GMAT and VTS Timeloop Software Manual

Introduction

This manual aims to guide you through the basic functionalities of NASA's General Mission Analysis Tool (GMAT) and VTS Timeloop, which will be used during the laboratory. It is recommended to thoroughly familiarize yourself with the steps below before proceeding with the mission scenarios.

Part 1: General Mission Analysis Tool (GMAT)

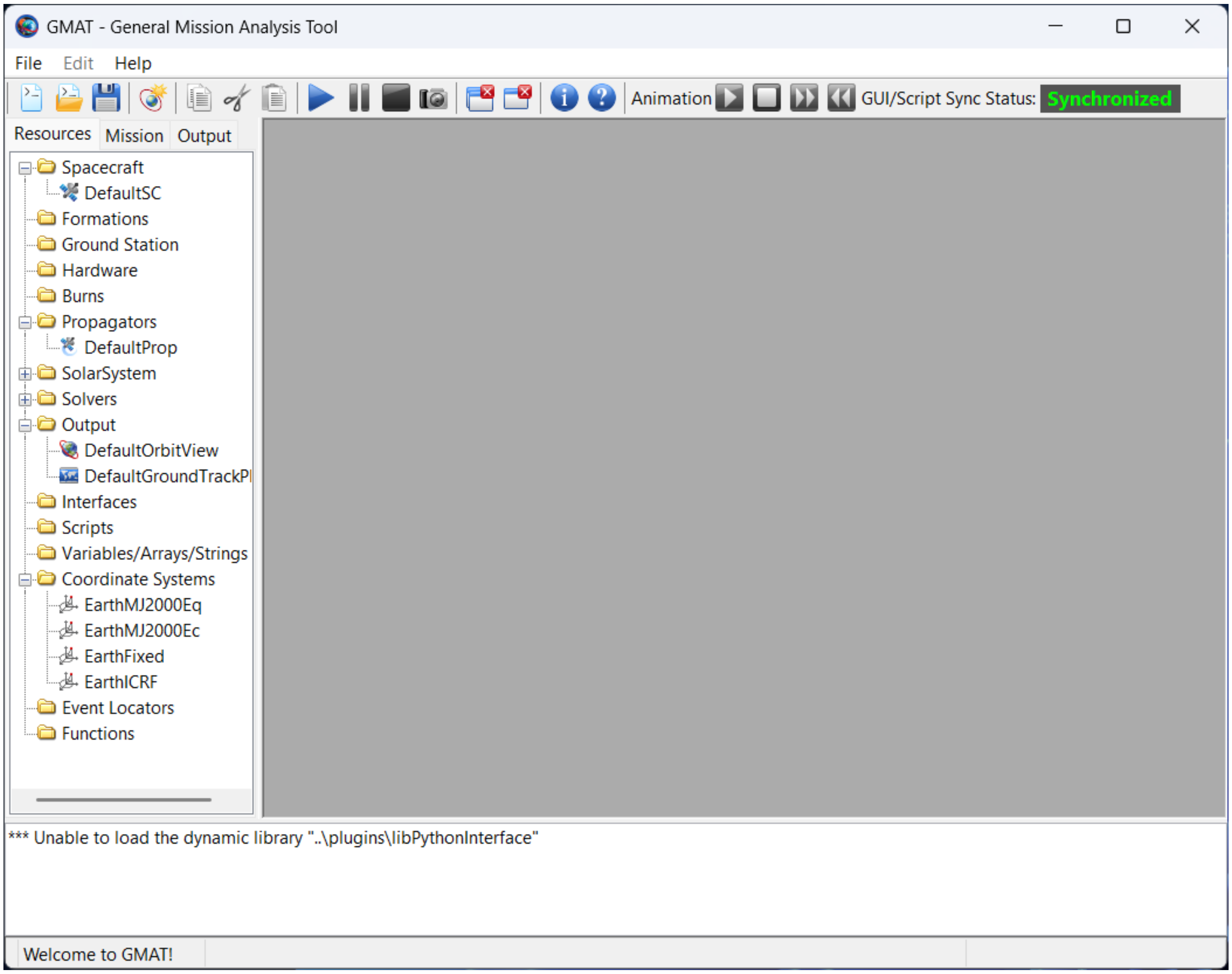
1.1. Installation and First Launch

- **Installation:** Follow the instructions available on the official GMAT website (https://software.nasa.gov/software/GSC-17177-1). Ensure you download the version appropriate for your operating system.
- **First Launch:** After installation, launch GMAT. Familiarize yourself with the main application window.

1.2. Overview of the GMAT User Interface

The main components of the GMAT interface are:

- **Resources/Mission/Output Tree:** On the left side, contains all mission elements (spacecraft, propagators, coordinate systems, plots, reports, etc.).
- **Workspace:** On the right side, the gray area, will display all windows, plots and text editors as you open them from the Tree on the left.
- **Message Window Panel:** At the bottom, displays logs, errors, and warnings.
- **Toolbar:** At the top, contains buttons for running simulations, saving, opening, etc.



1.3. Basic Steps for Creating a Mission in GMAT

The following outlines a typical workflow for creating a new mission.

