

The First ~~100~~ ~~200~~ 272 CubeSats

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EEE Parts for Small Missions Workshop
NASA Goddard Space Flight Center
11 September 2014

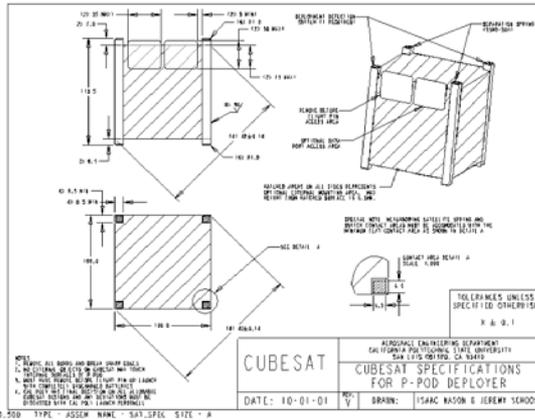


Beginning with the End



- Did you know that there are a lot of CubeSats?
 - No, you don't understand how many there are!
 - A CubeSat census
- How did we get here?
 - P-PODs, ISIPODS and J-SSODs
- No one knows where this is headed
 - Building tiny versions of big satellites
 - Building new satellites for new missions
- Toy, tool or debris cloud?

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 NASA selects 33 CubeSats to fly (backlog of 59)
 - 2013 130th flight (!)

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
 - ESPA
 - 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!)



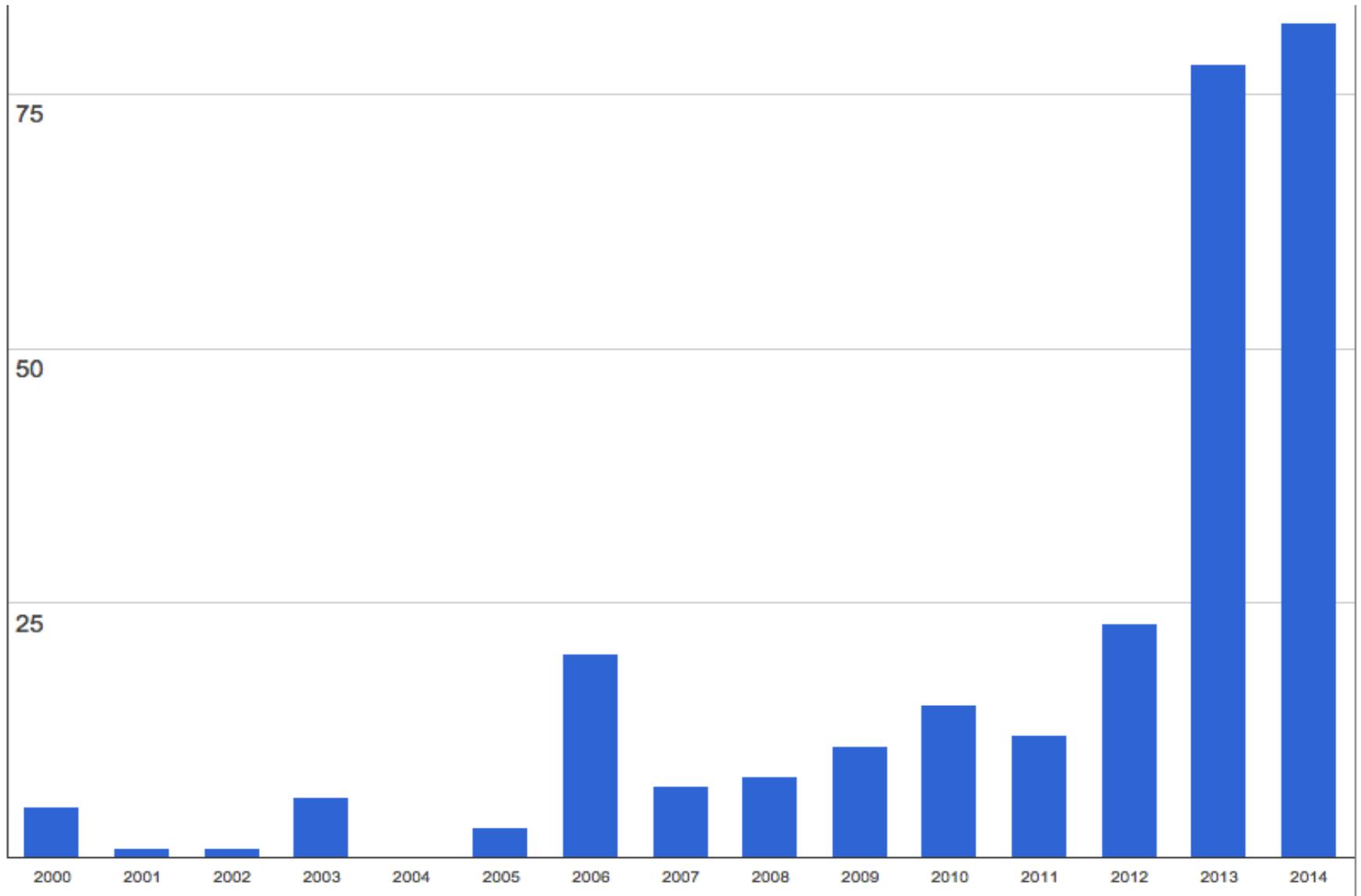
Everyone is Exceptional



- A “mission” consists of all of the spacecraft necessary to meet the mission (i.e., a two-spacecraft tether mission is 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
- I still don't know what to do with PlanetLabs



