



Frequency Allocation for Government-funded CubeSats: NSF Paves the Way

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Introduction

- The CubeSat and Amateur Radio communities have always had a mutually beneficial relationship
 - University CubeSat teams bring exciting ideas, education, and new operators to the table
 - Amateurs bring RF knowledge, ground station experience, and spectrum
- Consequently, most CubeSats launched used the Amateur-Satellite Service for communications, even satellites that don't fit into the Amateur-Satellite Service
- Funding issues prevent NSF CubeSats from using Amateur radio frequencies
- This paper intends to show that obtaining an NTIA license is possible for NSF-sponsored CubeSats

CubeSat Launches (1 of 2)

- Eurockot Launch (30 June 2003)
 - AAU1 CubeSat
 - DTU sat-1
 - CanX-1
 - Cute-1 (CO-55)
 - QuakeSat-1
 - XI-IV (CO-57)
- SSETI Express (27 Oct 2005)
 - XI-V (CO-58)
 - NCube-2
 - UWE-1
- M-V-8 Launch (22 Feb 2006)
 - Cute-1.7+APD (CO-56)
- Dnepr Launch 1 (26 July 2006)
(launch failure)
- Minotaur 1 (11 Dec 2006)
 - GeneSat-1 (2.4GHz)
- Dnepr Launch 2 (17 Apr 2007)
 - CSTB1
 - AeroCube-2
 - CP4
 - Libertad-1
 - CAPE1
 - CP3
 - MAST
- PSLV-C9 (28 Apr 2008)
 - Delfi-C3 (DO-64)
 - SEEDS-2 (CO-66)
 - CanX-2
 - AAUSAT-II
 - Cute 1.7+APD II (CO-65)
 - Compass-1
- Falcon Launch 1 (2 Aug 2008)
(launch failure)

Green = Amateur
Red = Experimental
Blue = NTIA
Purple = ISM

CubeSat Launches (2 of 2)

- Minotaur-1 (19 May 2009)
 - AeroCube-3
 - CP-6
 - HawkSat-1
 - PharmaSat (2.4 GHz)
- ISILaunch 01 (23 Sep 2009)
 - BEESAT
 - UWE-2
 - ITUpSAT1
 - SwissCube
- Japanese H-IIA F17 (20 May 2010)
 - K-Sat
 - Waseda-SAT2
 - Negai Star
- PSLV-C15 (12 July 2010)
 - Tlsat-1
 - STUDSAT
- STP-S26 (19 Nov 2010)
 - RAX-1 (2.4 GHz)
 - O/ORES (2.4 GHz)
 - NanoSail-D2
- Falcon 9-002 (8 Dec 2010)
 - Perseus (4)
 - QbX (2)
 - SMDC-ONE
 - Mayflower
- Taurus XL (4 Mar 2011)
(launch failure)
- PSLV-C18 (12 Oct 2011)
 - Jungu
- ELaNa 3/NPP (28 Oct 2011)
 - M-Cubed
 - DICE (2)
 - Explorer-1'
 - RAX-2 (2.4 GHz)
 - AubieSat-1

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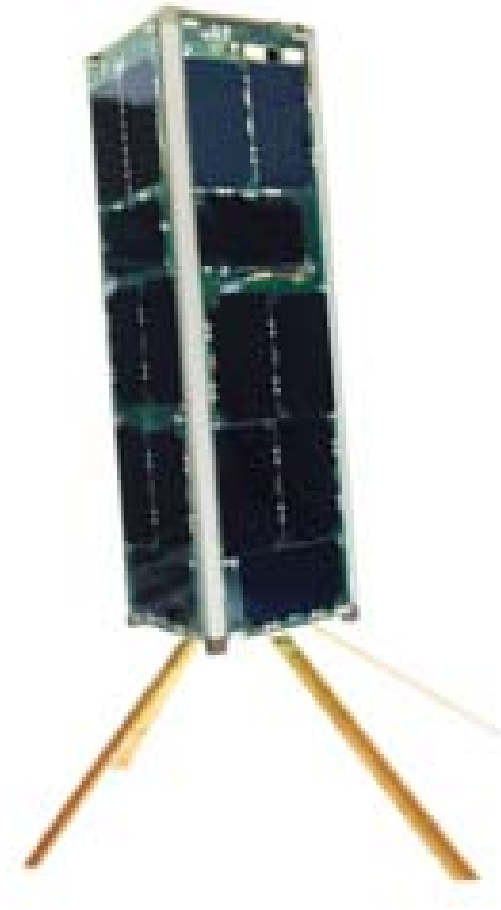
Totals:
40 Amateur
3 Experimental
9 NTIA
7 ISM
55 CubeSats

