TITLE PAGE

# TABLE OF CONTENTS

[1 TABLE OF CONTENTS 2](#_Toc468651488)

[2 INTRODUCTION 3](#_Toc468651489)

[2.1 Background 3](#_Toc468651490)

[2.2 Motivation 3](#_Toc468651491)

[3 THEORY OF HALO ORBITS 4](#_Toc468651492)

[3.1 Lagrange Points 4](#_Toc468651493)

[3.1.1 Periodic stationary orbits around L points 4](#_Toc468651494)

[3.1.2 Halo orbit 6](#_Toc468651495)

[3.2 Circular Restricted Three Body Problem (CR3BP) 8](#_Toc468651496)

[3.2.1 Equations of motion in non-dimensional form 9](#_Toc468651497)

[3.2.2 Lagrange (or libration) points 11](#_Toc468651498)

[3.3 N-Body Problem 12](#_Toc468651499)

[3.3.1 Equations of Motion 12](#_Toc468651500)

[3.3.2 Difference from CRTBP 12](#_Toc468651501)

[4 METHODOLOGY OF PRECISE ORBIT SIMULATION 13](#_Toc468651502)

[4.1 Force Model 16](#_Toc468651503)

[4.1.1 Space Environment around SEM L2 16](#_Toc468651504)

[4.1.2 Overview of characteristics 16](#_Toc468651505)

[4.1.3 Gravitational perturbation sources 17](#_Toc468651506)

[4.1.4 Solar Radiation Pressure 20](#_Toc468651507)

[4.1.5 Spacecraft Maneuvers 23](#_Toc468651508)

[4.2 Numerical Integration 24](#_Toc468651509)

[4.2.1 Numerical integrators 24](#_Toc468651510)

[5 SIMULATION AND TESTS 25](#_Toc468651511)

[5.1 Simulation 25](#_Toc468651512)

[5.1.1 Orbit Propagation 25](#_Toc468651513)

[5.1.2 Maneuver Calculation 26](#_Toc468651514)

[5.2 Test Cases and Results 26](#_Toc468651515)

[5.2.1 Force Model Simplification 26](#_Toc468651516)

[6 CONCLUSION 27](#_Toc468651517)

[7 REFERENCES 28](#_Toc468651518)

# INTRODUCTION

* Description of motivation and research problem (2 paragraphs, min. half a page in total)

## Background

* Advantages of L2 orbits and why it is popular for science/exoplanet missions (1 paragraph)
* L2 missions (1 small paragraph for each mission)
* Irassi mission description (similar to previous in format, but longer – half a page), (Irassi mission specific information: Buinhas, L., Ferrer-Gil, E., & Forstner, R. (2016, March). IRASSI: InfraRed astronomy satellite swarm interferometry—Mission concept and description. In Aerospace Conference, 2016 IEEE (pp. 1-20). IEEE.

## Motivation

* Detailed description of motivation with references (1 page)

# THEORY OF HALO ORBITS

## Lagrange Points

* Description of lagrange points (1 paragraph)
* Figure of lagrange points in the sun-earth-moon system (figure)
* Lagrange point stability (1 paragraph)

Should I include the information of Jacobian, zero-velocities and other info on what libration points mean mathematically in more details?

*DO I need to delve deep into stability of L-points, zero-velocity-regions and Jacobi integral?*

### Periodic orbits around L points

* Periodic and quasi-periodic orbits, orbit types (distinguish between L2 and other libration points), short description of orbits other than halo (half a page)
* Halo orbits, characteristics, advantages over other libration orbits (half a page)

Should I actually describe the process of finding the HALO orbits here or it is unnecessary?

## Circular Restricted Three Body Problem (CR3BP)

* History of the problem, who studied it (1 small paragraph)
* Assumptions (1 small paragraph)
* Rotating reference frame description with figure (1 small paragraph)(figure)
* Equations of motion in non-dimensional form (equations with assumptions)(approx. 1 page)
* How lagrange points are derived from the equation (optional)(half a page)

## N-Body Problem

* Description (1 paragraph)
* General Equations of Motion (barycentric)
* Difference from CRTBP, why it is more realistic (1 parapraph)

# METHODOLOGY OF PRECISE ORBIT SIMULATION

* Description of the methodology (min. 1 page, max. 3 pages)

## Force Model

* Introductory small paragraph

### Space Environment around SEM L2

* Description of the space environment around L2 and overview of characteristics (min. 1 page, max. 3 pages)
* One big table of the effects with their magnitudes (table)

### Gravitational perturbation sources (approx. 1 page)

* Description (approx. 1 page)
* Table with the effects of all solar system bodies (table)
* Earth centric equations of motion (newtonian dynamics) (approx. 1 page)

### Solar Radiation Pressure

* Description (half a page)
* Equations with the assumptions (max. 2 pages)

### Spacecraft Maneuvers

* Description (half a page)
* Theory (not the implementation) on how to calculate the manuvers (max. 2 pages)

*HERE WOULD BE THE IMPORTANT PART ABOUT HALO COMPUTATION AND APPLYNG MANEUVERS -> Working on it now*

## Numerical Integration

* Describe generic numerical integration process (theory) (1 page)
* Literature search on numerical integrators used in astrodynamics applications (one big paragraph)

### Numerical integrators

* Introductory paragraph to outline which integrators will be described and if they have types e.g. fixed step, extrapolation etc. Montenbruck’s book. (min. half a page)

#### Integrator 1

* Describe the integrator

#### Integrator 2

* Describe the integrator

So on..

# SIMULATION AND TESTS

## Simulation

### Orbit Propagation

* Description of orbit propagation (half a page)

#### Force model

* Describe which model has been used, refer to the equation in theory section and state which values, bodies, libraries, etc. has been used. (approx. 2 pages)
* Describe everything necessary other than theory here for simulation.

#### Numerical Integration

* Describe which integrators has been used, refer to the theory section (approx. 1 page)
* Describe everything you used other than theory here.

### Maneuver Calculation

* Describe methodology of calculating maneuver with a flow chart (min. half a page)(figure: flow chart)
* Describe differential corrector, and the function used (approx.. 1 page)
* Describe event handling, stopping conditions, time frames (approx.. 1 page)

## Test Cases and Results

* Repeat motivation in the introductory paragraph and outline the tests (1 small paragraph)

### Force Model Simplification

#### Test description

* Describe the test, state what we are changing and why, state what remains the same, list the test cases in a table (approx. 1 page) (table)

Should I include numerical computation of halo orbits for different amplitudes?

How do we know which amplitude do we have/need? Given by UniBw? Or has to be calculated?

#### Force Model Simplification Test Results

* Plots of orbits created for each case
* Plots of differences in the coordinates, velocities and calculated maneuvers
* Apply the maneuvers created from simplified case to the full model and show if it is successful or unsuccessful staying in the orbit

#### Comparison of Integrators Test description

* Describe the test, state what we are changing and why, state what remains the same, list the test cases in a table (approx. 1 page) (table)

#### Comparison of Integrators Test Results

* Plots of orbits created for each case
* Plots of differences in the coordinates, velocities and calculated maneuvers
* Apply the maneuvers created from the worst case to the best case and show if it is successful or unsuccessful staying in the orbit

# CONCLUSION

* To be written when chapter 5 is finished.

# REFERENCES

* Make it an automatic table