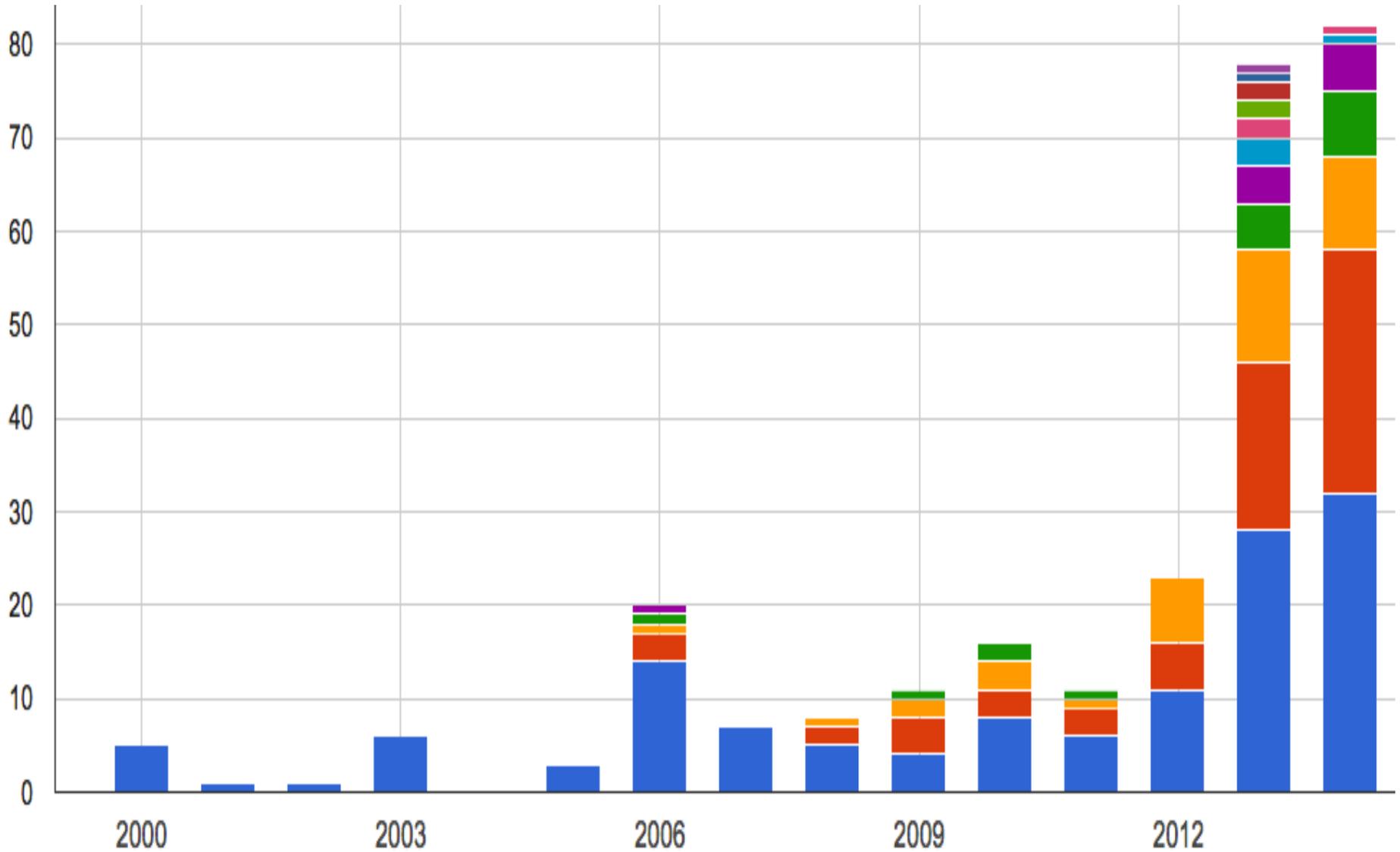
Number of CubeSats On-Orbit



It's Raining CubeSats!

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Number of CubeSats Per Launch



It's Raining CubeSats!