NSF Program

- Started in 2008 by Therese Jorgensen, Division of Atmospheric and Geospace Sciences at NSF
- Two goals: education and space weather
- \$900k per award
- NSF has a Spectrum Management Department that can help CubeSats get licenses for transmission in government bands
- Currently 8 CubeSats funded
 - 3 NTIA
 - 4 Amateur
 - 1 Undecided
- New call coming out in Spring 2012

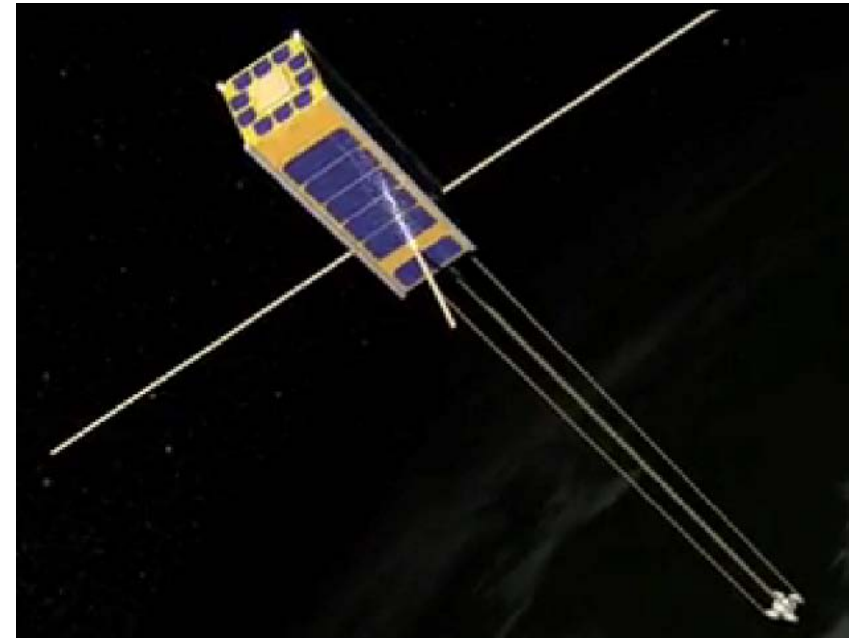
RAX

- University of Michigan and SRI International
 - UHF Radar receiver experiment
 - One 3U CubeSat
 - **Amateur: 437.505 MHz**
 - **Microhard MHX-2400 S-band ISM**
 - Launched 19 November 2010
 - Power problems ended mission early
-
- RAX-2 Launched 28 October 2011
 - Operating normally



