BLUE CANYON TECHNOLOGIES

Spacecraft Buses, Systems & Solutions

On-Orbit Performance of the BCT XB-1 Spacecraft and GN&C Components

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About BCT

- BCT is a small business founded in 2008 by industry veterans previously from Ball Aerospace and the Laboratory for Atmospheric and Space Physics (LASP)
- Advancing the state of the art in small satellites:
  - Smallsat components & systems (Nano Star Trackers, Reaction Wheels, Power Systems)
  - Precision pointing Spacecraft Buses
  - Complete small spacecraft turnkey systems
- BCT Staff have developed, tested and flown systems on more than 30 space missions
- Staff & Facility:
  - Staff of over 50 and growing (engineering, production, procurement, support)
  - 23,000 square feet for manufacturing, test, and mission operations center
  - Recent equipment & systems automation investments
  - IR&D: Design enhancements for volume manufacturing & test

Inc. 5000 #162 2016

In 2016, Inc. Magazine listed BCT as the Number 1 Fastest Growing Private Engineering Company in the United States, and #162 overall.

XB Spacecraft

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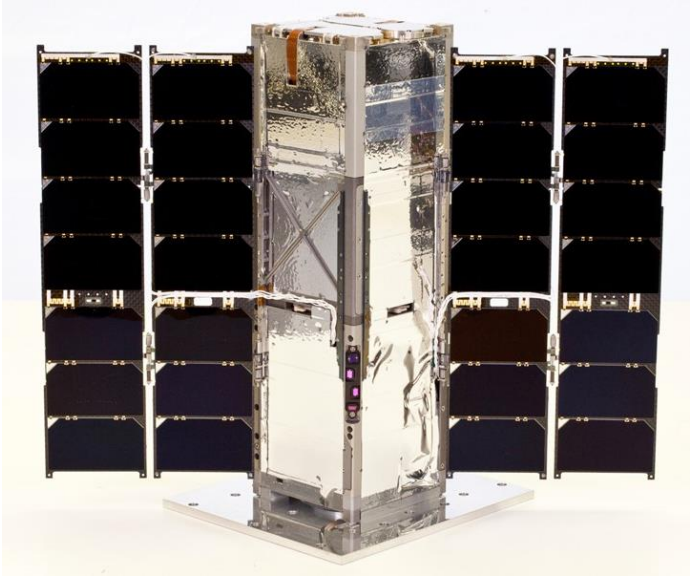
- **Spacecraft Bus**
  - **Guidance Navigation & Control (GN&C)** 3-axis control & stellar navigation
  - **Electrical Power Subsystem (EPS)** battery, solar arrays, charge control, & power distribution and telemetry
  - **Command and Data Handling (C&DH)** onboard data formatting, command, control, and telemetry for the various subsystems, and payload interfaces
  - **RF communications (RF Comm)** multiple options (x-Band, S-Band, UHF, or GlobalStar)
  - **Payload Accommodation** serial interfaces over various formats including I2C, SPI, or LVDS as well as discrete digital telemetry inputs and analog data inputs
- **Integration & Test**
- **Launch Vehicle Integration**
- **Mission Operations**

RAVAN Background

- RAVAN XB-3 (3U CubeSat) launched on November 11, 2016 on Atlas V
  - Earth radiation mission led by Johns Hopkins University Applied Physics Laboratory (APL)
  - Funded through NASA ESTO's InVEST program
  - Sun synchronous orbit, ~580 km
- First flight of BCT XB spacecraft
- Operated out of BCT facility in Boulder, CO
- Originally 6 month mission, extended until April 2018