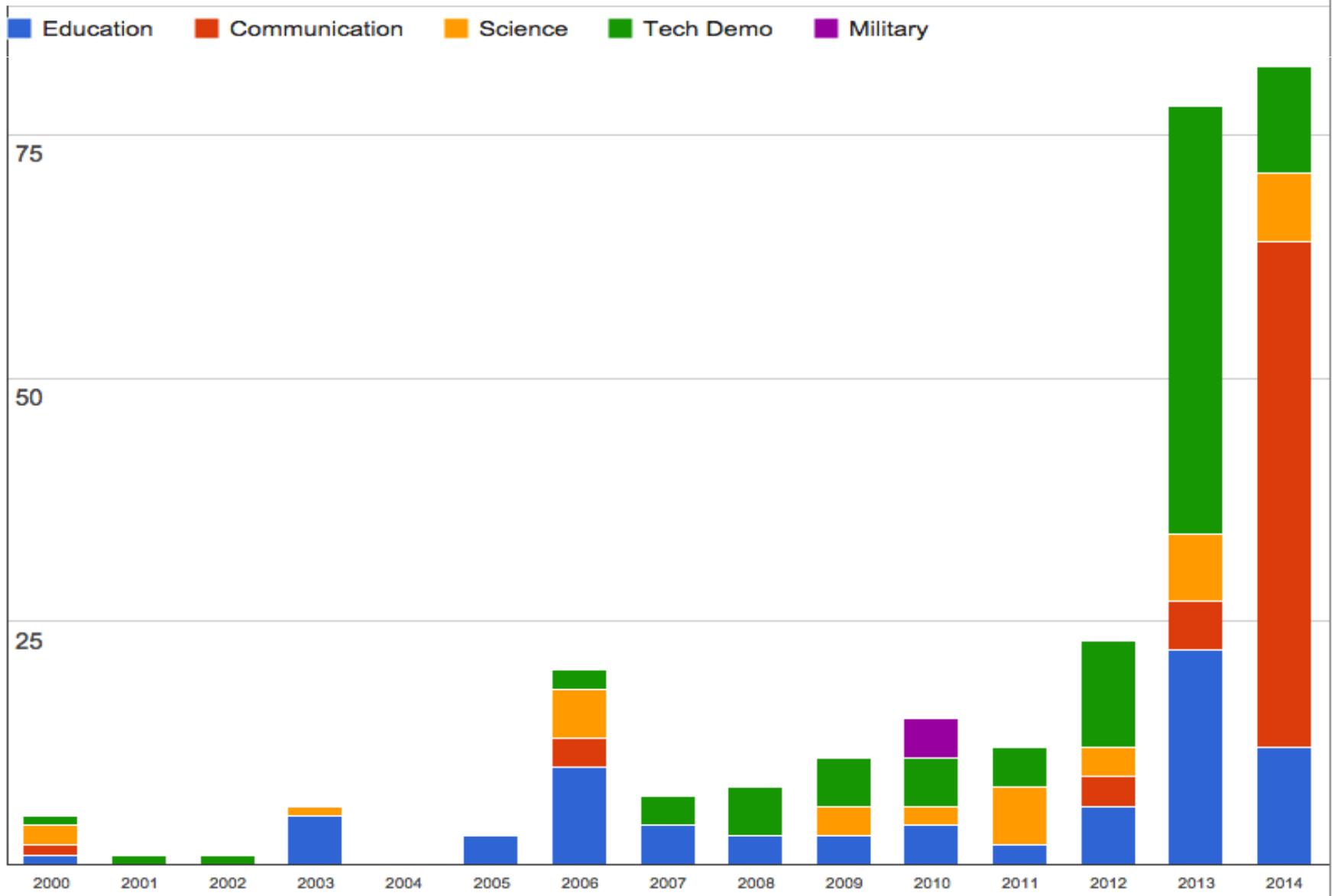
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Why Fly CubeSats?



- 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



It's Raining CubeSats!

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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
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- Where are the crazy, new missions?

