USS Langley

The World's First Open Source Webserver in Space

USS Langley

BACKGROUND

Why Put the Internet in Space?

- 2/3 of the world does not have internet access… at all!
- Many regions don’t have internet backbone and no means to install it.

Q2 2013 Monthly Global Data Usage				
Region	Mobile Data (GB)	Fixed Data (GB)	Total (GB)	% With Access
North America	0.44	44.50	44.94	78.6%
Asia	1.10	35.40	36.50	27.5%
Europe	0.36	17.40	17.76	63.2%
Latin America	0.35	10.00	10.35	42.9%
Africa	0.02	No Data	0.02	15.6%

Why Put the Internet in Space?(con't)

- Create a provider of uniformly priced satellite internet.
- Currently no data services over 50kbps average with worldwide coverage
- Create a large satellite constellation, with high redundancy
- Host web services from space for military and disaster response applications

GEO Satellite Problems

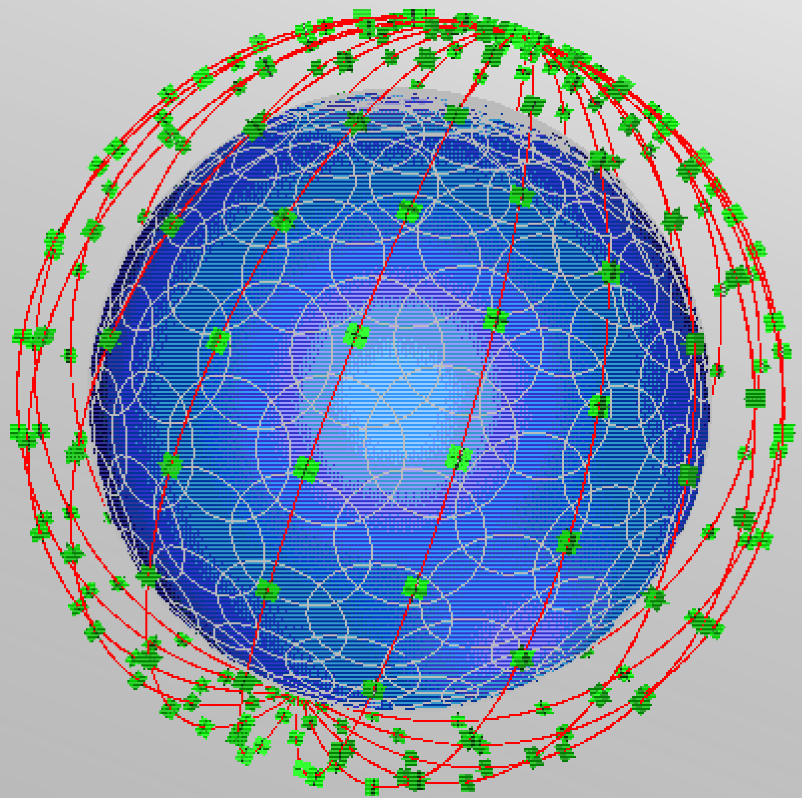

ViaSat-1, ViaSat Exede Satellite Internet

- Large costs for large, high altitude satellites (~$125m)
- Investment vs. useful mission life (15+ years)
- Technology goes out of style fast
- Latency (~238 ms)
- Cannot repair/ replace

Iridium NEXT Problems

- Scheduled for launch in 2015
- Estimated $2.9 Billion total cost to orbit
- 66 Satellites in high LEO (800km)
- 1.5 to 8 Mbps with 3 Million user capacity
- Cannot scale service or replace technology
- Expensive equipment and subscription
- Expensive to replace broken satellites
- Small market for expensive global data (500,000 current Iridium subscribers, 90% commercial)

