Unix Space Server (USS) Project

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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?

Background

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

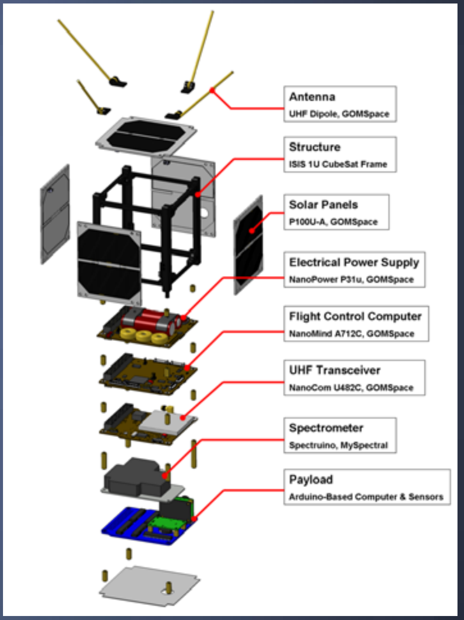
- ArduSat - Summer 2013
- Nanosatisfi LLC

Linux

- Strand - Linux processor and smartphone – February 2013

TCP/IP

- NASA - 2008 - Developed DTN for use in space (funding cut)

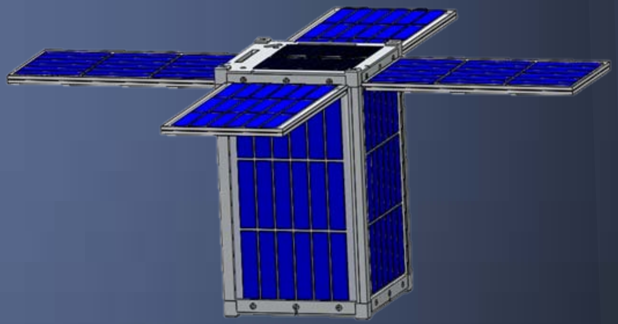


ArduSat Design

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.

Mission Objectives

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.

