REVIEWER'S OPINION OF FINAL THESIS

I. IDENTIFICATION DATA

Thesis name:	**Robust attitude control of cubesat spacecraft**
Author's name:	**Bc. Dominik Beňo**
Type of thesis :	master
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Control Engineering
Thesis reviewer:	Doc. Ing. MSc. Martin Klaučo, PhD.
Reviewer's department:	Department of Information Engineering and Process Control, Slovak University of Technology in Bratislava

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment **challenging**

Evaluation of thesis difficulty of assignment.

I consider the assignment challenging. The student must overcome several challenges, mainly in overall integration of the state-of-the art simulator with control strategies, however, the choice of controllers fall within well-known and traditional scope of control design.

Satisfaction of assignment **fulfilled**

Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.

The student has fulfilled all particular goals of the thesis, and the simulation based on the Monte Carlo concepts provided added value for further research.

Method of conception **correct**

Assess that student has chosen correct approach or solution methods.

Method covered by the student to achieve the goals were correct. Namely the choice of types of controllers and the validation reflects well-known procedures established also in the current stage of research. Simulations based on Monte Carlo concept is very relevant in order to prove the qualities of designed controllers. The choice of the controllers however eludes my understanding, since usually a discrete-time version of the LQ controller with saturation and anti-windup arrangement would be more practical and more challenging for the student to consider.

Technical level **B - very good.**

Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.

The thesis outline is straightforward in terms on: derive the model, design the controller, verify closed-loop performance. The choice of Monte Carlo simulation adds novelty to the evaluation, however, I'm not sure if the author has sufficiently enough describe the procedure so the results can be easily reproduced, but I conclude, that the concept is correct.

Formal and language level, scope of thesis **C - good.**

Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.

The overall quality and language arrangement of the delivered thesis is adequate, as well as the reading flow. However, the thesis lacks proper explanation of several mathematical equations, and confusing notation. Furthermore, I summarize several additional points.

Reported issues are:

- Missing definitions of some abbreviations, like what is the meaning of the letter "U" in the "6U CubeSat" platform
- Chapters should be ended with text paragraphs, no by standalone equations.
- Equations should be referenced with parentheses, or with the $\eqref{}$ command.
- the r^i in Eq. (2.8) means exponentiation of r to the power of i? Or its i-th component of the vector r

- The thesis should be written in plural, i.e., "…we model the satellite…" instead of "…I model the satellite…" (page 5, Section 2.2)

Formal comments related to typography:

- Author should take the advantage of a non-breakable space to ensure that single letter prepositions do not end alone at the end of lines, or that numbered references are not glued with the text itself.
- Sub-indices shall be written in the upright font, if the subindex is part of the notation, e.g., J_{B}
- A shall be used to offset the non-negative components in the matrix in Eq. (2.5)
- In Figure 5.3 (and others) the variable notation overlaps with the arrows
- Axis font size in several figures are too small to read (e.g. Figure 5.4)

Selection of sources, citation correctness **A - excellent.**

Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.

The author has used fairly small set of references; however, they are all relevant and up to date. Other readers can be inspired by this thesis mainly in the domain of mathematical modeling and by comparing results from the closed-loop simulations.

Additional commentary and evaluation

Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.

-- there are no addition comments --

III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

I general, I consider the thesis well written, the concepts and tasks were adequately presented, and the thesis is easy to read. I very strongly support the choice and results done by simulation based on the Monte Carlo concepts, which brings relevant validation of the closed-loop performance. On the other hand, I would expect more viable theory concerning the control design, mainly in the discrete time domain with some level of the constraint handling.

Questions:

1. In Section 3.3 is stated, that a linearized model will be used to design controllers. Elaborate on gaps between the linearized model and original non-linear model. I assume that for closed-loop implementation, a non-linear model is used, henceforth, is it possible, that the model mismatch can significantly degrade the quality of the control?
2. In Section 3.6 the author claims that "*no Kalman filter is used to estimate the state vector*". Does this assumption hold also for the actual implementation in CubeSat? Do you have all the measurements available and there is no need for further filtration?
3. Control design presented in the Chapter 5 is derived for continuous time applications, is a continuous time LQ controller relevant for actual CubeSat control? Did you convert the implementation of controllers to discrete-time for simulations with the "42Simulator"?
4. Closed-loop scheme presented in the Figure 5.3 is missing the traditional saturation block and anti-windup arrangement. Did you consider constraints on control inputs? To what extent is consideration of the control inputs relevant in your application?

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I evaluate handed thesis with classification grade **B - very good.**

Date: **11.6.2024** Signature: