A 3D Visualization Plugin for SIMSAT

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ABSTRACT

SIMSAT does not currently provide an integrated solution for displaying spacecraft simulation data as a virtual 3D environment. We propose a solution for simulation data visualization that integrates with SIMSAT and provides a representation of the simulation in a virtual 3D environment without relying on external tools.
A SIMSAT plugin has been developed which enables visualization of the simulated environment and spacecraft in an interactive 3D space. The plugin displays a navigable three dimensional Earth globe with spacecraft and ground stations displayed and positioned according to the simulation parameters. The 3D model of the spacecraft is oriented according to the attitude data in the simulation. The orbital elements of the spacecraft are obtained from the simulation and propagated into the future in order to display a path representing the orbit. The propagated orbit data is used to determine the next ground station passes according to the ground station visibility masks. The time and location of acquisition and loss of signal events are displayed on the globe. Orbit propagation and ground station pass calculations occur at a high rate without user noticeable delays.
The plugin is a promising tool for users and developers of SIMSAT based simulations. Integration with SIMSAT reduces the work environment complexity since no other tools are necessary. The 3D visualization of orbit and ground station position provides an intuitive overview of the simulation. The orientation of the 3D model of the spacecraft can be used for understanding antenna pointing as well as sun incidence angle on solar panels. Future work will consist in improving current features and adding new ones according to user feedback.
Visualizing the spacecraft and ground station positions, as well as the where and when the next ground pass is going to take place is easier for the user when it is presented in a 3D navigable environment. By integrating with SIMSAT simulation officers and developers can easily get a detailed overview of the current status of the simulated spacecraft.

INTRODUCTION

The SIMSAT MMI is the primary tool used by simulation officers when operating a spacecraft simulator based on the SIMULUS product from the European Space Agency (ESA). It is also used by developers of spacecraft simulators based on SIMULUS while developing or maintaining those simulators, and by members of the Flight Control Team (FCT) during daily work. The SIMSAT MMI provides an interface for users to monitor and interact with running simulations via alphanumeric displays (ANDs) and graphic displays (GRDs), but it does not provide a virtual 3D representation of the spacecraft orbit or of the ground station positions.
To address this situation, we have developed an alternative to monitor spacecraft position and attitude, ground station location and visibility mask, and pass location and time. The solution was to create SIMSAT-View, a plugin for the SIMSAT MMI which displays the information in an intuitive way. Fig. 1 shows the SIMSAT MMI running with SIMSAT-View.

