

CubeSat

Mission Success (or Not): Trends and Recommendations

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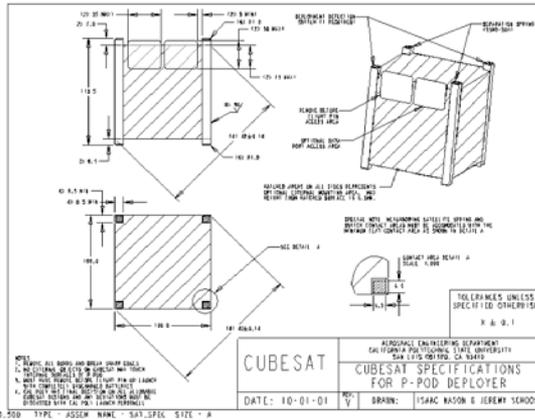
NASA Electronics Parts and Packaging Program
2015 Electronics Technology Workshop
NASA Goddard Space Flight Center
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- CubeSats: more of 'em than you think
 - An (incomplete) CubeSat census
 - It's okay to feel overwhelmed
- All CubeSats are not created equal
 - Nor are they equally endowed with rights for life, liberty or the pursuit of mission success
 - Hobby, mini-me, or smallsat?
- Recommendations and best guesses
 - Sharing best practices
 - A plea for data



Shortest-Ever Course on CubeSats

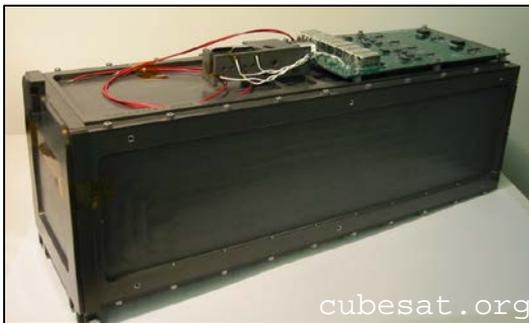


- Twiggs (Stanford) and Puig-Suari (Cal Poly) defined a standard for carrying 10 cm, 1 kg cubes into space

- *[The real innovation was the P-POD]*

- Timeline

- 1999 Concept definition
- 2003 First flight
- 2010 70th flight
- 2012 100th flight; NASA selects 33 CubeSats to fly (backlog of 59)
- 2014 Planet Labs flies dozens
- 2015 400th flight (probably)



Tilting at Windmills



- At CubeSat scales the primary constraint is **volume**, not mass (!)
- Micro/nano/pico mass boundaries don't fit
 - An 0.8-kg 1U ("pico" satellite) has a lot in common with a 5-kg 3U ("nano" satellite)
 - A 5-kg 3U has less in common with a 20-kg Marmon-clamped secondary
- What do I propose? Interfaces
 - CubeSat (all the variants)
 - NLAS / CSD (the 6U)
 - ESPA / ASAP
 - XPOD (Canada)



How the Sausage Was Made



- A “CubeSat” is ...
 - A deployed free-flyer
 - That fits in a **standardized container**
 - That meets (most of) the CubeSat Design Specifications
- Building the database
 - Launch logs (thank you, Gunter’s Space Page and Jonathan’s Space Report!)
 - Census data
 - Public operations logs, blogs, Tweets (thank you, DK3WN and Bryan Klofas!)



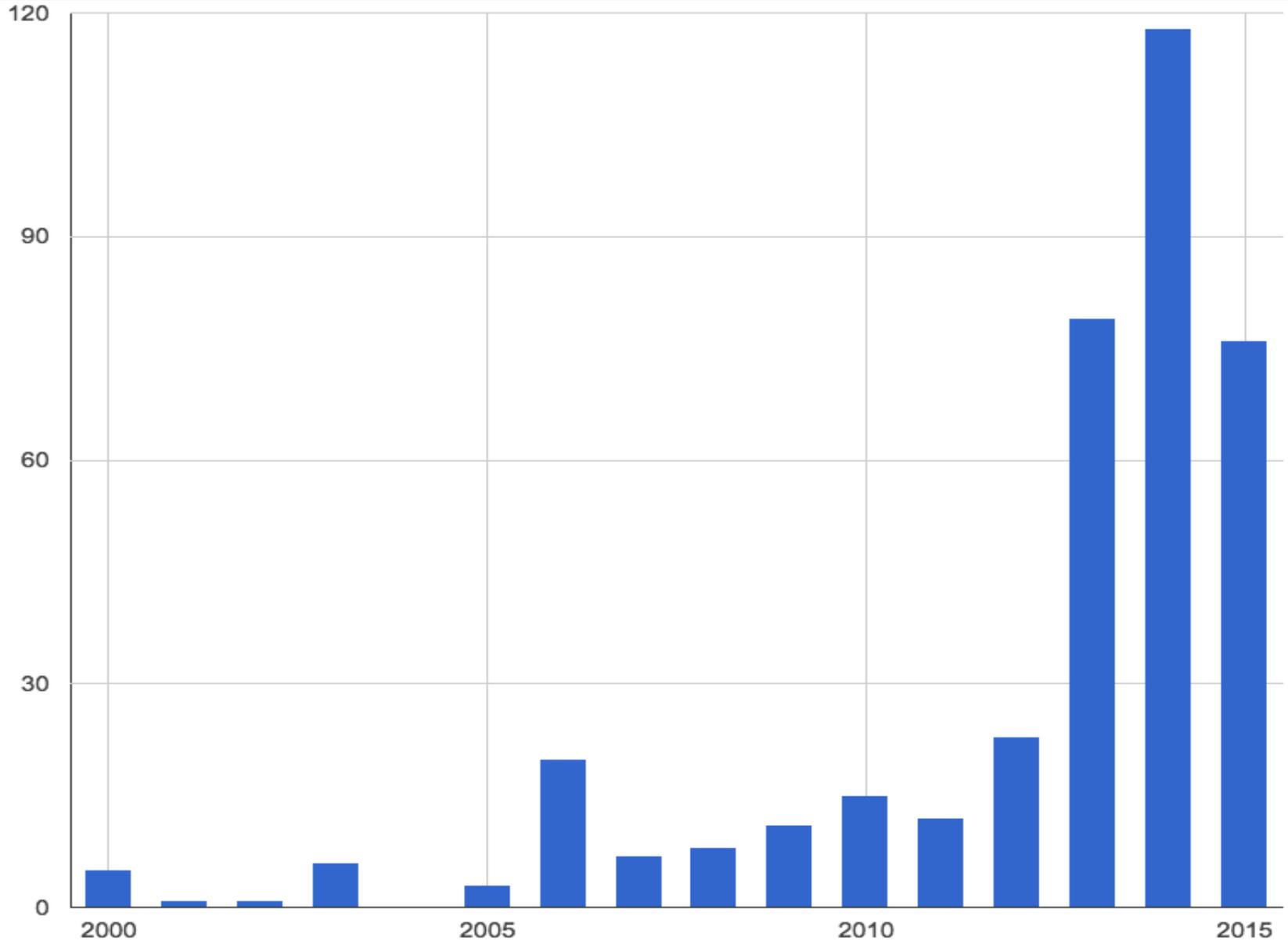
We're on a mission ... or are we?



