User defined file path, either absolute, or relative to Environment Base File Path
Default: None

**Subelements** None

**<light>**

**Description** The light element is used to specify a light source for illuminating the scene.

**Format** <light type="string" parent="ID" color="r g b" unitDistance="unit" pos="x y z" forward="x y z" intensity="value" unitAngle =”unit” spotCutoff="value" range=”value”/>

**Attributes**

*type*

| | |
|---|---|
| Description: | Defines the type of the light |
| Occurrence: | Required |
| Type: | String |
| Values: | point, directional |
| Default: | None |

*parent*

| | |
|---|---|
| Description: | Defines a parent object to which the light is attached such that if the parent object moves, the light moves with it. |
| Occurrence: | Optional |
| Type: | String |
| Values: | Valid identification key of object defined within initialization section |
| Default: | Empty String |

*color*

| | |
|---|---|
| Description: | Color of the light |
| Occurrence: | Optional |
| Type: | Set of three doubles for Red, Green, and Blue |
| Values: | User defined set of three doubles clamped at 0 and 1 |
| Default: | 1 1 1 |

*unitDistance*

| | |
|---|---|
| Description: | Units for distance to be applied to the light position |
| Occurrence: | Optional |
| Type: | String |
| Values: | millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile |
| Default: | Scene unit of distance |

*pos*

| | |
|---|---|
| Description: | Defines the position of the light in world coordinates or relative to the parent object, if specified. |
| Occurrence: | Optional |
| Type: | Set of three doubles |

Values: User defined
Default: 0 0 0

*forward*

Description: Defines the forward direction for the light source in world coordinates or relative to the parent object, if specified.
Occurrence: Optional
Type: Set of three doubles
Values: User defined unit vector
Default: 0 0 1

*intensity*

Description: Defines the intensity of the light source
Occurrence: Optional
Type: Double
Values: 0 to 100
Default: 100

*unitAngle*

Description: Units for angle to be applied to this light's spotCutoff
Occurrence: Optional
Type: String
Values: degree, radian
Default: Scene unit of angle

*spotCutoff*

Description: For a point light source, defines the spot cutoff angle
Occurrence: Optional
Type: Double
Values: If in degrees, 0 to 90, or the special value of 180
If in radians, 0 to PI/2 or special value of PI
Default: 180 degrees or PI radians

*range*

Description: Defines the range of the light using the unitDistance
Occurrence: Optional
Type: Double
Values: User defined
Default: infinite

**Subelements** **None**

**<camera>**

**Description** Provides the ability to define a camera, or view into the scene, that will be available to the user of a visualization system leveraging the mission file. Note, the first camera specified defines the initial view into the scene.

**Format** <camera name="string" unitAngle="unit" fov="value" unitDistance="unit" pos="x y z" up="x y z" forward="x y z" parent="ID" track="ID2"/>

**Attributes**

*name*

Description: Provides a descriptive name for the camera
Occurrence: Required
Type: String
Values: User defined
Default: None

*unitAngle*

Description: Units for angle to be applied to this camera's data
Occurrence: Optional
Type: String
Values: degree, radian
Default: Scene unit of angle

*fov*

Description: Defines the field of view of the camera.
Occurrence: Optional
Type: Double
Values: 0<FOV<180 if Angle Units are in degrees, 0<FOV<PI if Angle Units are in Radians
Default: Application Defined

*unitDistance*

Description: Units for distance to be applied to the camera's data
Occurrence: Optional
Type: String
Values: millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile
Default: Scene unit of distance

*pos*

Description: Defines the position of the camera in world coordinates or relative to the parent object, if specified.
Occurrence: Optional

Type: Set of three doubles
Values: User defined
Default: 0 0 0

*up*

Description: Defines the up axis of the camera in world coordinates or relative to the parent object, if specified.
Occurrence: Optional
Type: Set of three doubles
Values: User defined unit vector orthogonal to “forward” direction
Default: 0 1 0

*forward*

Description: Defines the forward direction for the camera in world coordinates or relative to the parent object, if specified.
Occurrence: Optional
Type: Set of three doubles
Values: User defined unit vector orthogonal to “up” direction
Default: 0 0 1

*parent*

Description: Defines a parent object to attach the camera to such that if the parent object moves, the camera moves with it.
Occurrence: Optional
Type: String
Values: Valid identification key of object defined within initialization section.
Default: Empty String

*track*

Description: Defines an object that the camera will track.
Occurrence: Optional
Type: String
Values: Valid identification key of object defined within initialization section.
Default: Empty String

**Subelements** None

**<objects>**

**Description** Provides the container for all objects and the associated hierarchy.

**Format** <objects baseFilePath="dir/">

**Attributes**

*baseFilePath*

| | |
|---|---|
| Description: | Provides a default path location where all future filePaths may be relative to |
| Occurrence: | Optional |
| Type: | String |
| Values: | User defined |
| Default: | Scene Base File Path |

**Subelements** object (0..N)
terrain (0..N)

**<object>**

**Description** The object element is used to identify an object to be included within the scene. Objects are one of the main building blocks of hierarchy within a scene.

**Format** <object id="ID" isStatic="value" name="string">

**Attributes**

*id*

| | |
|---|---|
| Description: | Unique identification key for the object within the scope of other objects, terrain, thrusters, and joints. |
| Occurrence: | Required |
| Type: | String |
| Values: | User defined |
| Default: | None |

*name*

| | |
|---|---|
| Description: | Provides a descriptive name to the object. |
| Occurrence: | Required |
| Type: | String |
| Values: | User defined |
| Default: | None |

*isStatic*

| | |
|---|---|
| Description: | Defines whether the object is static or dynamic. Static objects cannot be updated within time based telemetry stream, including parenting, visibility or scale. |
| Occurrence: | Optional |
| Type: | Integer |
| Values: | 0 (False), 1 (True) |
| Default: | 1 |

**Subelements** note (0..1)
offset (0..1)
geometry (0..1)
object (0..N)
joint (0..N)
thruster (0..N)
terrain (0..N)

**<offset>**

**Description** The offset element is used to provide the location and orientation of the object relative to the parent object. This is used for static objects, thrusters, and terrain.

**Format** <offset unitDistance="unit" pos="x y z" quat="x y z w"/>

**Attributes**

*unitDistance*

| | |
|---|---|
| Description: | Units for distance to be applied to the offset data |
| Occurrence: | Optional |
| Type: | String |
| Values: | millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile |
| Default: | Scene unit of distance |

*pos*

| | |
|---|---|
| Description: | Defines the static position of the object in world coordinates or relative to the parent object, if specified. |
| Occurrence: | Optional |
| Type: | Set of three doubles |
| Values: | User defined |
| Default: | 0 0 0 |

*quat*

| | |
|---|---|
| Description: | Defines the static orientation of the object relative to the parent object. |
| Occurrence: | Optional |
| Type: | Right Hand Unit Quaternion, specified in X Y Z W order |
| Values: | User defined |
| Default: | 0 0 0 1 |

**Subelements** None

**<geometry>**

**Description** The geometry element is a container for any geometry that should be loaded for display of the object.

**Format** <geometry> … </geometry>

**Attributes** None
**Subelements** model (1..N)

**<model> (Object)**

**Description** The model element provides the information needed to load in a geometry data file. The type of file (polygonal formats) can be determined from the file extension.

**Format** <model unitDistance="unit" pos="x y z" quat="x y z w" unitModel="unit" scale="1" filePath="dir1/base.tif"/>

**Attributes**

*unitDistance*

| | |
|---|---|
| Description: | Units for distance to be applied to the offset data |
| Occurrence: | Optional |
| Type: | String |
| Values: | millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile |
| Default: | Scene unit of distance |

*pos*

| | |
|---|---|
| Description: | Defines the offset of the object in world coordinates or relative to the parent object, if specified. |
| Occurrence: | Optional |
| Type: | Set of three doubles |
| Values: | User defined |
| Default: | 0 0 0 |

*quat*

| | |
|---|---|
| Description: | Defines the static orientation of the object relative to the parent object. |
| Occurrence: | Optional |
| Type: | Right Hand Unit Quaternion, specified in X Y Z W order |
| Values: | User defined |
| Default: | 0 0 0 1 |

*scale*

| | |
|---|---|
| Description: | Provides the ability to scale the model |
| Occurrence: | Optional |
| Type: | Double |

Values: User defined
Default: 1.0

*unitModel*

Description: Units for distance to be applied to the geometry data
Occurrence: Optional
Type: String
Values: millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile
Default: Scene unit of distance

*filePath*

Description: Path to a model file
Occurrence: Required
Type: String
Values: User defined file path, either absolute, or relative to Objects Base File Path
Default: None

**Subelements** None

**<joint>**

**Description** A joint element is used to define a specialized object that represents a one degree of freedom joint within the hierarchy.

