



# The Future of CubeSat Data Communications

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# CubeSat Launches (1 of 3)

- Eurockot Launch (30 June 2003)
  - AAU1 CubeSat
  - DTU<sub>sat</sub>-1 (DOA)
  - CanX-1 (DOA)
  - Cute-1 (CO-55)
  - QuakeSat-1
  - XI-IV (CO-57)
- SSETI Express (27 Oct 2005)
  - XI-V (CO-58)
  - NCube-2 (DOA)
  - 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
  - Compass-1
- Falcon Launch 1 (2 Aug 2008)  
(launch failure)

Green = Amateur  
Red = Experimental  
Blue = Non-Amateur

# CubeSat Launches (2 of 3)

- Minotaur-1 (19 May 2009)
  - AeroCube-3
  - CP-6
  - HawkSat-1 (DOA)
  - PharmaSat (2.4 GHz)
- 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 (437 MHz)
- ELaNa-1/Taurus XL (4 Mar 2011)  
(launch failure)
- PSLV-C18 (12 Oct 2011)
  - Jungu

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# CubeSat Launches (3 of 3)

- 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 (DOA)
  - E-st@r (DOA)
  - Goliat
  - PW-Sat
  - MaSat-1
  - UniCubeSat (DOA)
- ELaNa-6/NROL-36 (13 Sep 2012)
  - SMDC-ONE (2)
  - AeroCube-4 (3)
  - Aeneas (437 MHz) (2.4 GHz)
  - CSSWE
  - CP5
  - CXBN
  - CINEMA
  - Re
- ISS (4 Oct 2012)
  - FITSat-1 (5.8 GHz)
  - TechEdSat
  - F-1
  - WE-WISH
  - RAIKO (13 GHz)

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TX Totals:  
53 Amateur  
18 Experimental  
15 Non-Amateur

- 77 CubeSats delivered to orbit
- 19 CubeSats launched but failed to make orbit
- 7 CubeSats DOA
- 17 CubeSats decayed or deorbited