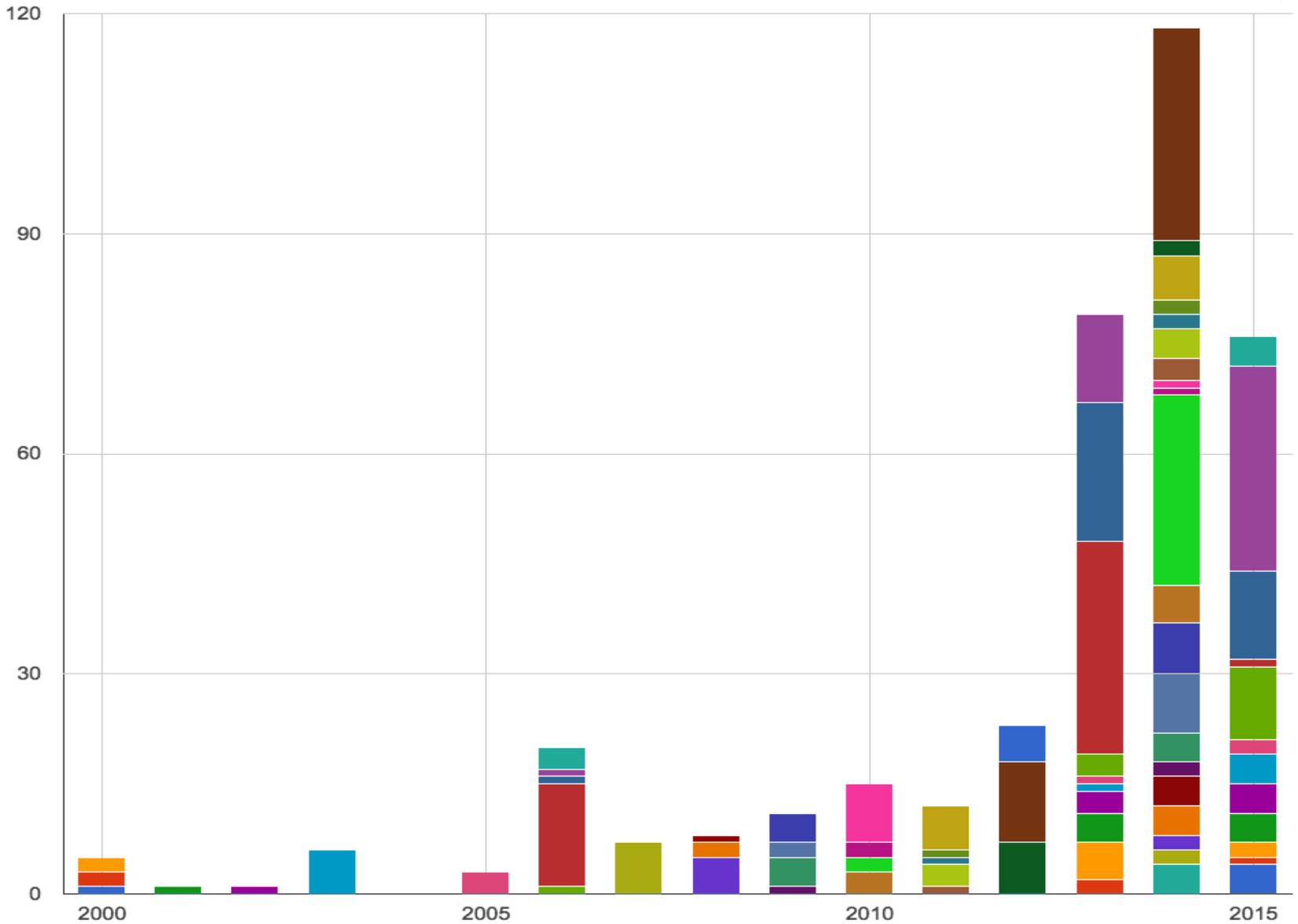
- A “mission” consists of all of the spacecraft necessary to meet the mission (i.e., a multi-spacecraft tether mission is just one mission)
- The mission begins when it is free-flying, not when it leaves Earth (e.g. Dragon/Cygnus cargo missions)
- The mission ends when
 - The team announces the end (all too rare!)
 - When the Union of Concerned Scientists removes it from their database
 - When I cannot find any evidence of activity



