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

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Abstract

In the beginning, the CubeSat project was a loose collaboration of universities proving that students could build and launch satellites. Building the entire spacecraft on a shoestring budget, these universities partnered with local radio amateurs and used amateur radio frequencies to downlink the small amount of housekeeping data generated.

As the CubeSat project enters its second decade, several large government agencies have started funding CubeSat projects for various missions, in such areas as space weather, imaging, defense, communications, and education. It violates the intent of the Amateur service, and may violate NTIA rules, for government-funded CubeSats to use amateur radio frequencies for communications.

The National Science Foundation (NSF) has been funding space weather CubeSat projects for several years, and is using its Electromagnetic Spectrum Management group to find short- and long-term solutions to these issues. This paper describes the current NSF CubeSats and efforts to transition away from amateur radio frequencies.

Contents

1 Introduction

The CubeSat Project was started in 2001 by Dr. Jordi Puig-Suari at California Polytechnic State University (Cal Poly) and Professor Robert Twiggs at Stanford University. The concept is very simple: if your CubeSat fits into this box, it will get launched at the next available opportunity. The launch vehicle and orbit may not be known when you start building your satellite, but as long as your payload can accept a wide range of orbits, it will get into space[1].

For several reasons, the CubeSat community has always embraced amateur radio. Amateurs have been building satellites for decades, and enjoy sharing their knowledge of the process. Amateur radio hardware is relatively inexpensive and easy to set up, perfect for universities with limited funds and no prior experience building satellites or ground stations. Amateur radio satellite builders volunteer their time to help universities select or build a radio for the spacecraft. Amateur satellite licenses are easy to get, just fill out a simple form and wait a few months. Hundreds of amateurs across the world can send you telemetry from your spacecraft, and uplink commands if necessary to revive a failing satellite[2].

Of the 47 CubeSats launched to date, only 13 have not used amateur radio frequencies: CSTB1, AeroCube-2, MAST, CanX-2, AeroCube-3, K-Sat, and seven CubeSats on the latest Falcon-9 flight[3]. The seven CubeSats on this latest Falcon-9 flight went through the National Telecommunications and Information Administration (NTIA) process with a military agency as the sponsor, and received a frequency allocation before launch.

However, there is a downside to using amateur radio frequencies. The amateur community is tiring of CubeSats using their spectrum. The allocations of 25 kHz or less do not support high-speed downlinks. All downlink telemetry data and formats must be unencrypted and published, so anybody with a receiver can find out detailed information about the spacecraft and payload.

2 Benefits of Federal Frequency Allocation

While an amateur frequency authorization is fairly easy to obtain, there are many advantages to receiving dedicated spectrum for a CubeSat project. Legally, federally funded projects must go through the NTIA for frequency authorization, and the federal government can't authorize amateur radio frequencies.

While amateur frequency authorizations are usually very narrow–25 kHz or less–NTIA and FCC satellite authorizations can be tens of megahertz wide for high-speed downlinks. See Appendix B for a table of available spectrums for satellite communications between 100 MHz and 6 GHz.

Encryption is also permitted for projects that require it, although NSF CubeSats do not (generally) encrypt their downlink.

3 Current NSF Allocations

The NSF CubeSat program is the first government program for space science missions on CubeSats. It was started in 2008 by Therese Jorgensen in the Division of Atmospheric and Geospace Sciences. As with all NSF programs, education is a large component, and continuing student involvement is required for all teams[4].

To date there have been three calls for proposals, with eight research projects selected. Table 1 shows a summary of the teams' current licensing approaches. Only three of the eight NSF CubeSat projects are trying to go through the federal licensing process, with one team undecided about what to do.

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.

Table 2 summarizes the modulation schemes and radios involved with each satellites communication subsystem.

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.

3.1 RAX

The Radio Aurora eXplorer (RAX) 3U CubeSat from the University of Michigan and SRI International measured small-scale plasma density irregularities in the Earth's ionosphere. RAX contained an on-board radar receiver that listened for coherent radar echoes from magnetic field-aligned irregularities illuminated by megawatt-class ground-based radar systems[5, 6].

