A Modular Hardware and Software Architecture for a Student-Designed BioCubeSat Prototype using Autonomous Operations

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Abstract

BAMMsat-on-BEXUS (BoB) is a student-led project working to design, manufacture, and fly a CubeSat-compatible payload on a stratospheric balloon. **BAMMsat** (Biology, Astrobiology, Medicine, and Materials Science on satellite) is a modular CubeSat-format laboratory termed a **bioCubeSat**. The project follows a typical yet streamlined space mission framework, therefore we prioritise simple yet robust and cost-effective solutions.

Objectives

- To demonstrate core bioCubeSat technology, establishing the capability to perform biological experiments in space.
- Validate flight operations, with a particular focus on autonomous operations for biological experiments.
- Increase TRL for future bioCubeSat spaceflight.
- Eventually enable better and cheaper research in space environments.

BioCubeSat Heritage

The concept of biological experiments on CubeSats has been established in LEO by NASA and a private company, SpacePharma. To date, seven bioCubeSats have successfully launched into orbit. While the volume and mass restrictions in CubeSats are challenging, the success of these systems is proven and de-risks the basic concept of bioCubeSats.

Timeline

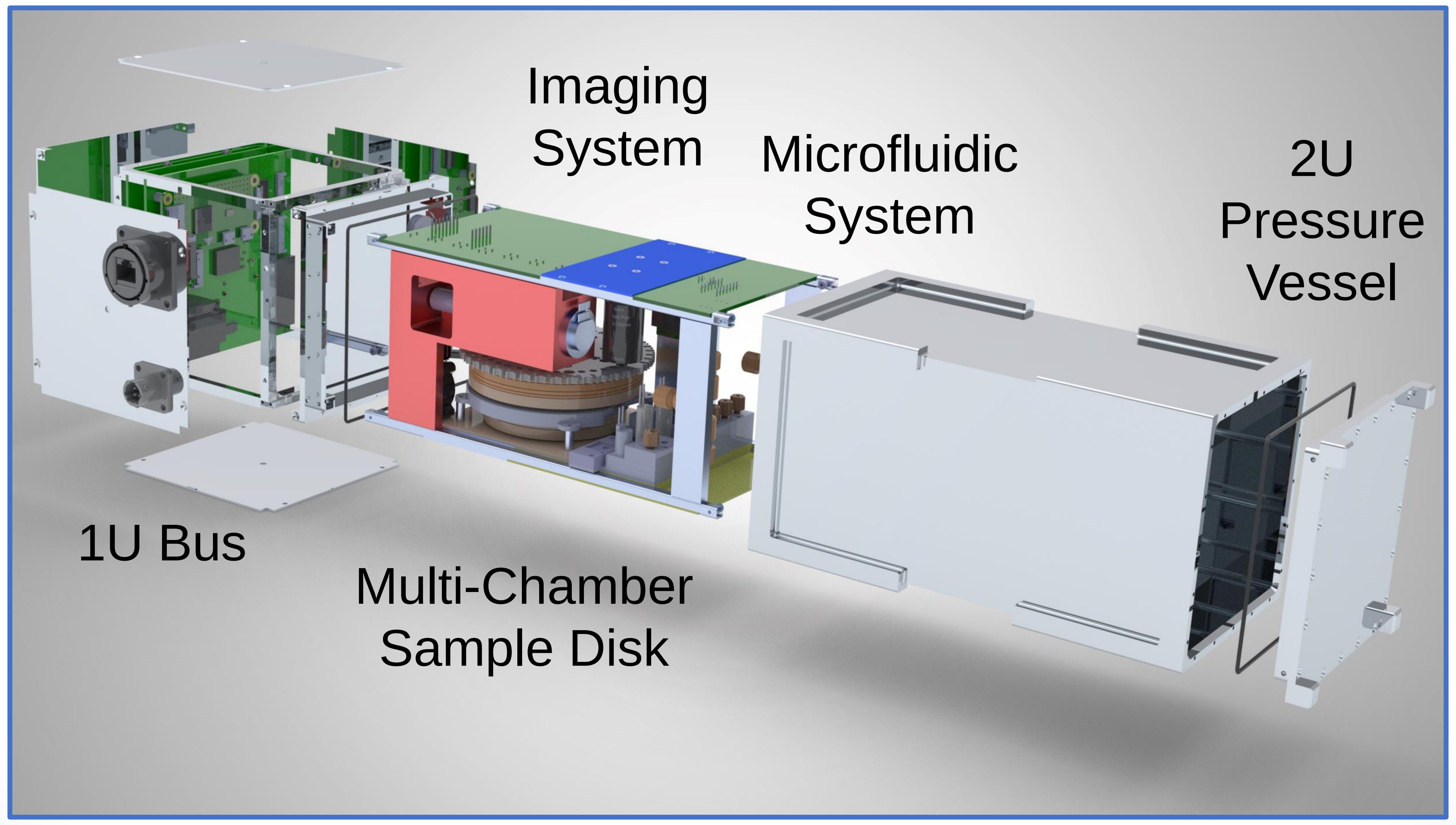
1. GeneSat – 2006, NASA
2. PharmaSat – 2009, NASA
3. O/OREOS – 2010, NASA
4. SporeSat – 2014, NASA
5. Dido-2 – 2017, SpacePharma
6. EcAMSat – 2017, NASA
7. Dido-3 – 2020, SpacePharma
8. BioSentinel – NET 2021, NASA, Targeting beyond LEO