Number of CubeSats On-Orbit



Number of CubeSats Per Launch



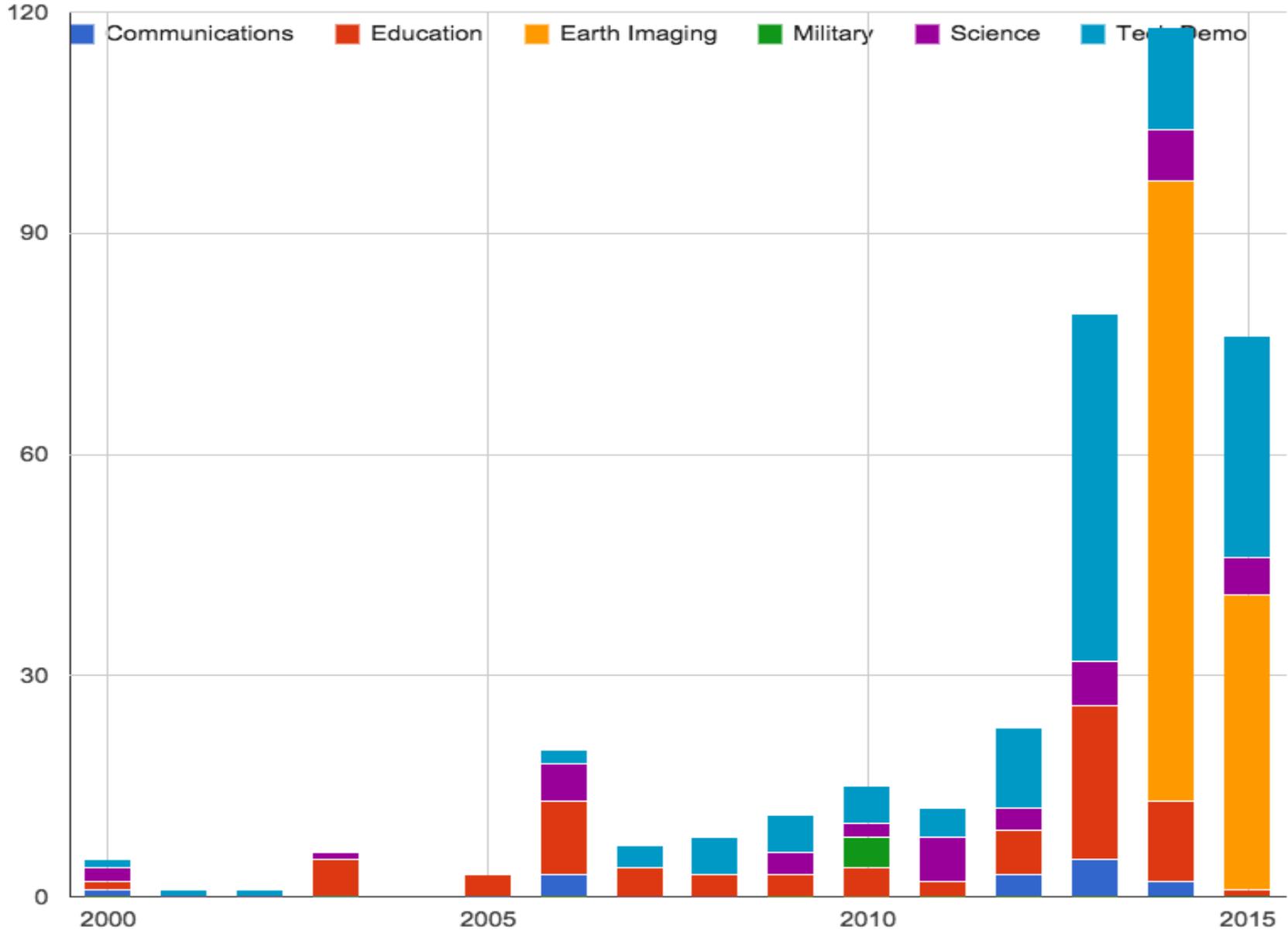
Why Fly CubeSats?



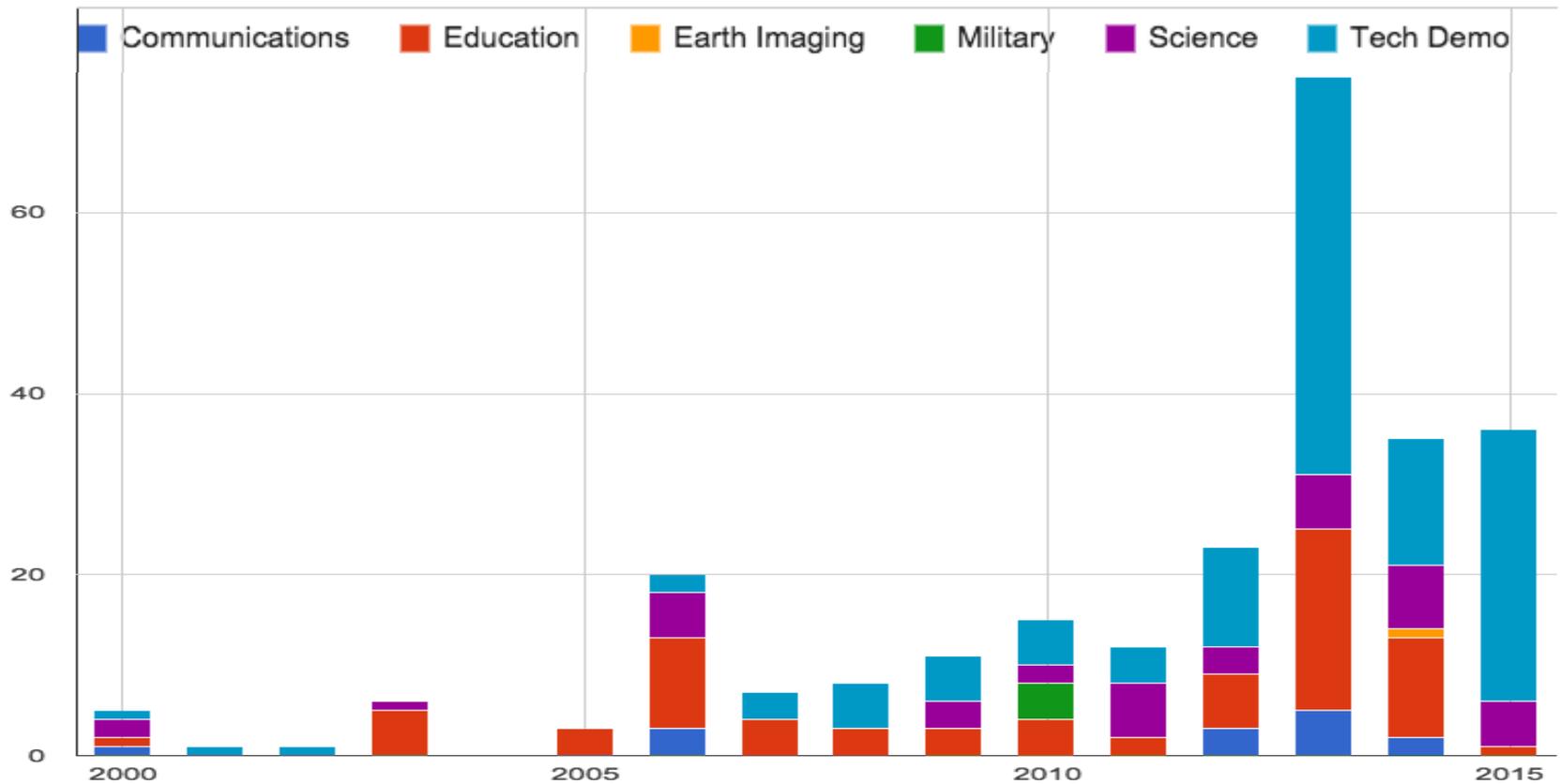
- Giving Youngsters Something to Do
 - Nothing teaches systems engineering like, well, doing systems engineering
 - Let students (or fresh-outs) burn their fingers on short, low-consequence missions
- The Mission Fits
 - Single-instrument science
 - Flight-testing new technologies
 - Low-rate communications (but persistent!)
 - Modest power, data and lifetime needs
 - Rapid(ish) turnaround
- High-Risk, High-Reward



CubeSat by Mission Type



CubeSat by Mission Type (No Planet Labs)



Tiny Versions of Big Satellites



- Science on a Budget
 - RAX
 - CINEMA
 - HRBE
- Risk Reduction for New Technologies
 - STRAND-1
 - AeroCubes
- Constellations at a New Price Points
 - Planet Labs' Dove
 - Prometheus