CubeSat Solution

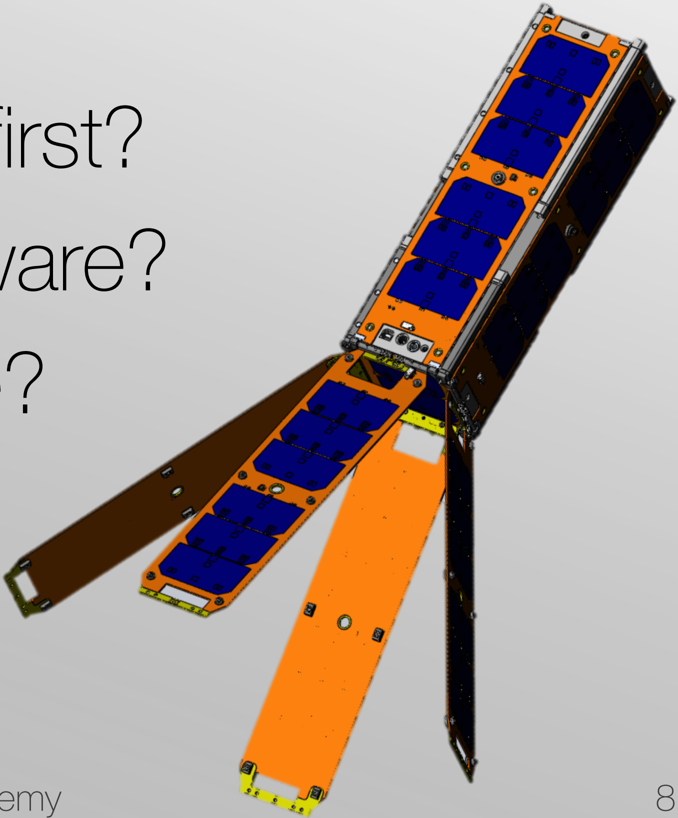


Full earth coverage from LEO constellation

- Low cost for low earth orbit (LEO) satellites (<$250k)
- Shorter life (2 years)
- Technology is replaced and updated constantly
- Latency (<10ms)
- If one breaks (or gets attacked) then launch more

Proof of Concept

- 100% coverage and high bandwidth would require hundreds of satellites (24 per plane, 24 planes = 576)
- Why not test a single one first?
- Can we use existing hardware?
- Has this been done before? (Surrey, NASA EPOXI)
- What is it going to cost?



The Unix Space Server (USS)

- TCP/IP protocols for simplicity and integration to current network
- Open source, Linux based web server for ease of integration and customizability
- Commercial off the shelf (COTS) hardware for reliability and cost
- CubeSat form factor
- Simple flight software and payload integration

USS Langley*

MISSION OVERVIEW

*Named after the first aircraft carrier CV-1, the *USS Langley*

Mission Statement

The mission of USS Langley is to host a web server from space utilizing standard internet protocol (IP), commercial off the shelf (COTS) components, and Linux-based server management.

Mission Objectives

Primary Mission Objectives:

- Demonstrate the 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 the use of small communication satellites in LEO as a proof of concept for a satellite constellation.

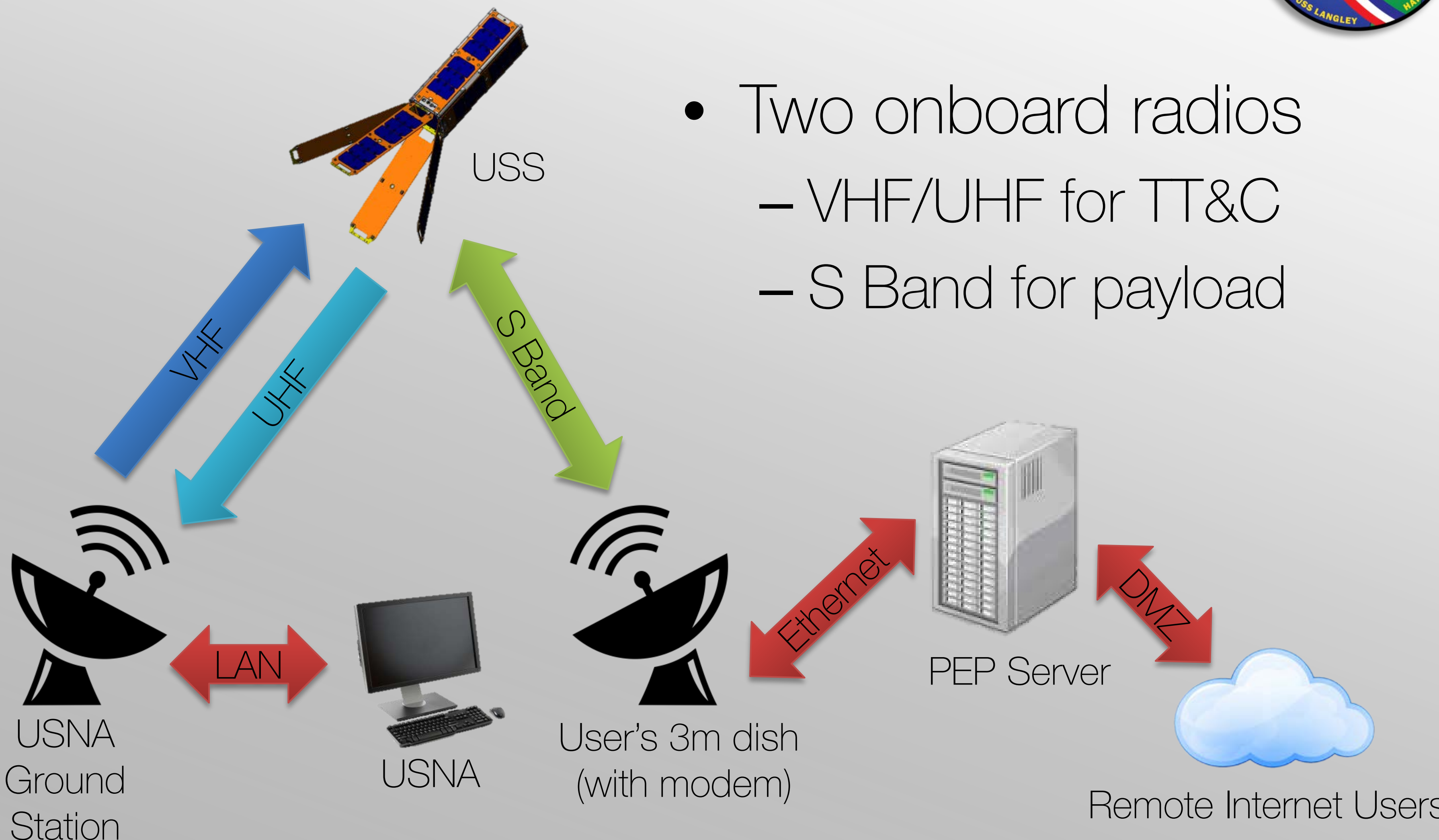
Mission Objectives

Secondary Mission Objectives:

- Compare packet transfer speeds of space-based versus terrestrial network paths.
- Investigate different types of TCP/IP congestion protocols.
- Investigate the potential to improve global internet coverage, including coverage of remote regions of the globe.

USS Langley CONOPS

- Two onboard radios
  - VHF/UHF for TT&C
  - S Band for payload



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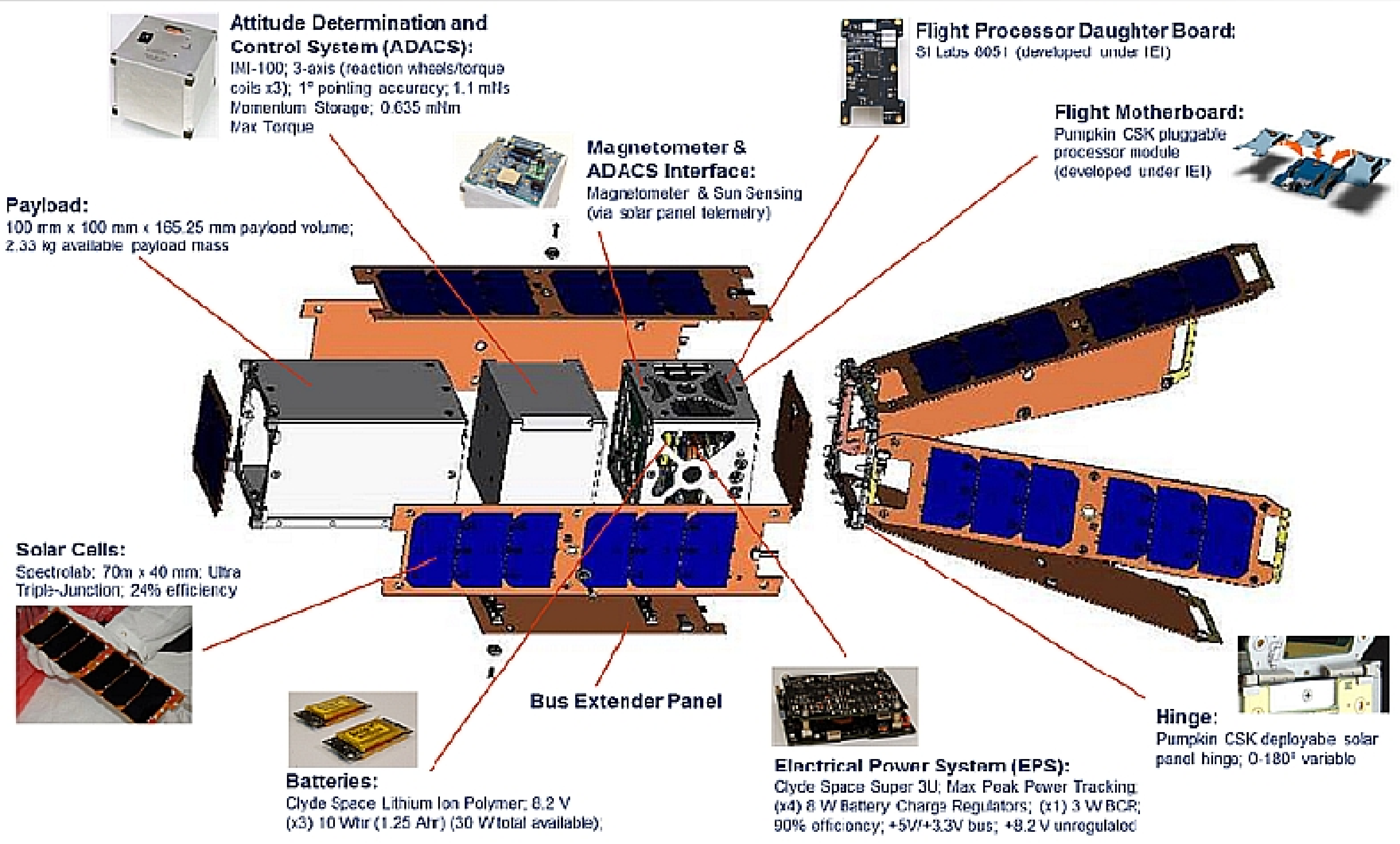
DESIGN OVERVIEW