Because RAX was the first NSF-sponsored CubeSat, the infrastructure to apply for other radio services was not in place at the beginning of the project, so amateur frequencies were used. The primary downlink was at 437.505 MHz 9600 baud FSK. RAX also contained a secondary downlink using a Microhard MHX-2400 in the 2.4GHz ISM band, but this radio was never turned on.

RAX failed prematurely a few months after launch due to power generation problems[7]. While this failure was unfortunate, all the satellite subsystems were tested and performed well during its short life. A second spacecraft, RAX-2, is scheduled to fly on 27 October 2011 on the ELaNa3/NPP mission from Vandenberg, California. It has improved attitude determination sensors and reengineered solar panels[8].

3.2 Firefly

The Firefly 3U CubeSat from Siena College and NASA Goddard Space Flight Center is exploring the causal links between ground lightning and terrestrial gamma ray flashes, with associated energetic electrons ejected from the atmosphere. These electrons are thought to become trapped in the inner radiation belts and impact the energy balance of the near-Earth magnetosphere.

Firefly is pursuing a frequency allocation in the 401 MHz Space Research band. Firefly elected to use NASA Goddard as the sponsoring agency, as the PI works there. It uses an AstroDev Colony-2 UHF radio at 38.4 kbaud on the spacecraft, and a commercial Microdyne receiver at Goddard's large 18m dish[9].

3.3 FIREBIRD

The Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics (FIREBIRD) is a two 1.5U CubeSat mission from the University of New Hampshire and Montana State University. It is investigating the size, persistence, and energy dependence of relativistic electron bursts from the inner radiation belts[10].

FIREBIRD is using amateur radio frequencies for downlink in the 145 MHz band. It has not received its IARU frequency authorization yet. The FIREBIRD team intends to use the FUNcube Dongle software-defined radio as the primary ground station radio[11].

3.4 DICE

The Dynamic Ionosphere CubeSat Experiment (DICE) mission from Utah State University and ASTRA contains two identical 1.5U CubeSats measuring ionospheric density and electric field variability associated with the formation of geomagnetic storm enhanced density plumes. These features have been observed to occur daily over the US during magnetic storm disturbances and are thought to severely disrupt terrestrial communication and navigation systems[12].

DICE contains an L3 Cadet radio, transmitting in the 460-470 MHz Meteorological-satellite (space-to-Earth) allocation. There are several footnotes to this allocation, including US201, which defines a maximum power flux-density at the Earth's surface. A link analysis shows the maximum power that the spacecraft can transmit is roughly 1 watt of power into the dipole antenna, even with the large bandwidth required for the high data rate[13].

This CubeSat is scheduled for launch on 27 October 2011 on the ELaNa3/NPP mission from Vandenberg, California, and is the first NSF CubeSat launched to have completed the NTIA spectrum certification and frequency authorization process.

3.5 CINEMA

The CubeSat for Ions, Neutrals, Electrons, MAgnetic fields (CINEMA) from UC Berkeley and Kyung Hee University (South Korea) is a focused investigation of energetic ions, electrons, and neutrals at high ecliptic latitude, and will map out strong geomagnetic currents and energetic neutral atoms associated with stormtime precipitation. This science is important for fundamental space weather and space plasma physics research[14].

CINEMA has obtained their Stage 4 Spectrum Certification for the 2200-2290 MHz Space Research band. It uses a small 2.2 GHz Emhiser EDTC-01E1A102 transmitter that outputs 1 watt of RF power with a data rate of 1 Mbps. Kyung Hee University is also building an exact replica of CINEMA for launch at a later date[15].

3.6 CSSWE

The Colorado Student Space Weather Experiment (CSSWE) from the University of Colorado-Boulder will measure the energetics of solar-produced relativistic electrons and protons during periods of intense solar flare activity and its impacts on the Earth's outer radiation belts[16, 17].

The CSSWE team has elected to obtain an Experimental License through the FCC in the UHF Amateur Satellite band, and have received their allocation of 437.345 MHz from the IARU. They are using an AstroDev Lithium radio on the spacecraft and a Kenwood TS-2000 radio for the ground station[18].

