KySat Space Express CDR

University of Kentucky
Lexington, Kentucky
29 October 2007

http://www.kysat.com
Overview

- Mission Background
- Hardware Systems
- Flight Software
- Mechanical Systems
- Communication Systems
- Ground Software
- WSMR Logistics
Mission Background
Mission Objectives

- Did you get to space?
- Did it work?
- Training Mission
- Flight Testing Hardware and Software
- Flight Testing Processes
Launch Provider

- Lunar Rocket & Rover Co.
  - Launch vehicle: Shadow 1 DART Sounding Rocket
  - Launch site: White Sands Missile Range, NM
  - Flight time: 4 mins.
  - None Recoverable Payload
  - Launch Date: December 5th
Launch Requirements

- Weight will determine the final altitude of the rocket.
- The payload must remain *off* while on the launch pad until the rocket has started accelerating.
  - A re-settable RBF pin must be used. This pin must physically disconnect power from the payload when inserted.
  - An acceleration switch must be used to turn *on* the payload once the rocket has started accelerating; the payload cannot be active until the rocket has begun accelerating.
- The payload must be able to survive the environmental conditions of the Shadow 1 Rocket:
  - 47 G’s Acceleration, 2.1 sec. burn reaches 5,000 ft
  - 6 Hz Spin
  - 100C
  - Max Altitude of 150 Km
Shadow 1 Payload

- Hardware Payload Carrier
- Electrical Power System
- Command & Data Handling System
- Communication System
- Telemetry Payload
- Ground Station
Hardware Systems Review

Mr. Samuel Hishmeh
Requirements

- Provide Flight Hardware
  - EPS
  - Radio
  - Telemetry Hardware
  - Flight Processor
- Interface with Teams
  - Mechanical
  - Software
Hardware Overview

- Temperature
- 2 Axis Acceleration
- Pressure
- I2C ADC
- I2C
- MSP430
- UART
- JTAG
- VHF Radio
- MPXM2102A
- ADXL278
- ADR395
- 5V Ref
- 3.3V
- 5V
- 9V

Legend:
- Sensor
- Hardware
- Flight Processor
EPS Hardware

Electrical Power System
## Power Budget

### Battery 1

<table>
<thead>
<tr>
<th>Part</th>
<th>Supply V</th>
<th>Max i (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Sensor</td>
<td>3.3</td>
<td>0.400</td>
</tr>
<tr>
<td>Pressure Sensor</td>
<td>5.0</td>
<td>6.000</td>
</tr>
<tr>
<td>MSP430</td>
<td>3.3</td>
<td>5.000</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>5.0</td>
<td>2.900</td>
</tr>
<tr>
<td>5V ADC Reference</td>
<td>9.0</td>
<td>0.140</td>
</tr>
<tr>
<td>I2C ADC</td>
<td>5.0</td>
<td>1.000</td>
</tr>
<tr>
<td><strong>Total Current</strong></td>
<td><strong>15.44</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Battery Capacity</strong></td>
<td>580mAh</td>
<td></td>
</tr>
<tr>
<td><strong>Possible Flight Time</strong></td>
<td>37 hours</td>
<td></td>
</tr>
</tbody>
</table>

### Battery 2

<table>
<thead>
<tr>
<th>Part</th>
<th>Supply V</th>
<th>Max i (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro Track 300 Radio</td>
<td>5.0</td>
<td>180.0</td>
</tr>
<tr>
<td><strong>Total Current</strong></td>
<td><strong>180.00</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Battery Capacity</strong></td>
<td>580mAh</td>
<td></td>
</tr>
<tr>
<td><strong>Possible Flight Time</strong></td>
<td>3 hours</td>
<td></td>
</tr>
</tbody>
</table>
Testing

- Errors and Fixes
  - I2C ADC Input Voltage
  - Parallel Batteries Failed
  - Temperature Sensors
Risks

- Temperature
  - Battery Overheating
  - Radio Overheating

- Pressure
  - Battery Chemistry

- g Force
  - Solder Joints
  - Antenna Connector

- Component Failure
  - Acceleration Switch
  - Battery Failure
KySat

Flight Software Review

Mr. Tom Dodson
Requirements and Constraints

- The Micro Trak 300 will corrupt packets if sent too quickly, the minimum wait time between packets was empirically determined to be 1500 ms.
- The software should send packets as fast as possible, which, taking the limitations of the packet radio into account, is a single packet every 1.5 seconds.
Packet Format