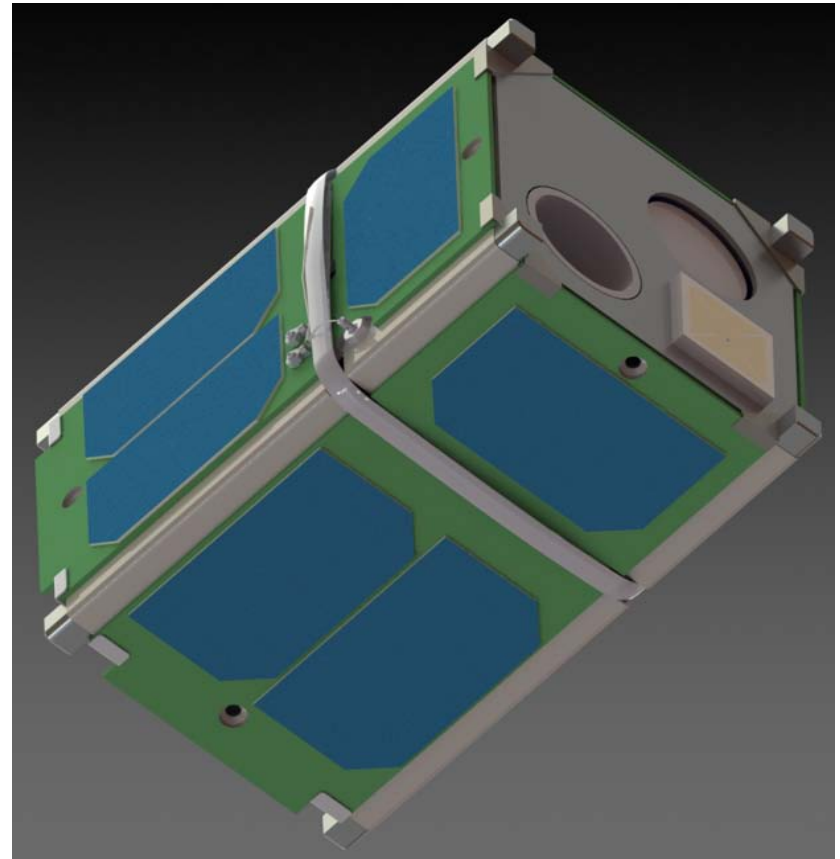
Firefly

- Siena College and NASA Goddard Space Flight Center
- Will measure links between ground lightning and terrestrial gamma ray flashes
- One 3U CubeSat
- Space Research: 401 MHz



FIREBIRD

- Montana State University and University of New Hampshire
- Will measure relativistic electron bursts from the inner radiation belts
- Two 1.5U CubeSats
- **Amateur: 145 MHz**



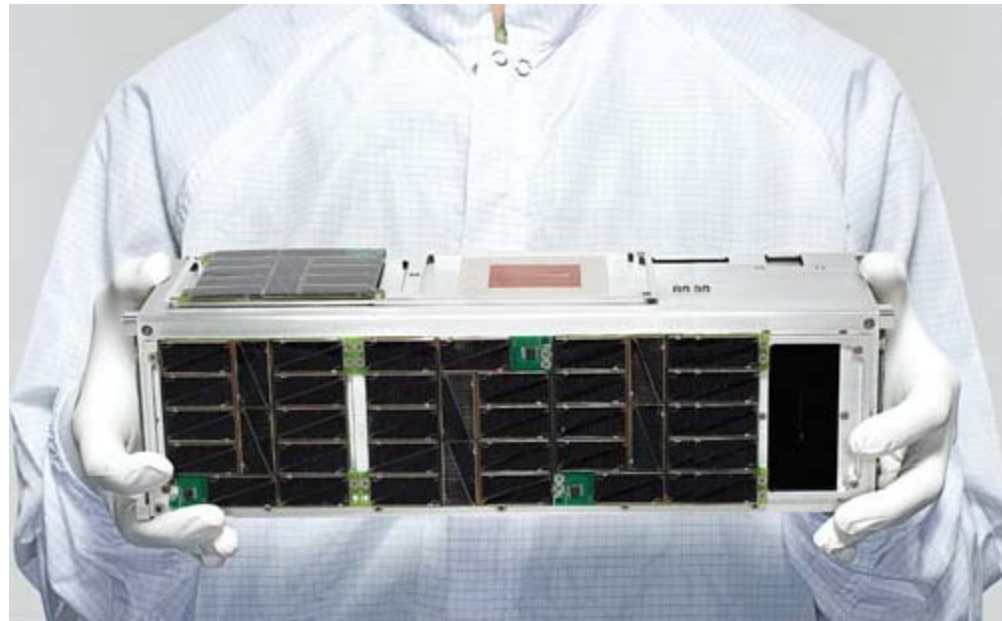
DICE

- ASTRA LLC and Utah State University
 - Measuring ionospheric density
 - Two 1.5U CubeSats
 - **Meteorological Satellite: 460 MHz**
-
- Launched 28 October 2011
 - Successful contact