3.7 CADRE

The Cubesat-investigating Atmospheric Density Response to Extreme driving (CADRE) mission from the University of Michigan proposes to measure the density and composition of a perturbed thermosphere using the novel Wind, Ion, and Neutral Composition Spectrograph (WINCS) sensor[19]. CADRE is the second NSF CubeSat award to the University of Michigan.

CADRE is one of the newest NSF CubeSats, awarded in Spring 2011. The team is still exploring communication subsystem options, but CADRE will most likely follow RAX with an amateur license in the 437 UHF Amateur Satellite band using an AstroDev Lithium radio. They are also planning an S-band downlink, with the radio and band still to be defined[20].

3.8 EXOCUBE

EXOCUBE, from Scientific Solutions Inc., Cal Poly, and the University of Wisconsin, is a 3U CubeSat that will measure global neutral and ion densities of select species using a mass spectrometer. Existing NSF ground radar sites will provide calibration data for the payload.

EXOCUBE is the newest NSF CubeSat, with funding awarded in September 2011. The team is planning to use the second-generation Cal Poly CubeSat bus, with an integrated Axsem 5042 transceiver chip[21]. This chip can tune from 400 to 470 MHz, but the team has not decided whether they are going to use amateur radio frequencies or apply for a federal allocation.

3.9 Summary

Of the current crop of NSF CubeSats, only three are going through the federal licensing process. The other four are using amateur radio frequencies, with the newest EXOCUBE undecided as to which path to take. In discussing the reasons for pursuing the amateur radio route, most of the teams noted that the amateur application process is much simpler and shorter than the federal licensing process. Many of the teams are also familiar with the amateur radio process from building and launching prior CubeSats.

With respect to getting into orbit, Table 2 shows that most of the current NSF CubeSats are using the Educational Launch of Nanosatellites (ELaNa) program. Run by Garrett Skrobot at Kennedy Space Center, the ELaNa program provides inexpensive launches for educational projects. As a launch service for educational CubeSats, it integrates nicely with the educational requirements of the NSF CubeSat program, and there is close collaboration between the two programs[22].

4 Short-term Solutions

The short-term licensing solution for current NSF CubeSats includes using an allocation for an existing service. A CubeSat Developer needs only to determine which service they fit into, certify the hardware, and apply for a specific frequency. This process is described in the next three sections.

4.1 Potential Radio Services

All spectrums in the United States are allocated to a specific service, such as Broadcasting for television stations or Aeronautical Mobile for airplanes. Before a frequency can be requested, CubeSat developers must determine which service they fit into. The list below describes some possible radio services for current and future NSF CubeSats. These descriptions are taken from Article 1, Section III of the Radio Regulations[23].

Space Operation-Satellite: A radiocommunication service concerned exclusively with the operation of spacecraft, in particular space tracking, space telemetry and space telecommand.

Earth Exploration-Satellite Service: A radiocommunication service between Earth stations and one or more space stations, which may include links between space stations, in which:

- information relating to the characteristics of the Earth and its natural phenomena, including data relating to the state of the environment, is obtained from active sensors or passive sensors on Earth satellites;
- similar information is collected from airborne or Earth-based platforms;
- such information may be distributed to Earth stations within the system concerned;
- platform interrogation may be included.

Meteorological-Satellite Service: An Earth exploration-satellite service for meteorological purposes.

Space Research-Satellite: A radiocommunication service in which spacecraft or other objects in space are used for scientific or technological research purposes.

Table 3 in Appendix B shows a list of the allocations for the above services from 100 MHz to 6 GHz. For pertinent footnoes, see the official NTIA Red Book and FCC Table of Frequency Allocations.

4.2 Federal Licensing Process (NTIA)

Federally funded CubeSat projects must apply through their funding agency for Spectrum Certification and Frequency Authorization. Each funding agency has a group in charge of spectrum management. This group can help the team fill out the necessary paperwork, keep track of all the licensing requirements, etc. Figure 1 shows a flow diagram of this process.

