



## CubeSat Frequency Allocation

CubeSat Developers' Workshop  
San Luis Obispo, CA  
20 April 2012

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# Introduction

- Frequency coordination/allocation is the longest part
- Traditionally, 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 and other government CubeSats from using Amateur radio frequencies
- Paper:
  - “Frequency Allocation for Government-funded CubeSats: NSF Paves the Way”
  - In Proceedings of the AMSAT-NA Symposium, San Jose, November 2011

# CubeSat Launches (1 of 2)

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

- Eurockot Launch (30 June 2003)
  - AAU1 CubeSat
  - DTUosat-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)
- Minotaur-1 (19 May 2009)
  - AeroCube-3
  - CP-6
  - HawkSat-1
  - PharmaSat (2.4 GHz)

# CubeSat Launches (2 of 2)

- 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' FU2
  - RAX-2 (2.4 GHz)
  - AubieSat-1
- Vega (20 Feb 2012)
  - Xatcobeo
  - Robusta
  - e-st@r
  - Goliat
  - PW-Sat
  - MaSat-1
  - UniCubeSat

Green = Amateur  
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Totals:  
47 Amateur  
3 Experimental  
9 NTIA  
8 ISM  
62 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 due Spring 2012

# 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 <sup>1</sup>	FIREBIRD	145 MHz	Amateur	FCC	MSU	Not submitted
	DICE	460 MHz	Meteorological Satellite	NTIA	NSF	Certified
2	CINEMA	2.2 GHz	Space Research <sup>2</sup>	NTIA	NSF	Certified
	CSSWE	437.345 MHz	Experimental	FCC	UColorado	Coordinated
3	CADRE	437 MHz	Amateur	FCC	UMich	Not submitted
	ExoCube	UHF	?	?	?	Not submitted

<sup>1</sup> 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.

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

# Downlink Summary

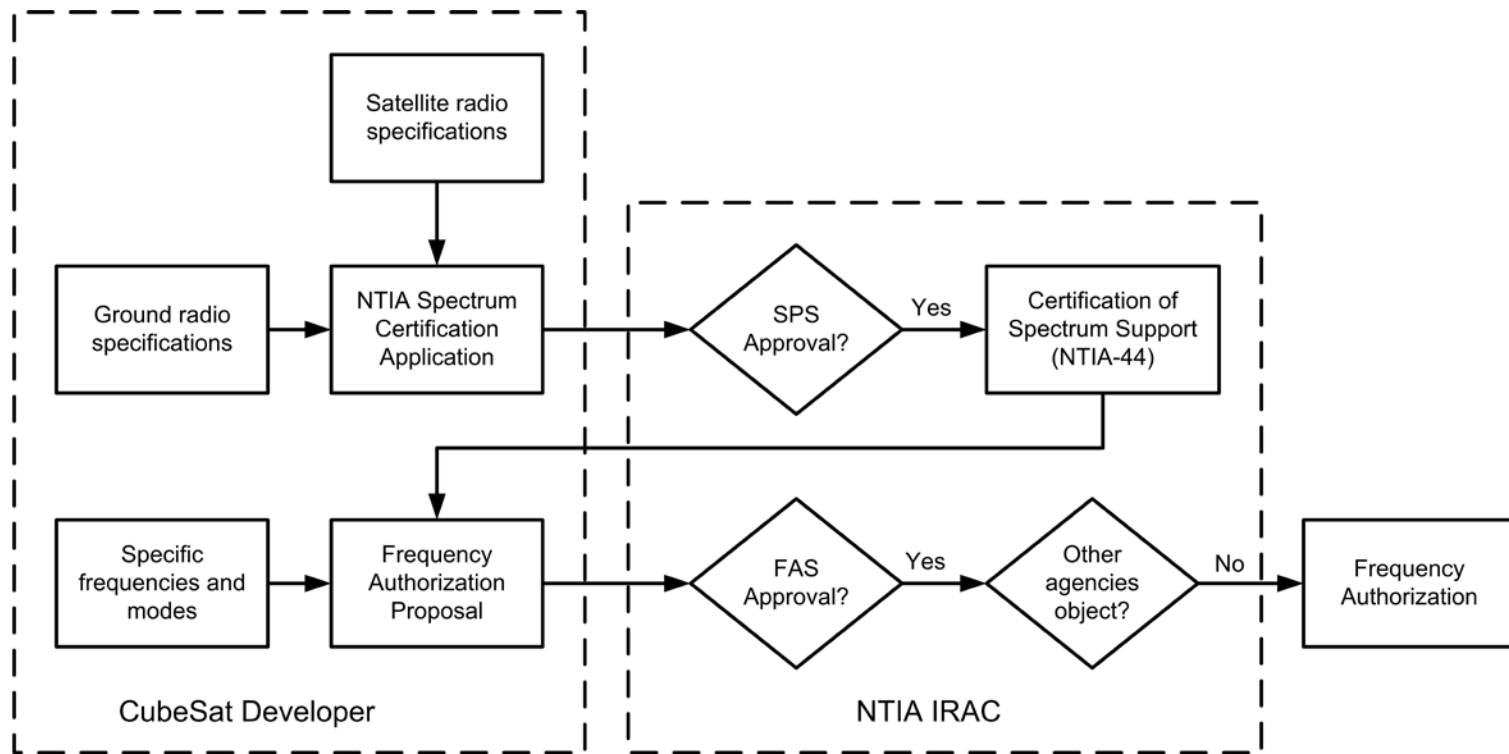
Table 2: Summary of spacecraft transmitters.