Colony-1 Bus Overview



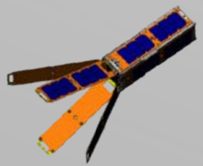
Communications Budget

Uplink/Downlink Reversible		Data Rate kbps		
Parameter	Units	500	1000	2000
Distance at 10 Degrees Elevation	km	1802.6	1802.6	1802.6
Transmission Power	dBm	33.0	33.0	33.0
Transmission Loss	dB	-2.0	-2.0	-2.0
Transmission Antenna Gain	dB	34.0	34.0	34.0
Transmission Antenna Beamwidth	degrees	2.9	2.9	2.9
EIRP	dBm	65.0	65.0	65.0
Free Space Loss	dB	-165.2	-165.2	-165.2
Combined Pointing Loss	dB	-14.6	-14.6	-14.6
Receiver Antenna Gain	dB	11.4	11.4	11.4
Receiver Antenna Beamwidth	degrees	39.0	39.0	39.0
Receiver Loss	dB	-0.8	-0.8	-0.8
Receiver Sensitivity	dBm	-108.0	-104.0	-100.0
Link Margin at 10 Degrees Elevation	dB	3.8	-0.2	-4.2
Link Margin at 30 Degrees Elevation	dB	9.85	5.85	1.85
Link Margin at 60 Degrees Elevation	dB	21.33	17.33	13.33
Link Margin at 90 Degrees Elevation	dB	26.84	22.84	18.84

Communications Budget

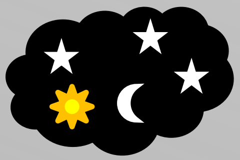
USS

- 33dBm P_{TX}
- 0.8dB L_{TX}
- 11.4dBi G_{TX}
- = 43.6dBm EIRP



Space

- 12.6dB $L_{Point\text{-}Sat}$
- 165.2dB L_{FS}
- 2.0dB $L_{Point\text{-}Ground}$
- = -179.8dB L_{PL}



Ground Station

- 34dBi G_{RX}
- 2.0dB L_{RX}
- = +32dBm Rx_{FOM}

Worst Case 250kbps

43.6dBm + -179.8dB + +32dBm = -104.2dBm P_{RX}

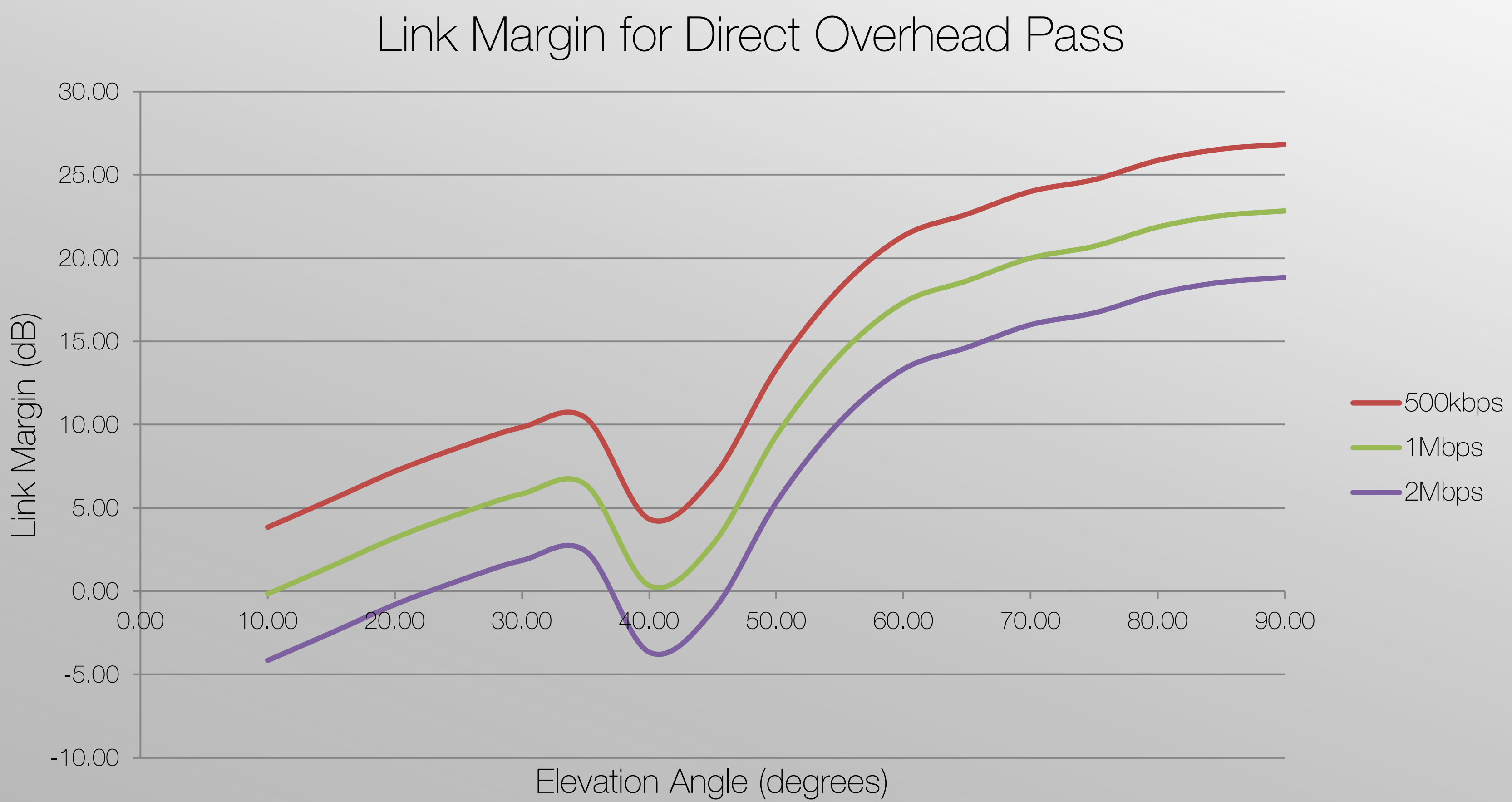
- -108dBm Rx_{SEN}
- = 3.8dB Margin!