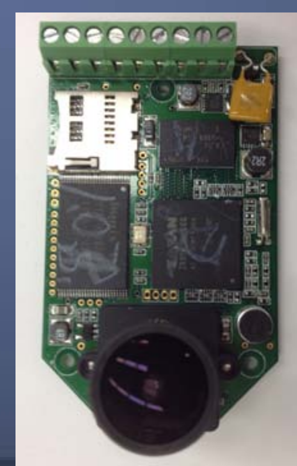
Design Concepts

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

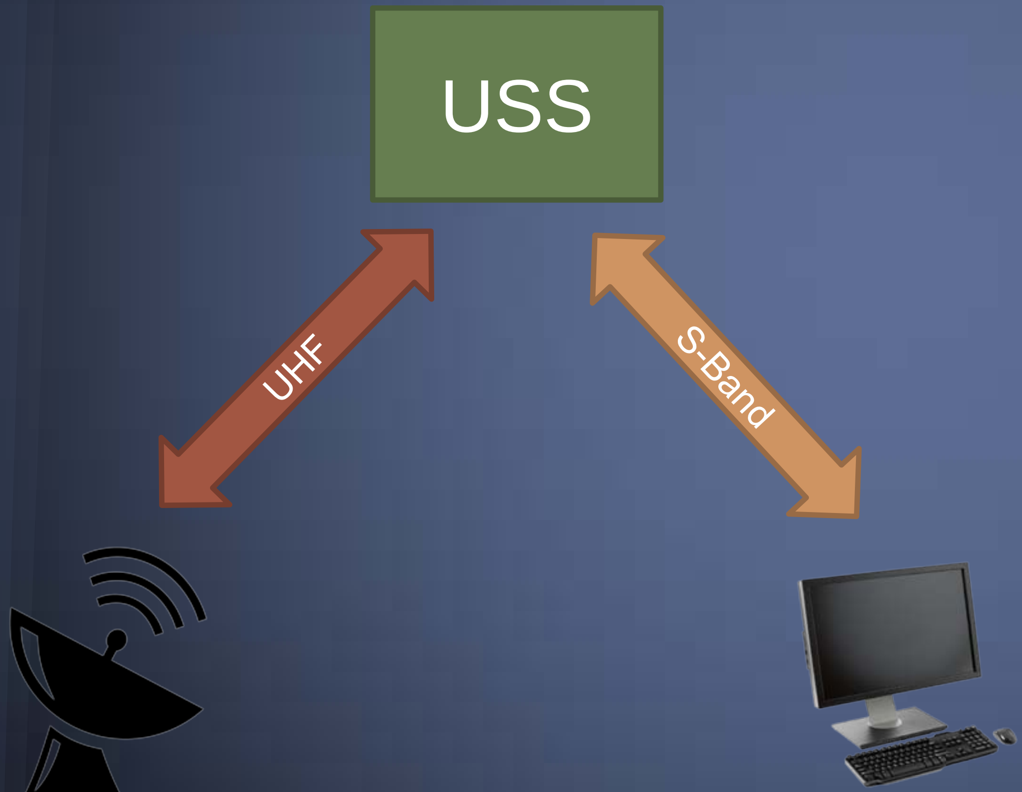
BeagleBoard-xM



HD camera

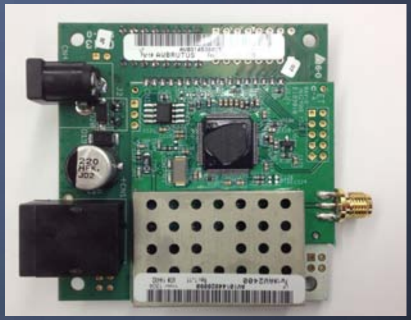
Communications Subsystem

ConOps



S-Band - Payload

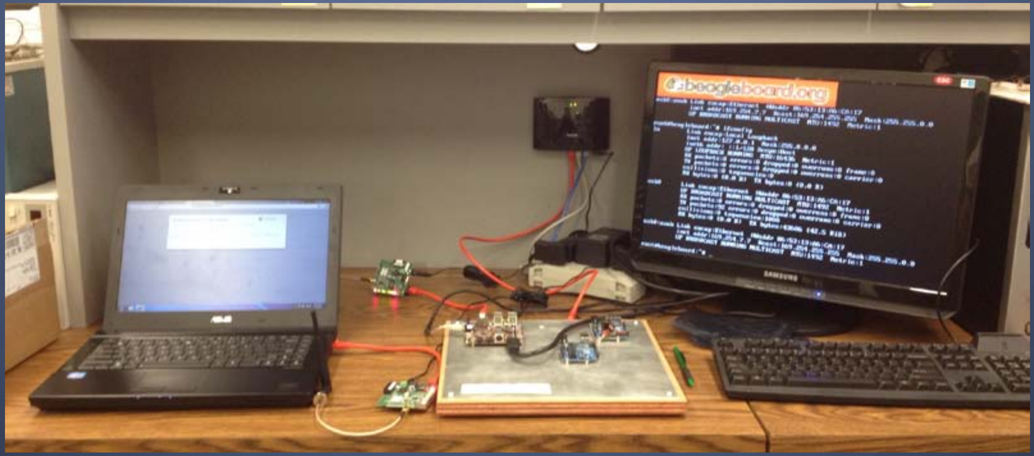
- 2.4 GHz
- 128 bit AES encryption
- 935 Kbps
- Transmit: 1.7 W
- Receive: 0.8 W
- -40 ºC to +80 ºC temp range