- Packets represent discrete sensor samples
- Mission Time is the number of ticks of a 100Hz timer since startup or reset
- Temperature 0 is the temperature from the I²C temperature sensor
- Temperature 1 is read from the MSP430 temperature sensor
Send Packet

- Packet TX function is provided a set of raw telemetry points
- Raw data encoded with MIME codec for transmission over AX.25 link
- Data rate is limited, in software, to a single packet every 1.5 seconds in order to avoid corruption by the radio
Peripheral Allocation

- Timer A
  - Hardware timer (52μs resolution)

- Timer B
  - Mission time ticks (100 Hz)

- USART0
  - UART and SPI not used
  - I2C
    - Telemetry package
      - Temperature
      - Pressure (via I2C ADC)
      - Accelerometers (via I2C ADC)

- USART1
  - UART
    - VHF Radio
  - SPI not used

- ADC
  - Built-in temperature sensor
Changes since PDR

- Only one I²C temperature sensor
  - Schematic mistakes swapped the I2C data and clock lines
- Summary packets were dropped from the design
  - Selective retransmits were not implemented
  - Retransmitting summary information was not an effective use of limited bandwidth
- Salvo RTOS was not used
  - Single loop architecture was adequate for the design constraints
- RTC was removed from the design
  - 100Hz Timer B ticks were adequate for a 4 minute mission
  - RTC did not have sub-second accuracy
- Watchdog timer was added to design
  - Watchdog timer incorporated to reset processor if it is not ‘kicked’ every 4.4 ms
  - Has the side effect of resetting mission time, but the data can be easily rectified on the ground
  - Improves reliability in case of bugs, SEUs, or hardware glitches causing halting
Test Plan

- **Hardware testing**
  - Test integration of KySat1 code
  - Test telemetry package

- **Unit testing**
  - SW libraries (new codecs)
  - Tasks and/or high-level functions

- **Integration testing**
  - Software module had no user interactivity, so testing was performed by allowing the payload to operate on the bench for much longer than the expected mission time.
Risks

- Hardware failure during flight
  - Software cannot determine when a sensor has failed, but failure of a single sensor will not cause halting

- Bug causing halting
  - Watchdog timer
  - During testing, payload was left continuously operating on the bench for 10 mission times and did not halt or reset
Questions?
Mr. Michael Gailey

KySat

Mechanical Systems Review
Payload Carrier Requirements

- Snug fit into payload tube
- Hold/support payload, radio, antenna and battery
- Survive flight environment
- No RF interference
- Easy integration with LRR
Payload Carrier

- Rubber Duck Antenna
- Micro Trak 300
- PCB
- Batteries
- RBF switch
- Nose Cone
PCB Carrier Specs

- Length: 19 inches
- Diameter: 1.4 inches
- Hole Size: 1/8 inches diameter
- Board Size: 1in. x 6in.
- CG Location: ~6.9 in. from nose end
Materials

- Carrier: **Alumilite**
  - High temperature urethane
  - Good strength properties

- Board Coating:
  - Uncoated for initial delivery
  - **Parylene or urethane** coatings will be examined
  - May be swapped on the day before launch

- Mechanical Support Adhesives:
  - Will be tested October 30th and fully applied during final integration on November 1st
  - Heavy components and wire harnesses: **2-Part Epoxy**
  - Antenna end: **Rubber grommet and silicone or epoxy**
  - Batteries: **Kapton tape**

- Fasteners
  - Steel screws and nuts (4-40)
  - Nylon washers to elevate boards slightly
## Mass Budget

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier</td>
<td>64 g</td>
</tr>
<tr>
<td>Batteries</td>
<td>91 g</td>
</tr>
<tr>
<td>Payload PCB</td>
<td>21 g</td>
</tr>
<tr>
<td>Radio Board</td>
<td>20 g</td>
</tr>
<tr>
<td>Antenna</td>
<td>15 g</td>
</tr>
<tr>
<td>Fasteners</td>
<td>10 g</td>
</tr>
<tr>
<td>Epoxies and Coatings</td>
<td>14 g</td>
</tr>
<tr>
<td>Total Mass</td>
<td>236 g</td>
</tr>
</tbody>
</table>
Risks