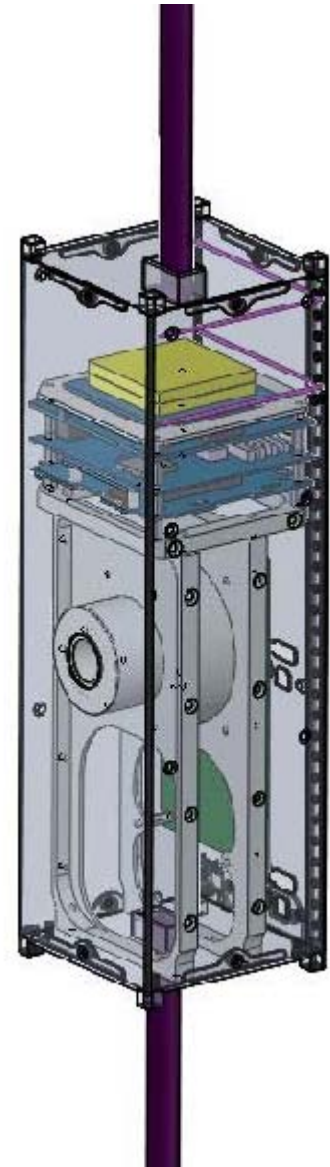
CINEMA

- University of California Berkeley and Kyung Hee University
 - Will measure ions, electrons, and neutrals at high ecliptic latitudes
 - One (plus two) 3U CubeSat
 - [Space Research: 2.2 GHz](#)
-
- Scheduled for launch on ELaNa6/OUTSat



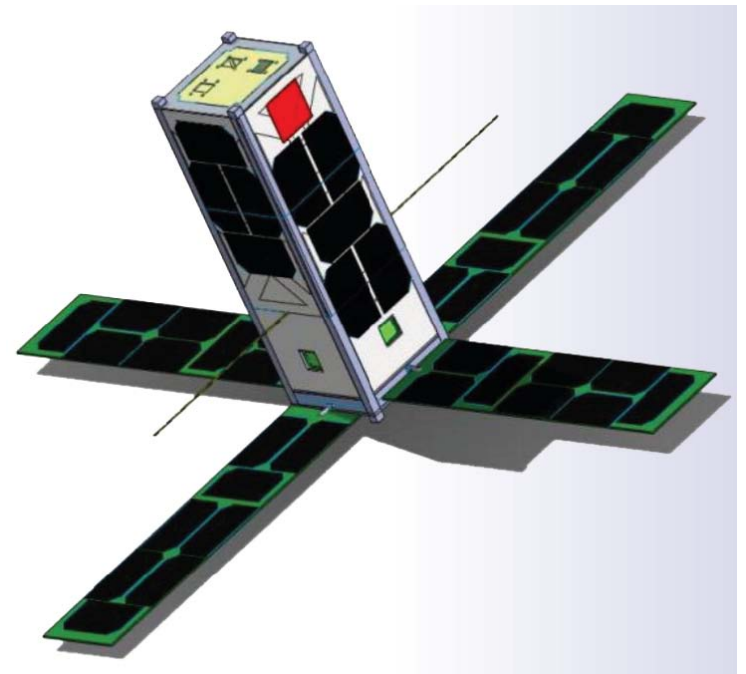
CSSWE

- University of Colorado-Boulder
 - Will measure impacts of solar flares on the earth's outer radiation belts
 - One 3U CubeSat
 - **Experimental: 437.345 MHz**
-
- Scheduled for launch on ELaNa6/OUTSat



