IPEX
Maximizing 1U Payload Potential

Eric Stanton

Mission and Spacecraft Overview

IPEX – Intelligent Payload Experiment

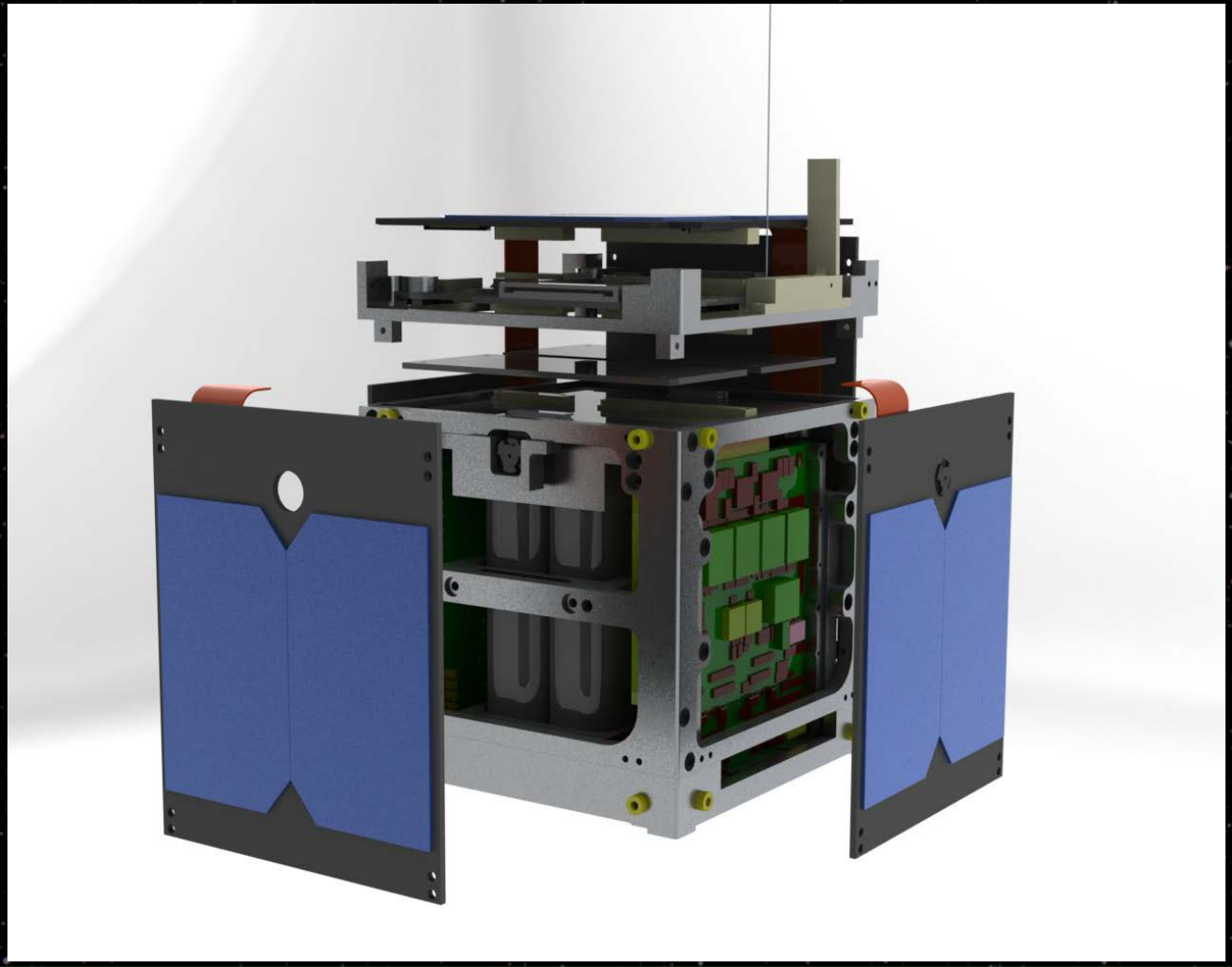
- The mission of IPEX is to demonstrate operation of autonomous instrument processing, downlink operations, and ground station operations, utilizing the Space Cube Mini payload processing unit to validate a reduction in data product downlink.

- JPL manages the project and develops the autonomous flight software and ground station software, CASPER and ASPEN.

- NASA's Goddard Space Flight Center develops the Space Cube Mini payload processing unit.

- Cal Poly designs the space craft bus, cameras, attitude control, flight avionics software, and integrates/builds the flight unit.

