



CubeSat Communications Survey Update

2011 Summer Developers' Workshop
Utah State University

Bryan Klofas
SRI International
bryan.klofas@sri.com



Background

- “A Survey of CubeSat Communication Systems,” by Bryan Klofas, Kyle Leveque, and Jason Anderson
- Presented at the 2008 Developers Workshop at Cal Poly
 - PSLV-C9 CubeSats published in November/December 2009
AMSAT-NA Journal

Previous CubeSats

(2003-2008)



- Eurockot Launch

- AAU1 CubeSat
- DTUsat-1
- CanX-1
- Cute-1 (CO-55)
- QuakeSat-1
- XI-IV (CO-57)

- SSETI Express

- XI-V (CO-58)
- NCube-2
- UWE-1

- M-V-8 Launch

- Cute-1.7+APD (CO-56)

- Dnepr Launch 1

- Minotaur Launch 1

- GeneSat-1

- Dnepr Launch 2

- CSTB1
- AeroCube-2
- CP4
- Libertad-1
- CAPE1
- CP3
- MAST

- PSLV-C9

- Delfi-C3 (DO-64)
- SEEDS-2 (CO-66)
- CanX-2
- AAUSAT-II
- Cute 1.7+APD II (CO-65)
- Compass-1

- Falcon Launch 1

Total: 24

Current CubeSats

(2009-August 2011)



- Minotaur-1
 - AeroCube-3
 - CP-6
 - HawkSat-1
 - PharmaSat
- ISILaunch 01
 - BEESAT
 - UWE-2
 - ITUpSAT1
 - SwissCube
- Japanese H-IIA F17
 - K-Sat
 - Waseda-SAT2
 - Negai Star
- PSLV-C15
 - Tlsat-1
 - STUDSAT
- STP-S26
 - RAX-1
 - O/ORES
 - NanoSail-D2
- Falcon 9-002
 - Perseus (4)
 - QbX (2)
 - SMDC-ONE
 - Mayflower
- Taurus XL

Total: 24

Minotaur 1

19 May 2009



- **AeroCube-3**
 - FreeWave Technologies
 - 900 MHz frequency hopping, 2 watts
- **CP-6**
 - CC1000
 - 437 MHz, 1200 baud, 1 watt
- **HawkSat-1**
 - MicroHard MHX-425
 - 425 MHz, 1 watt
 - Never heard from in space
- **PharmaSat**
 - 437 MHz beacon, 1 watt
 - MicroHard MHX-2400



AeroCube-3



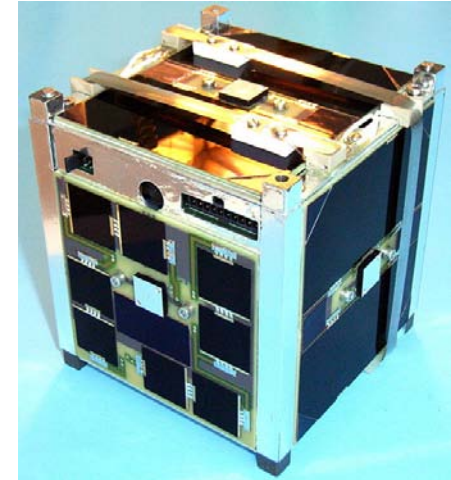
CP6

ISILaunch 01

PSLV-C14, 23 September 2009



- **BEESAT-1**
 - 436 MHz custom radio
 - 4800 and 9600 bps GMSK
- **UWE-2**
 - 437.385 MHz, 1200 bps AX.25
- **ITUpSAT1**
 - 437.325 MHz 19.2 kbps and CW
 - 1 watt
- **SwissCube**
 - Custom built radio
 - 437.505 MHz, 1200 bps FSK and CW
 - 500 mW



BEESAT-1



ITUpSAT1

Japanese H-IIA F17

20 May 2010



- K-Sat

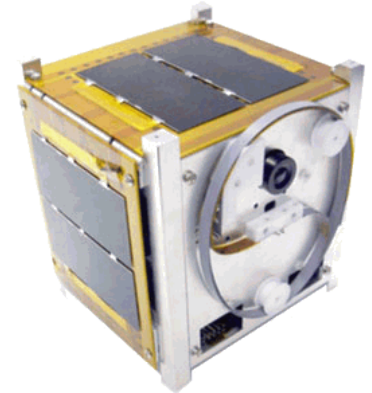
- Uplink: 10 kbps S-band
- Downlink: 10 kbps/1 Mbps 13.275 GHz
- 200mW BPSK

