AE4866 - Propagation & Optimization in Astrodynamics - Homework Assignment 1

For most astrodynamics problems analytical solutions are not (readily) available, and one has to numerically integrate a propagation model that best represents the dynamics of the system at hand. Since there are many numerical integration methods available, and also many different propagation models, the selection of the best combination of the two is not always straightforward.

For this homework assignment you will study the impact of the choice of numerical integrator in combination with a selected propagation model on the numerical propagation results. The astrodynamics problem at hand will be your allocated assignment topic. Use the Tudat model as provided on Github as a starting point:

`https://github.com/Tudat/PropagationOptimizationAssignments`

Fill in your given individual set of model parameters in the code. For the topic you have been assigned, and these parameter values, see Brightspace:

`https://brightspace.tudelft.nl/d2l/le/content/133656/Home`

This homework assignment is an individual one. Collaboration with your fellow students is allowed, but each student must write his/her own unique code and report. The deadline for homework #1 is Friday, March 1, 12:00 (noon), to be submitted through Brightspace.For late submissions, 1 point (out of the total of 10) will be subtracted per day. So, when handing in the report x days late, $\lceil x \rceil$ points will be deducted.

For additional instructions and/or tips for the homework, refer to the working lecture slides on Brightspace:

`https://brightspace.tudelft.nl/d2l/le/content/133656/Home`

For your analysis of the integrator/propagator settings, formulate your own requirements on accuracy (and possibly other quantities, such as runtime). There is no need to provide a single number for the requirement, but you should identify a range of reasonable values (*e.g.* position error requirement will be between 10 m and 1 km). These requirements that you define will obviously influence your model selection. However, the model selection also constrains your requirements. For instance, propagator/integrator settings that result in a propagation runtime of 1 day are inherently infeasible. Perform some preliminary runs to gain insight into the properties of your model.

In your discusson of results, clearly relate theory, results, discussion and conclusions, showing how an obtained result leads to a certain conclusion, and how this relates to theoretical predictions.

(a) $\boxed{\textbf{25 points}}$ Given the Cowell propagator, study and discuss the effect of different integration methods and associated parameters on the accuracy of the solution. Per method, think of varying tolerances and/or step sizes, using values that you can argue are suitable for your problem. Make sure to validate your arguments with your propagation results. Consider all options that are available, either qualitatively or quantitatively. If you decide to choose the former, motivate that choice using a sound argumentation. Hint: when analyzing the results, motivate your choice of benchmark.

(b) $\boxed{\textbf{35 points}}$ For a fixed-step integrator of your choice (based your choice on the outcome of the previous question), study and discuss the effect of different propagation models on the accuracy of the solution. Consider all options that are available, either qualitatively or quantitatively. If you decide to choose the former, motivate that choice using a sound argumentation.

(c) $\boxed{\textbf{15 points}}$ Given the results from the two previous sub-questions, perform a combined analysis of integrator and propagator settings. At the very least, compare selected propagators for several variable step-size integrators. Investigate the behaviour of the solution's accuracy, for settings that you deem relevant for your problem. What are the conclusions you can draw about the combination of integrator and propagator settings? Discuss what the best settings (or 'class' of settings) are for *your* topic, based on your results, argumentation, and the accuracy requirement range (and possibly other requirements) as you've defined them.

(d) **15 points** By considering the overall physical and numerical properties of you problem, discuss which *model extensions* you can think of to obtain more reppresentative/realistic results? At the very least, be concrete in your proposed model extensions and associated discussion, backing this up with preliminary simulation where this is useful/feasible. Hint: think as a mission designer who has to present his/her findings during a final review.

(e) **10 points** Reporting technique: present your findings in a concise and efficient manner.

- The report must not exceed 10 (content) pages in length, including figures, tables, equations and appendices. Use no more than 4 pages for text.
- On the front page: include a link to your private GitHub repository containing the code that you use for this assignment, the hours you spent, and the people with whom you have worked/discussed.
- All margins should be at least 2 cm (on A4 page size).
- The minimum font size is 10pt.
- Readability of the report is an important element for the grading.
- Hint: For a compact presentation of the results, think about what you should plot and how you can combine the results of multiple runs.
- Hint: Ensure that the information you want to convey can be properly read from your plots.