Step 1: Creating a `Spacecraft` Object

1. In the Resources Tree, right-click on the `Spacecraft` folder and select `Add Spacecraft`.
2. Name your spacecraft (e.g., `MySat`). Note: `DefaultSC` might already be created, double-click to edit it!
3. In the opened spacecraft configuration window, you can define its parameters:
   - `Epoch format`: Date format used for the mission; Modified Julian Date, Gregorian (e.g., `UTCGregorian`).
   - `Epoch`: Initial date and time of the mission (e.g., `01 Jan 2025 12:00:00.000 UTCG`).
   - `CoordinateSystem`: The coordinate system in which you define the initial state (e.g., `EarthMJ2000Eq` - Earth Mean J2000 Equatorial).
   - `state Type`: Type of orbital elements for display and editing (e.g., `Keplerian`).
   - Enter values for the 6 Keplerian elements (SMA, ECC, INC, RAAN, AOP, TA/MA - see scenarios).
   - In the `Ballistic/Mass` tab you can also define mass (`DryMass`), ballistic coefficients (`DragCoefficient`, `DragArea`), solar radiation pressure coefficients, etc., if required by the force model.
4. Click `Apply` and `OK`.

Step 2: Defining Coordinate Systems (if different from default)

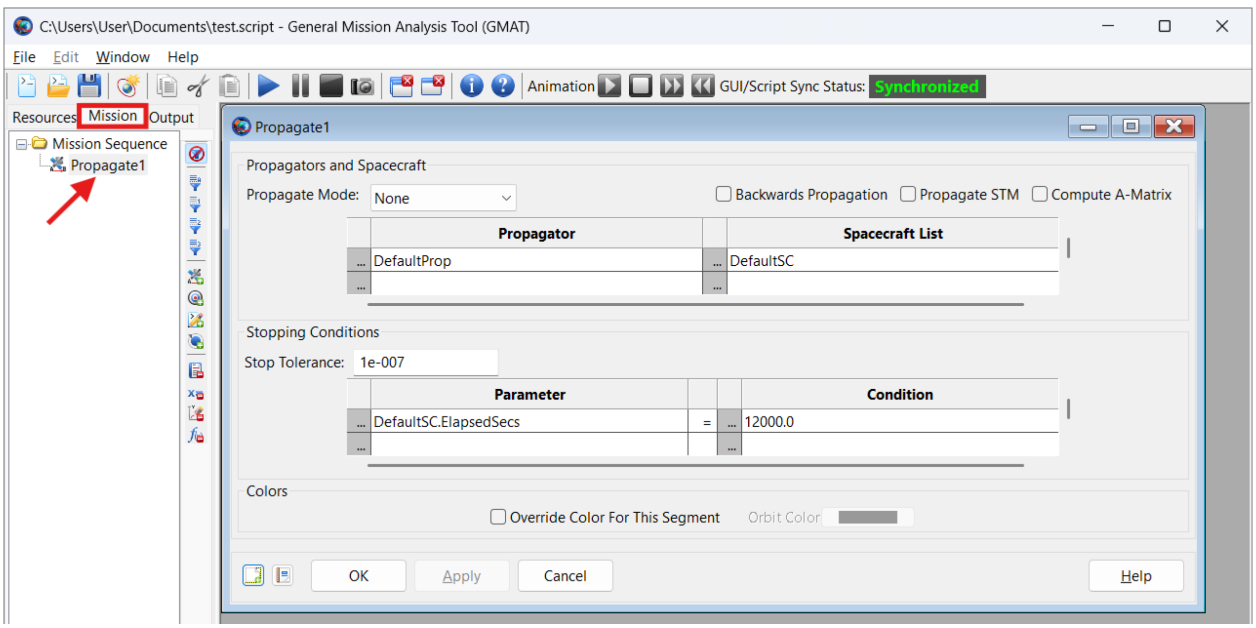
- GMAT uses standard systems by default (e.g., `EarthMJ2000Eq`, `EarthFixed`). Usually, there's no need to create new ones for basic LEO missions.

Step 3: Configuring the Propagator (e.g., `Prop_Default`)

1. In the Resources Tree, find the `Propagators` folder, and within it, the default propagator (e.g., `DefaultProp`). Double-click it.
2. In the propagator configuration window (optional to configure, defaults are ok for this excercise):
   - `ForceModel`: Select the force model. Click `Edit` next to `ForceModel`.
     - `PrimaryBody`: Usually `Earth`.
     - `GravityField`: Earth's gravity field model (e.g., `JGM-2` or `JGM-3` of a specific degree and order, e.g., `4x4`).
     - `Atmosphere`: Atmosphere model (e.g., `JacchiaRoberts` or `MSISE90`), if you want to include drag.
     - `SolarRadiationPressure`: If you want to include solar radiation pressure.
     - Add other forces as needed (e.g., Moon's gravity, Sun's gravity).
   - `Integrator`: Type of numerical integrator (e.g., `RungeKutta89`).
   - `InitialStepSize`: Initial time step for integration (e.g., `60` seconds).
3. Click `Apply` and `OK`.

