COSMIC X-RAY BACKGROUND NANOSATELLITE

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SMALLSAT
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OVERVIEW

- Introduction
- Team and SSC
- Morehead State University
- Science Mission Objectives
- ConOPs
- Science Instrument: CZT Array
- Spacecraft
- Schedule
- Flight Status
- Flight Program: NASA ELaNa, SRI and CalPoly
- Conclusions
CUBESATS NOW PRODUCING SCIENCE

• CUBESAT technology has now evolved to the point where valuable science research is supported
  • RAX-2 (University of Michigan)
  • DICE (SSDL)
  • E1-P (HRBE) (Montana State University)
  • SwissCube, Others…
• Launching on ELaNa VI: CXBN, CCSWE, STARE…
• Given current budget climate for fundamental research, it is inevitable that Smallsats will increasingly become major contributors as science platforms
Where Is Morehead State University?
MOREHEAD STATE UNIVERSITY
SPACE SCIENCE FACILITY AND LABS

- Space Systems Laboratory
- Spacecraft Verification Facility
- EM Anechoic Chamber on-line
- Clean Room
- RF and Microwave Laboratory
- Mission Operations Center
- 21 M Space Tracking Antenna
SPACE MISSIONS RECENT/UNDERWAY

• **KySat-2:** (Redo of Kentucky-based CubeSat launch attempted in April 2011 - with Univ. of Ky and KySpace)

• **GlioLab:** precursor missions with KySpace and the MSU Dept of Biology launched on the last two US Space Shuttle flights in May and June 2011

• **UniSat-5:** (Italian/Morehead satellite to be launched from Russia in November 2012 – launches BobTwiggs’ first PocketQub)

• **TechSat-1:** DoD satellite for the Space and Missile Defense Command (under development with Radiance, Honeywell, Tethers Unltd.)

• **CXBN:** Cosmic X-Ray Background Explorer selected for flight by NASA ELaNa Program – flight scheduled for September 2012
CXBN MISSION GOALS

• Goal is to Increase the precision of measurements of the Cosmic X-Ray Background in the 30-50 keV range (2-5% measurement)

• Constrain models that explain the relative contribution of cosmic X-Ray sources to the CXRB

• Produce data that will lend insight into the underlying physics of the Diffuse X-Ray Background

• Provide flight heritage for CZT-based X-Ray-Gamma Ray Detector and CubeSat technologies
Remaining Big Bang Mystery

- Hot, Inflationary $\Lambda$CDM Model Predicts CMB
- CMB is Well Understood
- Observed DXRB Not Well Understood
Previous measurements of DXRB disagree by about 10%
SCIENCE – THE X AND GAMMA RAY SKY

- Is the Diffuse X-Ray Background (DXRB) due to AGNs that are too distant to resolve with our telescopes or something else?

“... the cosmic X-ray background (CXB), still remains one of the most interesting topics of X-ray astronomy and observational cosmology.”

- Revnivtsev et al., A&A 444, 2005
CXBN – OVERVIEW AND CONOPS

• Scientific 2U CubeSat – CZT X-Ray Detector System
• Store and forward architecture mission
  • Constantly powered payload
  • Spin-stabilized, Sun-pointing
  • Foldout panels
  • High inclination (66°)
  • UHF: 2 contacts per day ~ 10 minute
• S/C built entirely in-house @ MSU
TIMELINE – MILESTONES

- 01/31/11  NASA Award Letter Received
- 02/09/11  Kickoff Webinar
- 04/21/11  PDR
- 08/31/11  CDR
- 11/18/11  MRR
- 12/31/11  Delta-MRR
- 01/04/12  Delivery
- 08/30/12  Launch Date

- <12 Month Development, Internally Morehead Funded
DESIGN – MEASURING DXRB WITH CZT

- Spacecraft will spin about the sun pointing axis at 1/6 Hz
- Detector to sweeps out a 36 Field of View (FOV) over with each rotation
- Full sky Coverage over time
- Goal is 1 megasecond of science data
• X-Ray Detector 30-50 KeV
• Fabricated by Black Forest Engineering
• 2 cm x 1 cm block of CZT
• Collimator set 36° FOV
• Graded Z shield - Lead, Tin, Cu
• Good SNR for weak sources
• Calibrated with Cal sources and Crab Nebula
• Should see 1 count/sec from Crab and 1 cps from background
Simulations Performed in GEANT4

Incident Cosmic ray protons with spectrum from 10 MeV to 10 GeV simulated through material of the collimator, including shielding, and the Al window.

