



Survey of CubeSat Communication Systems: 2009-2012

Bryan Klofas

SRI International

bryan.klofas@sri.com

10th Annual CubeSat Developers' Workshop

San Luis Obispo, California

26 April 2013

Two Survey Papers

- “A Survey of CubeSat Communication Systems”
 - Paper presented at the CubeSat Developers’ Workshop 2008
 - By Bryan Klofas, Jason Anderson, and Kyle Leveque
 - Covers the CubeSats from start of program to 2008

- “A Survey of CubeSat Communication Systems: 2009-2012”
 - Paper presented at the CubeSat Developers’ Workshop 2013
 - By Bryan Klofas and Kyle Leveque
 - Covers the CubeSats from 2009 to ELaNa-6/NROL-36 launch in 2012

Summary of CubeSat Launches 2009 to 2012

- Minotaur-1 (19 May 2009)
 - AeroCube-3
 - CP6
 - HawkSat-1
 - PharmaSat
- ISILaunch 01 (23 Sep 2009)
 - BEESAT-1
 - UWE-2
 - ITUpSAT-1
 - SwissCube
- H-IIA F17 (20 May 2010)
 - Hayato
 - Waseda-SAT2
 - Negai-Star
- NLS-6/PSLV-C15 (12 July 2010)
 - Tisat-1
 - StudSat
- STP-S26 (19 Nov 2010)
 - RAX-1
 - O/OREOS
 - NanoSail-D2
- Falcon 9-002 (8 Dec 2010)
 - Perseus (4)
 - QbX (2)
 - SMDC-ONE
 - Mayflower
- PSLV-C18 (12 Oct 2011)
 - Jugnu

Summary of CubeSat Launches 2009 to 2012

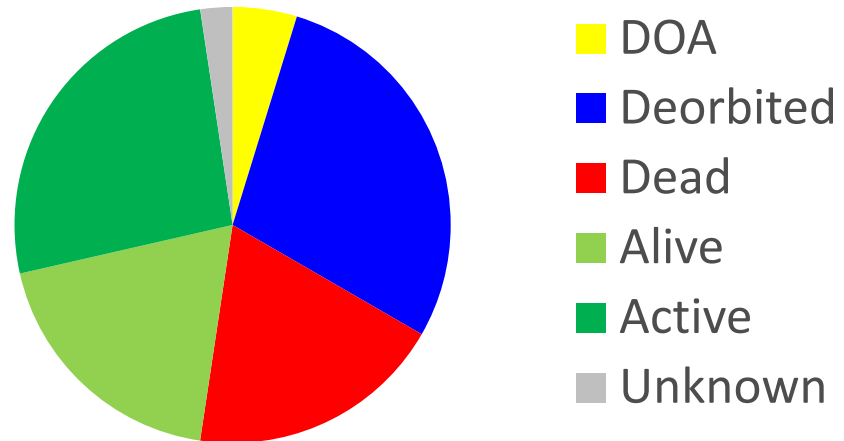
- ELaNa-3/NPP (28 Oct 2011)
 - AubieSat-1
 - DICE (2)
 - HRBE
 - M-Cubed
 - RAX-2
- Vega VV01 (13 Feb 2012)
 - Xatcobeo
 - ROBUSTA
 - e-st@r
 - Goliat
 - PW-Sat
 - Masat-1
 - UniCubeSat-GG
- ELaNa-6/NROL-36 (13 Sep 2012)
 - SMDC-ONE (2)
 - AeroCube-4 (3)
 - Aeneas
 - CSSWE
 - CP5
 - CXBN
 - CINEMA
 - Re

Recent Launches (Not Discussed)

- ISS (4 Oct 2012)
 - FITSat-1
 - TechEdSat-1
 - F-1
 - WE-WISH
 - RAIKO
- PSLV-C20 (25 Feb 2013)
 - STRaND-1
 - AAUSAT3
- Bion M1 (19 April 2013)
 - OSSI-1
 - SOMP
 - BEESAT-2
 - BEESAT-3
 - Dove-2
- Antares (21 April 2013)
 - PhoneSat (3)
 - Dove-1
- Long March (26 April 2013)
 - Turksat-3USAT
 - CubeBug-1
 - NEE-01 Pegasus

