SSC14-WK-8

E. coli AntiMicrobial Satellite (EcAMSat): Science Payload System Development and Test

Travis Boone, Aaron Cohen, Matthew Chin, Tori Chinn, Charlie Friedericks, Evan Jackson, Mahmonir Keyhan, Matthew Lera, AC Matin, David Mayer, Christopher Middour, Macarena Parra, Antonio Ricco, Stevan Spremo

NASA Ames Research Center
Moffett Field, CA 94035
stevan.m.spremo@nasa.gov

June 19, 2014

Abstract

The E. coli AntiMicrobial Satellite (EcAMSat) mission will investigate space microgravity effects on the dose-dependent antibiotic response and resistance of wildtype and mutant strains of uropathogenic Escherichia coli, a bacterial pathogen responsible for urinary tract infection in humans and animals. EcAMSat is the first biological science CubeSat built by NASA in the 6U configuration, and it will feature the fifth biological CubeSat payload developed by the NASA/Ames Research Center and the fourth mission to conduct a peer-reviewed biological science experiment. Building on the hardware flight heritage of GeneSat, PharmaSat-1, and O/OREOS, EcAMSat features a fluidics payload that can create and precisely administer 4 concentrations of antibiotic solution to microwell-dwelling cultures of E. coli. It measures the time-dependent metabolic activity of the bacterial cultures, as well as their optical densities, using a dedicated 3-color LED-based absorbance monitoring system for each of the 48 microwells. We will report payload laboratory characterization results and preparation of the EcAMSat spacecraft for spaceflight in the coming year.

1 Introduction

The EcAMSat mission was started as a NASA Ames Mission of Opportunity (MoO-1), selected under the Stand Alone Missions of Opportunity (SALMON) Announcement of Opportunity (AO). The mission was designed to take advantage of off the shelf hardware with flight heritage on several previous flight projects to provide an increased value return on investment. The existing flight backup hardware for the PharmaSat mission was utilized to construct the flight unit and spares for EcAMSat, with only some small modifications to the spacecraft electronics, and an adaptation of the structural elements to adapt to the 6U spacecraft form-factor. EcAMSat is classified as Class D Prototype Payload Hardware as per NASA Procedural Requirement (NPR) 8705.4, which enabled a rapid and low cost development, owed in part to increased risk tolerance.

While EcAMSat is currently not manifested for a launch, flight hardware is complete and a launch is expected in the 2014 to 2016 timeframe. [3]

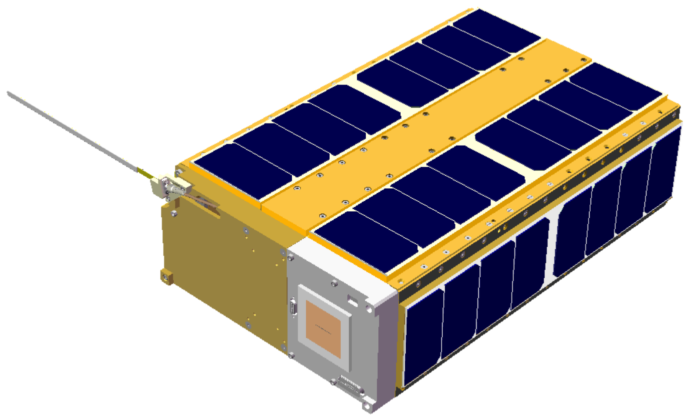

Figure 1: EcAMSat CAD model

2 The 6U Structure

NASA Ames 6U architecture shown in Figure 2 was designed around the intent to fly up to three different payloads: two 2U payloads and one 0.5U payload. The remainder of the 6U spacecraft volume is utilized with a heritage nanosat bus and a Payload Interface Board allowing the bus to accept additional inputs from extra payloads and solar panels. Future bus development could allow for increased payload volume through integration of the Payload Interface Board into the spacecraft bus. Due to budgetary constraints and limited launch access, only the EcAMSat payload was selected for this flight. The remaining volume has been utilized with ballast/balance mass and increased attitude control.

