National Aeronautics and Space Administration

Ames

Discovery Innovations Solutions

EcAMSat Spacecraft Mission:

The Success Story of NASA's First 6U CubeSat

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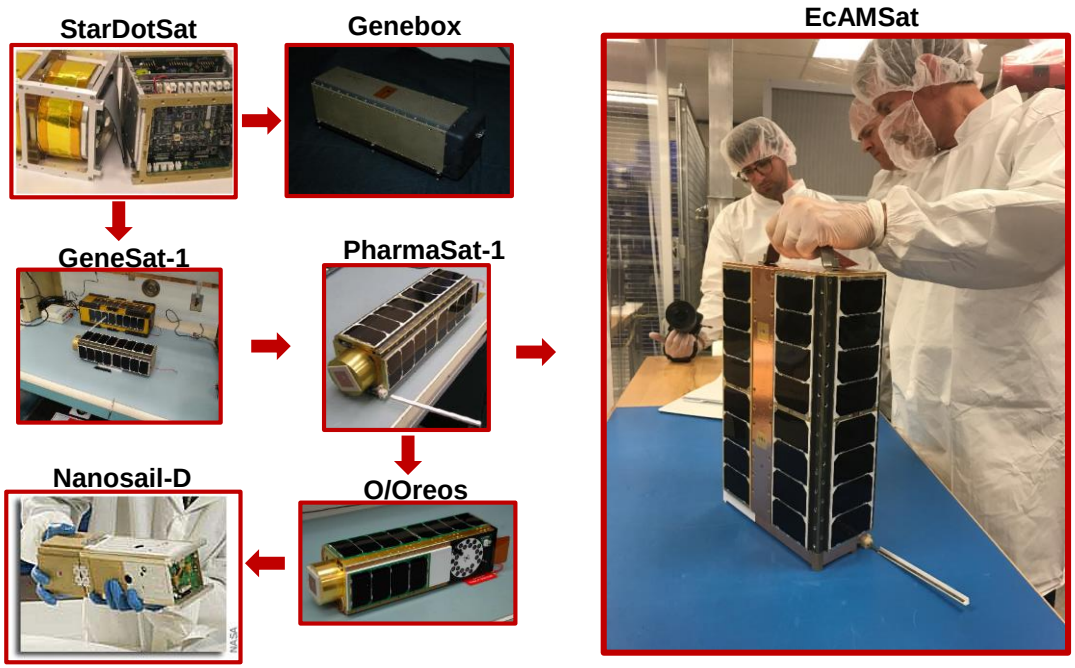
EcAMSat Project Manager

NASA ARC

BACKGROUND

NASA Ames Biological NanoSat History

- **StarDotSat Bus**
  - Developed by Stanford University
- **NASA NanoSat Bus 1.0**
  - GeneBox (2006)
  - GeneSat (2006)
    -First NASA Cubesat
  - PreSat & NanoSail-D (2008)
    -LV Failed To Reach Orbit
  - PharmaSat (2009)
  - O/OREOS (2010)
  - NanoSail-D2 (2010)
  - EcAMSat (2017) First NASA 6U
- **Core team members had extensive Small Satellite Experience**



EcAMSat History

- **Spaceflight Effects on Bacterial Antibiotic Resistance and Its Genetic Basis "AntiMicrobialSat"**
  - Originally Proposed to NASA in December 2009
- **MisST Mission of Opportunity "MoO1" Payload "PharmaSat II"**
  - Science Requirements Review (ScR) - 27 October 2010
- **Mission of Opportunity - Mo01 "AntiMicrobialSat"**
  - Phase A Review – 18 March 2011
- **EcAMSat**
  - PDR – 28 February 2013
  - CDR – 4 September 2013
  - Flight Hardware Available (FHA) Review – 5 June 2014 (Spacecraft Ready for Launch and NASA HQ requested to place in storage awaiting launch opportunity)
  - **Manifested on SpaceX FormoSat-5 – October 2014**
  - Place EcAMSat Spacecraft in storage to conserve funding "Pre-Storage Review" – 2 December 2015
  - **De-manifested from SpaceX – January 2017**
  - **Manifested on OA-8E – May 2017**
  - Mission Readiness Review – 18 October 2017
  - Nanoracks Integration October 25, 2017
  - Launch November 12, 2017
  - ISS Deployment November 20, 2017
  - Mission Outbrief – 6 March 2018

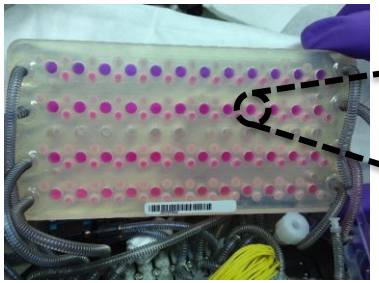
Scientific Background

EcAMSat Principal Investigator: Dr. AC Matin, Stanford University

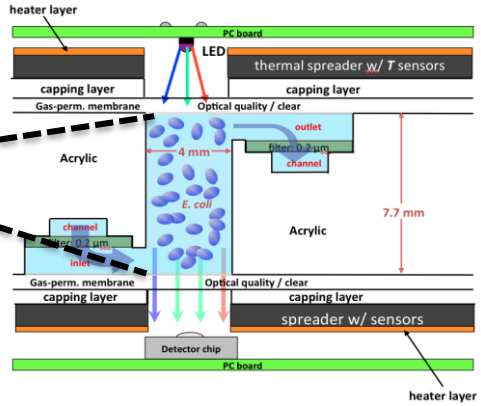
- **The EcAMSat science objective is to investigate the effect of microgravity on the resistance of the uropathogenic strain of Escherichia coli (UPEC) to an appropriate antibiotic and the role of a gene previously identified with respect to antibiotic resistance in this bacterium.**
- **Human immune response is compromised in microgravity**
- **EcAMSat looked at this problem for E. coli, (uropathogenic Escherichia coli)**
  - UPEC causes urinary tract infections
  - The antibiotic used in EcAMSat (gentamicin) is used to treat UTI's and was chosen for this experiment
- **Does E. coli gentamicin resistance change in microgravity, in wild-type strains as well as in Δ*rpoS* mutant strains?**

- **Alternating wells loaded with WT and Δ*rpoS* mutant strains**
- **Each bank receives a different antibiotic dose (control, low, medium, high)**

48 Well Fluidic Card



Cross section of 1 well



Source: Dr. AC Matin, EcAMSat Pre-Storage Review 2015

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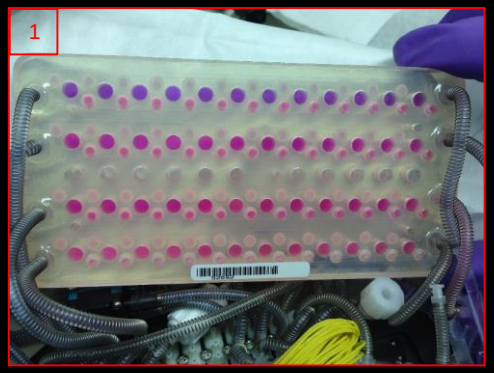
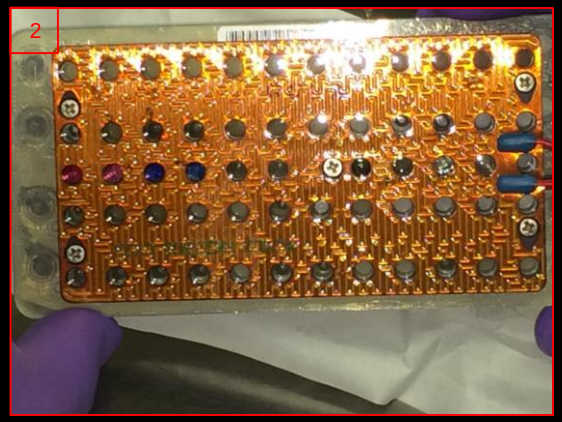
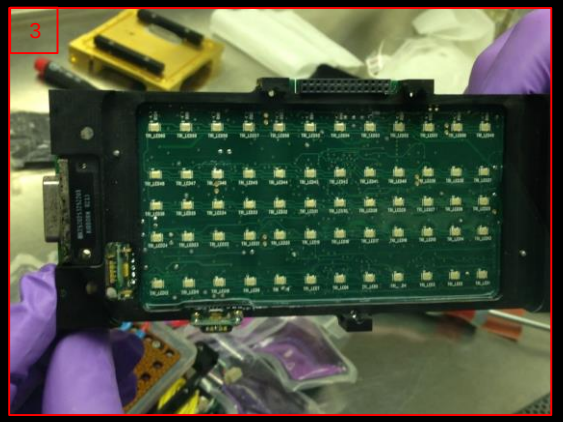
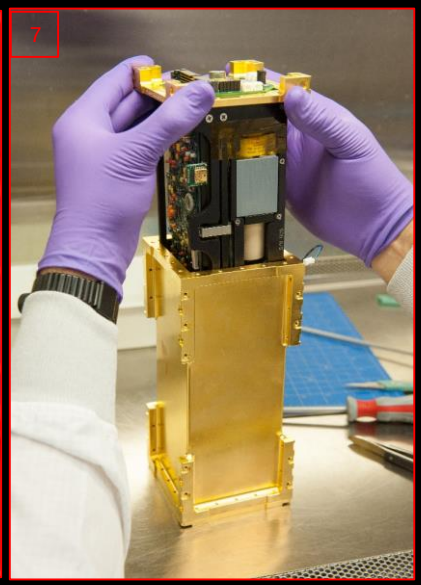


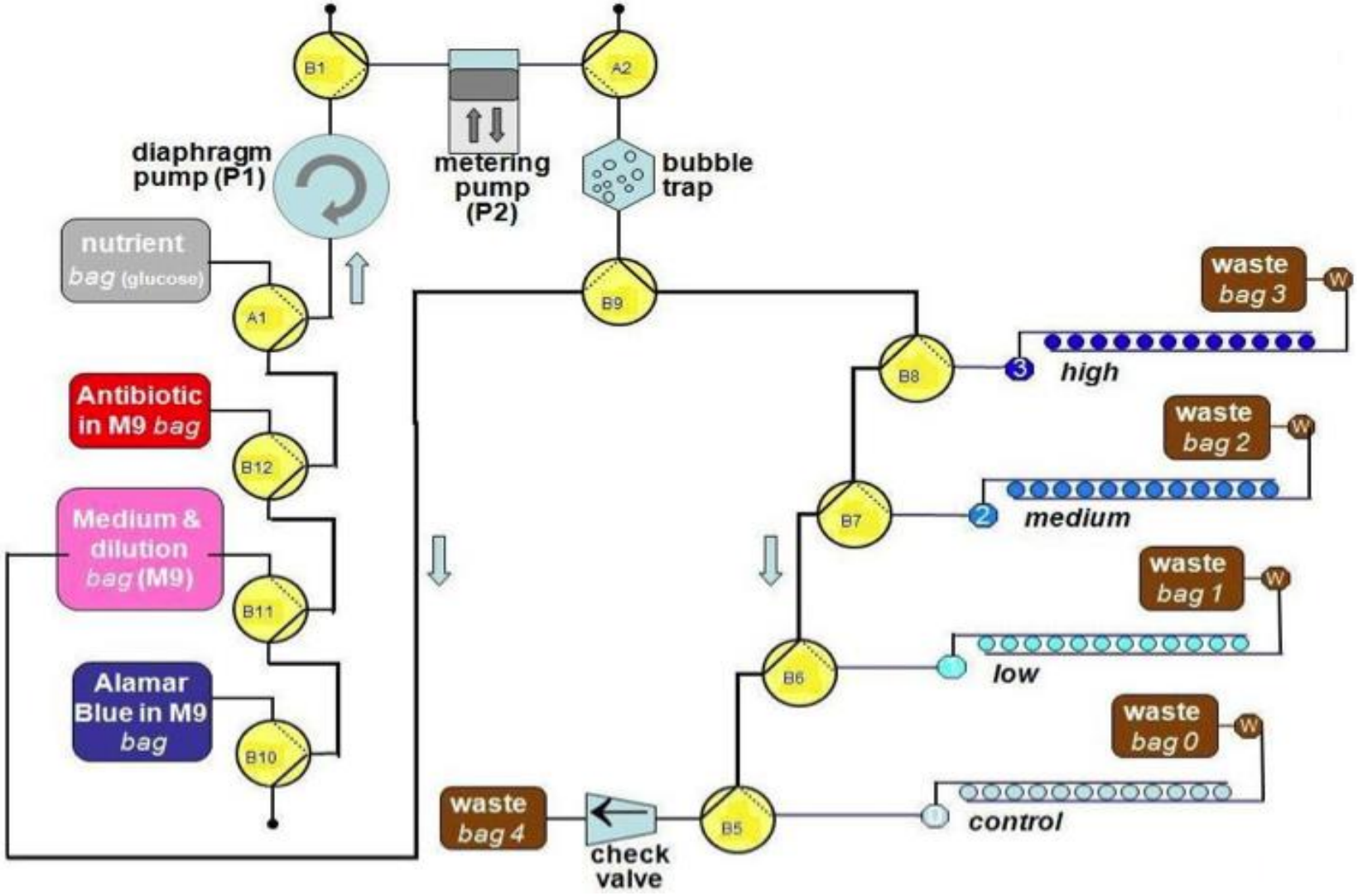




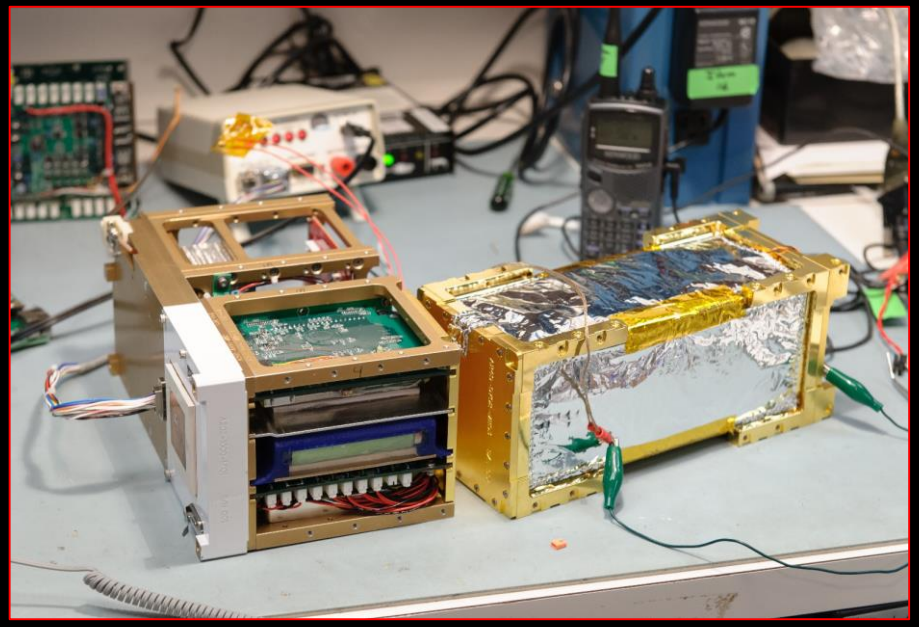


NASA Facebook Live Payload Explanation:
https://www.facebook.com/nasaames/videos/10154737475201394/

EcAMSat PayloadConfiguration

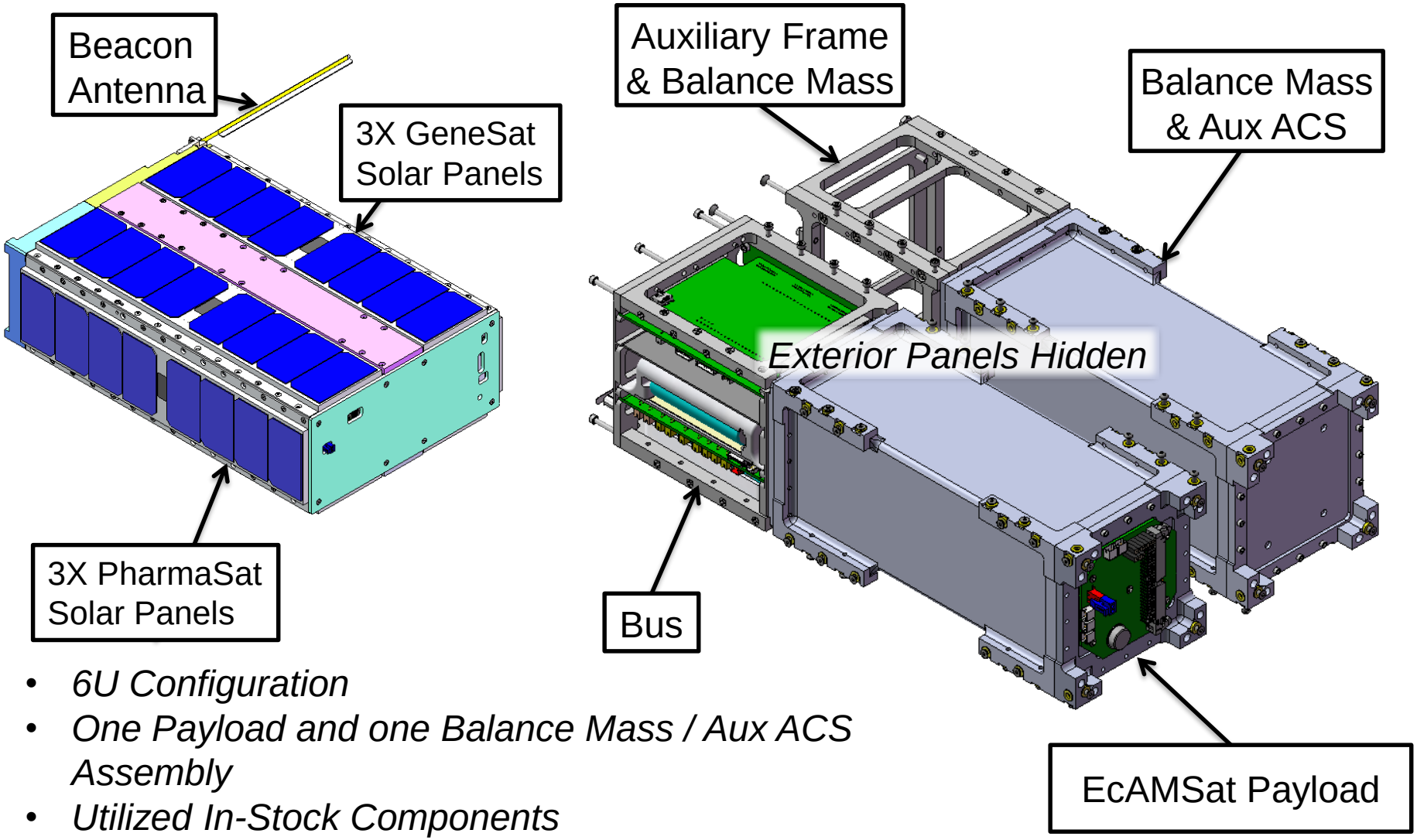


EcAMSat Spacecraft Flight Build



SYSTEM OVERVIEW

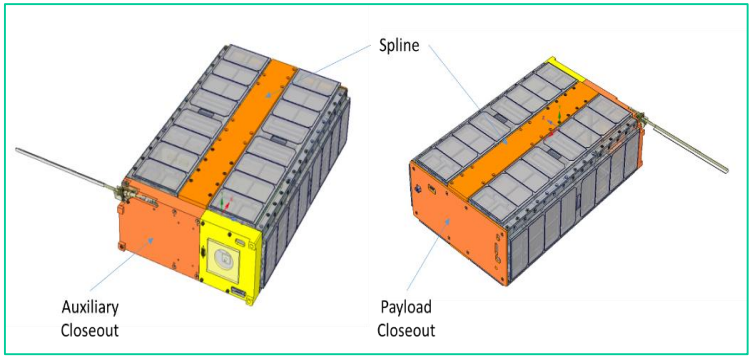
Mechanical Layout



- *6U Configuration*
- *One Payload and one Balance Mass / Aux ACS Assembly*
- *Utilized In-Stock Components*
- *Combination of GeneSat and PharmaSat Solar Panels*

Electrical & Thermal Modifications

- **NanoSat 1.0 Bus modified to support additional solar panels & payloads**
  - Solar Panel area increased to accommodate higher payload temperature set point
  - Payload modifications made when EcAMSat branched into its own mission
- **Thermal system rework during switch from low-inclination (ISS) orbit to SSO**
  - Copper tape was added to Alodine surfaces to increase spacecraft steady-state temperature
  - Added to Auxiliary closeout panel, solar-panel splines & payload closeout panel
  - Dropped predicted average heater duty cycle from 90% to 60%
  - Analysis Data Flow
    - Orbital Dynamics - 6DOF De-tumble (MATLAB)
    - STK Solar Angle Vectors
    - Thermal Desktop Modeling
    - MATLAB power simulation



Orange indicates the addition of copper surfaces

LAUNCH & DEPLOYMENT

Launch Vehicle Opportunity Summary

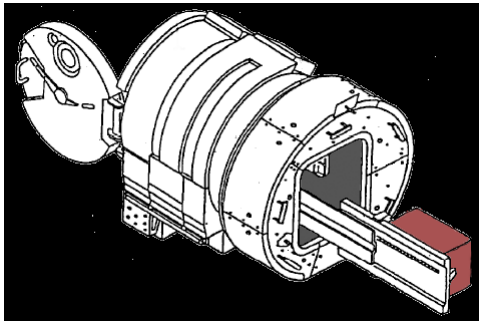
- **SpaceX FormoSat-5**
  - Launch vehicle experienced 6 schedule slips
  - Final schedule slip resulted in all secondary payloads demanifesting
- **Orbital OA-8E**
  - Manifest to flight occurred in unprecedented <6 month timeframe for this class of biological satellite
  - Modifications made to spacecraft for ISS safety purposes (changed out clock batteries to approved chemistry)
  - PSRP process was conducted with a expedited schedule