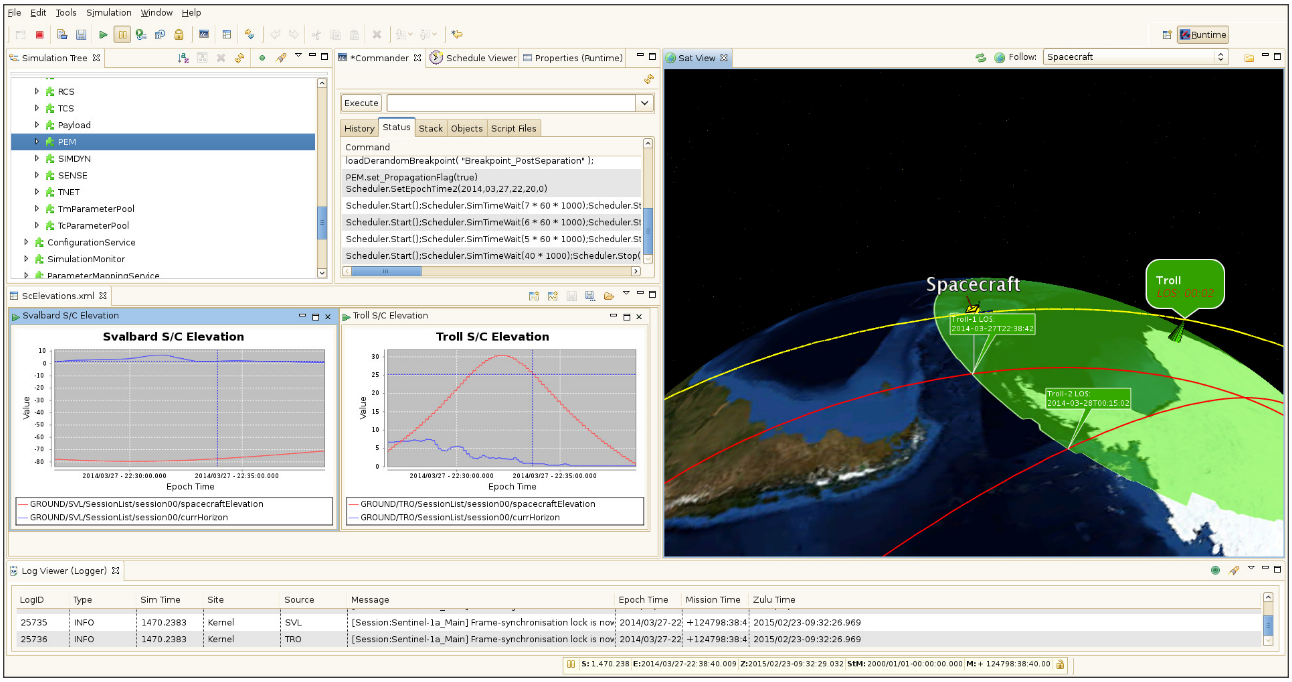

Fig. 1. SIMSAT MMI with SIMSAT-View showing the spacecraft reaching the point of LOS. Notice the GRD with the Troll S/C Elevation just reaching the threshold of the visibility horizon.

OBJECTIVES

The objective of SIMSAT-View is to provide a better way for users of SIMSAT to visualize simulation data. The following features were identified to be implemented in SIMSAT-View:

- Earth globe visualization, including display of low-resolution satellite imagery.
- Spacecraft orbit and ground track display, determined from the spacecraft orbital elements in the simulation at a high rate without user noticeable delays.
- Spacecraft position and attitude, retrieved at a high rate without user noticeable delays.
- Configurable overlays displaying simulation data, as a complement to SIMSAT MMI ANDs.
- Configurable ground station position and visibility masks.
- Ground station acquisition of signal (AOS) and loss of signal (LOS) event determination at a high rate without user noticeable delays, based on the propagated spacecraft orbit and configured ground station data.

IMPLEMENTATION

The SIMSAT MMI has been developed using the Eclipse Rich Client Platform (RCP). Eclipse RCP provides extensibility features which allow the integration of plug-ins into an application. SIMSAT-View has been developed as an Eclipse RCP plugin that extends the functionalities of the SIMSAT MMI. Eclipse RCP is a Java based technology and SIMSAT-View has been developed in the same language. The developed plugin provides an extra eclipse RCP view for the SIMSAT MMI.

3D Environment

The NASA World Wind (WW) Java SDK[1] was used for the 3D environment implementation. WW SDK provides Java libraries that offer an interactive virtual 3D environment for displaying and interacting with geographic data.
WW provides SIMSAT-View with both a 3D globe and flat Earth visualization. The 3D globe representation provides no distortions to the ground station visibility areas, but the flat Earth representation displays all assets simultaneously. WW uses Earth fixed coordinates to manage all the represented assets in SIMSAT-View, so the conversion between Earth fixed Earth centred and Earth equatorial is made with a transformation matrix provided by the Position and Environment Model (PEM) running in the simulation. Fig. 2 shows the two representations of Earth in SIMSAT-View: globe view and flat map.

