Upcoming Amateur Radio CubeSats: The Flood Has Arrived

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1 Introduction

In the next several months, approximately 58 CubeSats will be launched into space on four upcoming launches. This represents an approximately 50% increase in the number of CubeSats currently orbiting the earth. This expected increase has created strain for licensing and coordinating organizations, such as the Federal Communications Commission (FCC) and the International Amateur Radio Union (IARU).

In this paper, we will review the manifests of these four upcoming launches, explain recent clarifications to the licensing rules, and discuss the downlink frequencies and licensing service for each of the CubeSats.

2 Changes to CubeSat Licensing

As mentioned at several recent workshops [1, 2, 3], the FCC and International Telecommunications Union (ITU) are in the process of clamping down on licensing for small satellites. Only satellites that provide benefit to the amateur radio community, such as a transponder that the average ham operator can use, are allowed to follow the amateur satellite service rules.

The FCC and National Telecommunications and Information Administration (NTIA) are also clamping down on the difference between private or commercial satellites, which obtain a license through the FCC, and government satellites, which acquire a license through the NTIA. Only government-funded and government-operated satellites may apply for a government license through the NTIA; all others must apply through the FCC.

In March 2013, the FCC released a public notice titled "Guidance on Obtaining Licenses for Small Satellites" (DA-13-445). While this document helps clarify the licensing process and rules related to small satellite communications, it does not provide any guidance on which service the satellite operator should select. Many CubeSats still use amateur radio frequencies due to the hardware readily available for those frequencies. Only when satellite and ground station radio hardware on other frequencies is easily available and flight-proven will CubeSats migrate away from amateur satellite frequencies.

3 ORS-3/ELaNa-4

Scheduled for launch in early November 2013, the ORS-3/ELaNa-4 launch is a collaboration between the Operationally Responsive Space (ORS) office and the Educational Launch of Nanosatellite (ELaNa) Program. It is the first launch of the CubeStack Adapter, commonly called the "wafer." The CubeStack Adapter is built by Moog CSA Engineering, mounts between the upper stage of the rocket and the primary payload, and holds up to eight 3U CubeSat dispensers [4, 5]. This launch in November will include two CubeStack Adapters, with STPSat-3 as the primary spacecraft.

This is the first CubeSat launch for which the FCC encouraged all non-government CubeSats to obtain experimental licenses. The CubeSat integration team, in this case Cal Poly State University, filled out all the appropriate paperwork related to the experimental license, and forwarded the orbital debris and lifetime analysis reports to the FCC. If the radio frequency allocation the team was attempting to obtain fell within the amateur satellite service, the FCC also required a coordination letter from the IARU.

Table 1: ELaNa-4 and ORS CubeSats on the ORS-3 Launch [6, 7, 8].

Satellite	**Size**	**Downlink**	**License**
COPPER	1U	437.290 MHz	Experimental
TJ3Sat	1U	437.320 MHz	Experimental
Vermont Lunar Cube	1U	437.305 MHz	Experimental
SwampSat	1U	437.385 MHz	Experimental
CAPE-2	1U	437.325 MHz	Experimental
Ho'oponopono-2	3U	437.220 MHz	Experimental
PhoneSat-v2.4	1U	437.425 MHz	Experimental
Trailblazer	1U	437.425 MHz	Experimental
DragonSat-1	1U	145.870 MHz	Experimental
KySat-2	1U	437.405 MHz	Experimental
ChargerSat-1	1U	437.405 MHz	Experimental
NPS-SCAT	1U	437.525 MHz	Government
Black Knight 1	1U	437.345 MHz	Government
ORS 1	3U		Government
ORS 2	3U		Government
ORS 3	3U		Government
Prometheus 1	3U		Government
Prometheus 2	3U		Government
Prometheus 3	3U		Government
Prometheus 4	3U		Government
SENSE 1	3U	2.2 GHz	Government
SENSE 2	3U	2.2 GHz	Government
FireFly	3U	425 MHz	Government
Horus	3U	915 MHz	Government

4 ISS Launch

Organized by NanoRacks, the four CubeSats described below were brought up to the International Space Station (ISS) on the Japanese HTV-4 vehicle in March 2013. They are expected to be deployed from the two Japanese J-SSOD deployers in early November 2013.

