

Command and Data Handling and Flight Software

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4/24/24–CubeSat Developers Workshop 3

3UCubed: 3 Universities; 3U CubeSats; Upwelling, Uplifting Undergraduates

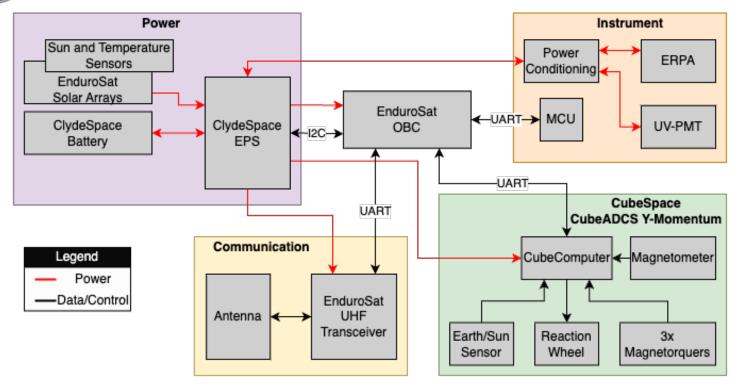


Introduction

- The IMAP Student Collaboration goals are *to augment IMAP science return, develop hands-on research experience for students, and contribute to diversifying space science.*
- **3UCubed**: 3 Universities; 3 CubeSats; Upwelling, Uplifting Undergraduates
- Three universities: Sonoma State University, Howard University, University of New Hampshire
 - Each university builds their own EM (3 EMs).
 - Our measure of success is to deliver to CSLI and launch one CubeSat (1 FM).
 - a strong recruitment and retention program, with a dedicated online community.
- Mission model
 - Two instruments being developed, combined size $\leq 1.5 U$
 - Joint work on the design between the three universities with specific work aligned with experience (UNH on instrument, SSU on ground station and FSW, HU on thermal).







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Instrument Design

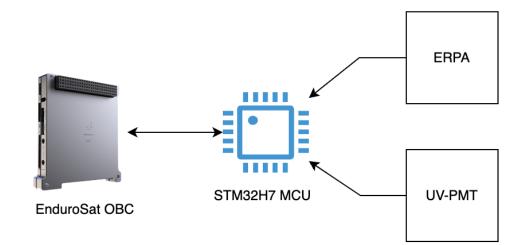
• Two Instruments:

- Ultraviolet-Photo-Multiplier-Tube (UV-PMT)
- Electron Retarding Potential Analyzer (ERPA)

• STM32 Microcontroller Unit:

- Collects analog data from instruments
- Packetizes instrument data
- Sends data to OBC

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Instrument Data Packets

- Instrument data split into packets
 - Each ERPA packet: 48 bits
 - Sent to OBC every 6.25ms
 - Each ERPA HK Packet: 48 bits
 - Sent to OBC every 6.25ms
 - Each UV-PMT packet: 48 bits
 - Sent to OBC every 125ms
 - Each Housekeeping packet: 228 bits
 - Sent to OBC every 5s
- During testing, instrument MCU sends data to a computer
 - Computer runs GUI program to interpret and display incoming data

ERPA Packet Structure

| SYNC | SEQ | ERPA | SYNC | SEQ |
|--------------------------|-----------------------|-------------------|-----------------------------|---------------------|
| Fixed 2-byte hexadecimal | 2-byte packet counter | ERPA data reading | Fixed 2-byte hexadecimal | 2-byte pack counter |

UV-PMT Packet Structure

| SYNC | SEQ | РМТ | | |
|--------------------------|-----------------------|------------------|--|--|
| Fixed 2-byte hexadecimal | 2-byte packet counter | PMT data reading | | |

Housekeeping Packet Structure

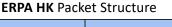
| SYNC | SEQ | МСИнк | TMP x4 | V мон х9 |
|--------------------------|-----------------------|---------------------|---------------------|-------------------------|
| Fixed 2-byte hexadecimal | 2-byte packet counter | MCU Housekeeping | I2C temp sensors | Voltage Monitor ADCs |

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SWDMON



| | | 5140 | | SWI MON | | |
|--|--|--------------------------|-----------------------|-----------------------------|--|--|
| | | Fixed 2-byte hexadecimal | 2-byte packet counter | ERPA SWP voltage reading | | |

SSU 🖑

Instrument Test with Computer

- Student created graphical user interface for reading instrument and instrument-MCU Data.
 - Ability to control behaviors of instrument MCU
 - Enable GPIOs
 - Increase SWP DAC output
 - Put MCU into Sleep Mode (Lowpower)
 - Wake MCU up from sleep

