

CubeSat Survey

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Abstract

In recent years, there has been a significant migration towards small satellite missions due to their reduced cost and development time. Specifically, CubeSats have become increasingly popular not only in university environments, but government and private industries as well. The standardization of these 10 cm CubeSats has also allowed for rideshare opportunities, thus finding a launch service provider is much simpler, allowing for more frequent access to space. CubeSat standards also allow for commercial off the shelf (COTS) hardware components to be made available at reasonable prices, however there is no standard software as of 2014. NASA Independent Verification and Validation (IV&V) facility has requested a survey of CubeSats to provide additional insight into all previous CubeSat missions. This information will assist them in developing a standard software to be used for all future IV&V CubeSat missions as well as missions at NASA Goddard Space Flight Center (GSFC).

1 Introduction

The CubeSat Project, developed in 1999 by Professor Jordi Puig-Suari of California Polytechnic State University (Cal Poly), San Luis Obispo and Professor Bob Twiggs of Stanford University's Space Systems Development Laboratory (SSDL), was an initial attempt at standardizing design parameters for small satellites in order to reduce cost and development time. As a result, these standards have allowed for more frequent launches and therefore easier access to space due to the low-budget nature of CubeSats [1]. The CubeSat Project outlines the standards required for CubeSat development while describing specific parameters (i.e. dimensions, mass, deployment mechanisms, etc.) that must be met for the spacecraft to qualify as a CubeSat.

When considering dimensions, a 1U (1 unit) CubeSat must have the dimensions of 10cm x 10cm x 10cm. Alternate configurations exist and include 2U and 3U CubeSats with dimensions of 10cm x 10cm x 20cm and 10cm x 10cm x 30cm, respectively (see Figure 1). In addition to dimensions, mass limitations prohibit CubeSats from exceeding 1.3 kg per unit (U), meaning a 2U CubeSat must not exceed 2.6 kg while a 3U must not exceed 4.0 kg. These limitations also limit the amount of power available for use on the spacecraft. The specified dimensions pose limitations regarding the surface area available for solar panels. Previous studies have shown that the average power of a CubeSat can vary from 1W (1U) and 5W (3U). However, assuming the spacecraft still meets

the mass requirements, deployable solar panels can be used to significantly increase the amount of available power (i.e. a 3U CubeSat with deployable panels can have up to 20W of available power) [2].

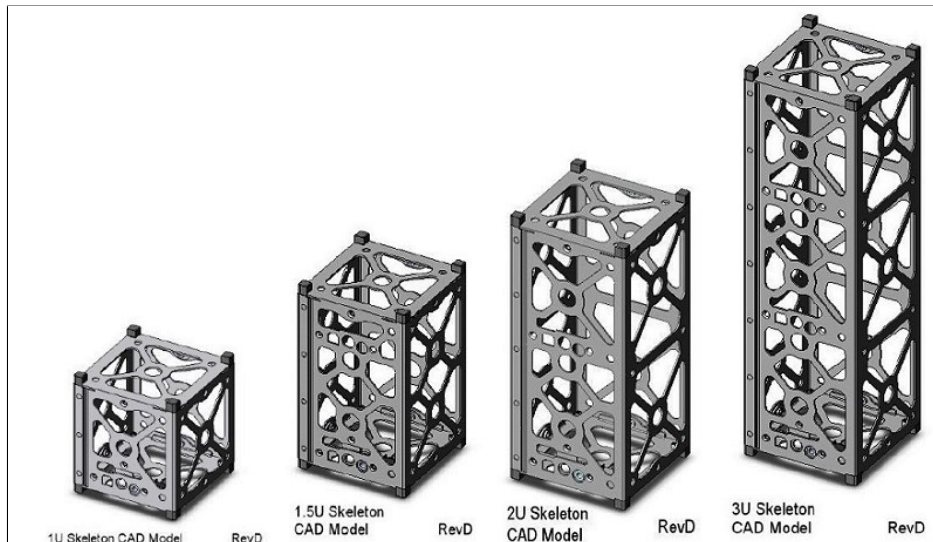


Figure 1: Example of CubeSat Configurations[3]

CubeSats that meet dimension and mass requirements can be launched from the Poly Picosatellite Orbital Deployer (P-POD) developed by Cal Poly. The P-POD serves as a standardized deployment system for up to three 1U CubeSats or any equivalent combination. Any CubeSat being deployed from a P-POD must adhere to additional specific guidelines in the CubeSat Design Specifications document in order to ensure compatibility for a successful deployment. Some recently proposed experiments, however, have been designed for 6U CubeSat structures, resulting in the need for an alternative deployer. Fortunately, NASA Wallops, NASA Ames, as well as other institutions have come up with designs for 6U deployers, all of which have been tested and have received a TRL of at least 6 [4].

