Unix Space Server (USS) Project
CubeSat Developers' Workshop
Cal Poly - April 26, 2013

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Inspiration for research

• Is there a way to use Lower Earth Orbit to host a webserver?
• Can spacebound communications speed up the internet?
• Can it increase global coverage?
• What limitations exist for TCP/IP or Linux in Space?
• Attempts to use it previously?
• Worth the costs?
TCP/IP
• IP protocols are well known and used
• Easy access to payload server from existing technology
• Little space heritage (especially in LEO)

Linux
• New (and controversial) in the CubeSat Community
• Inexpensive and open source
• Power Concerns
Other Flight Attempts

Arduino
- ArduSat - Summer 2013
- Nanosatisfi LLC

Linux
- Strand - Linux processor and smartphone - February 2013

TCP/IP
- NASA - 2008 - Developed DTN for use in space (funding cut)
Introduction to USS

USS is a small satellite in development at the Naval Academy that is focused on:

• Using a CubeSat form factor
• Commercial-off-the-shelf
• Open Source where possible
• Simple flight software and payload integration
The mission of USS is to host a web server from space utilizing standard internet protocol (IP), COTS components, and Linux-based server management.
Primary Mission Objectives:

- Demonstrate use of a Linux kernel as a webserver on a CubeSat.
- Utilize a standard uniform resource locator (URL) and IP address accessible to any internet user whenever the satellite has an established downlink connection.
- Demonstrate use of IP in space communication.
Mission Objectives

Secondary Mission Objectives:

• Compare packet transfer speeds of space-based versus terrestrial network paths.

• Investigate the potential of small satellite constellations as networks.

• Investigate the potential to improve global internet coverage, including coverage of remote regions of the globe.
Technical Objectives

6 Phases of the USS Design

- Concept
- Feasibility
- Payload / Comms.
- Final Design
- Testing
- Launch
Completed Objectives

Phase 0 - Spring 2012 - Concept Development - Complete
● Is it possible to use IP in space communication?
● Why are Linux and IP not already in use if it is possible?

Phase 1 - Fall 2012 - Concept Feasibility - Complete
● Select hardware components for use onboard USS.
● Develop a working Linux server on a BeagleBoard.
● Develop a working program to be used as flight software on an Arduino.
● Determine a requirement for electrical power subsystem onboard the satellite, excluding communication power requirements.
● Estimate the total satellite mass.
Current Objectives

Phase 2 - Spring 2013 - Communications Development

- Develop TCP/IP communications link (uplink/ downlink for payload).
- Host a server over determined RF frequency with website and URL.
- Develop Communications link using another standard, tested protocol for flight computer.
- Network and establish communication between the BeagleBoard and the Arduino.
- Test composite unit and develop a more accurate EPS requirement for both processors and communication.
- Characterize access time and necessary orbit requirements.
Future Objectives

Phase 3 - Fall 2013 - Construction and Final Design

- Phase into a Capstone Design Project.
- Develop a satellite structure and thermal management system.
- Develop a final communications suite for optimal data rates and server uptime.
- Construct a satellite and acquire necessary structure/solar panels/batteries/other subsystems using space tested COTS equipment.
Future Objectives (con't)

**Phase 4 - Spring 2014 - Testing and Optimization**
- Test the satellite at GSFC or USNA for thermal and structural integrity.
- Test satellite operations using the Snowflake Project or mounting the payload to a UAV.
- Achieve a duty cycle in testing of at least 25%.

**Phase 5 - Post USNA - Launch**
- This is the operations phase, and includes launch, checkout, and on-orbit space application testing.
Design Concepts

A look at the USS Subsystems
Mission Payload Subsystem

- The main payload on the USS is the server hosted on a BeagleBoard-xM
- Hosted over S-Band with up to a 1Mbps data rate
- 1Ghz processor, 512MB ram, 32GB Flash Drive
- 3.0W average power required
- Server will host a website and a live stream of images from an onboard HD camera
Communications Subsystem

ConOps

- S-Band - Payload
  - 2.4 GHz
  - 128 bit AES encryption
  - 935 Kbps
  - Transmit: 1.7 W
  - Receive: 0.8 W
  - -40 ºC to +80 ºC temp range
Preliminary Test Results

- Server is operational and communicating over S-Band link (in the lab at 935kbs)
- The C&DH is under development and communicating over UHF
Satellite Configuration

Preliminary Study
Command and Data Handling Subsystem

- Arduino Pro used as main C&DH module
- ArduIMU for GPS, Accelerometer, Magnetometer and Gyrometer
- Module will directly control the power bus of the satellite
- Accessible over UHF communications
- For simplicity, it will always be on after launch
- Possible integration of two Arduinos in serial for rad hardening
- 5V and less than 0.36 W average power required
Electrical Power Subsystem

3U Colony-1
- 20 Whr EPS / Battery* onboard
- 43 solar cells on 7 arrays
- 8.3v, 5v, 3.3v bus