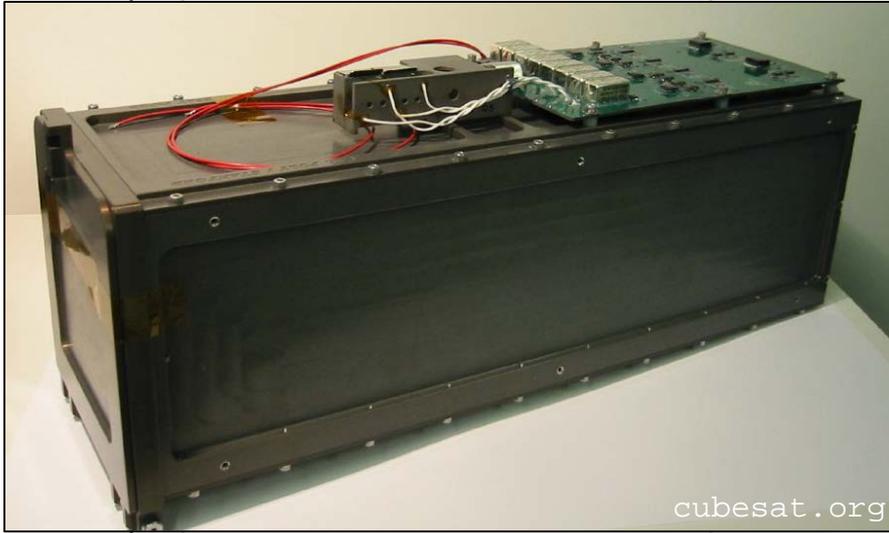
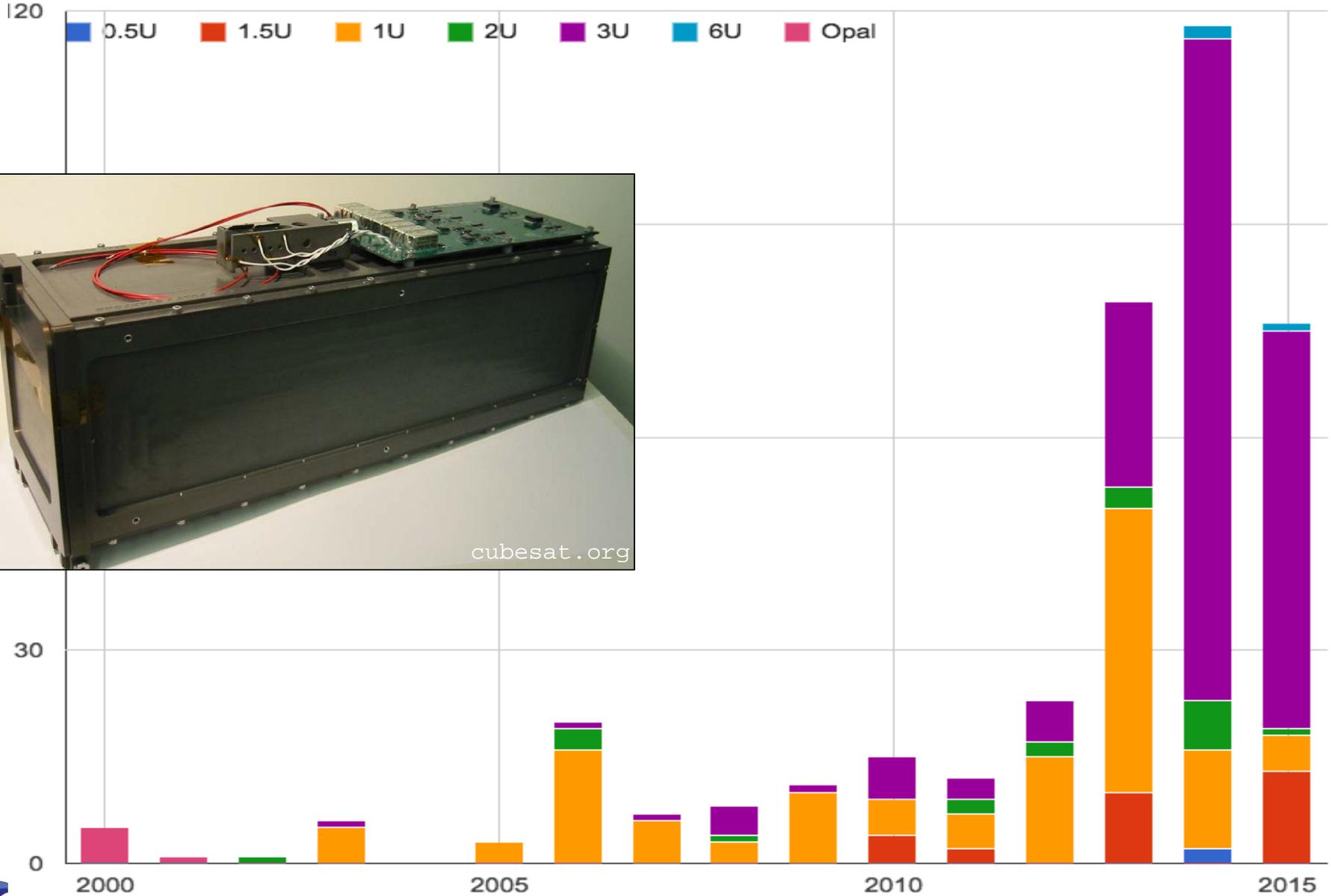
Tiny Versions of Big Satellites