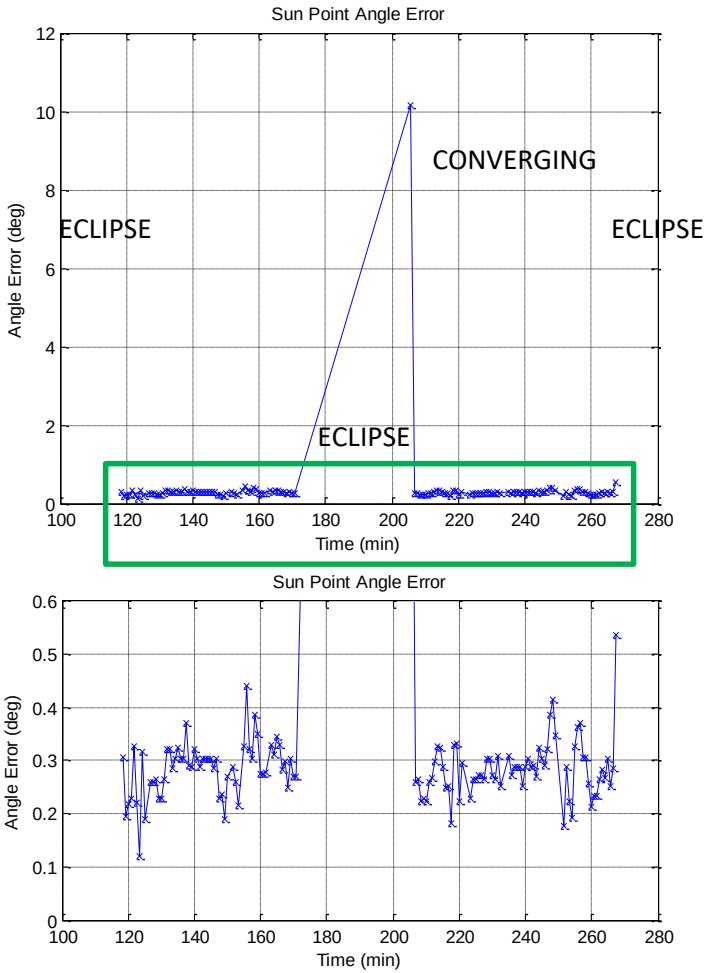


RAVAN
Radiometer Assessment Using Vertically Aligned Nanotubes

APL JOHNS HOPKINS APPLIED PHYSICS LABORATORY

RAVAN Safe Mode Performance

- Autonomously maintains spacecraft safety in safe mode using coarse sun sensors with reaction wheels
- Successfully demonstrated after RAVAN deployment
- Control error is less than 0.6°
  - 2 orbits of data shown with eclipse times excluded
  - Misalignment of sun sensor to panel normal is not included



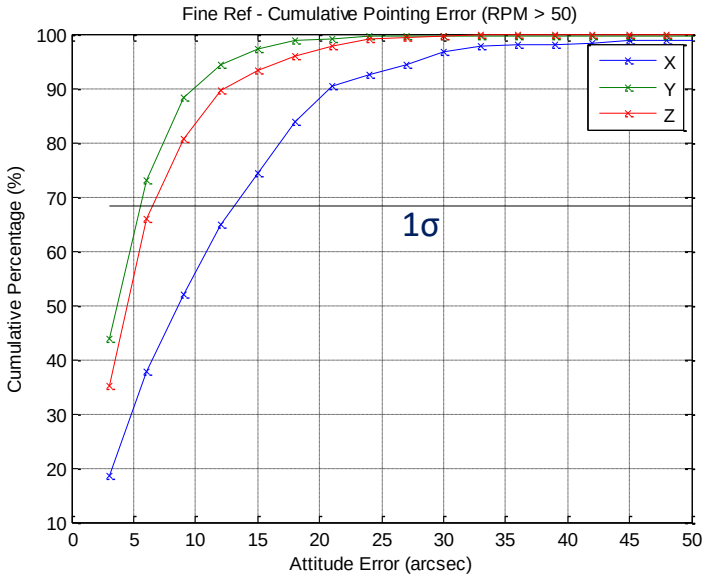
RAVAN Fine Pointing Performance (normal mission operations)

