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EcAMSat Spacecraft Mission: The Success Story of NASA's First 6U CubeSat

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NASA ARC



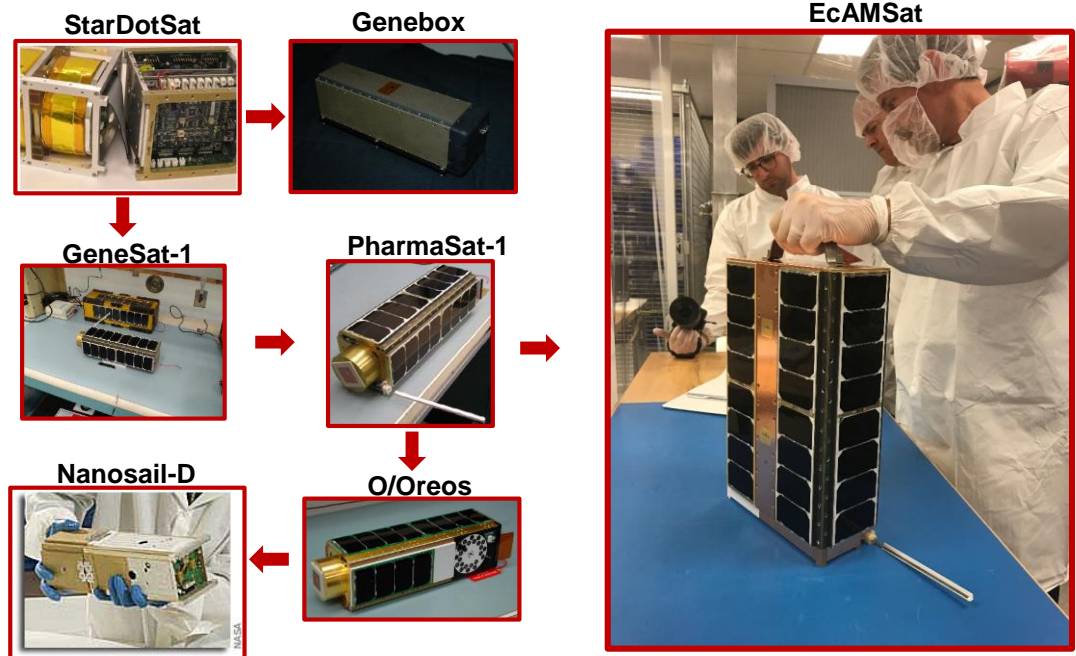
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BACKGROUND

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**





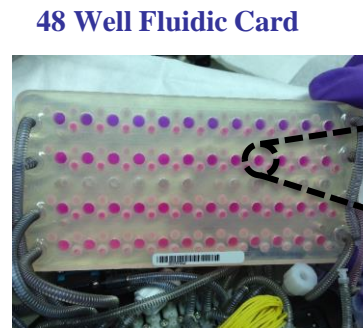
EcAMSat History

- **Spaceflight Effects on Bacterial Antibiotic Resistance and Its Genetic Basis “AntiMicrobialSat”**
 - Originally Proposed to NASA in December 2009
- **MisST Mission of Opportunity “Mo01” 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