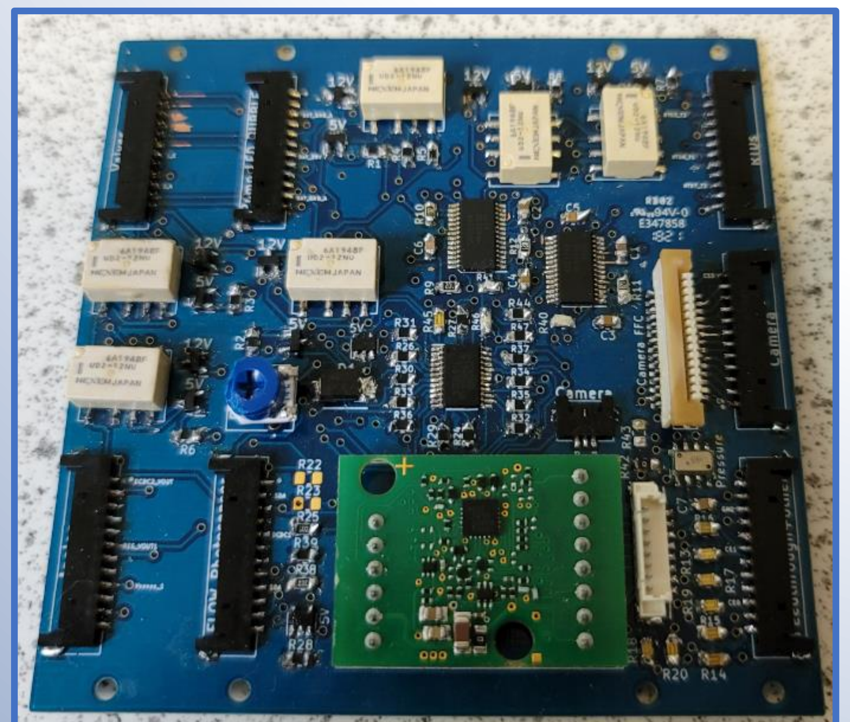
? **BAMMsat** – TBD

System Architecture

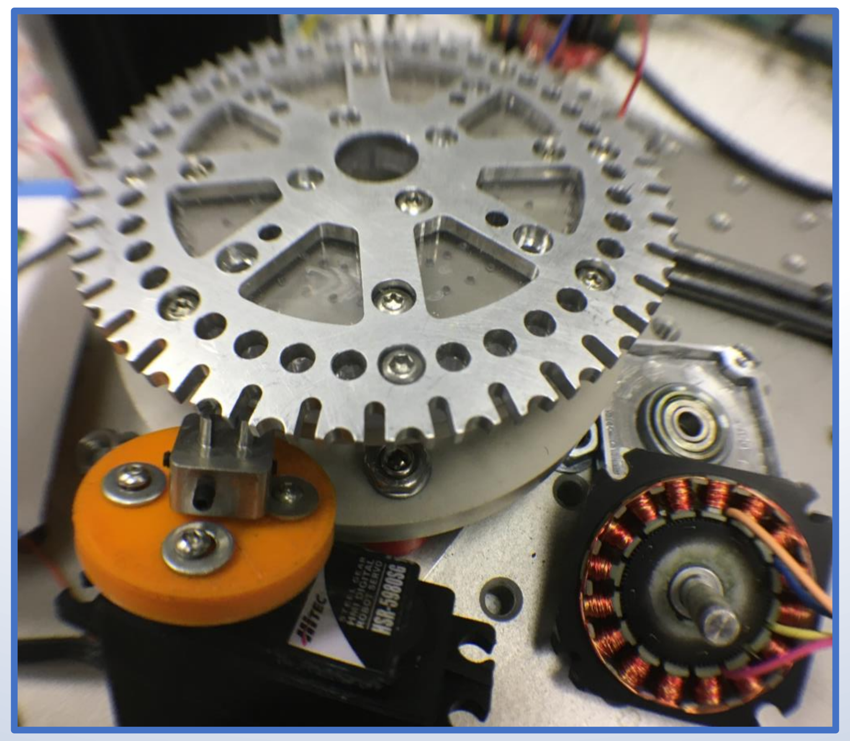
The architecture of the BoB bioCubeSat can be summarised in five major subsystems:

1. The **1U Bus** containing the Command and Data Handling system and electrical interfaces to the BEXUS gondola.
2. The **Multi-Chamber Sample Disk** system which contains the motor to provide rotation to the sample disk and rotary valve, enabling discrete sample chamber access.
3. The **Imaging System** which can take pictures of the biological specimen by means of a CSI-2 interfaced Raspberry Pi camera and a miniaturized optical lens system.
4. The **Microfluidic System** which comprises a fluidic valve manifold, a pump, and a suite of fluidic pressure, flow rate, and bubble sensors.
5. The **Thermal Control System** utilizing three-wire resistance temperature detectors and coil and film heaters in the 2U pressure vessel, maintaining environmental control for the biological samples.