The ISS launch contains two identical ArduSat 1U CubeSats, financed through crowd funding and built by NanoSatisfi. Each satellite contains 17 ATmega328P Arduino processors, and a suite of sensors. The general public can rent time on the spacecraft to perform basic experiments for a nominal fee [9]. The third CubeSat, Pico Dragon, is a 1U CubeSat developed by the Vietnam Academy of Science and Technology, and will take pictures of the earth. The fourth CubeSat, TechEdSat-3, contains an advanced avionics system, and the main payload is an exo-brake passive de-orbit system [10].

All the CubeSats on this launch are in the UHF amateur satellite band, but only Pico Dragon is licensed under the amateur satellite service, as shown in Table 2.

Table 2: CubeSats deployed from the ISS [9].

Satellite	**Size**	**Downlink**	**License**
ArduSat-1	1U	437.325 MHz	Experimental
ArduSat-X	1U	437.345 MHz	Experimental
Pico Dragon	1U	437.250 MHz	Amateur Satellite
TechEdSat-3P	3U	437.465 MHz	Experimental

5 Dnepr

The Dnepr rocket is scheduled to be launched in late November 2013 from the Dombarovsky launch site in Yasny, Russia. The rocket will transport 18 CubeSats and 5 PocketQubs into a 720 km orbit at 98 degrees. This is the biggest launch of secondary satellites since the Dnepr-1 launch crashed in July 2006. Some of the satellites of interest to the amateur radio community on this launch include:

FUNcube-1 is built for AMSAT-UK by Innovative Solutions in Space (ISIS), and contains a 20 kHz inverting linear transponder, with the uplink at 435.140 MHz and the downlink at 145.960 MHz. It also contains a BPSK telemetry channel at 145.935 MHz [11].

ZACube-1 is the first CubeSat from South Africa, and contains a 14.099 MHz HF beacon. This will be used as an on-orbit source for ionospheric measurements for the DARN network over Antarctica.

Delfi-n3xt also contains a linear transponder, an earlier version of the one inside FUNcube-1. It will be activated some of the time [12].

TRITON-1 contains an amateur radio transponder that will activate when the primary mission of AIS ship tracking ends.

ISIS provides launch integration and launch support services for the first 9 ISIPODs listed below in Table 3, and the rest of the CubeSats and PocketQubs will be deployed from UniSat-5.

UniSat-5 is a microsatellite, approximately 45 cm on each side, built by the GAUSS team at the University of Roma La Sapienza in Italy. It contains custom-built deployers for four CubeSats and four PocketQubs. The four CubeSats inside UniSat-5 will be deployed from two Planted Elementary Platforms for Picosatellite Orbital Deployment (PEPPOD). The PUCP-SAT-1 1U CubeSat will deploy the Pocket-PUCP PocketQub.

UniSat-5 will also launch the first PocketQubs, a femtosatellite standard conceived by Professor Bob Twiggs at Stanford University in 2009 [13]. At approximately 50 mm per side and less than 125 grams (roughly one-eighth the size of a 1U CubeSat), these PocketQubs are deployed from a Morehead Roma Femtosat Orbital Deployer (MR-FOD). Each MR-FOD can hold two 1Q-sized PocketQubs. UniSat-5 contains three MR-FOD deployers.

Table 3: CubeSats and PocketQubs on the Dnepr Launch [12, 14, 15].

Satellite	**Size**	**Downlink**	**License**
FUNcube-1	1U	145.960 MHz	Amateur Satellite
ZACube-1	1U	437.345 MHz	Amateur Satellite
HiNcube	1U	437.305 MHz	Amateur Satellite
First-MOVE	1U	145.970 MHz	Amateur Satellite
UWE-3	1U	437.385 MHz	Amateur Satellite
Velox-PII	1U	145.980 MHz	Amateur Satellite
NEE-02 KRYSAOR	1U	980 MHz	Experimental?
CubeBug-2	2U	437.445 MHz	Amateur Satellite
KHUSAT-1	3U	2.2 GHz	Space Research
KHUSAT-2	3U	2.2 GHz	Space Research
TRITON-1	3U	145.815 MHz	Amateur Satellite
Delfi-n3xt	3U	145.900 MHz	Amateur Satellite
OPTOS	3U	402 MHz	Earth-exploration Satellite
Dove-3	3U	8.2 GHz	Experimental
PUCP-SAT-1	1U	145.840 MHz	Amateur Satellite
Pocket-PUCP	1Q	437.200 MHz	Amateur Satellite
ICUBE-1	1U	145.947 MHz	Amateur Satellite
HUMSAT-D	1U	437.325 MHz	Amateur Satellite
Dove-4	3U	8.2 GHz	Experimental
SWEsat (Eagle-1)	1Q	437.465 MHz	Experimental
$50sat (Eagle-2)	1Q	437.505 MHz	Experimental
QBScout-S1	2Q	437.525 MHz	Experimental
WREN	1Q	437.405 MHz	Amateur Satellite

