Space Master by Pitch

Version 1.1.2

User's Guide

Table of Contents

1. Purpose of the Space Master

The Space Master is a generic HLA federate that implements the Master and Pacer role of the SISO Space Reference FOM. It is intended to be used for demonstration and testing of federates and federations that implement the Space Reference FOM. This document describes the Space Master and how to use it.

The Space Master is a command-line based program that runs on Windows, Linux and Mac. It requires an HLA Evolved RTI with Java bindings. It is based on the Space Reference FOM draft of February 2017.

Pitch provides two federates that complement the Space Master:

- The **Earth Environment** federate. This federate provides an Earth Fixed reference frame. It can be used for testing purposes, if no other environment federate is available. It can also be used by federations where the scenario only needs to use the Earth Fixed reference frame.

- The **Web Space Monitor**. This federate presents lists and pictures of reference frames and physical entities that are present in a Space Reference FOM federation. It is useful for inspecting and troubleshooting scenarios. Since the user interface is presented in a web browser, it is easy to access from anywhere.

These three federates can be run together in a federation to provide a complete Space Reference FOM federation, but without a scenario.

Bibliography

The following documents provide extensive information that the Space Master builds upon:

- IEEE 1516-2010 Standard for Modeling and Simulation (M&S) High Level Architecture (HLA), available from www.ieee.org.

- SISO-STD-0XX-20XX Standard for the Space Reference Federation Object Model (Space FOM) Version 0.1D (draft). To be published on www.sisostds.org.

2. Space Reference FOM Background

To put together a federation that is compliant with the Space Reference FOM, it is important to understand the following background.

Fundamental scenario information

There are two types of fundamental scenario information that is necessary to run a federation: the epoch of the time line and the coordinate systems, expressed through reference frames.

Epoch: It is necessary to specify a physical time, for example 2015-12-24 14:00 UTC, when the scenario starts and the HLA logical time is zero. See chapter 5 of the SISO Space Reference FOM for more details on time.

Reference frames: The space reference FOM needs one or more reference frames, in which any entity can specify its position, for example reference frames relating to the Sun, Earth, Mars and the Moon. These relate to each other in parent-child relationships, forming a tree. An Earth related coordinate system may for example be the parent of a Moon coordinate system. The top-most reference frame is the Root reference frame in this tree. See chapter 6 of the SISO Space Reference FOM for more details in reference frames.

Federate roles

Three key federate roles that are required in a federation. These can be implemented by the same or separate federates. The roles are:

Master. This federate controls the execution control, which includes initialization and management of the transitions between the states Initializing, Running, Freeze and Shutdown.

Pacer. This federate manages the relationship between the logical scenario time in the simulation and the real time (wall clock time). This makes is possible to run the simulation in real time, faster, or slower than real time.

Root Reference Frame Publisher (RRFP). This federate registers and updates the Root Reference Frame which forms the basis for any tree of coordinate systems.

The Space Master has the Master and the Pacer role. Since an RRFP is always required, a small sample RRFP, called the Earth Environment is provided.

See chapter 4 of the SISO Space Reference FOM for more details on federation composition.

Types of federates

Federates are categorized based on two properties:

Required or optional. A required federate must be present before the initialization can start.

Early joiner or late joiner. An early joiner will participate in the initialization and be part of the simulation from logical time zero. A late joiner will not participate in the initialization and can join any time it sees fit.

3. Initialization steps

The Space Master performs the following steps when initializing a Space Reference FOM federation. See chapter 8 of the SISO Space Reference FOM for more details on initialization.

Step 1: Connection.
The Space Master connects to the RTI and joins a federation. The connection parameters are specified in the Space Master configuration file.

Step 2: Required Federates Check.
The Space Master checks that all required federates have joined. These federates are specified in the Space Master configuration file.

Step 3: Sync Point Registration
The Space Master register two predefined sync points (initialization_started and objects_discovered) as well as some optional Multi-Phase Initilization sync points. These optional sync points are specified in the Space Master configuration file.

Step 4: ExCO Registration:
The Space Master registers the Execution Control (ExCO) object instance.

Step 5: Wait For Required Objects
The Space Master waits for federates to signal that they have discovered all objects that the require and achieved the "objects_discovered" sync point.

Step 6: ExCO Time Setup
The Space Master updates the Epoch attribute of the ExCO.

Step 7: Root Reference Frame Discovery
The Space Master waits for the discovery of the Root Reference Frame and updates the ExCO object with its name.

MPI Phase 0..n
The Space Reference FOM offers the possibility to go through a set of federation specific initialization steps. In each step, federates exchange initialization data and then achieves a sync point. The Space Master monitors that these sync points are achieved in the correct order.

Step 8: Set up Time Management
The Space Master enables Time management (regulating/constrained). The sync point "initialization_started" is achieved and "initialization complete" is registered.

Step 9: Go to Run
The Space Master sets the run-mode of ExCO to Running. Pacing starts.

