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Cubesats:

Little Objects,

Big Spectrum Challenges

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Little Objects

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What is a Cubesat?

- A Cubesat is a standardized form of a class of satellites known as nanosatellites or picosatellites
  - Cubesats straddle the border between the two definitions
- Standard Cubesat specification:
  - 10 x 10 x 10 cm (“1U Cubesat”)
  - 10 x 10 x 20 cm, 10 x 10 x 30 cm (2U, 3U Cubesat)
  - No more than 1.33/2.66/4 kg (1U/2U/3U)

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Classes of satellites

"Small" satellites, particularly nano and picosatellites are increasingly used for science (and other) purposes

Denomination	Mass (kg)
Large and medium	500 to several thousand
Minisatellite	100 -500
Microsatellite	10 - 100
Nanosatellite	1-10
Picosatellite	0.1-1

- **E.g. : http://en.wikipedia.org/wiki/Miniaturized_satellite**
- **For nano and picosatellite experiments the Cubesat standard has been adopted by developers and is used (almost) universally**

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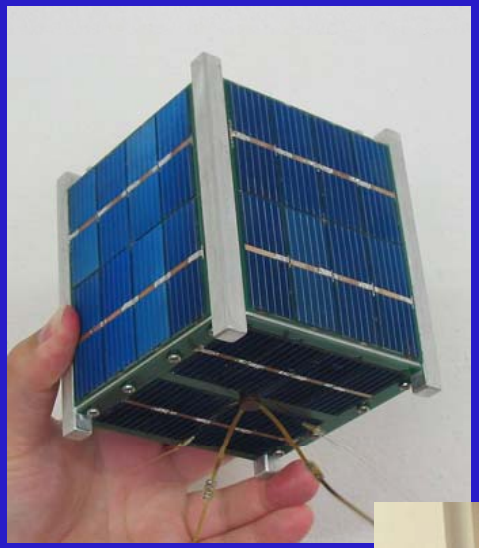
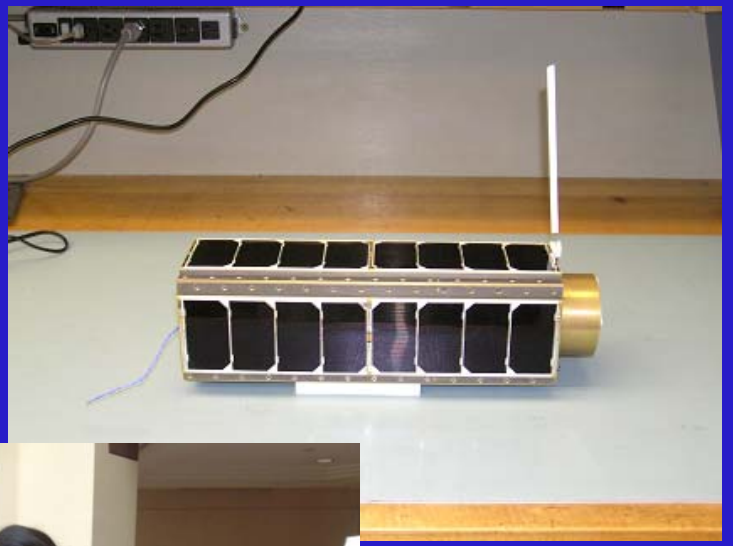
Cubesats





