Acta Astronautica 121 (2016) 13–22

Contents lists available at ScienceDirect

Acta Astronautica

journal homepage: www.elsevier.com/locate/actaastro

E-st@r-I experience: Valuable knowledge for improving the e-st@r-II design ☆

S. Corpino *, G. Obiols-Rabasa, R. Mozzillo, F. Nichele

Department of Mechanical and Aerospace Engineering, Politecnico di Torino, Torino, Italy

ARTICLE INFO

Article history:
Received 26 November 2014
Received in revised form
24 November 2015
Accepted 20 December 2015
Available online 29 December 2015

Keywords:
CubeSat
CubeSat verification
Spacecraft design
Spacecraft lifecycle
Assembly Integration and Verification
Space engineering education

ABSTRACT

Many universities all over the world have now established hands-on education programs based on CubeSats. These small and cheap platforms are becoming more and more attractive also for other-than-educational missions, such as technology demonstration, science applications, and Earth observation. This new paradigm requires the development of adequate technology to increase CubeSat performance and mission reliability, because educationally-driven missions have often failed. In 2013 the ESA Education Office launched the *Fly Your Satellite! Programme* which aims at increasing CubeSat mission reliability through several actions: to improve design implementation, to define best practices for conducting the verification process, and to make the CubeSat community aware of the importance of verification. Within this framework, the CubeSat team at Politecnico di Torino developed the e-st@r-II CubeSat as follow-on of the e-st@r-I satellite, launched in 2012 on the VEGA Maiden Flight. E-st@r-I and e-st@r-II are both 1U satellites with educational and technology demonstration objectives: to give hands-on experience to university students and to test an active attitude determination and control system based on inertial and magnetic measurements with magnetic actuation. This paper describes the know-how gained thanks to the e-st@r-I mission, and how this heritage has been translated into the improvement of the new CubeSat in several areas and lifecycle phases. The CubeSat design has been reviewed to reduce the complexity of the assembly procedure and to deal with possible failures of the on-board computer, for example re-coding the software in the communications subsystem. New procedures have been designed and assessed for the verification campaign accordingly to ECSS rules and with the support of ESA specialists. Different operative modes have been implemented to handle some anomalies observed during the operations of the first satellite. A new version of the on-board software is one of the main modifications. In particular, the activation sequence of the satellite has been modified to have a stepwise switch-on of the satellite. In conclusion, the e-st@r-I experience has provided valuable lessons during its development, verification and on-orbit operations. This know-how has become crucial for the development of the e-st@r-II CubeSat as illustrated in this article.

1. Introduction

The number of CubeSats in Earth orbit has increased since 2003, when six of them were deployed in the first multiple CubeSat launch [1]. The CubeSat standard was born within the academia with a pure educational purpose [2]. Low-cost and fast-delivery features were key

☆ This paper was presented during the 65th IAC in Toronto.

* Corresponding author. Tel.: +0039 0110906867,
Mobile: +0039 3358383181.
E-mail addresses: sabrina.corpino@polito.it (S. Corpino),
gerard.obiols@polito.it (G. Obiols-Rabasa),
raffaele.mozzillo@polito.it (R. Mozzillo),
fabio.nichele@polito.it (F. Nichele).

http://dx.doi.org/10.1016/j.actaastro.2015.12.027
0094-5765/

parameters playing a crucial role for the standard definition. These factors led to a high number of CubeSats developed by universities in the first decade, mainly with education as primary objective; technology demonstration, scientific experiments and/or Earth observation have been secondary objectives for most of them [3]. However, in the last years space agencies and private companies recognised CubeSats as attractive space platforms to accomplish technology demonstration and scientific experiments, with a significant cost reduction and a relatively faster development time, from design to operations, compared with traditional larger-satellite missions.

CubeSats allow to build brand new architectures, which would be unattainable with bigger satellites. Constellations of nano-satellites in LEO are becoming a reality [4,5], while the CubeSat community is exploring the possible applications of CubeSats for interplanetary missions [6,7], and one unit for technology demonstration of future missions to the Moon has already been launched [8].

Despite the number of developed CubeSats increased substantially during the last years, around half of the total launched CubeSats have suffered a failure. Their mission's rate of success still is unacceptable in view of the opening possibilities for science and Earth observation missions.