1.5U PSAT
- 10 Whr EPS / Battery*
- 16 Cells on 6 face arrays
- 2 Watts average power (tumbling)
- Possible integration with HaWK sun seeking solar arrays for more power

Clyde Space EPS

Colony-1 (3U)

PSat (1.5U)
Power Required

<table>
<thead>
<tr>
<th>BeagleBoard -xM</th>
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<tbody>
<tr>
<td>Voltage (ave)</td>
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<tr>
<td>Current</td>
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<td>Power</td>
<td>W</td>
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Power Available (1st Order, Tumbling)

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<tr>
<th>Orientations</th>
<th>Number</th>
<th>% time in sun</th>
<th>Theta</th>
<th>P(Theta)</th>
<th>P(Time)</th>
<th>V(Theta)</th>
<th>V(Time)</th>
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<td>1.96</td>
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<td>1U Face</td>
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<td>7.69%</td>
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<td>2.08</td>
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<td>1U Edge</td>
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<td>1.83</td>
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<td>Total</td>
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<td></td>
<td>2.15</td>
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<td>4.85</td>
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Attitude Determination and Control Subsystem

3U Colony-1
- Full ADCS system with reactions wheels
- Limited ability to point satellite at ground stations due to drag

1.5U PSAT
- Passive magneto-torquer system
- Possible active ADCS with ArduIMU and active magneto-torquers

ArduIMU v3
Two potential launch opportunities:

- Deliver Jun 2014 for an Oct-Nov 2014 launch
- Deliver Jul 2014 for a Dec 2014 launch

*Both launches are in LEO, elliptical (approx 400 - 750km) with approximately 60 degree inclination.*
## Cost Analysis

### 1st order estimated 1.5U satellite cost

<table>
<thead>
<tr>
<th>Subsystems</th>
<th>Items</th>
<th>Cost ($)</th>
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<tbody>
<tr>
<td>Structure</td>
<td>Body</td>
<td>$1,450.00</td>
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<tr>
<td>EPS</td>
<td>1.5U EPS + Batt</td>
<td>$5,700.00</td>
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<tr>
<td>Solar Panels</td>
<td>1.5U Solar Panels</td>
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<td>Arduino</td>
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<tr>
<td>Payload</td>
<td>Beagle Board</td>
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<td></td>
<td>Sensors</td>
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<td>Comms</td>
<td>Sband / UHF</td>
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<td>Thermal Devices</td>
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<td>ADCS</td>
<td>Magnetorquer Rod</td>
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<tr>
<td>Wiring/ Harness</td>
<td>Estimate</td>
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<tr>
<td>Support Structures</td>
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<tr>
<td><strong>Total Satellite Cost</strong></td>
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<td><strong>$35,500.00</strong></td>
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</table>
Conclusions

USS Project Summary
Feasibility

- The main concern for this project is power, still determining feasible duty cycle.
- The communications link is still in work, with design trades for power / gain / beamwidth still ongoing.
- Radiation is a concern with COTS hardware however hardening it would increase cost (why not send up two for the same price?)
Next Steps

• Starting Fall 2013 USS will begin the final design phase of the satellite
• The project will become a "Capstone Project" at USNA (senior thesis)
• Test payload in an operational environment in a high altitude balloon
Acknowledgments

Primary Advisor - CDR Allen Blocker
Secondary Advisor - Asst. Prof. Jin Kang
Coding Assistant - MIDN 2/C Ganesh Harihara
Questions?
Unix Space Server

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## Peak Power in Operational Modes

<table>
<thead>
<tr>
<th>Powered Devices</th>
<th>Launch</th>
<th>Safe Hold</th>
<th>Receive Only</th>
<th>Payload Up</th>
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</thead>
<tbody>
<tr>
<td>Coms- UHF -TX</td>
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<td>1.7</td>
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<td>Coms- UHF -RX</td>
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<td>0.2</td>
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<tr>
<td>Coms- S Band -TX</td>
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<td>OFF</td>
<td>OFF</td>
<td>2</td>
</tr>
<tr>
<td>Coms- S Band -RX</td>
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<td>0.2</td>
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<tr>
<td>C&amp;DH - Arduino</td>
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<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>EPS</td>
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<tr>
<td>PAY - BeagleBoard</td>
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<tr>
<td>ADCS</td>
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<td><strong>Peak Power Consumption</strong></td>
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## Duty Cycles by Orbit

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<td>1</td>
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<tr>
<td>Coms- S Band -TX</td>
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<td>0.25</td>
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<tr>
<td>Coms- S Band -RX</td>
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<td>1</td>
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<tr>
<td>C&amp;DH - Arduino</td>
<td>OFF</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>EPS</td>
<td>OFF</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>PAY - BeagleBoard</td>
<td>OFF</td>
<td>OFF</td>
<td>0.25</td>
<td>1</td>
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<tr>
<td>ADCS</td>
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### Average Power Operational Modes

<table>
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<th>Powered Devices</th>
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<th>Receive Only</th>
<th>Payload Up</th>
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<tbody>
<tr>
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<td>C&amp;DH - Arduino</td>
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</tr>
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<td>EPS</td>
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