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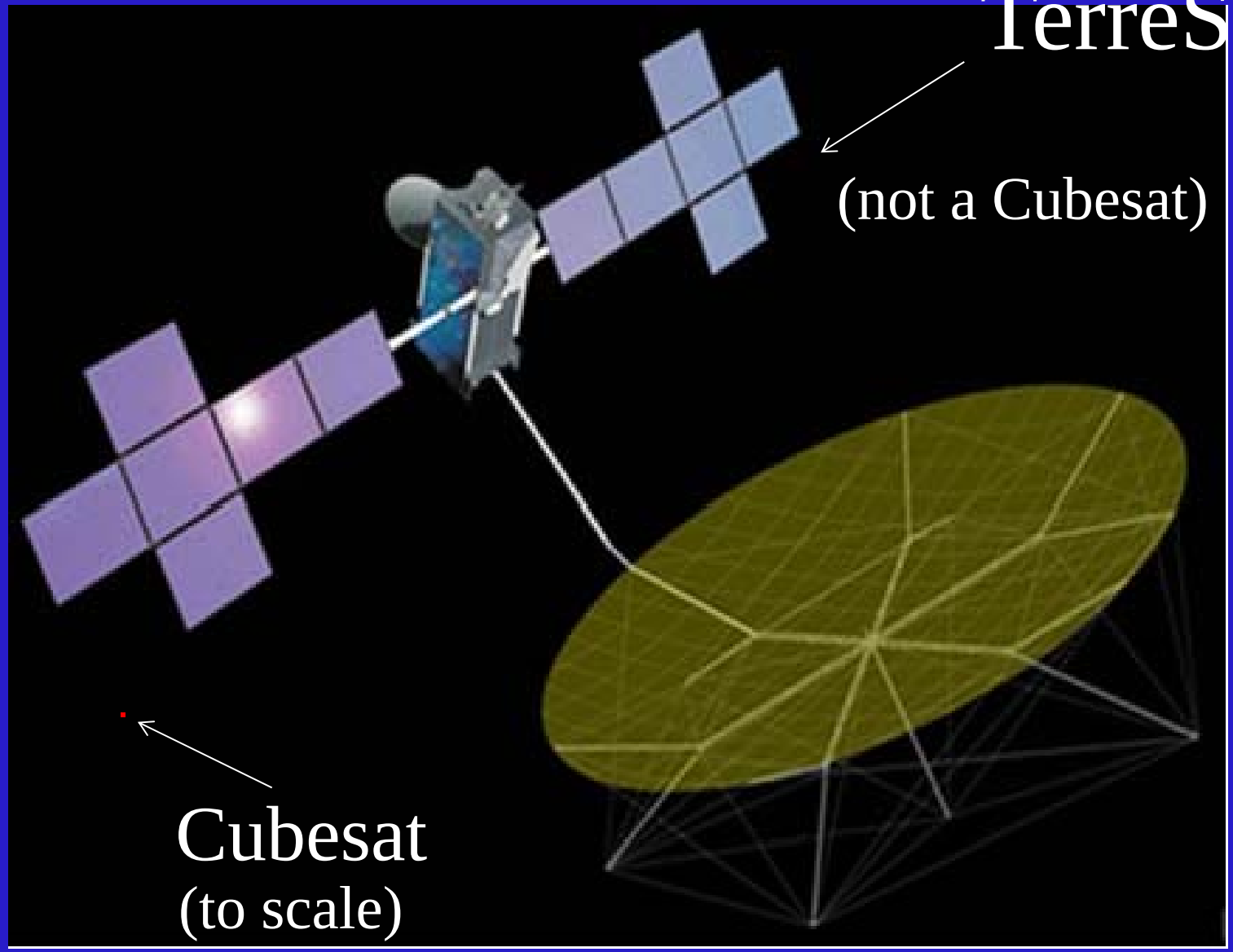
Comparison of a regular satellite to a Cubesat



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What's special about Cubesats?

- Cubesats are cheap
  - NSF awards are typically ~$900k, covers complete cycle – design/construction/launch/operation
  - Many Cubesats are launched for much less
- Cubesats are opportunistic
  - Fly as spare cargo on launches of bigger payloads
- Cubesats are educational
  - Many Cubesats are built as part of thesis projects
- Cubesats are fast
  - Total time from design to launch can be a few months
  - Missions often last for 5 years or less (sometimes just a few days)
- Cubesats are innovative
  - New paradigms for satellite design & operation

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Cubesat Background

- The Cubesat standard grew out of work at California Polytechnic State University (Cal Poly) and Stanford
- First Cubesat launched in 2003
- About 100 Cubesats have been launched since then, by many countries
  - 48 more on the docket for 2013 alone
  - Colombia & Ecuador's first-ever satellites were Cubesats
- In 2008, NSF began a funding program dedicated to Cubesats
- NASA has established the "Educational Launch of Nanosatellites" (ELaNa) and CubeSat Launch Initiative (CSLI) programs

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What can Cubesats do?