The standards developed by Cal Poly have resulted in a significant increase in the number of small satellite missions launched over the past few years [5]. This is partially due to the development of commercial off-the-shelf (COTS) components specifically designed to meet all CubeSat requirements. Because of this, CubeSats have become relatively inexpensive, making them ideal educational tools in university and classroom settings. With the development of COTS components, there are a variety of options for various processors and operating systems; however, these options may not always meet the criteria required for various missions. It is for this reason that NASA IV&V has been asked to develop a portable, pure software build-and-test system that will provide the capability to develop, debug, and test software on a standard personal computer with no specialized hardware. Once this is developed, it is expected to be used in collaboration with NASA GSFC's SpaceCube development and testing.

2 Results of Survey

To determine possible options for a standardized NASA IV&V software, a comprehensive survey was conducted on past, present, and future CubeSat missions. This survey initially consisted of all CubeSat missions able to be found online and totaled slightly over 250 missions. For this particular

report, it was decided that the focus would be on domestic missions which narrowed the search to approximately 150 missions, some of which had been launched while others were still only proposed concepts. This list was consolidated once more to focus on already launched missions as well as missions with launch services confirmed in upcoming years. As a result, a comprehensive list of approximately 115 CubeSats has been developed. The information collected in this survey can be categorized as shown in Table 1. This section of the report will provide a summary of data collected as a result of the survey.

Table 1: Summary of Data Collected for CubeSat Survey

Mission Information	Launch Information	IV&V Information
Name of Satellite	Launch Date	Processor
Mission Objective	Launch Vehicle/Mission	Orbit
Sponsor	Mission Status	Uplink/Downlink
Manufacturer	Deployer	Attitude Determination
Domestic	Program	Attitude Control
Size	Orbit Parameters	Orbit Determination
Mass		Miscellaneous

A market assessment conducted by SpaceWorks Enterprises, Inc. in 2014 showed that of the nanosatellites launched between 2009 and 2013, 47% can be categorized as 1U CubeSats. Although not enough information is given to determine how many 2U and 3U CubeSats have been launched, there seems to be a significant trend towards 3U CubeSat missions based on the information in Figure 2. These results show the increase in CubeSat missions over recent years and gives reason to believe this trend will continue in the near future.

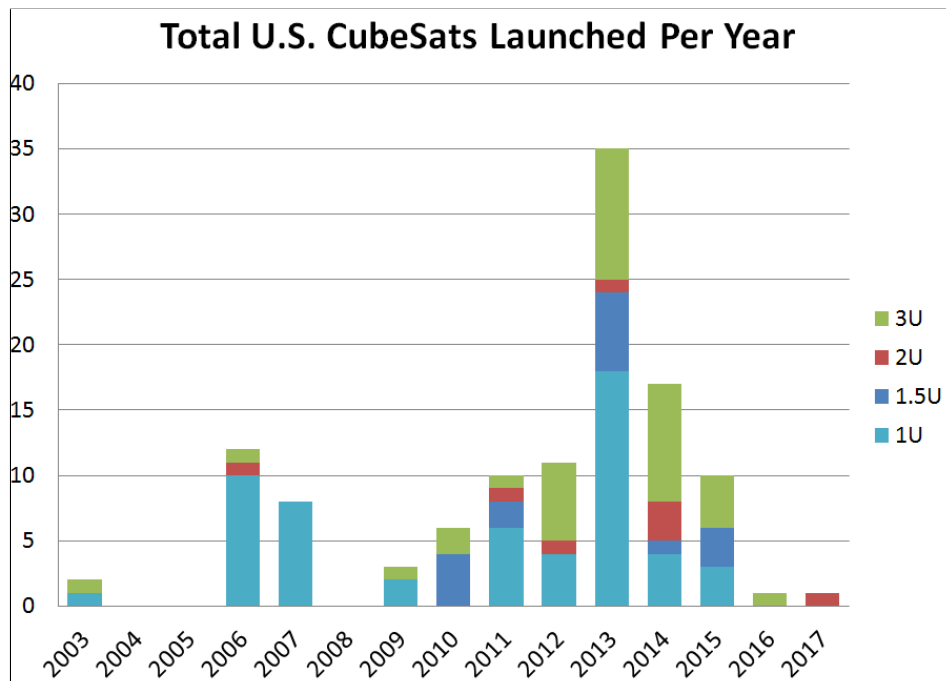


Figure 2: Results of survey showing the size and number of CubeSats launched per year as of August 2014 (based on 116 CubeSats with applicable data)