Tried different angles to determine the probability that an proton interaction produces a secondary particle that deposits energy in the CZT in a single strip +/- one strip (3X3 Energy deposit).

Fold in the rate of cosmic ray protons to determine an absolute background hit rate in the CZT of relevant energy depositions.
ESTIMATED BACKGROUND IN CXBN – ASSUME 0.08HZ/CM²•SR PROTON RATE × 22.9CM² × 1 SR

Secondaries from Cosmic Protons interacting in the Collimator + Al window
Overall rate of particles hitting CZT with Edep < 500KeV = 4X10⁻³ Hz

For $10^6$ s of running, this estimate the number of background events
CXBN CZT DETECTOR PAYLOAD WITH CAL SOURCES

CZT Array Collimator  Cal Sources Assembly  Cal Sources Cap
FIRST DATA WITH INTEGRATED SCIENCE ARRAY

BFE322 CZT Dec 2 00:55:25 2011 Jernigan DataSet 2

Signal1 = Reset1 (solid)
Signal2 = Reset2 (dotted)
Reset1 = (v2+v3+v4+v5)/4
Reset2 = v4
Signal1 = (v8+v9+v10)/3
Signal2 = v9

Equivalen X-ray Energy (300 mv ~ 59.5 keV)
SPACECRAFT OVERVIEW

- Custom C&DH
- Custom ADCS
- Custom PMAD
- COTS/Custom Comms
C&DH

• **MCU – MSP430**
  - 65 mA – active
  - 3 – 16-bit timers
  - Direct memory access

• Reprogrammable from Radio

• Reprograms Subsystems
  - Payload
  - EPS
ADCS – SENSORS

• Dual Sun Sensor (DSS)
  • +Z Boresight measurement
  • Quadrant photodiode system
  • Medium and Fine field of views
• MEMS IMU package
  • Tri-Axis Gyros and Magnetometers
  • Temperature Sensor
• Canopus Pipper – roll position
  • Photodiode array system
  • Run by payload – synchronized data
ADCS - CONTROL

- Magnetic Torque Coils
  - 3 Axis Control
  - H-Bridge driven by PWM from C&DH
  - Checked polarity in single axis Helmholtz chamber
  - ~500 mA average
  - $1.6 \times 10^{-4}$ Nm torque
COMMS – RADIO

- UHF Transceiver – AstroDev Li-1
  - Flight heritage
  - GFSK
  - 437.525 MHz
  - Transmit power: 31.5 dBm
  - Beacon
  - Backdoor reset
  - Ping
  - Ping w/ telemetry
  - Provides BSL entry to C&DH
COMMS – ANTENNAS

- 1/4 Wave Steel Blades
  - Quadrature monopole array
  - Phase network for RHCP
  - Tune to $S_{11}$
  - Verified in anechoic chamber
EPS

- **Generation**
  - 4x Deployable Solar Panels
  - ~15 W total after sun pointing

- **Storage**
  - Molicel 18650 Li-ion batteries
  - 1S4P configuration – buck/boost
  - 2200 mAh

- **Management and Distribution**
  - Direct Energy Transfer and Shunt Regulation
  - 3.3V and 5V regulated rails, Deployable cut circuit
  - 7 Revisions !!!
TEST & STRUCTURE

- Aluminum 6061-T6
- Type III Hard Anodized
- Central mounting concept
  - “Mounting block”
  - 2 Walls
  - All Subsystems Support
- Vibration test
  - Multi unit qual
  - Vacuum
  - Out-Gas
FLIGHT/LAUNCH STATUS

• On NASA-DoD OUTSat Mission
• On the Launch Pad at VAFB
• ULA Launch Information Lists August 30
UNIVERSITY CUBESATS AND NASA ELANA

• Special Thank You to NASA LSP, SRI, and Calpoly
• NASA LSP Responsible for Flight Opportunities Otherwise Not Available to Universities
• Provides Incredible Opportunities for Students
• Pushes the Envelope of Technology by Relaxing Risk Aversion
• Now Producing Valuable Science
• Big Science Ahead with Small Platforms…