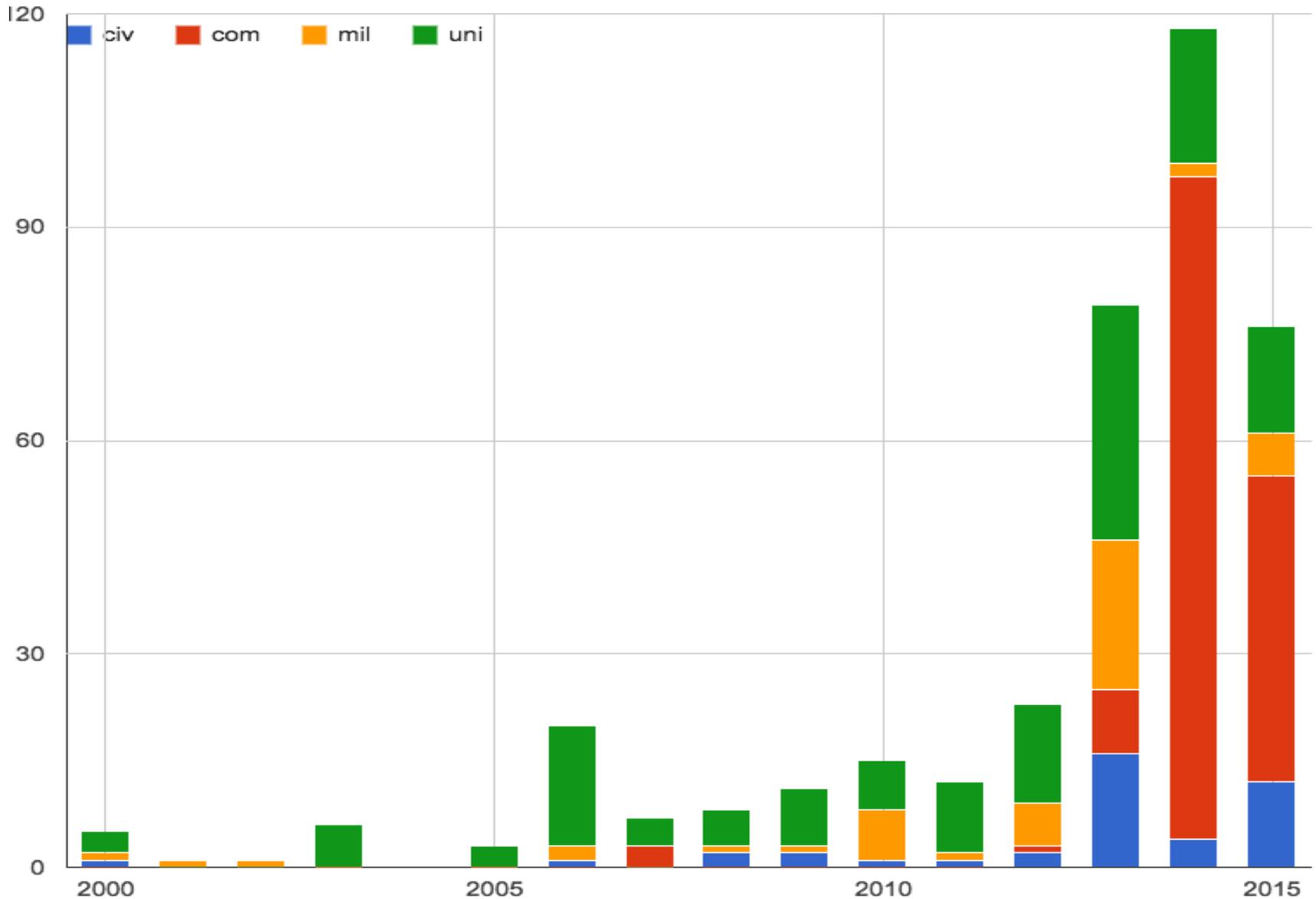
- Science on a Budget
 - RAX
 - CINEMA
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- Risk Reduction for New Technologies
 - STRAND-1
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- Constellations at a New Price Points
 - Planet Labs' Dove
 - Prometheus
- Where are the crazy, new missions?



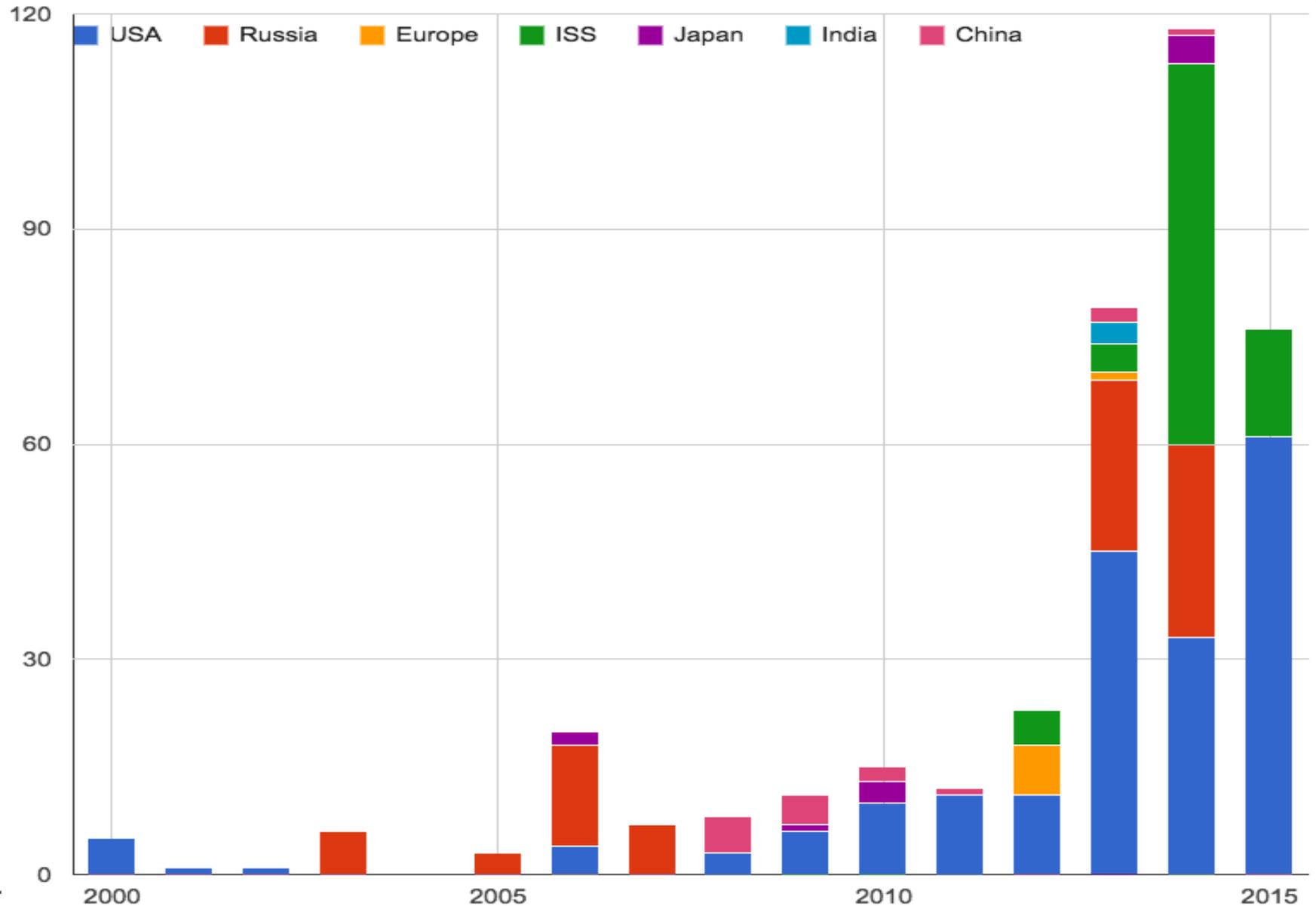
CubeSat by Form Factor



CubeSat by Contractor Type



Nationality of Launch Vehicle



None of These Things are Quite Like the Others ...