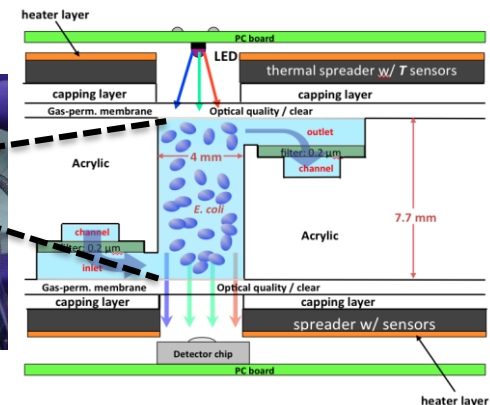
Scientific Background

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



Cross section of 1 well

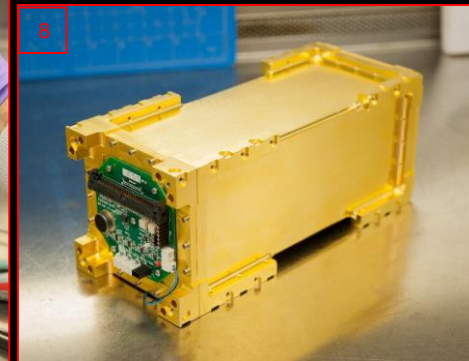
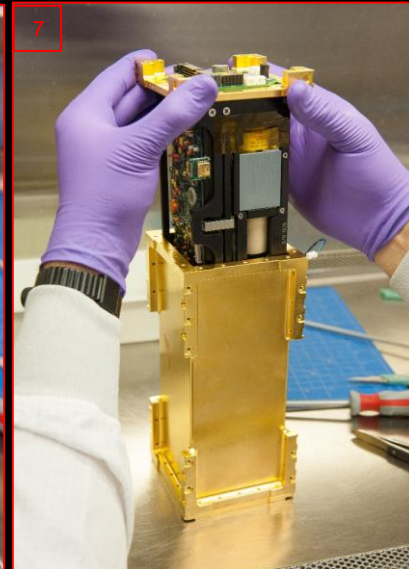
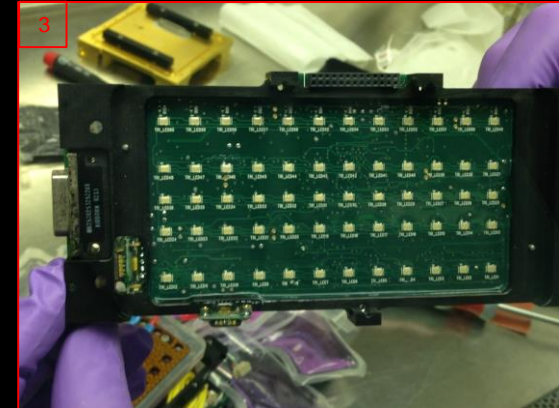
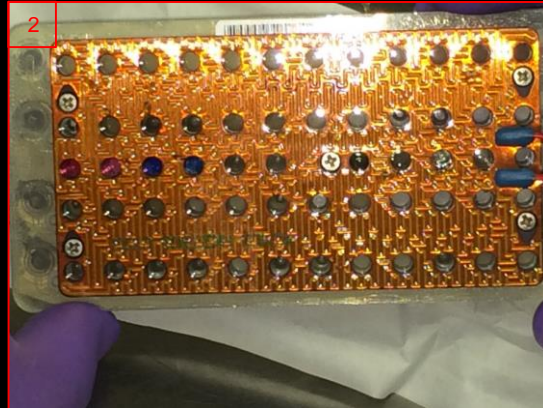
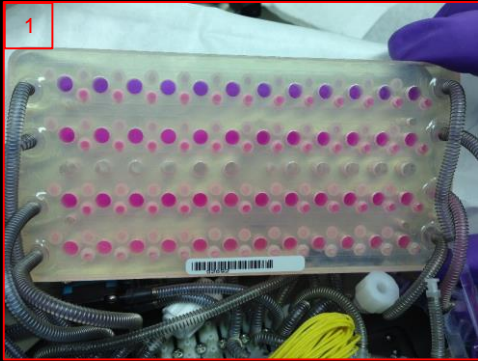




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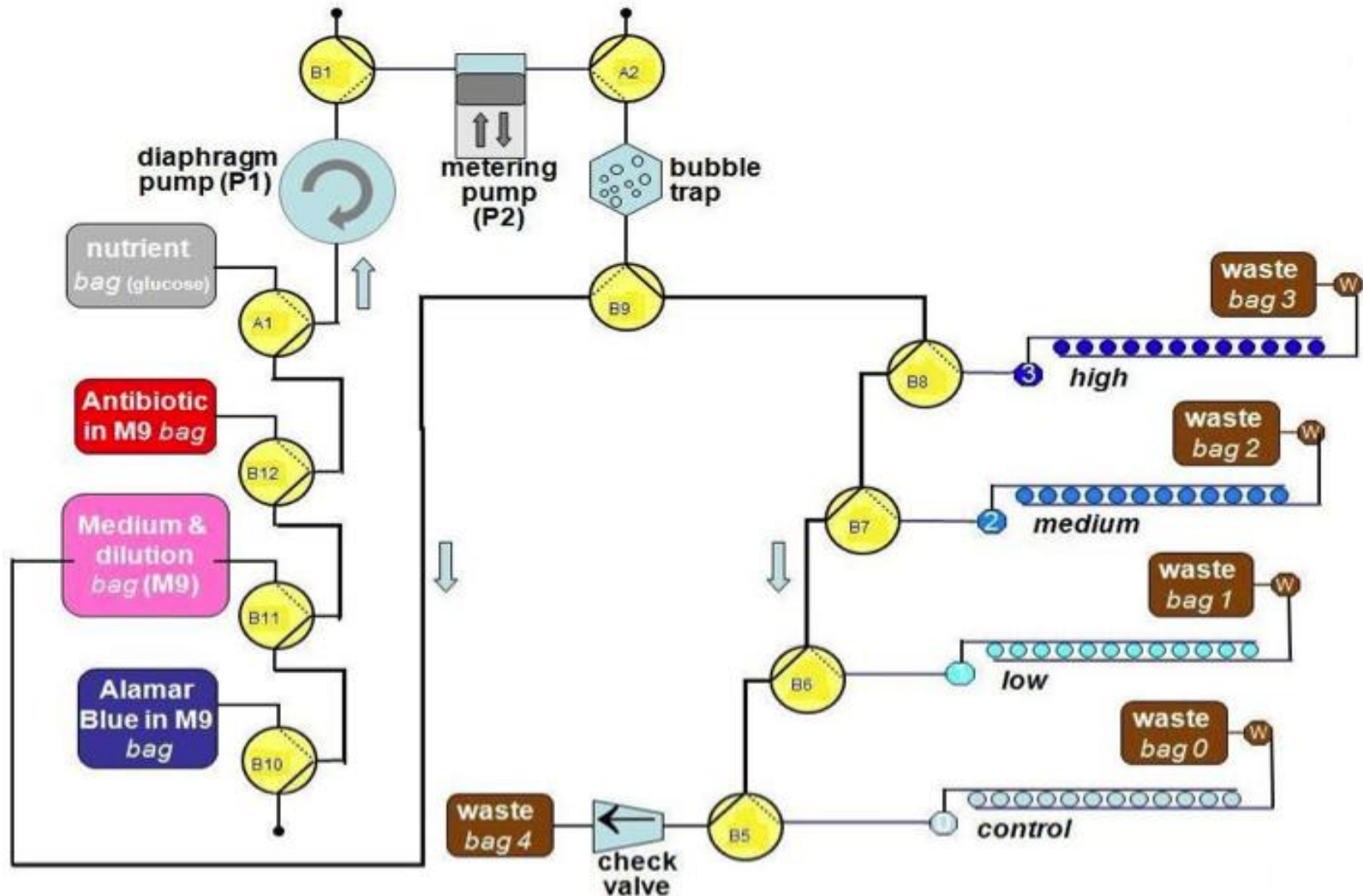
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NASA Facebook Live Payload Explanation:
<https://www.facebook.com/nasaames/videos/10154737475201394/>