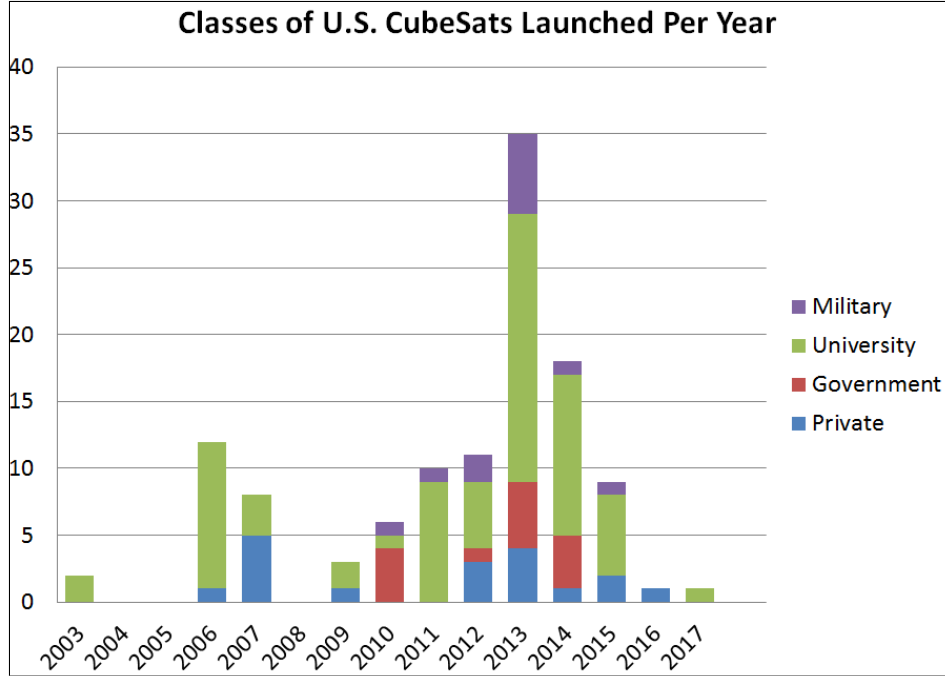


Figure 3: Results of survey showing the number of U.S. CubeSats launched per year, divided by class, as of August 2014 (based on 116 CubeSats with applicable data)

Figure 3 shows the number of U.S. CubeSats launched per year based on class (i.e. private, government, university, military, etc.). It is obvious that a majority of launches have been for university missions and educational purposes. However, there has been a significant increase seen in government missions as well as privately funded missions.

When considering verification and validation software, it is of most importance to determine the processor and operating system used for as many CubeSat missions as possible. This will provide insight into which processors are most effective and capable of ensuring successful mission operations. Of the CubeSats surveyed, almost 38% used PIC processors. Of these processors, 52% used the PIC18. These results are summarized in Figure 4. In addition, it should be noted that of these processors, Pumpkin currently provides Pluggable Processor Modules (PPM) available with their CubeSat Kit which is capable of incorporating the following processors with the flight module: SiLabs C805, PIC24, PIC33, and TI MSP430.

As far as operating systems are concerned, Salvo and Linux were the two most commonly used in the CubeSat missions surveyed. Salvo is available with the purchase of any Pumpkin PPM and is included with the purchase of a Pumpkin CubeSat Kit.

3 Discussion of Results

Based on the information collected from this survey, a majority of CubeSat missions have used PIC processors (specifically PIC18) with either Linux or Salvo operating systems. The availability of Pumpkin CubeSat kits is likely a major contributor to these results, although this was not confirmed in this survey. It is our recommendation that NASA IV&V use their previous knowledge and experience with processors and operating systems to create their own verification and validation software. Some aspects to consider are cost, user interface, and power requirements, each which