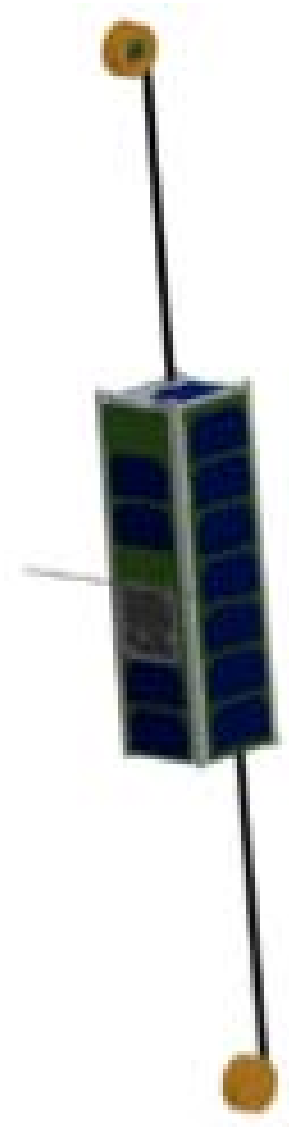
CADRE

- University of Michigan
- Will measure the density and composition of a perturbed thermosphere
- One 3U CubeSat
- Amateur: 437 MHz (Undecided)



EXOCUBE

- Scientific Solutions, Cal Poly, and University of Wisconsin
- Will measure neutral and ion densities using a mass spectrometer
- One 3U CubeSat
- UHF Frequencies Undecided



License Summary

Table 1: Summary of NSF CubeSat Licenses.

Award	Satellite	Downlink	License			
			Type	Agency	Sponsor	Status
1	RAX	437.505 MHz	Amateur	FCC	UMich	Granted
	Firefly	401 MHz	Space Research	NTIA	NASA Wallops	Submitted
ARRA ¹	FIREBIRD	145 MHz	Amateur	FCC	MSU	Not submitted
	DICE	460 MHz	Meteorological Satellite	NTIA	NSF	Certified
2	CINEMA	2.2 GHz	Space Research ²	NTIA	NSF	Certified
	CSSWE	437.345 MHz	Experimental	FCC	UColorado	Coordinated
3	CADRE	437 MHz	Amateur	FCC	UMich	Not submitted
	ExoCube	UHF	?	?	?	Not submitted

¹ These two awards were paid for by The American Recovery and Reinvestment Act of 2009. NSF will not coordinate or fund a launch for these satellites, so the award was increased to compensate.

² Because larger satellite projects at UC Berkeley also use these frequencies, they have existing knowledge and hardware for these frequencies.

