Chickadee: A new nanosat format for hands-on education and technology maturation

Supriya Chakrabarti
Lowell Center for Space Science and Technology (LoCSST)
University of Massachusetts Lowell
600 Suffolk Ave, Lowell, MA 01854, USA
supriya_chakrabarti@uml.edu

Sunip K. Mukherjee
Lowell Center for Space Science and Technology (LoCSST)
University of Massachusetts Lowell
600 Suffolk Ave, Lowell, MA 01854, USA
sunip_mukherjee@uml.edu

Mitchell E. Bailey
Lowell Center for Space Science and Technology (LoCSST)
University of Massachusetts Lowell
600 Suffolk Ave, Lowell, MA 01854, USA
mitchell_bailey@student.uml.edu

***Abstract*— We describe Chickadee, a new nanosat format that occupies the optional extra volume of CubeSat launchers. For 1U CubeSats, it provides roughly the same volume and mass allotment within a 0.6 U cuboid for the payload. An approximately 0.28 U short cylinder attached to the cuboid, the so-called Tuna Can, houses the spacecraft bus systems. Chickadee's use of the excess capacity of the launchers would provide frequent and low-cost access to space. The spacecraft bus could also be accommodated within a standard CubeSat format.**

The design of the spacecraft bus is flexible and all common functions such as power management and, attitude determination and control systems, fits inside the Tuna Can. The basic system is quite suitable for laboratory experimentation and most student-developed payloads. We also note that, Chickadee can also be used by professionals to mature their space-bound technologies. Depending upon the spacecraft resource requirement needs, Chickadee can support larger payloads occupying up to a 3U volume.

Chickadee provides a push-pin interface for power and data over USB2 protocol. In its minimal configuration, the spacecraft can generate 1.2W of peak power when only one face of the cuboid containing the solar panel is illuminated. In a different configuration with four deployable solar panels and an 8 W-h battery pack, the spacecraft could generate up to 5W of continuous power. The base configuration of the spacecraft uses the 915 or 1240 MHz amateur band for radio communications. Using magnetic torquers, Chickadee can provide pointing stability of approximately 5 degrees. An arm-based microcontroller runs memory-safe code that controls each subsystem, while the subsystems work cooperatively. An arm-based computer running Linux is also available for the payload, if necessary.

In this presentation we will describe Chickadee and results of from our prototyping and testing efforts, including an upcoming suborbital flight.

Keywords—CubeSat, student payload, hands-on education, technology maturation.

I. Introduction

Since 2015, Smallsats, satellites with mass 1,200 kg or lower, have dominated the space industry using many of the usual metrics [1]. In 2024, 97% of all spacecraft launched were Smallsats that involved over 200 different operators. What is even more impressive is that the total number of launched Smallsats grew more than tenfold in less than 10 years! In each of the past three years, approximately 100 operators launched their first satellite. In terms of applications, communications and remote sensing have dominated the market, while technology development came consistently in third place. Lastly, users of hands-on education remained one of the users of small sats, with no less than 17 academic institutions have launched more than five Smallsats each, and every year new cohorts are joining their ranks.

As a post-secondary, public academic institution that is included in the Carnegie classification of institutions of higher education as Research 1 (R1: Doctoral Universities – Very high research activity), we recently initiated new undergraduate and graduate programs in Aerospace engineering and sciences. The development of Chickadee and related elements are consistent with the curriculum.

Specifically, we are developing Chickadee with several applications in mind. As an academic institution, we note that its small size and relative ease of use makes it ideal for laboratory experimentation. In that sense, it is akin to an engineering model, that is sometimes called FlatSat [2], which are useful in for early design error detection and correction. Thus, they shorten critical flight system development and validation time. Barcellos et. al. [3] undertook a comprehensive review of various FlatSats that have been and noted that since 1990 till 2023, when their paper was published, nearly 340 SmallSat publications referenced the use of FlatSats. Chickadee is different from most, if not all, of the FlastSats, because it can be used not just as a FlatSat, but as a fully capable satellite. We anticipate that the cost of the Chickadee spacecraft bus system containing all subsystems will be low enough to make it accessible to universities and possibly high schools. Its smallest configuration can support a payload occupying approximately 0.5U volume. Furthermore, it can support the addition of conventional CubeSats of up to 3U format.

An equally important objective of Chickadee is its suitability of technology maturation. It was developed with space startup community in mind. We believe that the 0.5U payload volume of the smallest Chickadee model should be adequate for many of the technologies that would benefit from operation in Low

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Earth Orbit (LEO), thus maturing them to a Technology Readiness Level (TRL) of 8 or greater.

