The Colorado Student Space Weather Experiment (CSSWE)

Command & Data Handling
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Objectives

- **Science Objectives**
  - Understand the relationships between solar energetic protons (SEPs), flares, and coronal mass ejections (CMEs)
  - Characterize the variations in Earth’s radiation belt electrons
- **High energy solar particles** $(p^+, e^-)$ **travel along** magnetic field lines
  - Oscillate between N and S magnetic pole
CubeSat Overview

- Subsystems
  - EPS
  - C&DH
  - REPTile
  - Structures
  - ADCS
  - Systems
  - COMM
  - INTF
  - Thermal
REPTile

- Relativistic Electron and Proton Telescope integrated little experiment (REPTile) to measure dangerous energetic electrons and protons

Motivation
- Potentially fatal to spacecraft and astronauts
- April 5, 2010 - Intelsat Galaxy 15 fails due to unexpected particle flux increase
C&DH Overview

Requirements

- Command REPTile to take science data
- Gather HK data from the CubeSat subsystems
- Perform fault detection and correction (FDC)
- Send science and housekeeping data to COMM
- Receive commands from ground station
- Provide a single-wire reset to all powered subsystems
Mission Timeline

(T-0) Launch

(T+2h) Deployment, Start-up

(T+12h) Antenna Deployment

(T+1.5d) Power Stabilization, Beacon Begin

(T+30d) Begin science ops

(T+14d) GN Contact, Spacecraft Commissioning
C&DH Block Diagram

AX.25 : 256 bytes downlink to GN

21 (science) 3 (time stamp) 6 (ADCS)

2 CRC + (8 x 30 bytes) + 1 Header + 13 Extra = 256 bytes
C&DH Hardware - Pumpkin

- The flight module has two components
  - Motherboard
  - PPM A3 – MSP430F2618
- Both are provided by Pumpkin

- SD Card – SanDisk 2GB
- Pumpkin development board – Pumpkin Inc.
- TI MSP430F2618 64 pin target board + debug tools
C&DH Software

- **Salvo Real-time Operating System (RTOS)**
  - Co-operative RTOS
  - Works with CrossWorks IDE (Rowley Associates)

- **EFFS-THIN Library – HCC Embedded**
  - API for accessing file-system on SD-Card
  - Library only available
C&DH- COMM Interface

- GMSK Modem
- MSP430F 2618
- C&DH

Data Bus
- Parallel
- I/O Control
- Registry Control

Science, HK & Commands
- SPI
- Reset Signals

SPI

Host Microcontroller
REPTile Data – C&DH

- C&DH collects REPTile data
  - Every 6 seconds (top most priority – receiveTask)
  - Useful Science Data at high latitudes

- Data dumped based on Two Timestamps
  - Timestamps resistant to C&DH reset

- REPTile
  - Magnetometer
  - Timestamp
  - Housekeeping
  - Packet Margin – 13.2%

- 545,642 bytes of data every day
Science Data Packet Format

- Science data stored on SD card in samples (30 bytes)
- Science data - packetized in 256 byte chunks (AX.25)
  - 1 packet per 48 seconds = 461 KB/day
  - Note, not all of the science data will be down-linked
- 3 byte timestamps allows for 6 months with 1 second resolution

<table>
<thead>
<tr>
<th>Header (1 byte)</th>
<th>8 samples (240 bytes)</th>
<th>Checksum (2 bytes)</th>
<th>Extra (13 bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timestamp (3 bytes)</td>
<td>REPTile science (21 bytes)</td>
<td>Magnetometer (6 bytes)</td>
<td></td>
</tr>
</tbody>
</table>
C&DH Architecture – Operational Modes

SAFE

GN Command

Time-out/Battery charge

Battery charge

TRANSMIT

SCIENCE

GN Command

Time-out/Battery charge

GN Command

CONFIGURATION

Time-out/ Config Complete

GN Command
Summary

- C&DH Operational Modes
- RTOS vs Infinite Loop
  - Decision should be based on a thorough study of requirements
- Communication Interfaces – SPI, I²C
  - SD Card
  - SPI – faster throughput than I²C
Thank You !!