Downlink Summary

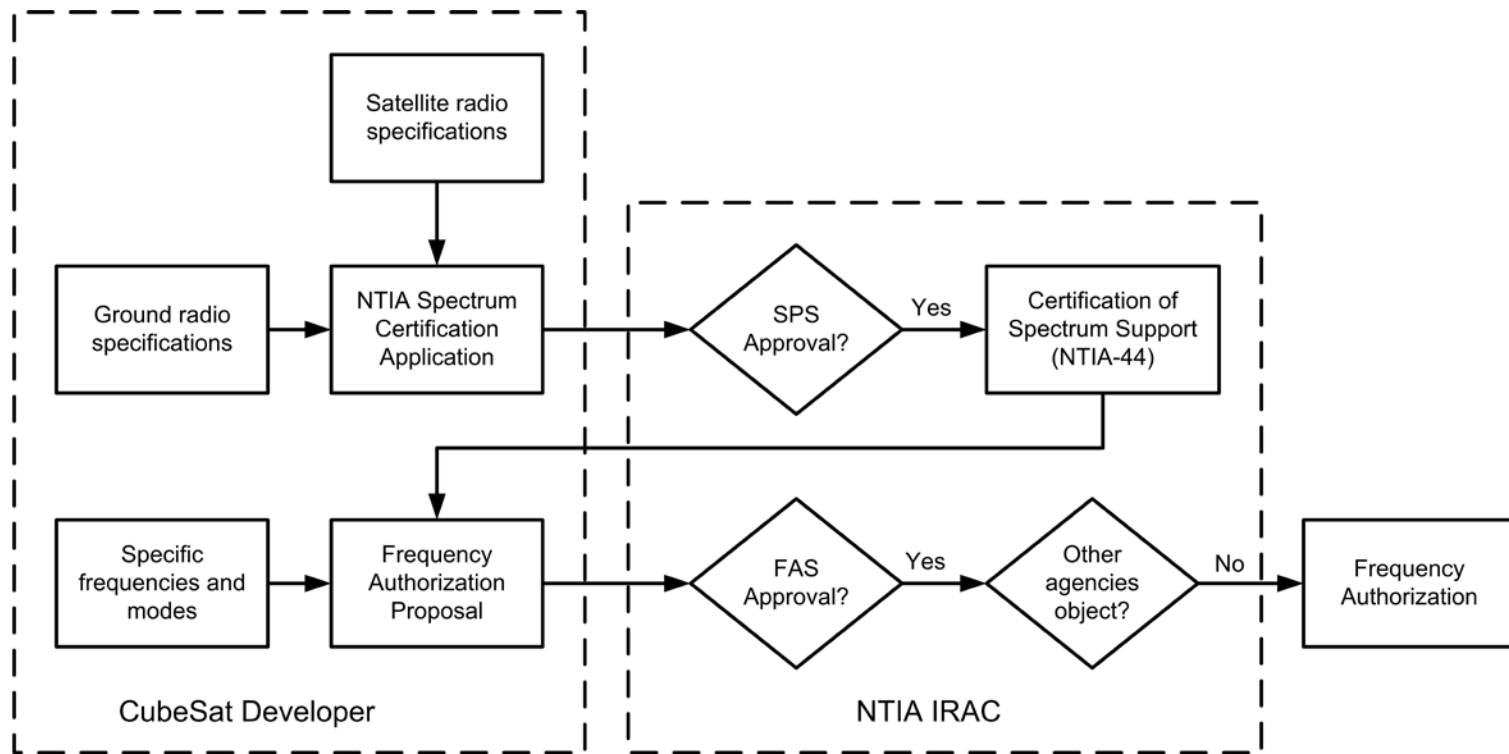
Table 2: Summary of spacecraft transmitters.

Satellite	Downlink	Modulation	Spacecraft TX	Groundstation RX	Launch
RAX	437.505 MHz	9600 baud FSK	AstroDev Helium	Icom 910	STP-S26 ¹
Firefly	401 MHz	38.4 kbps FSK	AstroDev Colony-2	Microdyne 1200-MRC	ELaNa Approved
FIREBIRD	145 MHz	19200 baud FSK	AstroDev Helium	FUNcube Dongle	ELaNa Approved
DICE	460 MHz	1.5 Mbps BPSK	L3 Cadet	USRP	ELaNa3/NPP
CINEMA	2.2 GHz	1 Mbps	Emhiser	11m dish	ELaNa6/OUTSat
CSSWE	437.345 MHz	9600 baud FSK	AstroDev Lithium	TS-2000	ELaNa3/OUTSat
CADRE	437 MHz	9600 baud FSK	AstroDev Lithium	Icom 910	ELaNa ²
ExoCube	UHF	9600 baud FSK	AX5042	Yaesu 847	ELaNa ²

¹ As opposed to all the other NSF CubeSats discussed in this paper, RAX was actually launched on this rocket in November 2010.

² These teams will presumably apply for the ELaNa program in the November 2011 call, although they may not actually be launched through the ELaNa program.

NTIA Process



- Andy Clegg and Tom Gergely from NSF help teams navigate this application process
- DICE and CINEMA successfully completed this process
- Long term prospects for a “small satellite” group under Space Research Service looks very promising; see paper

Summary/Recent News

- NSF-funded CubeSats are beginning to move away from using Amateur Radio frequencies
- However, this process will take time as the process is worked out and documented
- Long-term “small satellite” allocation is moving forward, but expect process to take 10 more years
- Miscommunication between FCC, ITU, and CubeSats on latest ELaNa launch on 28 October 2011
 - 4 days before launch the ITU asks why all the CubeSats are unlicensed
 - Situation cleared up before launch
 - All CubeSats heard from

Thank You

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