Communications (con't)

- S Band radio features 250kbps, 500kbps, 1Mbps, and 2Mbps data rates
- Adjustable in flight, mid pass, from the ground
- Allows for data rate to increase as elevation angle increases
- Helical antenna has large null
- Highest data rates not usable at or near horizon
- 250 and 500kbps offer same results because of same receive sensitivity
- Downlink of 300+ MB per day

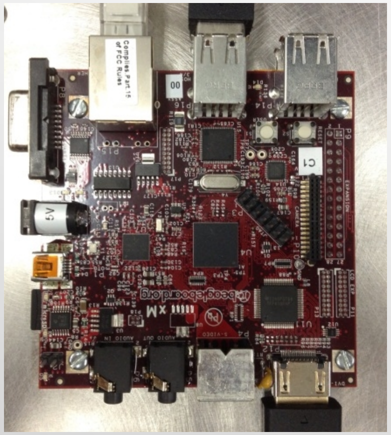
Data Rate	kbps	500	1000	2000	Variable
Average Pass Length	seconds	463.0	463.0	112.0	463.0
Average Pass Per Day	#	6.2	6.2	1.2	6.2
Data Protocol Overhead	%	20.0	20.0	20.0	20.0
Data per day	bits/day	1.2E+09	2.3E+09	2.1E+08	2.9E+09
Data per day	MB/day	144.2	288.4	26.7	358.3

Communications (con't)