Questions ?
BACKUP SLIDES
C&DH Architecture – Operational Modes

- **SAFE**
  - Beacon 0 – Lowest Power Mode (C&DH+COMM)
    - Battery 25% charge, Lowest Beacon Rate
  - Beacon Min – C&DH + COMM + EPS HK
    - Battery 40% charge, Min. Beacon Rate
  - Beacon Max – C&DH + COMM + All HK, Max. Beacon Rate
    - Battery 80% charge, Max. Beacon Rate

- **SCIENCE**
  - scienceTake – Turn on REPTile, I²C Ready
    - Poll EPS HK, Turn on Reptile, USCI_B0 Ready
  - scienceReceive – dedicated I²C (USCI_B0 Module), shared I²C (USCI_B1 Module)
    - Receive REPTile, ADCS science data
  - RTCReceive – shared I²C (USCI_B1 Module)
    - Receive Time-stamp data from RTC
  - scienceStore – dedicated SPI (USCI_A1 Module)
    - Store Science Data Sample in SDCard
  - HKReceive - shared I²C (USCI_B1 Module)
    - Receive HK data
  - HKStore - dedicated SPI (USCI_A1 Module)
    - Store HK Data Sample in SDCard
C&DH Architecture – Operational Modes

- Transmit
  - scienceRetrieve - dedicated SPI (USCI_A1 Module)
    - Retrieve relevant time-stamp science data from SD Card
  - HKRetrieve - dedicated SPI (USCI_A1 Module)
    - Retrieve relevant time-stamp HK data from SD Card
  - sendData - dedicated SPI (USCI_A0 Module)
    - Send Science, HK data samples to COMM via USCI_A0

- Configuration
  - Default
    - Configuration parameters, change mode
Communication Interfaces

- **SPI**
  - Full duplex communication
  - Higher throughput than \( I^2C \)

- **\( I^2C \)**
  - Half duplex communication
  - 100 kbit/s (up to 3.4 Mbit/s)
Command Data Packet Format

- Command Data Packet routed by COMM to C&DH
- Data packet size follows AX.25 format– 256 bytes
- Functional op-code identifies configuration parameters – Beacon period, HK Data collection frequency, depth of discharge for safe mode, ignore HK data, time-out, turn off specific detectors, C&DH reset (by COMM)
Operational Modes

**Safe Mode**
- **Launch**: Power Disconnected
- **Charging**:
  - 10% Charge (EPS)
  - 15% Charge (EPS)
  - 20% Charge
  - 30% Charge
- **Beacon 0**
- **Beacon Min**
- **Beacon Max**

**Science Mode**
- **TRANSMIT**
- **Science**

**Fault Detected**
- Or 40% Charge

**Ground Network Command**
- Link time-out

**Ground Network Command**
- All systems on, science on

**Science Mode**
- All systems on, pause science
- GN commands -> COMM
- GN commands -> C&DH

**Operational Details**
- Ground Network Command
- Ground Beacon Command
- Link time-out
Microcontroller Unit

MSP430F2618 MCU

- Low power
- Shared design and programming environment with C&DH
- Shared learning curve with C&DH
- Relatively few external components required
GMSK Modem

SX1231 UHF Modem Transceiver

- GMSK Modulation
- Provides majority of Front End
- Requires few external components
- Low power consumption
- Variable transmit power
Software Flow Diagram

Start COMM Processor

New data && There are < 5 outstanding ACKs

Yes

Packetize Data

Calculate CRC

Send to GN (with Bit stuffing)

No

Listen for new data from GN

If new data from GN

Yes

Decode Packet

No

Update ACK count

Retransmit unACKed packets

If ACK time expired

Yes

Send command to C&DH

No
C&DH - Tasks Interaction

<table>
<thead>
<tr>
<th>Priority</th>
<th>Task</th>
<th>CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Check Devices</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Command Task</td>
<td></td>
</tr>
<tr>
<td></td>
<td>External Interrupt</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Command Task</td>
<td></td>
</tr>
</tbody>
</table>

SCIENCE MODE

<table>
<thead>
<tr>
<th>Task</th>
<th>CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive Science</td>
<td></td>
</tr>
<tr>
<td>Store Science</td>
<td></td>
</tr>
<tr>
<td>Poll HK</td>
<td></td>
</tr>
<tr>
<td>Poll HK</td>
<td></td>
</tr>
<tr>
<td>Store HK</td>
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Time

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