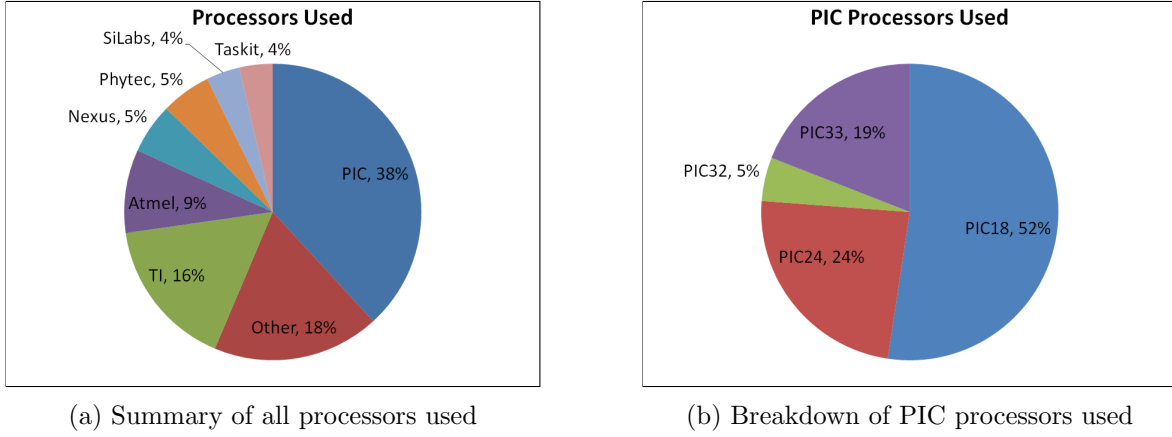


Figure 4: Summary of processors used in CubeSats

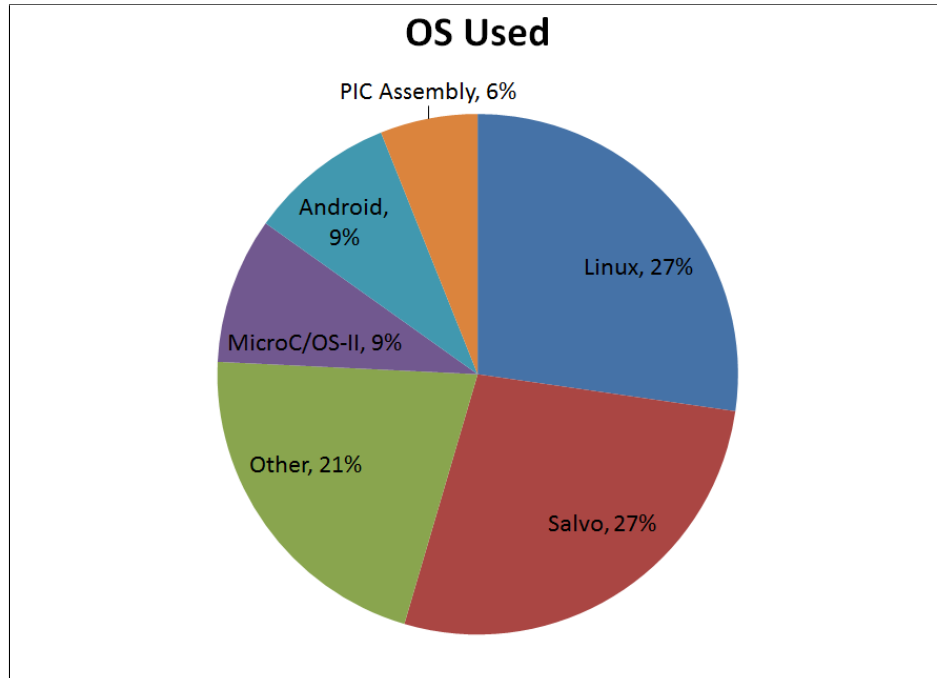


Figure 5: Results of survey showing the percentage of OS used in CubeSat missions

will be determined by the nature of the mission. However, it should be noted that the results of this survey lead us to believe that successful missions can be achieved through the use of PIC processors and Linux or Salvo operating systems. As a reference, processor specifications are compared and summarized in TABLE (working on this).

4 Future Work

References

- [1] California Polytechnic State University, San Luis Obispo, "CubeSat Design Specifications Rev. 13," February 2014.

- [2] Clark, C. and Logan, R., “Power Budgets for Mission Success,” ClydeSpace, April 2011.
- [3] Naik, S. R., “CubeSat Constellation around Mars,” 2011.
- [4] Mission Design Division Staff, “Small Spacecraft Technology State of the Art,” Tech. rep., NASA Ames Research Center, July 2014.
- [5] Buchen, E. and DePasquale, D., “2014 Nano/Microsatellite Market Assessment,” SpaceWorks Enterprises, Inc., 2011.