Step 4: Defining Mission Commands (Mission Sequence)

1. Above the Resources Tree, find `Mission` tab and locate `Mission Sequence` tree. Double-click to open the editor.
2. A basic mission sequence for simple propagation might look like this:



3. When you click the button in bottom-left corner (`Show Script`) or click `F7` on your keyboard, you will see the code equivalent of the Propagator. Something like this: `gmat Propagate DefaultProp(MySat) {MySat.ElapsedSecs = 86400.0}; // Propagate for 86400 seconds (1 day)` Or propagate until a certain number of orbits are completed: `gmat Propagate DefaultProp(MySat) {MySat.Earth.PeriapsisCount = 3}; // Propagate for 3 periapsis passages`

Step 5: Generating Output Data

- **`ReportFile` (Text Report File):**
  1. In the Resources Tree, right-click on `Output` and select `Add -> ReportFile`.
  2. Give it a name (e.g., `OrbitDataReport`).

3. In the configuration window:
   - `Filename`: Name of the output file (e.g., `orbit_data.txt`).
   - `Parameters`: Add parameters you want to save (e.g., `MySat.UTCGEpoch`, `MySat.EarthMJ2000Eq.X`, `MySat.EarthMJ2000Eq.Y`, `MySat.EarthMJ2000Eq.Z`, `MySat.Earth.Altitude`, `MySat.Earth.Latitude`, `MySat.Earth.Longitude`).
4. Click `OK` to close

- **`OrbitView` (3D Orbit Visualization):**

  1. In the Resources Tree, right-click on `Output` and select `Add -> OrbitView`. `DefaultOrbitView` might already be created, edit it.
  2. Give it a name (e.g., `MyOrbitView`).
  3. In the configuration:
     - Add `MySat` to the list of objects to display.
     - Configure other options (view coordinate system, orbit visibility, Earth visibility, etc.).
  4. No command needs to be added to the script; plots are updated automatically.

- **`GroundTrackPlot` (Ground Track Plot):**

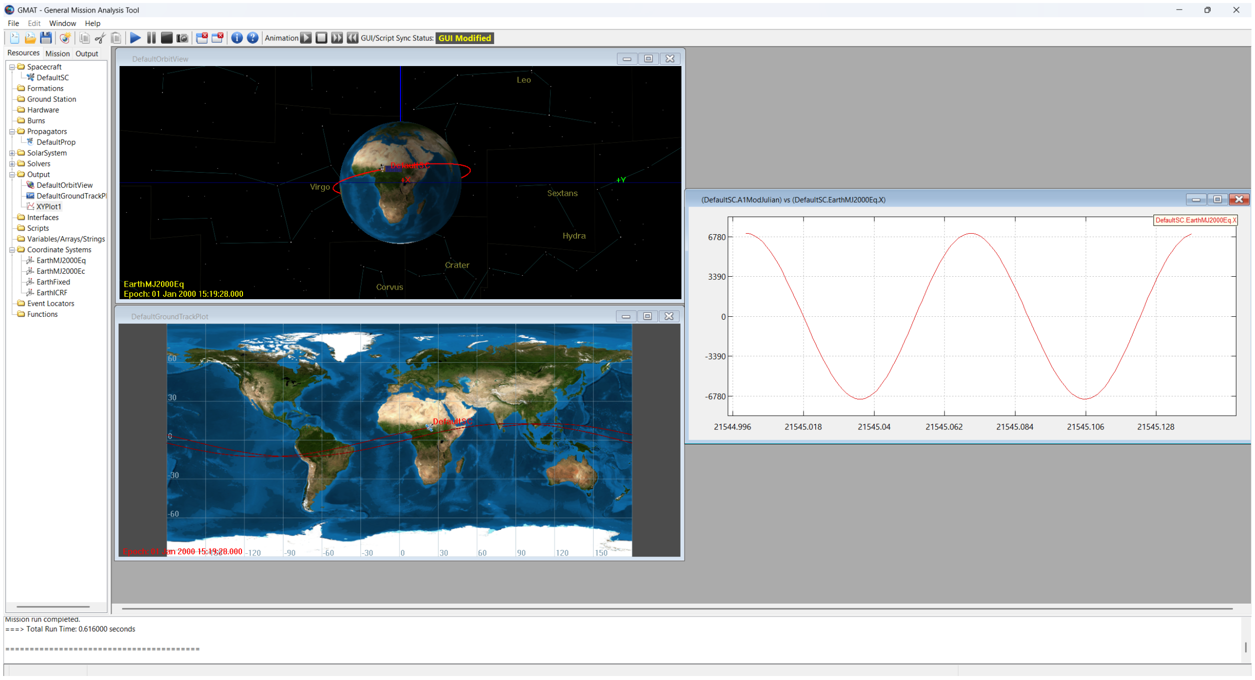
  1. Similar to `OrbitView`, add an `XYPlot` (or `GroundTrackPlot`).
  2. Configure axes: X as `MySat.Earth.Longitude`, Y as `MySat.Earth.Latitude`.

- **Exporting Ephemeris Data (e.g., CCSDS OEM):**

  - GMAT can generate ephemeris files in the CCSDS OEM (Orbit Ephemeris Message) standard.
  - In the Resources Tree, right-click on `Output` and select `Add -> EphemerisFile`.
  - Configure the file type as `CCSDS-OEM`.
  - Specify the object (`Spacecraft`), coordinate system, epoch format, and output time step.

1.4. Running the Simulation and Analyzing Results

1. **Save the mission:** Click the floppy disk icon or `File -> Save`.
2. **Run the mission:** Click the green “Run” button (arrow).
3. Observe messages in the `Message Window` panel.
4. After the simulation finishes, open the generated report files and analyze the plots (`OrbitView`, `GroundTrackPlot`).