Fitting a 1U Payload into a 1U CubeSat



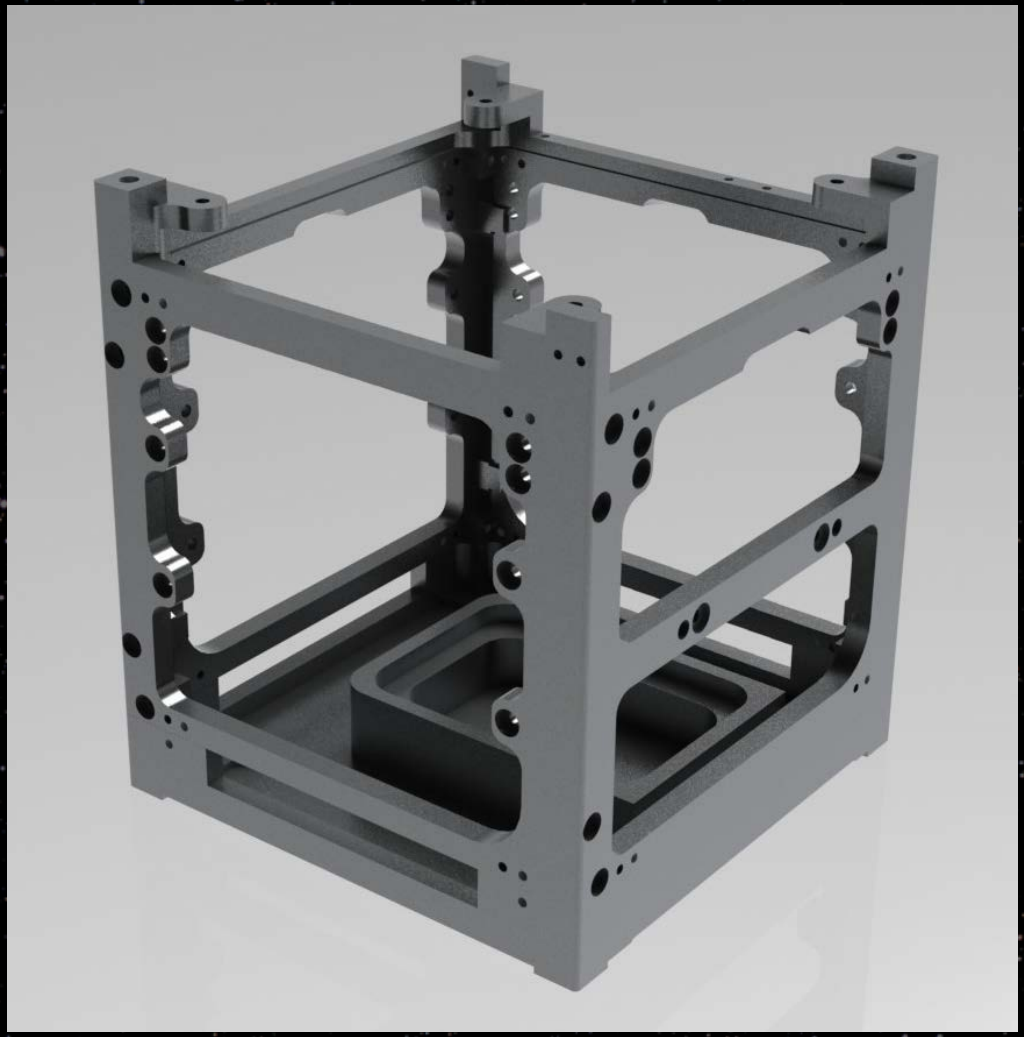
Detail of Spacecraft

1. Mechanical and Structural Components
2. Circuit Boards
3. Antenna Design
4. Passive Magnetics Design
5. Base Flight Software

Detail of Spacecraft

HyperCube

- Modular Design
  - Easily adjustable bracket mounts
- Modifications for IPEX
  - Added mount points to side panels for SC Mini
  - Added mount point for battery bracket
  - New Shoe design that incorporates battery mount
  - Chamfers for cameras
  - Mount point for antenna

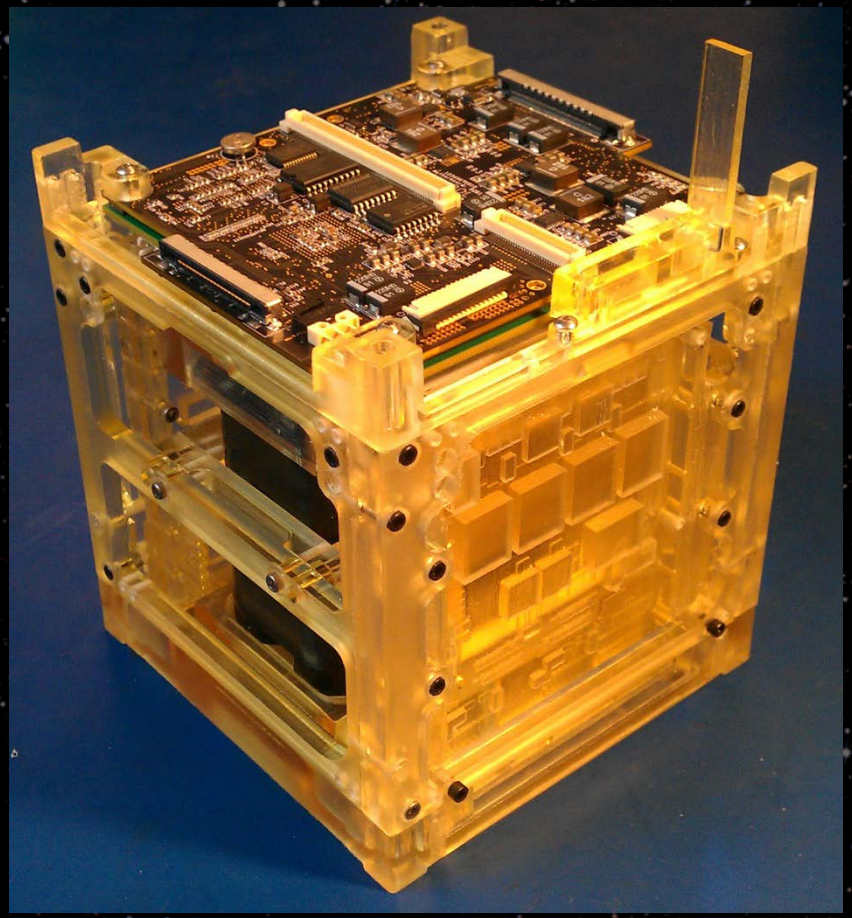


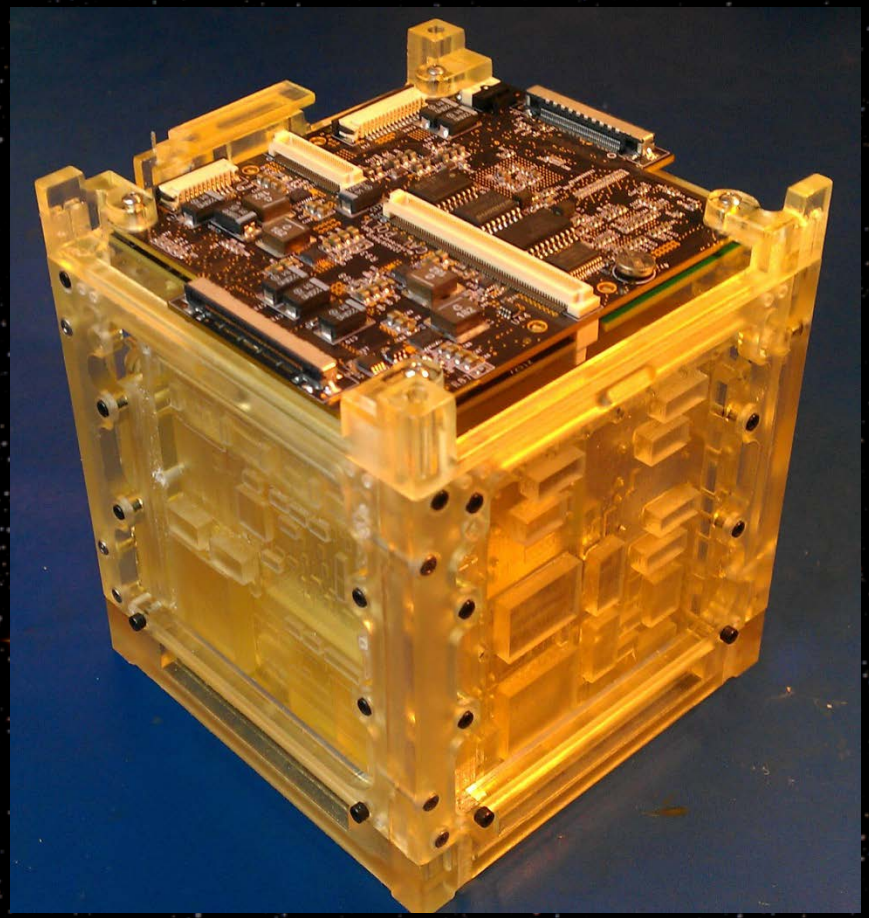
SpaceCube Mini Mounting

- Aluminum 6061 construction
- Brackets will dump heat to structure
- Additional heat can be routed to the batteries

