IPEX
Maximizing 1U Payload Potential

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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
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

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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

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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

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Circuit Board: Systemboard_R3

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

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.
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

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

**Calculate Instantaneous Field of View (IFOV)**
\[
\text{IFOV} = 2\arctan\left(\frac{d_{\text{pixel}}}{2f}\right)
\]

**Calculate Maximum Acceptable Rotation Velocity (V_rad)**
\[
V_{\text{rad}} = \frac{\text{IFOV}(0.1 \text{ pixels/integration})}{(t_{\text{int}})}
\]

\[
V_{\text{rad}} = 0.037 \text{ degrees/sec}
\]
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)

Angular rotation rates for D = 0.5000

Angular rotation rates for D = 0.5889

Angular rotation rates for D = 0.7000

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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)

- **Casper** sends a sequence.
- **Telemetry** schedules sensor collection.
- **Datalogger** processes the sequence.
- **IPEX Specific**
  - **Space Cube Mini**
    - Yes: TCP Connection
    - No: Execute commands sequentially
  - **Is sequence meant for Space Cube Mini**
    - Yes: Cal Poly Motherboard
    - No:
  - **Sensor or sequence?**
    - Yes: Store readings into a sqlite database
    - No:

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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

<table>
<thead>
<tr>
<th>Activity</th>
<th>Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand-by</td>
<td>300mW</td>
</tr>
<tr>
<td>Taking a picture</td>
<td>350mW</td>
</tr>
<tr>
<td>Transmitting</td>
<td>2W</td>
</tr>
<tr>
<td>Running Space Cube Mini</td>
<td>11.2W</td>
</tr>
<tr>
<td>Average input power</td>
<td>2W</td>
</tr>
</tbody>
</table>
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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Architecture Overview

MODE:

"DEGRADED"

KERNEL

Static System Processes

Watchdog  Beacon  System Manager  Communication

PolySat Library Base

Event Handler  Configuration Management  Basic Cmd Handler

Interprocess Communication  Error/Debug Interface

"FULL"

Static Mission Processes

Datalogger  Telemetry  Payload

PolySat Library Full

Database  Payload Drivers

Key

Single Module

Multiple Instances Can Exist
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