CubeSat Mission Success: Are We Getting Better?

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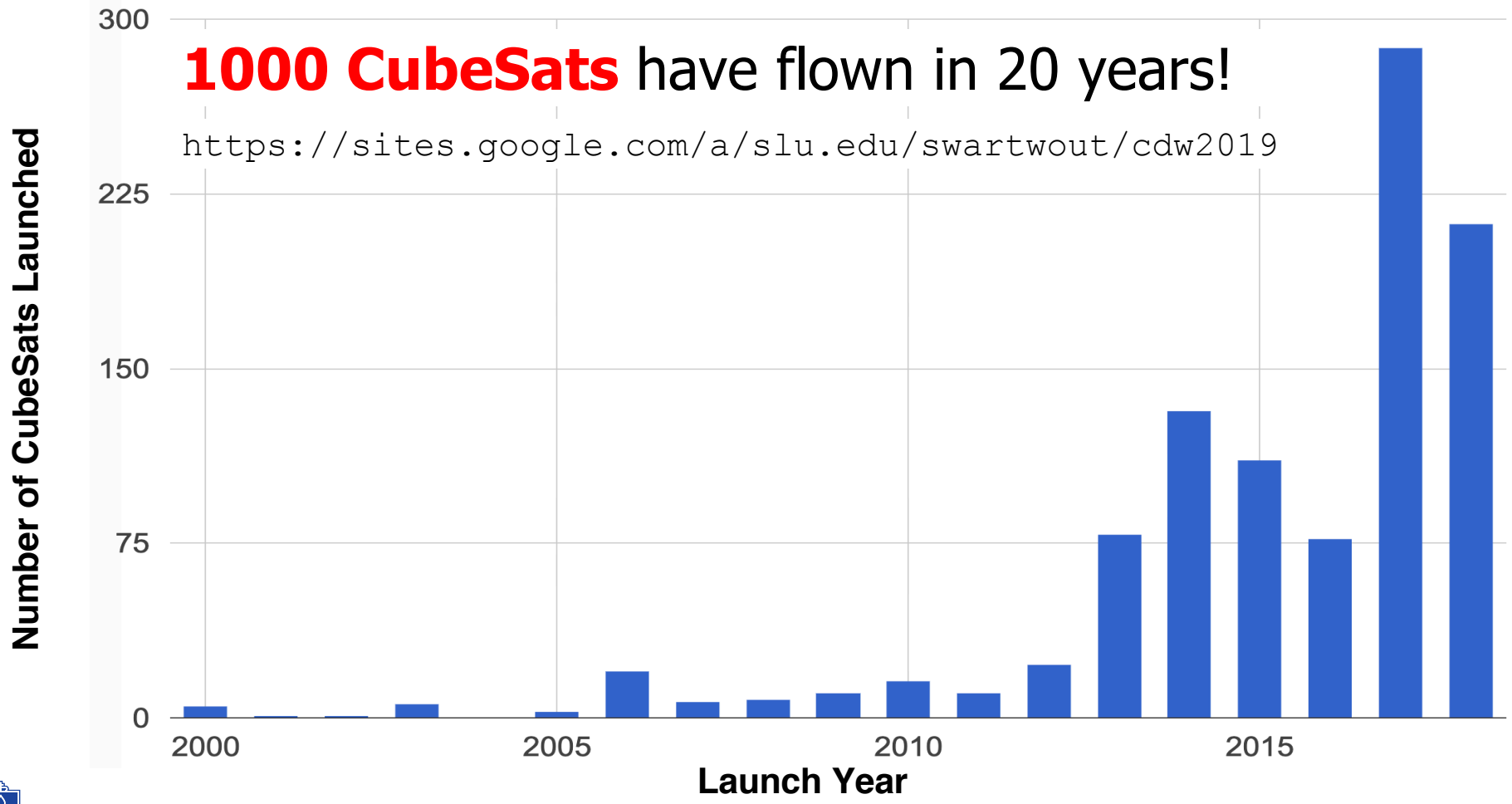
PARKS COLLEGE OF ENGINEERING,
AVIATION AND TECHNOLOGY