EcAMSat Payload Configuration





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EcAMSat Spacecraft Flight Build



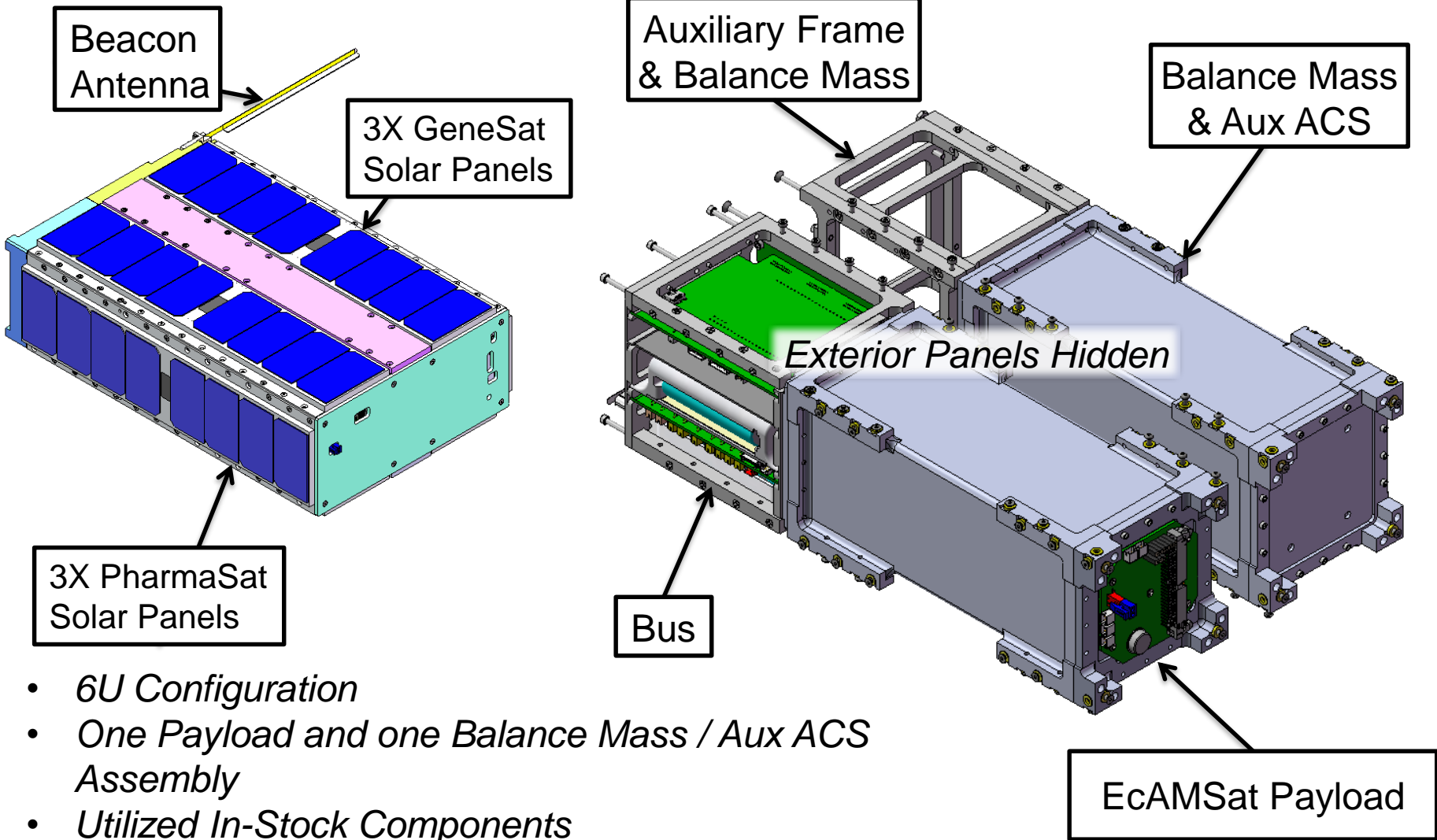


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SYSTEM OVERVIEW

Mechanical Layout

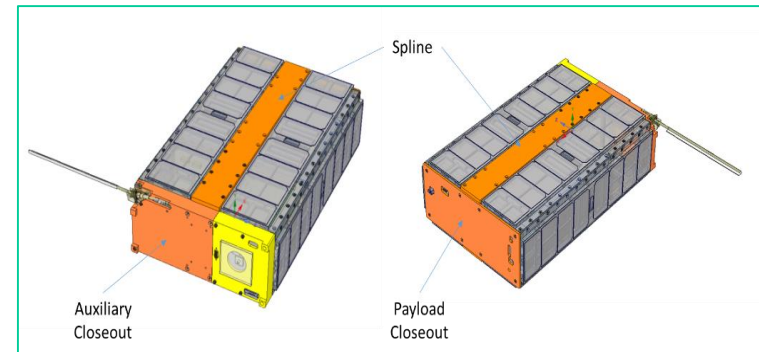


- *6U Configuration*
- *One Payload and one Balance Mass / Aux ACS Assembly*
- *Utilized In-Stock Components*
- *Combination of GeneSat and PharmaSat Solar Panels*



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



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LAUNCH & DEPLOYMENT



