Space Technology Laboratory: GMAT and VTS Timeloop

1. Main Laboratory Objective

The main objective of this laboratory is to familiarize students with the fundamental tools and techniques used in the design, analysis, and visualization of space missions. Students will gain practical skills in operating NASA's General Mission Analysis Tool (GMAT) for orbital dynamics simulation and VTS Timeloop for advanced visualization of mission data and satellite sensor operations.

2. Description of Tools Used

- **NASA General Mission Analysis Tool (GMAT):**
  - An advanced, open-source software developed by NASA.
  - Used for designing, optimizing, and analyzing space mission trajectories, from Earth orbits to interplanetary missions.
  - Enables precise modeling of forces acting on a spacecraft, orbit propagation, and maneuver analysis.
  - More information: https://software.nasa.gov/software/GSC-17177-1
- **VTS Timeloop:**
  - Professional software for dynamic 3D visualization of space missions.
  - Allows for the creation of interactive scenarios, import of mission data (including CCSDS formats), and visualization of trajectories, satellite orientations, sensor coverage, and other key mission aspects.
  - Aids in better understanding mission dynamics and effective presentation of analysis results.
  - More information: https://timeloop.fr/vts/
- **TLE2nadir:**
  - VTS Timeloop generator plugin to generate a nadir-pointing vector for sensor visualisation.
  - Orients the spacecraft to point towards earth.
  - More information: https://github.com/yasiupl/TLE2nadir

3. General Laboratory Procedure

The laboratory is divided into two main parts, focusing on each tool respectively:

- **Part 1: Exploring Orbital Mechanics with GMAT**
  - Students will work individually with the GMAT program.
  - The main task will be to configure different types of orbits by modifying Keplerian parameters.
  - Analysis of the influence of individual parameters on the shape, size, and orientation of the orbit, as well as on the satellite's ground track.
- **Part 2: Mission Visualization and Sensor Operation with VTS Timeloop**
  - Students, working in groups, will use VTS Timeloop.
  - The task will be to propose orbital parameters for specific types of satellite missions and to define and visualize the operation of a sensor.
  - Comparison of results and capabilities of different mission configurations.

4. Expected Outcomes and Acquired Skills

Upon completion of the laboratory, students should:

- Understand basic concepts of celestial mechanics and orbital dynamics.
- Be able to independently configure and conduct a simple space mission simulation in GMAT.
- Understand the influence of individual Keplerian elements on orbit characteristics.
- Be able to import mission data and create advanced visualizations in VTS Timeloop.

- Be able to define basic parameters of satellite sensors and analyze their coverage.
- Be able to interpret simulation and visualization results in the context of mission objectives.
- Acquire skills in working with professional software used in the space industry.

5. Grading/Report Requirements

Detailed requirements for laboratory grading and report preparation will be provided by the instructor. Typically, they may include:

- Submission of GMAT configuration files/scripts.
- Screenshots or short animations from VTS Timeloop.
- Answers to control questions included in the manual and scenarios.
- A brief analysis and conclusions from the exercises performed.
- Active participation in group discussions (for the VTS part).

6. Additional Materials

- **Detailed software operation manual:** MANUAL_GMAT.md and MANUAL_VTS.md
- **Set of mission scenarios for implementation:** SCENARIOS.md

We wish you fruitful work!