20 Years (!?!?) of CubeSats

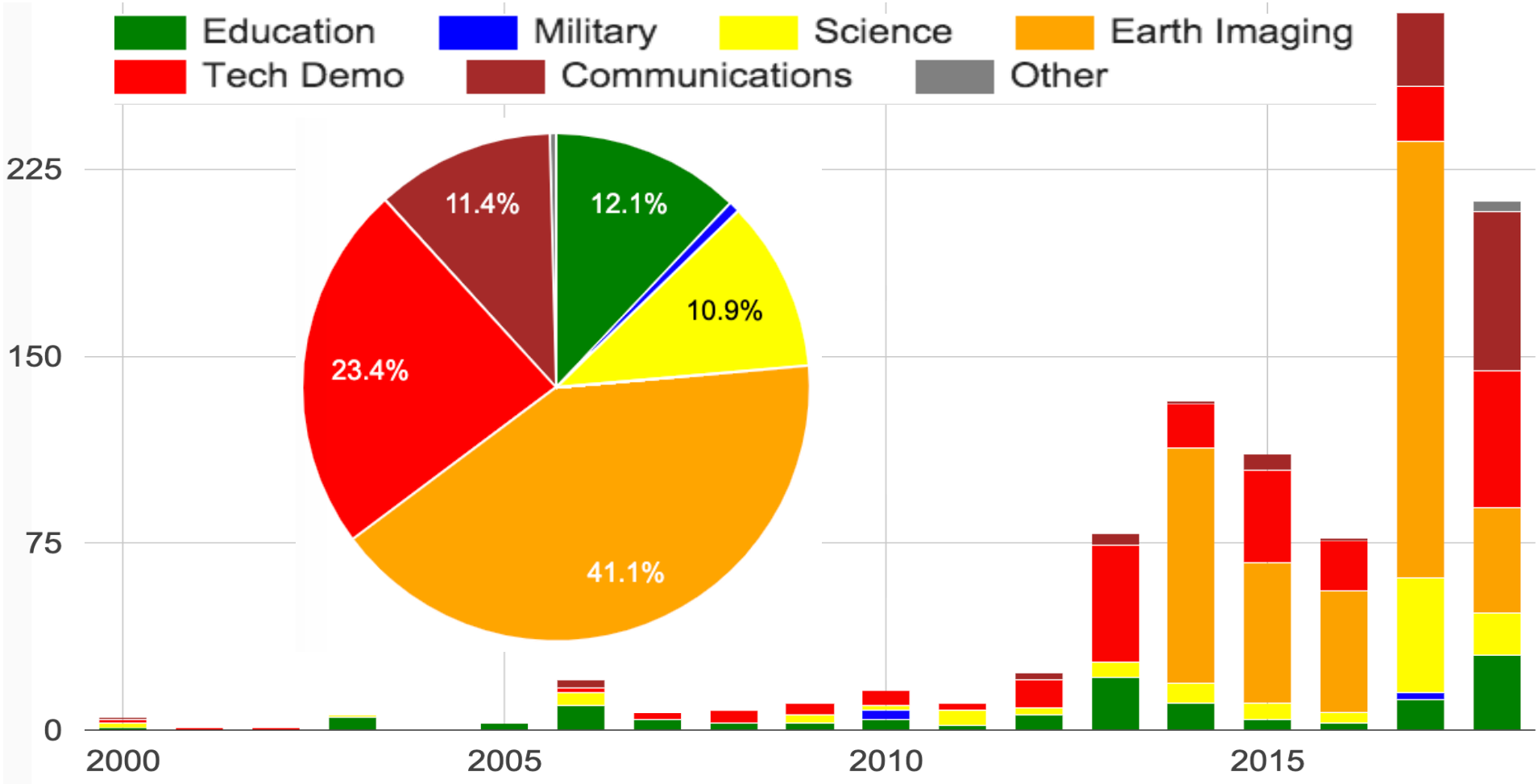


“I’ll Take Potpourri for $400, Alex”