Finally, the highly modular and reusable architecture of Chickadee along with the use of a standard payload interface makes it extensible and expandable to different formats. Each subsystem includes a microcontroller and makes extensive use of watchdogs in its flight software. We believe that this approach should shorten the schedule necessary for the preflight Assembly, Integration and Test (AIT) activities.

II. Chickadee

A. *Why create another nanosatellite format?*

In 2016, UMass Lowell was awarded a CubeSat mission by the NASA Undergraduate Student Instrumentation Program (USIP). A team of undergraduate students developed a complete 3U CubeSat mission called, SPACE HAUC (Science Program Around Communications Engineering with High-Achieving Undergraduate Cadres), whose payload was a 16-element X-band phased array. It launched in August, 2021 aboard a SpaceX Dragon [4] and was carried to the International Space Station (ISS). From the ISS, SPACE HAUC was deployed by a NanoRacks CubeSat Deployer (NRCSD) [5]. During the pre-flight integration tests, we discover an unused space in the deployer (Fig. 1 and Fig. 2).

Upon discovering the unused volume during our AIT activities, we also found out that that the Dove satellites used in the Planetscope constellation [7], uses this volume, as shown in Fig. 3. Dove, and other satellites have used the available extra volume as a 3U+ satellite. We wanted to investigate a) if a stand-alone satellite format could be developed that utilizes the extra volume and, b) the type of applications, such a satellite could be best suited. This led to the Chickadee design.

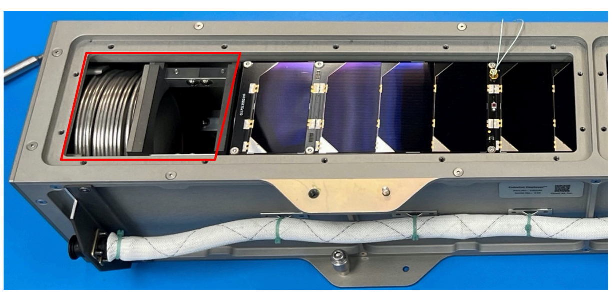

Fig. 1. SPACE HAUC satellite in the 6U Nanoracks deployer with another 3U satellite occupied in a 3U volume on the right (not shown). The red highlighted area shown on the left is considered extra volume available (see Fig. 2) consisting of apprxomately a 0.6 U cuboid and a short cylinder with approximately a 0.3 U volume (sometimes known as “Tuna Can”). Chickadee was designed to utilize this extra volume.

B. *Design Requirements*

We recognized that given the Size, Weight and Power (SWAP) restrictions, Chickadee would have some limitations. Nonetheless, a review of the key requirements and rationale we imposed on our design listed below will show that the system will have ready applications in education, technology validation as well as student projects and other uses.

1. Since many 1U CubeSats, allow up to 0.5 U volume for the payload, the design must ensure that such a volume is available in the basic version of the design.
2. As CubeSats come in many formats, we require that Chickadee accommodates up to additional 3U formats.
3. Most, if not all, spacecraft bust functions shall be incorporated in the short cylinder (the Tuna Can).
4. At a minimum, the spacecraft bus must include batteries to support initial contact with the ground station and some initialization functions.
5. Four sides of the Cuboid shall be available for solar panels.
6. The design shall also include the possibility of deploying four solar panels, once in orbit.
7. The spacecraft bus shall have UHF communication capability.
8. The spacecraft (and the payload) must be able to meet the launch loads for CubeSat dispensers (Deployers) and able to operate in LEO environment.

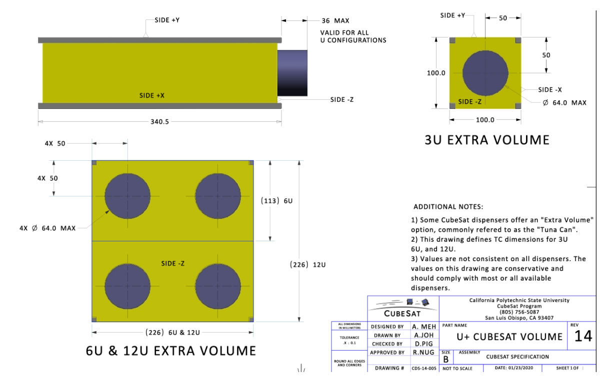

Fig. 2. CubeSat Design Specification (1U – 12U) REV 14.1, CP-CDS-R14.1. Note the details describing the available extra volume. [Online] Available: https://static1.squarespace.com/static/5418c831e4b0fa4ecac1bacd/t/62193b7fc9e72e0053f00910/1645820809779/CDS+REV14_1+2022-02-09.pdf.

