Recent Advances in CubeSat Swarm Technologies
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Outline

• Introduction to NASA Ames

• Overview of CubeSats and Nanosatellites
  • Past, present, and future missions and capabilities

• The Edison Demonstration of SmallSat Networks (EDSN) Mission
About the Speaker

• Grew up in Palo Alto, CA

• Involved in FIRST Robotics in high School

• Bachelor’s in Mechanical Engineering from Cal Poly, San Luis Obispo, Spring 2007

• PhD in Mechanical Engineering from UC Davis, Winter 2013

I really have no idea what that math on the white board is all about…
A Diverse Range of Research Topics

- Aeronautics Research
  - Fault tolerance, next generation aircraft, air traffic management
- Thermal Protection Systems
- Information Systems
  - Super computers, quantum computers
- Robotics and Intelligent Systems
- Small Spacecraft

NASA Ames Research Center, founded in 1939
How Small is Small?

Curiosity Rover: $2.5B

LADEE Spacecraft: $250M

EDSN Swarm: < $25M
A Brief Aside: The Attitude Determination and Control System (ADCS)

- The ADCS is responsible for determining how the spacecraft is oriented and changing that orientation as necessary
  - The spacecraft equivalent of cruise control in a typical car

- In space, we determine our orientation by looking for the sun, looking for specific stars, or measuring our spin rate

- Orientation is changed using spinning wheels, thrusters, or magnetic actuators
CubeSat (Nanosatellite) Development at NASA Ames
CubeSats at NASA Ames

- Single cube is 10cm x 10cm x 10cm and denoted as 1U (CubeSat standard)
  - Natural discretization and modularity
- Typical spacecraft range from 1U - 3U in size
- Volume/mass restrictions make many traditional spacecraft design approaches untenable
- NASA Ames has produced many scientific CubeSats
  - GeneSat-1, PharmaSat, NanoSail-D, O/OREOS
  - Studied topics related to fundamental biology
Rapid, Inexpensive Access to Space
An Increasing Range of Capabilities

- NASA Ames is expanding its range of CubeSat missions to include 1U, 1.5U, and 6U form factors
- The 1U PhoneSat series of missions leverages open source Android and Java technologies
- EcAmSat represents the first 6U spacecraft built by NASA Ames
- What could we do with multiple CubeSats?

The PhoneSat spacecraft makes use of a Google Nexus One phone

EcAmSat will be the first 6U spacecraft launched by NASA Ames
The Edison Demonstration of SmallSat Networks (EDSN) Mission
Mission Overview

• A swarm of eight 1.5U CubeSats deployed to low Earth orbit
  • To be launched on a Department of Defense rocket in late 2015
• Objective is to prove a range of concepts required for future multi-point science missions
• All eight spacecraft are identical
  • Carry a radiation measurement experiment (EPISEM) provided by Montana State University, all the standard spacecraft subsystems, and three different radios
• Ground Station support provided by Santa Clara University
Under the Hood

- Reaction wheels
- 2 distinct UHF antennae
- EPISEM Payload
- Nexus one phone board
- Battery pack
Before and After
Integration and Testing Challenges

• To guarantee a swarm of 8 flight units can be successfully delivered a total of 16 units will be built
  • 4 Engineering Development Units (EDUs) and 12 flight units
  • Best-performing 8 will be selected from the 12 flight units

• Every unit must be tested for basic aliveness/functionality as well as minimally acceptable performance
  • Re-tests occur after major testing events (thermal/vacuum, shock and vibe)

• In addition to functional and performance tests, it is necessary to perform a mission simulation test to ensure that all mission objectives will be met
Spacecraft Build-Up

100K Cleanroom

PCB Stack Up (no chassis) → Aliveness Test → Chassis → Abbrev. Functional Test

Components

Solar Panels

Calibrations
Pointing Test
Comprehensive Performance Test

Transport Case
Sample Testing Workflow
Functional and Performance Testing

• Verify that spacecraft was built correctly and that software was loaded correctly

• Testable functions:
  • Reaction wheel directions
  • Torque coil directions
  • Radio transmit/receive
  • GPS receive
  • EPISEM packet collection
  • Phone functionality
  • Sensor functionality

At least we look good in hair nets….
Mission Simulation Test

- Verify that autonomous spacecraft operations can be carried out as expected

- Testable functions:
  - Delayed start-up after tip-off from launch vehicle
  - Detumble operations
  - “Spoofed” GPS receive
  - EPISEM packet collection
  - Spacecraft Crosslink
  - Data downlink
Lessons Learned

• CubeSats performing both science and attitude control must be very densely packed—assembly is complicated!

• 16 spacecraft (even CubeSats) require a lot of space in which to be built
  • One large clean room? Multiple clean rooms?

• Produce flight software releases early and often
  • Crucial for de-bugging software in a timely manner
Questions?
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