AvaLan Wireless AW2400

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



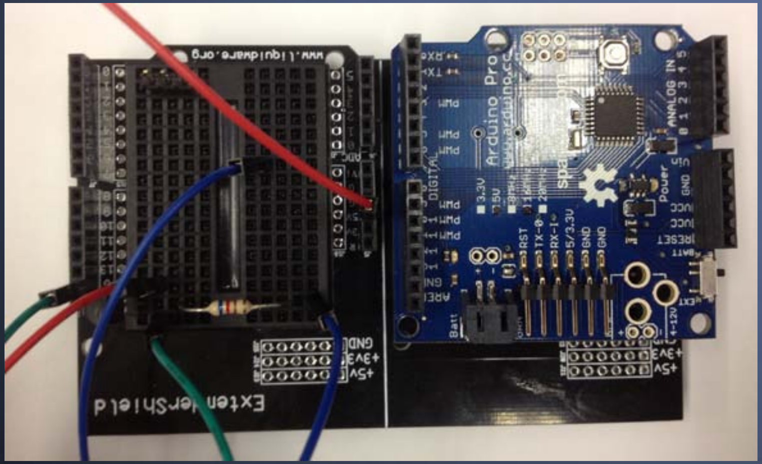
Ground Station and Development Platform

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



Arduino Pro (5V/16MHz)

IMU / GPS Telemetry Test Unit

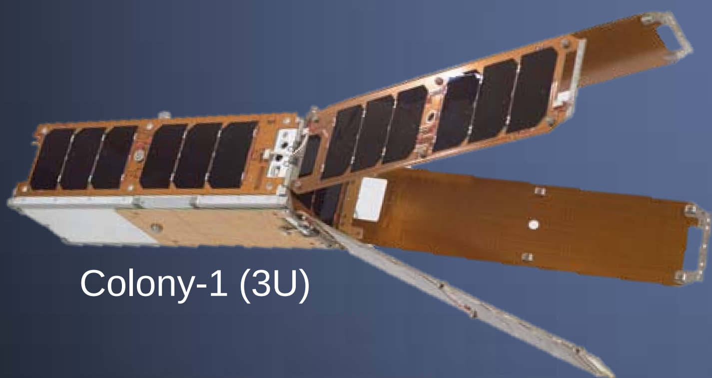
Electrical Power Subsystem

3U Colony-1

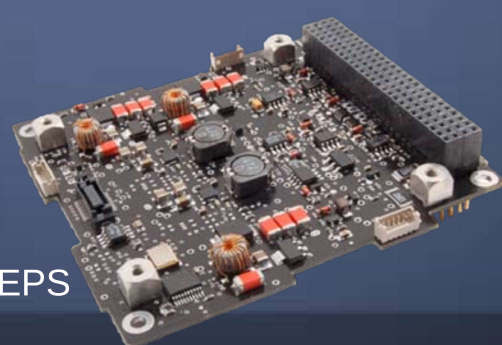
- 20 Whr EPS/ Battery* onboard
- 43 solar cells on 7 arrays
- 8.3v,5v,3.3v bus

1.5U PSAT

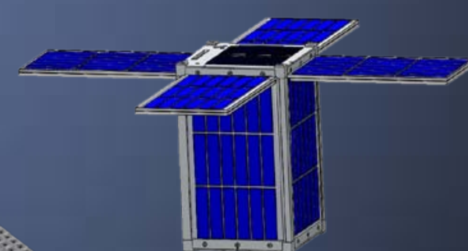
- 10 Whr EPS / Battery*
- 16 Cells on 6 face arrays
- 2 Watts average power (tumbling)
- Possible integration with HaWK sun seeking solar arrays for more power



Colony-1 (3U)



Clyde Space EPS



PSat (1.5U)

EPS (con't)

Power Required

BeagleBoard -xM		
Voltage (ave)	V	5.0
Current	A	0.6
Power	W	3.0
Arduino		
Voltage (ave)	V	9.0
Current	A	0.04
Power	W	0.36

Power Available (1st Order, Tumbling)

Orientations	Number	% time in sun	Theta	P(Theta)	P(Time)	V(Theta)	V(Time)
Corner	8	30.77%	45	1.96	0.60	4.43	1.36
1.5U Face	4	15.38%	0	3.12	0.48	7.05	1.08
1.5U Edge	4	15.38%	45	2.20	0.33	4.99	0.77
1U Face	2	7.69%	0	2.08	0.16	4.7	0.36
1U Edge	8	30.77%	45	1.83	0.56	4.15	1.28
Total	26	1			**2.15**		**4.85**