4. Execution modes

After Initialization has completed, there are three execution modes:

Running Mode

The Pacer federate advances logical time. Note that the Space Master is also a Pacer. By default, the time is advanced one second at a time with a time scale factor 1.0, i.e. one scenario second per real time second. The time scale factor and the look-ahead can be configured in the Space Master configuration file before execution. Note that only HLA Time Management and the local computer clock is used. Central Timing Equipment (CTE) isn't supported.

Freeze mode

The federation can enter and exit Freeze mode, during which time will not be advanced.

Shutdown

The federation can Enter shutdown mode, when all federates will shut down. This cannot be reversed. In some cases, it may be desirable to first enter Freeze mode before shutting down.

There are two ways that the execution mode can change:

- Any federate can send a Mode Transition Request (MTR) interaction, according to the Space Reference FOM. The Space Master subscribes to these interactions and will follow them accordingly.
- By typing a command on the Space Master console.

See chapter 8 of the SISO Space Reference FOM for more details on execution control.

5. The Earth Environment federate

The Space Master needs a Root Reference Frame Publisher in the federation in order to complete initialization. To facilitate testing, a small federate called the Earth Environment federate is provided. It publishes the Earth Fixed reference frame from the SISO Space Reference FOM standard.

To use this federate, it is recommended that you

1. Specify the name of this federate in the root reference frame publisher spot in the Space Master configuration

2. Start the Space Master first and then the Earth Environment federate. The Space Master will first discover that this federate has joined, and then discover the Earth Fixed reference frame.

6. Configuring the Space Master

Below is an example of a configuration file for the Space Master.

```
master.federation.ipaddress = "localhost"
master.federation.port = 8989
master.federation.federationname = "SEE 2018"
master.federation.federatename = "Space Master"
master.federation.federatetype = "Master"
master.federation.lookahead = 1000000
master.federation.epoch = 17131.83333333334
master.federation.mpisyncpoints = ["MP1", "MP2"]
master.federation.pacingfederate="Space Master"
master.federation.rootreferenceframepublisher="EarthEnvironment"
master.federation.requiredfederates = ["Recorder", "MyOtherFederate"]
master.federation.timescalefactor = 1
master.federation.leastcommontimestep = 1000000
master.federation.minimumfreezedelay = 1000000
master.federation.verbose = false
```

Some comments:

The lookahead/federation time step is given as an integer value, specifying the time in microseconds. The default is 1 000 000, i.e. one second.

To calculate the Epoch, which is expressed in Truncated Julian Date, you can use the NASA web site: https://gammaray.msfc.nasa.gov/tools/date_convert/

A time scale factor of two (2) means that the simulation will execute twice as fast as the real time. To execute slower, for example at half the real-time speed, enter 0.5.

Minimum freeze delay is an offset to help calculate a good scenario time to transition to freeze. It should be set to at least 1 to be able to correctly calculate the next available scenario time to freeze at.

Verbose can be set to true if extra output regarding announcements of transitions and synchronization points, as well as synchronization of synchronization points.

7. Running the Space Master

Below is an example of running the Space Master on a console. Note that it can be run both in interactive (step-by-step) mode, which is suitable for debugging, and automatic mode, without user input.

The commands are as follows:

F Go to freeze. Can be issued during run.

R Go to run. Can be issued during freeze.

S Go to shutdown. Can be entered during run and freeze.

Note that the above transitions can also be performed by issuing Mode Transfer Request interactions. These can be sent during initialization, which means that a federation may go directly from initialization to freeze or shutdown.

Example execution

```
Welcome to Space Master. Select a mode
[M] for Manual. Lets you select when to proceed with each step
[A] for Automatic. Runs all steps automatically as soon as they are available.
> M
Step 1: Connection
Press 'ENTER' to connect to the RTI at localhost:8989
Connecting ... Connected

Step 2: Required Federates Check
Waiting for:
Recorder
EarthEnvironment
Required Federate Discovered: Recorder
Waiting for:
EarthEnvironment
Required Federate Discovered: EarthEnvironment
All required federates has joined. Press 'ENTER' to continue

Step 3: Synch Point Registration
Press 'ENTER' to register Sync Points

Step 4: ExCO Registration
Press 'ENTER' to create ExCO object

Step 5: Wait For Required Objects
Press 'ENTER' to achieve and wait for synchronization for Sync-Point objects discovered

Step 6: ExCO Time Setup
Press 'ENTER' to start this step

Step 7: Root Reference Frame Discovery
Root Reference Frame found: EarthFixed

Step 8: Set up Time Management
Press 'ENTER' to start this step

Step 9: Go to Run
Press 'ENTER' to start this step
```

```
Available commands are as follows:
F       Go to freeze. Can be issued during run.
R       Go to run. Can be issued during freeze.
S       Go to shutdown. Can be entered during run and freeze.

>
```