PlanetLabs' Dove Constellation



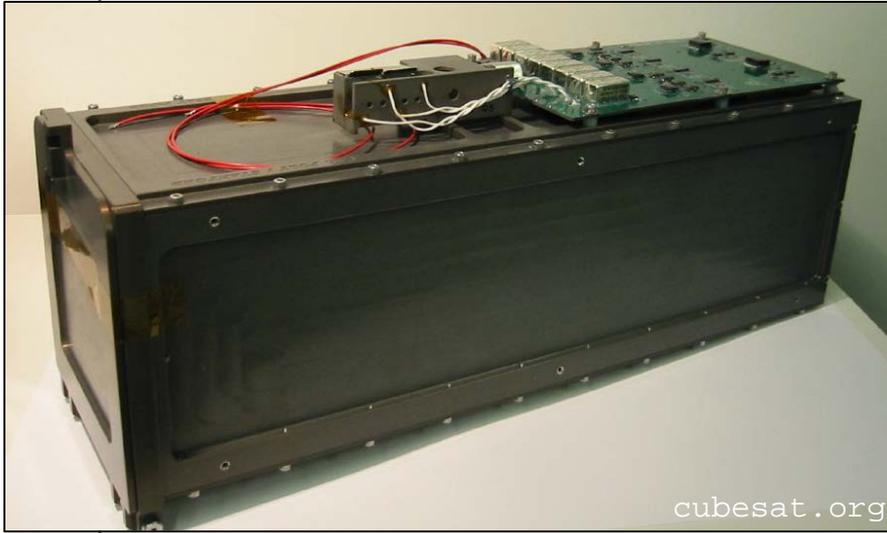
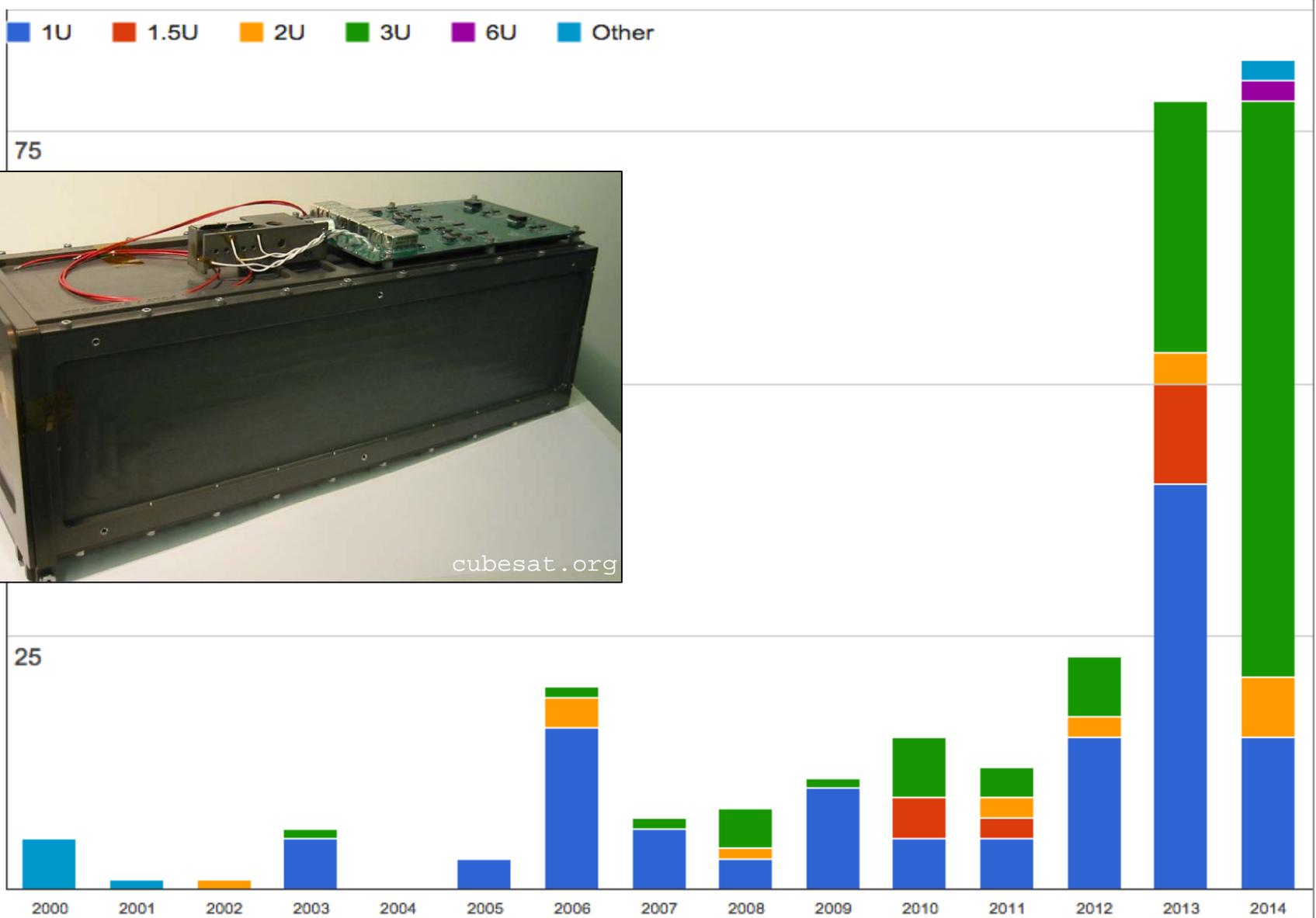
nasa.gov



