

### I. IDENTIFICATION DATA

<b>Thesis name:</b>	Enhancement of the Thermal Design of a Cold Gas Iodine Thruster
<b>Author's name:</b>	Roger Pereira
<b>Type of thesis :</b>	master
<b>Faculty/Institute:</b>	Faculty of Electrical Engineering (FEE)
<b>Department:</b>	Department of Cybernetics and Robotics
<b>Thesis supervisor:</b>	Javier Martínez Martínez
<b>Supervisor's department:</b>	Department of Fluid Dynamics and Thermal Control

### II. EVALUATION OF INDIVIDUAL CRITERIA

#### Assignment challenging

##### Evaluation of thesis difficulty of assignment.

The thesis scope was the improvement of the thermal control of the I2T5 propulsion system, by minimizing the thermal losses. The propulsion system is a cold gas thruster operating with iodine, which uses passive thermal control. It became the first iodine thruster that has flown to space, and therefore the experimental results in orbit for this kind of systems are very scarce. During this first flight, the heat losses in the thruster caused minor problems during the operation, which needed therefore a correction for the future. The objective of the thesis was to find alternative configurations that could minimize these heat losses and improve the thermal behavior of the thruster.

#### 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.

Despite the fact that the COVID crisis was very challenging for Mr. Pereira, since the beginning of the quarantine was coincident with the start of his thesis work, he was able to fulfill the requirements of the problem given, and offer some solutions that can be directly implemented. In addition to this, he worked in parallel with other additional tasks, such as the validation of an in orbit thermal propagator developed at the company, or the thermal modelling of the other propulsion system developed, the NPT30. The main outcome of the thesis is the proposal of some configurations that can limit the impact of thermal losses in the thruster. The thesis could be extended in terms of additional geometries to be studied, or a complete redesign of the thruster's thermal management system, but the student proposed already several solutions to be considered.

#### Activity and independence when creating final thesis B - very good.

##### Assess that student had positive approach, time limits were met, conception was regularly consulted and was well prepared for consultations. Assess student's ability to work independently.

The student was able to meet deadlines, integrated well in the group as well as was able to interact correctly with the rest of the members of the team. When it was required, the student was able to present the results obtained, and tried to predict the changes that would be produced with a different configuration. The student's work was in general independent, and when he had difficulties, the discussions were productive for him to advance in his work.

#### 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 student was able to explore the literature to acquire a more into detail knowledge of the subject of thermal control, and in the end of his internship he was able to use this knowledge acquired to build the theoretical part of his thesis. As well, he had in the start of his thesis period a basic knowledge of thermal control, and a good knowledge of other subjects, which allowed him to be able to advance faster in the understanding of the topic. As an example of a technical challenge that the student addressed is the use of thermal network models for the prediction of the heat transfer in spacecraft thermal control.

## SUPERVISOR'S OPINION OF FINAL THESIS

### Formal and language level, scope of thesis

**A - excellent.**

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

The thesis was written in a formal language, maintaining a correct orthography and with an appropriate scientific notation from the beginning. After a few initial minor comments the student was able to deliver a version of the thesis that integrated these. The thesis was well structured, maintaining an initial introduction and a theoretical support for the rest of the analysis, and developing from them the numerical simulations and the small experimental campaign performed, which gave support for the conclusions and improvements proposed.

### Selection of sources, citation correctness

**B - very good.**

*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 student used mainly two type of resources; internal publications, and external articles and scientific publications related to heat transfer. The last ones served mainly for him to build the theoretical knowledge to face the problem, whereas the first are mainly related to the specific thermal control problem of the I2T5 and of the thrusters in general. Under my opinion, the student referred to biography when needed, and this does not seem to interfere at all with his own rational thinking and developed conclusions.

### 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.*

The student presented as expected a list of configurations and predicted the impact that they would have in the thermal behavior of the I2T5 thruster. The results obtained were already integrated to evaluate their impact, and the student started an experimental campaign to do so. The student used for doing so both analytical calculations and a dedicated FEM software, acquiring the necessary knowledge to perform the calculations. The student showed maturity and a good approach during his internship not only in the technical side, but also in the use of his soft skills, such as the interaction with the rest of the group.

## III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

*Summarize thesis aspects that swayed your final evaluation.*

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

Date: 31.8.2020

Signature:

Czech Technical University  
Faculty of Electrical Engineering  
Department of Control Engineering

**CTU Diploma Project review- 2nd reviewer's evaluation of master thesis with title  
" The I2T5: Enhancement of the Thermal Design of an Iodine Cold Gas Thruster " by Space  
Master student Roger Pereira**

I find that the goal of the thesis project fulfills the requirements of a master thesis in space technology. The thesis concerns re-design of a an Ionide Cold Gas Thruster to decrease the heat-loss due to conductive thermal contact between the tank and the thruster, which was discovered during the first flight.

In chapter 2 the author gives a background to the different heat transfer mechanisms and their couplings. Thermal modeling (thermal circuits) are presented. The thermal environment of the space, making up the radiative case is also presented. The background part is well written and easy to read, and gives the relevant information for the following chapters

In the first part of chapter 3, the author describes the suggested improvements (material, configuration and geometry) and the simulation results. In this part a weakness is that the geometry change is not clearly motivated. Why this shape? Why this size?

In chapter 3.4 a test setup in vacuum chamber is presented, and then compared to the test of the base set up, performed earlier, by the company. The main weakness of the thesis is the analysis and discussion regarding the test result and the differences between the two. Chapter 3.5 presents simulations including the space thermal environment. The thesis would have benefited from a more extensive discussion regarding the results.

**Summary:**

The student has put in a sufficient effort into the task.

The result of the thesis project may contribute to a future solution to the problem addressed. More tests should have been performed, and compared to simulations, but this was out of control for the student, due to limited access to the facilities.

Based on the review above I recommend to grade the thesis by B. The oral presentation is still to be graded.

This review serves solely for the purposes of the diploma project defense at CTU. LTU official evaluation for the SpaceMaster double degree will follow the thesis defense and may differ from this review report and suggested grade.

Kiruna, September 25 2020

Dr. Anita Enmark  
Luleå University of Technology