Launch & Deployment

- **EcAMSat was deployed via the NanoRacks Doublewide Deployer (NRDD) with rail modifications.**
  - Existing “tab-rail” 6U deployer modified to support NASA 6U standard.
  - NRDD configuration did not exist 4 months prior to launch
  - Rapid build, fit checks and environmental testing was conducted on a flight unit.
- **EcAMSat was deployed via the NanoRacks Doublewide Deployer (NRDD) with rail modifications.**

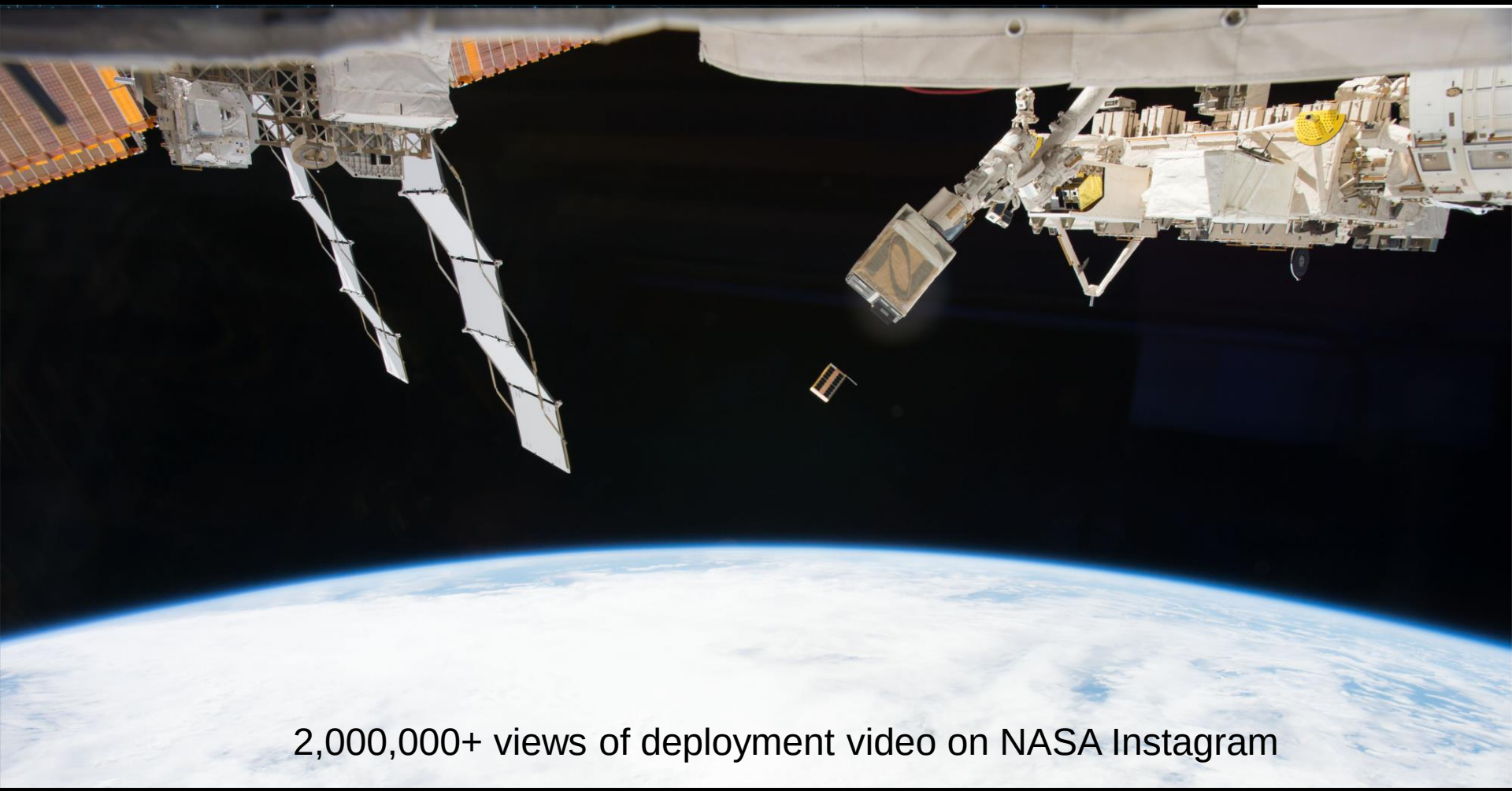
NRDD in Soft Stowage Bag

NRDD



JEM Airlock Slide Table

Orbital OA-8E ISS Resupply Launch



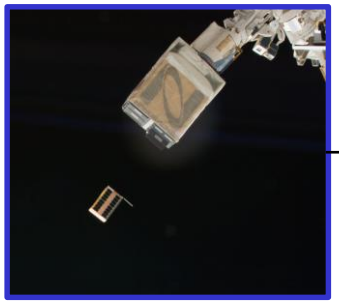
2,000,000+ views of deployment video on NASA Instagram