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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

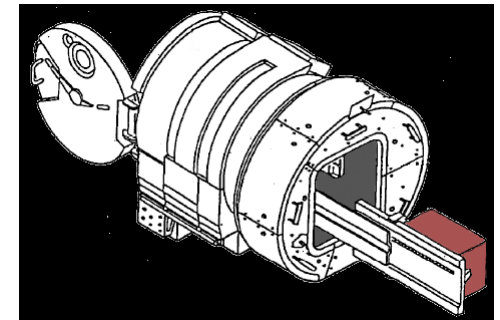
- **EcAMSat was deployed via the NanoRacks Doublewide Deployer (NRDD) with rail modifications.**
 - Existing “tab-rail” 6U deployer modified to support NASA 6U standard.
 - NRDD configuration did not exist 4 months prior to launch
 - Rapid build, fit checks and environmental testing was conducted on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



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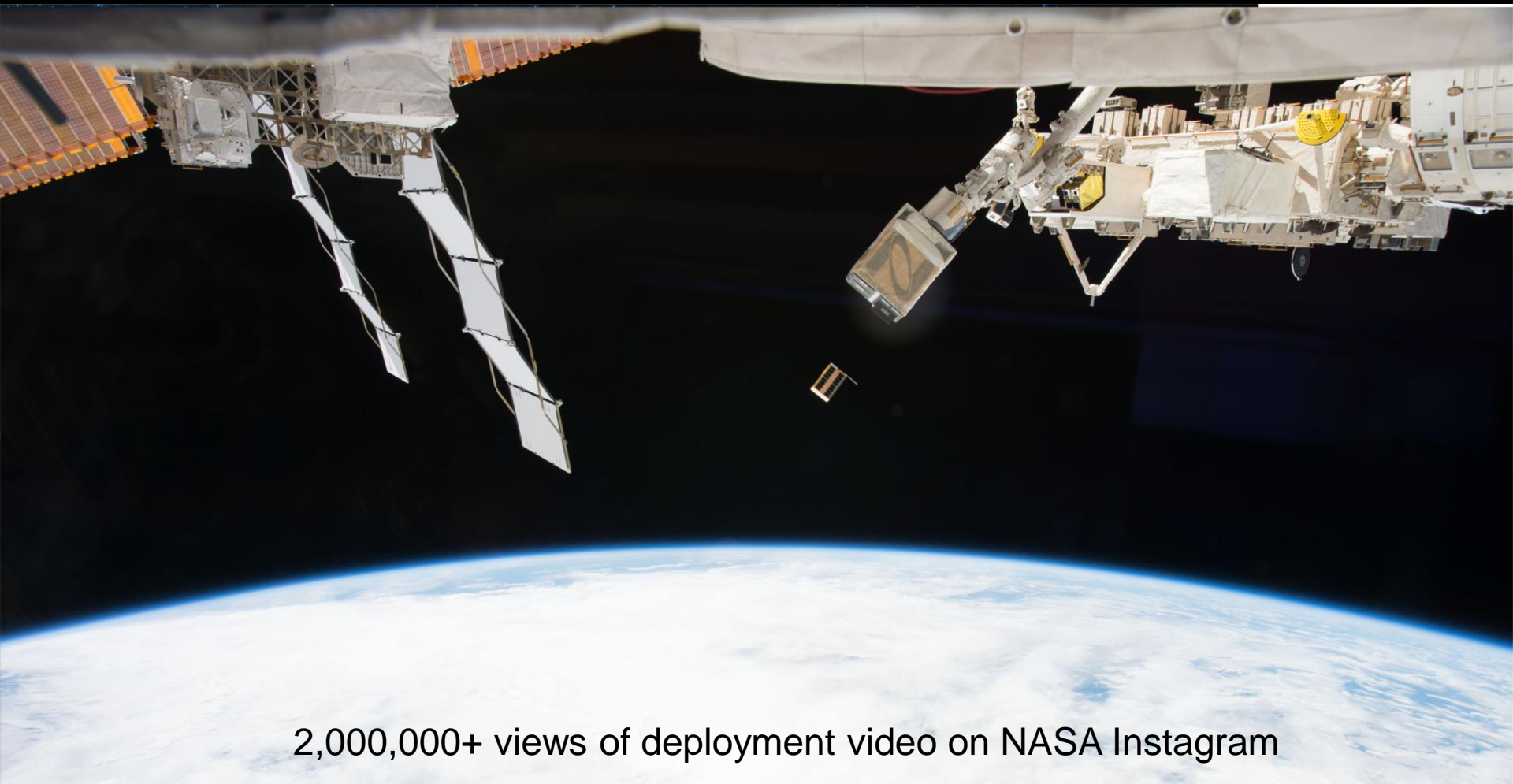