**Format** <joint id="ID3" type="type" name="string">…</joint>

**Attributes**

*id*

Description: Unique identification key for the object within the scope of other objects, terrain, thrusters, and joints.
Occurrence: Required
Type: String
Values: User defined
Default: None

*name*

Description: Provides a descriptive name to the joint.
Occurrence: Required
Type: String
Values: User defined
Default: None

*type*

Description: Defines the type of single degree of freedom.
Occurrence: Required

Type: String
Values: rotational, translational
Default: None

**Subelements** note (0..1)
pin (0..1)
geometry (0..1)
object (0..N)
joint (0..N)
thruster (0..N)

**<pin>**

**Description** The pin element defines the location and direction of the joint relative to the parent object. Based on the type of joint, the Z axis of the joint represents either the rotation vector or the translation axis.

**Format** <pin unitDistance="unit" pos="x y z" quat="x y z w"/>

**Attributes**

*unitDistance*

Description: Units for distance to be applied to the pin data
Occurrence: Optional
Type: String
Values: millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile
Default: Scene unit of distance

*pos*

Description: Defines the pin position relative to the parent object.
Occurrence: Optional
Type: Set of three doubles
Values: User defined
Default: 0 0 0

*quat*

Description: Defines the orientation of the pin relative to the parent object.
Occurrence: Optional
Type: Right Hand Unit Quaternion, specified in X Y Z W order
Values: User defined
Default: 0 0 0 1

**Subelements** None

**<thruster>**

**Description** A thruster element is used to define a specialized object that represents a thruster plume within the scene hierarchy.

**Format** <thruster id="ID" name="string">

**Attributes**

*id*

Description: Unique identification key for the object within the scope of other objects, terrain, thrusters, and joints.
Occurrence: Required
Type: String
Values: User defined
Default: None

*name*

Description: Provides a descriptive name to the joint.
Occurrence: Required
Type: String
Values: User defined
Default: None

**Subelements** note (0..1)
offset (0..1)
geometry (0..1)

**<terrain>**

**Description** The terrain element is used to identify topological data to be included within the scene.

**Format** <terrain id="ID" name="string">

**Attributes**

*id*

Description: Unique identification key for the terrain within the scope of other terrain, objects, thrusters, and joints.
Occurrence: Required
Type: String
Values: User defined
Default: None

*name*

Description: Provides a descriptive name to the terrain.
Occurrence: Required
Type: String
Values: User defined
Default: None

**Subelements** note (0..1)
offset (0..1)
geometry (0..1)
object (0..N)
terrain (0..N)

**<model> (Terrain)**

**Description** The model element provides the information needed to load in a geometry data file. Polygonal formats can be determined from the file extension.

**Format** <model type=”type” unitDistance="unit" pos="x y z" quat="x y z w" unitModel="unit" scale="1" filePath="dir1/base.tif" tiling="1 1" offset="0 0" textureFilePath="dir2/base.png"/>

**Attributes**

*type*

| | |
|---|---|
| Description: | Provides the type of the topological data |
| Occurrence: | Required |
| Type: | String |
| Values: | heightmap, polygonal |
| Default: | None |

*unitDistance*

| | |
|---|---|
| Description: | Units for distance to be applied to the offset data |
| Occurrence: | Optional |
| Type: | String |
| Values: | millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile |
| Default: | Scene unit of distance |

*pos*

| | |
|---|---|
| Description: | Defines the offset of the object in world coordinates or relative to the parent object, if specified. |
| Occurrence: | Optional |
| Type: | Set of three doubles |
| Values: | User defined |
| Default: | 0 0 0 |

*quat*

| | |
|---|---|
| Description: | Defines the static orientation of the object relative to the parent object. |
| Occurrence: | Optional |
| Type: | Right Hand Unit Quaternion, specified in X Y Z W order |
| Values: | User defined |

Default: 0 0 0 1

*scale*

Description: Provides the ability to scale the model
Occurrence: Optional
Type: Double
Values: User defined
Default: 1.0

*unitModel*

Description: Units for distance to be applied to the geometry data
Occurrence: Optional
Type: String
Values: millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile
Default: Scene unit of distance

*filePath*

Description: Path to a model file
Occurrence: Required
Type: String
Values: User defined file path, either absolute, or relative to Objects Base File Path
Default: None

*tiling*

Description: The number of repetitions of the texture to use in the width and height directions
Occurrence: Optional
Type: Set of two integers
Values: User defined set of two non-negative non-zero integers
Default: 1 1

*offset*

Description: The offset of the top left corner of the texture from the texture origin of the geometry
Occurrence: Optional
Type: Set of two integers
Values: User defined set of two non-negative integers
Default: 0 0

*textureFilePath*

Description: Path to a texture file
Occurrence: Optional
Type: String

Values: User defined file path, either absolute, or relative to Objects Base File Path
Default: None

**Subelements** None

## 5.3.3. Telemetry Section Element Definitions

**<telemetries>**

**Description** Provides the container for all references to valid telemetry files that connect the specified scene to time based data.

**Format** <telemetries baseFilePath=”dir/”> . . . </telemetries>

**Attributes**

*baseFilePath*

Description: Provides a default path location where all future filePaths within the telemetries element may be relative to
Occurrence: Optional
Type: String
Values: User defined
Default: Mission Base File Path

**Subelements** telemetry (1..N)

**<telemetry>**

**Description** Declares a given data source for use with the mission file.

**Format** <telemetry name="string" type="type" format="format" epoch="YYYY-MM-DDTHH:mm:ss.ssZ” source=”location”> … </telemetry>

**Attributes**

*name*

Description: Provides a shortened descriptive name of the telemetry.
Occurrence: Required
Type: String
Values: User defined
Default: None

*type*

Description: Defines the type of telemetry as either a discrete data file or a data set that will be streamed via the network.
Occurrence: Required
Type: String

| | |
|---|---|
| Values: | file, network |
| Default: | None |

*format*

| | |
|---|---|
| Description: | Defines the format of the data set. |
| Occurrence: | Required |
| Type: | String |
| Values: | MPC, MPC2, MPC3 |
| Default: | None |

*epoch*

| | |
|---|---|
| Description: | Used to specify a Gregorian date/time value in UTC that should map to time "zero" of the simulation data, i.e. the double precision time value 0.0. This value is used when the data is being integrated with other data. |
| Occurrence: | Optional |
| Type: | String, following ISO 8601 standard YYYY-MM-DDTHH:mm:ss.ssZ |
| Values: | User Defined |
| Default: | Mission Epoch |

*source*

| | |
|---|---|
| Description: | Provides the location of the data set. File names are provided as paths relative to source file location. |
| Occurrence: | Required |
| Type: | String |
| Values: | IP:Port or user defined file path. File path is either absolute, or relative to Telemetries Base File Path |
| Default: | None |

**Subelements** note (0..1)

## 5.4. Data File

The data file contains all the dynamic data generated from an analysis or simulation that is to be visualized or integrated with other data. Contained within the file are two main sections, the initialization section, and the time based data section. The template is shown below, followed by a description for each element and attribute.

The general syntax is shown below.

```
<mpcData version=”3.0”>
    <!-- Data Initialization -->
    <init name="Sample" epoch="2013-05-17T19:22:10.00Z" author="author">
        <note>Description of the data contained</note>
        <units time="unit" distance="unit" angle="unit" force="unit"/>
```

```
            <metaData id=" ID" type="type" unitLabel="label"/>
            <terrain id="ID"/>
            <object unitDistance="unit" unitAngle="unit" id="ID">
                  <metaData id="ID" type="type" unitLabel="label"/>
            </object>
            <joint unitAngle="degree" id="ID">
                  <metaData id="ID" type="type"/>
      </joint>
      <thruster unitForce="unit" id="ID">
                  <metaData id="ID" type="type"/>
            </thruster>
        </init>
        <!-- Time Based data -->
        <time value="N">
            <event value=”string”/>
            <metaData id="ID" value=”value”/>
            <object id="ID" pos="x y z" vel="x y z" quat="x y z w" angularVel="rate x y
            z" cg="x y z" scale="x y z" vis="1" parent="ID">
                  <metaData id="ID" value=”value”/>
            </object>
            <joint id="ID" value="value">
                  <metaData id="ID" value=”value”/>
            </joint>
            <thruster id="ID" value="value">
                  <metaData id="ID" value=”value”/>
            </thruster>
        </time>
        <time value = “N+1”>
            …
        </time>
</mpcData>
```

## 5.4.1. Data Level Element Definitions

**<mpcData>**

**Description** All elements of the MPC data file are contained within the mpcData element. It encompasses the initialization and time data.

