Bachelor Thesis Spring 2022

Parachute Reefing System for Sounding Rockets

Luca Jost

1. Introduction

The association Akademische Raumfahrt Initiative Schweiz (ARIS) offers a variety of topics for hands-on projects and student works around systems and components to be integrated in future rockets.

A multi-stage recovery system is needed to reduce load and drift of sounding rockets at their decent. Traditionally, a drogue parachute is deployed at apogee and the main parachute is released at a lower altitude. If a parachute inflates too rapidly, it can cause extreme shock to the overall parachute system, which may result in rigging and consequently in its malfunctioning.

Reefing prevents a parachute from opening too rapidly. Given an active reefing system, as portrayed in Figure 1, the main parachute can be deployed at apogee and opens slowly at lower altitudes. This helps to control load and drift, and additionally reduces the overall size and weight of the recovery system.

As the rockets that are developed by ARIS are getting bigger and heavier, new methods are needed to reduce weights and loads. Here, an active reefing system could just prove useful.

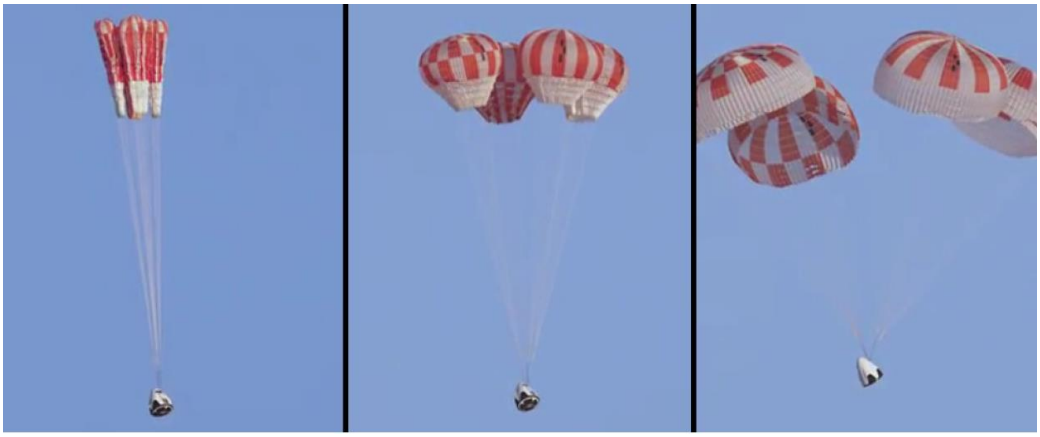


Figure 1: Active reefing system of the Dragon space capsule from SpaceX.

2. Task Definition

Reefing in the space industry is often achieved by cutting lines inside the parachute. For example, two lines are cut inside the parachute shown in Figure 1 by using pyrotechnic line cutters that are activated by an electric signal. The line cutters are typically small enough for being placed inside the parachutes, as shown in Figure 2.

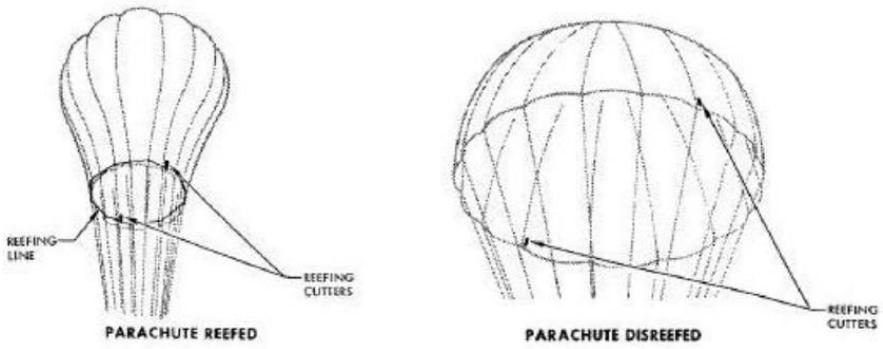


Figure 2: Illustration of a line cutter placement.

In this bachelor thesis, methods for cutting a parachute line shall be investigated and a line cutter system which utilizes such a method and can be accommodated in a parachute of an ARIS rocket shall be developed.