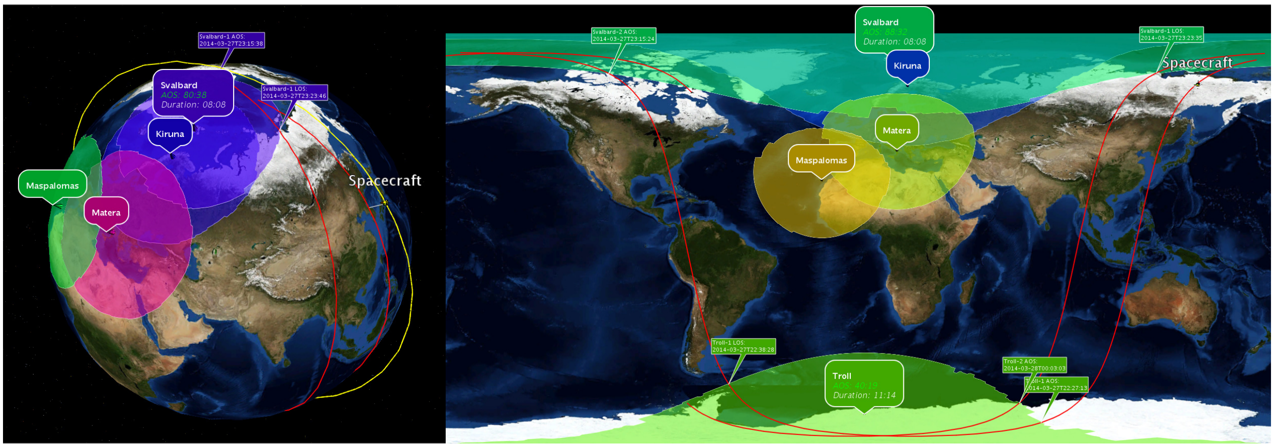

Fig. 2. SIMSAT-View's 3D Globe and Flat Map showing the spacecraft's orbit propagation tracks and ground station visibility areas.

Earth Rotation
When in 3D Globe mode, the Earth rotates according to the simulation's Epoch time. By connecting the Earth models to the running simulation we determine the rotation of the Earth rotation in the simulation and then rotate it accordingly in SIMSAT-View.

SIMSAT-View Layers

Each item represented in SIMSAT-View has a corresponding layer implementation responsible for the rendering of assets in SIMSAT-View. Each layer is responsible for rendering the different assets according to the information provided by the simulation. Each layer polls the simulation and provides WW with the correct values with which to represent them in SIMSAT-View. Layers are configured via the SIMSAT-View configuration file.

Spacecraft Layer
The spacecraft layer represents a simulated spacecraft. It is represented in the virtual environment by a cube with an axes system, thus representing the position and attitude of the spacecraft. The layer has the option of showing a ground track and an orbit track showing the propagated orbit in space and on ground. A nadir line is also displayed. Fig 3. shows an orbiting spacecraft with all the track lines active.

