Preface

Acknowledgements

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David.

Contents

Acronyms

ACL Access Control List. 114

API Application Programming Interface. 14, 15, 47, 48

APRS Automatic Position Reporting System. 11, 29–31, 35

ASCII American Standard Code for Information Interchange. 4, 25, 35, 40, 101, 103, 106, 109

ASOS Automated Surface Observing System. 17

AWOS Automated Weather Observing System. 17

AWS Automatic Weather Station. 17–31, 33, 35–40, 42–45, 48–51, 53, 55–57, 59, 63, 65, 71, 78–81, 85, 88–95, 98–100, 104, 108, 110–114

AX.25 Link Access Protocol for Amateur Packet Radio. 29, 30

BSON Binary-JSON. 101

CPU Central processing unit. 20, 31, 42, 65

CSV Comma-Separated Values. 5, 36, 113

CWOP Citizen Weather Observer Program. 11, 13, 14, 29, 35, 59, 60, 71, 113

DDoS Distributed denial-of-service. 114

DNS Dynamic Name Server. 73

DoS Denial-of-service. 114

ECMWF European Centre for Medium-Range Weather Forecasts. 12

FMI Finnish Meteorological Institute. 12, 15

FTP File Transfer Protocol. 34, 35, 39, 40, 43–45, 89, 113

GDPFS Global Data-processing and Forecasting System. 35, 44, 113

GOS Global Observing System. 35, 41, 44, 48, 49, 53, 113

GPRS General Packet Radio Service. 24, 26, 27

GSM Global System for Mobile Communications. 24, 26, 27

GTS Global Telecommunication System and WMO Information System. 35

GUI Graphical User Interface. 42, 95, 99, 117, 118

HTTP Hyper Transfer Text Protocol. 40, 48, 57, 76, 89, 91

ICAO International Civil Aviation Organization. 36, 113

IETF Internet Engineering Task Force. 34, 114

IO in / out. 20, 40

IP Internet Protocol. 45, 58, 69, 73, 87, 102, 103, 106, 109

ISO International Standard Organization. 56, 59, 75

JSON JavaScript Object Notation. 46, 48, 50, 53, 65, 67, 69, 77, 79, 86, 89–91, 96, 97, 99–101

kB Kilobyte. 20, 22, 23, 110

kbit kilobits. 22, 71, 93, 95

MB Megabyte. 21, 22

Mbits Megabits. 22, 71

METAR Meteorological Service For International Air Navigation. 36, 37

MHz Megahertz. 20

NAT Network address translation. 51, 73

NMEA-0183 National Marine Electronics Association 0183. 4, 25, 35

NOAA National Oceanic and Atmospheric Administration. 12, 18, 71, 113

NTP Network Time Protocol. 75, 101

OS Operating System. 49, 55, 57, 94

P2P Peer to peer. 47–51, 54, 55, 57, 58, 69, 70, 74, 86, 89, 91, 95, 98, 110, 113, 114

PROM Programmable Read-Only Memory. 25

PTH Pressure, Temperature, Humidity. 43

PTU Pressure, Temperature and Humidity. 78, 79, 82, 86, 110

RAM Random-access memory. 20

RFC Request for Comments. 34, 50, 51, 55, 59, 65, 75, 98

RS-232 Recommended Standard 232. 4, 22, 23, 33, 93

RS-422 Recommended Standard 422. 4, 22, 23

RS-485 Recommended Standard 485. 4, 22

RTT Round-trip time. 95

SDI-12 Serial Data Interface at 1200 Baud. 4, 25

SHA Secure Hash Algorithm. 59, 60

SI Système international d'unités - International System of Units. 9

SMB Server Message Block. 39, 40, 45

SOA Service-oriented architecture. 46, 47, 51, 52, 57, 62

TCP Transmission Control Protocol. 45, 61, 73, 96, 98, 102–111, 114

TLS Transport Layer Security. 114

TSV Tab-separated values. 5, 36

UML Unified Modeling Language. 97, 100

UMTS Universal Mobile Telecommunications System. 24, 26, 27

URI Uniform Resource Identifier. 59

URL Uniform Resource Locator. 59, 60

USB Universal Serial Bus. 4, 22, 26, 33

UTC Coordinated Universal Time. 75

UTF Universal Character Set - Transformation Format. 65

UTM Universal Transverse Mercator. 72, 93

WMO World Meteorological Organization. 11, 12, 15, 17, 18, 20, 21, 31, 33, 35, 36, 41, 48, 60, 77, 113, 114

XML eXtensible Markup Language. 67

List of Figures

List of Tables

Chapter 1

Introduction

The relationship between human beings and space has existed since the beginning of time. It has always been a source of mystery, something we want to understand. More than 4000 years ago, the Egyptians and the Babylonians were influenced by the movements of the sun and the planets and, based on those movements, developed calendars for their crops. Later, the ancient Greeks developed the concept of *astronomy*, the science of the heavens. Subsequently, we can find philosophers such as Nicolaus Copernicus, Johannes Kepler, who explained the motion of the planets, and Galileo Galilei. In the 17th century, Sir Isaac Newton invented calculus, developed his law of gravitaion and performed important experiments in optics.