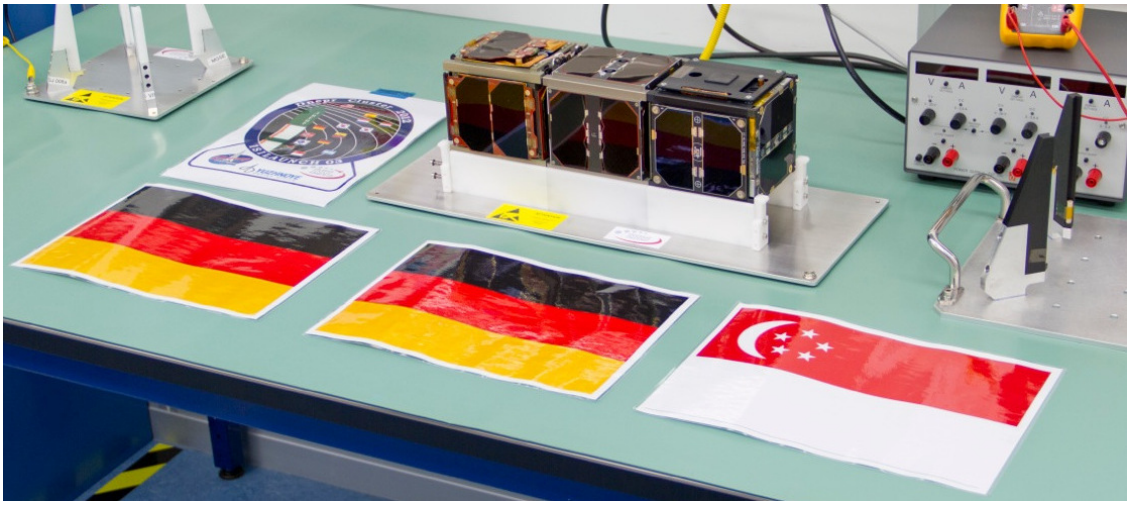

Figure 1: First-MOVE, UWE-3, and Velox-PII CubeSats before integration into the ISIPOD [16].

6 NROL-39/ELaNa-2

This joint NRO and NASA launch is scheduled for early December 2013 from Vandenberg, California. Also called GEMSat, the deployer is a Naval Postgraduate School CubeSat Launcher (NPSCuL) mounted to the aft bulkhead carrier of an Atlas V rocket. The NPSCuL was built by students at the Naval Postgraduate School. The CubeSats on this launch include:

IPEX, which contains an FPGA payload for the Jet Propulsion Laboratory, and was built by Cal Poly State University [17].

CUNYSat-1, which contains a GPS radio occultation receiver, and was built by students at Medgar Evers College in the City University of New York.

FIREBIRD, which is a two 1.5U mission built by Montana State University for the National Science Foundation. It will look at relativistic electron bursts in the magnetosphere [18].

The GEMSat integration team, consisting of Cal Poly State University, SRI International, and NPS, managed the CubeSat integration and coordinated the frequency license applications.

Table 4: CubeSats on the ELaNa-2 launch [19, 20].

Satellite	**Size**	**Downlink**	**License**
IPEX	1U	437.270 MHz	Experimental
MCubed-2	1U	437.485 MHz	Experimental
CUNYSat-1	1U	437.505 MHz	Experimental
FIREBIRD A	1.5U	437.405 MHz	Experimental
FIREBIRD B	1.5U	437.230 MHz	Experimental
Alice	3U		Government
Aerocube-5a	1.5U	915 MHz	Experimental
Aerocube-5b	1.5U	915 MHz	Experimental
SMDC-ONE 2.2	3U		Government
SMDC-ONE 2.3	3U		Government
TacSat-6	3U		Government
SNAP	3U		Government

7 Conclusion

If the four launches happen with minimal delays, the upcoming months promise to be very exciting for the UHF amateur radio spectrum. Many new CubeSats and PocketQubs will be on orbit, and every launch will create a scramble to match satellites with object numbers.