4.2.1 Spectrum Certification

The NTIA spectrum licensing process consists of four steps, outlined below. If a CubeSat is federally funded by an agency other than the NSF, such as NASA or DOD, the same rules and procedures apply.

Step 1. Prepare NTIA Spectrum Certification Application by assembling basic technical data about the space-based and ground-based elements. This technical data should include all aspects of the communication system, such as transmitters, receivers, and antennas. This step can take several weeks, depending on how much technical data is provided by the equipment manufacturers.

Step 2. NSF (or other sponsoring agency) submits application to NTIA for Stage 4 (Operational Certification) for ground- and space-based elements. This application is submitted to the Spectrum Planning Subcommittee (SPS) of NTIA's Interdepartment Radio Advisory Committee (IRAC). It can take longer than 6 months to obtain spectrum certification.

At this point, a Certification of Spectrum Support document (Form NTIA-44) is generated, stating that the hardware used is capable of transmitting an appropriately clean RF signal within the stated bands. Hardware only needs to obtain Spectrum Certification once, so if a previous team has certified the hardware you do not need to do the previous two steps.

Once this document is obtained, the CubeSat developer begins the Frequency Authorization process to obtain a specific frequency for satellite communications. As of this writing, both CINEMA and DICE have obtained their Stage 4 Certification of Spectrum Support[24, 25].

4.2.2 Frequency Authorization

After the satellite and ground station hardware is certified, then specific frequency and modulation schemes can be applied for. This is called Frequency Authorization.

Step 3. Prepare Frequency Authorization Proposal for authorization to transmit at specific frequencies. This proposal describes the exact frequencies, modulation schemes, transmit power, antenna gain, orbit characteristics, etc., that the CubeSat developer would like to use. If all of the data are known, then the process of electronically preparing and submitting the assignment request is straightforward.

Step 4. NSF (or other sponsoring agency) submits Frequency Authorization Proposal to the Frequency Assignment Subcommittee (FAS) of the IRAC. If there are no problems with the request, and if neither the NTIA nor any other agency (including the FCC) objects to the assignment request, then the assignment may be approved in as little as two weeks. However, if there are problems with the request, if other agencies are concerned with the proposed frequency use, or if the system does not comply with applicable rules, it may take weeks or months to get approval of the assignment, and some desired characteristics, such as frequency and power, may need to be modified.

After obtaining a Frequency Authorization, the CubeSat developer can now legally transmit on the specific frequencies outlined in the authorization.

As can be seen, this process takes a long time, potentially more than a year. For many CubeSat projects, this time is equal to or greater than designing, building, testing, and launching their satellite into space. Since the communications subsystem design is not finalized for several months after project kickoff, there is often not enough time to go through this process, which explains why CubeSat developers to go the amateur radio route[26, 27].