- **Buckling Failure**
  - At the longest unsupported segment
  - $F_{\text{max}} = 584$ lb
  - $F_{\text{exp}} = 0.7\text{lb} \times 50\text{g} = 35$ lb
  - Factor of Safety = 16

- **Fastener Failure**
  - Shear stress in the four steel screws holding the radio board and antenna
  - For steel, $\tau_u = 21,000$ psi
  - $\tau_{\text{exp}} = 192$ psi
  - Factor of Safety = 109
Risks

- **Thermal Risk**
  - Maximum Temperature: 200°F
  - Possible risk for epoxies and coatings
  - Minimal impact due to short mission duration
Changes since PDR

- Steel fasteners instead of nylon
- Kapton tape used to fasten batteries
- Staking heavy components only
- Your name in space SD card
- Richard Hackney memorial added
Communication Systems Review

Mr. Prasanna Padmanabhan
Flight Communication

- Micro-Trak 300 operates on 144.39 MHz
  - Transmit power : 300mW (24.7dBm)
  - Current consumption : 180mA
  - Data rate : 1200 Baud AFSK
  - PCB dimensions : 1 X 3.3 Inches
  - Weight : < 1 ounce
  - Connector : SMA Female
Flight Communication

- 2M Rocket antenna
  - Yaesu VX-2R hand held radio antenna
    - Low gain (-12 db) reasonably Omni-directional pattern
  - Connector : SMA Male
Ground Station Hardware

- **Yagi antenna @ 146/437 MHz**
  - Mfg. and model: Arrow antenna
  - No. of Elements: 3
  - Boom Length: 37 ½ ”
  - Gain: 6 db

- **Kenwood Hand held radio TH-D7A**
  - Has a built in TNC
  - Sensitivity: < 0.18 uV (-121.89 dBm) for 12 db SINAD

- **Kenwood TM-D700A for ground communications**
Ground Station Hardware

Mobile Ground Station Schematic for Space Express

Arrow Antenna

Kenwood TH-D7A

PG-2W

PG-4W

BNC to SMA

7Ah +12 V
Lead acid battery

120 V AC inverter

AC adapter

Serial Splitter

Laptop PC1

Hyperterminal

Laptop PC2

Ground Software

Suitcase
Ground Station Hardware

- Cables and connectors
  - Arrow Antenna to Kenwood Radio connector is a BNC to SMA adapter
  - PC Programming Cable (PG-4W)
  - Serial to USB
  - NiCad Battery pack 9v 600 mAh (PB-39)
  - DC Fused cord (PG-2W)
  - Filtered Cigarette Lighter cord (PG-3J)
  - Rapid Charger (PB-38/39)
  - 7Ah Lead Acid 12v Backup Battery
  - Tripod with Mast
  - Laptops with spare batteries
  - Ac Adapter for Laptop
  - Inverter

25 October 2007
Ground Station Hardware

- Running Hyperterminal

![Hyperterminal Configuration Screen]

- COM9 Properties window showing settings:
  - Bits per second: 9600
  - Data bits: 8
  - Parity: None
  - Stop bits: 1
  - Flow control: None

- HyperTerminal window displaying:
  - RPM3-869/914-17 Radio Packet Modem
  - Firmware: V1.6
  - Serial No: 65535
  - config
  - baud 9600 bps
  - throughput max
  - unit 0
  - site 0
  - flow none
  - serdly 2 (x10ms)
  - shdn on
  - retry 5
  - ackmode on
  - remote off
  - strm on

25 October 2007
Ground Architecture

- The rocket is to be launched at an angle of 83° with respect to the ground from White Sands Missile Range, New Mexico.
- We expect the trajectory of the DART to be mostly parabolic (as the nosecone weighs heavier than the tail) with a maximum height of 150 Km.

- The distance from the launch site to the point where the trajectory peak occurs equals $150 \cot 83° (\Delta apb)$, approximately 12 miles.
Ground Architecture

- GS 1 will be located at a distance of 1000ft behind the launch site to make sure that the initial communication is established with the rocket and shall be in radio contact with the other ground stations, so as to being kept up-to-date about the launch proceedings.

- GS 2 at a distance of 9 miles (12 Cos 45°, Δabd) approximately along the ‘V’ from the launch site.