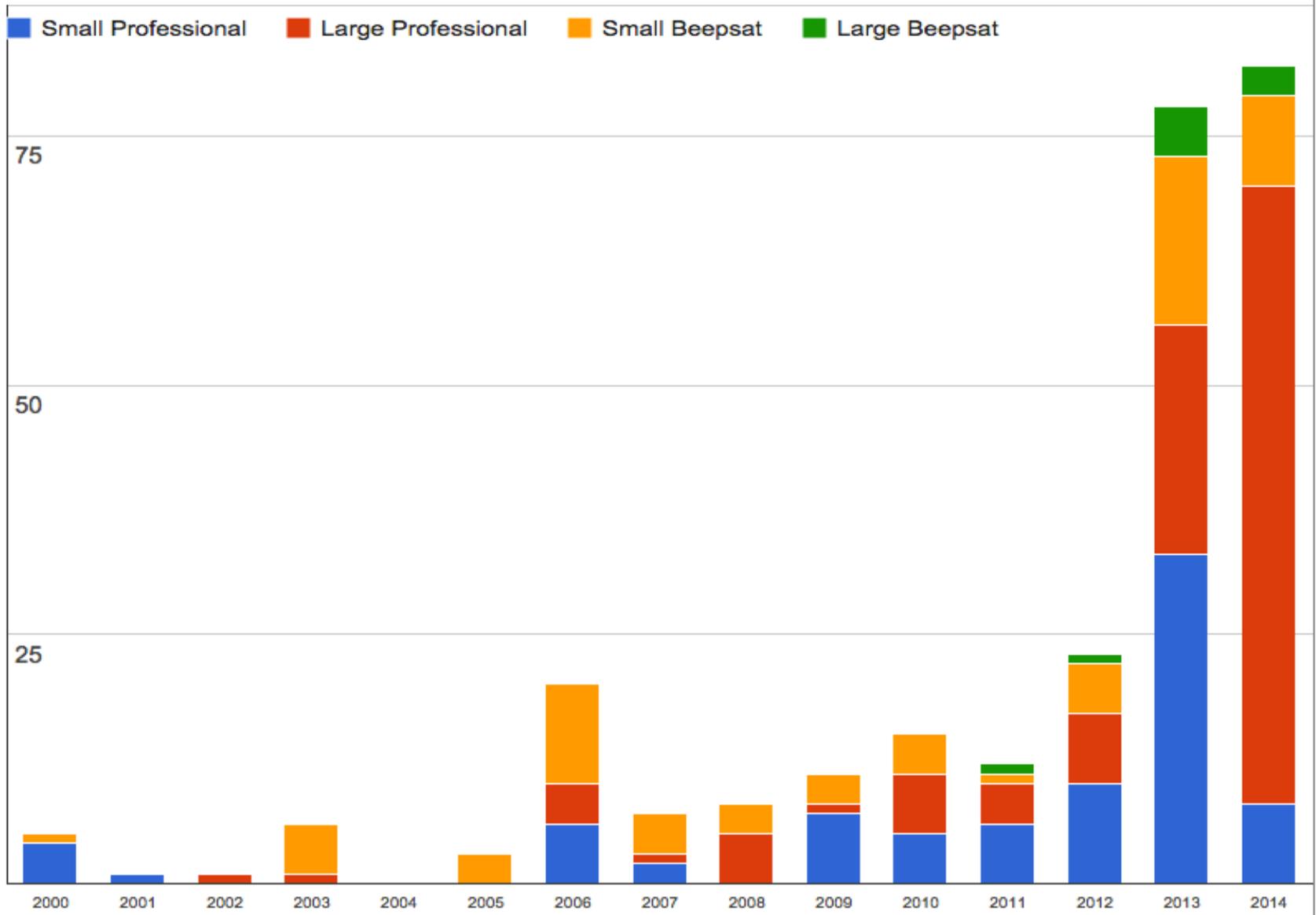
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CubeSat by Form Factor