1.5. Tips and Common Problems

- **Script errors:** Carefully check the syntax in the script editor. The message panel often indicates the line with the error.
- **Unstable propagation:** If the simulation "diverges" or ends with an error, try reducing the integrator's time step (`InitialStepSize`) or simplifying the force model.
- **Units:** Ensure you are using consistent units (GMAT defaults to km, seconds, degrees).
- **GMAT Documentation:** Use the extensive GMAT documentation available online ([suspicious link removed]) and the built-in help.

Part 2: VTS Timeloop

2.1. Installation and First Launch

- **Installation:** Follow the instructions provided by the VTS Timeloop developers: https://timeloop.fr/vts/download/. You might need to input your email to download the software, but it is free!
- **Dependencies:** You need `Python` and `Java 8` to be installed on your computer for all features to work correctly.
- **First Launch:** Launch VTS Timeloop. Familiarize yourself with the interface.

2.2. Overview of the VTS Timeloop User Interface

The VTS Timeloop interface typically consists of:

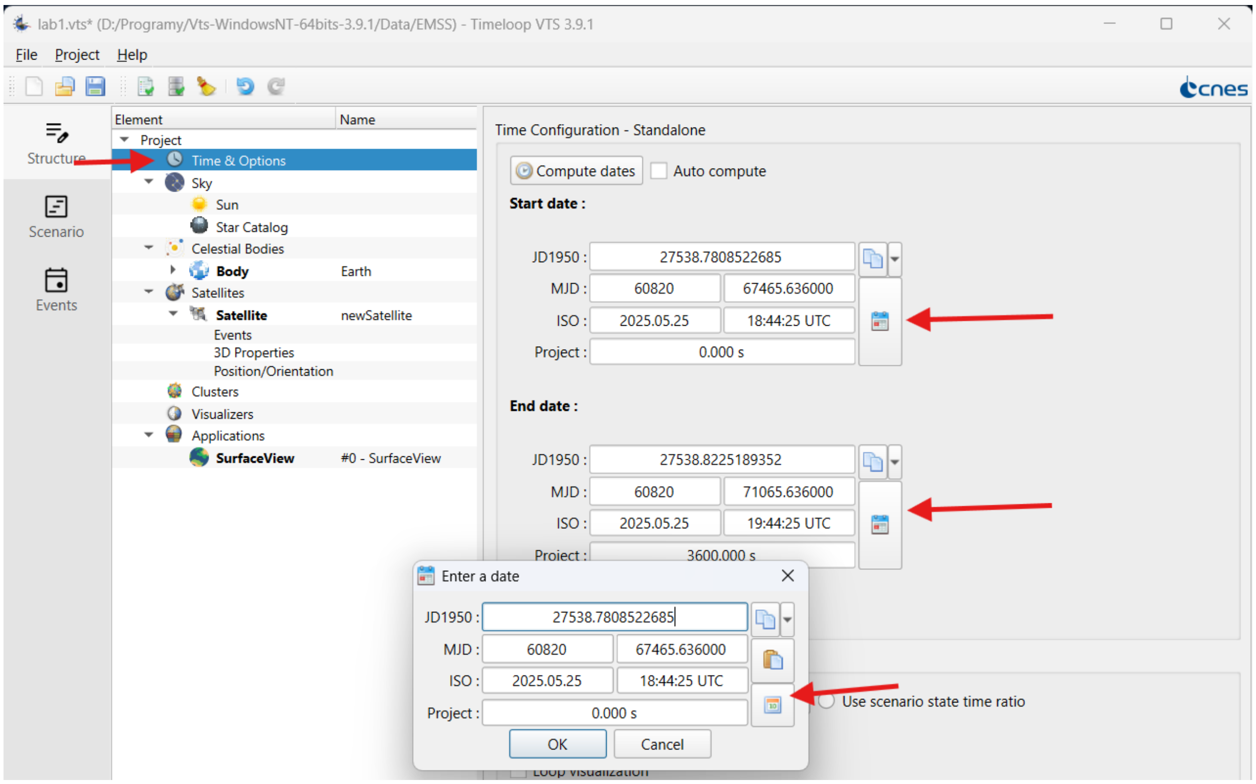
- **Structure Panel**: Includes a `Project tree` with all elements of the simulation; Time, Cellestial bodies, Satellites and Applications
- **Scene/Object Panel:** A list of all objects in the scene (satellites, sensors, ground stations, cellestial bodies).
- **Menu and Toolbar:** Access to import, save and validation of the project file.
- **Play button** (Bottom-left corner): Starts the simulation and opens defined Applications.

(Note: The exact appearance of the interface may vary depending on the VTS Timeloop version. The following steps are general.)

2.3. Basic Steps for Creating a Visualization in VTS Timeloop

Step 1: Creating a New Scene/Project

1. Typically, a default scene is created upon program launch, or you can create a new one via the menu (`File -> New Project`).
2. First, set the deired timeframe for the project:
    - Select `Time & Operations` and select apropriate `Start date` and `End date`.
    - Click the calendar icon to open the input window.
    - In the input window, you can input the date manually, or click the calendar icon to fill in todays date.
    - Select apropriate time frame; a day/a week between the dates.