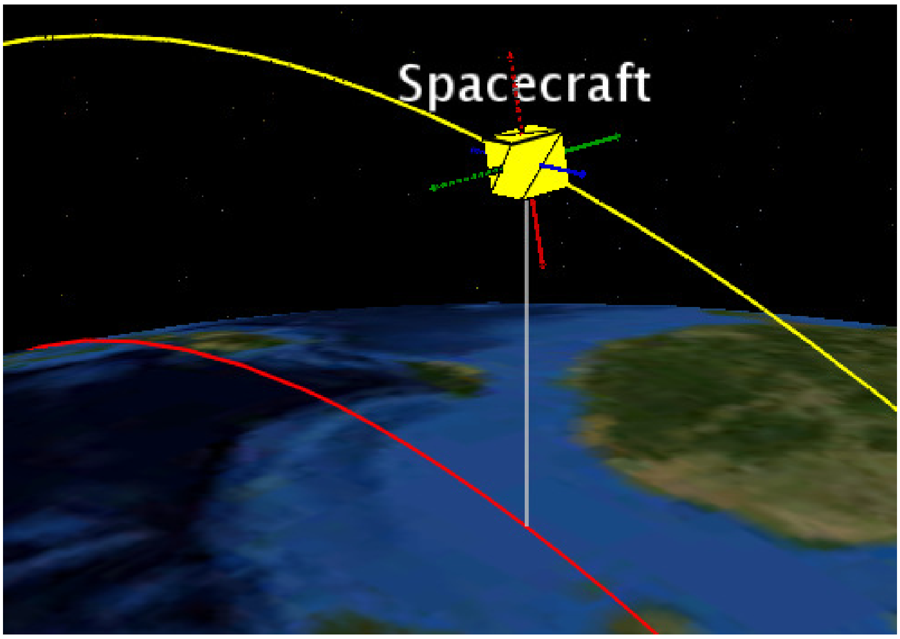

Fig. 3. Orbiting spacecraft with ground and orbit tracks, nadir line and attitude axes.

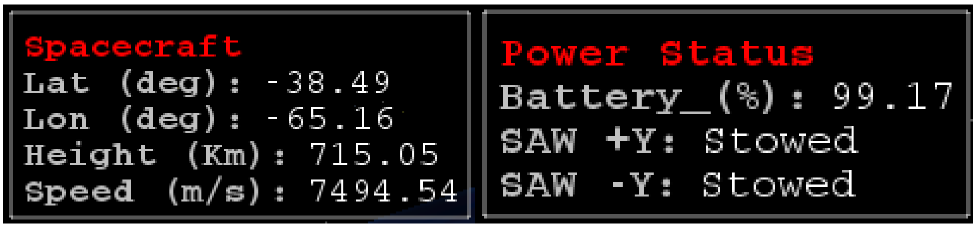

Fig. 4. Two overlays showing different information of the spacecraft. These displays are shown on top of SIMSAT-View and are continuously updated with information from the simulation. The user can configure what information is to be displayed.

Overlay Layer
Overlays are configurable displays that are shown on top of SIMSAT-View. Like a SIMSAT AND, they can be configured to show any value that exists in the simulation. Overlays are created in the SIMSAT-View configuration file by specifying the path in the simulation tree to the values that are to be displayed. An example of two overlays can be found in Fig. 4. Overlays are intended to be a complement to the SIMSAT ANDs, providing less features but having the advantage of being displayed directly on SIMSAT-View.

Ground Station Layer
Ground station layers provide a visual representation of ground station location as well as their visibility area and future passes. The ground station visibility mask is obtained from the SimGroundConfig.xml file which is commonly used in SIMULUS based simulators to configure the ground stations. Only the path to this file needs to be configured in order to set up the ground stations and their visibility masks in SIMSAT-View. Fig. 6 shows the visibility area of the Troll ground station with the predicted passes along its border. The time until the next predicted pass and its duration is displayed over the ground station.

Propagation Service

To calculate the future and past positions of the spacecraft in its orbit as well as the time and location of ground station AOS and LOS events, a propagation service has been implemented as a means to coordinate the aspects of orbit propagation in the different WW layers. Orbit propagation calculations are done using the Orekit[2] Java library.

Fig. 5. Spacecraft reaching the point of AOS at the Troll ground station. Note ground track over two orbits represented as a red line. Troll ground station visibility mask is represented as a green polygon. Point of AOS is indicated by a green text box which indicates the number of the pass as well as the time of AOS.