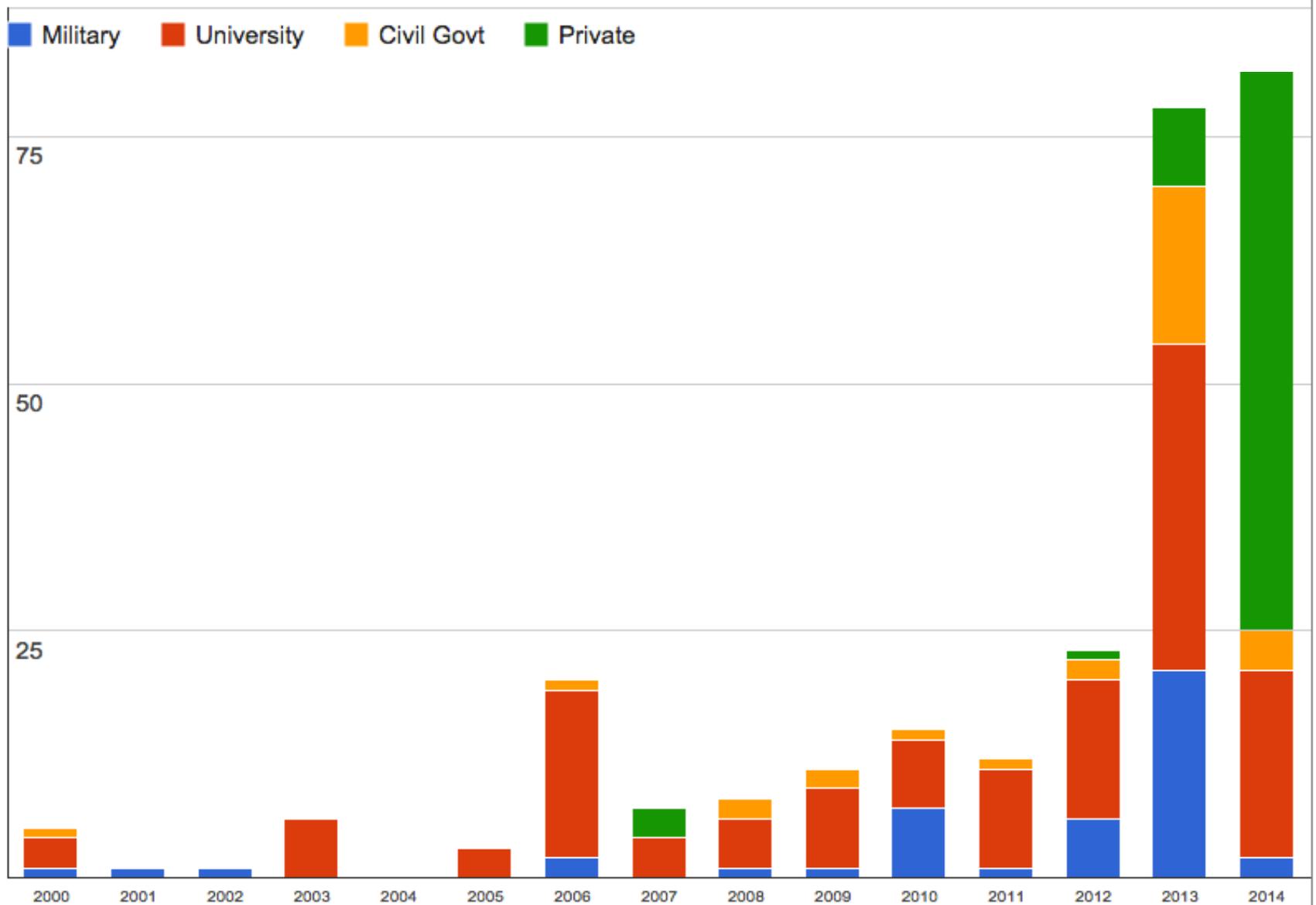
Even With CubeSats, Bigger is Better



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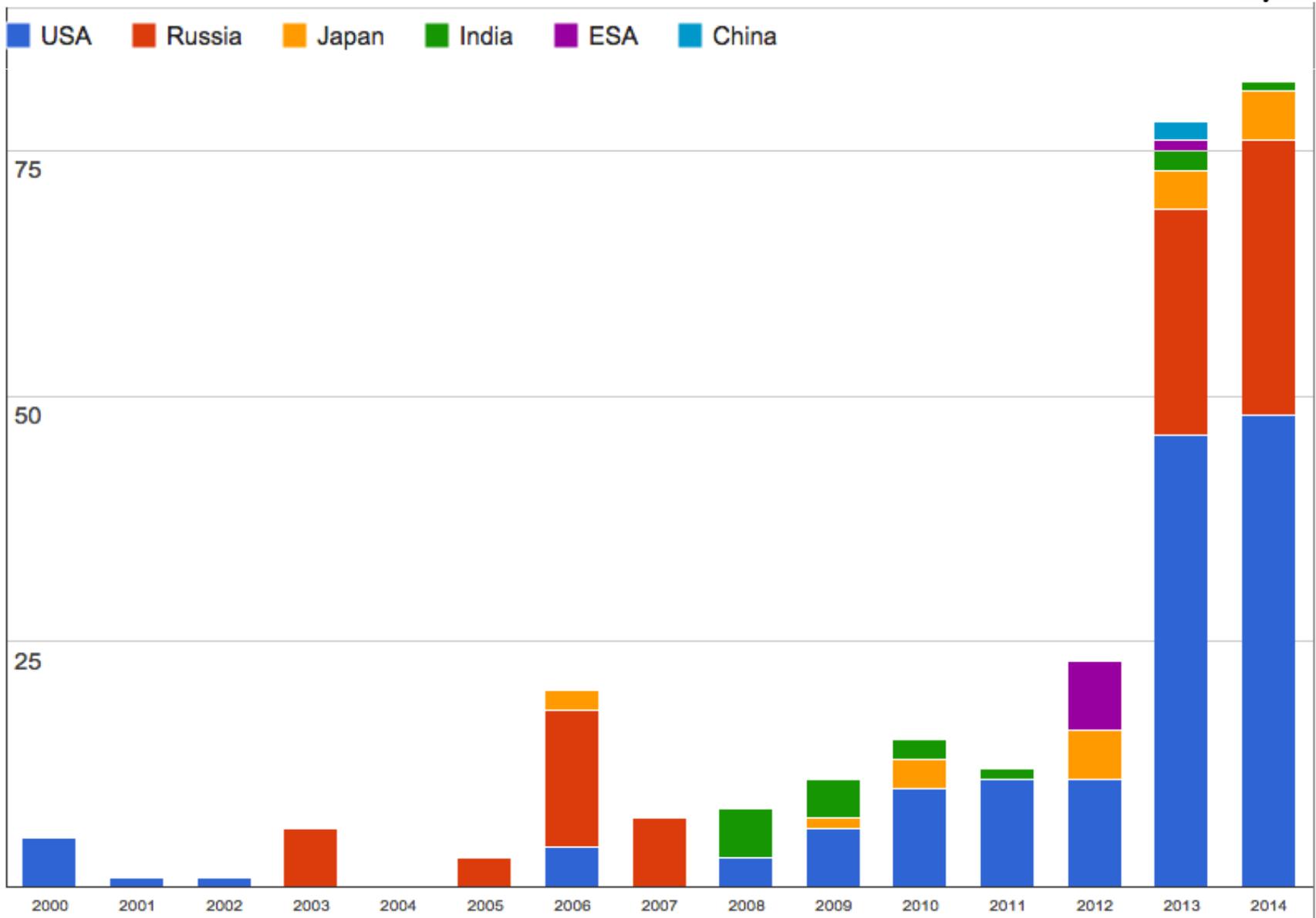
CubeSat by Contractor Type