- My definition of CubeSat:
  Anything that fits in a “standard” container
- Secret Sauce of CubeSats
  - Cheap launch
  - Willingness to aggressively trade scope to meet [fixed] schedule and cost
- Biggest Threats to CubeSats
  - Not trading scope against [fixed] schedule and cost
  - 1000 CubeSats is too big a number to ignore

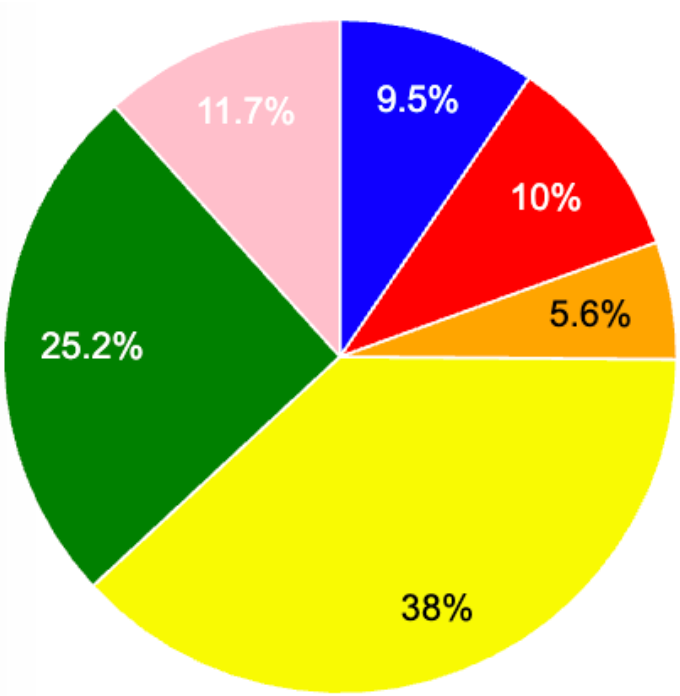
P.S. My data is only as good as what you’re willing to share

CubeSat by Mission Type

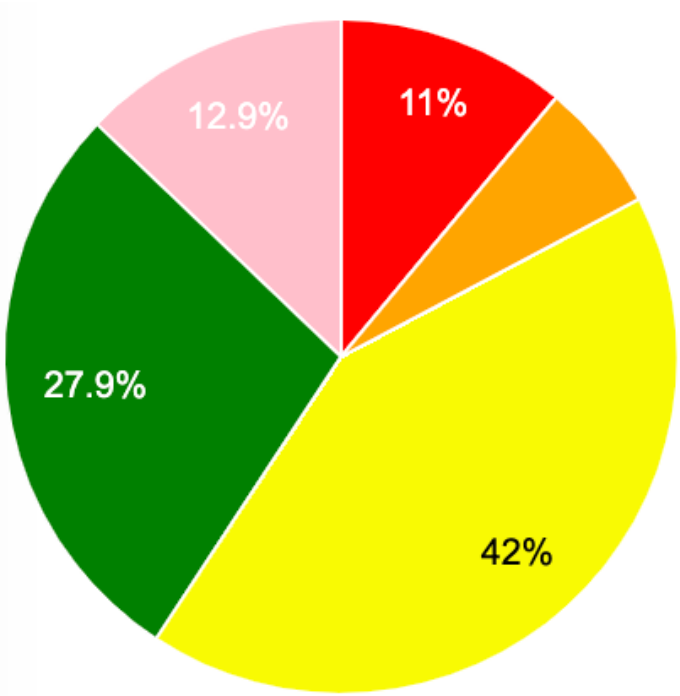


CubeSat Mission Status*, 2000-2018

All Missions
(1011)



All missions reaching orbit
(915)