Orbital OA-8E ISS Resupply Launch





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



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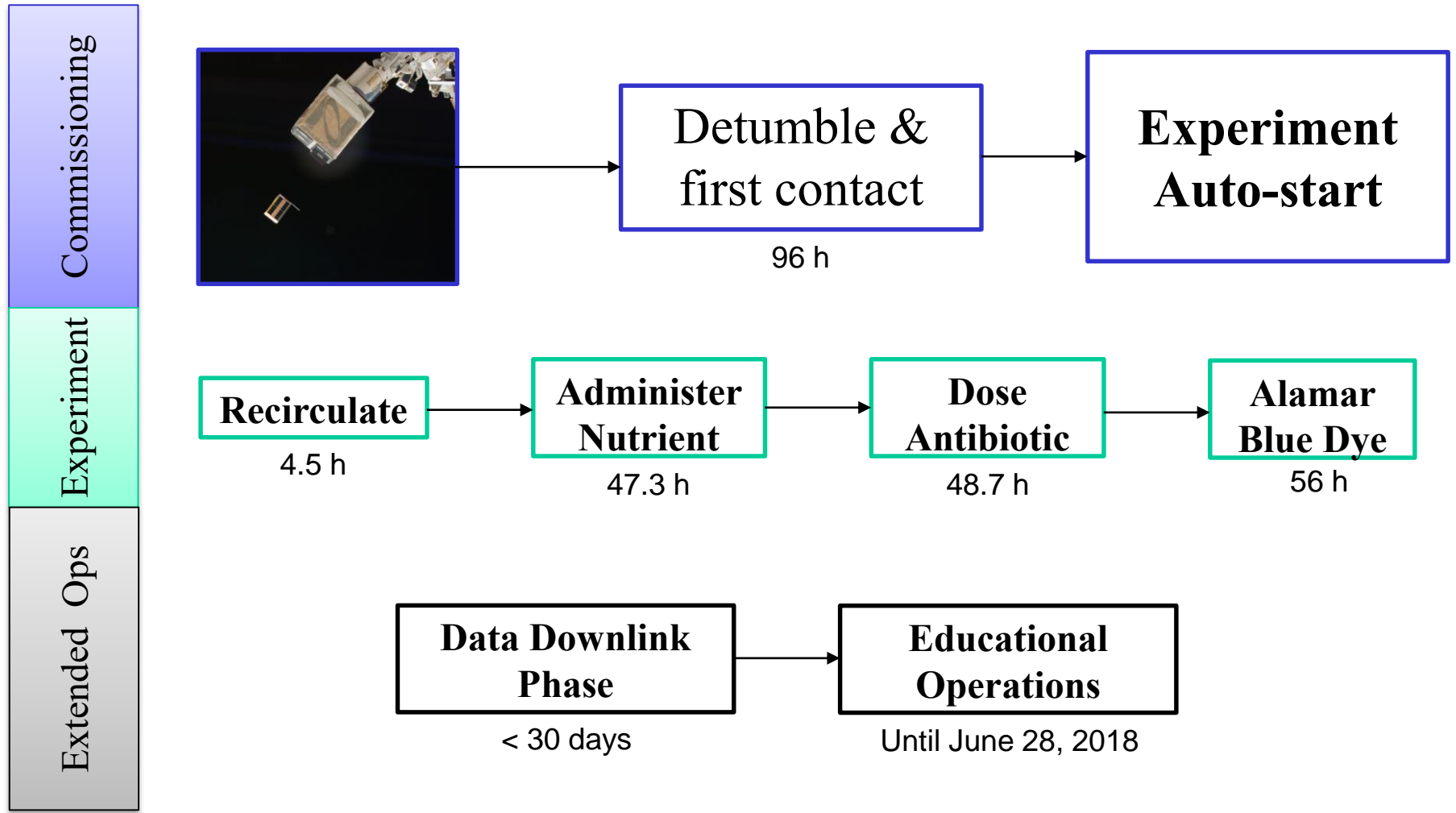


