JHU/APL CubeSat Summary

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APL
The Johns Hopkins University
APPLIED PHYSICS LABORATORY

Overview

- APL is providing active support for the CubeSat community
  - Advocacy for CubeSat/nanosatellite secondary payloads on missions in which APL is involved
  - Provide facilities at reduced or no cost
  - Mentoring/advising
  - Sponsor student interns
- APL is pursuing three paths for CubeSat involvement
  - Externally sponsored “high” value missions
  - Internally sponsored technology/concept demonstration missions
  - Donated payloads to CubeSat missions

“High” Value Missions

- Educating APL staff on CubeSat capabilities
  - Foster development of concepts that can meet sponsors’ critical challenges
- Evaluating the potential of CubeSats in the upcoming NASA SMEX AO

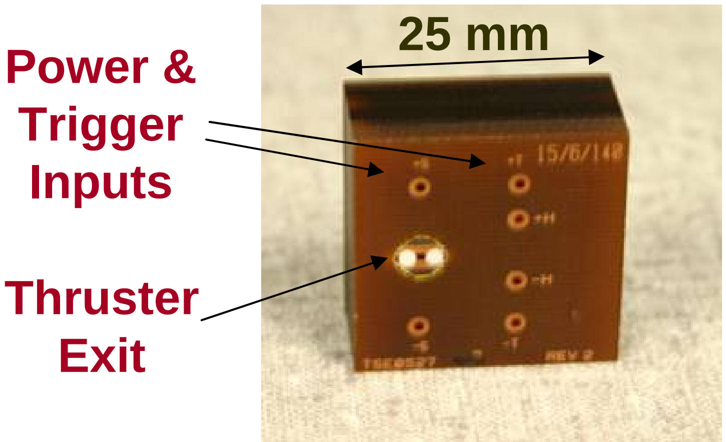
Internally Sponsored Technology/concept Demonstration Missions

- Initiated FY07 IRAD project
  - Held open call for CubeSat payload/mission ideas
  - Selected three concepts for further study
  - Met with numerous members of the CubeSat community to better understand capabilities and costs
    - Very interested to meet with other CubeSat providers during this conference
  - Downselect planned for early September 2007
  - High probability of a program start in FY08
- Three concepts
  - MEMS space weather sensor
  - Space networking
  - Proximity operations

Donated Payloads to CubeSat Missions

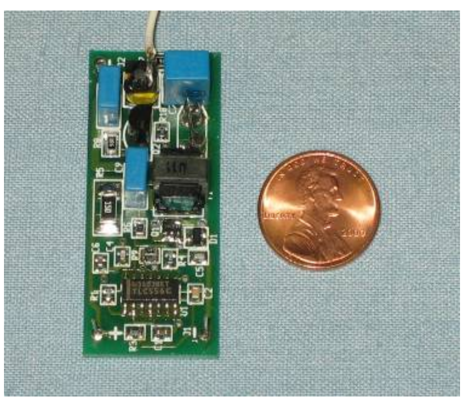
- APL is developing numerous technologies that would benefit from space flight
- Payloads would be donated to interested CubeSat teams
- Sample of technologies presented here
  - Complete package available upon request

Micro Liquid Pulsed Plasma Thrusters



- Water-fueled (current prototype)
- Arrays of thrusters possible in small, lightweight polyimide structures
- High Isp for efficient propellant utilization

- Fabricated using printed circuit board techniques
- Moderate voltages (~600V) simplify power processing electronics

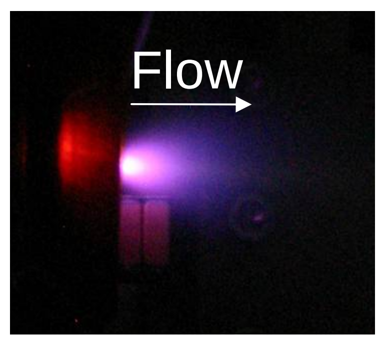


Prototype Power Processing Unit

Dry mass: 13.5 g w/ integral tank
(~1 cc capacity adds 1 g)

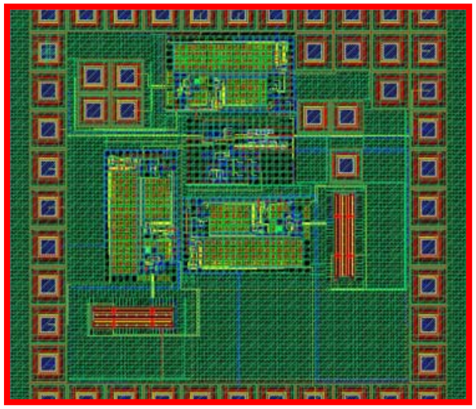
Size: 2.5 cm x 2.5 cm x 1.3 cm

Power: 100 mW (1 Hz firings)