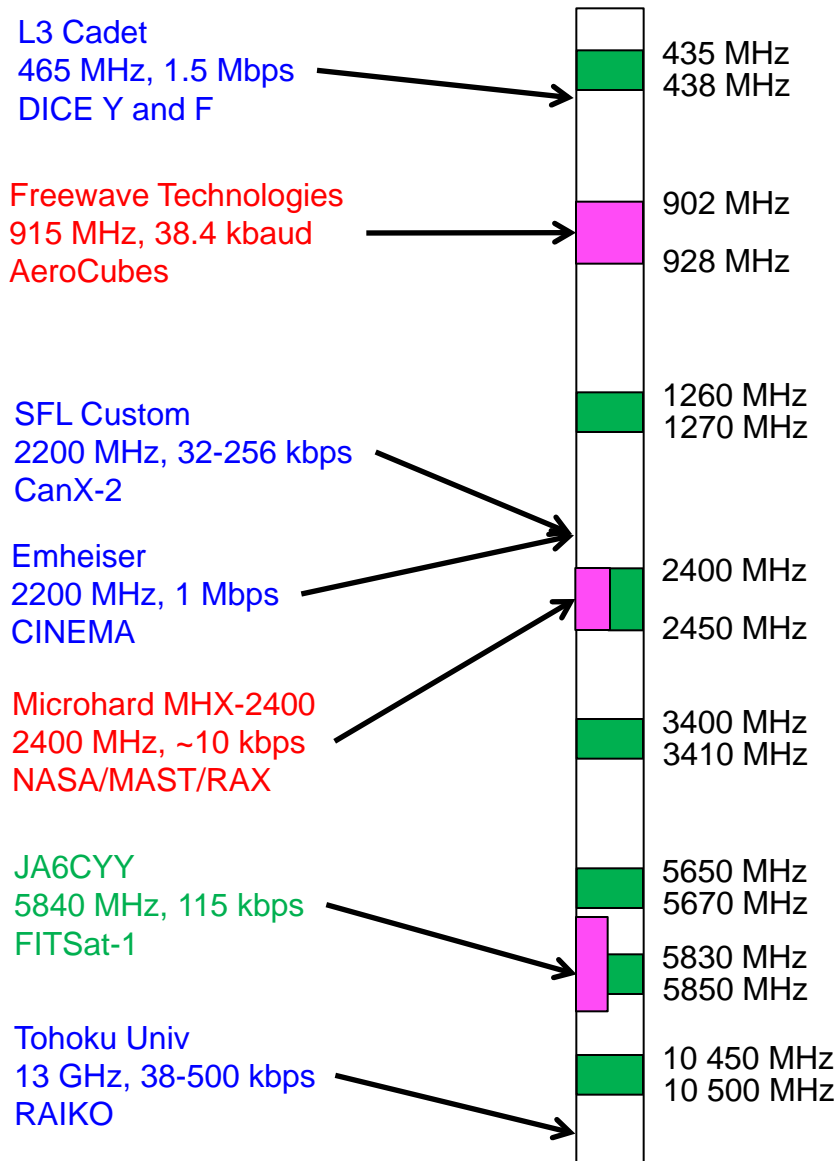
# Two Classes of CubeSats

- Beginner CubeSats
  - New teams playing the “systems integrator” role
  - Educational mission with simple payload
  - VHF or UHF Amateur Radio frequencies due to ease of license and hardware
  - CP4, Libertad-1, HRBE
- High-Performance CubeSats
  - Established CubeSat teams or teams with existing satellite programs
  - Typically NSF or other US Government funded
  - Complex or expensive payload with high data rate requirements
  - Higher bandwidth requirements force higher frequency
  - RAX, DICE, CINEMA, QbX, AeroCube

# Higher (than UHF) Frequency Satellites

- Are Amateurs interested in higher frequencies?
  - One group of Amateurs just want FM U/V
  - Another group wants HEO only
  - Another group wants microwave satellites
  - Higher frequencies are arguably more difficult/exotic/expensive
  - Evolution of communications
  - Yes, there is interest in higher frequencies
- Is the CubeSat community interested in higher frequencies?
  - 44 of 77 CubeSats are VHF/UHF Amateur Radio only
  - 56 transmitters in VHF/UHF Amateur Radio bands
  - Beep-sats will probably always use UHF Amateur Radio
    - CubeSats put into small slice of spectrum, other users (voice) protected
  - Higher performance satellites will go higher (to other services)
  - Yes, there is interest in higher frequencies

# Higher (than UHF) Frequency CubeSats



Green = Amateur  
 Red = Experimental  
 Blue = Non-Amateur  
 Purple = ISM

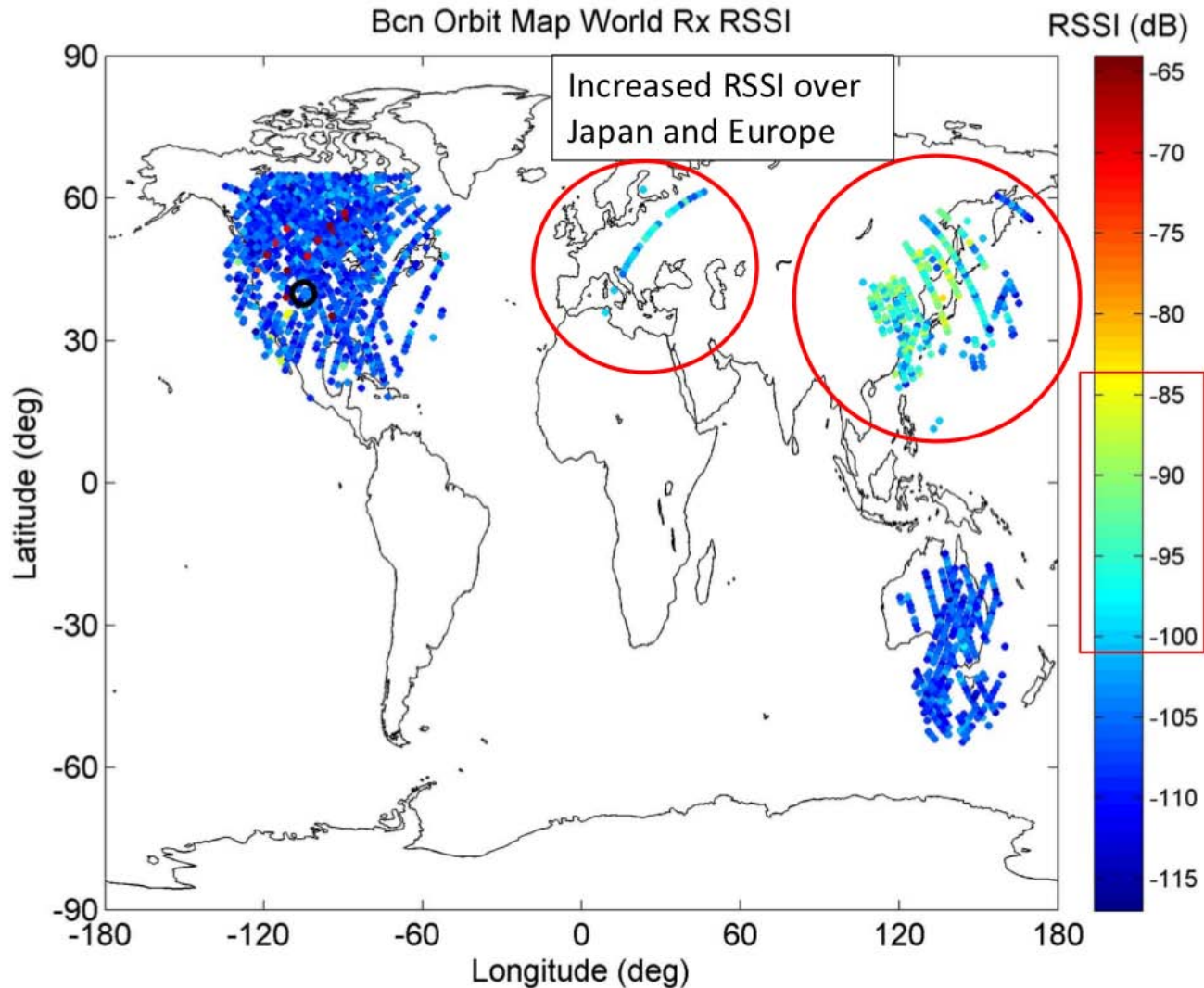
Not to scale!