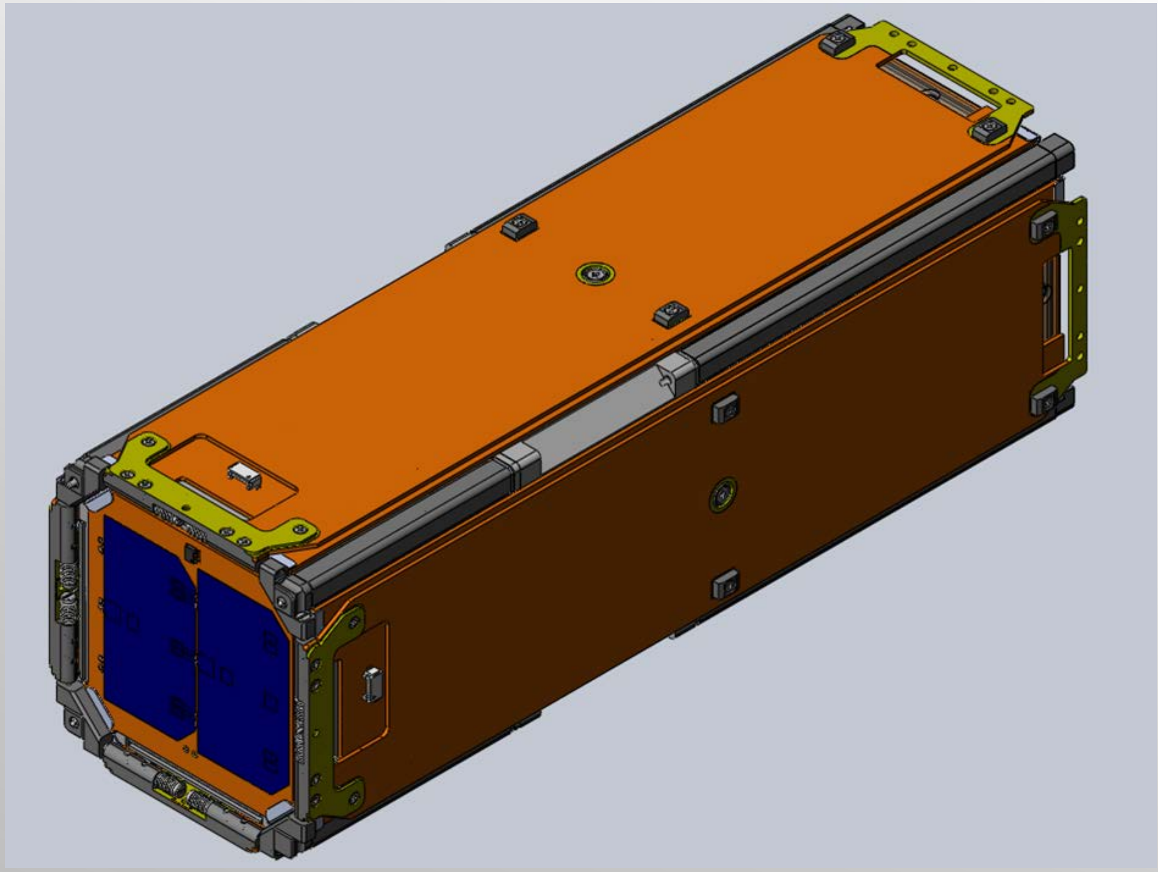
Payload

- The main payload on the USS is the server hosted on a BeagleBoard-xM
- Hosted over S Band radio (250kbps - 2Mbps)
- 1Ghz processor, 512MB ram, 32GB Flash Drive
- 3.0W average power required
- Server will host a website and a stream of images from an onboard camera



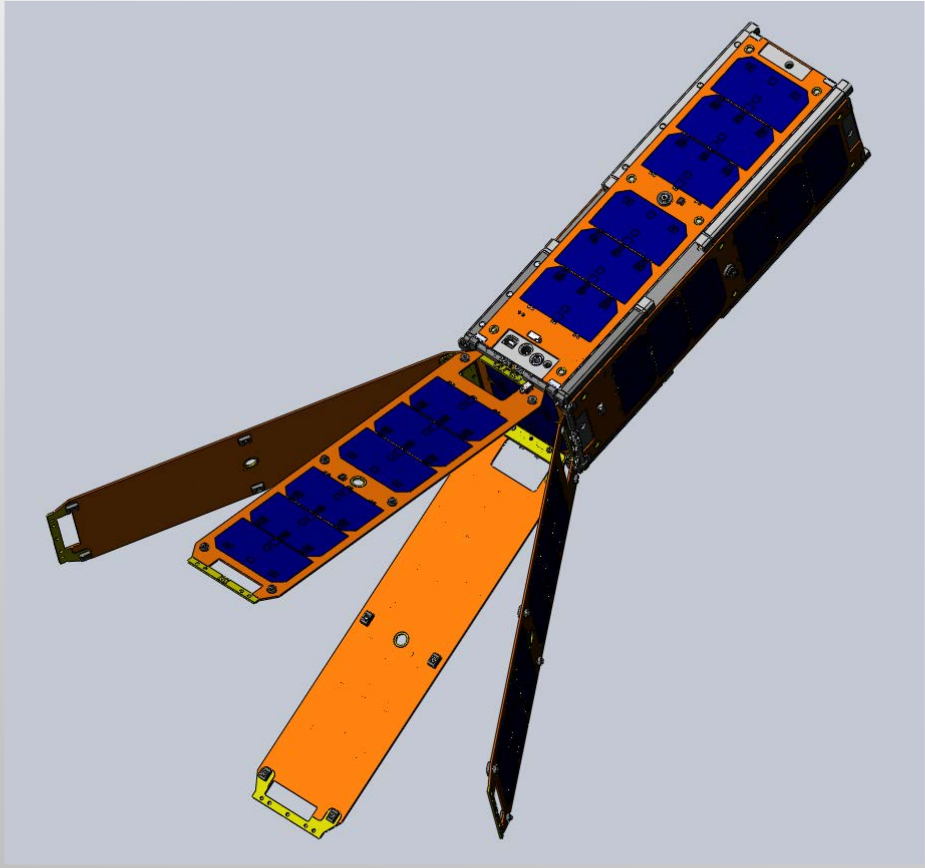
BeagleBoard-xM

LI-5M03 Camera



USS Langley Stowed

This is the configuration of the satellite during launch.