- Waseda-SAT2

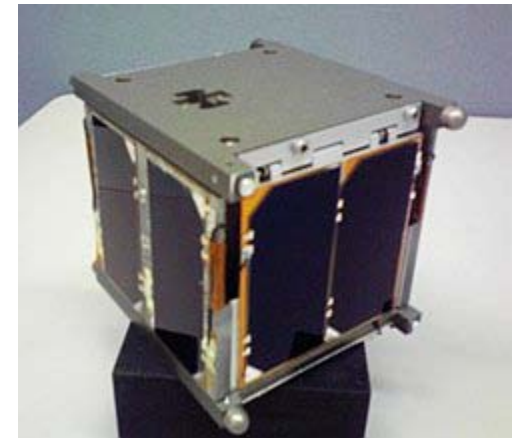
- Institute of Western Wireless radio
- 437.485MHz CW, 9600bps FSK

- Negai Star

- 437.305MHz CW, Packet 1200bps FSK AX.25



Negai Star



Waseda-SAT2

NLS6

PSLV-C15, 12 July 2010

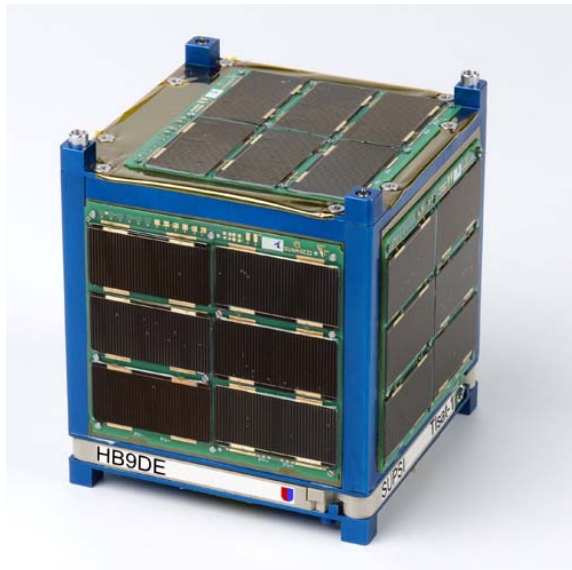


- Tlsat-1

- Alinco DJC-6 and Custom CW radio
- 437.305 MHz, 1200 baud AFSK

- STUDSAT

- 437.505 MHz, 9600 baud FSK and CW beacon



Tlsat-1



STUDSAT

STP-S26

Minotaur 4, 19 November 2010



- RAX-1

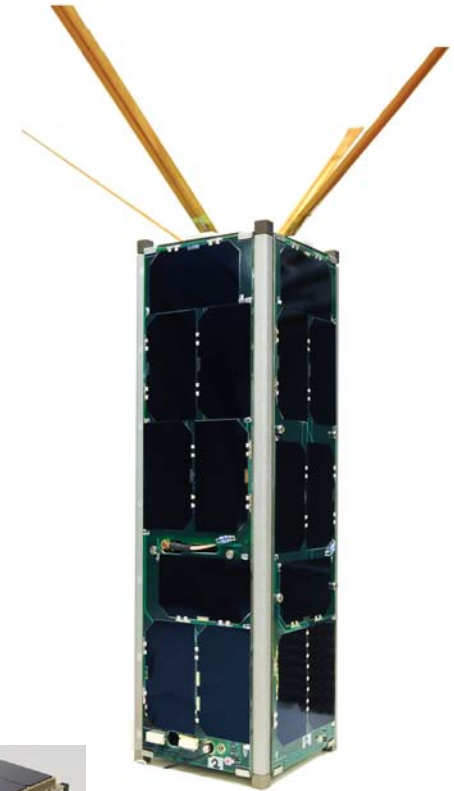
- AstroDev Helium Radio
- 437.505 MHz, 9600 baud FSK, 2W
- MHX-2400, never turned on

- O/ORES

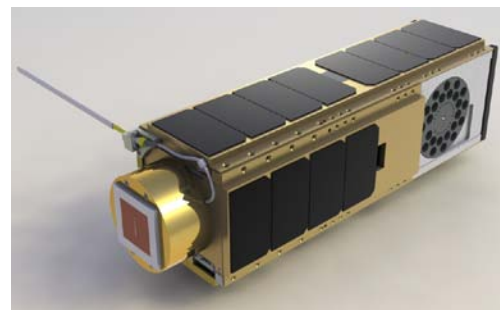
- 437.305 MHz AX.25 Stensat beacon
- MHX-2420 S-band