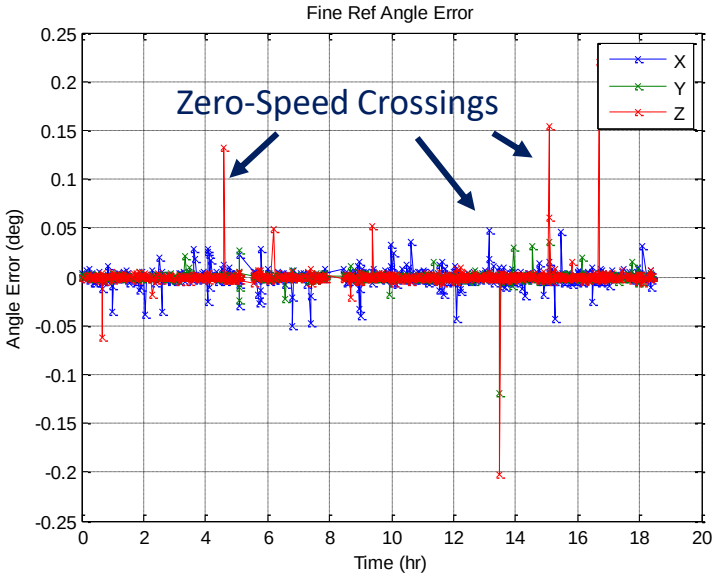
- Pointing performance (1σ) excluding wheel zero-speed crossings (< 50 RPM)
  - X axis: 14 asec *mostly about tracker boresight*
  - Y axis: 6 asec *across tracker boresight*
  - Z axis: 7 asec *mostly across tracker boresight*

- Results comparable to those obtained for MinXSS
  - MinXSS results match independent payload instrumentation
  - RAVAN payload not capable of similar measurements

- Pointing errors analyzed for 18 hours (12 orbits) of data
  - Attitude control with single tracker in the loop
  - Can operate both trackers in the loop for cross-boresight performance in all axes
  - No effort made to optimize wheel speeds or suspend torque rod operations

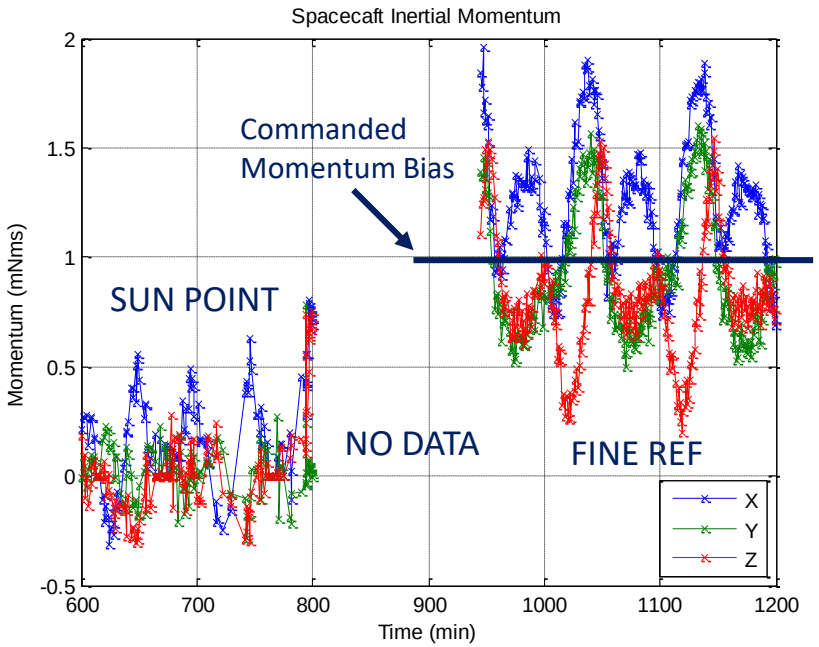
- Angle error includes occasional zero-speed wheel crossings that induce transient errors above baseline
  - 4 crossings/orbit
  - Mitigations available for missions that require them