| | | | IS Packet Interpreter | | | | |
|----------------|-------|--------|-----------------------|--------|------------------------|----------------|--|
| X | | | | | | | |
| CONTROLS | | | | | | | |
| @sys_on PB5 | | | | | | | |
| @ 3v3_en PC7 | | | | | | | |
| @ 5v_en PC10 | SYNC: | OXBBBB | SYNC: | OXAAAA | HK P. SYNC: | ACKET O | |
| | SEQ: | 1240 | SEQ: | 1607 | SEQ: | 1468 | |
| ⊚n3v3_en PC6 | ADC: | | ENDmon: | | vsense: | | |
| Suggest of | 1.00. | | SWP MON: | | vrefint: | | |
| | | | | | TMP1: | | |
| @n5v_en PC8 | | | TEMP1: | | TMP2: | | |
| | | | TEMP2: | | TMP3: | | |
| @ 15v_en PC9 | | | ADC: | | TMP4: | | |
| | | | | | BUSvmon: | | |
| @n200v_en PC13 | | | | | BUSimon: | | |
| Gurrent ene | | | SDN1 HIC | PH - | 2v5mon: | | |
| | | | | | 3v3mon: | | |
| 800v_en PB6 | | | SDN2 HIC | SH | 5vmon: | | |
| - | | | | | n3v3mon: | | |
| Step Up 🔒 | | | | | n5vmon: | | |
| | | | | | 15vmon: | 2.662 | |
| | | | | | 5vrefmon: n200vmon: | 2.685 2.907 | |
| Step Down 븆 | | | | | n800vmon: | 0.000000 | |
| | | | | | noovinon. | | |
| | | | | | | | |
| Sleep | | | | | | | |
| 100 | | | | | | | |
| Wake Up | | | | | | | |
| | | | | | | | |
| 12 | | | | | | | |
| RECORD | | | | | | | |
| | | | | | | | |
| | | | | | | | |

Student-created instrument data graphical user interface

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On Board Computer

UART

Message Queue

UART Interrupt

OBC

Data Cache

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Data Saving Task

Data Processing

- Instrument data is sent to the OBC via UART
- Data goes through a series of steps before it can be sent down to Earth
- Note:
 - \odot Interrupt limitations
 - \circ Inter-thread communication
 - More steps between SD Card and Ground station ConOps!



SD Card

Radio

Groundstation

ConOps

- The OBC goes into different states depending on the status of the satellite
- Safe

 \circ Power up/Error

- Detumbling
 - $\circ\,$ Too much spinning
- Communication

 \circ Ground station in range

- Science
 - $\circ\,$ Orbit in position for data collection
- Idle
 - o Default state

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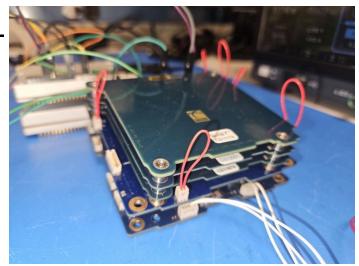
SCIENCE DETUMBLE SAFE IDLE 65≤GLAT≤80 Process Store raw OBC STATE Deployment instrument data instrument data 30-minutes delay If GS uplink received Downlink HK and Collect raw Power up instrument data instrument data Est: MEMS Rate Con: Detumble/Fast ormal Detumble Detumble If w>threshold Est: MEMS Rate lḟ ω⊲threshold Con: YSpin ADCS Est: FullEKF Con: YMomInit Est: FullEKF Est: FullEKF Est: FullEKF Con: YMonNadir Con: YMonNadir Con: YMonNadir Instrument Instrument Instrument Instrument INSTRUMENT start-up sleep sleep sleep Instrument ADC turned on

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Electrical Power System

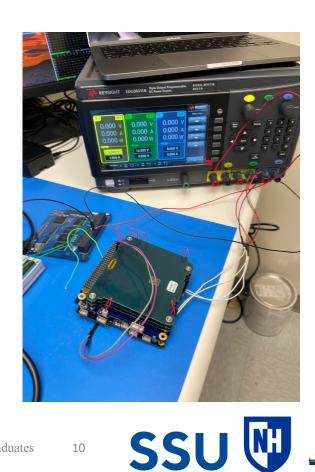
- I2C based ClydeSpace model 25-02452 EPS, alongside ClydeSpace BAT(battery) model 01-02685
- **Telecommands** are the foundation of commanding the EPS
 - o Write commands: establish events
 - Read commands: return resultant of a given event
- **Telemetry** data enables the OBC to monitor the continual operations of the EPS





Pre-Integration Testing

- Fabricated basic user interface to force OBC • commanding of ClydeSpace EPS using Endurosat SDK (software development kit) and customized FIDL file
 - Enabled for functionality testing of OBC and EPS communication
 - Ensured I2C network was functional
- Functionality testing included:
 - Obtaining the board status
 - Incrementing and reading the manual reset count
 - Powering the PDUs(Power Distribution Units) and checking their voltage/current



Electrical Power System Integration

- Integration focused on ClydeSpace EPS with Endurosat SDK generic EPS driver
- ClydeSpace telecommands needed to be **mapped** to Endurosat telecommands
- All commands that were **unsupported/supported** by ClydeSpace were **removed/added** from EnduroSat generic driver
- ClydeSpace EPS does not have a PIU (Power Integrated Unit mainboard) therefore housekeeping data needed **manual collection** implemented
- Communication with BATT was introduced in housekeeping collection

 EPS could not provide necessary telemetry for battery daughterboard data





Thank you

Any Questions?

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