Summary of CubeSat Launches 2009 to 2012

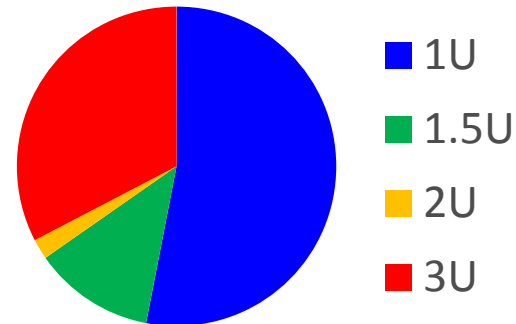
- 49 CubeSats Launched
 - 3 CubeSats failed to make orbit on ELaNa-1
- Status of CubeSats as of April 2013:
 - DOA: 2
 - Deorbited: 14
 - Dead: 9
 - Alive: 10
 - Active: 13
 - Unknown: 1



CubeSat Details: Size and Transmitters

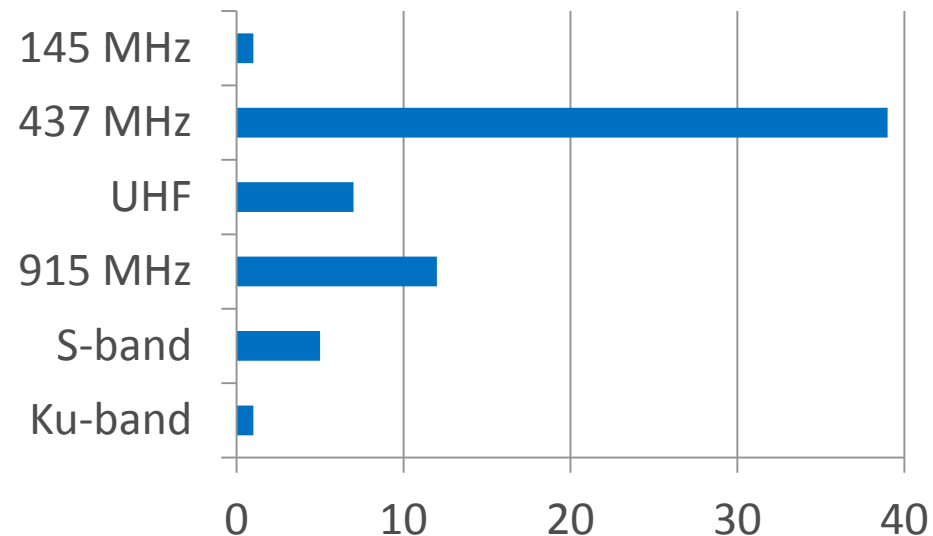
- Sizes of CubeSats (Total 49 CubeSats):

- 1U: 26
- 1.5U: 6
- 2U: 1
- 3U: 16



- Transmitters (Total 65 transmitters):