**Format** <mpcData version=”3.0”>…</mpcData>

**Attributes**

*version*

| | |
|---|---|
| Description: | Defines the version of the MPC file |
| Occurrence: | Required |
| Type: | String |
| Values: | 3.0 |
| Default: | None |

**Subelements** init (1..1)
time (1..N)

## 5.4.2. Initialization Section Element Definitions

**<init>**

**Description** Init is the main element tag for the section, enclosing all initialization elements. Only one init section is allowed within the data file and is required. All elements that are to be referenced within the Time section must be declared within the init section.

**Format** <init name="string" epoch="YYYY-MM-DDTHH:mm:ss.ssZ" author="string"> … </init>

**Attributes**

*name*

| | |
|---|---|
| Description: | Informative name can be provided for the data set |
| Occurrence: | Optional |
| Type: | String |
| Values: | User Defined |
| Default: | Empty String |

*epoch*

| | |
|---|---|
| Description: | Used to specify a Gregorian date/time value in UTC that should map to time "zero" of the simulation data, i.e. the double precision time value 0.0. This value is used when the data is being integrated with other data, including celestial body data. |
| Occurrence: | Optional |
| Type: | String, following ISO 8601 standard YYYY-MM-DDTHH:mm:ss.ssZ |
| Values: | User Defined |
| Default: | If used in conjunction with a mission file, the default epoch is inherited from the telemetry element, otherwise, application defined. |

*author*

| | |
|---|---|
| Description: | Name of the data provider |
| Occurrence: | Optional |
| Type: | String |
| Values: | User Defined |
| Default: | Empty String |

**Subelements** note (0..1)

**<note>**

**Description** A note is an element used to provide descriptions or additional information that may be of interest regarding the data. The data

contained within the note is not designed to be used by software reading MPC, other than for display purposes, but should be maintained with the MPC file if the file is imported and exported. Default value for a note is an empty string.

**Format** <note>string</note>

**Attributes** None
**Subelements** None

**<units>**

**Description** The units initialization is used to set the units for each of the supported type throughout the data file.

**Format** <units time="unit" distance="unit" angle="unit" force="unit"/>

**Attributes**

*time*

Description: Unit of time to be used in the absence of specification.
Occurrence: Optional
Type: String
Values: millisecond, second, minute, hour, day
Default: second

*distance*

Description: Unit of distance to be used in the absence of specification.
Occurrence: Optional
Type: String
Values: millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile
Default: meter

*angle*

Description: Unit of angle to be used in the absence of specification.
Occurrence: Optional
Type: String
Values: degree, radian
Default: degree

*force*

Description: Unit of force to be used in the absence of specification.
Occurrence: Optional
Type: String

Values: newton, pound
Default: newton

**Subelements** None

**<metaData>**

**Description** Meta data is used to declare a variable/parameter that will contain a dynamic value as a function of time. Declaring this outside an object, thruster, or joint associates this parameter at the mission level. Declaring this inside an object, thruster, or joint associates the parameter with the parent element.

**Format** <metaData id="ID" type="type" unitLabel=”label”/>

**Attributes**

*id*

Description: Unique identification key for the parameter within the scope of other meta data parameters within the object it is declared.
Occurrence: Required
Type: String
Values: User defined
Default: None

*type*

Description: Defines the parameter type
Occurrence: Required
Type: String
Values: string, double
Default: None

*unitLabel*

Description: Provides a label to be displayed with the value, such as units
Occurrence: Optional
Type: String
Values: User defined
Default: Empty string

**Subelements** None

**<object>**

**Description** Object is used to declare an object that will contain, or will be referenced by, data within the time based data section. When used in conjunction with a mission file, an object declared as static in the mission file shall not be dynamically re-parented, scaled, positioned, or oriented within the time elements.

**Format** <object unitDistance="unit" unitAngle="unit" id="ID" ofInterest=”value”> … </object>

**Attributes**

*id*

| | |
|---|---|
| Description: | Unique identification key for the object within the scope of other objects, terrain, thrusters, and joints. |
| Occurrence: | Required |
| Type: | String |
| Values: | User defined |
| Default: | None |

*unitDistance*

| | |
|---|---|
| Description: | Units for distance to be applied to this object’s data |
| Occurrence: | Optional |
| Type: | String |
| Values: | millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile |
| Default: | Init unit of distance |

*unitAngle*

| | |
|---|---|
| Description: | Units for angle to be applied to this object’s data |
| Occurrence: | Optional |
| Type: | String |
| Values: | degree, radian |
| Default: | Init unit of angle |

*ofInterest*

| | |
|---|---|
| Description: | Identification of the object as an object of interest within the simulation |
| Occurrence: | Optional |
| Type: | Integer |
| Values: | 0 (False), 1 (True) |
| Default: | 0 |

**Subelements** metaData (0..N)

**<terrain>**

**Description** Terrain is used to declare topological data that will be referenced within the time based data section. Terrain objects shall not be dynamically reparented, scaled, positioned, or oriented within the time elements.

**Format** <terrain id="ID"/>

**Attributes**

*id*

Description: Unique identification key for the object within the scope of other terrain, objects, thrusters, and joints.
Occurrence: Required
Type: String
Values: User defined
Default: None

**Subelements** None

**<thruster>**

**Description** Thruster is used to declare the visual representation of a thruster plume, where time based firing information of the thrust magnitude will be provided within the telemetry section. Thruster objects shall not be dynamically reparented or scaled within the time elements.

**Format** <thruster unitForce="unit" unitDistance=”unit” id="ID"/>

**Attributes**

*id*

Description: Unique identification key for the thruster within the scope of other objects, terrain, thrusters, and joints.
Occurrence: Required
Type: String
Values: User defined
Default: None

*unitForce*

Description: Units for force to be applied to this object’s data
Occurrence: Optional
Type: String
Values: newton, foot-pound
Default: Init unit of force

*unitDistance*

Description: Units for distance to be applied to this object’s data
Occurrence: Optional
Type: String
Values: millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile
Default: Init unit of distance

**Subelements** metaData (0..N)

**<joint>**

**Description** Joint is used to declare a single degree of freedom joint that will change as a function of time. Joint objects shall not be dynamically re-parented, scaled, positioned, or oriented within the time elements.

**Format** <joint unitAngle="unit" unitDistance=”unit” id="ID">

**Attributes**

*id*

Description: Unique identification key for the joint within the scope of other objects, terrain, thrusters, and joints.
Occurrence: Required
Type: String
Values: User defined
Default: None

*unitAngle*

Description: Units for angle to be applied to this object’s data
Occurrence: Optional
Type: String
Values: degree, radian
Default: Init unit of angle

*unitDistance*

Description: Units for distance to be applied to this object’s data
Occurrence: Optional
Type: String
Values: millimeter, centimeter, meter, kilometer, AU, inch, foot, yard, mile
Default: Init unit of distance

**Subelements** metaData (0..N)

## 5.4.3. Time Section Element Definitions

**<time>**

**Description** Each time step is enclosed in a “time” tag. Time tags shall be listed in time increasing order.

**Format** <time value="N">

**Attributes**

*value*

Description: Value contains the simulation time offset from the Epoch for the data contained within the tag.
Occurrence: Required
Type: Double

Values: User defined
Default: None

**Subelements** event (0..1)
object (0..N)
metaData (0..N)
joint (0..N)
thruster (0..N)

**<event>**

**Description** The event tag is used to capture a key occurrence that happened during this time within the simulation/data. It is a specialized type of meta data.

**Format** <event value="string"/>

**Attributes**

*value*

Description: Captures the name or description of the event.
Occurrence: Optional
Type: String
Values: User defined
Default: Last known set value

**Subelements** None

**<object>**

**Description** Objects are updated using the “object” tag and a series of attributes to define all data associated with an object.