*** See previous note (i.e., I can only know what you share)***

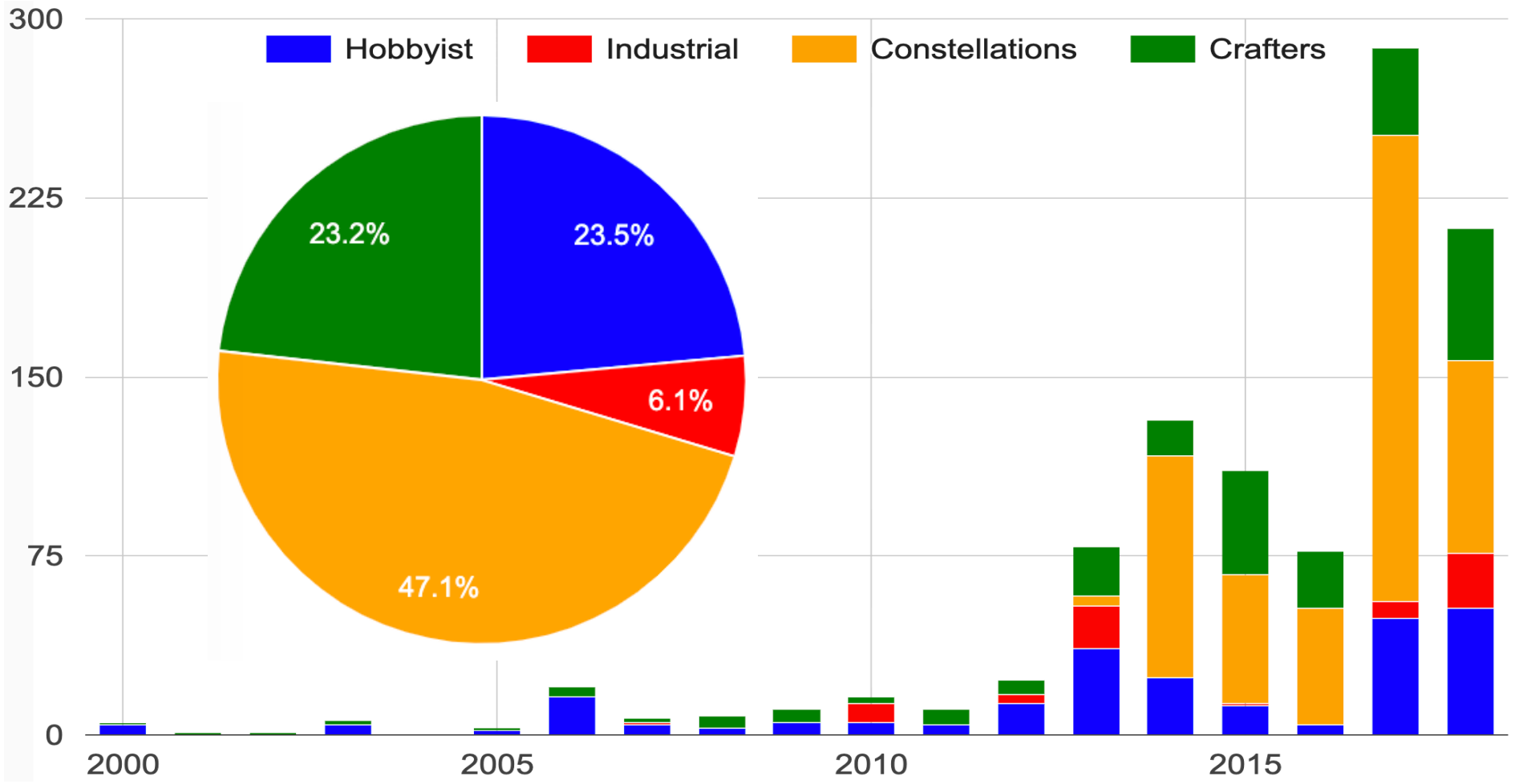
Truth in Advertising

- I don't have that data … nobody does
- Overheard at the 2018 NASA Smallsat Reliability Technical Interchange Meeting
  - Systems engineer, mid-sized contractor:
    "More than 90% of the failures I see on the ground or in space are not parts-related"
  - Technical engineer, small component supplier:
    "I second that"
  - Systems engineer, large contractor:
    "I third that"
  - The other 30+ engineers from four NASA centers, the DoD, several contractors and a lot of suppliers:
    [general agreement and nodding of heads]