ECAMSAT FLIGHT



Mission Concept of Operations

Nominal 252.5 hours between deployment and end of experiment

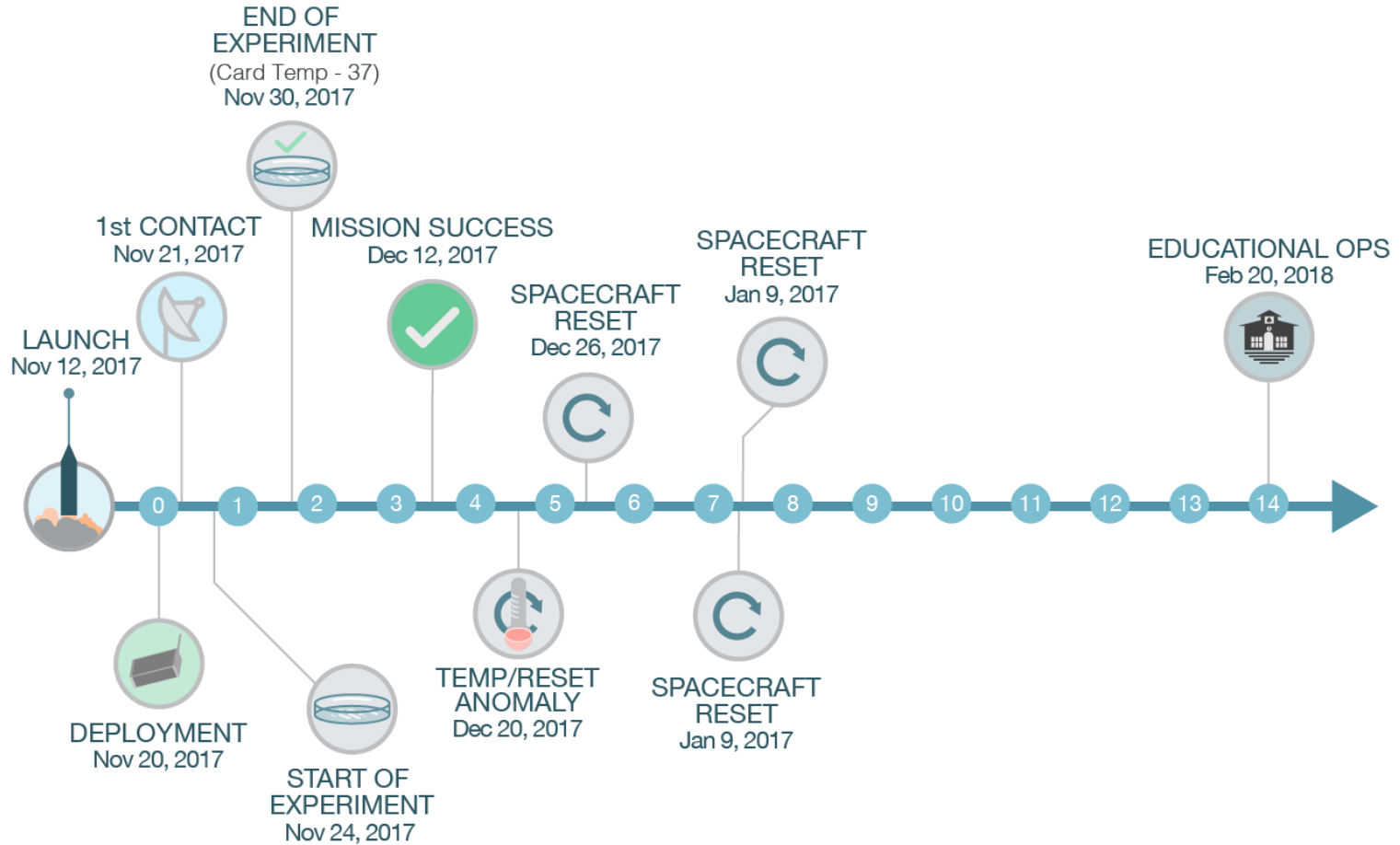




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Actual Mission Timeline





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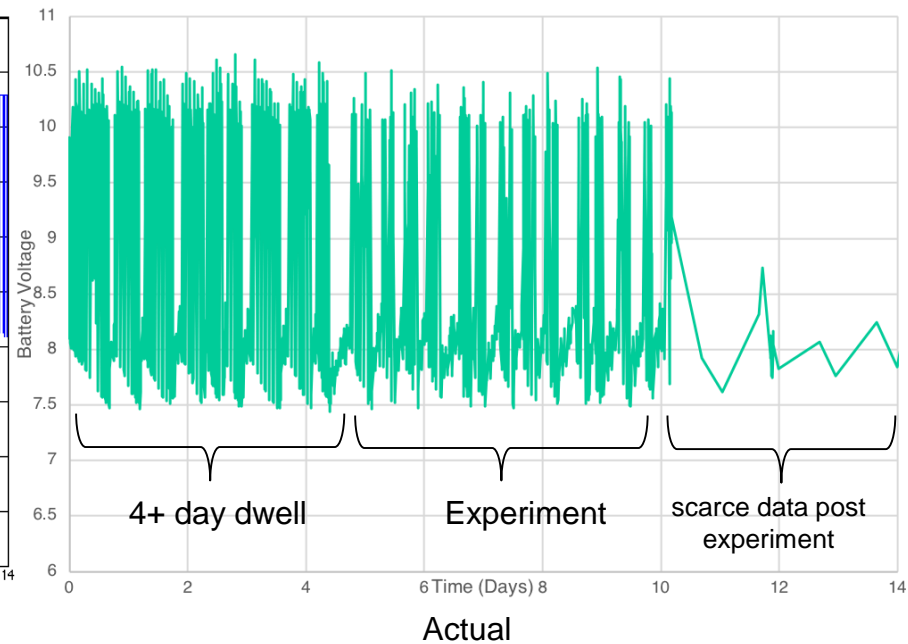
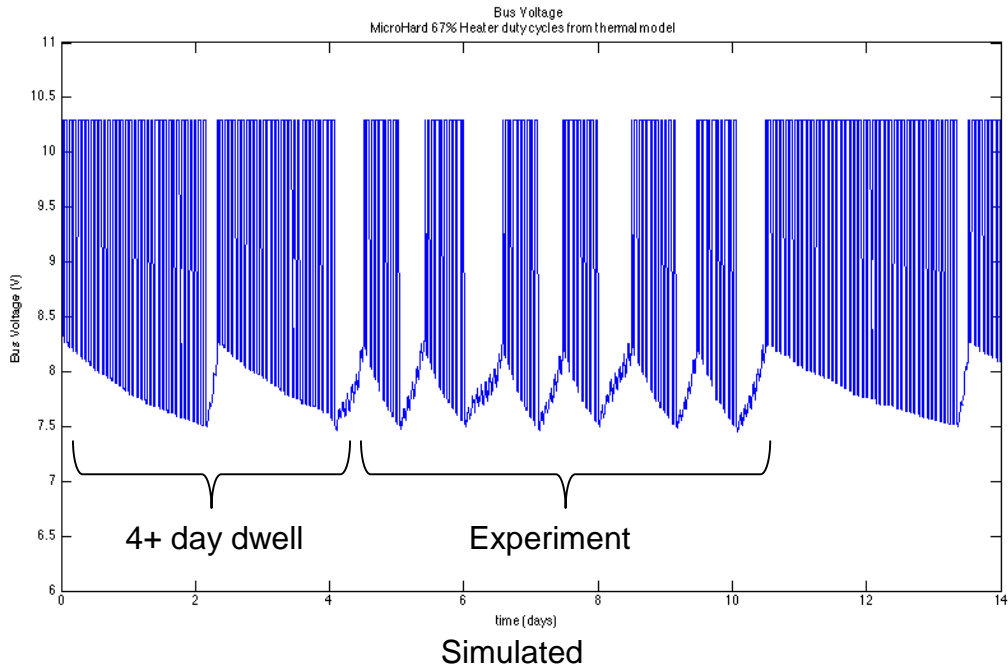