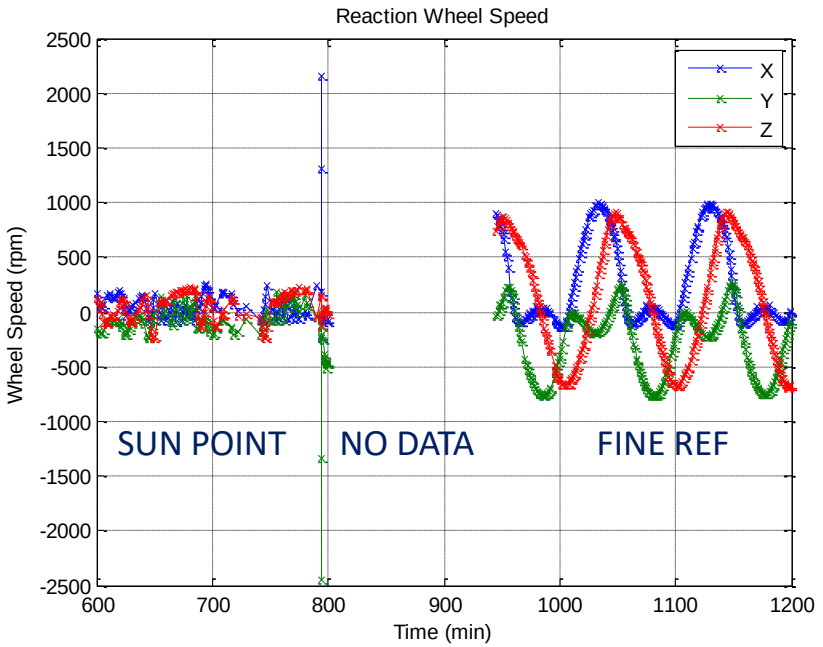




RAVAN Momentum Control

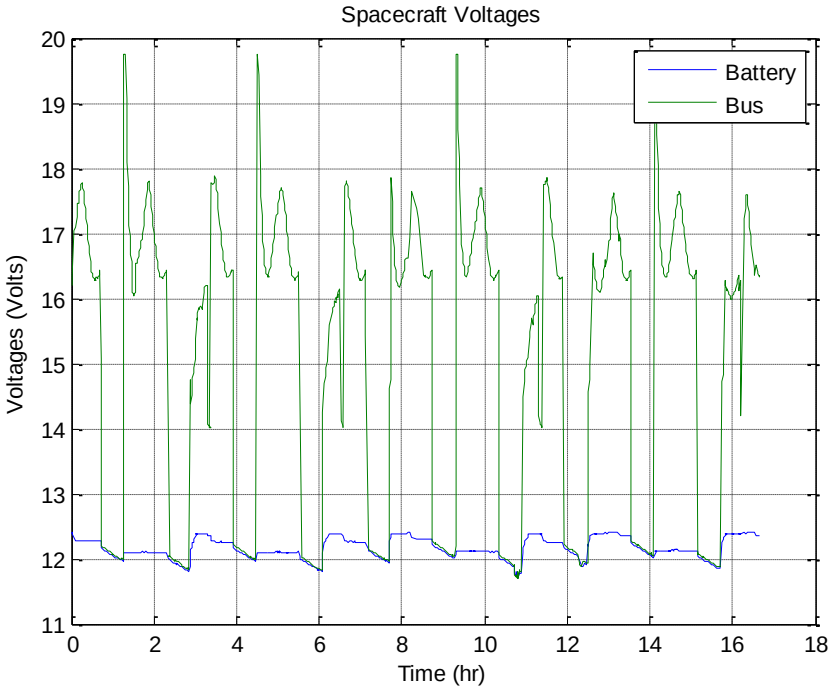
- Successfully demonstrated momentum control to a desired momentum
  - Torque rods used for momentum control
  - Momentum bias is configurable
- Figure shows transition between safe mode to fine reference pointing
  - Desired momentum in Fine Reference Point Mode is 1 mNms in all three axes and 0 mNms in Sun Point Mode
  - Enters Fine Reference Point Mode just before 800 seconds
  - Data decimated down to 50 seconds (and data between 800 and 950 seconds was not downlinked)