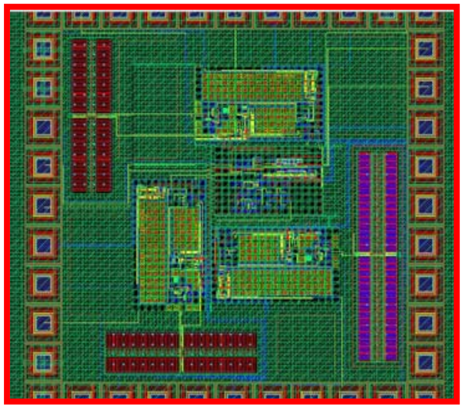


Micro-PPT Plume

MEMS Inertial Sensor Suite

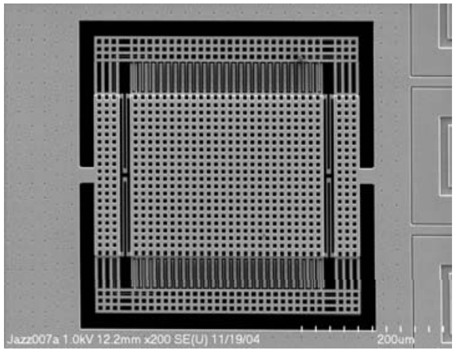


2-axis Magnetometer

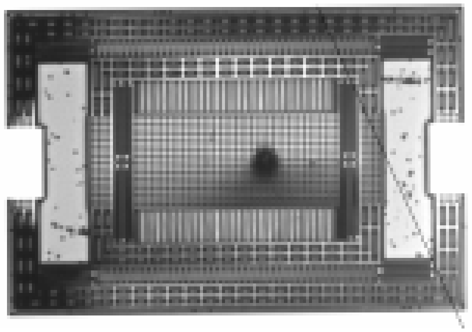


3-axis High-g Accelerometer

- 3-axis high-g accelerometer, 2-axis magnetometer, interface electronics on one 2.5 mm x 2.5 mm die
- Low-g accelerometer, gyro also fabricated with less integration
- Developed with MEMS lab at Carnegie Mellon University



Low-g Accelerometer



Gyro

Analog voltage outputs (eg, 275 µV/g for high-g accelerometer)