Detail of Spacecraft

Assembled IPEX Rapid Prototype

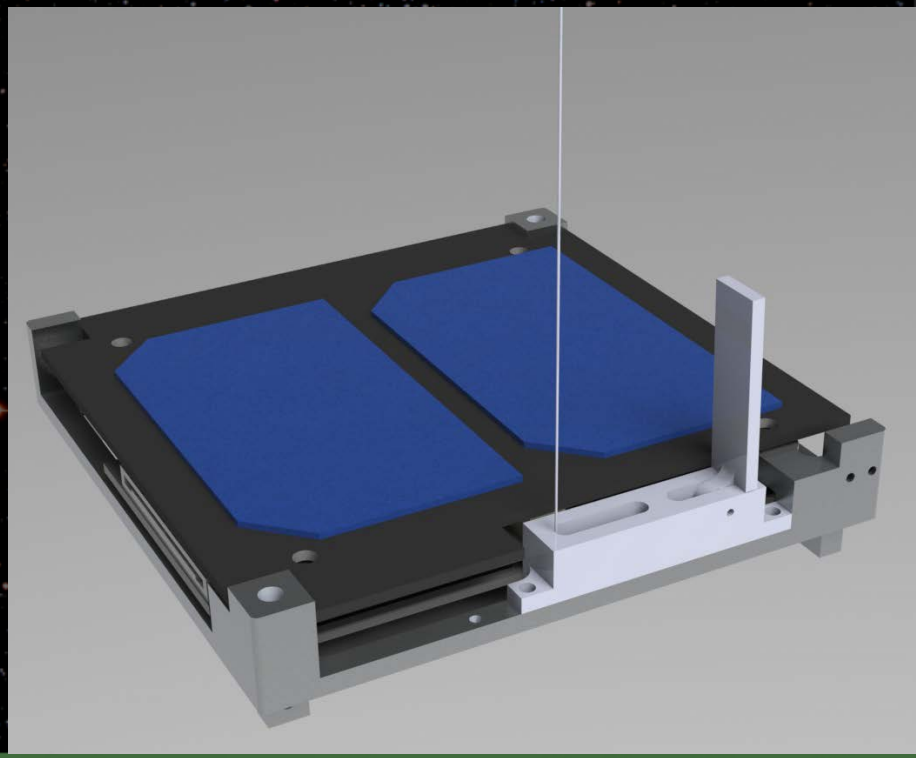




Detail of Spacecraft

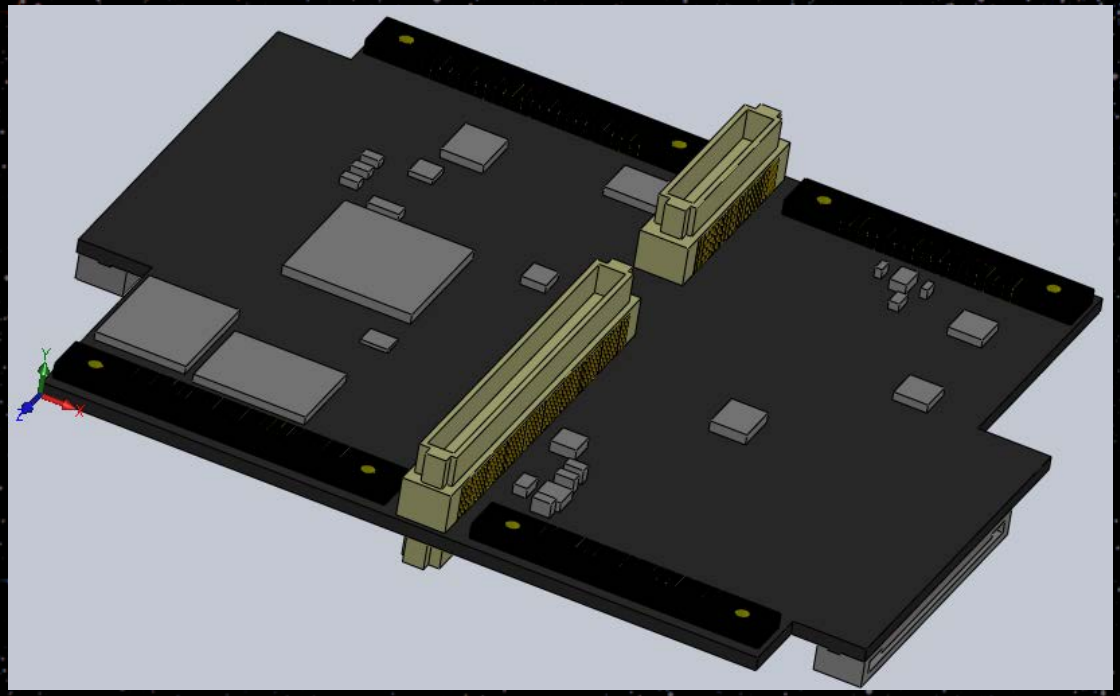
Deployable Monopole Antenna

- Monopole 70cm quarter-wave (17.5cm) NiTi wire antenna
- Spring loaded delrin stow container
- Burn wire deploy mechanism
- Mounts directly to the top hat