- GS 3 at a distance of 18 miles (12 Sec 45°, Δabe) approximately along the ‘V’ from the launch site.
# Link Budget

## Free Space Loss Calc.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Range in km</td>
<td>1.50E+02</td>
</tr>
<tr>
<td>Input Frequency in GHz</td>
<td>0.14439</td>
</tr>
<tr>
<td>Wavelength (meters)</td>
<td>2.077706212</td>
</tr>
<tr>
<td>Free Space Loss</td>
<td>1.21497E-12</td>
</tr>
<tr>
<td>FSL in dB</td>
<td>-119.1543324 dB</td>
</tr>
</tbody>
</table>

## Noise Calc.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input T op</td>
<td>400</td>
</tr>
<tr>
<td>Input B sys (MHz)</td>
<td>0.02</td>
</tr>
<tr>
<td>Noise Output power in W</td>
<td>1.104E-16</td>
</tr>
<tr>
<td>Noise Output power in dBm</td>
<td>-120.5703093 dBm</td>
</tr>
<tr>
<td>Pointing Losses</td>
<td>-3 db</td>
</tr>
<tr>
<td>Polarization Mismatch</td>
<td>-3 db</td>
</tr>
<tr>
<td>Impedance Mismatch</td>
<td>-0.5 db</td>
</tr>
<tr>
<td>Doppler Shift Loss</td>
<td>-0.5 db</td>
</tr>
</tbody>
</table>

## Input Power of Transmitter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Ant. gain rx</td>
<td>3.981071706</td>
</tr>
<tr>
<td>Input Ant. gain tx</td>
<td>0.063095734</td>
</tr>
</tbody>
</table>

## Power received

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power received</td>
<td>1.82679E-14 watts</td>
</tr>
<tr>
<td>SNR</td>
<td>165.4698775</td>
</tr>
</tbody>
</table>

## Margin

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ant Gain Rx</td>
<td>6 dB</td>
</tr>
<tr>
<td>Ant Gain Tx</td>
<td>-12 dB</td>
</tr>
<tr>
<td>Power received</td>
<td>-107.3831 dBm</td>
</tr>
<tr>
<td>SNR</td>
<td>22.18719 dB</td>
</tr>
</tbody>
</table>

25 October 2007
Changes since PDR

- Initial ground station antenna
  - Model: CUS-124WB
- Final ground station antenna
  - Model: Arrow-146/437

Comments

- Issues with mounting and pointing the antenna
- Gain factor and beam width were almost the same
Team members

- Prabhakara Rao Eluru
- Prasanna Padmanabhan
- Dale McClure

Deadlines

- Full-up Simulation - Nov 3rd
- Documentation - Nov 16th
Ground Software Review
Ground Station Software

- Modified from testing software developed and used by the KySat1 Flight Software team
  - Runs in Cygwin on windows
  - Uses ncurses library for user interface
- Runs on laptop connected to ground station’s TNC, catches packets from serial port and decodes and displays them in real time
- Logs received packets to text file for later analysis
- Used for testing payload
Ground Station Software

Legend: Incoming Outgoing
Use Arrow keys, PageUp, PageDown to scroll (Esc to exit)
WSMR Logistics and Schedule

Mr. Tyler Doering
Schedule Overview

Monday
- Arrival
- Briefing

Tuesday
- Acceptance Tests
- Integration
- Briefing

25 October 2007
## Schedule - Monday

<table>
<thead>
<tr>
<th>Time</th>
<th>Nominal CST</th>
<th>Team</th>
<th>Location</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-50 hours</td>
<td>07/12/03 08:00</td>
<td>All</td>
<td>HILC</td>
<td>Readiness Briefing</td>
</tr>
<tr>
<td>T-48 hours</td>
<td>07/12/03 10:00</td>
<td>GS</td>
<td>WSMR</td>
<td>Reconnaissance ground station locations</td>
</tr>
<tr>
<td>T-48 hours</td>
<td>07/12/03 10:00</td>
<td>Payload</td>
<td>WSMR</td>
<td>Payload Acceptance and Final Payload Preparations</td>
</tr>
<tr>
<td>T-44 hours</td>
<td>07/12/03 14:00</td>
<td>GS</td>
<td>WSMR</td>
<td>Radio unpacking and testing</td>
</tr>
<tr>
<td>T-43 hours</td>
<td>07/12/03 15:00</td>
<td>GS</td>
<td>WSMR</td>
<td>Prep Radios for HILC simulation</td>
</tr>
<tr>
<td>T-42 hours</td>
<td>07/12/03 16:00</td>
<td>All</td>
<td>HILC</td>
<td>Full-up Simulation/Acquire Missing Components</td>
</tr>
<tr>
<td>T-40.5 hours</td>
<td>07/12/03 18:30</td>
<td>GS</td>
<td>HILC</td>
<td>Pack Radios for WSMR Tests</td>
</tr>
<tr>
<td>T-40 hours</td>
<td>07/12/03 19:00</td>
<td>All</td>
<td>HILC</td>
<td>Debriefing</td>
</tr>
</tbody>
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# Schedule - Tuesday