**Format** <object id="ID" pos="x y z" vel="x y z" quat="x y z w" angularVel="r x y z" cg="x y z" scale="x y z" vis="1" parent="ID"> … </object>

**Attributes**

*id*

Description: The unique identification key of the object being set.
Occurrence: Required
Type: String
Values: Valid Identification Key of an object declared within the initialization
Default: None

*pos*

Description: Defines the position of the object relative to the reference frame used to capture the data.
Occurrence: Optional

Type: Set of three doubles
Values: User defined
Default: Last known set value

*vel*

Description: Defines the velocity of the object relative to the reference frame used to capture the data.
Occurrence: Optional
Type: Set of three doubles
Values: User defined
Default: Last known set value

*quat*

Description: Defines the orientation of the object relative to the reference frame used to capture the data.
Occurrence: Optional
Type: Right Hand Unit Quaternion, specified in X Y Z W order
Values: User defined
Default: Last known set value

*angularVel*

Description: Defines the angular velocity of the object relative to the reference frame used to capture the data.
Occurrence: Optional
Type: Set of 4 doubles defining Rate and Axis of rotation, specified in R X Y Z order
Values: User defined
Default: Last known set value

*cg*

Description: Defines the location of the center of gravity of the object relative to the design reference frame of the object as a function of time.
Occurrence: Optional
Type: Set of 3 doubles
Values: User defined
Default: Last known set value

*scale*

Description: Defines a scale value to be applied to the object at this time
Occurrence: Optional
Type: Set of 3 doubles
Values: User defined
Default: Last known set value

*vis*

| | |
|---|---|
| Description: | Provides an ability to hide or show the object |
| Occurrence: | Optional |
| Type: | Single integer |
| Values: | 0 (hide), 1 (show) |
| Default: | Last known set value |

*parent*

| | |
|---|---|
| Description: | Defines a new parent object or joint for the current object. All data for this object should now be provided relative to the new parent. |
| Occurrence: | Optional |
| Type: | String |
| Values: | Valid Identification Key of an object, joint, or terrain declared within the initialization |
| Default: | None |

**Subelements** metaData (0..N)

**<metaData>**

**Description** Meta data element found within the time element is used to declare the value of a meta data parameter. Meta data elements can be found at the mission level or within an object, thruster, or joint element.

**Format** <metaData id="ID" value="value"/>

**Attributes**

*id*

| | |
|---|---|
| Description: | The unique identification key of the parameter being set. |
| Occurrence: | Required |
| Type: | String |
| Values: | User defined |
| Default: | None |

*value*

| | |
|---|---|
| Description: | Defines the parameter type |
| Occurrence: | Required |
| Type: | String or Double based on initialization |
| Values: | User defined |
| Default: | Last known set value |

**Subelements** None

**<thruster>**

**Description** Thruster is used to update the value and position of a thruster declared within the initialization.

**Format** <thruster id="ID" value = “value” pos="x y z" quat="x y z w" >…</thruster>

**Attributes**

*id*

| | |
|---|---|
| Description: | The unique identification key for the thruster being updated. |
| Occurrence: | Required |
| Type: | String |
| Values: | Valid Identification Key of a thruster declared within the initialization |
| Default: | None |

*value*

| | |
|---|---|
| Description: | Value of force for the thruster |
| Occurrence: | Required |
| Type: | Double |
| Values: | User Defined |
| Default: | Last known value set |

*pos*

| | |
|---|---|
| Description: | Defines the position of the thruster relative to the reference frame used to capture the data. |
| Occurrence: | Optional |
| Type: | Set of three doubles |
| Values: | User defined |
| Default: | Last known set value |

*quat*

| | |
|---|---|
| Description: | Defines the orientation of the thruster relative to the reference frame used to capture the data. |
| Occurrence: | Optional |
| Type: | Right Hand Unit Quaternion, specified in X Y Z W order |
| Values: | User defined |
| Default: | Last known set value |

**Subelements** metaData (0..N)

**<joint>**

**Description** Joint is used to update the value of a joint declared within the initialization.

**Format** <joint id="ID" value = “value”>…</joint>

**Attributes**

*id*

| | |
|---|---|
| Description: | The unique identification key for the joint being updated. |
| Occurrence: | Required |
| Type: | String |
| Values: | Valid Identification Key of a joint declared within the initialization |
| Default: | None |

*value*

| | |
|---|---|
| Description: | Value of offset for the joint |
| Occurrence: | Required |
| Type: | Double |
| Values: | User Defined |
| Default: | Last known value set |

**Subelements** metaData (0..N)

# 6. The Distributed Observer Network

The Distributed Observer Network (DON) is the primary presentation tool for DPV and is designed to serve as a final publication tool for other simulators. The version of a simulation presented through DON is intended to be as close as visually possible to the original, therefore the tool is not allowed to perform calculations or generate new information. Analysis type activities are to be performed in tools other than DON, either by the original simulation tool or EVE (Exploration Visualization Environment).

DON supports models in OBJ format and textures in MTL. Specifications for these formats are available at http://www.martinreddy.net/gfx/3d/OBJ.spec and http://paulbourke.net/dataformats/mtl/, respectively.

# 7. Exploration Visualization Environment

EVE is the primary visualization tool for DPV and is designed for use early in the development process. Data can be provided from a variety of sources and combined within the EVE environment to visualize an integrated system. EVE also includes capabilities that can be used to help fill in missing data for preliminary analysis as needed. Visualizations created with its environment may be published to the DON for distribution.

EVE is built with OpenSceneGraph and can support models in OBJ, IVE, STL, FLT, DAE, and 3DS formats.

# APPENDIX A.
# Acronyms and Abbreviations

| | |
|---|---|
| 3DS | 3D Studio Graphics Model Format |
| AU | Astronomical Units |
| DAE | COLLADA File |
| DON | Distributed Observer Network |
| DPV | Data Presentation and Visualization |
| EVE | Exploration Visualization Environment |
| FLT | OpenFlight Model Format |
| FOV | Field of View |
| ICD | Interface Control Document |
| ISO | International Standards Organization |
| IVE | OpenSceneGraph Model Format |
| KSC | Kennedy Space Center |
| M | Modeler |
| M&S | Modeling and Simulation |
| MB | Mission Builder |
| MPC | Model Process Control |
| MTL | Wavefront Material Template Library |
| NASA | National Aeronautics and Space Administration |
| OBJ | Wavefront Object Model Format |
| P | Presenter |
| PNG | Portable Network Graphics |
| POST | Program to Optimize Simulated Trajectories |
| SD | Simulation Developer |
| STL | Stereolithography Interface Format |
| UTC | Coordinated Universal Time |
| XML | Extensible Markup Language |