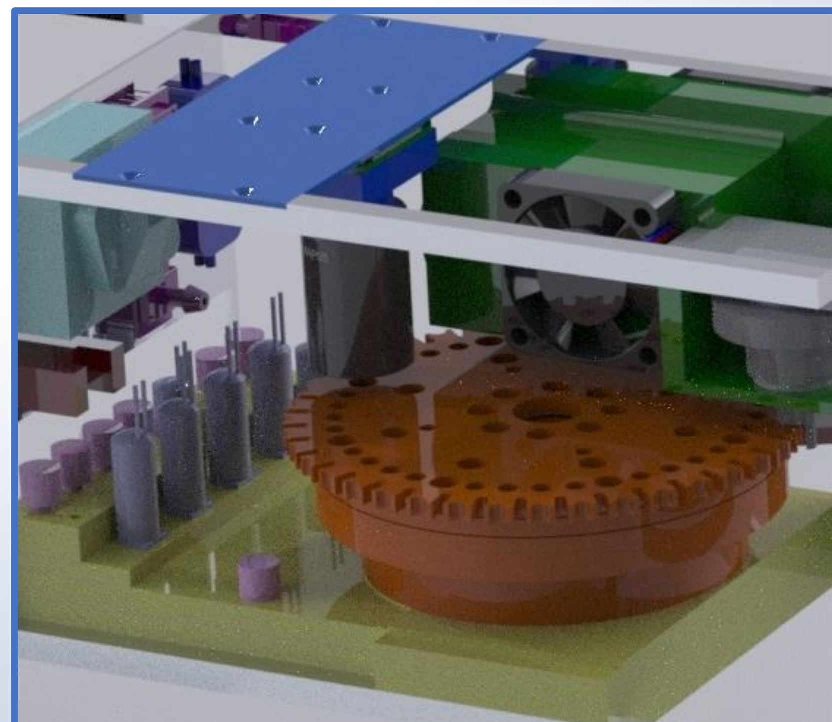




One of five bespoke PCBs



MCSD assembly

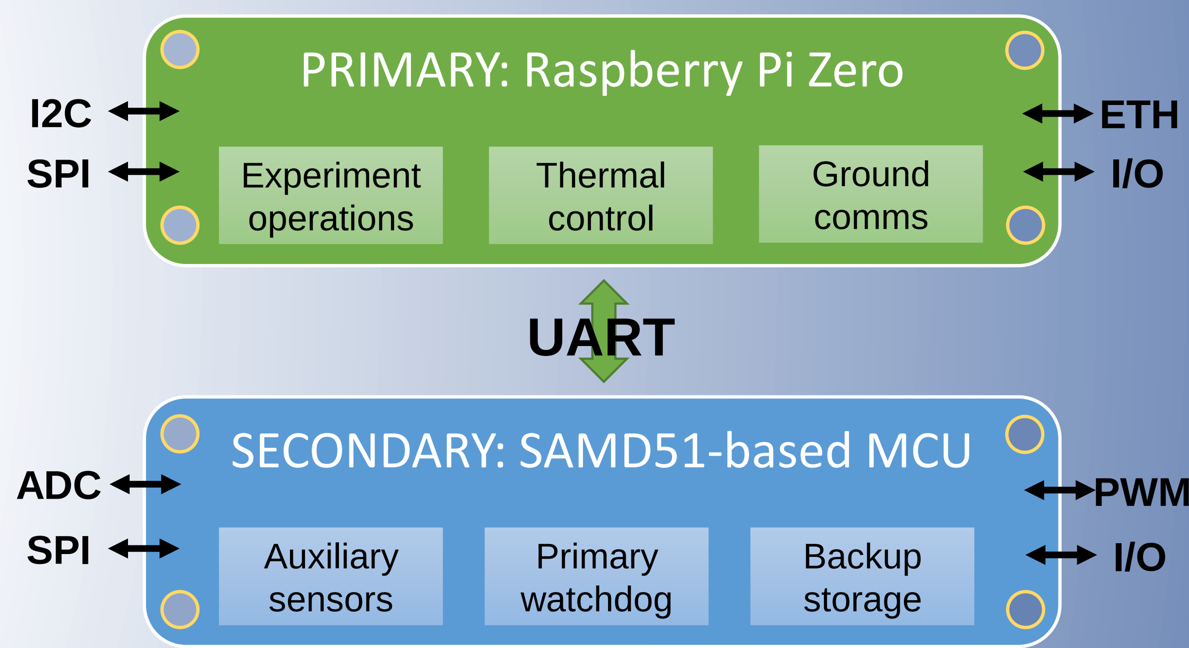


Experimentation area

www.bammsat.com

Computing

The design for BoB required a mixture of robust simplicity and a capability to enable prototyping of complex autonomous operations with a limited development timeline and budget. The payload contains two off-the-shelf flight computers, integrated with bespoke PCBs and running a combination of open-source and custom software in Python and C++.



Operations

For the initial BoB test flight, a fully autonomous experiment sequence is planned, with the aim to validate the biological operations. A combination of open-source and bespoke software is used for mission control. Ultimately, the BAMMsat system should be used by the scientific community to perform a wide range of experiments.

Capabilities include:

- Hosting up to 32 discrete samples.
- Microscopy of individual samples.
- Individual sample perturbation with multiple fluids.
- Sample temperature regulation (± 1°C).
- Monitoring of parameters including pressure, oxygen concentration, chamber pH, etc.

Future BAMMsat payloads in orbit can readily be adapted to perform autonomous experiments tailored to the specific needs of the scientific community.