ECAMSAT FLIGHT

Mission Concept of Operations

Nominal 252.5 hours between deployment and end of experiment

Commissioning



Detumble & first contact

96 h

Experiment Auto-start

Experiment

Recirculate

4.5 h

Administer Nutrient

47.3 h

Dose Antibiotic

48.7 h

Alamar Blue Dye

56 h

Extended Ops

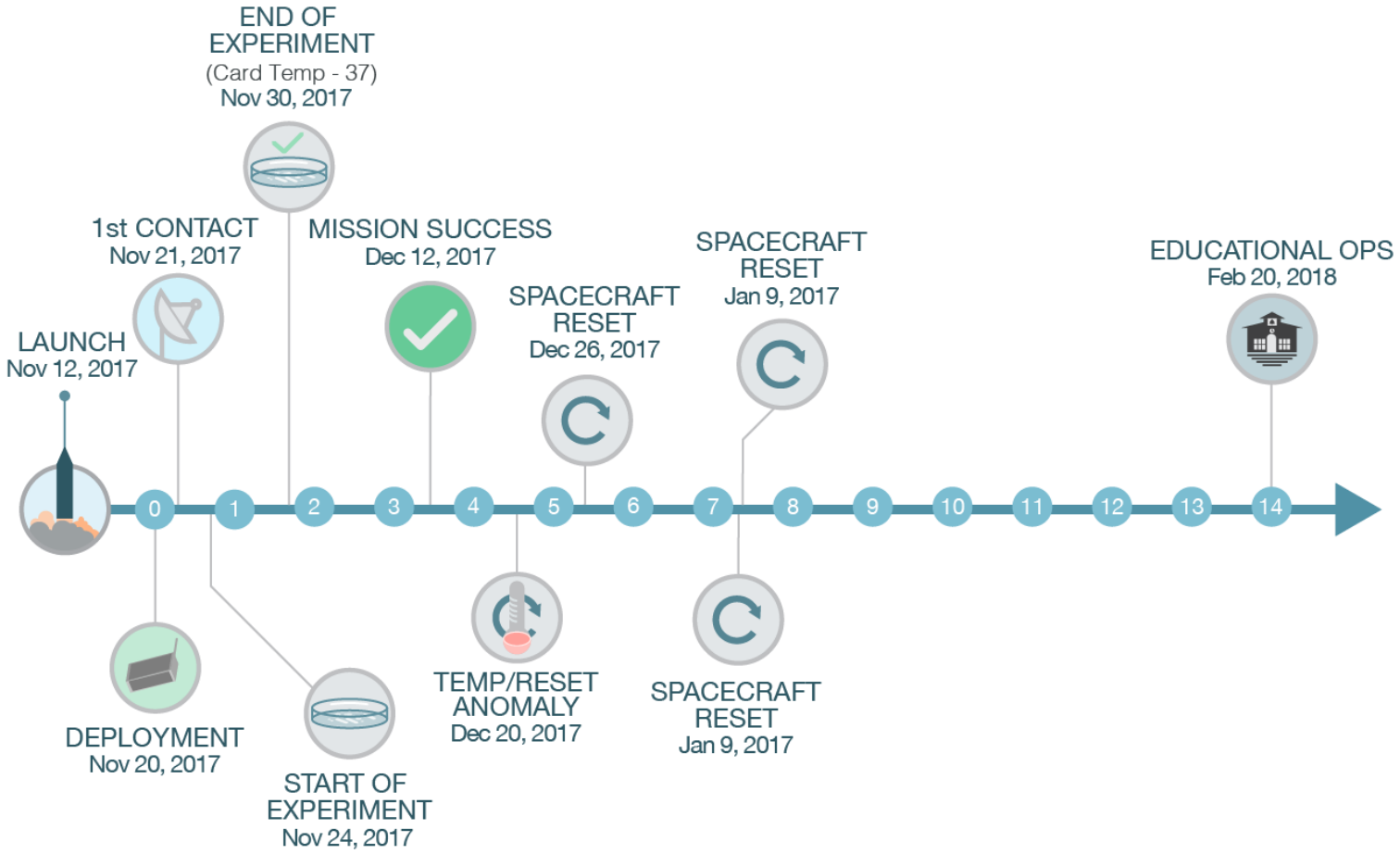
Data Downlink Phase

< 30 days

Educational Operations

Until June 28, 2018

Actual Mission Timeline

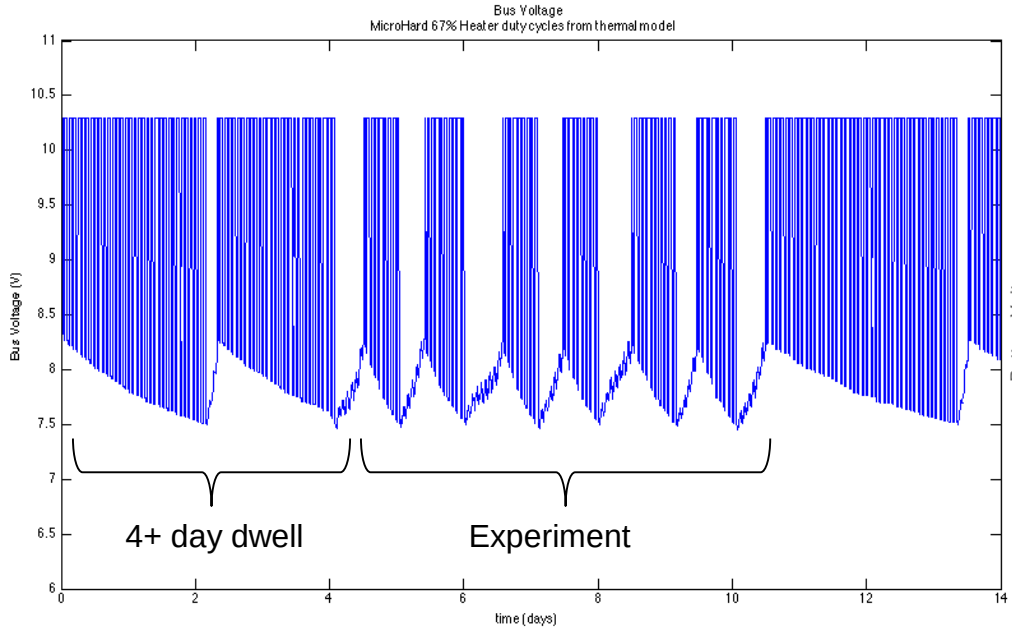