## APPENDIX B.
## XML Schema for MPC3 Mission File

```
<?xml version="1.0"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">

<xs:simpleType name="timeUnitsType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="millisecond"/>
    <xs:enumeration value="second"/>
    <xs:enumeration value="minute"/>
    <xs:enumeration value="hour"/>
    <xs:enumeration value="day"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="distanceUnitsType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="millimeter"/>
    <xs:enumeration value="centimeter"/>
    <xs:enumeration value="meter"/>
    <xs:enumeration value="kilometer"/>
    <xs:enumeration value="AU"/>
    <xs:enumeration value="inch"/>
    <xs:enumeration value="foot"/>
    <xs:enumeration value="yard"/>
    <xs:enumeration value="mile"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="angleUnitsType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="radian"/>
    <xs:enumeration value="degree"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="forceUnitsType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="newton"/>
    <xs:enumeration value="pound"/>
  </xs:restriction>
</xs:simpleType>

<xs:complexType name="unitsType">
  <xs:attribute name="time" type="timeUnitsType" default="second"/>
  <xs:attribute name="distance" type="distanceUnitsType" default="meter"/>
  <xs:attribute name="angle" type="angleUnitsType" default="degree"/>
  <xs:attribute name="force" type="forceUnitsType" default="newton"/>
</xs:complexType>

<xs:simpleType name="environmentType">
  <xs:restriction base="xs:string">
  <xs:enumeration value="Earth"/>
  <xs:enumeration value="Moon"/>
```

```
  <xs:enumeration value="Mars"/>
  <xs:enumeration value="Custom"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="tripleDoubleType">
  <xs:restriction base="xs:string">
    <xs:pattern value="^[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-9]+)?\s[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-
     9]+)?\s[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-9]+)?$"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="quadDoubleType">
  <xs:restriction base="xs:string">
    <xs:pattern value="^[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-9]+)?\s[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-
     9]+)?\s[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-9]+)?\s[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-9]+)?$"/>
  </xs:restriction>
</xs:simpleType >

<xs:simpleType name="rgbType">
  <xs:restriction base="xs:string">
    <xs:pattern value="^[0-1](\.[0-9]*)?\s[0-1]\.([0-9]*)?+\s[0-1](\.[0-9]*)?$"/>
   </xs:restriction>
</xs:simpleType>

<xs:simpleType name="doubleIntegerType">
  <xs:restriction base="xs:string">
    <xs:pattern value="^[0-9]+\s[0-9]+$"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="doubleIntegerTypeMin1">
  <xs:restriction base="xs:string">
    <xs:pattern value="^[1-9]+[0-9]*\s[1-9]+[0-9]*$"/>
  </xs:restriction>
</xs:simpleType>

<xs:complexType name="textureType">
  <xs:attribute name="tiling" type=" doubleIntegerTypeMin1" default="1 1"/>
  <xs:attribute name="offset" type="doubleIntegerType" default="0 0"/>
  <xs:attribute name="filePath" type="xs:string"/>
</xs:complexType>


<xs:simpleType name="lightStyleType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="point"/>
    <xs:enumeration value="directional"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="spotCutoffType">
  <xs:restriction base="xs:double">
    <xs:minInclusive value="0"/>
    <xs:maxInclusive value="180"/>
  </xs:restriction>
```

```
</xs:simpleType>

<xs:simpleType name="intensityType">
  <xs:restriction base="xs:integer">
    <xs:minInclusive value="0"/>
    <xs:maxInclusive value="100"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="cameraFovType">
  <xs:restriction base="xs:double">
    <xs:minExclusive value="0"/>
    <xs:maxExclusive value="180"/>
  </xs:restriction>
</xs:simpleType>

<xs:complexType name="geometryType">
  <xs:sequence>
    <xs:element name="model" minOccurs="1" maxOccurs="unbounded">
      <xs:complexType>
        <xs:attribute name="unitDistance" type="unitDistanceType"/>
        <xs:attribute name="pos" type="tripleDoubleType" default="0 0 0"/>
        <xs:attribute name="quat" type="quadDoubleType" default="0 0 0 1"/>
        <xs:attribute name="unitModel" type="unitDistanceType"/>
        <xs:attribute name="scale" type="xs:double" default="1"/>
        <xs:attribute name="filePath" type="xs:string"/>
      </xs:complexType>
    </xs:element>
  </xs:sequence>
</xs:complexType>

<xs:complexType name="terrainGeometryType">
  <xs:sequence>
    <xs:element name="model" minOccurs="1" maxOccurs="unbounded">
      <xs:complexType>
        <xs:attribute name="unitDistance" type="unitDistanceType"/>
        <xs:attribute name="pos" type="tripleDoubleType" default="0 0 0"/>
        <xs:attribute name="quat" type="quadDoubleType" default="0 0 0 1"/>
        <xs:attribute name="unitModel" type="unitDistanceType"/>
        <xs:attribute name="scale" type="xs:double" default="1"/>
        <xs:attribute name="filePath" type="xs:string"/>
        <xs:attribute name="tiling" type=" doubleIntegerTypeMin1" default="1 1"/>
        <xs:attribute name="offset" type="doubleIntegerType" default="0 0"/>
        <xs:attribute name="textureFilePath" type="xs:string"/>
      </xs:complexType>
    </xs:element>
  </xs:sequence>
</xs:complexType>

<xs:complexType name="offsetType">
  <xs:attribute name="unitDistance" type="unitDistanceType"/>
  <xs:attribute name="pos" type="tripleDoubleType" default="0 0 0"/>
  <xs:attribute name="quat" type="quadDoubleType" default="0 0 0 1"/>
</xs:complexType>

<xs:simpleType name="jointTypeType">
```

```
  <xs:restriction base="xs:string">
    <xs:enumeration value="rotational"/>
    <xs:enumeration value="translational"/>
  </xs:restriction>
</xs:simpleType>

<xs:complexType name="jointType">
  <xs:sequence>
    <xs:element name="note" type="xs:string" default="" minOccurs="0" maxOccurs="1"/>
    <xs:element name="pin" type="offsetType" minOccurs="0" maxOccurs="1"/>
    <xs:element name="geometry" type="geometryType" minOccurs="0" maxOccurs="1"/>
    <xs:element name="object" type="objectType" minOccurs="0" maxOccurs="unbounded"/>
    <xs:element name="joint" type="jointType" minOccurs="0" maxOccurs="unbounded"/>
    <xs:element name="thruster" type="thrusterType" minOccurs="0" maxOccurs="unbounded"/>
  </xs:sequence>
  <xs:attribute name="id" type="xs:string" use="required"/>
  <xs:attribute name="name" type="xs:string" use="required"/>
  <xs:attribute name="type" type="jointTypeType" use="required"/>
</xs:complexType>

<xs:complexType name="thrusterType">
    <xs:all>
      <xs:element name="note" type="xs:string" default="" minOccurs="0" maxOccurs="1"/>
      <xs:element name="offset" type="offsetType" minOccurs="0" maxOccurs="1"/>
      <xs:element name="geometry" type="geometryType" minOccurs="0" maxOccurs="1"/>
    </xs:all>
    <xs:attribute name="id" type="xs:string" use="required"/>
    <xs:attribute name="name" type="xs:string" use="required"/>
</xs:complexType>

<xs:complexType name="objectType">
  <xs:sequence>
    <xs:element name="note" type="xs:string" default="" minOccurs="0" maxOccurs="1"/>
    <xs:element name="offset" type="offsetType" minOccurs="0" maxOccurs="1"/>
    <xs:element name="geometry" type="geometryType" minOccurs="0" maxOccurs="1"/>
    <xs:element name="object" type="objectType" minOccurs="0" maxOccurs="unbounded"/>
    <xs:element name="joint" type="jointType" minOccurs="0" maxOccurs="unbounded"/>
    <xs:element name="thruster" type="thrusterType" minOccurs="0" maxOccurs="unbounded"/>
    <xs:element name="terain" type="terrainType" minOccurs="0" maxOccurs="unbounded"/>
  </xs:sequence>
  <xs:attribute name="id" type="xs:string" use="required"/>
  <xs:attribute name="name" type="xs:string" use="required"/>
  <xs:attribute name="isStatic" default="1">
    <xs:simpleType>
      <xs:restriction base="xs:integer">
        <xs:minInclusive value="0"/>
        <xs:maxInclusive value="1"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:attribute>
</xs:complexType>

<xs:complexType name="terrainType">
  <xs:sequence>
    <xs:element name="note" type="xs:string" default="" minOccurs="0" maxOccurs="1"/>
    <xs:element name="offset" type="offsetType" minOccurs="0" maxOccurs="1"/>
```

```
    <xs:element name="geometry" type=" terrainGeometryType " minOccurs="0" maxOccurs="1"/>
    <xs:element name="object" type="objectType" minOccurs="0" maxOccurs="unbounded"/>
    <xs:element name="terain" type="terrainType" minOccurs="0" maxOccurs="unbounded"/>
  </xs:sequence>
  <xs:attribute name="id" type="xs:string" use="required"/>
  <xs:attribute name="name" type="xs:string" use="required"/>
</xs:complexType>

<xs:simpleType name="telemetryDeliveryType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="file"/>
    <xs:enumeration value="network"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="telemetryFormatType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="MPC"/>
    <xs:enumeration value="MPC2"/>
    <xs:enumeration value="MPC3Data"/>
  </xs:restriction>
</xs:simpleType>

<xs:complexType name="skyboxType">
  <xs:all>
    <xs:element name="front" type="textureType" minOccurs="1" maxOccurs="1"/>
    <xs:element name="back" type="textureType" minOccurs="1" maxOccurs="1"/>
    <xs:element name="top" type="textureType" minOccurs="1" maxOccurs="1"/>
    <xs:element name="bottom" type="textureType" minOccurs="1" maxOccurs="1"/>
    <xs:element name="left" type="textureType" minOccurs="1" maxOccurs="1"/>
    <xs:element name="right" type="textureType" minOccurs="1" maxOccurs="1"/>
  </xs:all>
</xs:complexType>

<xs:complexType name="backgroundColorType">
    <xs:attribute name="color" type="rgbType" use="required"/>
</xs:complexType>

<xs:complexType name="lightType">
  <xs:attribute name="type" type="lightType" use="required"/>
  <xs:attribute name="parent" type="xs:string" default=""/>
  <xs:attribute name="color" type="rgbType" default="1 1 1"/>
  <xs:attribute name="unitDistance" type="unitDistanceType"/>
  <xs:attribute name="pos" type="tripleDoubleType" default="0 0 0"/>
  <xs:attribute name="forward" type="tripleDoubleType" default="0 0 1"/>
  <xs:attribute name="intensity" type="intensityType" default="100"/>
  <xs:attribute name="unitAngle" type="unitAngleType"/>
  <xs:attribute name="spotCutoff" type="spotCutoffType" default="180"/>
</xs:complexType>

<xs:complexType name="cameraType">
  <xs:attribute name="name" type="xs:string" use="required"/>
  <xs:attribute name="unitAngle" type="unitAngleType"/>
  <xs:attribute name="spotCutoff" type="cameraFovType" default="45"/>
  <xs:attribute name="unitDistance" type="unitDistanceType"/>
  <xs:attribute name="pos" type="tripleDoubleType" default="0 0 0"/>
```

```
  <xs:attribute name="up" type="tripleDoubleType" default="0 1 0"/>
  <xs:attribute name="forward" type="tripleDoubleType" default="0 0 1"/>
  <xs:attribute name="parent" type="xs:string" default=""/>
  <xs:attribute name="track" type="xs:string" default=""/>
</xs:complexType>

<xs:complexType name="telemetryType">
  <xs:all>
    <xs:element name="note" type="xs:string" default="" minOccurs="0" maxOccurs="1"/>
  </xs:all>
  <xs:attribute name="name" type="xs:string" use="required"/>
  <xs:attribute name="type" type="telemetryDeliveryType" use="required"/>
  <xs:attribute name="format" type="telemetryFormatType" use="required"/>
  <xs:attribute name="epoch" type="xs:dataTime"/>
  <xs:attribute name="source" type="xs:string" use="required"/>
</xs:complexType>

<xs:complexType name="environmentType">
  <xs:sequence>
    <xs:element name="backgroundColor" type="backgroundColorType" minOccurs="0"
     maxOccurs="1"/>
    <xs:element name="backgroundTexture" type="textureType" minOccurs="0" maxOccurs="1"/>
    <xs:element name="skybox" type="skyboxType" minOccurs="0" maxOccurs="1"/>
    <xs:element name="light" type="lightType" minOccurs="1" maxOccurs="unbounded"/>
    <xs:element name="camera" type="cameraType" minOccurs="1" maxOccurs="unbounded"/>
  </xs:sequence>
  <xs:attribute name="type" type="evironmentType" default="Custom"/>
  <xs:attribute name="up" type="tripleDoubleType" default="0 0 1"/>
  <xs:attribute name="forward" type="tripleDoubleType" default="1 0 0"/>
  <xs:attribute name="baseFilePath" type="xs:string"/>
</xs:complexType>

<xs:complexType name="objectsType">
  <xs:sequence>
    <xs:element name="terrain" type="terrainType" minOccurs="0" maxOccurs="unbounded"/>
    <xs:element name="object" type="objectType" minOccurs="0" maxOccurs="unbounded"/>
  </xs:sequence>
  <xs:attribute name="baseFilePath" type="xs:string"/>
</xs:complexType>

<xs:complexType name="sceneType">
  <xs:sequence>
    <xs:element name="note" type="xs:string" default="" minOccurs="0"/>
    <xs:element name="units" type="unitsType" minOccurs="0"/>
    <xs:element name="environment" type="environmentType" use="required"/>
    <xs:element name="objects" type="objectsType" use="required"/>
  </xs:sequence>
  <xs:attribute name="name" type="xs:string" default=""/>
  <xs:attribute name="baseFilePath" type="xs:string"/>
</xs:complexType>

<xs:complexType name="telemetriesType">
  <xs:sequence>
    <xs:element name="telemetry" type="telemetryType" minOccurs="1"
     maxOccurs="unbounded"/>
  </xs:sequence>
```

```
  <xs:attribute name="baseFilePath" type="xs:string"/>
</xs:complexType>

<xs:element name="mpcMission">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="note" type="xs:string" default="" minOccurs="0"/>
      <xs:element name="scene" type="sceneType" use="required" minOccurs="1"
       maxOccurs="1"/>
      <xs:element name="telemetries" type="telemetriesType" minOccurs="0" maxOccurs="1"/>
    </xs:sequence>
    <xs:attribute name="version" type="xs:string" use="required" fixed="3.0"/>
    <xs:attribute name="baseFilePath" type="xs:string"/>
    <xs:attribute name="epoch" type="xs:dataTime"/>
    <xs:attribute name="author" type="xs:string" default=""/>
  </xs:complexType>
</xs:element>
</xs:schema>
```