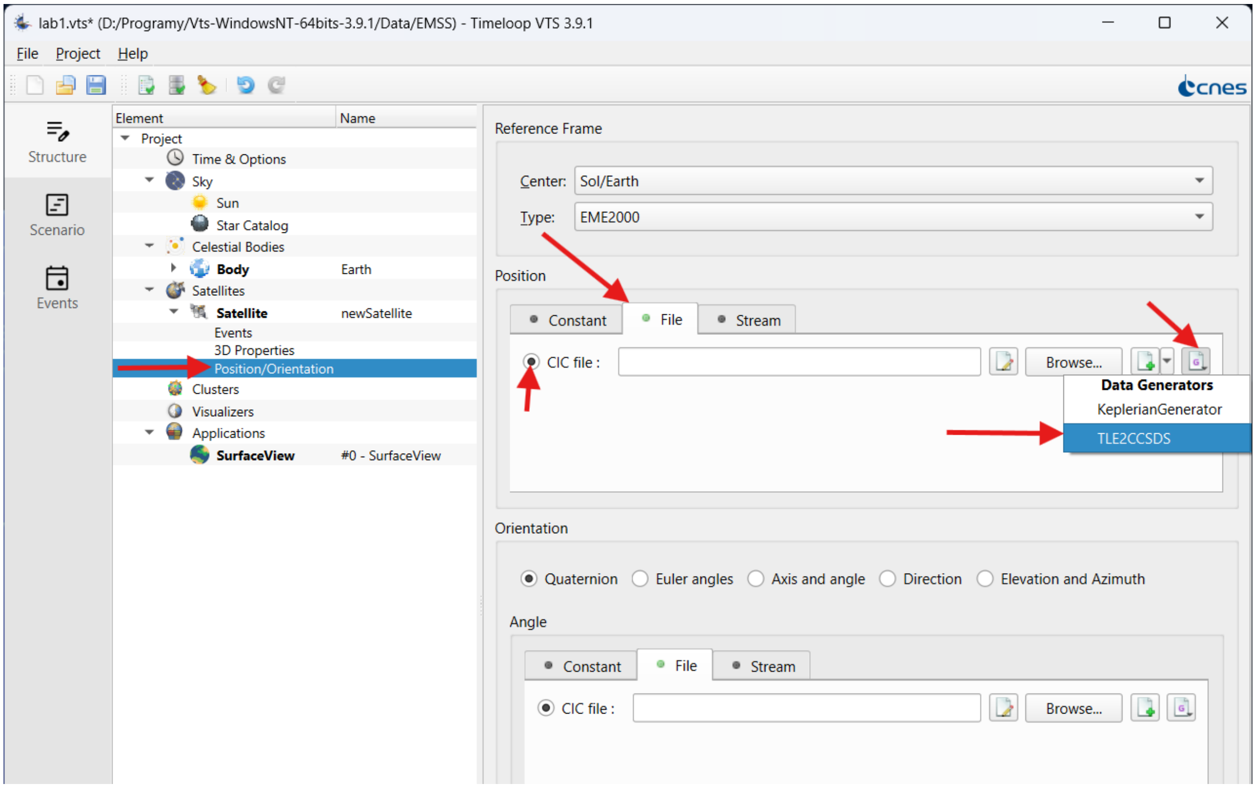


Step 2: Defining a Satellite

1. Add a new satellite object in the Satellite (e.g., `Add Object -> Satellite` or similar).
2. Give it a name (`Satellite Name`), Central body to orbit (`Sol/Earth`).
3. You can customise the colors of the spacecraft as they will be visible on the ground track and other plots. You can come back to these settings later.