PRELIMINARY FLIGHT RESULTS

Power Consumption

Battery Voltage

EcAMSat Flight Battery Voltage



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)

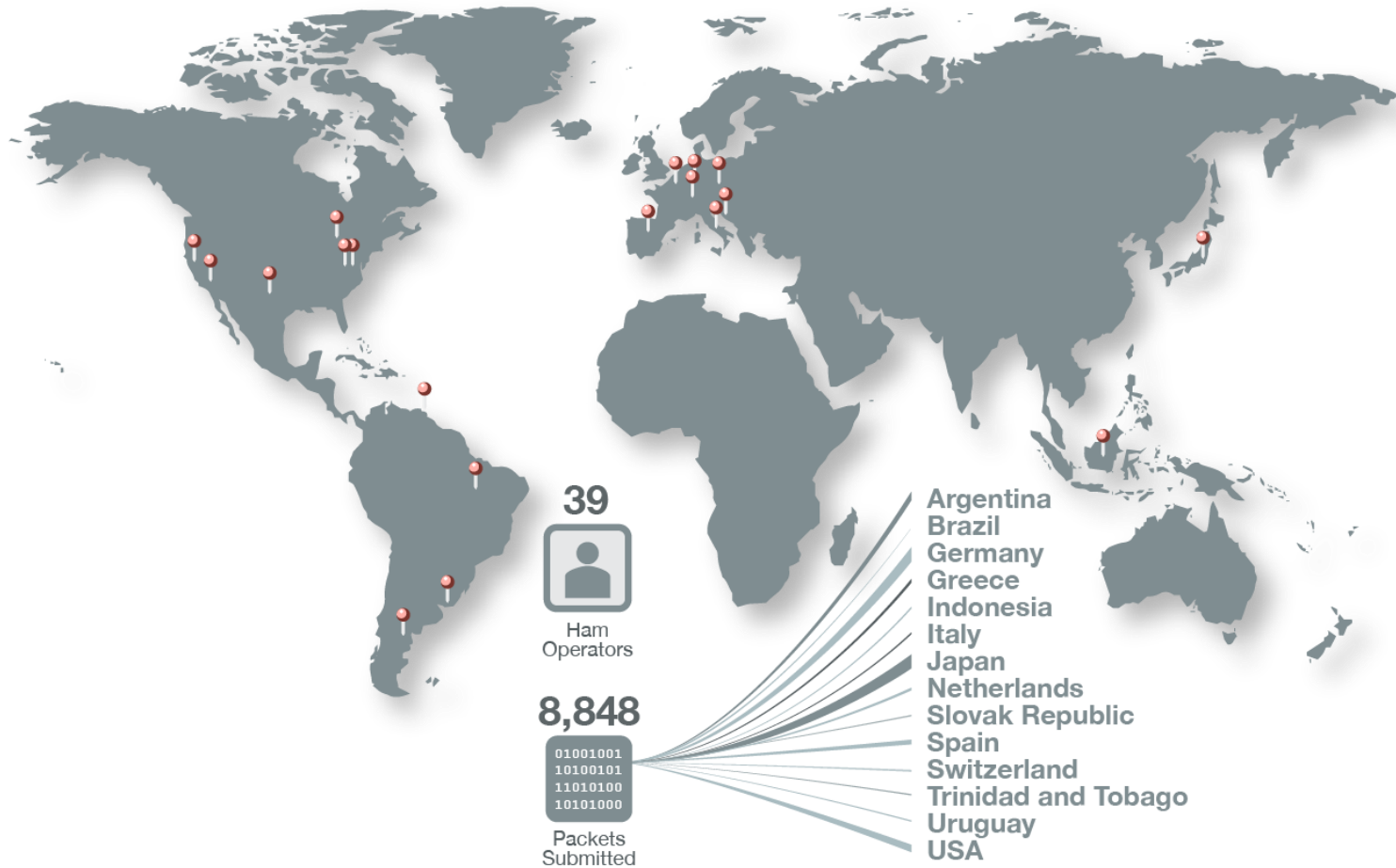
- **Education & Public Outreach**
 - 437.100 MHz AX.25 packets
- **39 Ham Radio operators from 14 different countries**
- **8,848 beacon packets submitted**