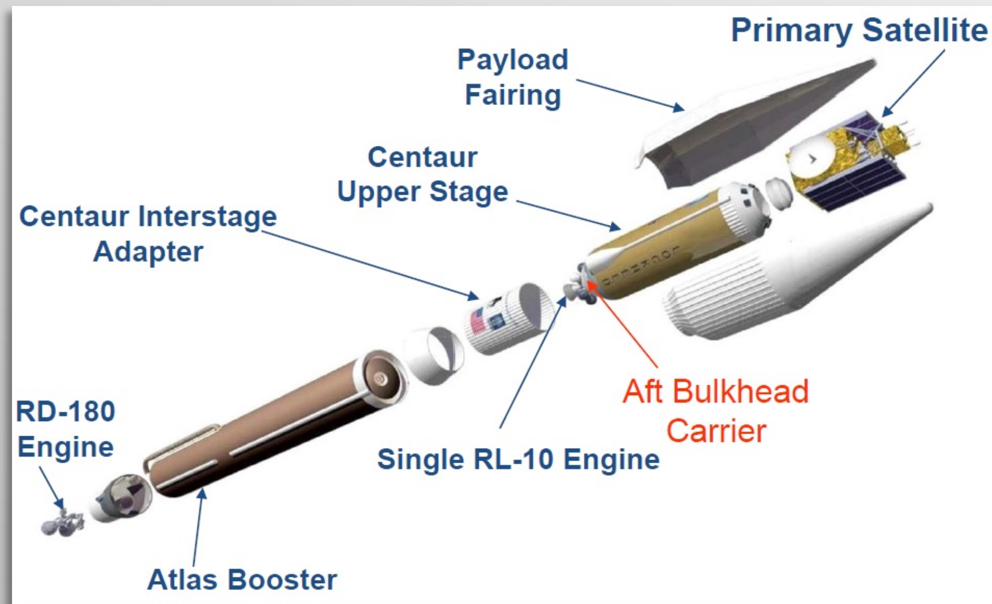


USS Langley Deployed

This is the configuration of the satellite during mission operations.

USS Langley Launch

- Deliver in Oct 2014
- August 2015 launch
- Perigee: ~400km
- Apogee: ~700km
- ~60° inclination



Atlas V with ABC

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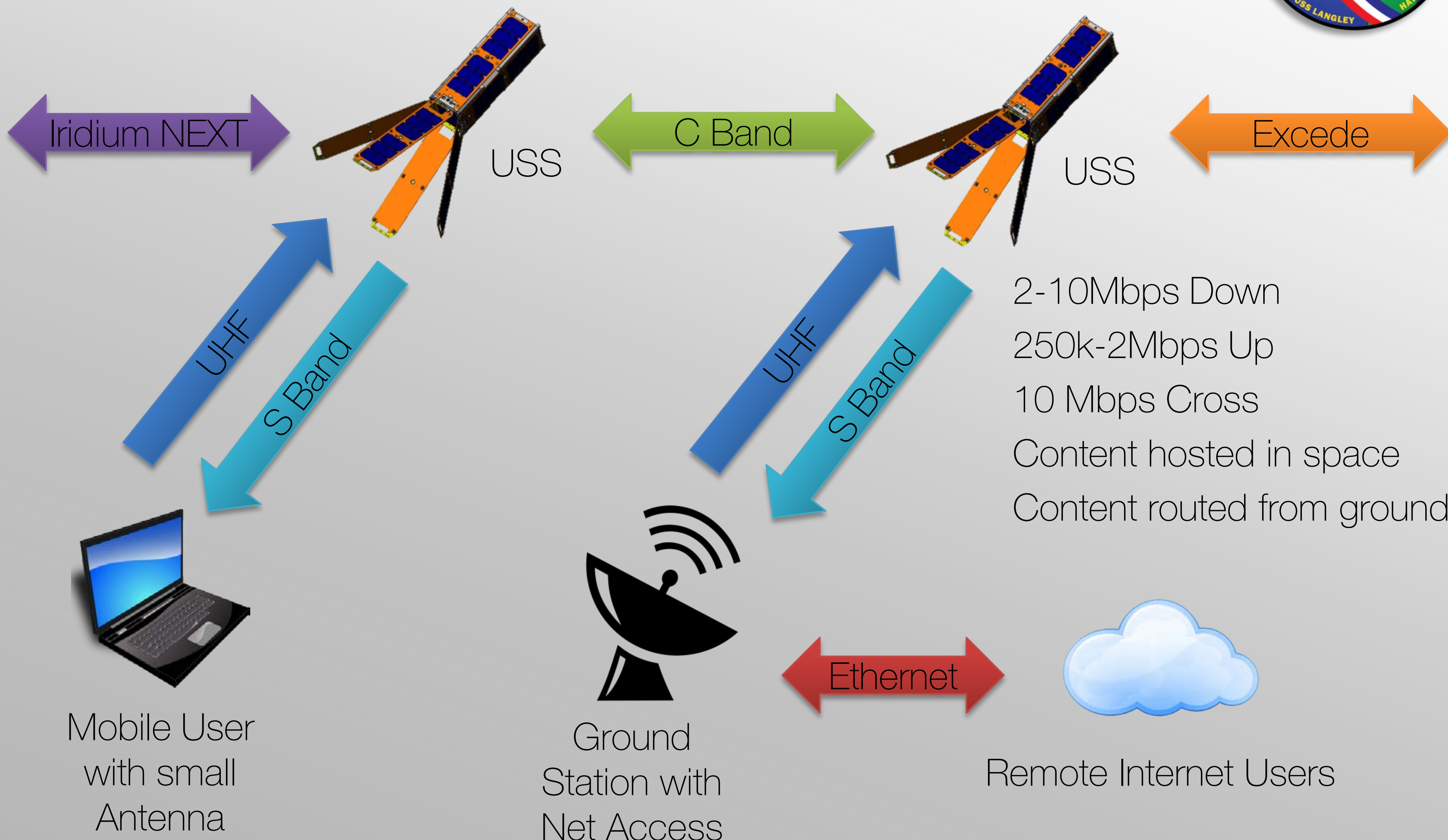
CONSTELLATION