None of These Things are Quite Like the Others …

- **Hobbyist**
  - No real experience in the field
  - Building for fun & future profit
  - **Ad hoc practices**
- **Industrialist**
  - Experienced builders of big spacecraft
  - Building under gov't contract
  - **Standard space system practices, with some truncation**
- **Crafter**
  - Experienced builders of small spacecraft
  - Working under contract
  - **Streamlined practices, experientially developed**
- **(Smallsat) Constellations**
  - Providing a geographically-distributed service (imaging, comm)
  - **Mission can be met with an ad hoc (?!?) implementation of orbits**
  - Spacecraft/launch costs are effectively free (I did say "*effectively*")

CubeSat by Developer Class



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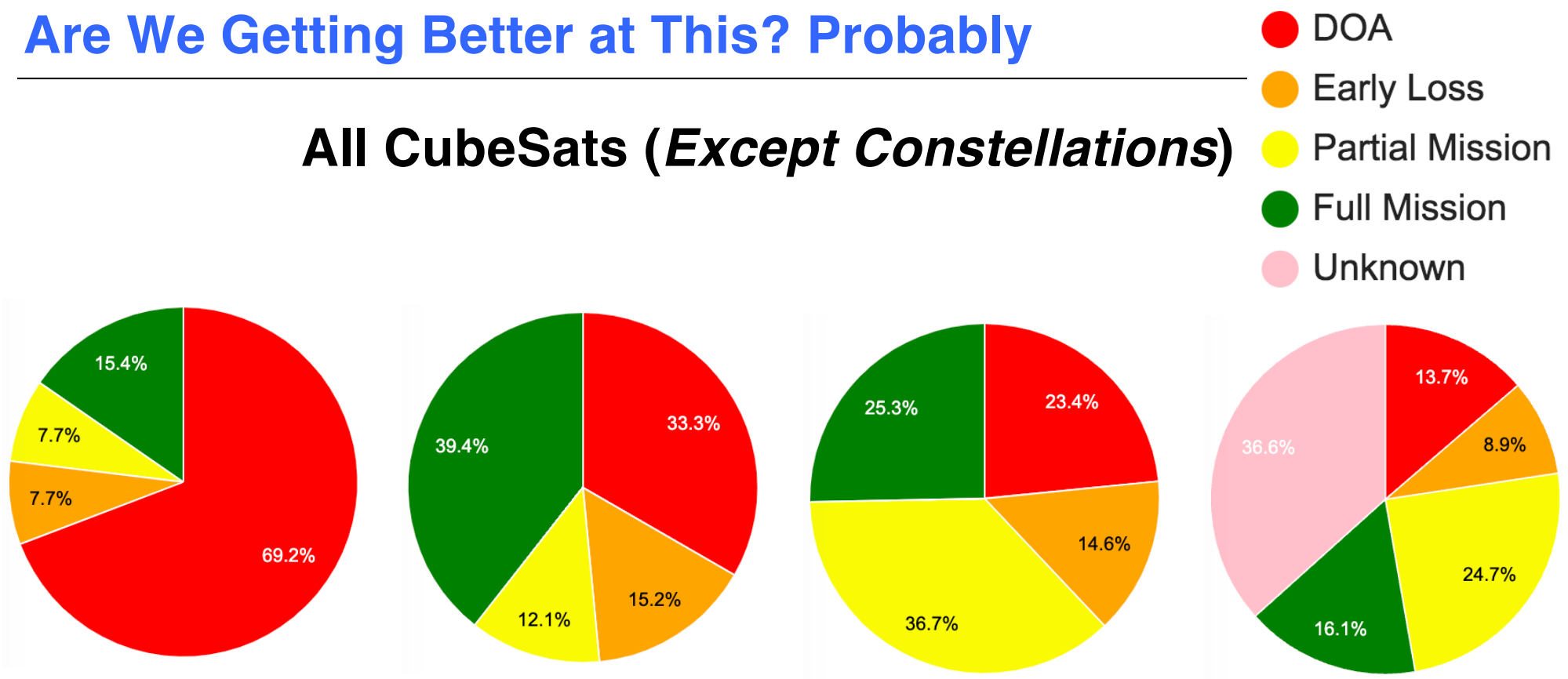
Are We Getting Better at This? Probably