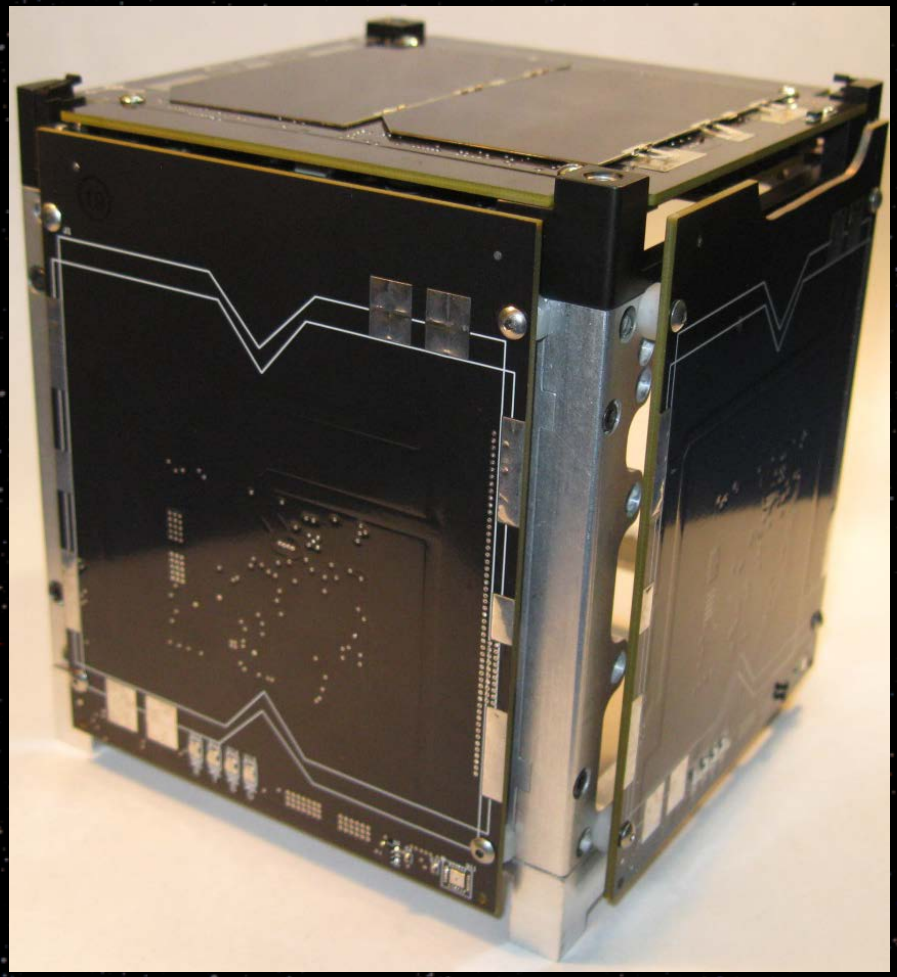
Circuit Board: Systemboard_R3

- Atmel AT91SAM9G20B Micro-Processor
- Power Supply to Side-Panels, Daughter Boards, Payload Interface Board
- Hardware Monitoring and Reboot Functionality



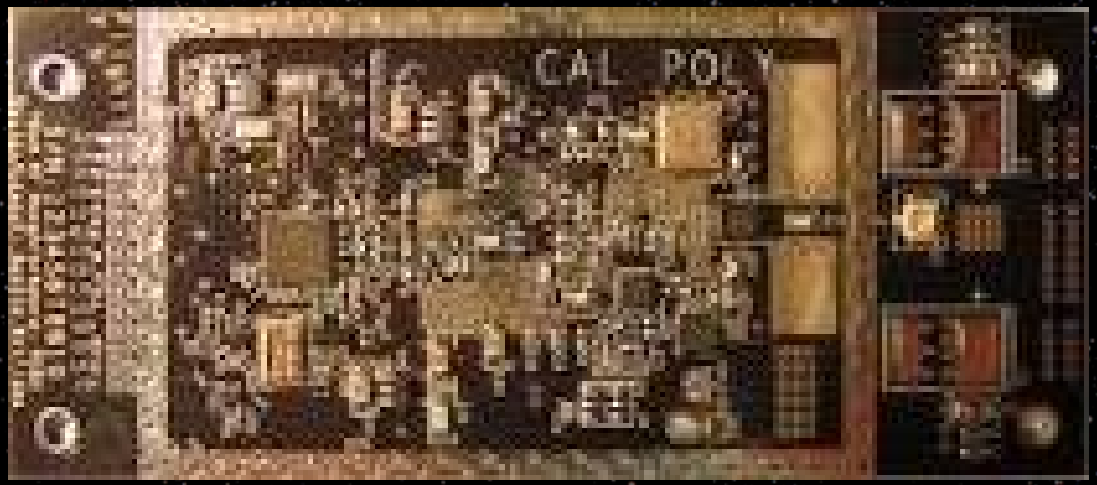
Circuit Board: Side-Panels R1

- Provides solar power from 2 UTJ Spectrolab solar panels (each)
- Embedded magnetorquers (not used on IPEX)
- Magnetometers and temperature sensors



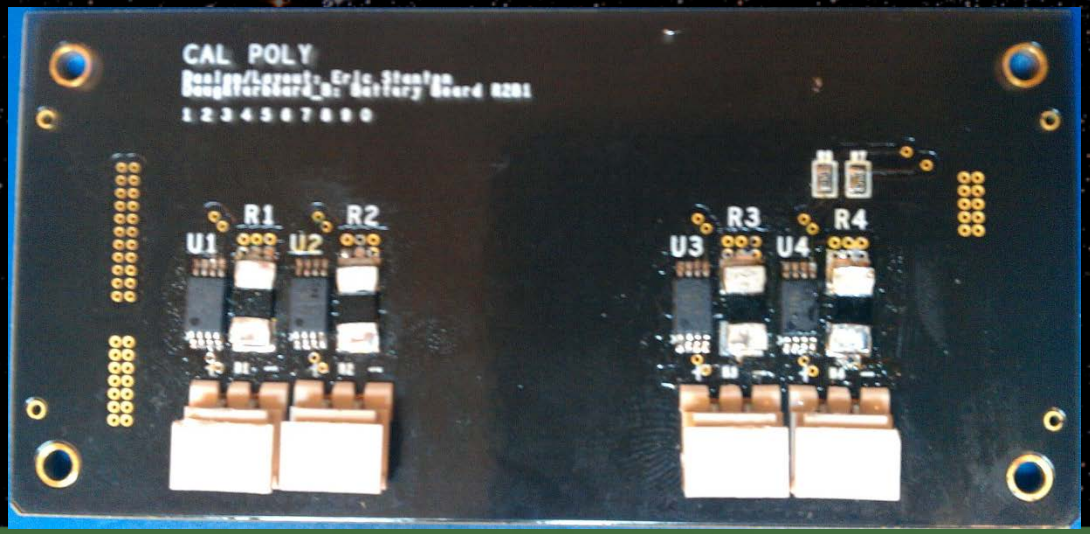
Circuit Board: UHF Communications Board R1

- Capable of a wide range of UHF frequencies
- Daughterboard A slot



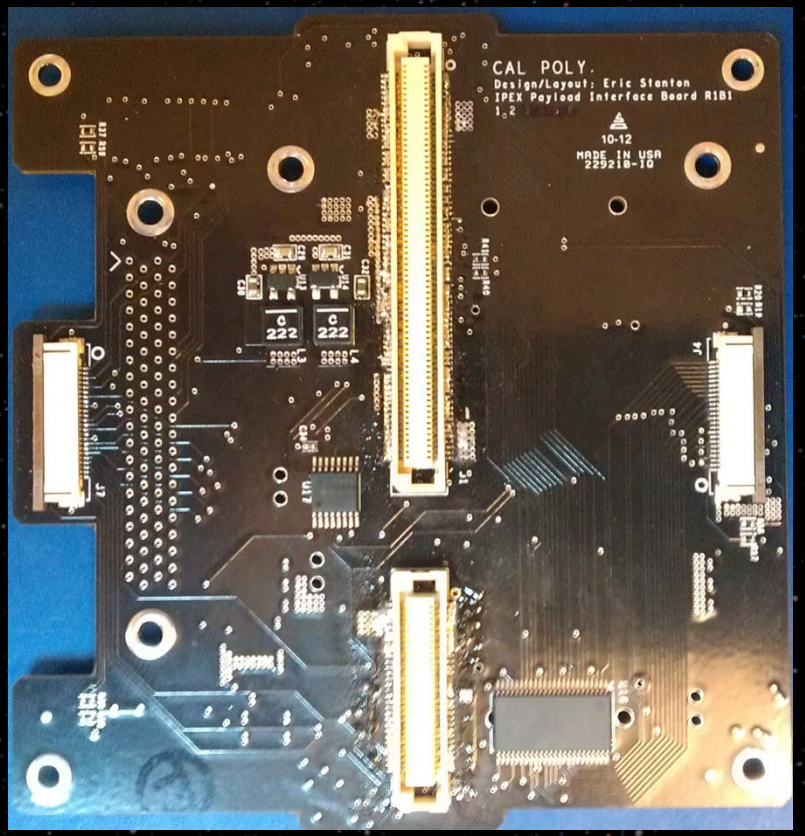
Circuit Board: Battery Monitor Board R2

- Battery connection and battery monitor circuits
- Daughterboard B slot
- Provides connections for up to 4 Rose Batteries (4500mAh, 3.6V), although only 3 will be used for IPEX
- Rose Batteries are UL listed and built-in protection circuit will not be removed
- Rose Batteries have been flown on CP2, CP3, CP4, CP5, and CP6.