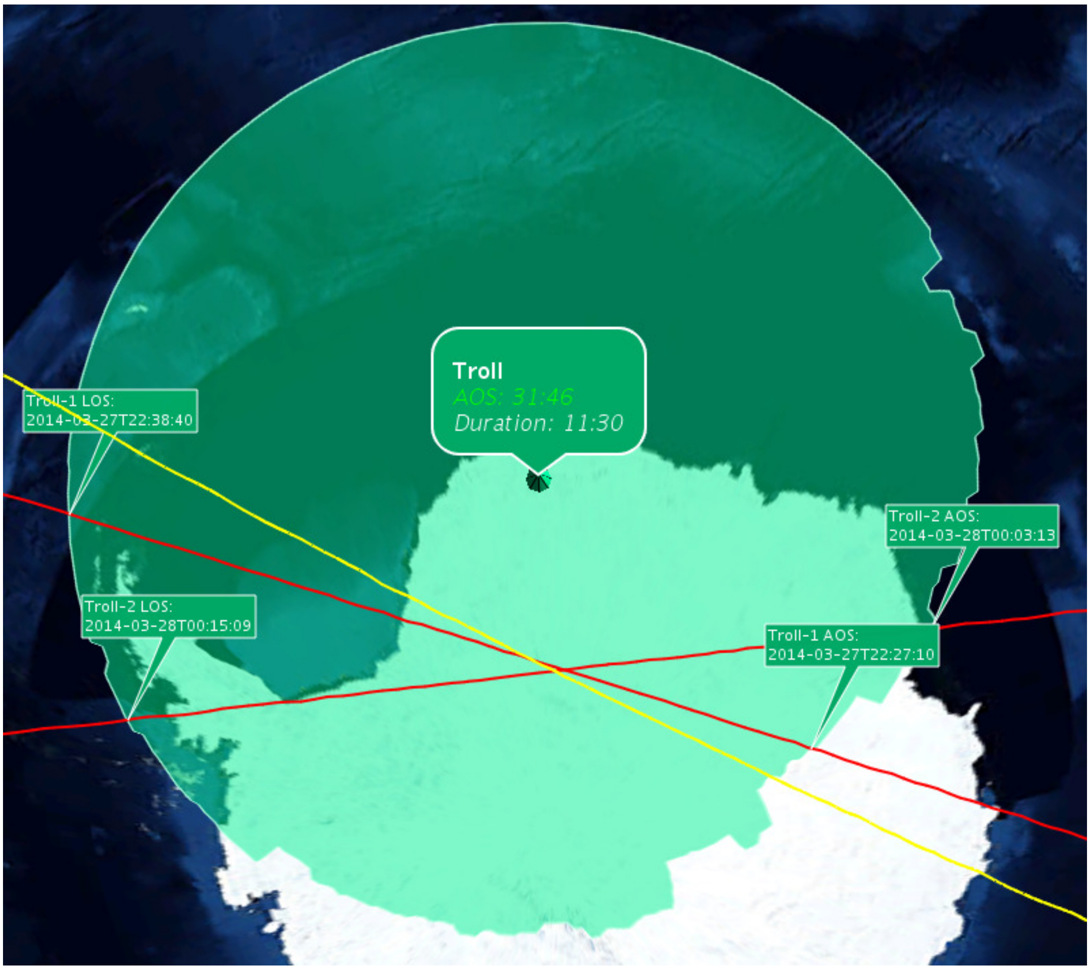

Fig 6. Troll ground station and visibilities with 2 future passes. Spacecraft will pass above the Troll-1 AOS mark and follow the red ground track until the Troll-1 LOS mark. After a full orbit around the Earth the same will happen for Troll-2.

Both the orbital elements of the spacecraft, taken from the PEM, and the ground stations location and visibility masks are fed into the orbit propagation models of Orekit, which then calculates future and past positions of the spacecraft along its orbit as well as location and time of ground station passes. Fig. 5 shows the spacecraft and its ground track as a red line approaching the horizon of a ground station for the first pass at Epoch time 2014-03-27T22:27:10, with the second pass occurring at 2014-03-28T00:03:14. The ground station visibility mask is displayed as a green polygon.

Configuration

SIMSAT-View provides the user with the ability to load different configuration files depending on what kind of visualization is desired. The configuration file is an XML file which has a description for each WW layer that is to be rendered in SIMSAT-View. The XML file has been designed to be simple so that it can be edited by the user without resorting to configuration tools. The user can load a different configuration at any time during simulation run time. Configuration options include:

PropagationService: maximum number of passes and number of periods.