CONOPS of Constellation



- 2-10Mbps Down
- 250k-2Mbps Up
- 10 Mbps Cross
- Content hosted in space
- Content routed from ground

Cost Analysis of USS Constellation

USS Constellation Cost Estimates per Satellite (100+ Satellites)		
Subsystem	Low Estimate (USD)	High Estimate (USD)
Structure	$2,000	$3,000
C&DH	$1,000	$2,000
EPS	$2,000	$6,000
Solar Panels	$50,000	$125,000
Comms	$3,000	$15,000
ADCS	$5,000	$40,000
Server Payload	$1,000	$2,000
Wiring/ Harness	$1,000	$4,000
Thermal/ Support	$1,000	$3,000
Total	**$66,000**	**$200,000**
Launch	$50,000	$100,000
Total for 576	$66,816,000	$172,800,000
Iridium Divisor	**43.40**	**16.78**

Cost Analysis (con’t)

- Every company that has tried this has had financial issues (Teledesic, Globalstar, and now Iridium)
- It is an issue of scalability and complexity of satellites (simple, cheap, breakable might be the solution)
- 20-40x less investment required means 20x less charged to consumers
- However, this system will need continuous launches

Cost Benefit of USS Constellation

Pros

- Great uptime
- Low Latency
- High revisit time
- Global coverage
- Redundancy
- Content hosted in space
  - Military and disaster response application

Cons

- Slower data rates vice GEO
- Constant relaunch
- Lots of handoff and crosslinks!
- Low orbit near ISS
- Harder to get FCC approval
- $200 Million investment (Big for small sats)

USS Langley

CONCLUSIONS

Feasibility Concerns

- Radiation is always a higher concern with non-space-rated COTS hardware, but developing radiation hardened boards would increase costs.
- Engineering costs and fabrications costs could be higher than expected (same on USS Langley)
- Need to stay under ~350km so NASA can sleep at night (<2 year lifetime)
- Availability and cost of launches

Next Steps

- Finish and launch the USS Langley
- Evaluate completion of primary and secondary mission objectives to evaluate USS Constellation feasibility
- Formulate a firm design, test crosslink and router capabilities in a secondary launch
- Get more ground stations onboard
- Open source as much of USS as possible!

USS Langley Design Team

1/C Sipe
Systems Engineer/
Project Manager

1/C Voss
Communications Lead

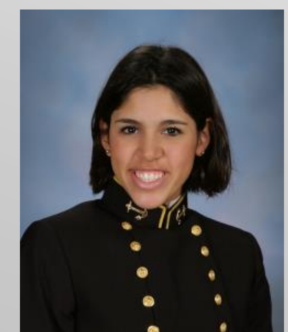
1/C Broll
Structures Lead

1/C Harihara
Programming Lead

1/C Edwards
C&DH Lead

1/C Chester
Logistics/ Asst
Project Manager

1/C Doyle
Ground Station &
I&T Lead



1/C Reyes
ADACS Lead

Acknowledgments

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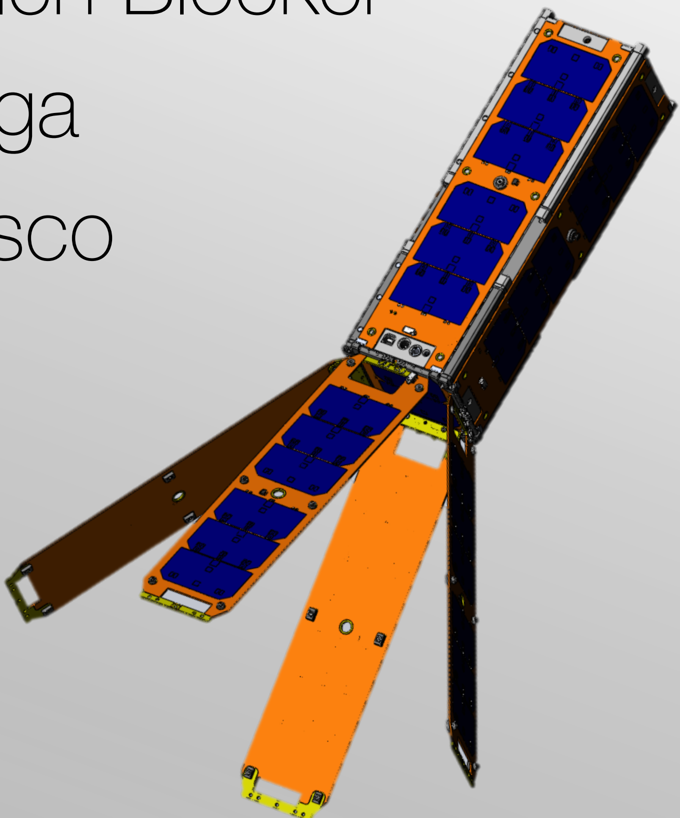
Secondary Advisor - CDR Allen Blocker

Lab Technitian - CDR Bruninga

Lab Technitian - Dante Marasco



QUESTIONS?

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