All CubeSats (*Except Constellations*)



2000-2004
13 missions

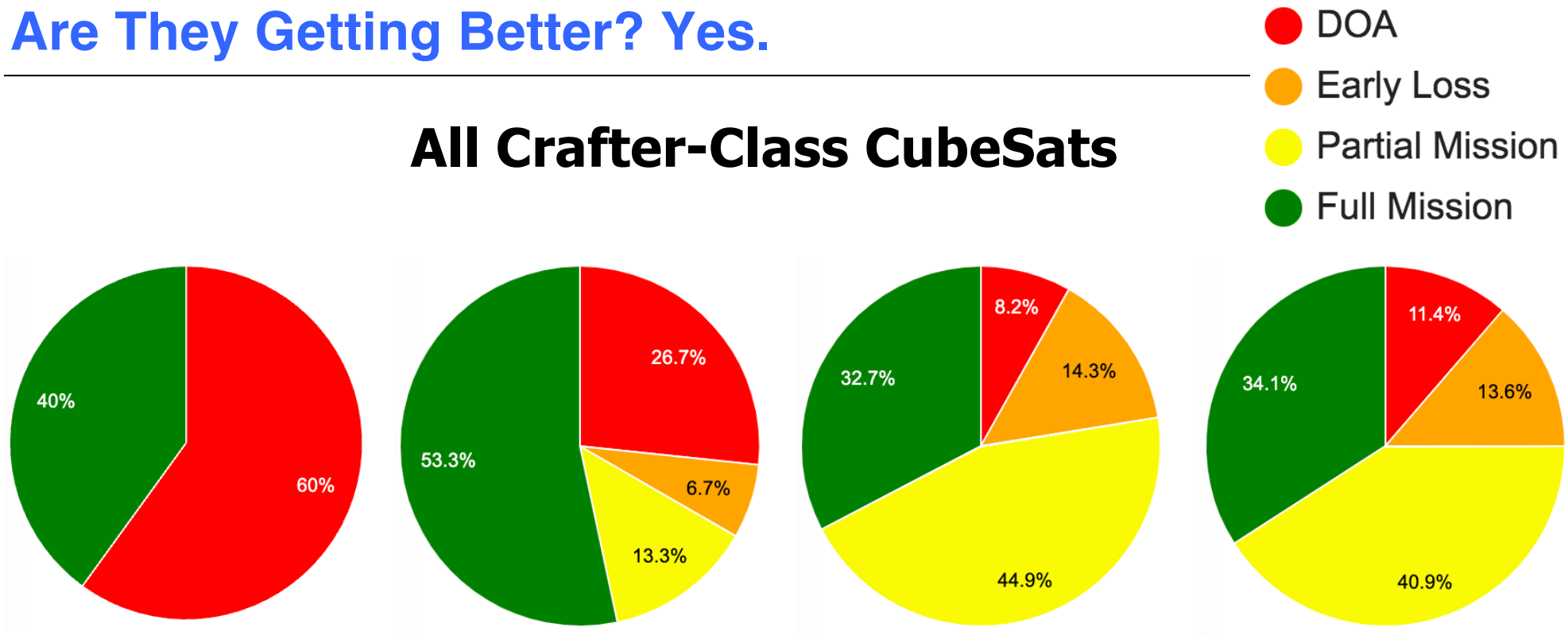
2005-2009
33 missions

2010-2014
158 missions

2015-2018
292 missions

Are They Getting Better? Yes.