Satellite	Downlink	Modulation	Spacecraft TX	Groundstation RX	Launch
RAX	437.505 MHz	9600 baud FSK	AstroDev Helium	Icom 910	STP-S26 <sup>1</sup>
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 <sup>2</sup>
ExoCube	UHF	9600 baud FSK	AX5042	Yaesu 847	ELaNa <sup>2</sup>

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

<sup>2</sup> 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



# Recent News

- NSF-funded CubeSats are beginning to move away from using Amateur Radio frequencies for high data rate CubeSats
- 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

# CubeSat High-Speed Downlink Communications

- Provide high-speed data downlinks for future CubeSat NSF missions
  - Expandable to all educational missions in the future
- Open standards/interoperable
  - Multiple Access
  - Published Documentation
- Meetings:
  - Proposed at CEDAR 2009 by Chuck Swenson
  - Discussed at SmallSat 2009
  - AGU meeting in December 2009 and 2010
  - Meeting at CubeSat Workshop 2012

# CHDC Results

- DICE:
  - Utah State University
  - Two 1.5U CubeSats using L3 Cadet Radio
  - 460-470 MHz Meteorological-satellite (space-to-Earth)
  - Power limitations require big dish on ground
  - Science operations begin next week
- CINEMA:
  - UC Berkeley
  - Single (+2) 3U CubeSat
  - 2200-2290 MHz Space Research (space-to-Earth)
  - Completed all licensing requirements
  - Manifested on ELaNa6/OUTSat, launch Aug 2012

# CHDC Meeting at this workshop

- NTIA is clamping down on the definition of Federal and non-Federal Cubesats
- Federal Satellite if:
  - Cubesat is government funded
  - Launched on a government rocket
  - Launched with a government primary
  - Ground stations are owned, operated, and funded by the government
  - Government has tight control over operations
- S-band 2200-2290 MHz is particularly affected
- FCC recommends CubeSats file for experimental licenses

# CHDC Meeting at this workshop

- Miscommunication between FCC, ITU, and CubeSats on latest ELaNa3/NPP launch on 28 October 2011
  - 4 days before launch the ITU asks why all the CubeSats are unlicensed
  - ITU SpaceCap data not filed for FCC-licensed CubeSats
  - After heroic effort by CubeSat PIs, the situation was cleared up before launch
  - Lesson Learned: Each team should ensure SpaceCap database is filled out and sent to ITU well before launch

# Thank You

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# 5<sup>th</sup> Annual Avila Beach Bonfire

- Tonight 6:30pm
- Burgers and Brauts provided
- See flyers for directions
  - South on 101, exit Avila Beach Drive
  - Pits on the beach near end of road