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Toward open source CubeSat design

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ABSTRACT

Today, open source software plays a significant role in information technology and consumer electronics. Open source hardware, which is the free exchange of a product's design information, is gaining popularity as well. Both ideologies are motivated by trading away competition against collaboration. In this paper we suggest the application of the open source movement to space technology. In the focus of our discussion are CubeSats, considered as an ideal playground for the introduction of technological and methodological novelties. We examine the legal background of open source designs and contrast the advantages of open source products for developers and users against closed source products. We then present an open source initiative for CubeSat technologies with the intention to encourage the CubeSat community to move towards open design.

1. Introduction

Space exploration and utilization has historically been governed by confidentiality, secrecy, and the monopolization of knowledge. Access to space has always been considered as a crucial asset, and the demonstration of "technological firsts" was used to demonstrate engineering supremacy [1]. It just seems too natural to protect the knowledge obtained during the course of the project's life cycle in order to take benefit from the work and financial resources that were invested. Therefore most of us live with the conviction that space is reserved to a few nations that have the know-how and financial resources for its exploitation.

On the other hand, a number of universities had started their own small satellite projects as early as in the 1980s, in order to provide hands-on training for students in this interdisciplinary field of high technology [2]. Here the technical details of systems were made much more accessible, such as in the form of publications and papers, although almost no attempts were made to publish detailed designs to a broader audience. Over time, several universities, mainly in US and Europe, had established small satellite programs for science and education (such as [3–6]).

In 1999 then, the CubeSat standard was created as a joint effort by professors Jordi Puig-Suari of California Polytechnic State University and Bob Twiggs of Stanford University [7]. The standard specifies mainly the mechanical interface requirements of a 1 kg, 10x10x10 cm^3 nanosatellite. Satellites adhering to this standard would be compatible with the Poly-PicoSatellite Orbital Deployer (P-POD), a standardized launch container developed as well at Stanford University [8]. The P-POD is attached to the upper stage of a launch rocket, carries between one and three of such CubeSats and deploys them into orbit. As such, the P-POD provides a first degree decoupling of the interface between satellite and launch rocket and eases the launcher integration process significantly.

The motivation for the invention of the CubeSat standard was to enable graduate students to design, build, test and operate satellites within their academic curriculum. The first CubeSats were launched in June 2003 and cumulated in an explosive growth of CubeSat launches in

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recent years. The success of CubeSats is attributed exactly to its standardized interface with respect to the launcher integration, which led to cheaper launch costs in the range of several tens of thousands of Euros and an accelerated launch preparation schedule.

Triggered by the success of CubeSats, a handful of start-up companies appeared during the second half of the first decade of 2000, and more followed. Founded mainly by graduates who worked on CubeSat missions during their studies, these companies kept strong ties with their (hosting) university, and focused mainly on supporting research and educational missions. Yet, despite having this academic background, the products were sold closed source, with some companies offering the design information for a significant surplus charge. Around the same time, industry and military entered the fast growing CubeSat sector and launched own CubeSat missions [9]. By 2013 a dramatic increase of CubeSats deployed in space is noticeable, as shown in Fig. 1. Most of the recent CubeSats were launched as clusters or fleets under the flag of private companies. Nonetheless, the academic world takes the largest share among CubeSat developers, as shown in Fig. 2.

From this it is evident that academia remains a major player in the CubeSat sector. As such, it has a strong impact on the future of the CubeSat program. The authors of this paper are convinced that CubeSats are not only an ideal tool for teaching hands-on space technology but also a great chance for opening up the access to space technology to a much larger audience, including students from emerging and developing countries.

However, the current trend of increasing commercialization is counter-productive to this objective, as we will elaborate in the following sections. We also observe that a number of universities have established “centres of excellence” for CubeSats, which capitalize on their in-house acquired knowledge. At the same time inter-university collaborations are minimal. This is arguably not in the original interest of the CubeSat concept, which stipulates the free exchange of design information and lessons learned. Therefore, we are convinced that the spirit of the terrestrial open source movement must enter the minds of developers in order to provide for a better prospect of the future of CubeSats.

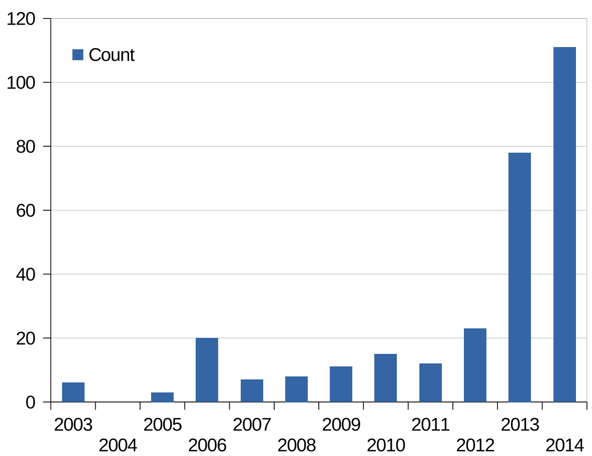

Fig. 1. CubeSats launched from 2003 to 2014. Compiled using data from M. Swartwout.

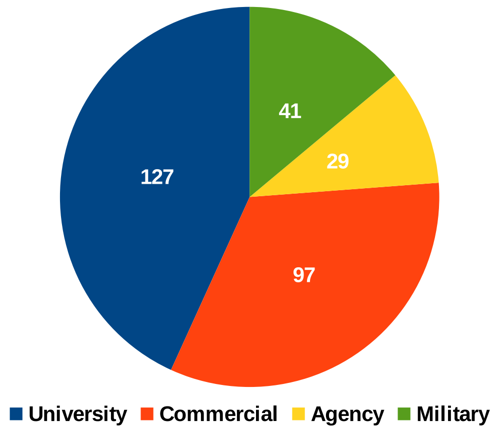

Fig. 2. Number of CubeSats that were launched from 2003 to 2014 grouped by ownership. Compiled using data from M. Swartwout.

In the following we first take a glance at the open source movement that exists in information technology and embedded design products and then define the term “open source design”. We then examine intellectual property rights and the major open source licenses available today. A large part of this paper is dedicated to show the disadvantages of closed source development versus the benefits gained by open source designs. Finally, a case study of an existing open source CubeSat initiative is presented.

2. Terrestrial open source movement

Open source software (OSS) is the backbone of modern society. It is present in almost every field of information technology, such as web servers, operating systems, software development tools, and mobile phones. Open source hardware (OSHW), as discussed in this context,[1] is a relatively new phenomenon that follows the same principles: to allow anyone access to its sources for modification, sharing, building, and selling.

A popular example is the Beagle Board [10], a single-board computer developed to provide education in the design and use of open source software and hardware in embedded computing. The board consist essentially of a powerful system on chip (SoC) processor (which however is proprietary) and a wide range of peripherals. It hosts Ubuntu, Android, and other open operating systems. Design files and extensive documentation are freely available.

In the same category falls the widely known Arduino [11]. It is an open design processing board that is bundled with an open source integrated development environment (IDE) and libraries. The IDE provides an easy usage of the microcontroller resources through a simplified programming language based on C/C++, allowing people to start

[1] Radio amateurs, hobbyists, and DIY communities have exchanged design information ever since; in this paper however we focus on projects that are made available to a wider public, mainly via the internet.