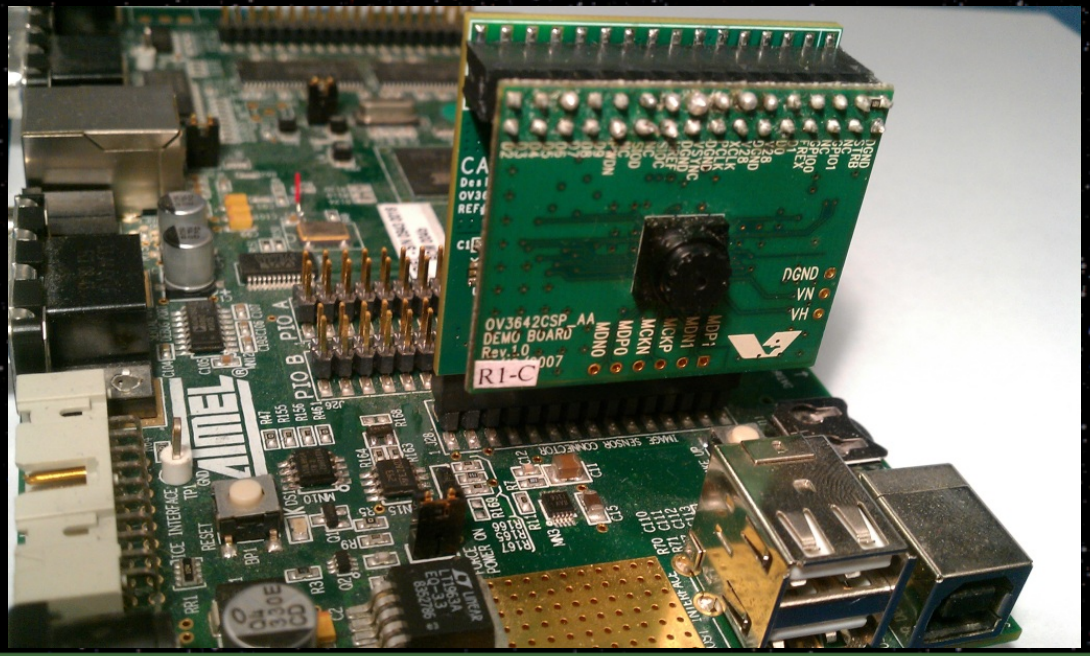
Circuit Board: Payload Interface Board R1

- Provides LVDS interface to Space Cube Mini
- Provides 5V0, 3V3, and 2V5 power supplies to Space Cube Mini
- Supports up to 4 OV3642 cameras
  - Images have been acquired through Atmel-OmniVision development boards (image on the second following page)



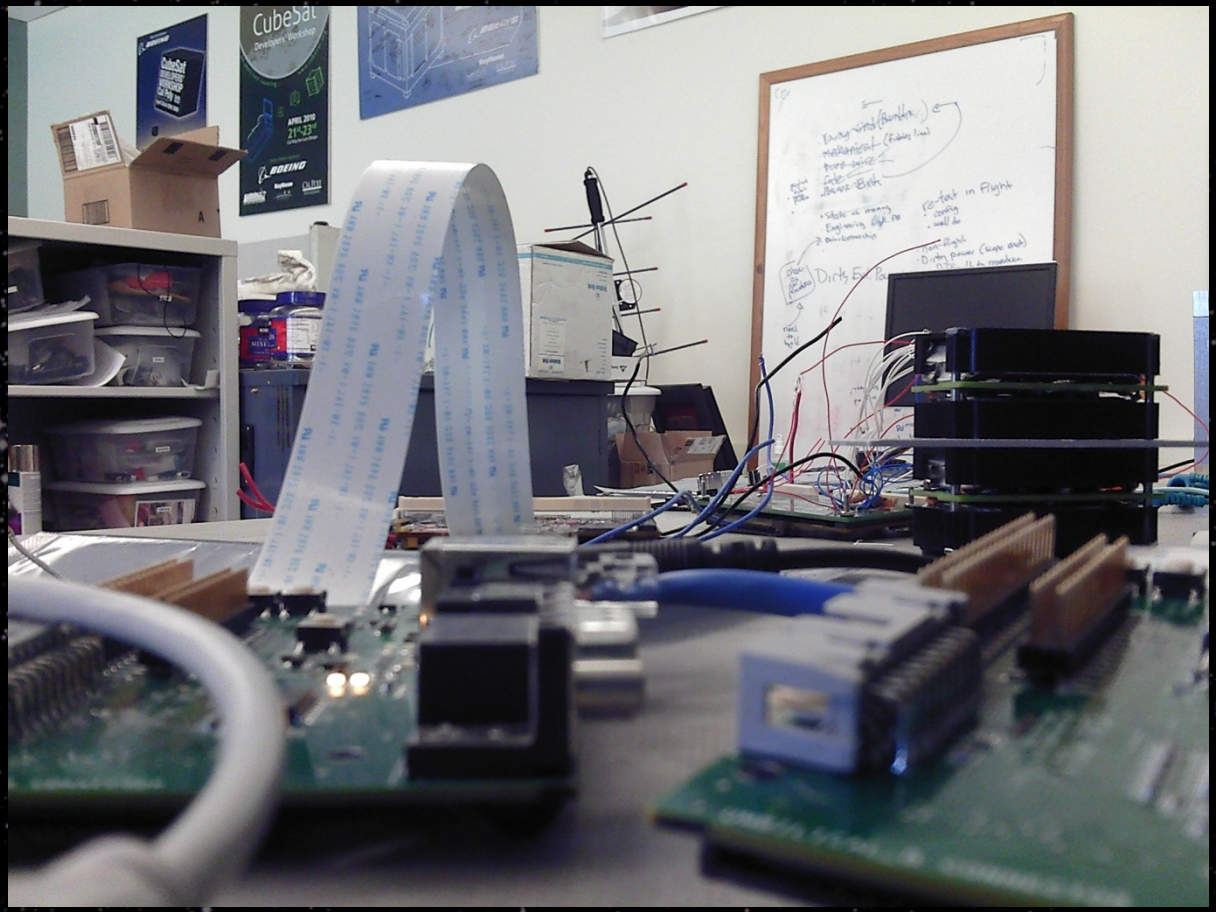
Circuit Board: Camera Development

- Interfaces the Atmel development board with the OmniVision OV3642 development board
- Allows testing for the camera's kernel driver image capture application



Circuit Board: Camera Development

One of the first images from the development board camera using the image capture test application.