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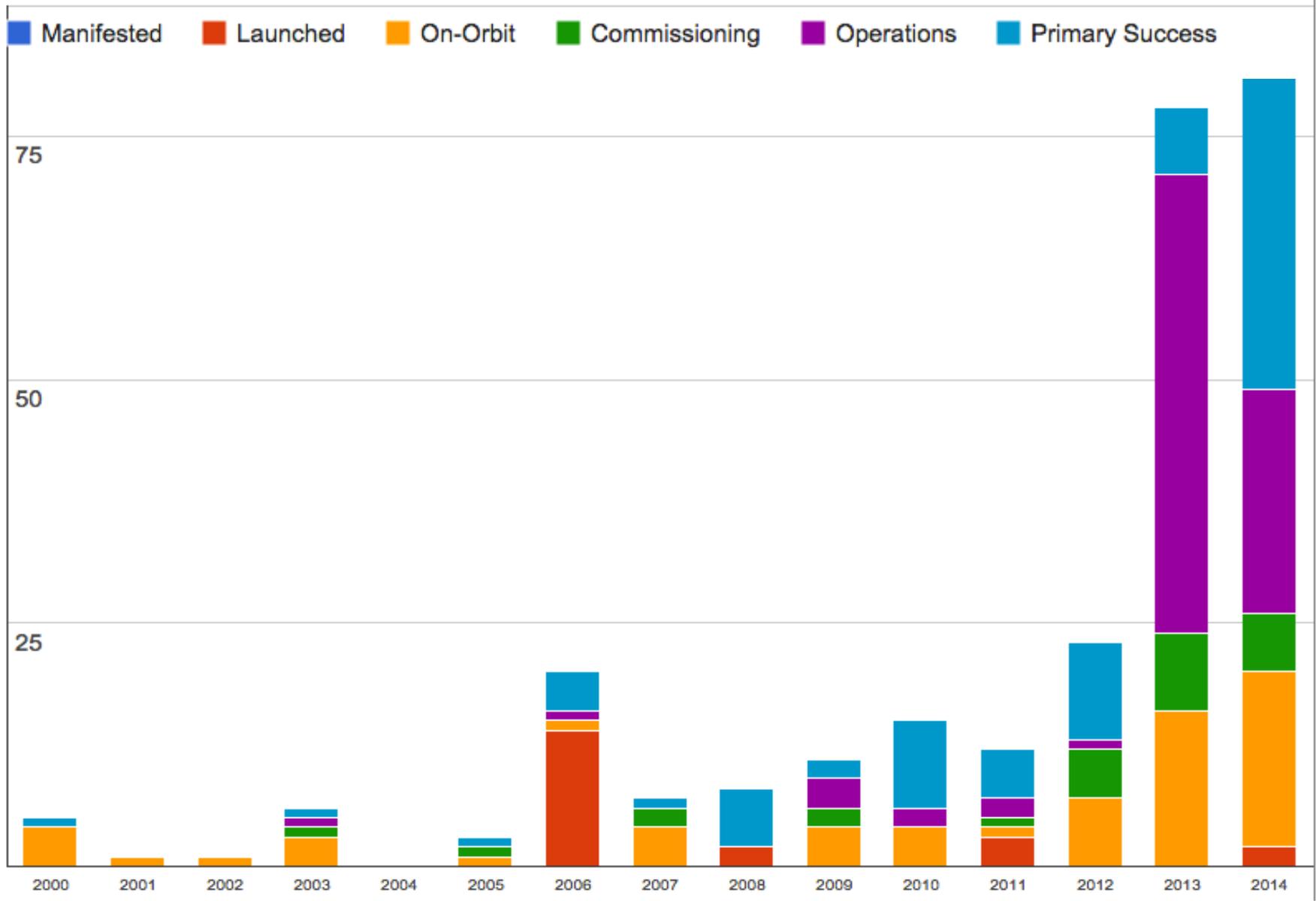
Nationality of Launch Vehicle



