X-ray Star Scanner for Spin-stabilized Microspacecraft

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Overview

• Motivation for the X-ray Star Scanner and Spin Stabilized Microspacecraft
• XSS Concept and Operation
• Expected XSS Performance
• Applications for Spin Stabilized Microspacecraft
• Summary and Future Work
Motivation

• Previous CubeSat missions typically passively stabilized
  – Fixed magnet with hysteresis rods
  – Aerodynamic
  – Uncontrolled tumblers

• New ADCS hardware for CubeSats tend to be miniaturized versions of larger ADCS hardware
  – Star cameras, IMU’s, reaction wheels
  – Large mass and power relative to CubeSat capabilities

• Spin-stabilized microspacecraft can perform a number of valuable missions
  – XSS enables arcminute level spin stabilized missions
  – Low power & mass allows larger payloads to be flown
XSS Concept

- Simple X-ray detector with collimator limits field of view
- As spacecraft spins, a series of pulses are created
- Each corresponds to the position of a star
- Attitude solution generated from unique pattern

Star Catalog
X-ray Star Catalog
XSS Block Diagram

X-ray Flux

Anticoincidence

Solid State Detector

Detector Electronics

Spin Rate Update

Orientation Update

X-ray Catalog

XSS Clock

FPGA

\[ \Omega \]

\[ \theta, \phi, \psi \]
Typical XSS Time History
XSS Measurement Algorithms - Spin

• Repeated pattern of pulses is a measure of spin rate
• Position of one X-ray source is a measure of spin phase
XSS Measurement Algorithms - Orientation

- Spacing between X-ray pulses is a measure of yaw angle
- Height of X-ray pulse is a measure of roll angle
XSS Performance

XSS Accuracy (arcmin)

Galactic Latitude (deg)

Galactic Longitude (deg)
Unique Features of XSS

- Provides **arcminute** level attitude determination from a small package
  - Target < 1 W, < 1 kg, < 50% of 1U CubeSat
- FPGA provides Plug-n-Play capability
- Must be used on spin stabilized spacecraft with arbitrarily large spin rate
  - Simple, stable platform for many applications
- Inherently radiation hard
  - Detectors are radiation hard
  - Detector electronics provided by FPGA core
- Cannot be blinded by sun or spoofed or jammed by adversaries
Spin Stabilized Smallsat Applications

• Sun-pointed missions
  – Solar physics
  – Space science

• Inertial Pointers
  – Astronomy missions (e.g. spectroscopy)
  – Measurements of fundamental physical constants
  – Space science
  – Imaging of specific earth targets

• Thompson Spinners
  – Earth observing missions
  – Multispectral imaging
  – Atmospheric measurements
  – Communication relays
Spin Stabilized Spacecraft Opportunities

• Interviewed members of user community
  – Small and large prime contractors
  – CubeSat developers

• Key findings
  – Limited but ongoing market for spinning platforms
    • Science and space weather
    • Lower cost ADCS for CubeSat clusters/swarms
    • Backup and safe mode applications
  – Target SWaP and performance would be interesting/useful
    • <1 kg
    • <1 W
    • ~500 cm^3 (10 cm x 10 cm x 5 cm)
    • ~1 Arcminute
Summary

• The X-ray Star Scanner will provide spin stabilized microspacecraft with arcminute level attitude knowledge capabilities in a small, low power package

• Precision spin stabilization will open up new, important missions for CubeSats and related microspacecraft

• XSS development currently in Phase I under JPL direction
  – Basic design being refined