Circuit Board: Camera Development

A rough calculation shows the limit on rotational velocity of the CubeSat such that we will obtain acceptable image quality without blurring.

Camera Specifications
Focal Length (f): 4mm
Integration Time (t_int): 67ms
Pixel Diameter (d_pixel): 1.75um

Calculate Instantaneous Field of View (IFOV)
IFOV = 2arctan(d_pixel/2f)
IFOV = 0.025 degrees

A commonly used value for pixel per rotation readout error such that blurring is unnoticeable is 0.1 pixels.

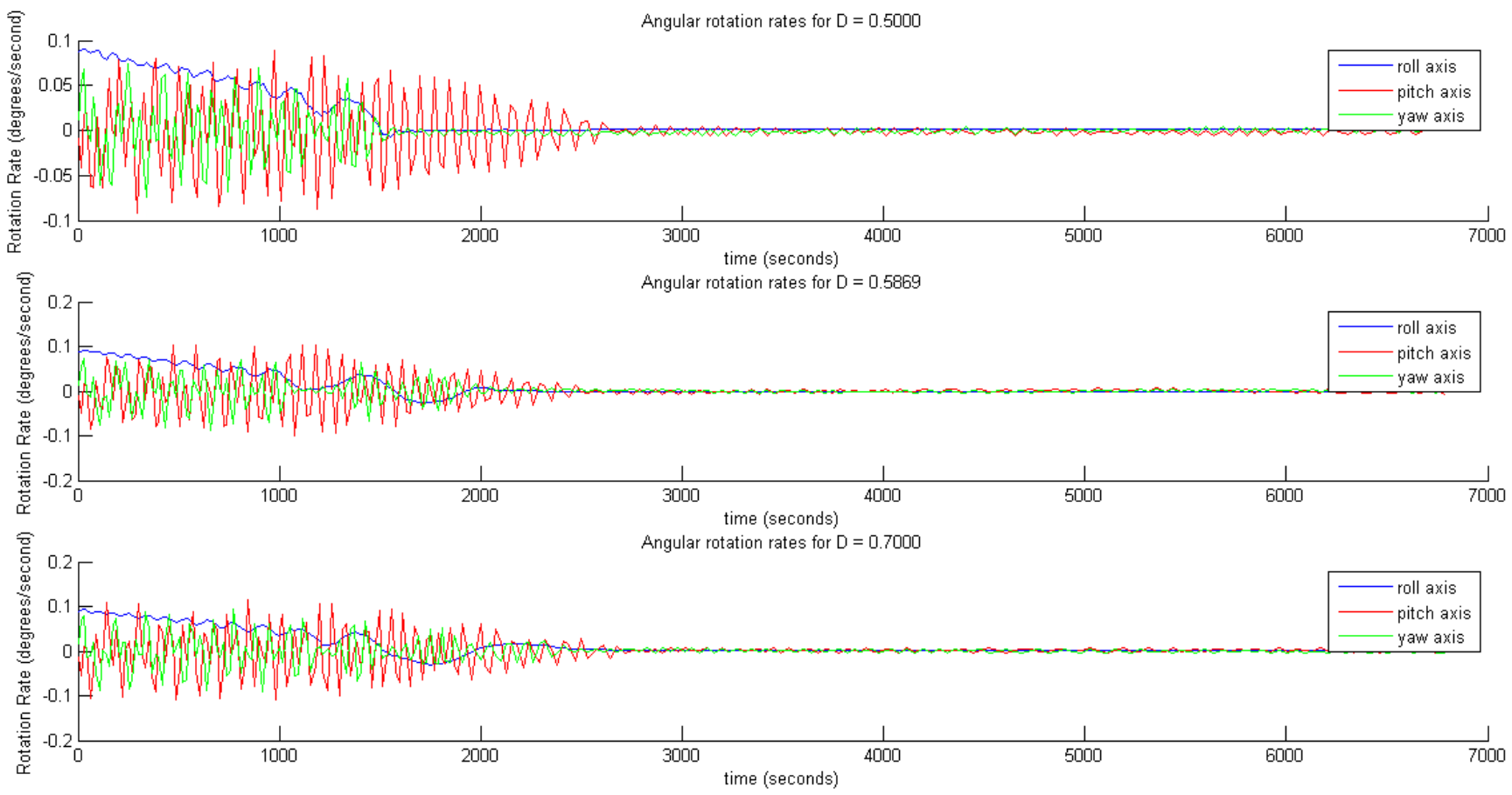
Calculate Maximum Acceptable Rotation Velocity (V_rad)
V_rad = (IFOV)(0.1 pixels/integration)/(t_int)

V_rad = 0.037 degrees/sec

Passive Magnetics Design

- Magnetic sizing and simulation using (KYSAT simulator program)
- Magnets will be placed along the inside of the structure's rails.
- Simulated results show that the stabilization is within 0.01 degrees/sec at steady state for each passive magnetic design.