# APPENDIX C.
# XML Schema for MPC3 Data File

```
<?xml version="1.0"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">

<xs:simpleType name="timeUnitsType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="millisecond"/>
    <xs:enumeration value="second"/>
    <xs:enumeration value="minute"/>
    <xs:enumeration value="hour"/>
    <xs:enumeration value="day"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="distanceUnitsType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="millimeter"/>
    <xs:enumeration value="centimeter"/>
    <xs:enumeration value="meter"/>
    <xs:enumeration value="kilometer"/>
    <xs:enumeration value="AU"/>
    <xs:enumeration value="inch"/>
    <xs:enumeration value="foot"/>
    <xs:enumeration value="yard"/>
    <xs:enumeration value="mile"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="angleUnitsType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="radian"/>
    <xs:enumeration value="degree"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="forceUnitsType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="newton"/>
    <xs:enumeration value="pound"/>
  </xs:restriction>
</xs:simpleType>

<xs:complexType name="unitsType">
    <xs:attribute name="time" type="timeUnitsType" default="second"/>
    <xs:attribute name="distance" type="distanceUnitsType" default="meter"/>
    <xs:attribute name="angle" type="angleUnitsType" default="degree"/>
    <xs:attribute name="force" type="forceUnitsType" default="newton"/>
</xs:complexType>

<xs:simpleType name="metaDataTypeType">
  <xs:restriction base="xs:string">
    <xs:enumeration value="string"/>
    <xs:enumeration value="double"/>
```

```
  </xs:restriction>
</xs:simpleType>

<xs:complexType name="metaDataType">
  <xs:attribute name="id" type="xs:string" use="required"/>
  <xs:attribute name="type" type="metaDataTypeType" use="required"/>
  <xs:attribute name="unitLabel" type="xs:string"/>
</xs:complexType>

<xs:complexType name="metaDataValueType">
  <xs:choice>
    <xs:element name="metaData">
      <xs:attribute name="id" type="xs:string" use="required"/>
      <xs:attribute name="value" type="xs:double" use="required">
    </xs:element>
    <xs:element name="metaData">
      <xs:attribute name="id" type="xs:string" use="required"/>
      <xs:attribute name="value" type="xs:string" use="required">
    </xs:element>
  </xs:choice>
</xs:complexType>

<xs:simpleType name="boolType">
  <xs:restriction base="xs:integer">
    <xs:minInclusive value="0"/>
    <xs:maxInclusive value="1"/>
  </xs:restriction>
</xs:simpleType>

<xs:complexType name="tripleDoubleType">
  <xs:restriction base="xs:string">
    <xs:pattern value="^[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-9]+)?\s[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-
    9]+)?\s[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-9]+)?$"/>
  </xs:restriction>
</xs:complexType>

<xs:complexType name="quadDoubleType">
  <xs:restriction base="xs:string">
    <xs:pattern value="^[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-9]+)?\s[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-
    9]+)?\s[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-9]+)?\s[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-9]+)?$"/>
  </xs:restriction>
</xs:complexType>

<xs:complexType name="objectInitType">
  <xs:sequence>
    <xs:element name="metaData" type="metaDataType" minOccurs="0"
    maxOccurs="unbounded"/>
  </xs:sequence>
  <xs:attribute name="id" type="xs:string" use="required"/>
  <xs:attribute name="unitAngle" type="unitAngleType"/>
  <xs:attribute name="unitDistance" type="unitDistanceType"/>
  <xs:attribute name="ofInterest" type="boolType"/>
</xs:complexType>

<xs:complexType name="thrusterInitType">
  <xs:sequence>
```

```
    <xs:element name="metaData" type="metaDataType" minOccurs="0"
     maxOccurs="unbounded"/>
  </xs:sequence>
  <xs:attribute name="id" type="xs:string" use="required"/>
  <xs:attribute name="unitForce" type="unitForceType"/>
  <xs:attribute name="unitDistance" type=" unitDistanceType "/>
</xs:complexType>

<xs:complexType name="jointInitType">
  <xs:sequence>
    <xs:element name="metaData" type="metaDataType" minOccurs="0"
     maxOccurs="unbounded"/>
  </xs:sequence>
  <xs:attribute name="id" type="xs:string" use="required"/>
  <xs:attribute name="unitAngle" type="unitAngleType"/>
</xs:complexType>

<xs:complexType name="terrainInitType">
  <xs:attribute name="id" type="xs:string" use="required"/>
</xs:complexType>

<xs:complexType name="objectType">
  <xs:sequence>
    <xs:element name="metaData" type="metaDataValueType" minOccurs="0"
     maxOCcurs="unbounded"/>
  </xs:sequence>
  <xs:attribute name="id" type="xs:string" use="required"/>
  <xs:attribute name="pos" type="tripleDoubleType"/>
  <xs:attribute name="vel" type="tripleDoubleType"/>
  <xs:attribute name="quat" type="quadDoubleType"/>
  <xs:attribute name="angularVel" type="quadDoubleType"/>
  <xs:attribute name="cg" type="tripleDoubleType"/>
  <xs:attribute name="scale" type="tripleDoubleType"/>
  <xs:attribute name="vis" type="boolType"/>
  <xs:attribute name="parent" type="xs:string"/>
</xs:complexType>

<xs:complexType name="jointType">
  <xs:sequence>
    <xs:element name="metaData" type="metaDataValueType" minOccurs="0"
     maxOCcurs="unbounded"/>
  </xs:sequence>
  <xs:attribute name="id" type="xs:string" use="required"/>
  <xs:attribute name="value" type="xs:double" use="required"/>
</xs:complexType>

<xs:complexType name="thrusterType">
  <xs:sequence>
    <xs:element name="metaData" type="metaDataValueType" minOccurs="0"
     maxOCcurs="unbounded"/>
  </xs:sequence>
  <xs:attribute name="id" type="xs:string" use="required"/>
  <xs:attribute name="value" type="xs:double" use="required"/>
  <xs:attribute name="pos" type="tripleDoubleType"/>
  <xs:attribute name="quat" type="quadDoubleType"/>
</xs:complexType>
```

```
<xs:element name="mpcData">
 <xs:complexType>
  <xs:sequence>
   <xs:element name="init" minOccurs="1" maxOccurs="1">
    <xs:complexType>
     <xs:sequence>
      <xs:element name="note" type="xs:string" default="" minOccurs="0"/>
      <xs:element name="units" type="unitsType" minOccurs="0"/>
      <xs:element name="metaData" type="metaDataType" minOccurs="0"
       maxOccurs="unbounded"/>
      <xs:element name="terrain" type="terrainInitType"/>
      <xs:element name="object" type="objectInitType"/>
      <xs:element name="joint" type="jointInitType"/>
      <xs:element name="thruster" type="thrusterInitType"/>
     </xs:sequence>
     <xs:attribute name="name" type="xs:string" default=""/>
     <xs:attribute name="epoch" type="xs:dataTime"/>
     <xs:attribute name="author" type="xs:string" default=""/>
    </xs:complexType>
   </xs:element>
   <xs:element name="time" minOccurs="0" maxOccurs="unbounded">
    <xs:complexType>
     <xs:sequence>
      <xs:element name="event" type="xs:string" minOccurs="0"/>
      <xs:element name="metaData" type="metaDataValueType" minOccurs="0"
       maxOccurs="unbounded"/>
      <xs:element name="object" type="objectType" minOccurs="0"
       maxOccurs="unbounded"/>
      <xs:element name="joint" type="jointType" minOccurs="0" maxOccurs="unbounded"/>
      <xs:element name="thruster" type="thrusterType" minOccurs="0"
       maxOccurs="unbounded"/>
     </xs:sequence>
     <xs:attribute name="value" type="xs:double" use="required"/>
    </xs:complexType>
   </xs:element>
  </xs:sequence>
  <xs:attribute name="version" type="xs:string" use="required" fixed="3.0"/>
 </cs:comlexType>
</xs:element>
</xs:schema>
```