The technological advancements of the 20th century, specially accelerated by the World War II, made physical exploration of space become possible. This thesis is oriented towards one of those advancements, artificial satellites.

A *satellite* is a natural or artificial object moving around a bigger body. This motion is defined as an orbit, enabled by the dominant force of gravity from the bigger body. In early 1945, the United States started the Vanguard Rocket development to launch a satellite. However, after several failed launches, it was de Soviet Union who took the advantage by launching the Sputnik-1 (Figure 1.1) on October 4, 1957. During the Cold War, the space race between the Sovient Union and the United States was a hard fight which made space technology advance quite rapidly.

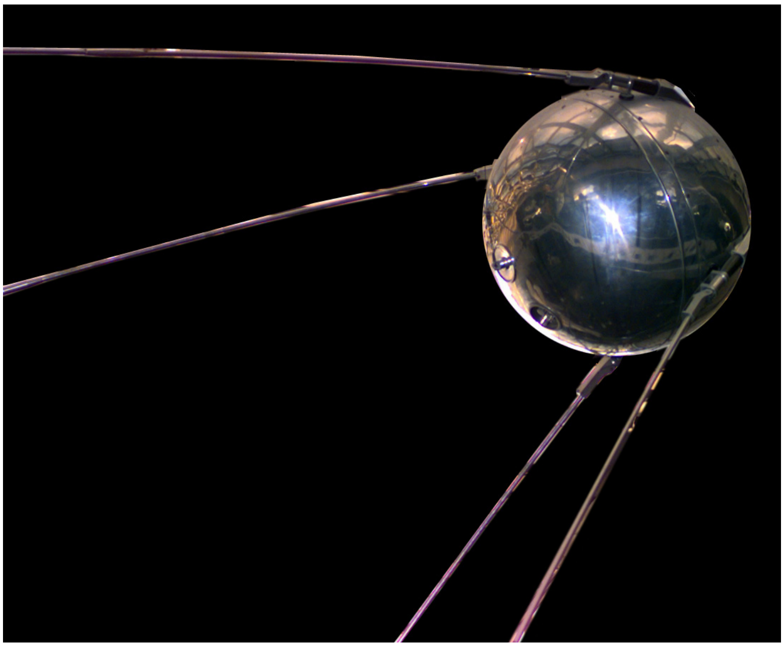

Figure 1.1: Sputnik 1 (NASA Public Domain)

Finally, on January 31, 1958 the United States managed to launch their first artificial satellite, the Explorer-1 (Figure 1.2).

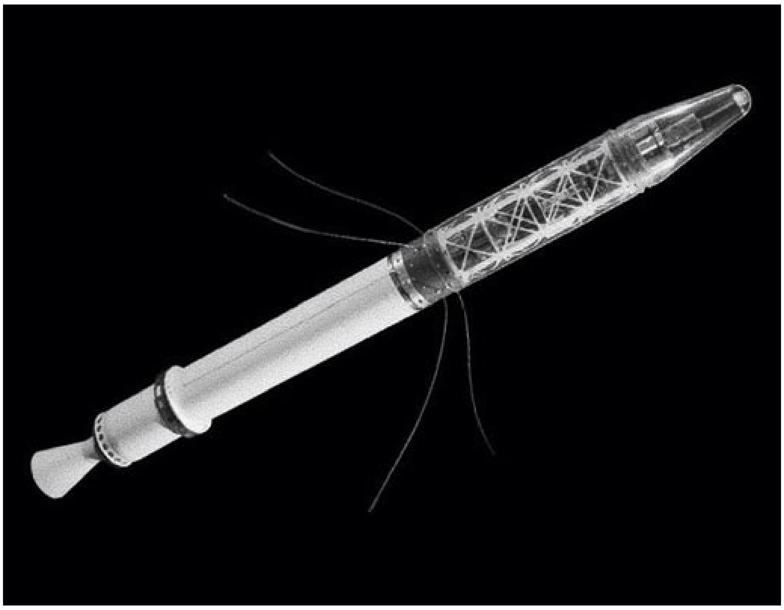

Figure 1.2: Explorer 1 (NASA Public Domain)