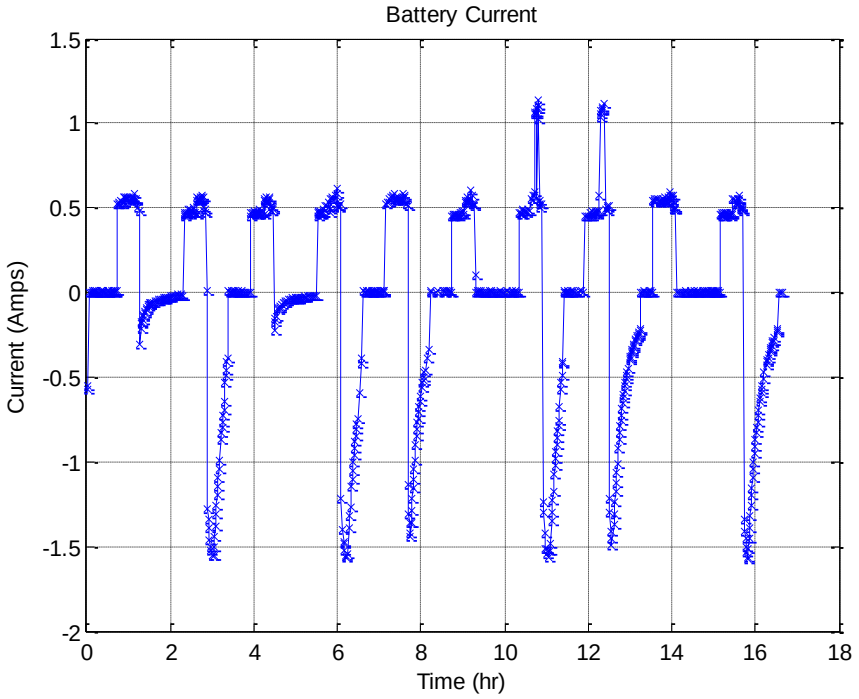




XB-3 Systems Performance

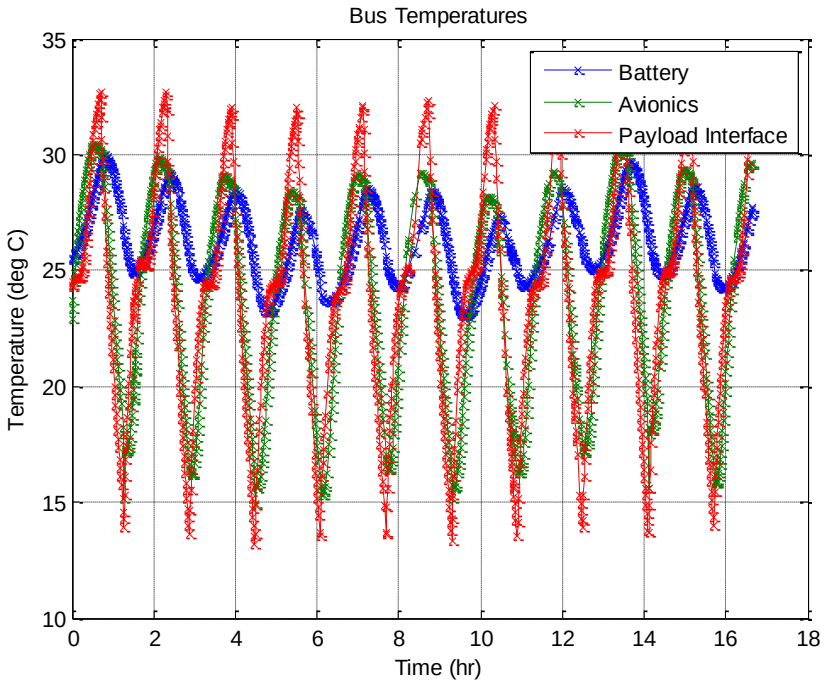
- Electrical Power Subsystem
  - Healthy bus and battery voltages
  - Battery charge and discharge current is nominal