Spacecraft: location in the simulation tree of PEM, PositionEcef and RollPitchYaw. Enabling and disabling of the ground and orbital track.

Overlay: position of the overlay in SIMSAT-View and location in the simulation tree of the items to display.

SimGroundConfig: location of the SimGroundConfig.xml file used for configuring the ground stations.

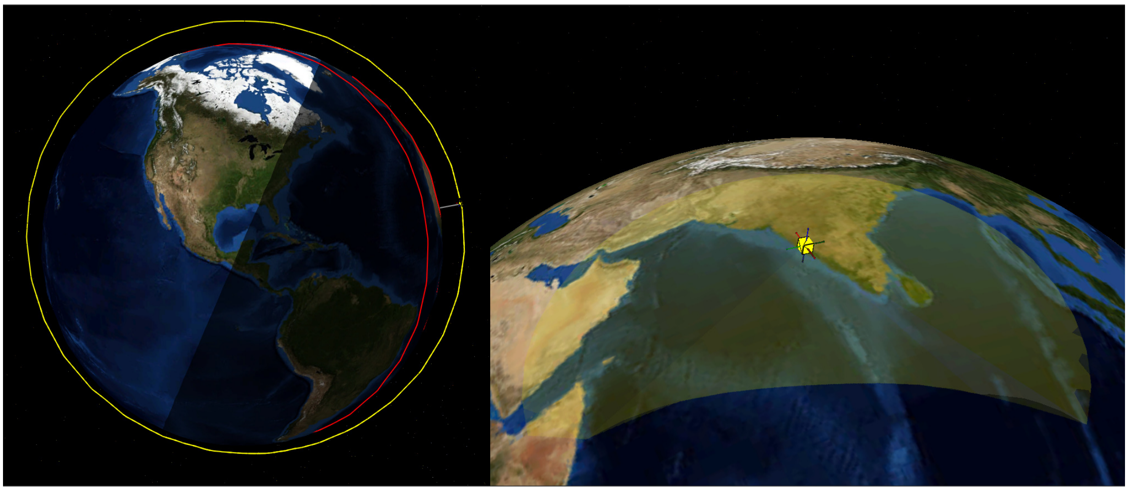

Fig. 7. Concept for sunlight and FOV cone.

CONCLUSIONS

Testing by Terma staff with experience in SIMULUS-based spacecraft simulator development as well as experience in performing simulation officer duties shows that SIMSAT-View is a promising tool for supporting those activities. The tool offers an easy to way to observe the spacecraft orbital position and attitude as well as time and location of future ground station passes. Finally, the use of SIMSAT-View with a spacecraft simulator has not been observed to affect simulator performance or stability.

FURTHER WORK

Future work includes gathering feedback from SIMSAT MMI users and SIMSAT-View testers and identifying areas of improvement. Some areas of improvement that are currently in the road map include:

- Sunlight: day/night shadowing for the globe. See Fig. 7.
- Field of view: a cone shape projected on the Earth globe representing the field of view (FOV) of the antennas of the spacecraft. See Fig. 7.
- Ground pass table: chronological table of future ground passes with AOS/LOS times and duration.
- 3D models: support for 3D models such as 3D Studio or Collada files which can be used for representing the spacecraft or the ground stations.
- Vector objects: representation of additional vectors in 3D space which can be used to display the spacecraft acceleration or solar panel orientation.
- Solar panels or other surfaces: representation of spacecraft features such as solar panels and antennas with correct position and orientation.
- Multiple views: support for multiple SIMSAT-View instances with different configurations loaded.
- Stand-alone operation: adapt SIMSAT-View to operate in a stand-alone way, capable of connecting to any running simulation.
- Solar system: support for the entire solar system and inter planetary missions.

REFERENCES

[1] WW Java SDK, NASA (http://WW.arc.nasa.gov/java/)

[2] OreKit, CS Systèmes (https://www.orekit.org/)