The project can be organized in work packages as follows:

- Analysis of all system requirements and specification of the line cutter system and its functionalities
- Development of a dedicated device, including design of printed circuit boards and selection of microcontroller, sensors (for detection of parachute ejection and cut initiation), actuators (for line cutting) and power supply (for battery-powered operation)
- Implementation of firmware (for example, using the C programming language and FreeRTOS operating system) for system steering and putting the developed device in operation
- Development of a test setup, and test and evaluation of one or several line cutter systems – and optionally the overall system including parachute and main flight computer – against selected metrics (for example, repeatability or reliability of cutting, responsiveness in terms of delays from initiation to completed cut or opening of chute, energy consumption of the line cutter system or the overall system)
- Optional extension from the standalone line cutter system to a networked system of one or several line cutters connected to the main flight computer through a wireless link (for example, 2.4 GHz LoRa radio), where the lines are cut upon reception of a control signal from the main computer and allow for controlled active reefing of the parachute at decent
- Optional flight test with a sounding rocket and an active reefing system

3. Goals

A working line cutter system shall be realized. The system shall satisfy the following requirements:

- device of small size to fit inside parachute of ARIS rocket
- durable device in order to withstand forces acted on it during the deployment of the parachute
- compatible interfaces with today existing ARIS systems
- battery powered device with rechargeable battery and battery life of several hours
- reliability in sensing the parachute ejection, cutting the lines and reefing the parachute
- redundancy built into the overall system for improved failure safety

The following main goals shall be achieved:

- In-depth knowledge of parachute reefing systems gained
- Hardware for line cutter system designed, manufactured, set up and tested subject to above requirements
- Firmware implemented as required to render the system fully functional
- Line cutting methods tested and at least one method operational
- Line cutter system validated according to above requirements and further evaluated by selected metrics
- All the work and its results documented comprehensively

4. Project Schedule

Plan a total of 360 working hours (12 ECTS x 30h / ECTS) per student.

At the beginning of the thesis, a project plan and specifications must be prepared and discussed with the advisors within the first two weeks. In the course of the thesis, regular review meetings are to be scheduled to check important work steps. The review meetings shall be documented by written meeting minutes.

We recommend that you document the thesis from the beginning and keep a lab journal. The lab journal can help you record your thoughts and allows to use them for later reference. The lab journal can be viewed by the advisors during meetings. However, the lab journal is not part of the final report.

5. Documentation

The thesis must be documented in a final report, which must contain all considerations, clarifications, calculations and investigations in detail in text and figures. The report should be written in a legible and clearly structured way. An external person with appropriate expertise shall be able to follow the report.

The report shall include the following sections:

- Table of content
- Abstract of 0.5 - 1 page length
- Original text of the task definition
- Introduction
- Main section including the chosen solution approach, evaluation of other considered solutions, solution description and results (for example, findings from tests, measurements, experiments)
- Summary of 2 - 4 pages length, including a self-critical assessment
- Appendix with all relevant data and detailed information, such as tools used or project plans created, including a comparison of the original project plan (target) and its final realization (actual)
- Bibliography

The report (without appendix and bibliography) should not exceed 60 pages.

The report must include a signed non-plagiarism declaration (declaration of independence).

Further guidelines for writing technical or scientific reports can be found, for example, in [1] and [2].

Three printed copies of the report must be submitted to the advisor. In addition, the report as well as all data relevant for the continuation of the work (for example, source code) shall be submitted in electronic form.

6. Assessment

Your thesis will be evaluated according to the following criteria:

- Organization: initiative and commitment, teamwork, independence, planning
- Working methods and project implementation: analysis, design and methodology
- Quality of results: degree of performance, ideas, approaches, originality, innovation, maturity of the solution
- Documentation: structure and presentation, text quality, clarity, completeness
- Final presentation/demo: presentation style and expression skills, competence in topic

7. Important Dates

Project start and move to the lab:	Week 6 – as from Monday, February 7, 2022
Final presentation/demo:	Week 22 – by arrangement
Submission of report:	Week 22 – by Friday, June 3, before 3 pm
Return workplace and key:	Week 23
Bachelor examination:	Week 25 or later – by arrangement

8. Administrative Information

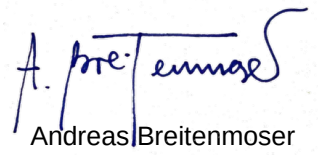
Advisor:	Prof. Andreas Breitenmoser (+41 58 257 46 56, andreas.breitenmoser@ost.ch)
Co-advisor ARIS:	Jonas Binz
Examiner/expert:	Theo Scheidegger
Meetings:	weekly, by arrangement
Workplace/lab:	allocation by A. Breitenmoser, room 6.003 at OST

9. References

[1] A. Verhein und A. Simeon, Werkzeugkasten Technische Berichte 1, 2013.

[2] P. Mayer, 77 mal wissenschaftliches Schreiben - eine Anleitung, Basel: Advanced Study Center, Universität Basel, 2010.

I wish you good luck with your project – have fun!



Rapperswil, February 2022

Andreas Breitenmoser