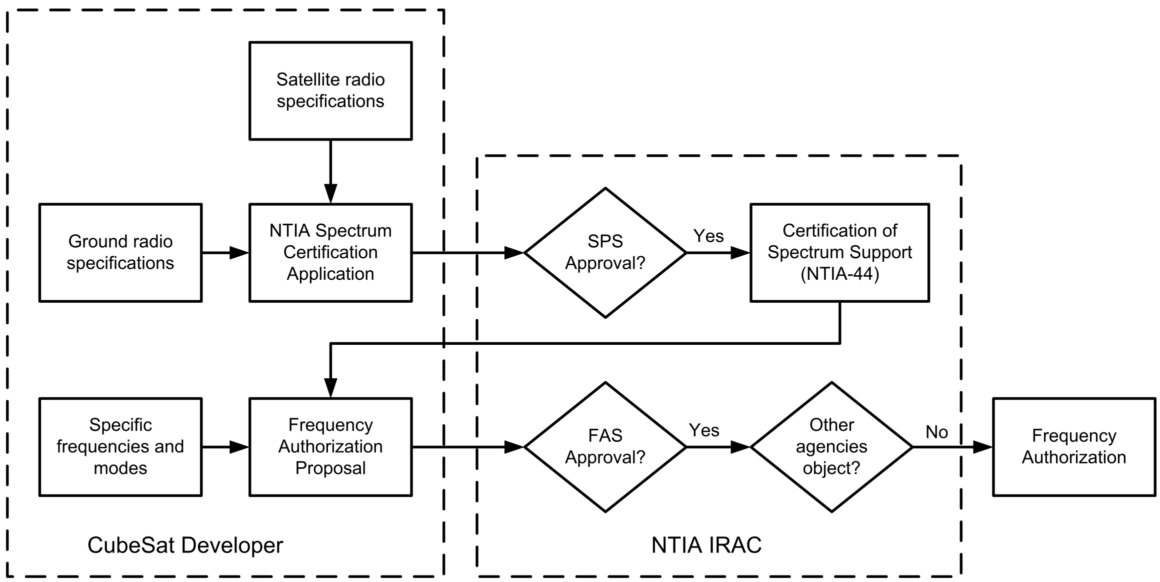

Figure 1: Flow diagram for the NTIA Spectrum Certification and Frequency Authorization process.

4.3 Non-Federal Licensing Process (FCC)

CubeSat programs whose main source of funding is not provided by the federal government, such as commercial companies, universities, individuals, or state space grant-type organizations, should apply to the FCC for spectrum certification and frequency authorization. The FCC rules governing all satellite communications are in 47 CFR Part 25. The FCC process is outside the scope of this paper.

5 Long-term Solutions

In addition to the short-term solutions outlined above, the NSF is working on a long-term solution that involves asking the International Telecommunications Union (ITU) and member states (US, Russia, France, etc.) which service small satellites fit under. This questionnaire is included in Appendix A.

Answers to these questions will define what a "small satellite" is, and determine which existing service these new small satellites fit under. Once this is determined, the small satellite community can begin looking for underutilized spectrum (within this existing service or different service) by performing spectrum surveys in their local neighborhoods. After determining ways to protect the primary users within the existing service, and if no existing users or member states object, the existing service definition can be changed, and a "small satellite" footnote or definition can be added to the ITU International Table of Frequency Allocations. After ratification by the US Congress, the NTIA and FCC draft the US laws regarding this new allocation, and modifications are made to the NTIA Red Book and FCC Table of Frequency Allocations. Defined users can then use this service for communications[28, 29].

This process takes many years. If all of the recommendations were approved and there were no objections, this process would take a minimum of eight years, making this new "small satellite" allocation a reality in 2020 or later.

6 Conclusion

While the Federal NTIA process can seem daunting to new CubeSat developers, the NSF is motivated to assist current and future NSF CubeSats navigate this maze and secure a federal frequency authorization. Federal frequency allocation is possible even with the reduced time schedules that CubeSat developers face.

While most CubeSat developers are focused on their short-term hardware delivery date, they should also be cognizant of the long-term ITU process of securing a "small satellite" chunk of spectrum. CubeSat developers can write papers in support of the questionnaire and conduct spectrum surveys to determine suitable frequencies.

6.1 Acknowledgements

Special thanks to Andy Clegg of the NSF for correcting and clarifying the NTIA licensing process, Richard Doe for clarifying and editing the science descriptions of the CubeSats, and Jan King for helping explain the complex ITU process.

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A ITU Proposal for Agenda Item

UNITED STATES OF AMERICA

DRAFT PROPOSALS FOR THE WORK OF THE CONFERENCE

Agenda Item 8.2: *to recommend to the Council, items for inclusion in the agenda for the next WRC, and to give its views on the preliminary agenda for the subsequent conference and on possible agenda items for future conferences, taking into account Resolution* ***806 (WRC-07)***

Background Information: The use of nanosatellites and picosatellites, satellites having mass less than 10 kg,[1] is increasing for a variety of applications, including meteorology, space research and telecommunications. A large number of administrations from all ITU regions have launched these satellites. Academic and research institutions are designing and developing many more projects, with launches planned over the next few years.