## APPENDIX D.
## Sample Mission File

```
<?xml version="1.0" encoding="utf-8"?>
<mpcMission version="3.0" epoch="2013-05-17T19:22:10.00Z" author="author">
   <note>File Description Here</note>
   <scene name="Sample">
      <note>Scene description</note>
      <units time="second" distance="meter" angle="degree" force="newton"/>
      <environment type="Earth" up="0 0 1" forward="1 0 0">
         <!-- Background option
         <backgroundColor color="r g b"/>
         <backgroundTexture tiling="1 1" offset="0 0" filePath="filepath"/>
         -->
         <skybox>
            <front tiling="1 1" offset="0 0" filePath="textures/earth/front.tif"/>
            <back tiling="1 1" offset="0 0" filePath="textures/earth/back.tif"/>
            <top tiling="1 1" offset="0 0" filePath="textures/earth/top.tif"/>
            <bottom tiling="1 1" offset="0 0" filePath="textures/earth/bottom.tif"/>
            <left tiling="1 1" offset="0 0" filePath="textures/earth/left.tif"/>
            <right tiling="1 1" offset="0 0" filePath="textures/earth/right.tif"/>
         </skybox>
         <light type="directional" color="1 1 1" forward="0 0 1" intensity="100"/>
         <light type="point" parent="Rover" color="1 1 1" unitDistance="kilometer" pos="10 0 0"
          forward="0 0 1" intensity="100" spotCutoff="40"/>
         <camera name="mainCam" fov="20" pos="10 10 0" up="0 0 1" forward="0 1 0" />
         <camera name="trackCam" unitAngle="degree" fov="20" unitDistance="inch" pos="10 10
          0" up="0 0 1" forward="0 1 0" track="obj1"/>
         <camera name="objCam" fov="20" parent="Rover" pos="1 0 0" up="0 0 1" forward="0 1
           0"/>
      </environment>
      <objects baseFilePath="data/">
         <terrain id="Base" name="Serenity Base">
            <note>Terrain; terrain ignores any pos/quat telemetry</note>
            <offset unitDistance="meter" pos="0 1 0" quat="0 0 1 1"/>
            <geometry>
               <model type=”heightmap” unitDistance="meter" pos="0 1 0" quat="0 0 1 1"
                scale="1" unitModel="feet" filePath="models/ base.tif " tiling="1 1" offset="0 0"
                textureFilePath="textures/base.png"/>
            </geometry>
         </terrain>
         <object id="Rover" name="Rover">
            <note>Normal Six Degree of Freedom Object</note>
            <geometry>
               <model unitDistance="meter" pos="0 1 0" quat="0 0 1 1" scale="1"
                 unitModel="meter" filePath="models/rover.obj"/>
            </geometry>
            <thruster id="Booster" name="Main Booster">
               <offset unitDistance="meter" pos="0 1 0" quat="0 0 1 1"/>
               <geometry>
```

```
                <model unitDistance="meter" pos="0 1 0" quat="0 0 1 1" scale="1"
                  unitModel="meter" filePath="models/plume.obj"/>
              </geometry>
            </thruster>
            <joint id="Pivot" type="rotate" name="Dish Pivot">
              <note>Single Degree of Freedom Rotational Joint</note>
              <pin unitDistance="meter" pos="0 1 0" quat="0 0 1 1"/>
              <geometry>
                <model unitDistance="meter" pos="0 1 0" quat="0 0 1 1" scale="1"
                  unitModel="meter" filePath="models/arm.obj"/>
              </geometry>
              <object id="Comm Dish" isStatic="1" name="Communications Dish">
                <note>Static objects inherit parent motion</note>
                <offset unitDistance="meter" pos="0 1 0" quat="0 0 1 1"/>
                <geometry>
                  <model unitDistance="meter" pos="0 1 0" quat="0 0 1 1" scale="1"
                    unitModel="meter" filePath="models/dish.obj"/>
                </geometry>
              </object>
            </joint>
          </object>
        </objects>
      </scene>
      <telemetries>
        <telemetry name="Proposed Sorty" type="file" format="MPC3" epoch="2013-05-
          17T19:22:10.00Z" source=”telemetry/t1.mpc3”>
          <note>Telemetry file description</note>
        </telemetry>
        <telemetry name="Collaborative Sorty" type="network" format="MPC3" epoch="2013-05-
          17T19:22:10.00Z" source”111.111.111.111:1000”>
          <note>Telemetry stream description</note>
        </telemetry>
      </telemetries>
    </mpcMission>
```