- Space weather monitoring
- Atmospheric/ionospheric/magnetospheric research
- Reconnaissance & imaging
- Satellite technology development
- Commercial applications
- Amateur radio
- Janitorial services
- Planet hunting
- Teaching
- Open Source

Article from ArllNow.com

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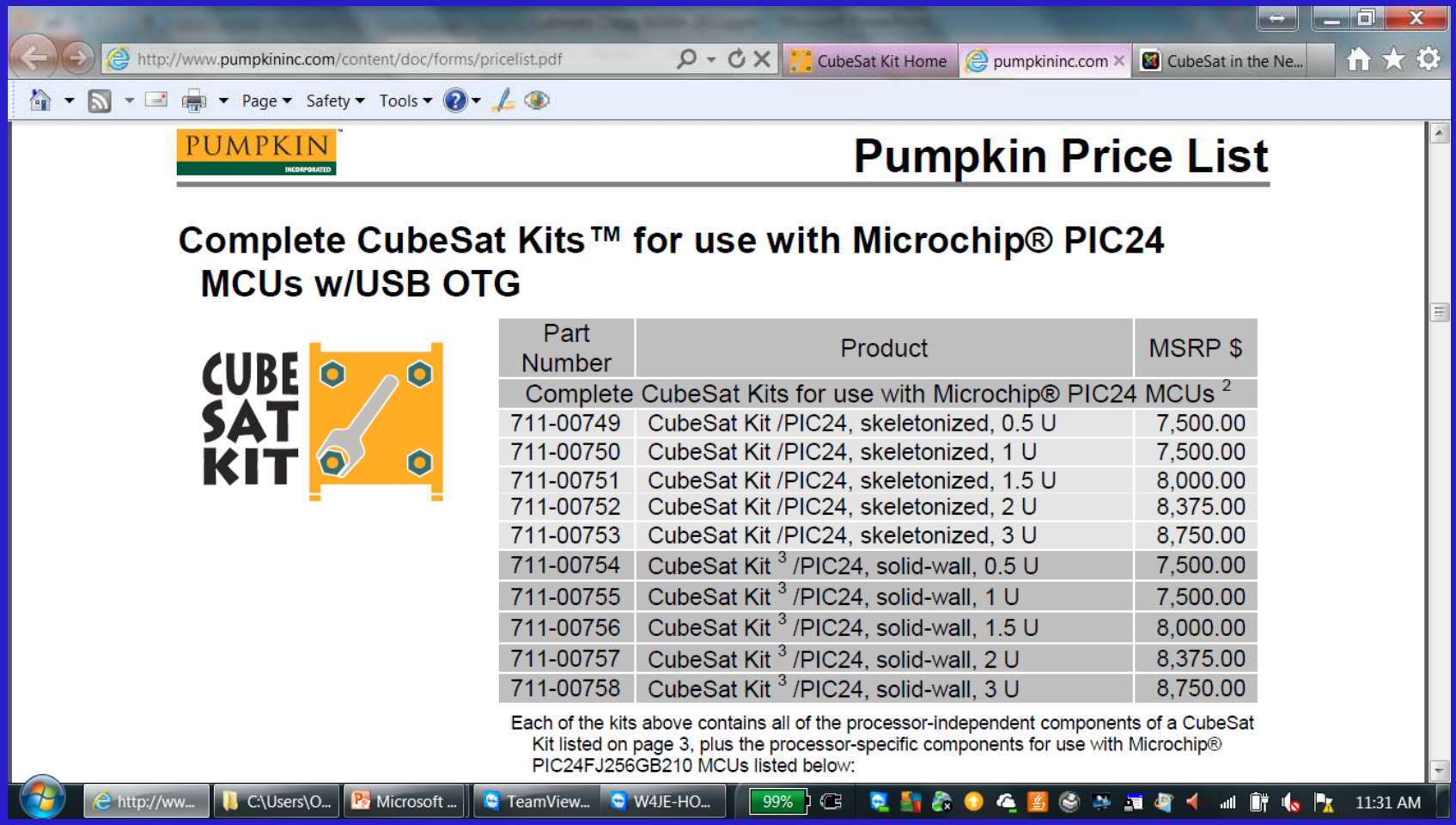
Even roll your own Cubesat!



http://www.pumpkininc.com/content/doc/forms/pricelist.pdf

CubeSat Kit Home | pumpkininc.com | CubeSat in the Ne...