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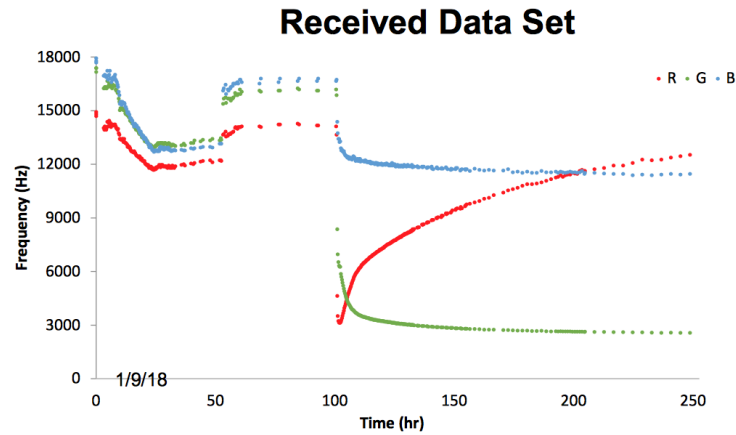
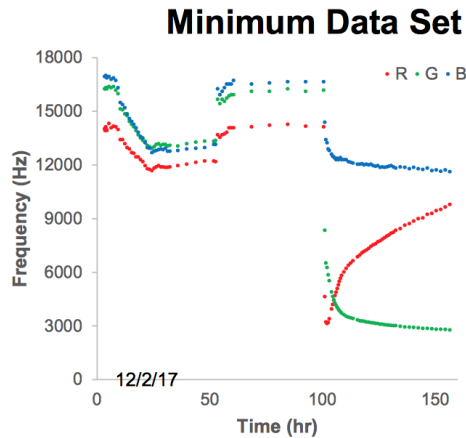


EPO - Beacon Submissions

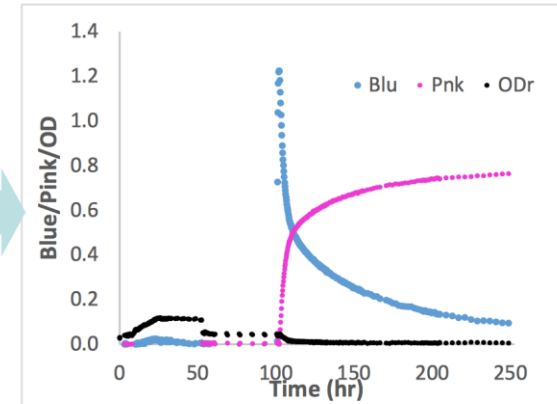
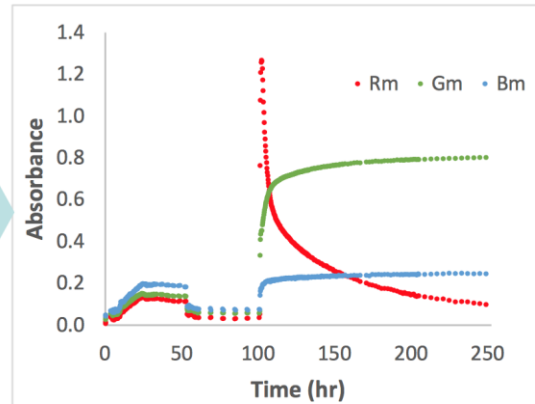
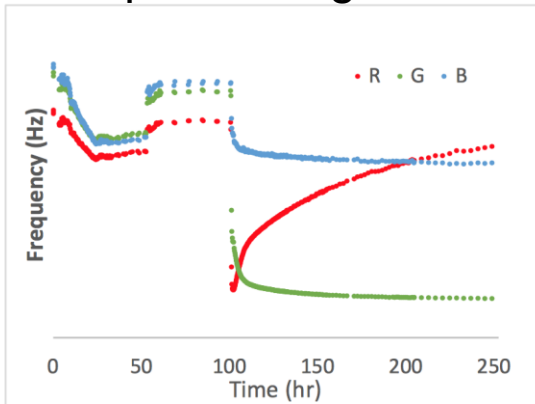


Scientific Data

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



Data processing:





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References

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

EcAMSat Mission Outbrief

EcAMSat Pre-Storage Review 2015