- NanoSail-D2

- Stensat beacon only
- 437.270 MHz AX.25



RAX-1



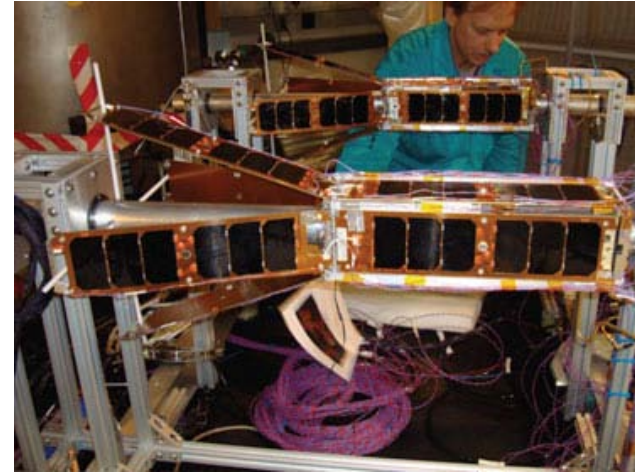
O/ORES

Falcon 9-002

8 December 2010



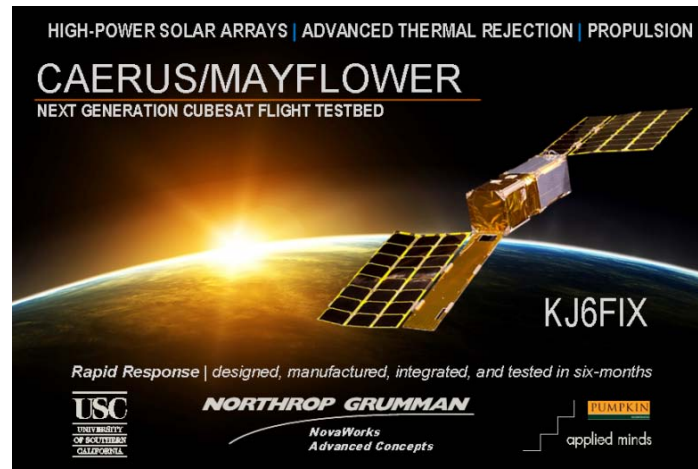
- Perseus (4)
- QbX (2)
- SMDC-ONE
 - UHF
- Caerus/Mayflower
 - 437.600 MHz, 1200 baud AFSK
 - 900 mW



QbX



Perseus



Mayflower



SMDC-ONE

Summary



- Downlink Frequencies
 - 13: 437 MHz amateur band
 - 1: 900 MHz
 - 2: S-band
 - 1: 13 GHz
 - 7: unknown
- 9 of 18 teams outside of US (11 of 18 earlier)
- Organizations
 - 11 University
 - 6 Government
 - 2 Private

NSF Current Approaches



	Downlink	Spacecraft TX	Ground Station RX
RAX (STP-S26)	437 MHz 9600 baud	AstroDev Helium	Icom 910
FireFly (Elana4/CRS-2)	401 MHz	AstroDev Colony-2	
FIREBIRD	145 MHz 19200 baud	AstroDev Helium	Icom 910
DICE (Elana3/NPP)	460 MHz 1.5 Mbps	L-3 Cadet	USRP
CINEMA (Elana6/OUTSat)	2.2 GHz 1 Mbps	Emhiser EDTC-01E1A102-UBC0	11m dish
CSSWE	437 MHz 9600 baud	SX1231 (all-in-one chip)	Kenwood TS-2000



NSF Current Frequency Allocations

Award	Project	PIs	Type	License			Downlink Frequencies
				Agency	Sponsor	Status	
# 1	RAX	Cutler/Bahcivan	Amateur/ISM	FCC	UMich	Granted	437 MHz; 2.4 GHz ISM
	FireFly	Rowland/Weatherwax	Space Research	NTIA	NASA	Submitted	400 MHz
ARRA	FIREBIRD	Klumpar/Spence	Amateur	FCC	MSU	Coordinated	145 MHz, 19200baud GMSK
	DICE	Crowley/Swenson	Meteorological Satellite	NTIA	NSF	Not submitted	460 MHz, 1.5Mbps
# 2	CINEMA	Lin	Space Research	NTIA	NSF	Submitted	2.2 GHz
	CSSWE	Li/Palo	Amateur	FCC	U Colorado	Coordinated	437 MHz

Questions?



- Thanks for your time
- bryan.klofas@sri.com