As of October 1, 2011 there were 966 operating satellites in orbit. About two-thirds of these were owned by the United States, Russia and China[1]. Their major types are:

- Communications: used for television, radio, Internet and telephone services.
- Navigation: using radio time signals, this satellites allow mobile receivers on the ground to determine their exact position. They are also used to determine the location of satellites situated in lower orbits.
- Exploration: used to observe distant planets, galaxies and other outer space objects by using telescopes and other sensors.
- Remote sensing: Remote sensing satellites are used to gather information about the nature and condition of Earth. The sensors in this kind of satellites receive electromagnetic emissions in several spectral bands and can detect the object's composition and temperature. Also, environmental conditions and so on. These satellites have also been widely used as military "spy satellites".

The constant evolution of technology and the growth of human needs have me the mission requirements rise throughout the last decades, thus, satellite mass has grown from Sputnik's 84 kg. and Explorer-1's 14k kg. to over 6,000 kg in 2007[2]. The main consequence of this, amongst others, has been an increment in mission costs.

To counter this trend, the small satellite movement was created by the academic community and it has shown how mission costs can be cut dramatically to a point in which a university can build a launch their own satellite. (Figure 1.3). Due to its success, it has become vigorous industry. Aalto-1 and ESTCube-1, projects with which this thesis is related, are nanosatellites, and the perfect example of this new concept.

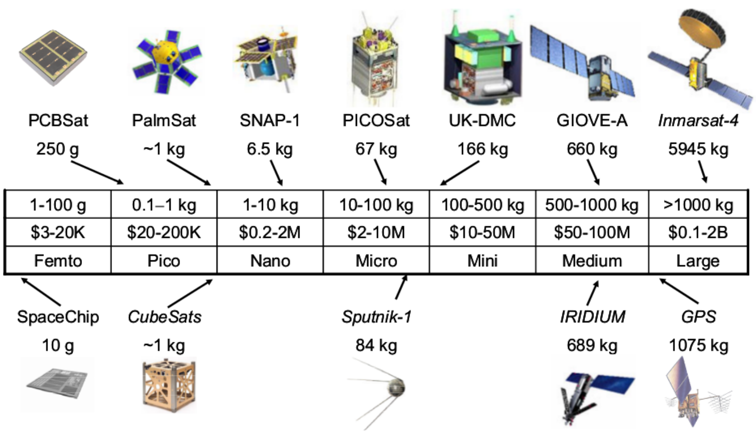

Figure 1.3: Satellite Mass and Cost Classification [2]

1.1 Background

As it was stated before, this thesis is closely related to two different projects. Aalto-1 and ESTCube. These two projects are based on the most common standard use by universities, CubeSat[3]. An open standard developed by the California Polytechnic State University and Stanford University.

1.1.1 Aalto-1

Led by Aalto University, Aalto-1 project aims to build a multi-payload remote sensing nanosatellite (Figure 1.4). The size of the satellite is approximately 34 cm x 10 cm x 10 cm with a mass of less than 4 kg[4].

Figure 1.4: Aalto-1

There are different institutions cooperating to make this possible. The main payload, the imaging spectrometer, has been designed and built by VTT Technical Research Centre of Finland. The Radiation Monitor (RADMON) has been designed by the Universities of Helsinki and Turku in cooperation with the Finnish Meteorological Institute (FMI). The Plasma Brake has been designed by a consortium including the FMI, the Department of Physics of the University of Helsinki, the Departments of Physics and Astronomy and Information Technology of the University of Turku, the Accelerator laboratory of the University of Jyväskylä, Aboa Space Resarch Oy, Oxford Instruments Oy and other Finnish companies. Meanwhile, Aalto University is responsible for designing and building the satellite platform and the day-to-day operation of the project.[5]

Aalto-1's mission is to validate the technologies used by the payloads in space environment and measure their performance. In addition, it is also an educational project. Students are the main workforce towards its success. Being the the first Finnish student satellite mission, it is a good tool to improve Finnish space teaching and also allow students to be in touch with prominent partners, both domestic and international, in the space technology field.

1.1.2 ESTCube-1

1.2 Problem statement

1.3 Research objectives and scope

1.4 Motivations

1.5 Outline of the thesis

Chapter 2

Orbits

One crucial topic that anyone working with satellites needs to understand is orbits and their characteristics. An orbit is the **gravitationally curved path of an object around a center of mass**. Examples of orbits can be the Earth around the Sun or artificial satellites around the Earth.