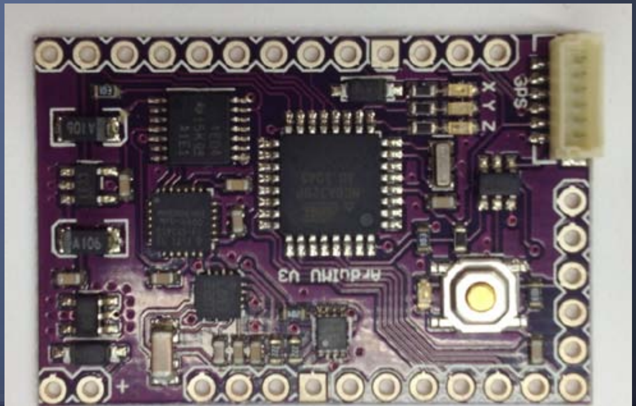
Attitude Determination and Control Subsystem

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

Orbit and Launch Opportunities

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 inclincation.

Cost Analysis

1st order estimated 1.5U satellite cost

Subsystems	Items	Cost ($)
Structure	Body	$1,450.00
EPS	1.5U EPS + Batt	$5,700.00
Solar Panels	1.5U Solar Panels	$17,700.00
C&DH	Arduino	$100.00
Payload	Beagle Board	$150.00
	Sensors	$500.00
Comms	Sband / UHF	$1,600.00
Thermal Devices	Estimate	$2,000.00
ADCS	Magnetorquer Rod	$1,300.00
Wiring/ Harness	Estimate	$4,000.00
Support Structures	Estimate	$1,000.00
Total Satellite Cost		**$35,500.00**

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

High Altitude Science Eagle Weather Balloon

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Questions?

USNA
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EPS (con’t)

Peak Power in Operational Modes

Powered Devices Units in Watts	Launch	Safe Hold	Receive Only	Payload Up
Coms- UHF -TX	OFF	1.7	OFF	1.7
Coms- UHF -RX	OFF	0.2	0.2	0.2
Coms- S Band -TX	OFF	OFF	OFF	2
Coms- S Band -RX	OFF	OFF	0.2	0.2
C&DH - Arduino	OFF	0.25	0.25	0.25
EPS	OFF	0.25	0.25	0.25
PAY - BeagleBoard	OFF	OFF	3	3
ADCS	OFF	OFF	OFF	0.1
Peak Power Consumption	0	2.4	3.9	7.7

EPS (con’t)

Duty Cycles by Orbit

Powered Devices	Launch	Safe Hold	Receive Only	Payload Up
Coms- UHF -TX	OFF	0.1	OFF	0.1
Coms- UHF -RX	OFF	1	1	1
Coms- S Band -TX	OFF	OFF	OFF	0.25
Coms- S Band -RX	OFF	OFF	1	1
C&DH - Arduino	OFF	1	1	1
EPS	OFF	1	1	1
PAY - BeagleBoard	OFF	OFF	0.25	1
ADCS	OFF	OFF	OFF	0.1

EPS (con't)

Average Power Operational Modes

Powered Devices	Launch	Safe Hold	Receive Only	Payload Up
Coms- UHF -TX	OFF	0.17	OFF	0.17
Coms- UHF -RX	OFF	0.2	0.2	0.2
Coms- S Band -TX	OFF	OFF	OFF	0.5
Coms- S Band -RX	OFF	OFF	0.2	0.2
C&DH - Arduino	OFF	0.25	0.25	0.25
EPS	OFF	0.25	0.25	0.25
PAY - BeagleBoard	OFF	OFF	0.75	3
ADCS	OFF	OFF	OFF	0.01
Average Power Consumption	0	0.87	1.65	4.58