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PUMPKIN INCORPORATED

Pumpkin Price List

Complete CubeSat Kits™ for use with Microchip® PIC24 MCUs w/USB OTG

CUBE SAT KIT

Part Number	Product	MSRP $
Complete CubeSat Kits for use with Microchip® PIC24 MCUs [2]		
711-00749	CubeSat Kit /PIC24, skeletonized, 0.5 U	7,500.00
711-00750	CubeSat Kit /PIC24, skeletonized, 1 U	7,500.00
711-00751	CubeSat Kit /PIC24, skeletonized, 1.5 U	8,000.00
711-00752	CubeSat Kit /PIC24, skeletonized, 2 U	8,375.00
711-00753	CubeSat Kit /PIC24, skeletonized, 3 U	8,750.00
711-00754	CubeSat Kit [3] /PIC24, solid-wall, 0.5 U	7,500.00
711-00755	CubeSat Kit [3] /PIC24, solid-wall, 1 U	7,500.00
711-00756	CubeSat Kit [3] /PIC24, solid-wall, 1.5 U	8,000.00
711-00757	CubeSat Kit [3] /PIC24, solid-wall, 2 U	8,375.00
711-00758	CubeSat Kit [3] /PIC24, solid-wall, 3 U	8,750.00

Each of the kits above contains all of the processor-independent components of a CubeSat Kit listed on page 3, plus the processor-specific components for use with Microchip® PIC24FJ256GB210 MCUs listed below:

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(Launch extra)

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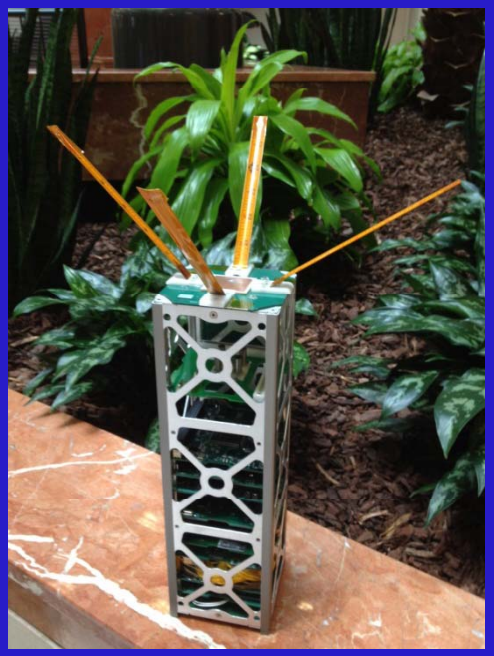
Cubesat Scrap Book

Boeing CubeSat TestBed1 (2007)

2011 Vandenberg Launch of NSF DICE & others with NPOES Prep Project

Tape measure antenna



2013 Wallops Orbital Sciences Antares launch, with Cygnus mass simulator and three experimental/amateur satellites

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Big Challenges

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Biggest Big Challenge for Cubesats

- **Frequencies**

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Regulatory Challenges for Cubesats

- All Cubesats need data and TT&C downlinks and uplinks, just like their big brothers
- Cubesats do not fit well into the existing national and international licensing/regulatory frameworks
- Most significant issues
  - Timescale
  - Orbital uncertainties
  - Frequency bands
  - Orbital debris mitigation