This section will cover the elements that describe and define an orbit, how it is represented on a map and in which way the elements that define a particular orbit can be delivered so they can be used by a computer.

2.1 Kepler's Laws

Planetary movements were first mathematically defined by the German mathematician, astronomer and astrologer Johannes Kepler in the 17th century. He concentrated his observations into three simple laws[6]:

- The orbit of each planet is an ellipse with the Sun occupying one focus.
- The line joining the Sun to a planet sweeps out equal areas in equal intervals of time.
- A planet's orbital period is proportional to the mean distance between the Sun and the planet, raised to the power of 3/2.

These laws apply to every celestial body. When analysing to bodies, if one is much bigger than the other, it conforms the "two-body problem". It assumes that both bodies are spherical and they are modelled as if they were point particles. This means that influences from any third body are discarded. The analysis of hits problem has resulted in six elements that completely define an orbit, which will be explained in the next section.

2.2 Classical Orbital Elements

The Classical Orbital Elements are six and uniquely identify an orbit. They also can be used to predict future positions.[7]

The first two elements, the orbit's size and shape are defined based on a 2D representation on an ellipse (Figure 2.1).

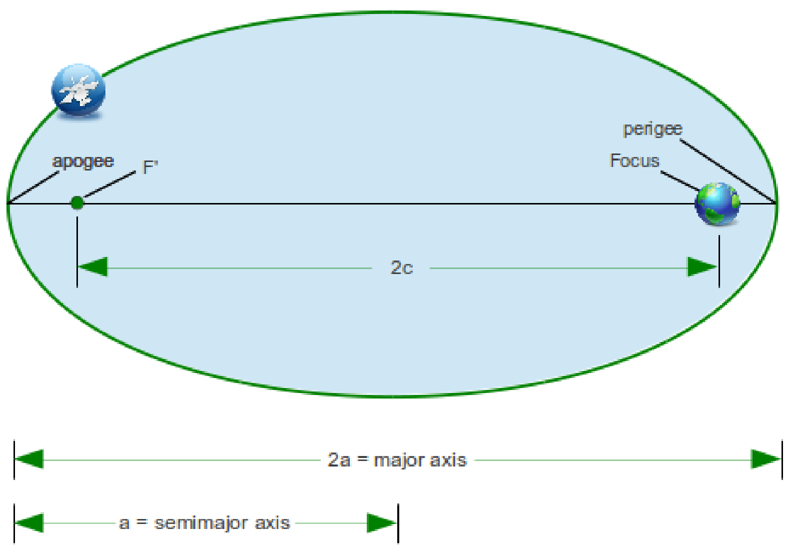

Figure 2.1: Semimajor Axis

- The *semimajor axis* (a) is one half the distance across the long axis of the orbit, and it represents the orbit's size.
- The *eccentricity* represents the shape of the orbit. It describes how much the ellipse is elongated compared to a circle. Based on the latter, the orbit can have the following shapes, as shown in Figure 2.2

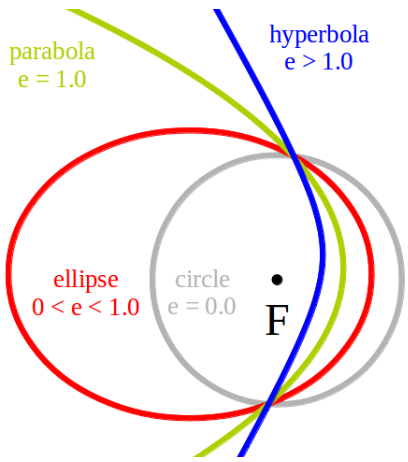

Figure 2.2: Eccentricity

Before jumping onto the next Orbital Elements it is necessary to point out that the Geocentric-equatorial Coordinate System will be used. It is now a 3D representation, where the fundamental plane is Earth's equatorial plane and the principal direction is in the vernal equinox direction.

The following orbital elements define the orientation of the orbital plane:

- The inclination (i) describes the tilt of the orbital plane with respect to the reference plane. It is measured at the ascending node. This is, where the orbit crosses with the reference plain when moving upwards.
- The right ascension of the ascending node (Ω) represents the angle between the principal direction and the point where the orbital plane crosses the reference plane from south to north measured eastward.

Based on this two elements, the orbits can be classified as shown in Table

Inclination	**Orbital Type**	**Diagram**
0° or 180°	Equatorial	

Table 2.1: Types of Orbits and Their Inclination [7].

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