Launch availability has been reduced due to the size and lack of maturation in launch capabilities for the 6U (1x 2x 3U) form-factor. As such, only low-altitude deployments have been presented, meaning mass must be increased (for the same outer dimensions) to lengthen orbit lifetime. An increase in mass, however, comes with its own cost: an increased moment of inertia, as a result the previous attitude control system will take longer to stabilize. EcAMSat must quickly stabilize to meet micro-g requirements before starting its experiment and must remain stable to maximize radio contact duration during low-altitude disturbances. These stability objectives required precision center-of-mass measurements (to reduce disturbance torques) and an increase in attitude control (to counteract disturbance torques). Engineers sought to maximize mass and precisely locate center of mass by placing stainless steel plates in unused payload volumes. Additional hysteresis rods and permanent magnets were added to reduce post-launch stabilization duration and increase radio pointing accuracy.

EcAMSat reduced costs by creating a 6U spacecraft comprised largely of previously built, heritage 3U spacecraft hardware. The only new components and assemblies required to create EcAMSat were modified

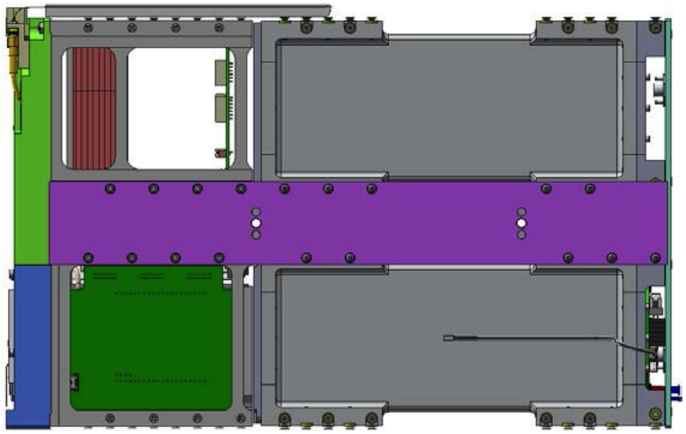

Figure 2: Top down view of structure, solar panels removed

cable assemblies (many just lengthened to accommodate the increased spacecraft dimensions), the Payload Interface Board (to increase spacecraft bus capabilities), and mechanical structure to hold what is essentially two 3U spacecraft together. This structure includes solar panel attachment panels (purple, center), auxiliary payload closeout panel (green, left end), and payload closeout panel (teal, right end). To ease assembly and integration, as well as simplify deployment pusher systems, the bus closeout panel (blue, left end) has volume to house the S-band radio antenna cable and umbilical cable connector. The aforementioned auxiliary payload closeout panel houses the beacon radio and provides a mounting location for the whip antenna.

3 Scientific Payload

The EcAMSat mission is a re-flight of the PharmaSat hardware flown in 2009. The major biological change from PharmaSat to EcAMSat was replacing yeast with E. Coli. The change in biological organism from eukaryote to bacteria allow for the testing of the antibiotic Gentamicin on wild type Uropathogenic E. coli (UPEC) and a gene knock out mutant.

To accommodate the differing biology, the fluidic system had to be altered. Fluidic cards used to house the biology and direct fluid flow were changed to have smaller filter sizes (.2 m from 1.2 m) to prevent cell escape. Temperature was changed to accommodate E. Coli from (27C to 37C) which required higher power supply. The original 3U design was converted to 6U to support the additional solar panels needed to provide more power for the heaters. Valves, plumbing and pumping phases were changed to accommodate differing experimental requirements.

For further information about the functionality of the PharmaSat payload system, there are several publications which explain the fluidics system in high detail [1, 2].

4 Software

EcAMSat was developed using a legacy codebase from the previous PharmaSat mission. The flight software consists of 3 firmware packages: Bus, Payload, and Fluidics. Each of these packages was developed in a C environment.

The Bus software provides control, monitoring, commanding and communications of Bus operations during phases of mission operations. The bus software also provides some services to the payload systems, such as data storage and communications routing.

EcAMSat contains one payload with two microcontrollers, each with their own distinct effort. The payload software effort provides control of the fight experiment, flight experiment sequencing, temperature control,

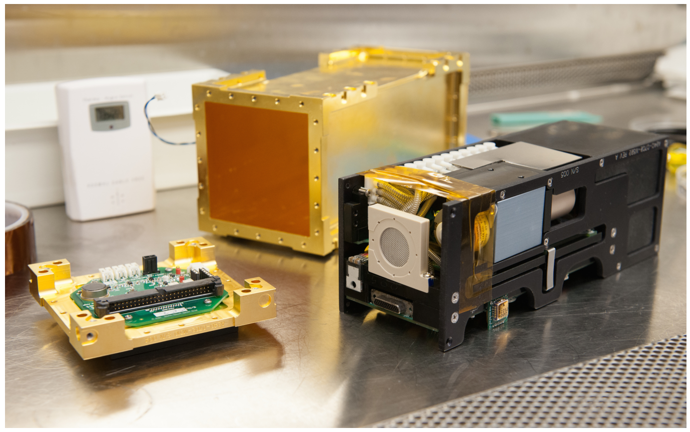

Figure 3: PharmaSat derived payload

data sampling, and data storage of the experiment during the Mission. The payload firmware package was heavily rewritten from the PharmaSat code with new experiment phases and different temperature settings.

The fluidics firmware package provides control over the pumps and valves systems. Given, the new fluidic system design, the software was completely rewritten to accommodate new flow speeds, anti-biotic mixing, bag volumes, and pump frequencies.

5 The Future of EcAMSat

At the time of writing this paper, EcAMSat is currently not manifested for launch, due to the launch availability issues discussed in Section 2. The flight unit has completed proto-qualification shock and vibration tests, along with center of gravity balancing. Once a launch is manifested, a thermal-vacuum and power management test can be conducted to assess system environmental performance in the expected orbital conditions.

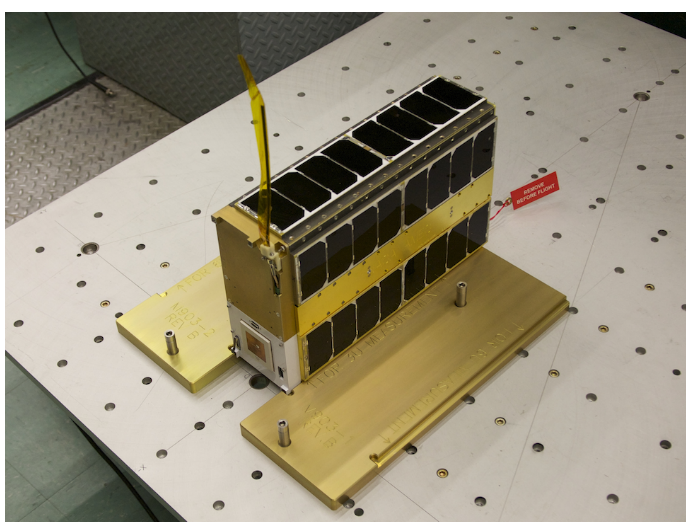

Figure 4: EcAMSat FLT-1 undergoing mass properties evaluation

References

[1] A. Ricco, M. Parra, D. Niesel, D. Ly, A. Kudlicki, M. McGinnis, and J. Hines. Results from the pharmasat nanosatellite mission: Dose dependence of growth and metabolic parameters for s. cerevisiae grown in microgravity and challenged by voriconazole. In *38th COSPAR Scientific Assembly*, volume 38, page 3418, 2010.

[2] A. J. Ricco, M. Parra, D. Niesel, M. Piccini, D. Ly, M. McGinnis, A. Kudlicki, J. W. Hines, L. Timucin, C. Beasley, et al. Pharmasat: drug dose response in microgravity from a free-flying integrated biofluidic/optical culture-and-analysis satellite. In *SPIE MOEMS-MEMS*, pages 79290T–79290T. International Society for Optics and Photonics, 2011.

[3] S. Spremo, G. Cappuccio, and D. Tomko. Nasa facts: E. coli antimicrobial satellite (ecamsat). 2013.