Step 3: Defining satellite position

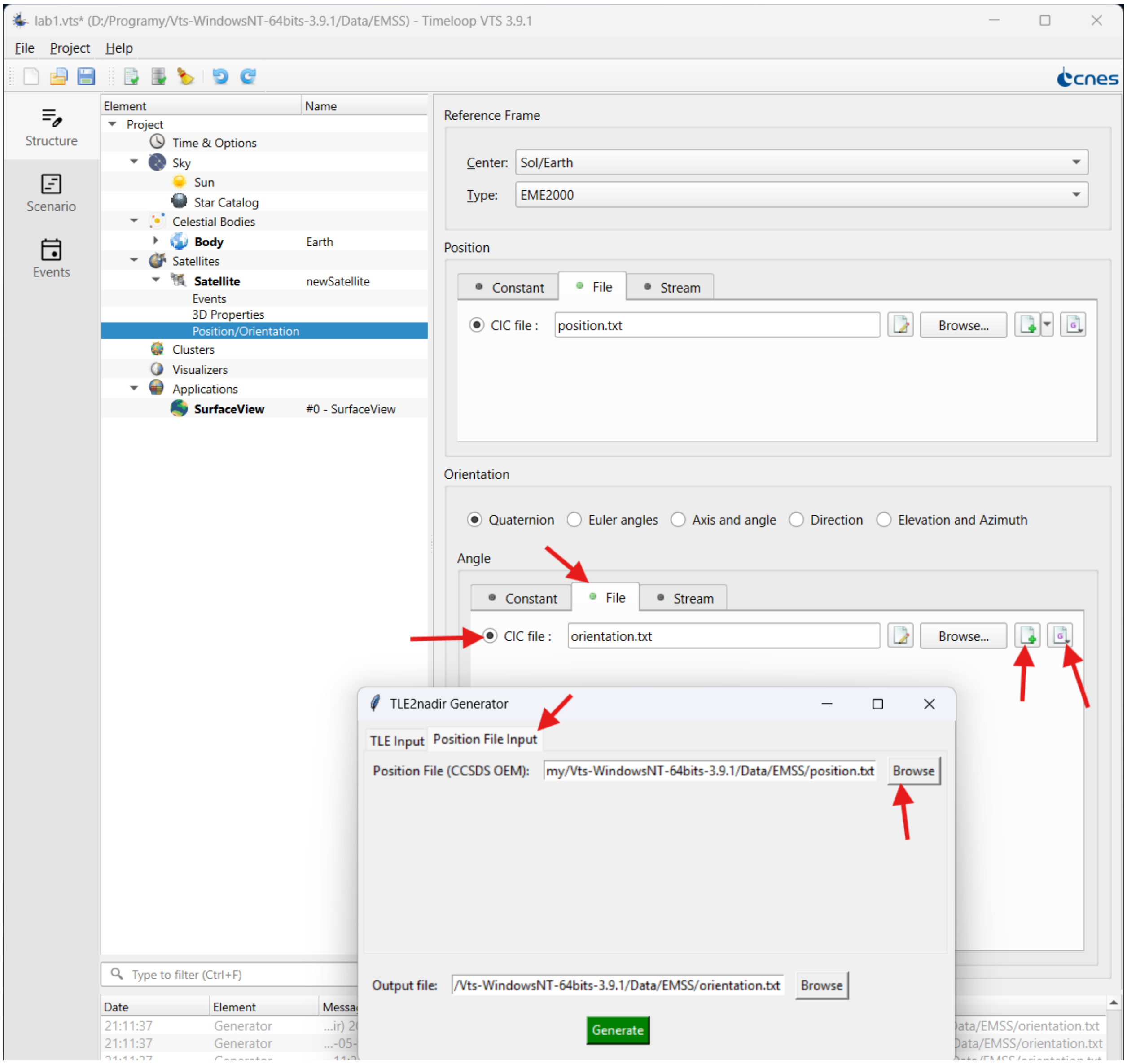
1. Select `Position/Orientation` in the `Project tree`
2. Select `File` in the `Position` section.
3. Now you can either select the file previously generated via GMAT, or generate a new Ephemersis file (plus button). To fill the created file with data, use the `KeplerianGenerator` (last button on the right).
4. Use Keplerian Orbit parameters established in GMAT.



Step 4: Defining satellite orienation

In order for the satellite to point towards earth, so that we can simulate what its sensor will see, we need to generate a orientation file. Otherwise, the satellite will point towards initial direction in the inertial space (i.e., towards stars).

1. Select `Position/Orientation` in the `Project tree`
2. Select `File` in the `Orientation` section.
3. Create a new Orientation file (plus button).
4. Use `TLE2nadir` Generator to generate a nadir-pointing vector from the position file:



Note: You might need to wait a moment when launching the generator for the first time. It will download the required dependencies in the background.

Step 5: Defining and Configuring Sensors

1. Right click on the satellite to which you want to add a sensor. Select `Add Sensor`.
2. Go to the newly created Sensor; you can change its name.
3. Go to `Sensor properites`; Choose the sensor type (e.g., elliptical, rectangular).
4. Configure sensor parameters: * **Shape and size:** E.g., cone angle for a conical sensor (`Half-angle around X/Y`). * **Range:** Minimum and maximum operating range (if applicable). * **Graphical properties:** Color, transparency of the sensor beam. * **Position/Orientation:** How the sensor is pointed relative to the satellite's axes. Default is towards the Z axis. Select `Orientation` -> `Axis and angle` -> `Angle` (e.g., 20 degrees) for the satellite to point 20 degrees off-nadir.

Play around with the `Half-angles` and Range to achive good visualisation of your satellite sensor.

Step 6: Adding Applications In order to visualise the satellite in 3D, lets add `Celestia`:

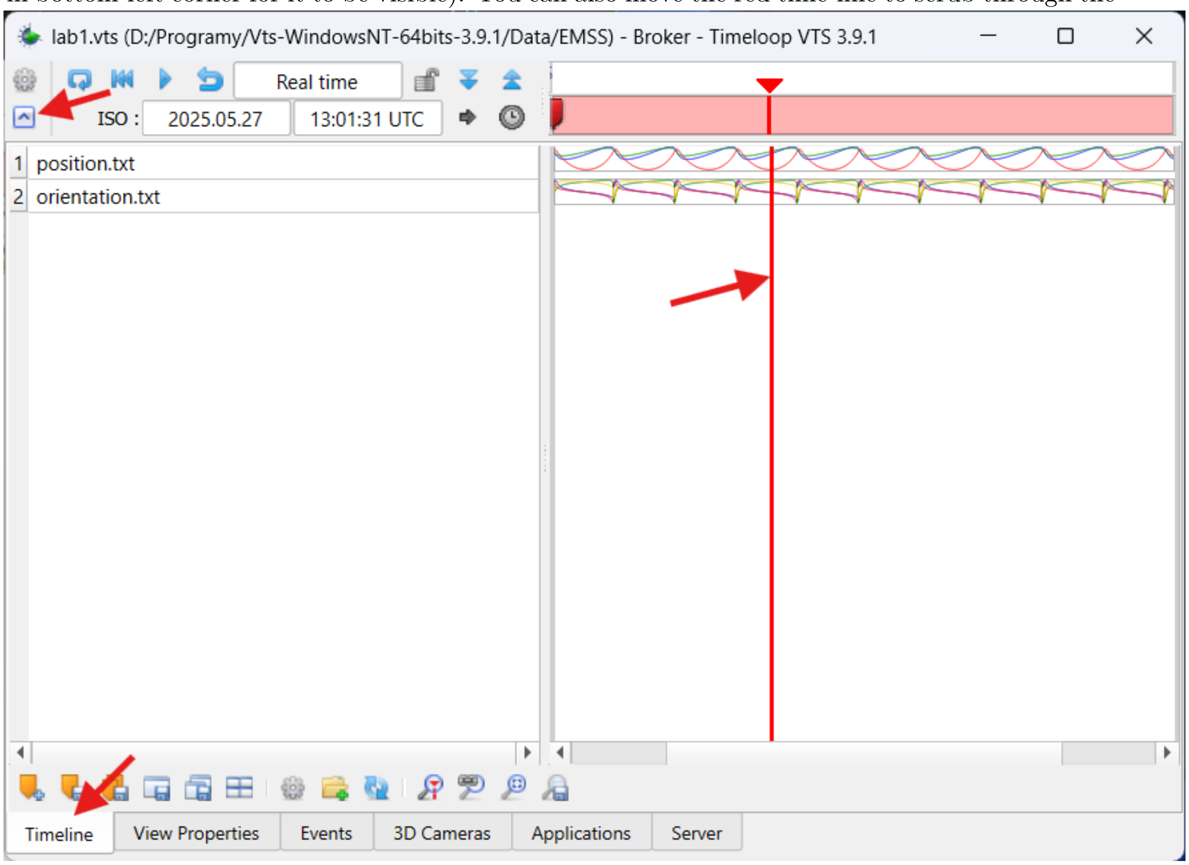
1. Right click on `Applications` in the Project tree.

2. `Add application -> Celestia`
3. Default settings should be enough.

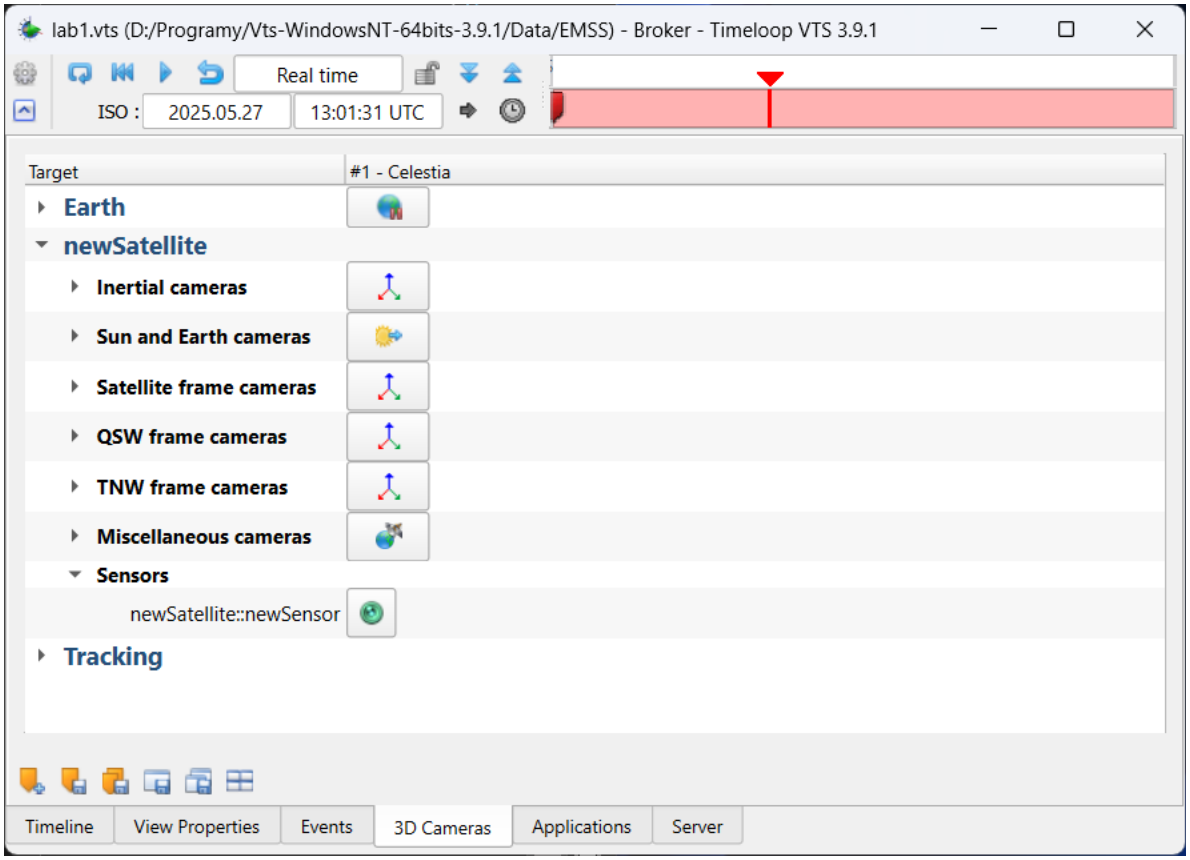
Step 7: Navigating in the 3D View and Time Control

Once everything is set-up, click `Play` in the bottom-left corner of the app. Check the console for any errors.