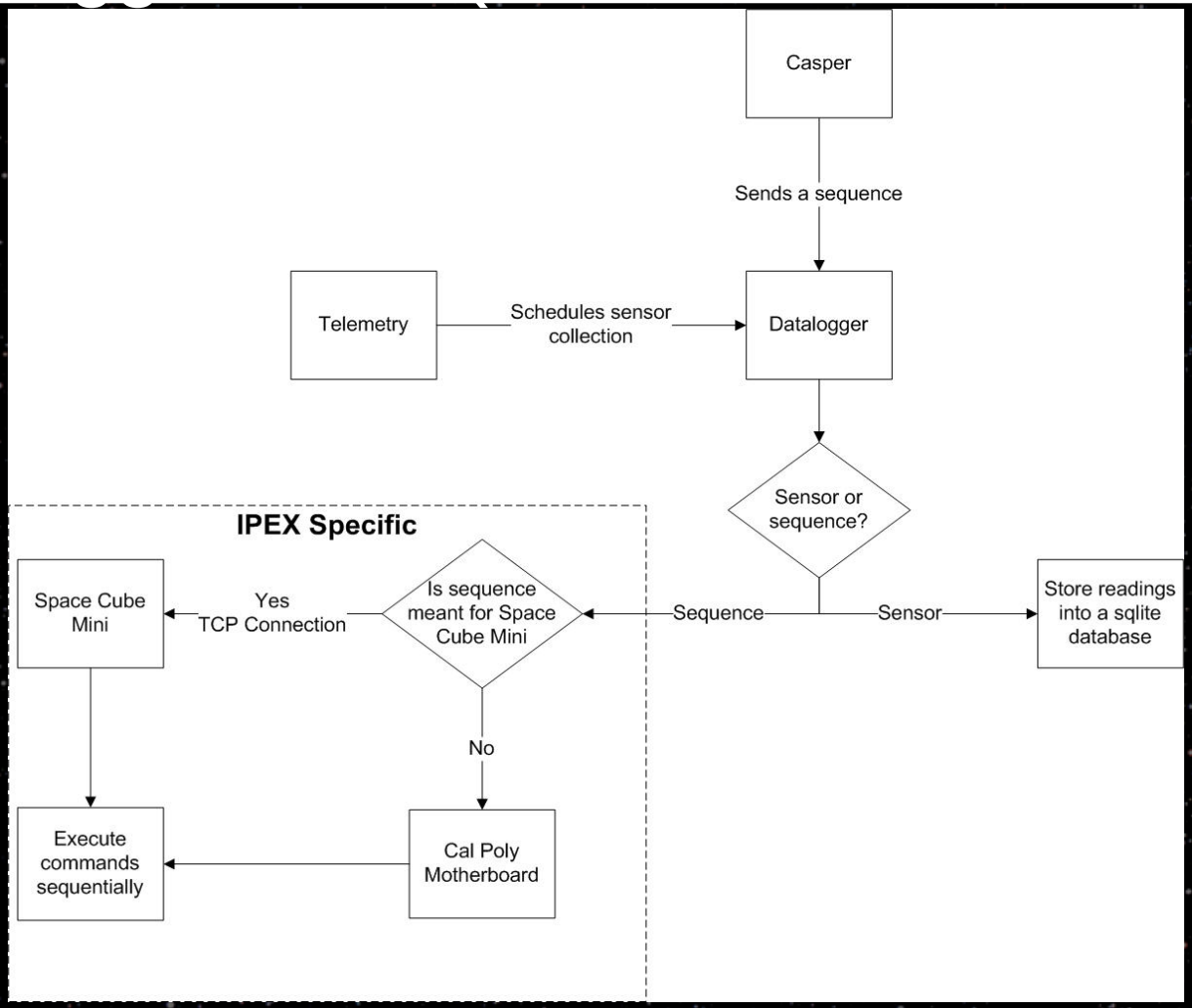
Passive Magnetics Design (rotation rate)



Software Overview

- Common Cal Poly base flight software
  - Process library
  - System Manager
  - Datalogger
  - Watchdog
  - Beacon
- PPP is run on top of the LVDS interconnect to create an IP connection between the Atmel and the Space Cube Mini. Standard IP-based protocols, such as UDP, SCP, and Rsync, will be used to send commands and data to the Space Cube Mini.
- IPEX Specific:
  - Space Cube Mini control process
  - Image capture
  - CASPER

Datalogger Flow (with IPEX Additions)



Operations

1. Power Budget
2. Communications Plan

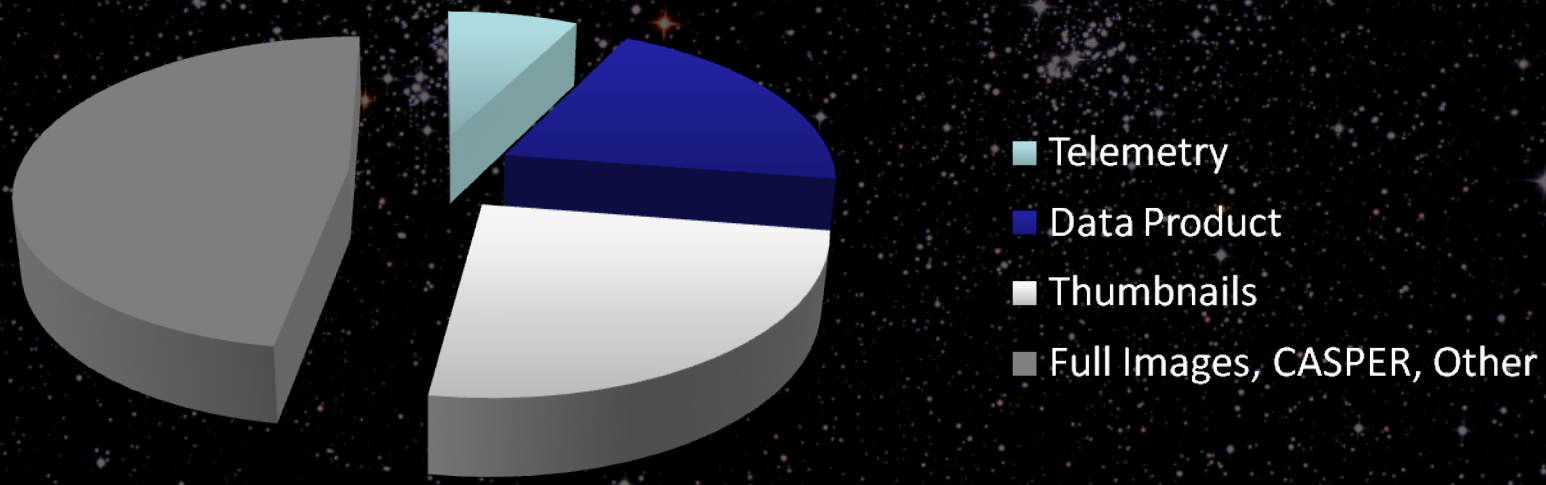
Power Budget Summary

- Space Cube Mini duty cycle based on longest eclipse time for sustained operations: 1.7%
- Transmitter Duty Cycle: 15%
- Max run time of Space Cube Mini (including stand-by power and regulator efficiencies) based off total battery energy: 3 hours

Stand-by	300mW
Taking a picture	350mW
Transmitting	2W
Running Space Cube Mini	11.2W
Average input power	2W

Communications Plan

- Operations are primarily automatic, managed by Cal Poly
- Solicit assistance from the HAM community to collect some data (e.g., telemetry from beacons)