# ELaNa-6/NROL-36 CubeSat Launch

- General Issues
  - Object identification is still very difficult; keps restriction problematic
  - Most satellites healthy and transmitting data
- SMDC-ONE (2):
- AeroCube-4 (3):
- Aeneas: 437.6 MHz packets strong, 437 MHz Microhard
- CSSWE: Science payload turned on, satellite healthy
- CP5: Strong downlink, weak uplink, satellite healthy
- CXBN: Weak downlink, satellite healthy
- CINEMA: Trouble commanding, satellite healthy
- Re: Demonstration of Boeing Colony 2 Bus, several issues being worked. MC3 also being developed/verified



# CSSWE RSSI Readings



- Using AstroDev Lithium radio at 437.345 MHz

# ISS CubeSat Launch (4 Oct 2012)

- **TechEdSat**
  - NASA Ames & San Jose State University
  - Telemetry at 437.465 MHz
  - Space Plug-n-play demonstration
- **F-1**
  - FPT University in Hanoi, Vietnam
  - 437.485 and 145.980 MHz FM
  - Camera for earth observation
- **FITSat-1**
  - Fukuoka Institute of Technology
  - 437.250 MHz CW, 437.445 MHz FM data
  - 115.2 kbps data at 5840 MHz
  - Camera and LED test
- **WE-WISH**
  - Meisei Amateur Radio Club
  - 437.505 CW and SSTV
  - Infrared camera for earth observation
- **RAIKO**
  - Wakayama and Tohoku University
  - Non-amateur 2.2 GHz and 13 GHz, up to 500 kbps
  - Photography

# ISS CubeSat Launch (4 Oct 2012)



Image courtesy of ISS/NASA: ISS033-E-009458 (4 Oct 2012)