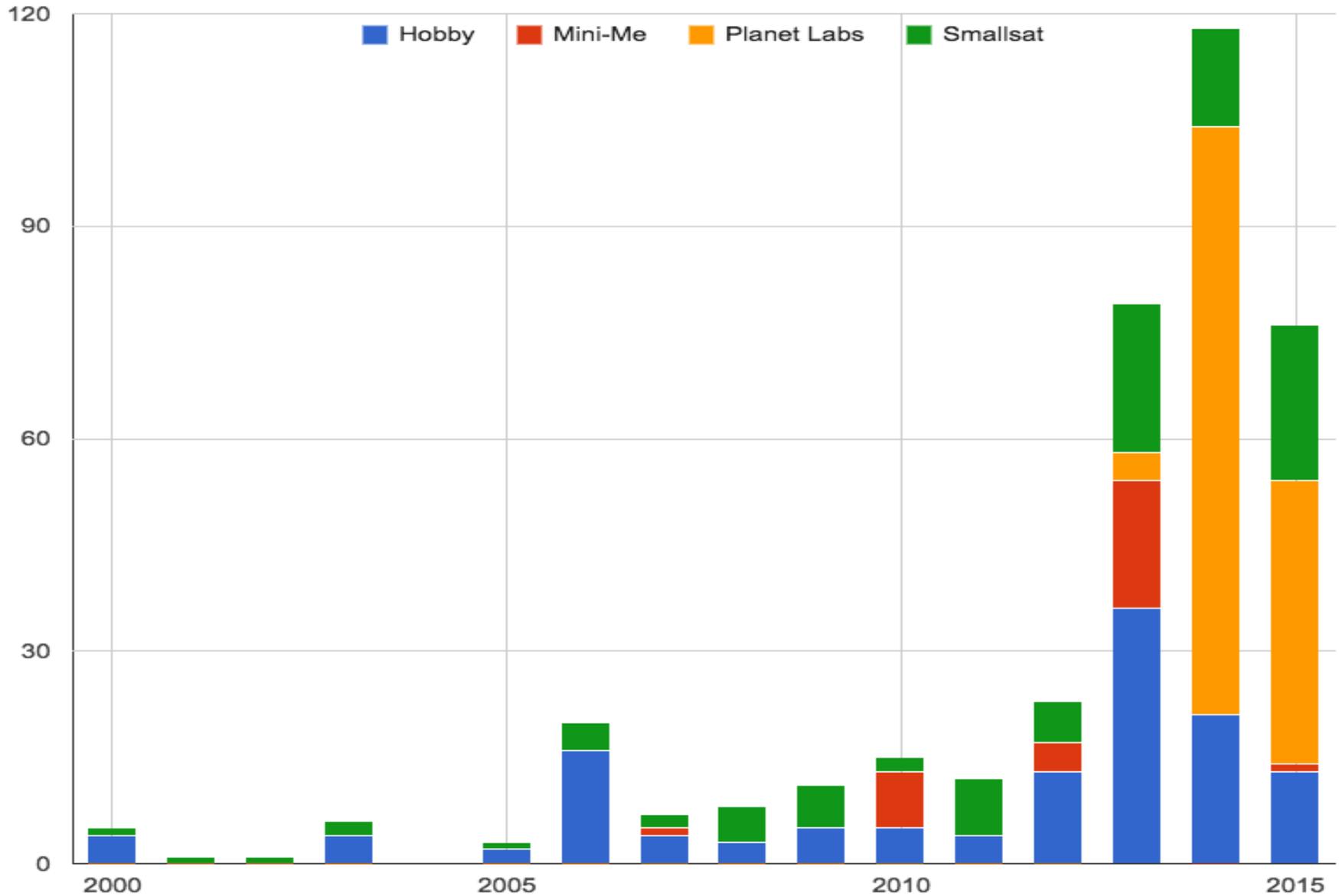


[With profound apologies for my working titles]

- Hobbyists
 - No real experience in the field
 - Building for fun & future profit
 - Ad hoc practices
- “Mini-Me”s
 - Experienced builders of big spacecraft
 - Building under gov’t contract
 - Standard space system practices, with some truncation
- SmallSatters
 - Experienced builders of small spacecraft
 - Building under contract (including services)
 - Streamlined practices, experientially developed
- And then, there’s Planet Labs