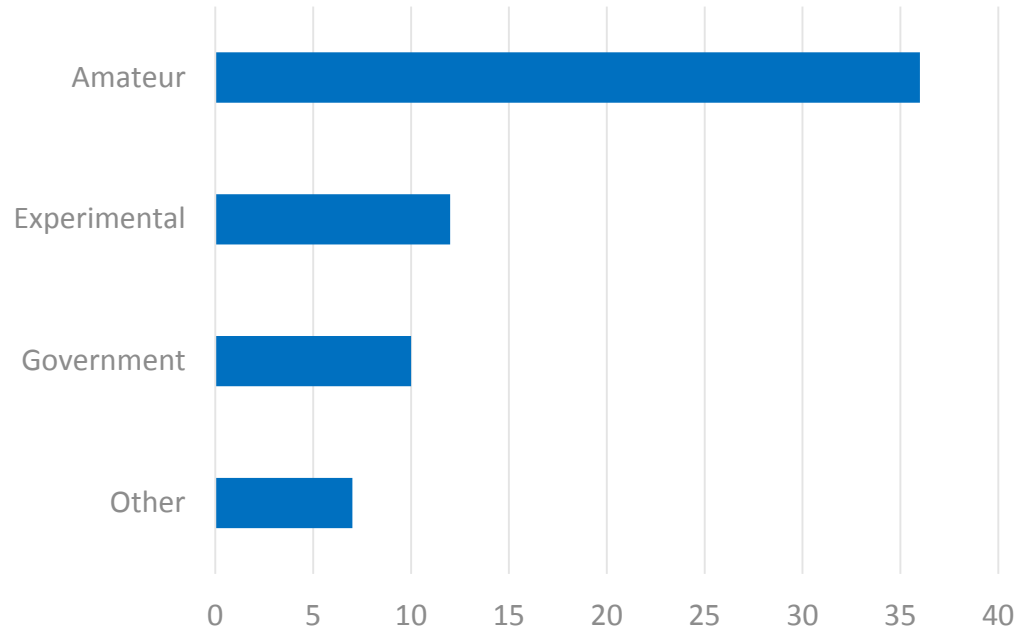
- 145 MHz amateur radio spectrum: 1
- 437 MHz amateur radio spectrum: 39
- Other UHF spectrum: 7
- 915 MHz ISM experimental: 12
- S-band: 5
- Ku-band: 1



Note: 60% of transmitters using Amateur-satellite frequencies!

CubeSat Details: Satellite Service Used

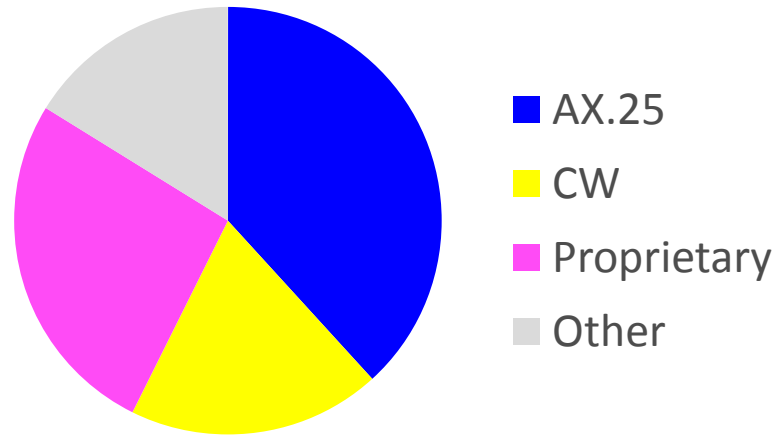
- Satellite Service (Total 65 transmitters):
 - Amateur: 36
 - Experimental: 12
 - Government: 10
 - Other:
 - Earth exploration: 1
 - Meteorological: 2
 - Space research: 1
 - Unlicensed/Unknown: 3



CubeSat Details: Protocols and Data Rates

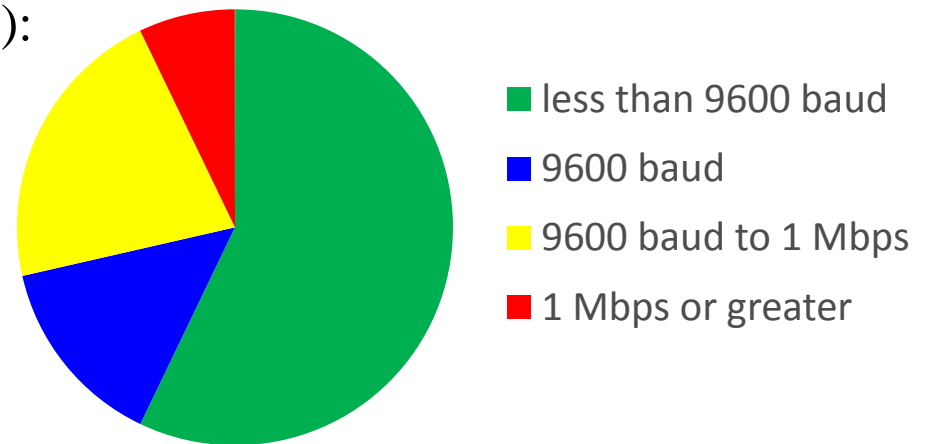
- Protocols (Total 68 transmitters):