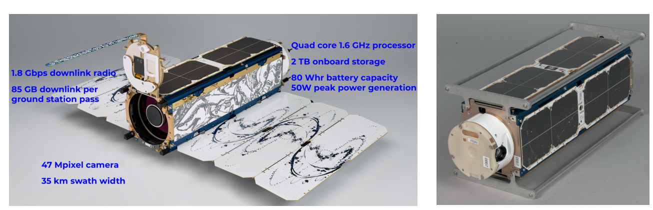

Fig. 3. Example of the Planet’s Dove satellite, which nominally is in a 3U CubeSat configuration, and utilizes the extra volume shown in Fig. 2. Photographs showing two different views of a Dove satellite. [Online] Available Left: https://www.planet.com/pulse/b14-the-cubesat-with-one-of-the-worlds-fastest-satellite-radios/. Right: https://airandspace.si.edu/collection-objects/dove-satellite/nasm_A20170023000.

III. Design approach

The Chickadee spacecraft bus design requirements are met using a modular system of four printed circuit (PC) boards, each having a specific function – Electrical Power System (EPS), Communication (COM), Attitude Determination and Control System (ADCS) and Payload Processing Unit (PPU). Each board operates autonomously and cooperate over a multi-master Controller Area Network (CAN) Bus.

The baseline version of Chickadee, shown in Fig.4, accommodates the payload in the 0.6 U cuboid. It is also designed to add a standard 3U CubeSat. Functions that require additional features can be incorporated by expanding the four-board stack. With the exception of the PPU, each of the other boards carries a microcontroller running the same base software. The inclusion of sensors and watchdogs are used to support Rust, a type-safe, memory-safe, compile-time memory managed language [8, 9] to develop software. Additional sensors and watchdogs are used to further improve on the stability of the subsystems.

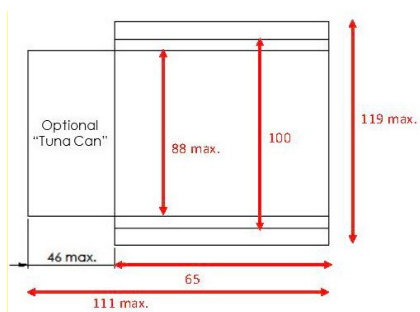

Fig. 4. Mechanical constraints of the baseline Chickadee satellite. All spapecraft bus functions are met using four hexagonal PC board and housed in the section labeled as Tuna Can. The entire system fits within the section shown with the red outlined box in Fig. 1.

As a mechanical fit check exercise, we have performed an accommodation study of the four electronics boards. Fig. 5 shows the design of four hexagonal boards performing key functions of the spacecraft bus can be incorporated in a modular fashion within the Tuna Can volume.

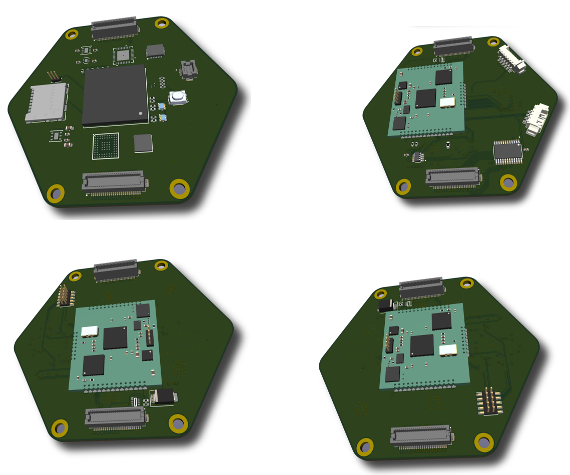

Fig. 5. Schematic diagrams of the four boards with the top left representing the PPU, top right the ACS, bottom left EPS and bottom right COM.

A 3-D printed version of the Tuna Can and the payload section was fabricated to continue the mechanical dimensional studies (Fig. 6). It also included four spring loaded wings that could carry solar cells and provide an estimated total continuous power of 5W. This exercise demonstrated that the design has 0.5U to accommodate, sufficient room for most common 1U CubeSat payloads.

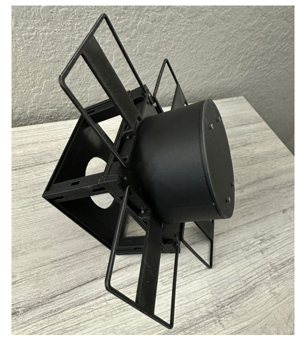

Fig. 6. A photograph showing the first implementation of Chickadee mechanical housing with four deployable wings that can carry solar cells to support its necessary functions.

IV. Current status

We are presently maturing the mechanical and electrical designs of the subsystems. A version of Chickadee containing only the attitude determination system and a special-purpose PPU and two optical imagers fitting within the 0.5U is being built. It will undergo all preflight environmental tests at UMass Lowell in summer of 2025, followed by a suborbital flight in Fall.

Acknowledgment

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