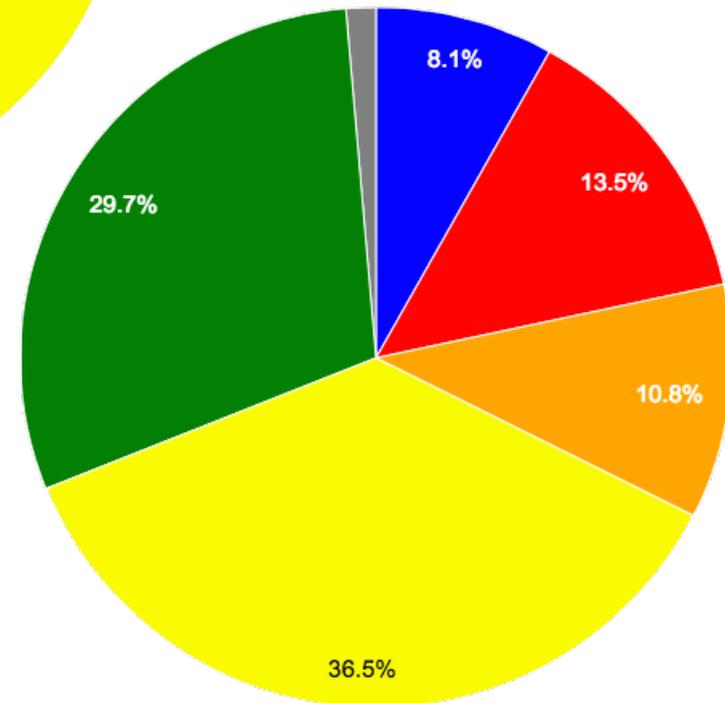
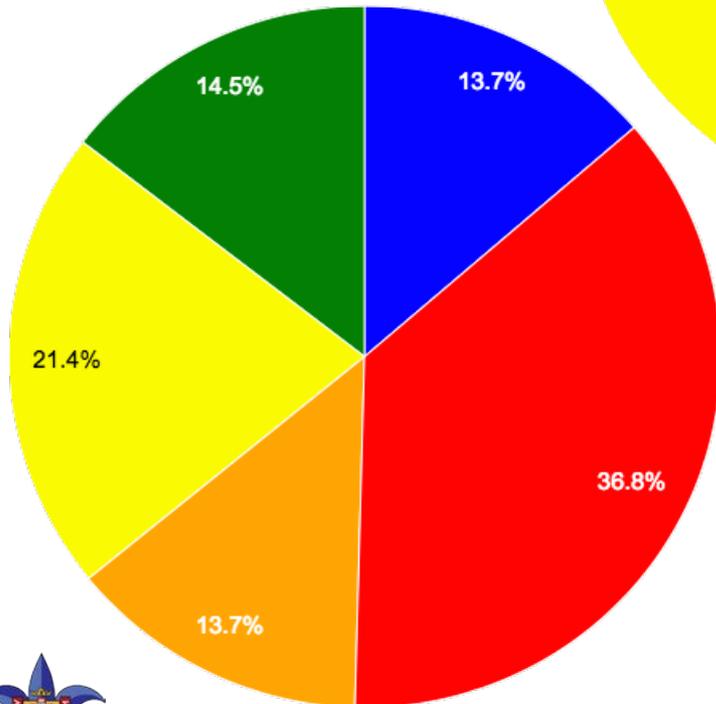
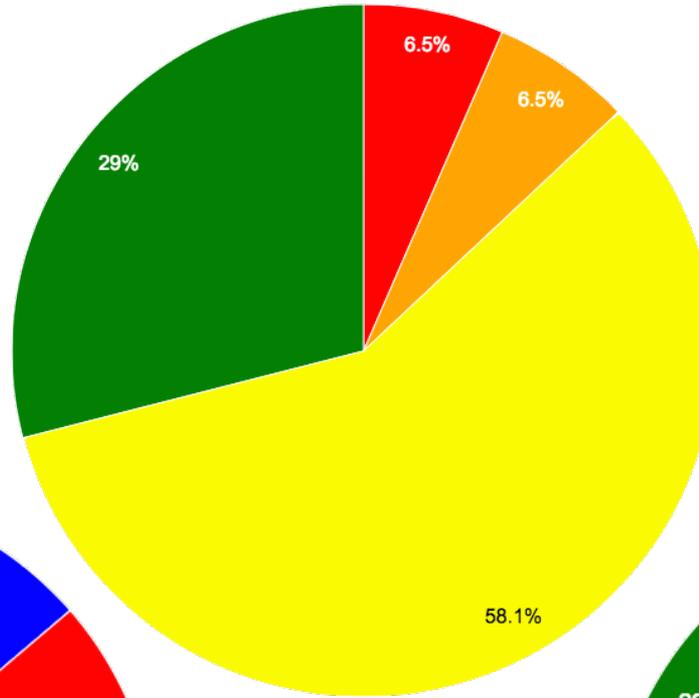
CubeSat by Developer Class



Do You Get What You Pay For?



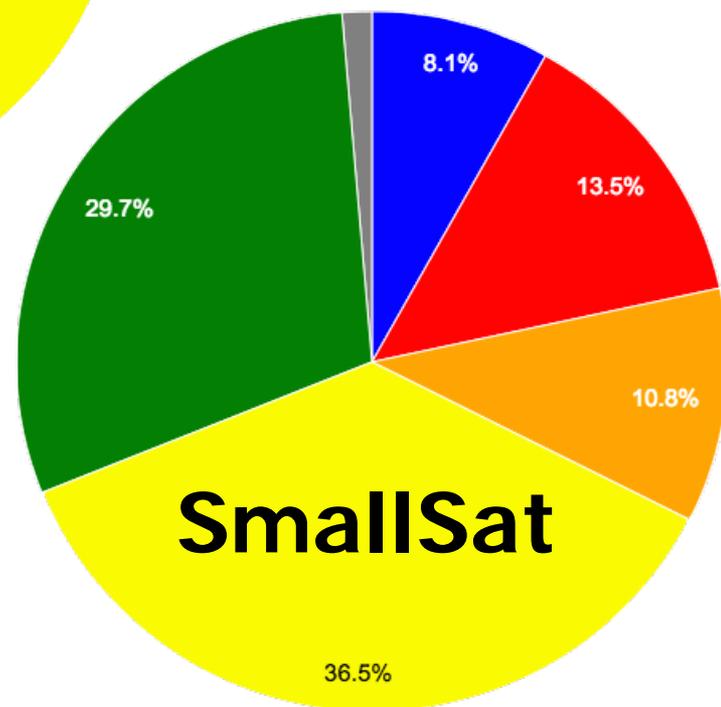
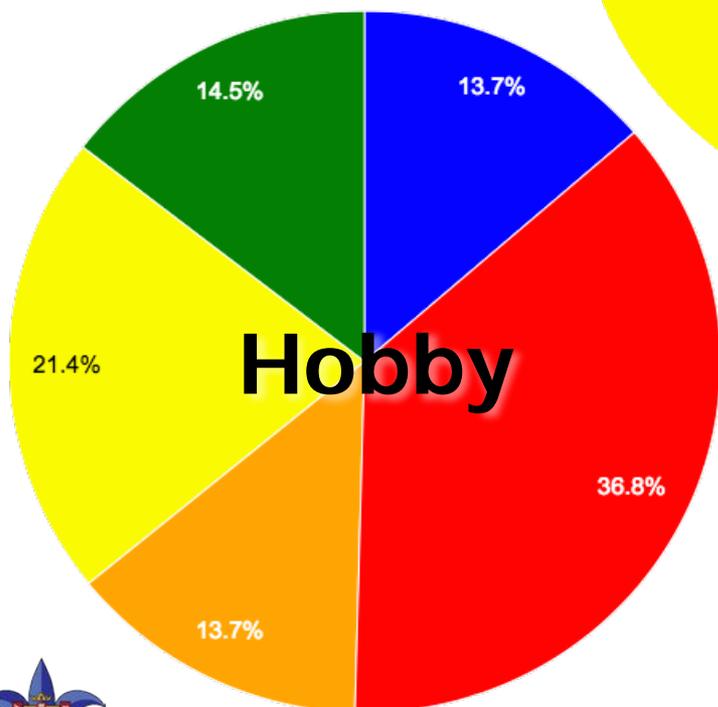
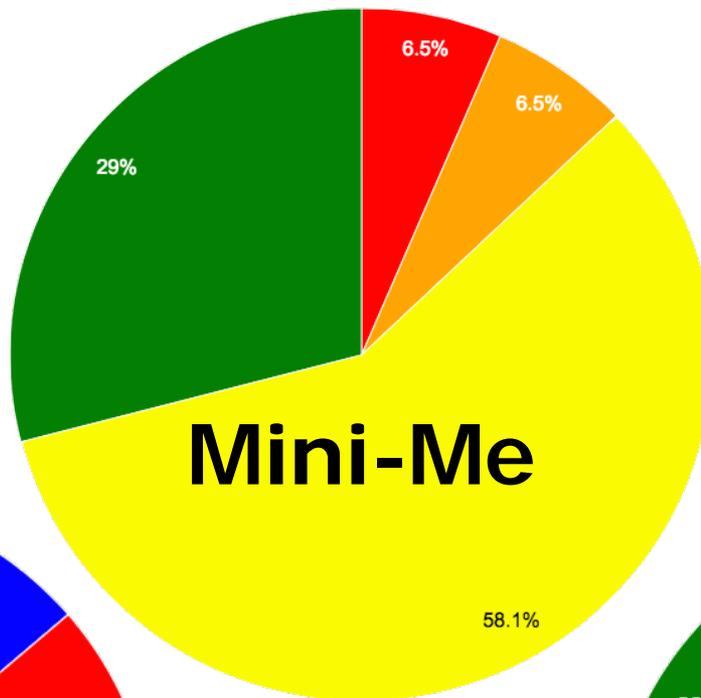
- Launch Fail
- DOA
- Early loss
- Partial Mission
- Full Mission
- Unknown