A possible way to increase the rate of success is to evaluate previous missions gathering lessons learned, extract possible failures and drawbacks, and deduce possible improvements for future projects. This activity has been conducted by the CubeSat Team at Politecnico di Torino [9] after the launch of our first CubeSat, e-st@r-I.

The Team was founded at the beginning of 2006 with the objective of giving hands-on experience opportunities to engineering students in the area of space missions and systems design. The activities are focused on the development of CubeSats and small platforms for technology demonstration, and on the definition of testing methodologies and tools. Scientific missions are being studied in collaboration with international partners [10]. To conduct these activities, the Team works in the Systems and Technologies for Aerospace Research Laboratory (STARLab), located in the Department of Mechanical and Aerospace Engineering (DIMEAS).

Recent projects include the CubeSat e-st@r-I, which was designed, developed, tested and launched in 2012 as first Italian CubeSat in orbit. The second unit, e-st@r-II, has been developed within the ESA's *Fly Your Satellite!* programme. It has already conducted functional verifications at ambient condition, and it is waiting for an available slot at the environmental test facilities at ESTEC for thermal-vacuum and vibration testing. 3STAR, a triple-unit CubeSat integrating a GNSS remote sensing payload [11], is also being designed in the STARLab.

In the present paper the authors describe the results and lessons learned from past activities and how they have been turned into design implementation for current and future projects. In Section 2, an overview of the e-st@r programme at Politecnico di Torino and a description of the e-st@r-I CubeSat is provided. Lessons learned from the e-st@r-I project are detailed in Section 3. Section 4 describes how the team applied the previous experience to improve the e-st@r-II design, verification plan and execution, and in-orbit operations plan. Finally, conclusions are drawn in Section 5.

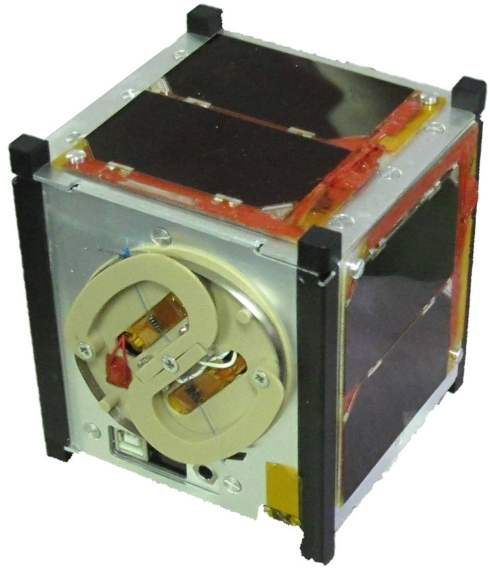

Fig. 1. Flight model of e-st@r-I CubeSat.

2. E-st@r programme

The e-st@r programme is the main activity led by the CubeSat Team. The programme has been set to give hands-on experience to university students, concurrently exploring the possibilities of novel space mission concepts and technology innovations. The first unit of the family, e-st@r-I, was a 1U CubeSat driven by educational and technology demonstration goals. The flight model is shown in Fig. 1.

The detailed description of the e-st@r-I platform is given in [12]. The satellite was manufactured using mainly COTS components. The payload was an active-attitude determination and control subsystem aimed at demonstrating autonomous attitude control capabilities based on magnetic actuation [13]. The satellite bus was equipped with a fully customised communications subsystem (COMSYS) based on the commercial transceiver BHX2 from Radiometrix [14] data sheet/url], while the antenna system was developed from scratch by the students [15]. The Electrical Power System (EPS) includes a Clyde Space Ltd distribution unit [16] and an in-house developed daughter-board, devoted to provide 1) mechanical and electrical connection between the batteries and the EPS motherboard, and 2) telemetry data to the bus.. The On-Board Computer (OBC) board was procured off-the-shelf from Pumpkin Inc. [17], while the software has been developed and tested in house by the team. The team also designed the structure, the manufacturing being provided by an external company. The launch of e-st@r-I took place on February 2012 from Centre Spatial Guyanais in Kourou, as part of the ESA's *Educational CubeSats on the VEGA Maiden Flight* programme.