Questions

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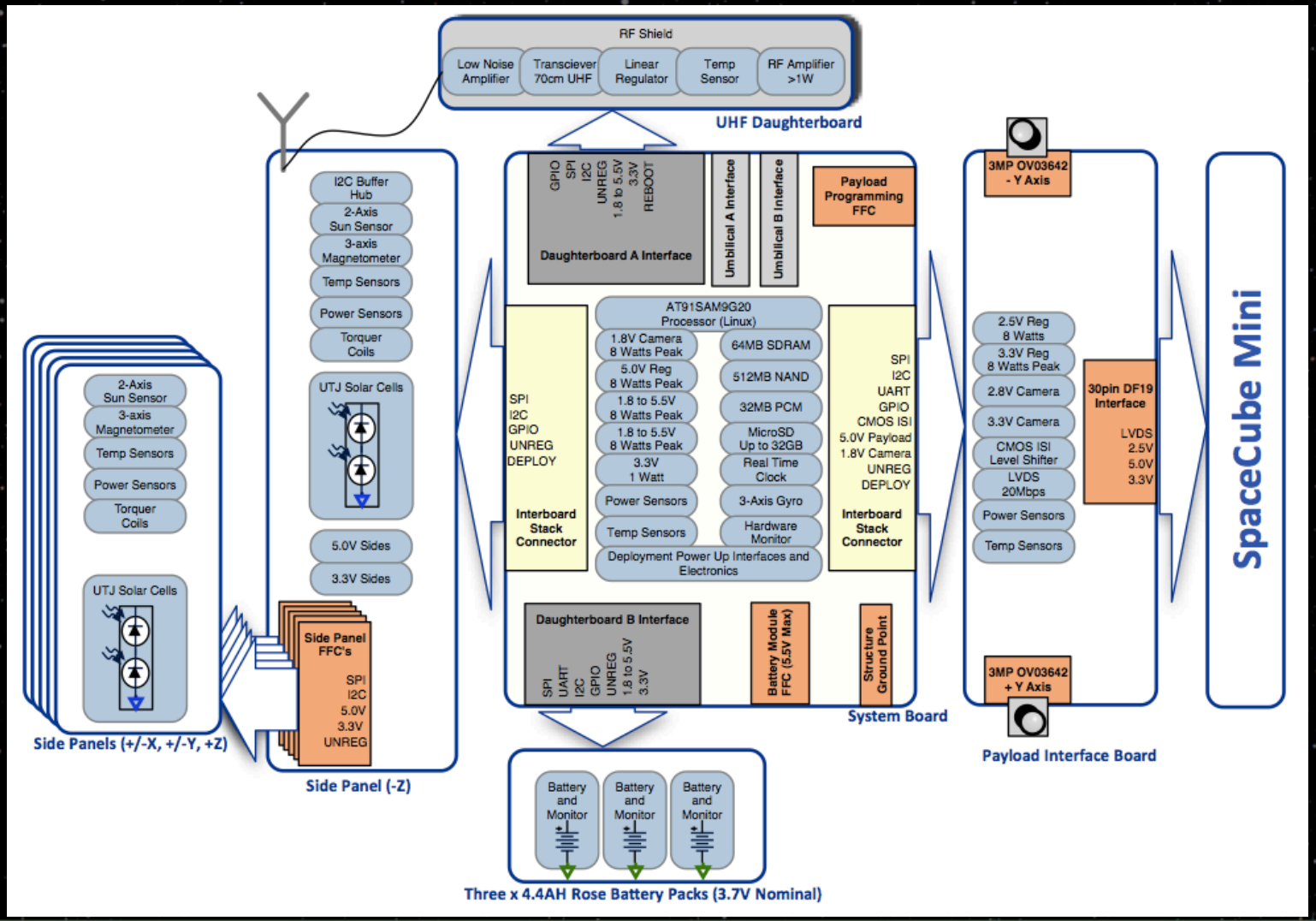
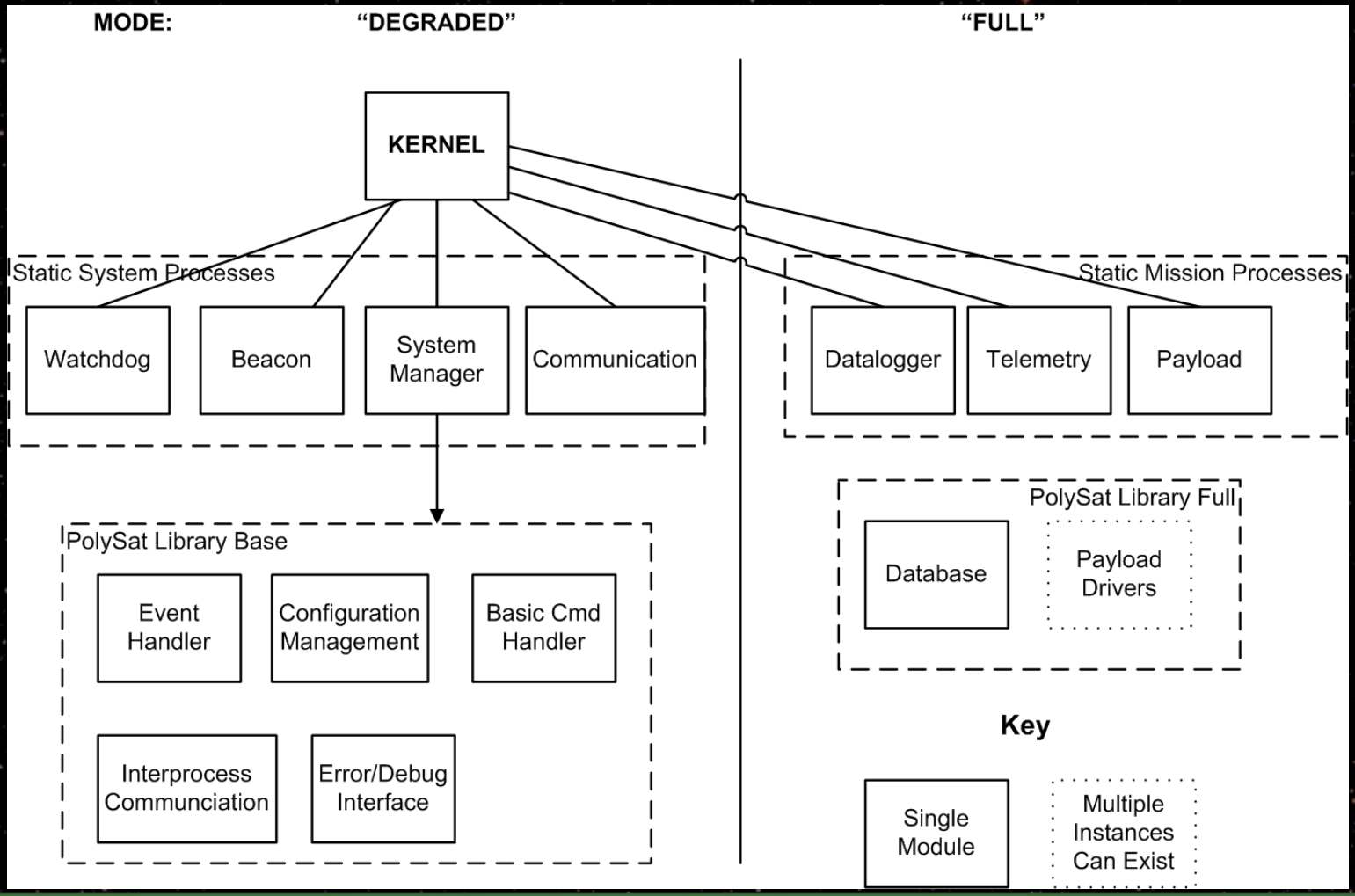
Electronics Diagram



Detail of Spacecraft

Architecture Overview



Day-in-the-Life Operations

- Imagers operate in daylight as prompted by CASPER
  - Up to 12 fps
  - Atmel could filter images or send all raw images to Space Cube Mini
- Space Cube Mini batch processing during eclipse, power permitting (4% duty cycle)
  - Space Cube Mini off during ground contacts
- Atmel batch processing