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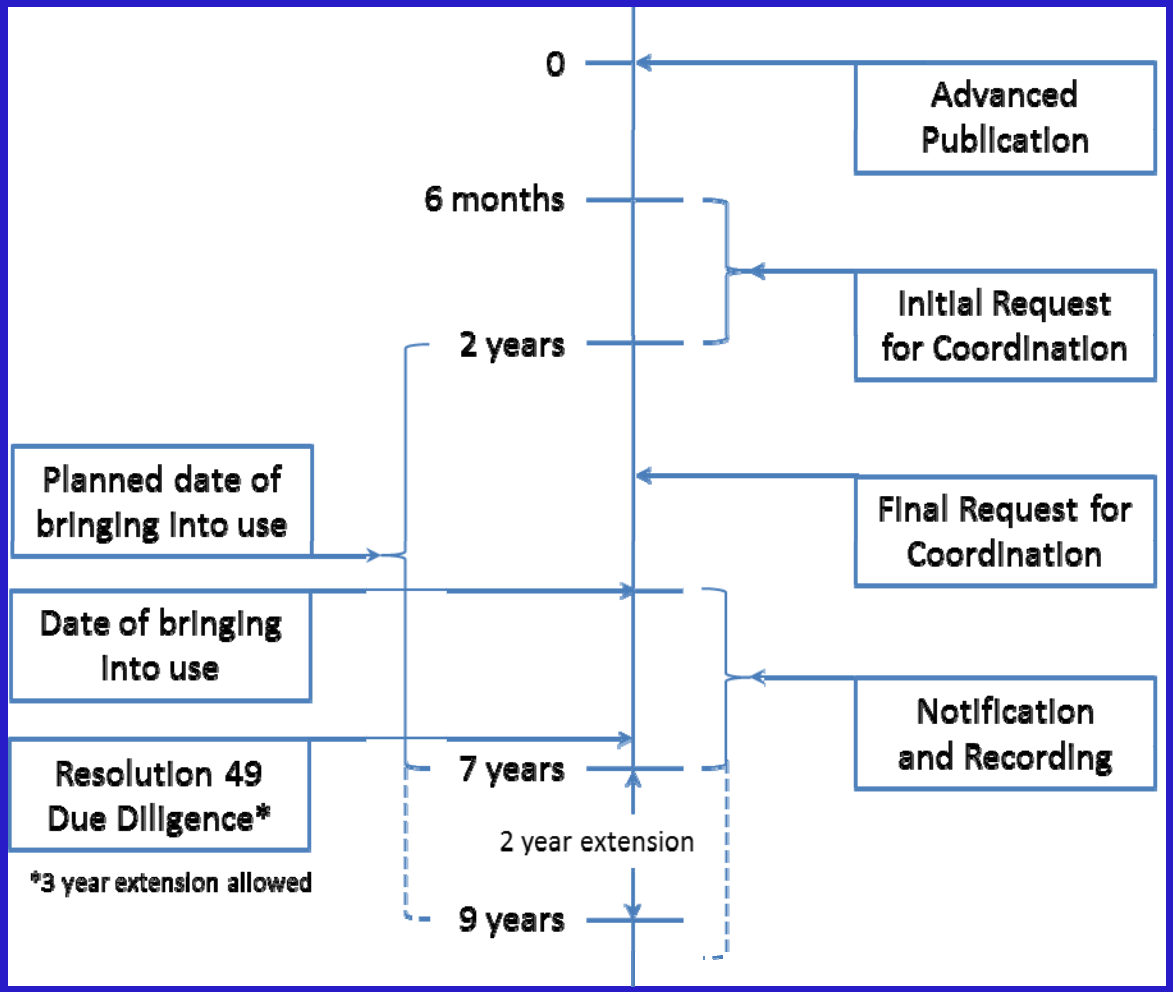
ITU API -> Due Diligence Timescale



Representative Cubesat timeline, preliminary design through launch

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An Actual Cubesat Timeline

Milestone	Days elapsed
Preliminary Design Review	0
Critical Design Review	53
Launch	206
In Orbit Tests	277
In Orbit Mission	287
De-orbit	392

Total time from preliminary design to end of mission ~ 1 year and 1 month!

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Orbital Uncertainties

- Cubesats utilize launches of opportunity
- Typically their exact orbit, or possibly even their approximate orbit, are unknown until months before launch
- Difficult to prepare satellite regulatory filings with little no orbital information
- Possible solution includes generic satellite filings that can cover different classes of potential Cubesats

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Frequency Use

- Bandwidth requirements for Cubesats vary between a few kHz to several MHz (so far)
- Satellite downlink spectrum is not easy to come by
- Keeping with low-cost, often COTS equipment, RF equipment tends to be lower-tech
  - S-band and below; often 500 MHz and below
- Downlink signal levels relatively low, because no significant power available and because omni or low-gain antennas must be used
  - No significant pointing capability
  - Low-gain antenna means that significant portion of satellite visibility is illuminated with RF
    - Creates potential international coordination issues, necessitating ITU filings (see previous challenge...)
- Ground stations often fairly basic
  - Amateur radio stations often employed

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Creative License

- Cubesats have used various band and various mechanisms for licensing
  - Frequently used: Amateur or amateur-satellite bands
    - But these are often not amateur radio satellites, amateur service rules sometimes violated, and amateur coordination authorities are becoming overwhelmed with requests
  - Experimental licenses (in the amateur bands)
    - Amateur coordination workload still an issue
  - EESS bands
    - Lower-frequency bands are congested with terrestrial communications
  - Government S-band
    - DoD cracking down on non-Fed use of this band
  - MSS (Iridium & Globalstar)
  - Other?

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Orbital Debris Mitigation

- Cubesats must have orbital debris mitigation plans just like their big brothers
  - Orbital debris mitigation is important part of FCC filings
  - No fuel, so purposeful destruction at end-of-life is difficult
  - Most Cubesats so far have been LEOs, so debris mitigation has typically been "it'll burn up in the atmosphere is 5-25 years."
  - But higher-orbit Cubesats are planned (including even lunar and interplanetary Cubesats)
  - Some work being done on tiny ion propulsion engines, which will provide small levels of station keeping and maneuvering capabilities

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Solutions?