## APPENDIX E.
## Sample Data File

```
<?xml version="1.0" encoding="utf-8"?>
<mpcData version="3.0">
   <init name="Sample" epoch="2013-05-17T19:22:10.00Z" author="author">
      <note>Simulated Sorty at Serenity Base; Live Sensor Capture</note>
      <units time="second" distance="meter" angle="degree" force="newton"/>
      <metaData id="Status" type="string"/>
      <metaData id="Temperature" type="double" unitLabel="degC"/>
      <terrain id="Base"/>
      <object unitDistance="inch" unitAngle="radian" id="Rover">
         <metaData id="Status" type="string"/>
         <metaData id="Engine Temperature" type="double" unitLabel="degC"/>
      </object>
      <joint unitAngle="degree" id="Pivot">
         <metaData id="Status" type="string"/>
      </joint>
      <thruster unitForce="newton" id="Booster">
         <metaData id="Status" type="string"/>
      </thruster>
   </init>
   <time value="0">
      <event>Mission Start</event>
      <metaData id="Status">Starting Mission</metaData>
      <metaData id="Temperature">24.78</metaData>
      <object id="Rover" pos="0 0 0" vel="0 0 0" quat="0 0 0 1" angularVel="0 1 0 0" cg="0 0 0"
       scale="1 1 1" vis="1" parent="Base">
         <metaData id="Status">Cold Start</metaData>
         <metaData id="Engine Temperature">24.78</metaData>
      </object>
      <joint id="Pivot" value="42">
         <metaData id="Status">Hard Stop</metaData>
      </joint>
      <thruster id="Booster" value="0">
         <metaData id="Status">Warmup</metaData>
      </thruster>
   </time>
   <time value="10">
      <event>Precheck Complete</event>
      <metaData id="Status">Deploying Rover</metaData>
      <metaData id="Temperature">24.78</metaData>
      <object id="Rover" pos="1 1 0" vel="1 1 0">
         <metaData id="Status">All Systems Go</metaData>
         <metaData id="Engine Temperature">30.42</metaData>
      </object>
      <thruster id="Booster" value="1000">
         <metaData id="Status">Full Throttle</metaData>
      </thruster>
   </time>
   <time value="20">
      <event>Waypoint 1</event>
      <metaData id="Status">Deploying Rover</metaData>
      <metaData id="Temperature">24.78</metaData>
      <object id="Rover" pos="10 10 0" vel="0 0 0">
```

```
            <metaData id="Status">Signal Loss</metaData>
        </object>
        <thruster id="Booster" value="0">
            <metaData id="Status">Shutdown</metaData>
        </thruster>
    </time>
    <time value="30">
        <object id="Rover" pos="10 11 0" vel="0 1 0"/>
    </time>
    <time value="40">
        <event>shutdown</event>
    </time>
</mpcData>
```

# APPENDIX F.
# Data Flow Use Cases

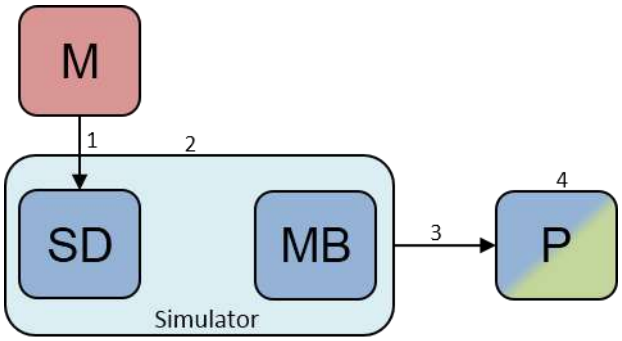
In the following examples, boxes will be colored to indicate who performs each roles as follows:

Red: Model Team
Blue: Simulator Team
Green: DPV Team

## F.1 Single Source, Graphical

**Scenario:** The authoritative data source is a single simulation tool with a built-in graphics display capability.

**Examples:** Delmia, ROAMS




(1) The design team(s) of the system(s) applicable to the simulation activity construct their 3D models and make them available to the simulation team.

(2) The simulation team integrates the models within their simulator and conducts the simulation activity.

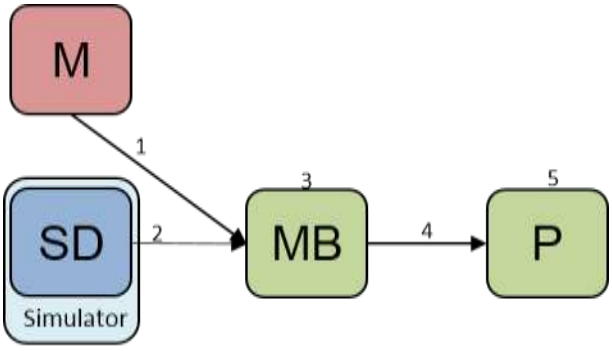
(3) The simulation team exports the simulation results and associated models in the proper formats for presentation, and provides the presenter with a single folder containing all exported data.

(4) The Presenter places the simulation folder containing the exported data into the DON Simulations folder, making it available to DON users. This step may be performed by the simulation team by providing the customer with a copy of DON containing the exported simulation, or it may be performed by the DPV team by placing the exported simulation on a server to make it available for download by existing DON Users.

## F.2 Single Source, Non-graphical

**Scenario:** The authoritative data source is a single simulation tool that lacks a built in graphics display capability.

**Example:** POST




(1) The design team(s) of the system(s) applicable to the simulation activity construct their 3D models and make them available to the DPV team.

(2) The simulation team conducts the simulation activity, exports the simulation results in the proper format for presentation, and makes the results available to the DPV team.

(3) The DPV team integrates the models with the simulation results to build the mission.

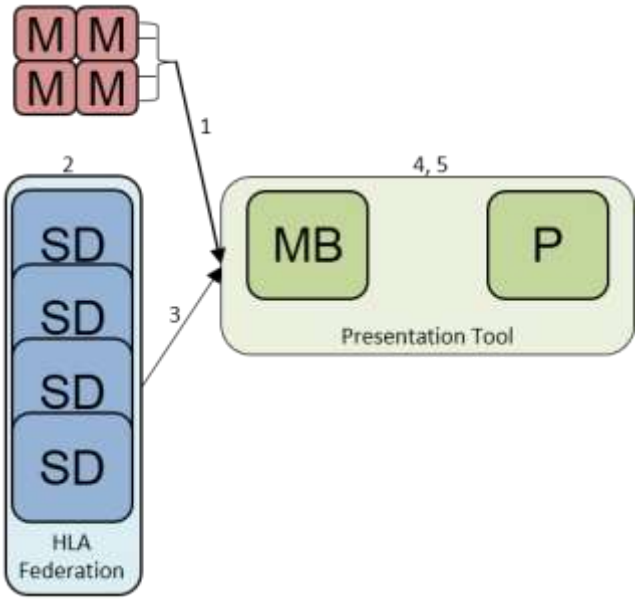
(4) The DPV team exports the mission in the proper formats for presentation and provides the presenter with a single folder containing all exported data.

(5) The DPV team places the simulation folder containing the exported data into the DON Simulations folder and either provides the customer with a copy of DON containing the exported simulation or places the exported simulation on a server to make it available for download by existing DON Users.

## F.3 Distributed Simulation Activity

**Scenario:** Multiple authoritative data sources are connected in an HLA federation, running together real-time, and using DPV tools to display the simulation as it occurs.

**Example:** integrated mission simulations




(1) The design teams of the systems applicable to the simulation activity construct their 3D models and make them available to the DPV team.

(2) The simulation teams join the HLA federation and conduct the simulation activity.

(3) The DPV team joins the presentation tool to the HLA federation to receive data during the simulation activity.

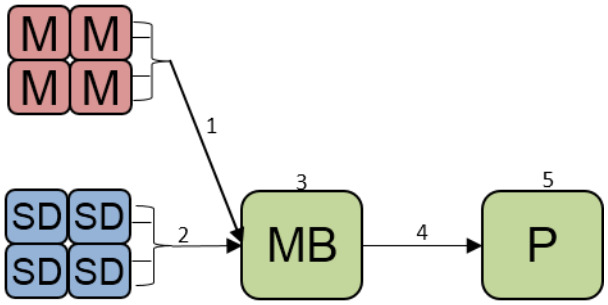
(4) The presentation tool integrates the data received from the HLA federation with the graphical models and updates the simulation in real-time.

(5) The presentation tool saves all received data and preserves it for future playback and distribution.

## F.4 Integration Activity

**Scenario:** Multiple authoritative data sources are providing simulation results that must be integrated with each other.

**Example:** exploration campaign scenarios




(1) The design teams of the systems applicable to the simulation activity construct their 3D models and make them available to the DPV team.

(2) The simulation teams conduct their respective simulation activities, export their simulation results in the proper format for presentation, and make the results available to the DPV team.

(3) The DPV team integrates the models with the simulation results to build the mission.

(4) The DPV team exports the mission in the proper formats for presentation and provides the presenter with a single folder containing all exported data.

(5) The DPV team places the simulation folder containing the exported data into the DON Simulations folder and either provides the customer with a copy of DON containing the exported simulation or places the exported simulation on a server to make it available for download by existing DON Users.