These satellite systems exhibit certain characteristics:

a) they are built at low cost using off-the-shelf equipment, often based on a standard structural design;[2]

b) they employ off-the-shelf radiocommunication hardware that is small, lightweight, economical, and adaptable to a wide variety of missions;

c) they are launched as secondary payloads when space is available on launch vehicles; thus the launch date is not known well in advance;

d) the launch vehicle deploys them in a low-Earth orbit, though orbital parameters are not known in advance with any precision;[3]

e) they generally have no attitude control and must use antennas with little directional gain for both uplinks and downlinks;

f) data download and command and control uplinks may involve a variety of earth stations depending on requirements, including earth stations not operated by those responsible for the satellite; and

g) their useful lifetime is unpredictable, but can range from a few weeks to a few years.

To date, a number of these satellites have been using frequency bands near 400 MHz allocated to the meteorological-satellite service or the amateur-satellite service for data downlinks, though the satellite mission may not be consistent with those services. This proposal addresses the need for one or more frequency bands to support command, control, and data relay for nanosatellites and picosatellites performing a variety of functions. It also addresses regulatory procedures for these satellites.

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[1] The terms *nanosatellite* and *picosatellite* may refer to satellites having mass in the range 1-10 kg, or less than 1 kg, respectively.

[2] The academic and amateur-satellite communities, and others, developed the *Cubesat* standard for low-cost satellites in the late 1990's; the basic *Cubesat* standard, now widely adopted, consists of a 10 cm cube with mass of about 1 kg; a nanosatellite may consist of several stacked *Cubesat* modules; some launch vehicles include spring-loaded containers designed to deploy satellites built to the *Cubesat* standard.

[3] The trajectory of the launch vehicle, which is optimized for delivery of the primary payload, largely determines the orbital parameters of the nanosatellite or picosatellite.

Proposal:

ADD USA/8.2/1

RESOLUTION XXX (WRC-12)

Preliminary Agenda for the 2019 World Radiocommunication Conference

Reasons: To add a new item to the preliminary agenda of WRC-19.

ADD USA/8.2 /2

2.AA to consider the results of ITU-R studies, and based on the studies designate up to 10 MHz of spectrum, along with appropriate regulatory procedures, to accommodate command, control and data relay for nanosatellites and picosatellites in the 400-2 025 MHz range, in accordance with Resolution **[ZZZ] (WRC-12)**.

Reasons: Nanosatellites and picosatellites have characteristics unlike those of larger satellites and provide a growing variety of functions, mostly in meteorology, space research, and Earth sciences.

ADD USA/8.2/3

RESOLUTION ZZZ (WRC-12)

Studies for identifying up to 10 MHz of spectrum for the space research service in the 400-2 025 MHz range for the operation of nanosatellites and picosatellites

The World Radiocommunication Conference (Geneva, 2012),

considering

a) that nanosatellites and picosatellites are low-cost satellites having mass no greater than 10 kg;

b) that the lifetime of these satellites ranges from a few weeks to a few years;

c) that these satellites are increasingly used in studies of the Earth, the Earth's atmosphere and the near-Earth environment, and in a variety of other fields;

d) that these satellites have distinctive characteristics that affect spectrum and regulatory requirements for command, control and data relay;

e) that it is desirable to have a designated band to accommodate command, control and data relay for these satellites;

f) that it is also desirable to have regulatory provisions for these satellites that take into account their unique characteristics;

g) that some experiments require the simultaneous operation of several such satellites and that fifty or more of these satellites may be released during a single launch;

recognizing

a) the need to protect existing services in the 400-2 025 MHz range;

b) that the requirements in Article 9 for the advanced publication of information of satellite systems that is not subject to coordination and Article 11 for notification and recording of frequency assignments apply,

resolves to invite ITU-R

1 to conduct studies to identify up to 10 MHz in the 400-2 025 MHz range to accommodate command, control and data relay operations for nanosatellites and picosatellites, while ensuring the protection of the services, particularly safety-of-life services, allocated to these bands;

2 to study the regulatory procedures applicable to these satellites,

resolves to invite WRC-19

1 to review the results of the studies in *resolves to invite ITU-R* 1 and 2, with a view to provide a designated band or bands in the space research service to accommodate command, control and data relay for nanosatellites and picosatellites on a primary, worldwide basis;

2 to consider appropriate modifications to the Table of Frequency Allocations and to develop appropriate regulatory provisions based on proposals from administrations,

invites administrations

to participate actively in the studies by submitting contributions to ITU-R.