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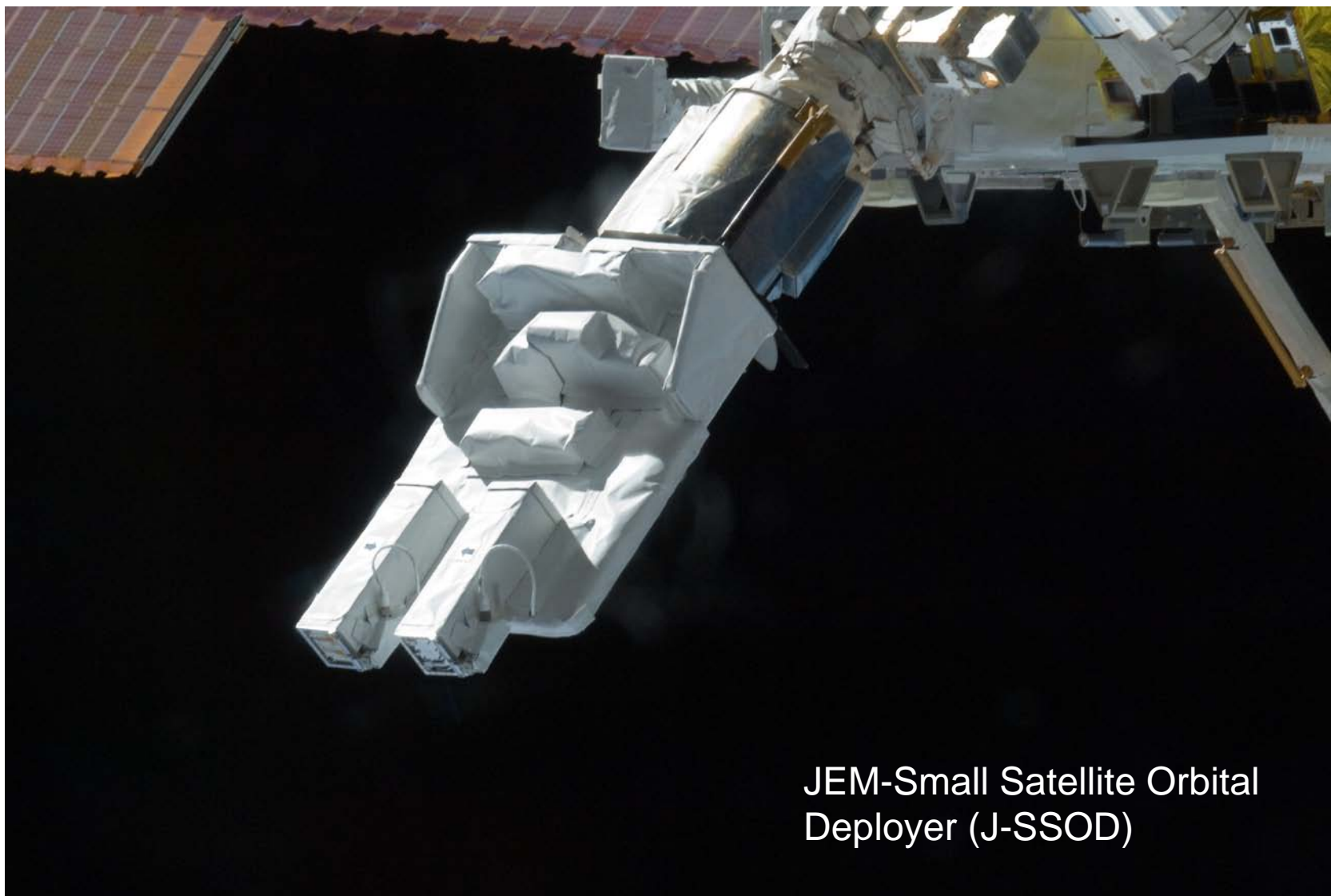
# ISS CubeSat Launch (4 Oct 2012)



Image courtesy of ISS/NASA: ISS033-E-009315 (4 Oct 2012)

Slide 12

## ISS CubeSat Launch (4 Oct 2012)



JEM-Small Satellite Orbital  
Deployer (J-SSOD)

# Future CubeSat Launches

- Cosmogia DOVE-1
  - Private company
  - Experimental license, 1200 baud AX.25 145.825 MHz StenSat
  - Coordinated through IARU
  - One satellite only; future satellites will use higher frequencies
  - SRI 60-ft dish is supporting higher frequency downlinks

# Conclusion

- Low data rate CubeSats will stay with Amateur Radio for the foreseeable future
- Higher data rate CubeSats are transitioning away from Amateur Radio bands
- Special Thanks to:
  - Mike Rupprecht DK3WN for insight into the Vega CubeSats
  - Scott Palo for CSSWE status and RSSI info
  - Giovanni Minelli for Re status
  - Tom Immel for CINEMA status
  - Ben Malphrus for CXBN status

# Thank You



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