



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

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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 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

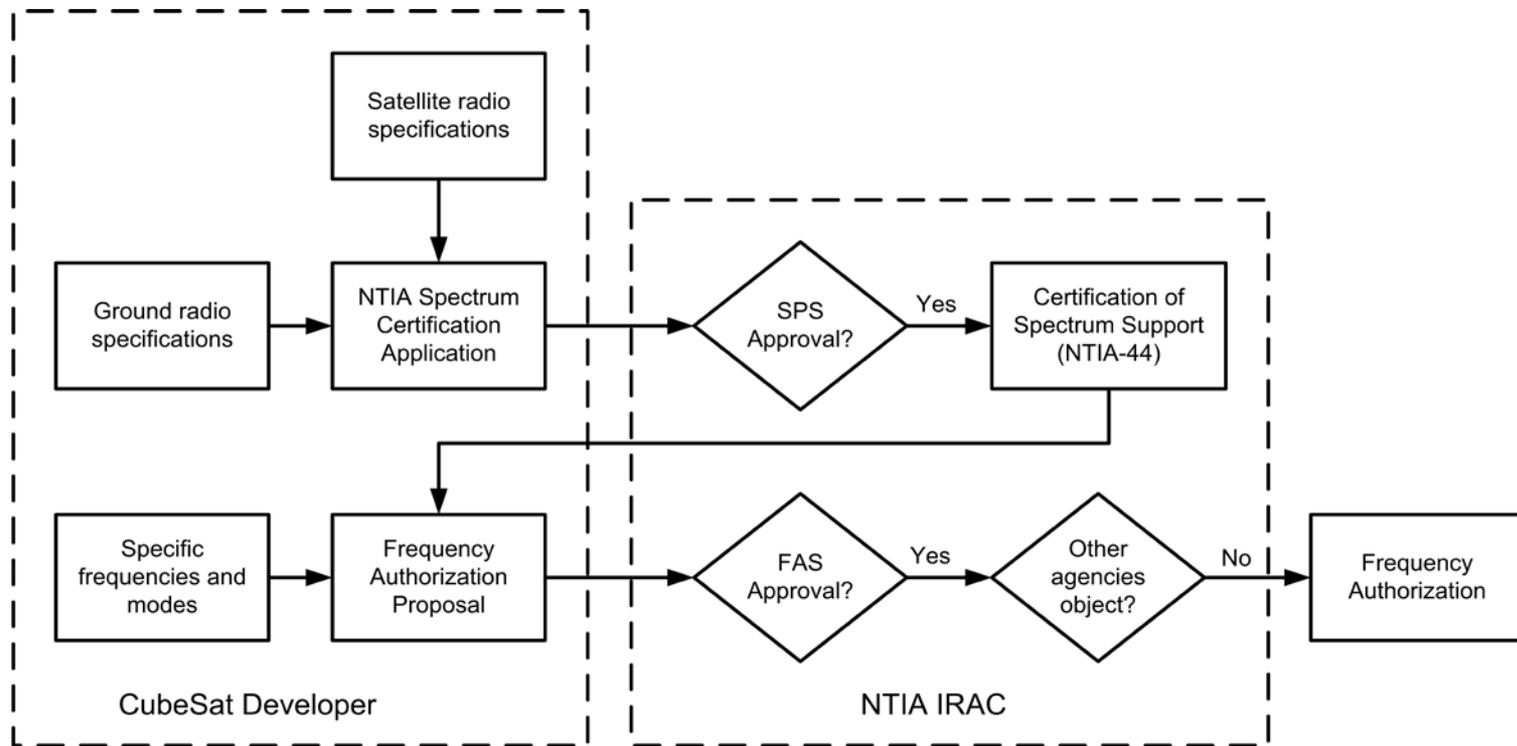
Table 2: Summary of spacecraft transmitters.

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

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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