Source: EcAMSat Mission Outbrief, Kitts/Rasay

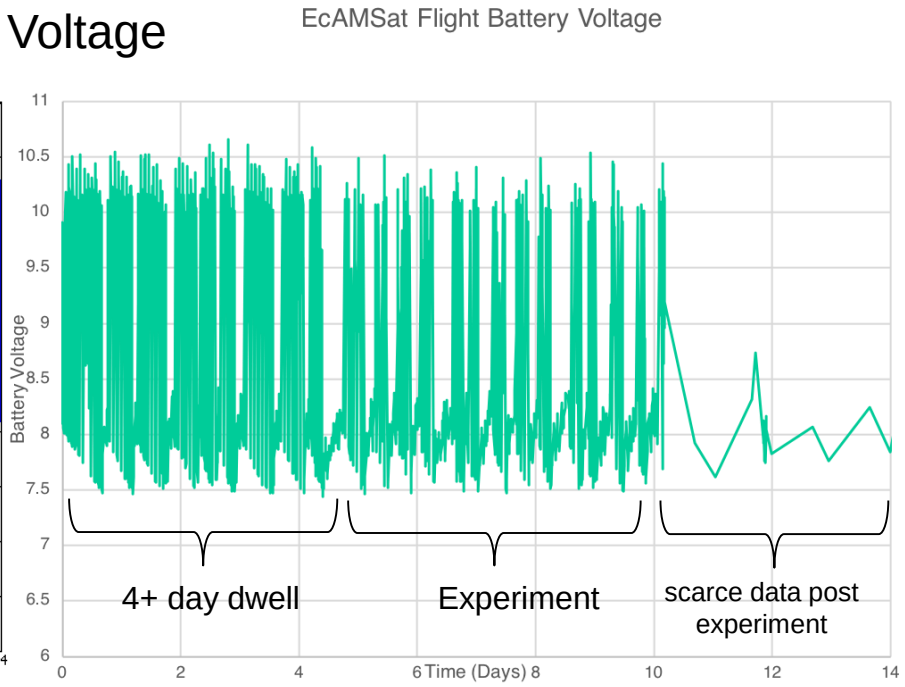
PRELIMINARY FLIGHT RESULTS

Power Consumption

Battery Voltage



Simulated



Actual

Communications Performance

- **NTIA licensed COTS radios on ISM and Amateur frequencies**

S-Band (MHX-2420)

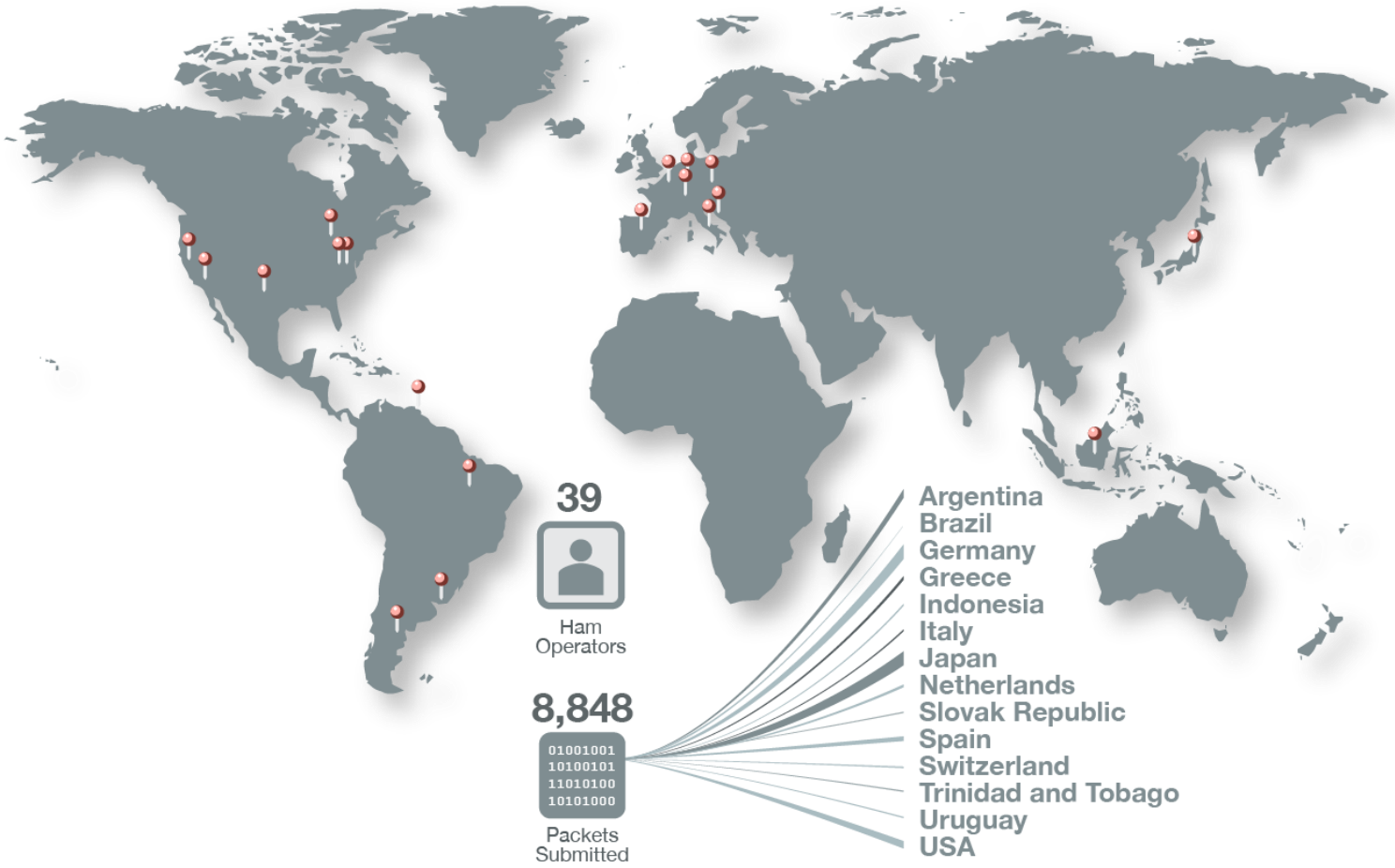
- **978 KB data downloaded**
  - Bus Health Data – 274 KB
  - Payload Data – 509 KB
  - Log File – 76 KB
- **10,373 commands sent with a 23% response rate**
- **Success criteria exceeded by 300%**