Volume: 0.5 cm^3

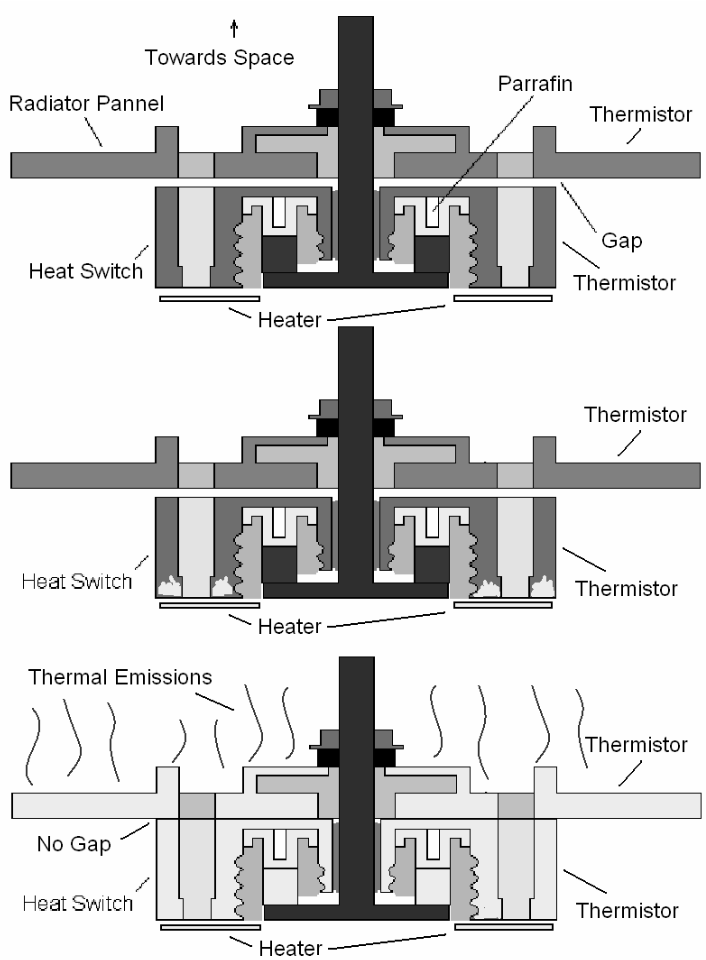
Power: 83 mW

Accelerometer is hermetically packaged; magnetometer is vacuum packaged

SPREAD and Spines Messaging Infrastructures

- Open-source infrastructures developed at JHU
- SPREAD toolkit for intra-spacecraft messaging:
  - Most effective for synchronizing multiple computing devices, distributed systems
  - Could run on top of 1553B, SpaceWire, and optical comm layers
  - Thousands of ground implementations, but no space demonstration
  - www.spread.org
- Spines for inter-spacecraft messaging:
  - Support for multi-hop mesh networks
  - Ideal for CubeSat constellations, swarms
  - Could also link satellites to ground station access
  - Demonstrated with 802.11 wireless routers
  - www.spines.org

Thermal Switch



Thermal switch when open (top) and closed (bottom)

- Switch becomes thermally conductive above threshold temperature
- Gap (vacuum) prevents thermal conduction below threshold
- Operates without active control; Heater used for demonstration

Mass: 25 g + radiator (~125 g)

Power: 3 W maximum for heater

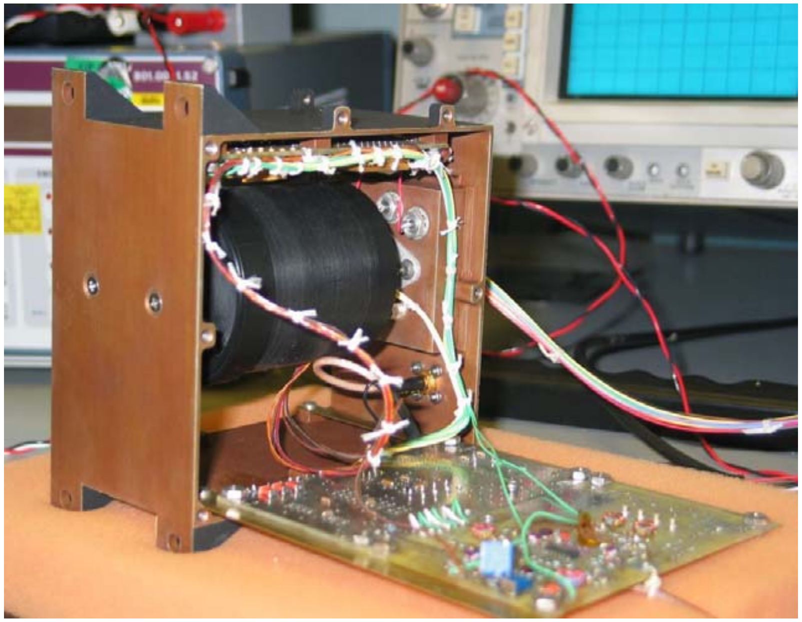
Data: 2 temperatures, heater current

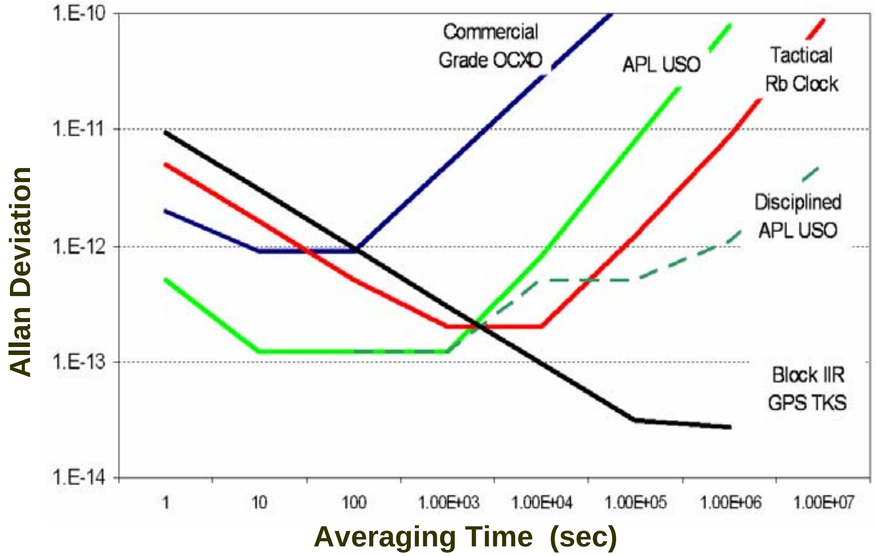
Size: 8.2 cm x 4.2 cm

Requires radiative panel

Prototyped in cooperation with Naval Academy

Disciplined Ultra-Stable Oscillator (USO)