Do You Get What You Pay For?



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Why Are Failure Rates So High?



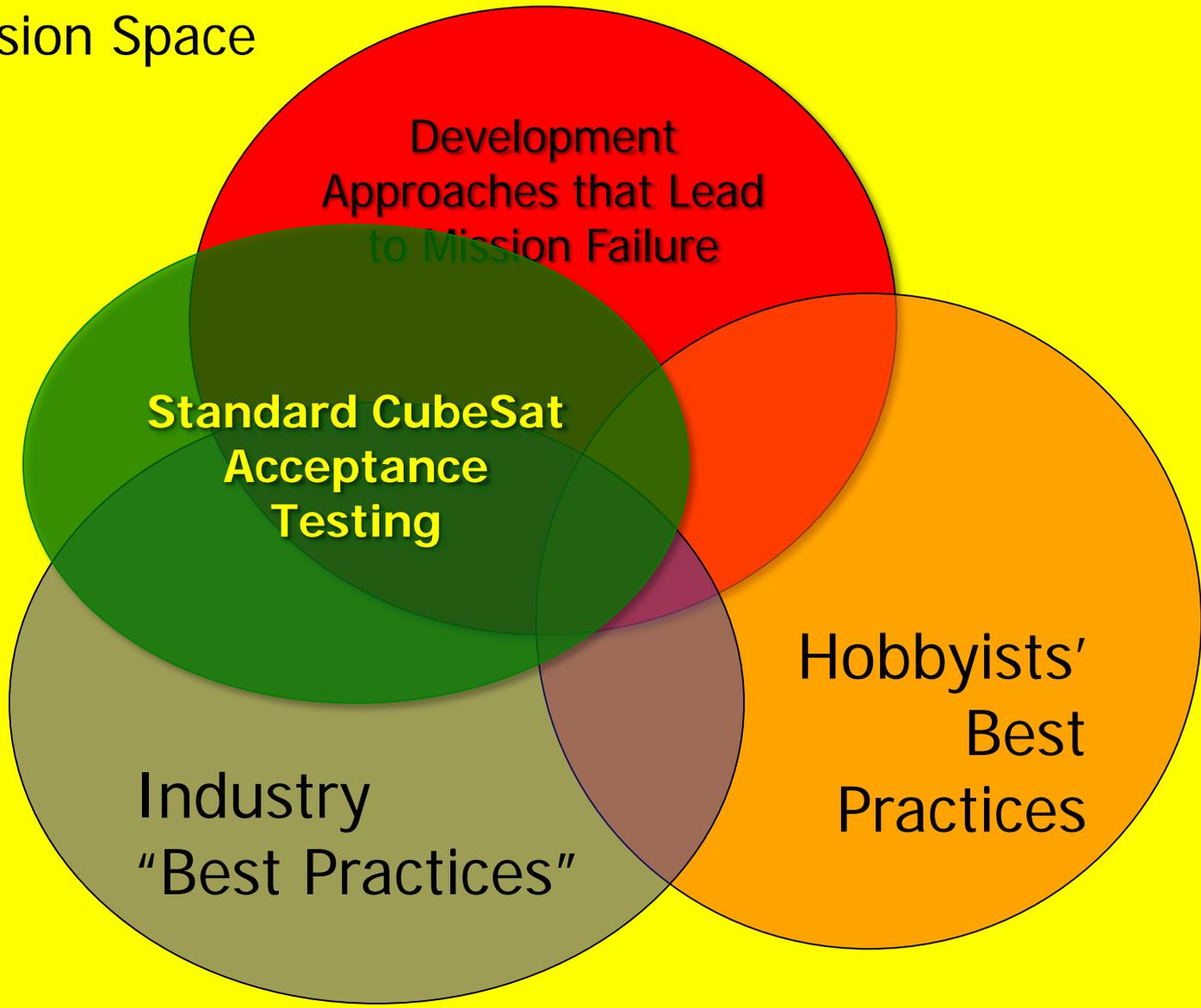
- Honest answer: I don't know, and neither does anyone else
- Observation: success rates go way up with 2nd, 3rd, etc. missions
- *[Insert shameless plug for a sponsored study]*
- My reasonably-educated guesses
 - Inadequate systems-level testing
 - Inadequate testing for workmanship
 - The disjoint set of testing, common practices and mission success



QA Approach: "Because I Said So!"



Mission Space



- Mission success
 - As long as new programs build new CubeSats, failure rates will be high
 - Experienced programs do (much) better
- The laws of physics are still against us
 - Power, communications and many instruments need aperture
 - There's a reason Boeing, Lockheed, Arianespace, Orbital, & SpaceX build bigger rockets, not smaller
- We've made a lot of work for these folks.
When do they revolt?
 - FCC (frequency allocation)
 - NOAA (imaging)
 - JSPOC (tracking)
 - Everyone (debris management)



Acknowledgements



- Satellite Census Data
 - Space-Track.org
 - Gunter's Space Page (<http://space.skyrocket.de/>)
 - Jonathan's Space Report (<http://planet4589.org/space/>)
- Mission Operations Assessments
 - Bryan Klofas (www.klofas.com/comm-table)
 - Mike Rupprecht, DK3WN (<http://www.dk3wn.info/p/>)
 - Union of Concerned Scientists (www.ucusa.org)
- Early Launch Supporters
 - NSF (Therese Moretto Jorgensen)
 - NASA ELaNa Program (Garrett Skrobot)
- Research Support
 - AFOSR (University Nanosat Program)
 - Saint Louis University (Presidents Research Initiative)



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