- AX.25: 26
- CW: 13
- Proprietary: 18
- Other/Unknown: 11



- Max data rates (Total 56 transmitters):

- < 9600 baud or CW: 32
- 9600 baud: 8
- 9600 baud to < 1 Mbps: 12
- 1 Mbps or greater: 4
 - Hayato, DICE, CINEMA



Recommendations

- Timeframe
 - Leave enough time to get licenses (greater than 1 year)
- Command Receivers
 - Never ever turn off command receivers
- Scheduled Downlinks and Beacons
 - Great if license allows
- Purchase Radios
 - COTS radios are well worth their cost
- Systems Engineering
 - Can the processor deliver data to the radio fast enough?

Public Notice DA: 13-445



PUBLIC NOTICE

Federal Communications Commission
445 12th St., S.W.
Washington, D.C. 20554

News Media Information 202 / 418-0500
Internet: <http://www.fcc.gov>
TTY: 1-888-835-5322

DA: 13-445
Released: March 15, 2013

GUIDANCE ON OBTAINING LICENSES FOR SMALL SATELLITES

The purpose of this Public Notice is to provide guidance concerning FCC licensing of spectrum for use by non-Federal small satellites, including satellites that fall within the categories of pico-satellites, nano-satellites and cubesats. The advent of such small satellite designs has brought with it dramatically lower launch costs, enabling a larger range of organizations to directly launch satellites. Institutions such as universities and research organizations that previously found it cost prohibitive to launch their own satellite can now participate in the exploration of space. Many of these participants may be unfamiliar with the spectrum licensing, scheduling and other requirements attendant on satellites. This Public Notice seeks to alert affected parties of these requirements and thus aid small satellite operators in the planning necessary for a successful launch operation.

Overview: Operators of non-Federal satellites employing radio communications must be licensed by the FCC. International regulations may also apply to such launches. Scheduling aspects associated with small satellites may be restrictive and require obtaining necessary licenses well in advance of a launch.

The Commission's rules set forth three different procedures for licensing satellites. The Commission's Part 25 rules are the primary vehicle for satellite licensing, and are used for licensing a wide range of satellite operations, including commercial communication and remote sensing satellites. The Commission's Part 5 rules cover experimental operations. The Commission's Part 97 rules cover amateur radio service satellite operations.¹

Currently, many small satellite missions involve experimental operations – *i.e.* scientific and research missions, including missions conducted under government contract – and many operate in amateur frequency bands. These satellites are therefore licensed under Parts 5 or 97 of our