UHF Beacon (Stensat)

- **Education & Public Outreach**
  - 437.100 MHz AX.25 packets
- **39 Ham Radio operators from 14 different countries**
- **8,848 beacon packets submitted**

Source: EcAMSat Mission Outbrief

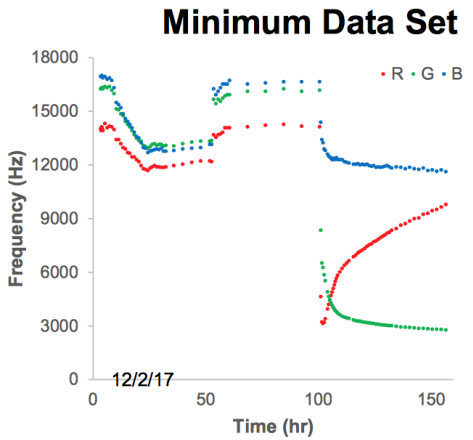
EPO - Beacon Submissions

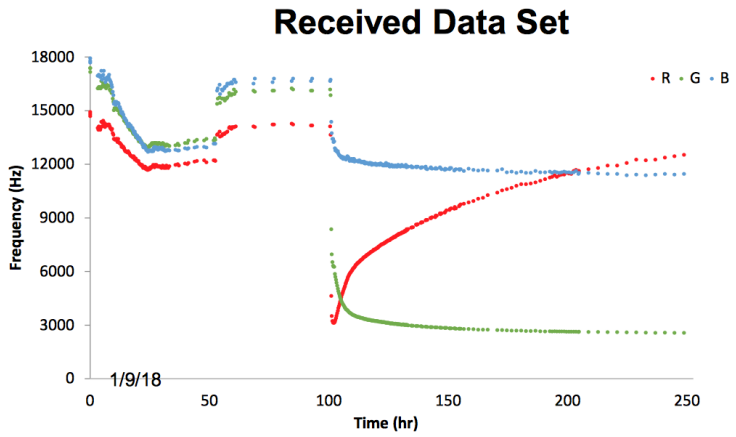


Source: EcAMSat Mission Outbrief, Kitts/Rasay

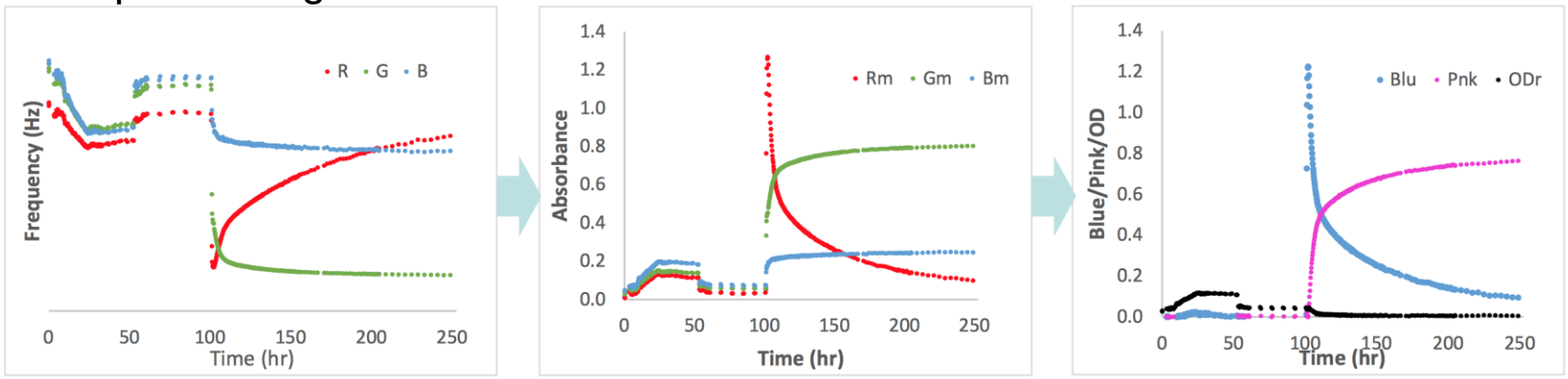
Scientific Data

- Received all required scientific data pages
- Downloaded additional data to exceed mission data collection requirements





Data processing:



Source: EcAMSat Mission Outbrief

References

https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1633&context=smallsat

EcAMSat Mission Outbrief

EcAMSat Pre-Storage Review 2015