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CubeSat by Mission Status



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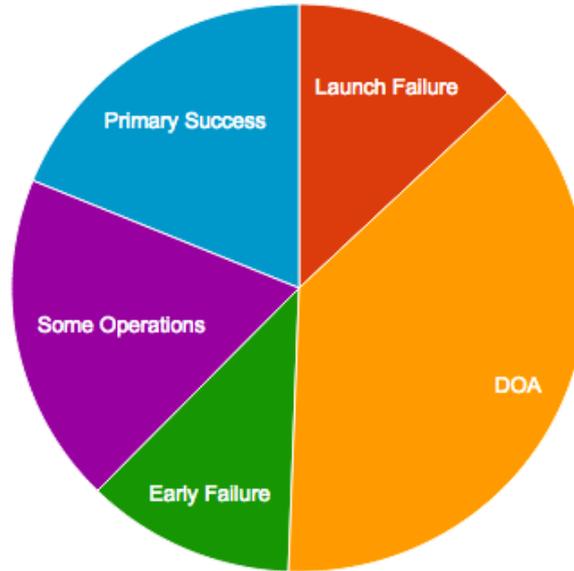
As it turns out, experience matters!



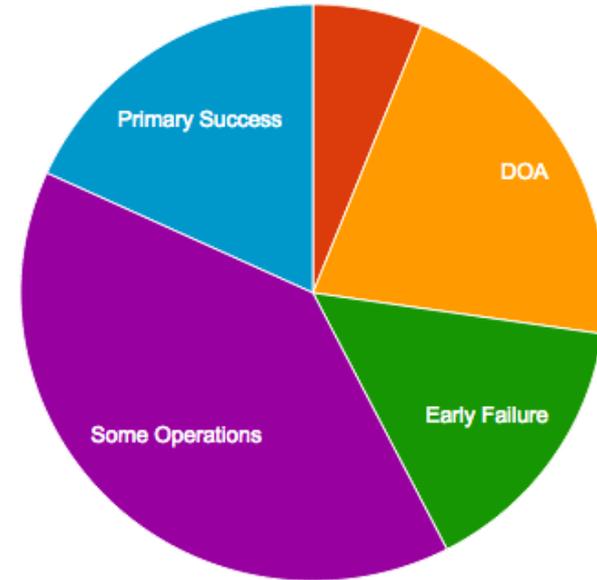
Success Rates of First Launches - All (2000-2014)



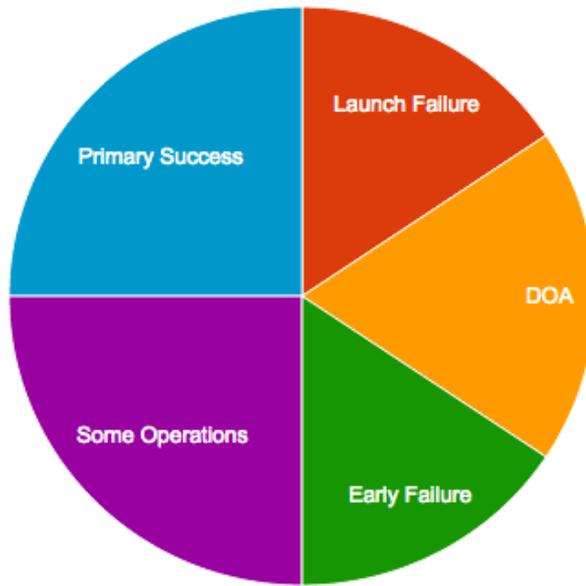
Success Rates of First Launches - University (2000-2014)



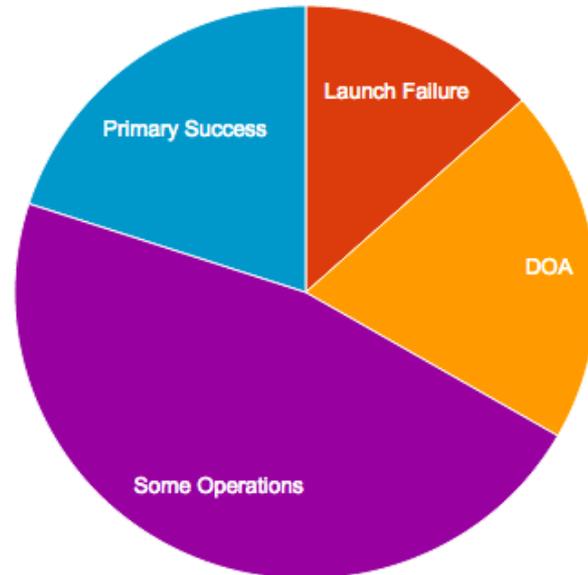
Success Rates of First Launches - Industry (2000-2014)



Success Rates of Second Launches - University (2000-2014)



Success Rates of Second Launches - Industry (2000-2014)



The Cynical Page



- 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)



Toys, Tools or Debris Cloud?



- Toys
 - Competition improved capability
 - When is a Beepsat more than a Beepsat?
- Tools
 - Published science
 - New components on the market
 - New capabilities (private/civil/military)
- Debris Cloud
 - Many spacecraft, launched in bunches
 - The 25-year rule
 - Oddly (?), the Americans are the most scrupulous in following the rules
 - ISS flights are particularly helpful



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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