<table>
<thead>
<tr>
<th>Time</th>
<th>Nominal CST</th>
<th>Team</th>
<th>Location</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-26 hours</td>
<td>07/12/04 08:00</td>
<td>All</td>
<td>HILC</td>
<td>Readiness Briefing</td>
</tr>
<tr>
<td>T-24 hours</td>
<td>07/12/04 10:00</td>
<td>GS</td>
<td>WSMR</td>
<td>GS setup launch configuration</td>
</tr>
<tr>
<td>T-24 hours</td>
<td>07/12/04 10:00</td>
<td>Payload</td>
<td>WSMR</td>
<td>Deliver Dart to LR&amp;R for integration/balance</td>
</tr>
<tr>
<td>T-22 hours</td>
<td>07/12/04 12:00</td>
<td>All</td>
<td>WSMR</td>
<td>GS Test</td>
</tr>
<tr>
<td>T-21 hours</td>
<td>07/12/04 13:00</td>
<td>GS</td>
<td>WSMR</td>
<td>Ready Ground Stations for Launch</td>
</tr>
<tr>
<td>T-17 hours</td>
<td>07/12/04 17:00</td>
<td>All</td>
<td>WSMR</td>
<td>Confirm successful payload Integration and Status Debriefing</td>
</tr>
<tr>
<td>T-15 hours</td>
<td>07/12/04 19:00</td>
<td>All</td>
<td>HILC</td>
<td>Debriefing</td>
</tr>
</tbody>
</table>
# Schedule - Wednesday

<table>
<thead>
<tr>
<th>Time</th>
<th>Nominal CST</th>
<th>Team</th>
<th>Location</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-4.5 hours</td>
<td>07/12/05 04:30</td>
<td>All</td>
<td>HILC</td>
<td>Final Readiness Check</td>
</tr>
<tr>
<td>T-4 hours</td>
<td>07/12/05 05:00</td>
<td>All</td>
<td>HILC</td>
<td>Depart Hotel</td>
</tr>
<tr>
<td>T-3 hours</td>
<td>07/12/05 06:00</td>
<td>All</td>
<td>WSMR</td>
<td>Arrive WSMR</td>
</tr>
<tr>
<td>T-2 hours</td>
<td>07/12/05 07:00</td>
<td>GS</td>
<td>WSMR</td>
<td>Ground station setup</td>
</tr>
<tr>
<td>T-60 minutes</td>
<td>07/12/05 08:00</td>
<td>All</td>
<td>WSMR</td>
<td>Transmit test packet</td>
</tr>
<tr>
<td>T-30 minutes</td>
<td>07/12/05 08:30</td>
<td>All</td>
<td>WSMR</td>
<td>Transmit Second Test Packet</td>
</tr>
<tr>
<td>T-0</td>
<td>07/12/05 09:00</td>
<td></td>
<td></td>
<td>Launch of KySat Space Express</td>
</tr>
<tr>
<td>T+10 minutes</td>
<td>07/12/05 09:10</td>
<td>GS</td>
<td>WSMR</td>
<td>Backup all Flight Data</td>
</tr>
<tr>
<td>T+30 minutes</td>
<td>07/12/05 09:30</td>
<td>GS</td>
<td>WSMR</td>
<td>Ground station packing</td>
</tr>
<tr>
<td>T+90 minutes</td>
<td>07/12/05 10:30</td>
<td>All</td>
<td>WSMR</td>
<td>On-site Mission Debriefing</td>
</tr>
<tr>
<td>T+6 hours</td>
<td>07/12/05 13:00</td>
<td>GS</td>
<td>HILC</td>
<td>prepare ground stations for return</td>
</tr>
</tbody>
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