USO shows best frequency stability through 1000 sec averaging time

- Provides time-tagging for sensor data down to 1 µsec resolution
- Referenced to GPS; only requires intermittent signal
- Up to 30 day autonomous timekeeping in LEO

Mass: 300 g*

Power: 3 – 5 W*

Volume: 200 cm^3 *

*Assumes packaging is integrated with bus

Requires GPS interface

USO based on proven APL technology; discipline has been laboratory demonstrated

MicroCam

- 1024 x 1024 pixels
- Monochrome
- Radiation hardened
- 1 Hz frame rate
- 10 ms to 0.5 s exposure time

Mass: 125 g without lens

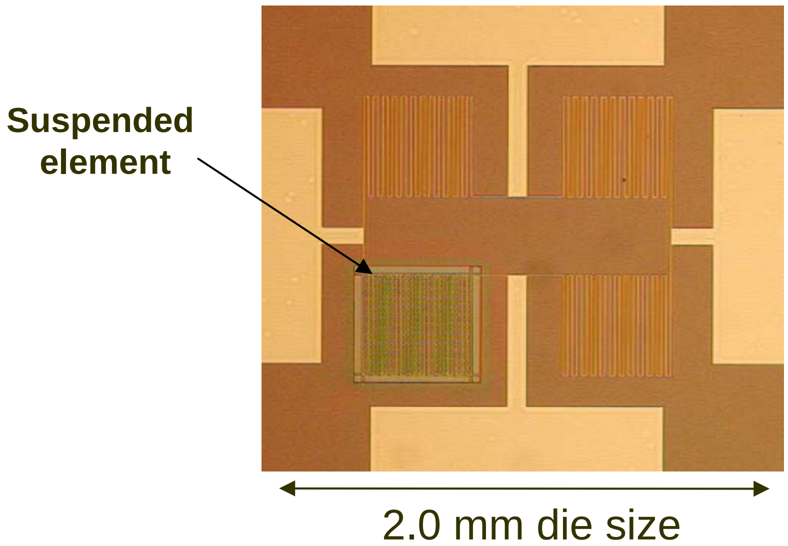
Size: 6.25 x 5.4 x 4.95 cm

Power: 0.6 W

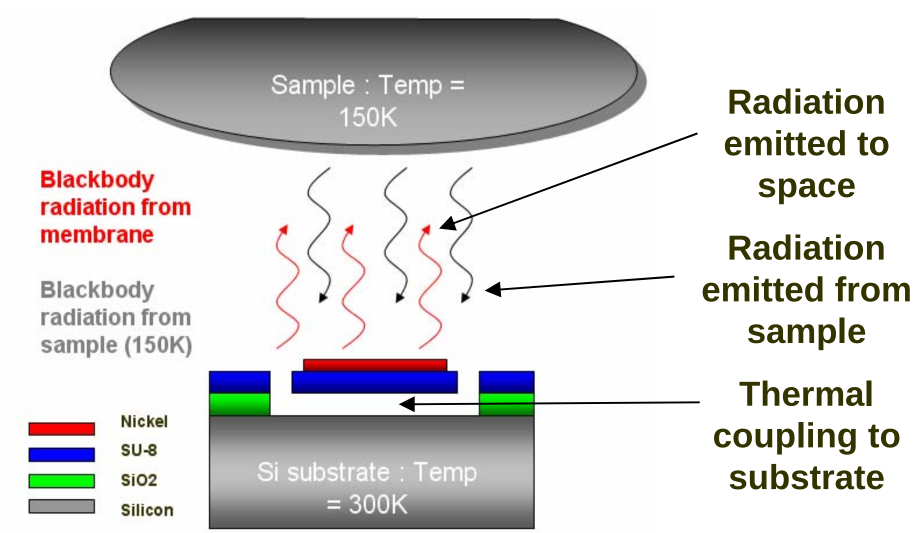
Data: 10.5 Mbits per frame; 10-bit LVDS raw output

Requires lens (C mount), clock, control, and power interfacing

MEMS Bolometer



- Bolometer measures total incident radiation
- Temperature (and resistance) of suspended element determined by blackbody radiation balance
- MEMS technology reduces size, power



Sensitivity of 7 nV/K, but 60 nV noise floor limits resolution to 9 K

Simple Interfacing (op-amps and ADC)

Summary

- APL is now actively engaging with the CubeSat community
- Open offer of assistance to CubeSat programs
- Considering use of CubeSats on high value science, technology, and concept demonstration missions such as SMEX
- Working to define an APL CubeSat program
  - In concert with a university partner
- Numerous technologies available for donation to CubeSat missions