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Regulatory Changes being Worked

- Preliminary agenda item for the 2018 World Radiocommunication Conference (AI 9.1.8 at WRC 15) that examines whether there is sufficient justification to modify ITU Radio Regulations to better facilitate nano- and picosatellites
- FCC and NTIA also examining possible improvements in rules

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Example

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A Case History: DICE

- September 2009: NSF award for Dual Ionospheric Cubesat Experiment (DICE) to Utah State University and others
- October 2009: Design and construction begins on DICE
- Early 2010: DICE responds to NASA ELaNa call
- Mid-2010: Notification of selection for October 2011 launch with NPOES Preparatory Project
- Late 2010: DICE team becomes aware of need for a license to transmit from space, and contacts NSF spectrum manager just 9 months from point at which spacecraft will be sealed for delivery and launch.
- Late 2010+1 hour: Panic sets in

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A Case History: DICE (cont'd)

- **Late 2010+2 hours – August 2011: DICE team and NSF spectrum management office goes into high gear.**
  - **DICE team performs all measurements and tests needed to submit spectrum certification request to IRAC**
  - **NSF prepares DICE spectrum certification documentation and rushes DICE certification through IRAC SPS in 30 days (6 months – 2 years is typical), then follows with applying for and obtaining a GMF assignment for DICE and its ground stations. Files for and receives ITU notification waiver from IRAC Space Systems Subcommittee. All approvals in place on Aug 25, 2011, three days prior to spacecraft being sealed for launch.**
- **October 28, 2011: DICE launched**

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A Case History: DICE (cont'd)

- October-November 2011: DICE team determines that downlink channel (463.5-466.5 MHz) is completely swamped with terrestrial (land mobile) interference at Wallops ground station facility
- December 2011: NSF applies for and receives a modified frequency assignment for 466.5-469.5 MHz. RFI issues improve.
- February 2012: New digital TV station comes on air, just a few miles from Wallops, on the immediately adjacent band, 470-476 MHz (U.S. channel 14). DICE downlink band is completely overwhelmed with (legal) OOBE
- February-December 2012: Consultations with NTIA and FCC; Informal coordination allows DICE and TV station to co-exist while TV station seeks authority to change channel
- December 2012 – present: TV station changes channel, all is well with DICE downlink

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Citizen Satellites

http://www.arlnow.com/2013/04/18/elementary-students-to-build-launc

Boeing: Boeing Picc

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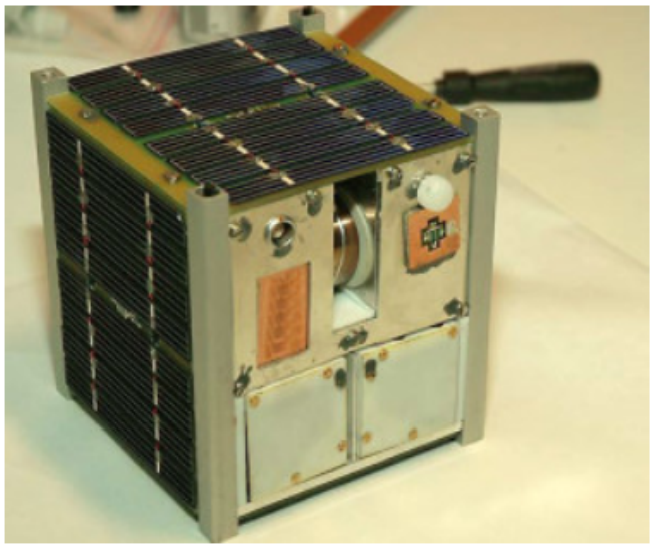
Elementary Students to Build, Launch Satellite

by Katie Pyzyk | April 18, 2013 at 11:00 am | 581 views | 13 Comments and 16 Reactions



(Updated at 12:05 p.m.) Students at St. Thomas More Cathedral School (STM) are taking part in what has been dubbed "Mission Possible." It's a rare opportunity build a satellite and launch it into orbit.

According to an article published this week by Satnews.com, students will get assistance from a NASA Mission Manager in building a CubeSat, which is a miniature satellite used for space research. The satellite will collect data to be used for school research in math and science.

Lenovo Battery: (99%) remaining