- **Navigation:** Use the mouse (left button to rotate, right to pan, wheel to zoom) or keyboard shortcuts to move around the 3D scene.
- **Time Control:** Use the time control panel to:
  - Set the initial date and time of the simulation.
  - Play (`Play`), pause (`Pause`) the simulation.
  - Change the playback speed (`Time Scale`).
  - Rewind and fast-forward time.
- **Timeline:** You can see the generated position and orientation data in the timeline (make sure to click the arrow in bottom-left corner for it to be visible). You can also move the red time-line to scrub through the

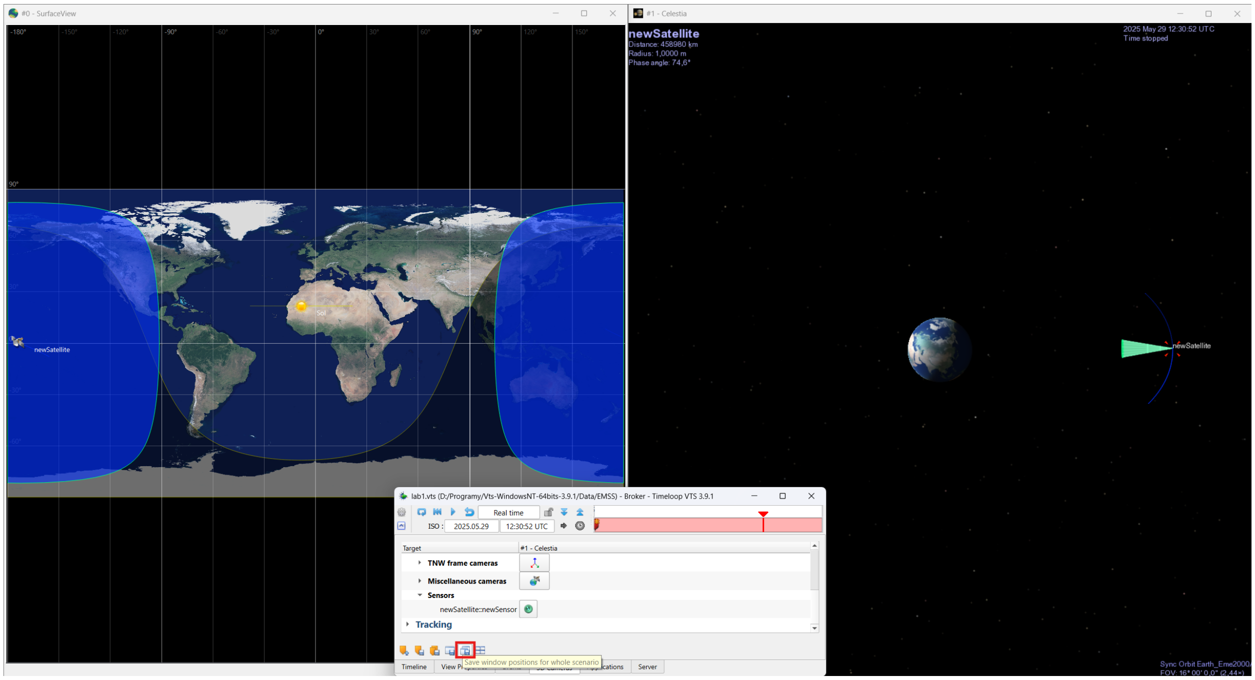


data.
- **3D Cameras:** You can change pre-defined views in Celestia using the `3D Cameras` tab.



Step 5: Visualizing Trajectory, Ground Track, Sensor Coverage

- Move the visualisation apps around the screen as you please. You can save their positions in the broker window. If you want the windows to open in the same spot on your screen every time you launch the simulation, you can save their positions using the buttons at the bottom (`Save window positions for the whole scenario`).



- Observe the satellite's movement along the orbit.
- Observe how the sensor beam moves across the Earth's surface or in space. Analyze coverage areas.

2.4. Exporting Views/Animations

- **Screenshots:** Use operating system's standard function to take screenshots of interesting views.
- **Animations:** VTS Timeloop supports animation export (e.g., to video format), refer to the relevant options in the menu (`Cog icon -> Record movie`).

2.5. Tips and Common Problems

- **Coordinate Systems:** Ensure all data (orbits, orientation) are defined and interpreted in consistent coordinate systems.
- **VTS Timeloop Documentation:** Use the official documentation, tutorials, or help provided by the program developers: https://timeloop.fr/static/doc/manual/index.html
- **File Formats:** Check which file formats are supported by your VTS Timeloop version for importing orbital data and 3D models.

Remember, practice makes perfect. The more you experiment with the options in both programs, the better you will understand their capabilities. Good luck!