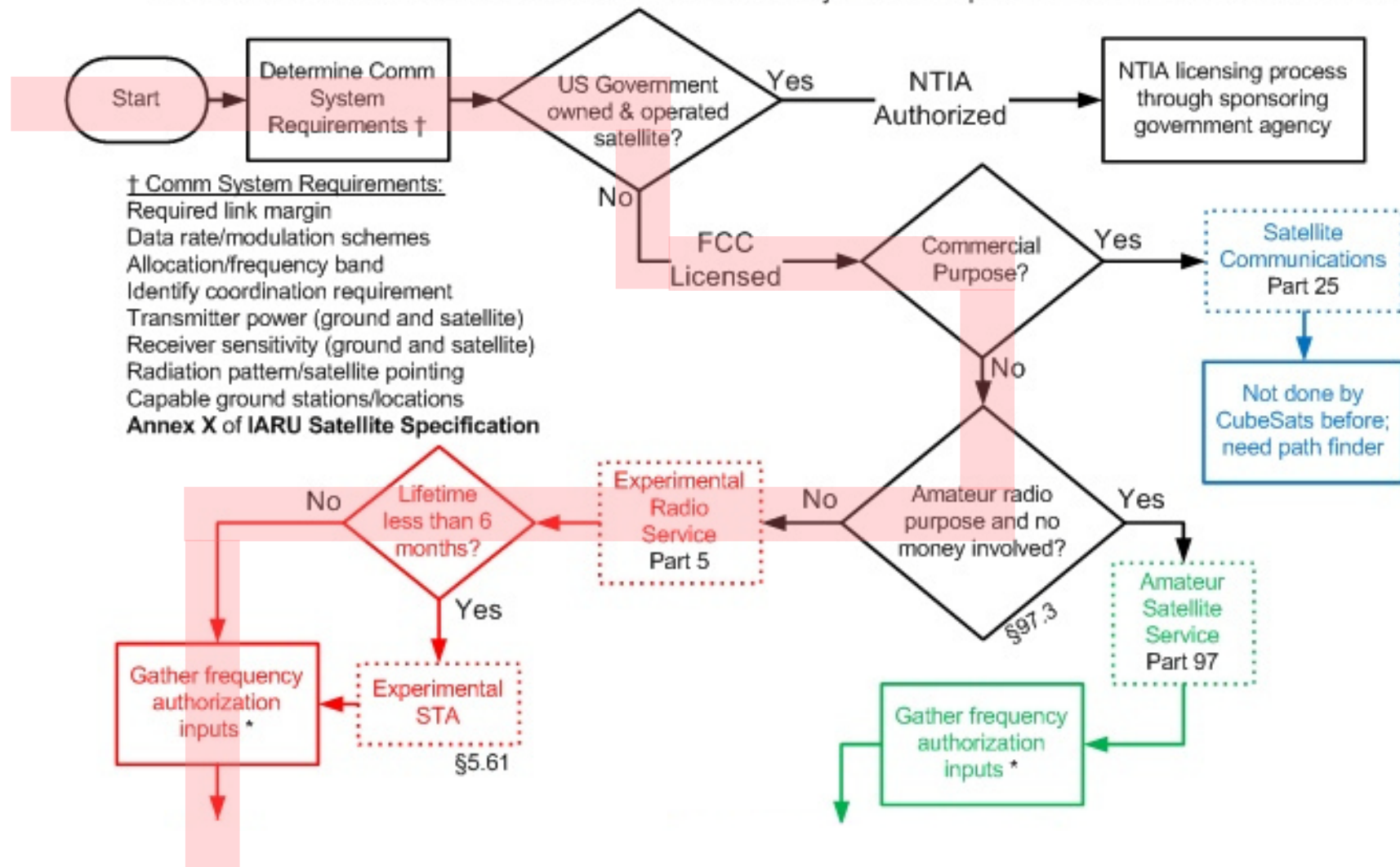
¹ The Commission's Part 97 rules do not provide for the issuance of a specific amateur satellite license document, but instead require a licensed amateur operator to provide information to the Commission prior to launch of the satellite. This information is used to meet obligations under International Telecommunication Union (ITU) regulations and to assess the applicant's orbital debris mitigation plans. Thus, for purposes of amateur satellite operations, this Public Notice discusses the relevant information filing requirements under our rules.