Reasons: Nanosatellites and picosatellites that have distinctive characteristics and are increasingly used for many purposes require a designated band that can be used for operations, including command, control, and data transmission.

ATTACHMENT

PROPOSAL FOR AGENDA ITEM

Subject: Proposed Future Agenda Item for WRC-2019, to conduct studies to identify up to 10 MHz in the 400-2 025 MHz range, designated for the operations of nanosatellites and picosatellites,
Origin: United States of America

Proposal: to consider the results of ITU-R studies, and based on the studies to identify up to 10 MHz of spectrum in the 400-2 025 MHz range, in order to support operations of nanosatellites and picosatellites, in accordance with Resolution [ZZZ] (WRC-12***).***

Background/reason: The use of nanosatellites and picosatellites is increasing for a variety of applications, including meteorology, space research, and telecommunications. The increasing variety of activities that are conducted from these satellites makes it necessary to find a dedicated band for their operations, under a suitable service.
Radiocommunication services concerned: services operating in the 400-2 025 MHz bands.

Indication of possible difficulties: TBD

Previous/ongoing studies on the issue: TBD

Studies to be carried out by: WP 7B	with the participation of**: *WP 4C, WP 5B, and WP7C***

ITU-R Study Groups concerned: SG7

ITU resource implications, including financial implications (refer to CV126)**: *Minimal***

Common regional proposal: Yes/No	***Multicountry proposal:*** Yes/No Number of countries**:**

Remarks

B Potential Frequency Bands

Table 3 is an excerpt from the NTIA Red Book. It shows the frequency allocations in the 100 MHz to 6 GHz range only for the services listed in Section 4.1. A blank cell means that the users have no privileges in that frequency range.

Footnotes listed next to the Service, such as the G42 footnote next to the Space Operations allocation in the 1755-1850 MHz frequency range, apply to that service only. Footnotes listed at the bottom of the cell indicate that all services are restricted by these footnotes, such as 5.392 and US303 in the 2200-2290 MHz frequency range. Footnotes are listed in the NTIA Red Book and FCC Table of Frequency Allocations, and readers are encouraged to understand them because several footnotes greatly restrict the communications potentials of specific bands.

There may be other services sharing the frequencies listed below. Refer to the official tables in the NTIA Red Book and the FCC Table of Frequency Allocations for details.

Services in capital letters (EARTH EXPLORATION-SATELLITE) indicate the primary user. Services with only the first letter capitalized (Earth exploration-satellite) indicate secondary users that must not create any interference to primary users and must accept any interference received.

Table 3: Potential CubeSat frequency bands 100 MHz to 6 GHz based on allocation.

Frequency	**Federal Table**	**Non-Federal Table**
137-137.025 MHz	SPACE OPERATION (space-to-Earth) METEOROLOGICAL-SATELLITE (space-to-Earth) SPACE RESEARCH (space-to-Earth)	
137.025-137.125 MHz	SPACE OPERATION (space-to-Earth) METEOROLOGICAL-SATELLITE (space-to-Earth) SPACE RESEARCH (space-to-Earth)	
137.175-137.825 MHz	SPACE OPERATION (space-to-Earth) METEOROLOGICAL-SATELLITE (space-to-Earth) SPACE RESEARCH (space-to-Earth)	
137.825-138 MHz	SPACE OPERATION (space-to-Earth) METEOROLOGICAL-SATELLITE (space-to-Earth) SPACE RESEARCH (space-to-Earth)	
400.15-401 MHz	METEOROLOGICAL-SATELLITE (space-to-Earth) SPACE RESEARCH (space-to-Earth) 5.263 Space operation (space-to-Earth) 5.264	SPACE RESEARCH (space-to-Earth) 5.263 Space operation (space-to-Earth) 5.264 US319
401-402 MHz	SPACE OPERATION (space-to-Earth) EARTH EXPLORATION-SATELLITE (Earth-to-space) METEOROLOGICAL-SATELLITE (Earth-to-space) US345 US384	SPACE OPERATION (space-to-Earth) Earth exploration-satellite (Earth-to-space) Meteorological-satellite (Earth-to-space) US345 US384

Table 3: Potential CubeSat frequency bands 100 MHz to 6 GHz based on allocation.

