

# OUFTI 1 & OUFTI 2

## Attitude Determination and Control System

Emilio R. Gordon

March 13, 2018

## Contents

<b>1</b>	<b>Introduction</b>	<b>3</b>
1.1	The OUFTI family . . . . .	5
1.2	OUFTI-1 . . . . .	5
1.3	OUFTI-2 . . . . .	5
1.4	Attitude Determination and Control System . . . . .	5
1.4.1	Passive attitude control and OUFTI-1 . . . . .	5
1.4.2	Active attitude control and OUFTI-2 . . . . .	5
<b>2</b>	<b>Mathematical modelling and Coordinate systems</b>	<b>5</b>
<b>3</b>	<b>Passive ADCS of OUFTI-1</b>	<b>5</b>
3.1	Attitude determination of OUFTI-1 . . . . .	5
<b>4</b>	<b>Active Control for Oufiti-2</b>	<b>5</b>
4.1	Payload, orbit and requirements . . . . .	5
4.2	Attitude determination . . . . .	5
4.2.1	Sun sensors . . . . .	5
4.2.2	Magnetometers . . . . .	5
4.2.3	Gyroscopes . . . . .	5
4.2.4	Star sensors . . . . .	5
4.3	Attitude control . . . . .	5
4.3.1	Magnetic torquers . . . . .	5
4.3.2	Momentum exchange devices . . . . .	5
4.3.3	Thrusters . . . . .	5
4.4	Existing hardware for active control . . . . .	5
4.5	Conclusion . . . . .	5
<b>5</b>	<b>Simulations of an active attitude control</b>	<b>5</b>
5.1	Application of quaternions to active control . . . . .	5
5.2	Attitude determination . . . . .	5
5.3	Torque free motion . . . . .	5
5.4	Attitude control models . . . . .	5
5.5	General parameters for the active control simulations . . . . .	5
5.6	PID controller . . . . .	5
5.7	The linear quadratic regulator controller . . . . .	5
5.8	Detumbling controller based on B-dot . . . . .	5
5.9	Attitude model with full controllability . . . . .	5
5.10	Attitude model with only magnetic torquers . . . . .	5
5.10.1	Magnetic torquers with one reaction wheel . . . . .	5

<b>6</b>	<b>Conclusions</b>	<b>5</b>
6.1	OUFTI-1 . . . . .	5
6.2	OUFTI-2 . . . . .	5

# 1 Introduction

In 2016, The university of Liege developed the first nanosatellites ever made in Belgium : OUFTI-1 and OUFTI-2. The satellite is led by students supported by professors much like our University's SatDev program. OUFTI-1 is a 1U cubesat and is the first satellite equipped with the amateur radio digital-communication protocol: the D-STAR technology. Other experiments that will be aboard OUFTI-1 are an innovative electrical power system as well as high-performance solar cells. The satellite is not required to point in one specific direction and the Attitude Determination and Control System (ADCS) subsystem relies on Passive Magnetic Attitude Stabilization (PMAS). The first part of this thesis presents this design made of a permanent magnet and hysteretic bars. The magnet orients the satellite along the Earth's magnetic field lines and the hysteretic bars damp its rotational velocities. The influence of the magnet on the hysteretic bars as well as the finite elongation of the bars are carefully studied. OUFTI-2 is the next satellite in the series. Its size is planned to be twice the size of OUFTI-1 and its main payload will be a radiometer to perform a direct measurement of the net heating of the Earth. The radiometer is developed in cooperation with the Royal Meteorological Institute of Belgium and is called Sun-earth IMBalance (SIMBA) radiometer. The second part of this master thesis focuses on the feasibility study of an active attitude control system which satisfies the requirements of the payload.



1.1	The OUFTI family
1.2	OUFTI-1
1.3	OUFTI-2
1.4	Attitude Determination and Control System
1.4.1	Passive attitude control and OUFTI-1
1.4.2	Active attitude control and OUFTI-2
2	Mathematical modelling and Coordinate systems
3	Passive ADCS of OUFTI-1
3.1	Attitude determination of OUFTI-1
4	Active Control for Oufiti-2
4.1	Payload, orbit and requirements
4.2	Attitude determination
4.2.1	Sun sensors
4.2.2	Magnetometers
4.2.3	Gyroscopes
4.2.4	Star sensors
4.3	Attitude control
4.3.1	Magnetic torquers
4.3.2	Momentum exchange devices
4.3.3	Thrusters
4.4	Existing hardware for active control
4.5	Conclusion
5	Simulations of an active attitude control
5.1	Application of quaternions to active control
5.2	Attitude determination
5.3	Torque free motion
5.4	Attitude control models
5.5	General parameters for the active control simulations
5.6	PID controller
5.7	The linear quadratic regulator controller
5.8	Detumbling controller based on B-dot
5.9	Attitude model with full controllability
5.10	Attitude model with only magnetic torquers
5.10.1	Magnetic torquers with one reaction wheel
6	Conclusions