Public Notice DA: 13-445

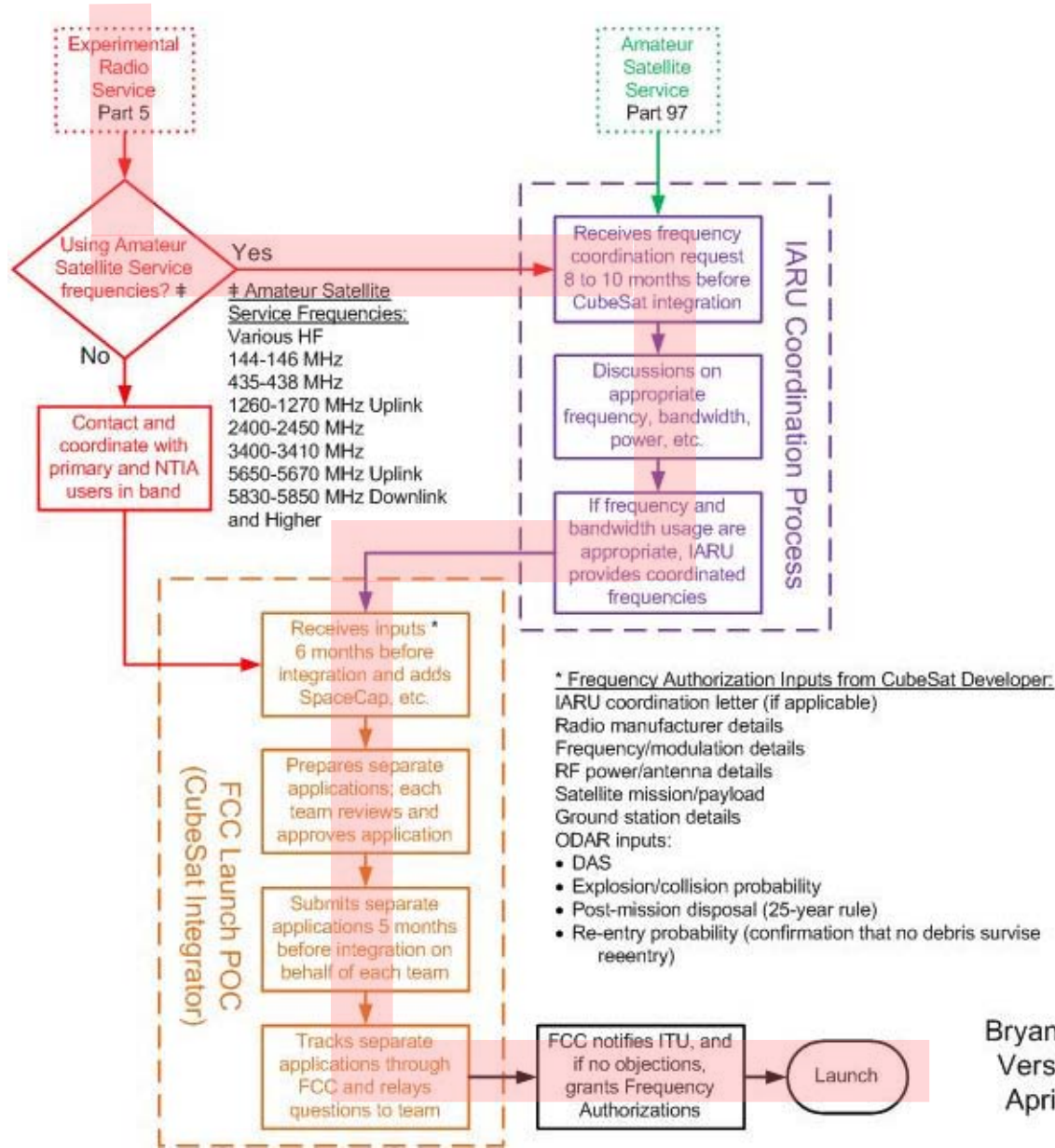
- Answers the questions:
 - Who is eligible?
 - What frequencies can be used?
 - Who should apply?
 - How does one apply?
 - What information is required to apply?
 - What are the post-launch requirements?
 - What is the duration of a license?
 - When is coordination with federal government agencies necessary?

Flow Chart: 1 of 2

Note: This flow chart is for United States CubeSat teams only. Rules and processes in other countries will differ.



Flow Chart: 2 of 2



Bryan Klofas
Version 12
April 2013

Thank You



Headquarters: Silicon Valley

SRI International

333 Ravenswood Avenue
Menlo Park, CA 94025-3493
650.859.2000

Washington, D.C.

SRI International

1100 Wilson Blvd., Suite 2800
Arlington, VA 22209-3915
703.524.2053

Princeton, New Jersey

SRI International Sarnoff

201 Washington Road
Princeton, NJ 08540
609.734.2553

*Additional U.S. and
international locations*

www.sri.com