Frequency	**Federal Table**	**Non-Federal Table**
402-403 MHz	EARTH EXPLORATION-SATELLITE (Earth-to-space) METEOROLOGICAL-SATELLITE (Earth-to-space) US345 US384	Earth exploration-satellite (Earth-to-space) Meteorological-satellite (Earth-to-space) US345 US384
410-420 MHz	SPACE RESEARCH (space-to-space) 5.268 US13 G5	US13
460-470 MHz	Meteorological-satellite (space-to-Earth) 5.287 5.288 5.289 US73 US201 US209	
1215-1240 MHz	EARTH EXPLORATION-SATELLITE (active) SPACE RESEARCH (active) 5.332	Earth exploration-satellite (active) Space research (active)
1240-1300 MHz	EARTH EXPLORATION-SATELLITE (active) SPACE RESEARCH (active) 5.332 5.335	Earth exploration-satellite (active) Space research (active) 5.282
1400-1427 MHz	EARTH EXPLORATION-SATELLITE (passive) SPACE RESEARCH (passive) 5.341 US246	
1660.5-1668.4 MHz	SPACE RESEARCH (passive) 5.341 US246	
1675-1700 MHz	METEOROLOGICAL-SATELLITE (space-to-Earth) 5.289 5.341 US211	
1700-1710 MHz	METEOROLOGICAL-SATELLITE (space-to-Earth) 5.289 5.341	METEOROLOGICAL-SATELLITE (space-to-Earth) 5.289 5.341
1755-1850 MHz	SPACE OPERATION (Earth-to-space) G42	
2025-2110 MHz	SPACE OPERATION (Earth-to-space) (space-to-space) EARTH EXPLORATION-SATELLITE (Earth-to-space) (space-to-space) SPACE RESEARCH (Earth-to-space) (space-to-space) 5.391 5.392 US90 US222 US346 US347 US393	

Table 3: Potential CubeSat frequency bands 100 MHz to 6 GHz based on allocation.

Frequency	Federal Table	Non-Federal Table
2200-2290 MHz	SPACE OPERATION (space-to-Earth) (space-to-space) EARTH EXPLORATION-SATELLITE (space-to-Earth) (space-to-space) SPACE RESEARCH (space-to-Earth) (space-to-space) 5.392 US303	
2655-2690 MHz	Earth exploration-satellite (passive) Space research (passive) US205	Earth exploration-satellite (passive) Space research (passive) US385
2690-2700 MHz	EARTH EXPLORATION-SATELLITE (passive) SPACE RESEARCH (passive) US246	
3100-3300 MHz	Earth exploration-satellite (active) Space research (active) US342	Earth exploration-satellite (active) Space research (active) US342
4990-5000 MHz	Space research (passive) US246	
5250-5255 MHz	EARTH EXPLORATION-SATELLITE (active) SPACE RESEARCH (active) 5.447D 5.448A	Earth exploration-satellite (active) Space research
5255-5350 MHz	EARTH EXPLORATION-SATELLITE (active) SPACE RESEARCH (active) 5.448A	Earth exploration-satellite (active) Space research (active) 5.448A
5350-5460 MHz	EARTH EXPLORATION-SATELLITE (active) 5.448B SPACE RESEARCH (active) US390 G130	Earth exploration-satellite (active) 5.448B Space research (active) US390
5460-5470 MHz	EARTH EXPLORATION-SATELLITE (active) SPACE RESEARCH (active) 5.448B US49 G130	Earth exploration-satellite (active) Space research (active) 5.448B US49
5470-5570 MHz	EARTH EXPLORATION-SATELLITE (active) SPACE RESEARCH (active) 5.448B US50 G131	Earth exploration-satellite (active) 5.448B Space research (active) US50