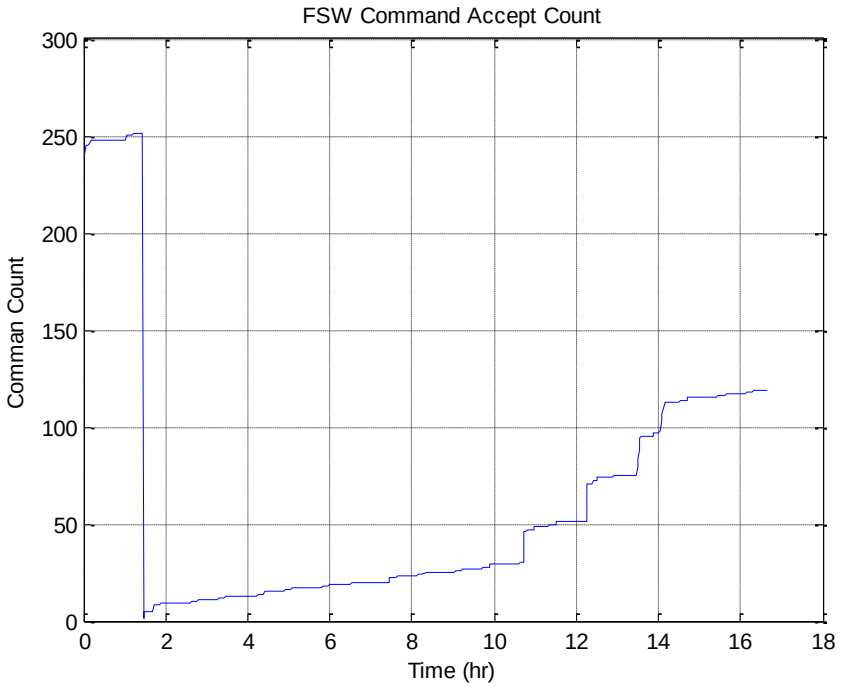




XB-3 Systems Performance

- Thermal
  - Bus temperatures well within allowable range
- Command and Telemetry
  - Flight software accepting and processing uplinked commands
- Communications
  - UHF comm working nominally





Recent BCT Launches

- MinXSS-1 (XACT)
  - CU-Boulder LASP 3U CubeSat deployed from ISS on May 16, 2016
  - 2016 Small Satellite Mission of the Year
- RAVAN (XB-3)
  - 1 year mission extension
- CYGNSS (8 Nano Star Trackers & 24 p015 Reaction Wheels)
  - 8 spacecraft launched on December 15, 2016 to orbit of 510 km
- IceCube (XACT)
  - NASA GSFC/WPS 3U CubeSat deployed from ISS on May 16, 2017
- SHARC (XACT)
  - AFRL 6U CubeSat deployed from ISS on May 17, 2017
- STP-H5 (Big Baffle Nano Star Tracker)
  - Hosted payload on ISS, working well

Future Work

- Dozens of XACT and XB-1 systems slated for numerous missions
  - Commercial, civil, DoD
  - Many deep-space (with thrusters) on NASA SLS EM-1
  - Delivering both systems in larger form factor for micro-sat missions
- NASA Tipping Point program driving major XACT enhancement
  - Millions of dollars investment into Hyper-XACT
  - Large improvements in pointing accuracy & control, radiation tolerance, performance over radiation and temperature, lifetime and reliability
  - Support “operational cubesat” mission posture (lower risk, higher reliability)
  - Flight delivery mid-2018
- BCT delivering 12U and microsat buses for GEO in 2018