Progress is also being made on licensing support for CubeSat developers. Launch integrators are now required by their funding agencies and mission managers to provide technical and logistical support for frequency selection and license acquisition, including the actual filing of the experimental licenses. This process ensures uniformity, completeness, and coordination of applications, thereby reducing some of the strain on the FCC and IARU. While this frequency licensing support is currently provided for US ELaNa launches only, it is recommended that international launch integrators provide these services.

To encourage CubeSats to move away from amateur radio frequencies, a recent meeting at the SmallSat Conference in Logan, Utah, was convened by the author to discuss emerging hardware radio solutions. Meeting participants discussed many high-speed data radio projects that use non-amateur frequencies in S-band, C-band, X-band, and Ka-band [21, 22, 23, 24].

References

[1] Tomas Gergely and Andrew Clegg. "CubeSat Issues: Where Are We?" Presented at the CubeSat High-Speed Downlink Communications meeting, held during the 9th Annual CubeSat Developers Workshop. San Luis Obispo, California. April 2012.

[2] Bryan Klofas and Kyle Leveque. "A Survey of CubeSat Communication Systems: 2009-2012." In Proceedings of the 10th Annual CubeSat Workshop. San Luis Obispo, California. April 2013.

[3] Peter B. de Selding. "Spectrum Cops Advising Small-satellite Owners of Obligations." SpaceNews. 27 September 2013.

[4] Gregory Sanford, Kenneth Brunetto, Joseph Maly, James Goodding, and Hans-Peter Dumm. "CubeStack Wafer Adapter for CubeSats on Small Launch Vehicles." In Proceedings of the 25th Annual AIAA/USU Conference on Small Satellites. SSC11-II-7. Logan, Utah. August 2011.

[5] Joe Maly. "ESPA CubeSat Accommodations and Qualification of 6U Mount (SUM)." Presented at the 10th Annual CubeSat Developers' Workshop. San Luis Obispo, California. April 2013.

[6] Justin Foley. Personal Communication. 2 October 2013.

[7] Thomas Adang. "ORS Program Status, 1 May 2013." Presented at the Space-based Lidar Winds Working Group. Miami, Florida. May 2012.

[8] "SENSE 1, 2." Gunter's Space Page. http://space.skyrocket.de/doc_sdat/sense.htm. Accessed 2 October 2013.

[9] Joel Spark. Personal Communication. 2 October 2013.

[10] A. Reuter, K. Ramus, J. Mojica, M. Bodmer, N. Hoppins, M. Scales, J. Benson, M. Murbach, and P. Papadopoulos. "The TechEdSAT-3P: The First Passive De-orbit Flight Test from the ISS." In Proceedings of the 10th International Planetary Probe Workshop. San Jose, California. June 2013.

[11] FunCube Website. http://www.funcube.org.uk. Accessed 25 September 2013.

[12] Wouter Weggelaar. Personal Communication. 2 October 2013.

[13] Bob Twiggs. "Making it Small." Presented at the 6th Annual CubeSat Developers Workshop. San Luis Obispo, California. April 2009.

[14] Benjamin Malphrus. Personal Communication. 3 October 2013.

[15] Chantal Cappelletti. Personal Communication. 4 October 2013.

[16] Jan Harder. "Successful Fit Check." Blog posting at http://move.lrt.mw.tum.de/. Accessed 1 October 2013.

[17] "CP8 (IPEX)." http://polysat.calpoly.edu/in-development/cp8-ipex/. Accessed 28 September 2013.

[18] Brian Larsen, Harlan Spence, David Klumpar, Larry Springer, and J. Bernard Blake. "Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics (FIREBIRD)." Presented at the 6th Annual CubeSat Developers Workshop. San Luis Obispo, California. April 2009.

[19] Simon Lee. Personal Communication. 1 October 2013.

[20] "Topaz 1, 2, 3, 4, 5." Gunter's Space Page. http://space.skyrocket.de/doc_sdat/fia-radar.htm. Accessed 2 October 2013.

[21] James Cutler. "Indigo." Presented at the CHDC Meeting during SmallSat. Logan, Utah. August 2013.

[22] Kyle Leveque and John Buonocore. "SRI High Speed Radio." Presented at the CHDC Meeting during SmallSat. Logan, Utah. August 2013.

[23] Courtney Duncan. "Iris for INSPIRE: CubeSat Compatible, DSN Compatible Transponder." Presented at the CHDC Meeting during SmallSat. Logan, Utah. August 2013.

[24] Jan King. "Ka-Band Transmitter for Small Spacecraft." Presented at the CHDC Meeting during SmallSat. Logan, Utah. August 2013.