All Crafter-Class CubeSats



2000-2004
5 missions

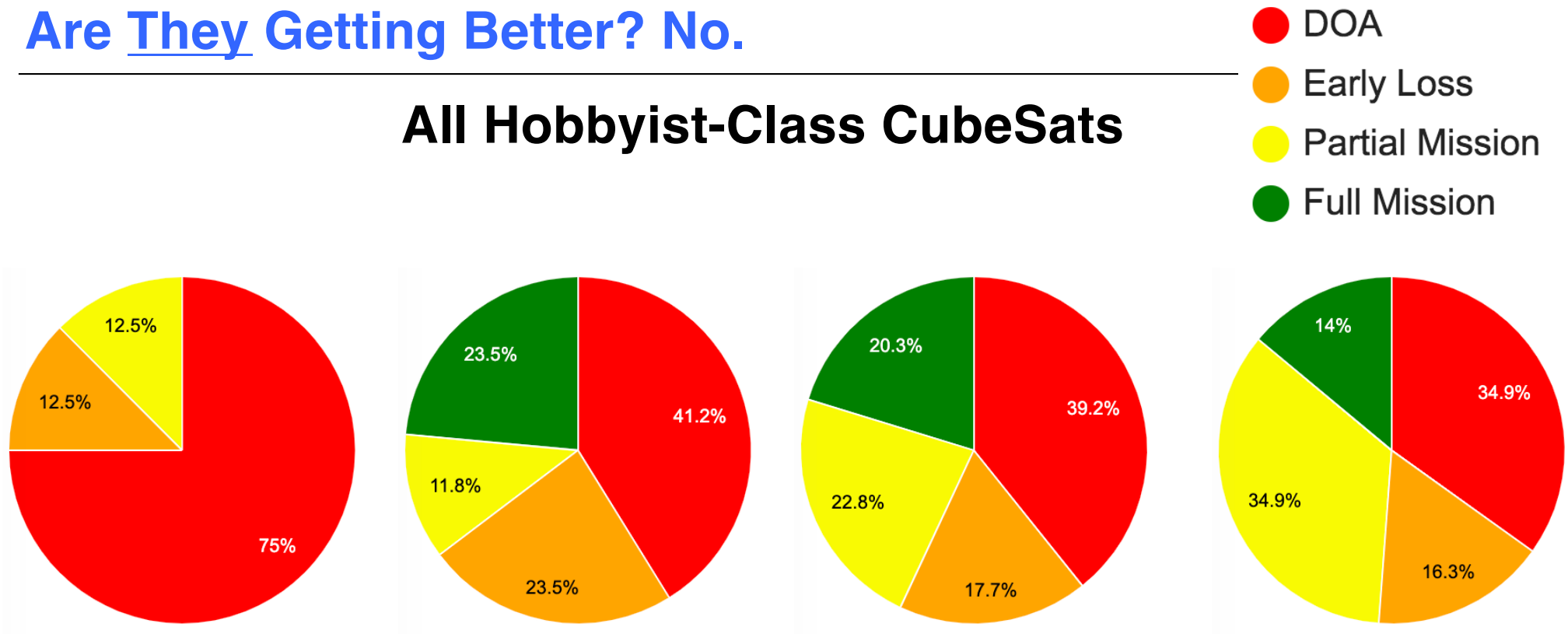
2005-2009
15 missions

2010-2014
49 missions

2015-2018
88* missions

Are They Getting Better? No.

All Hobbyist-Class CubeSats



2000-2004
8 missions

2005-2009
17 missions

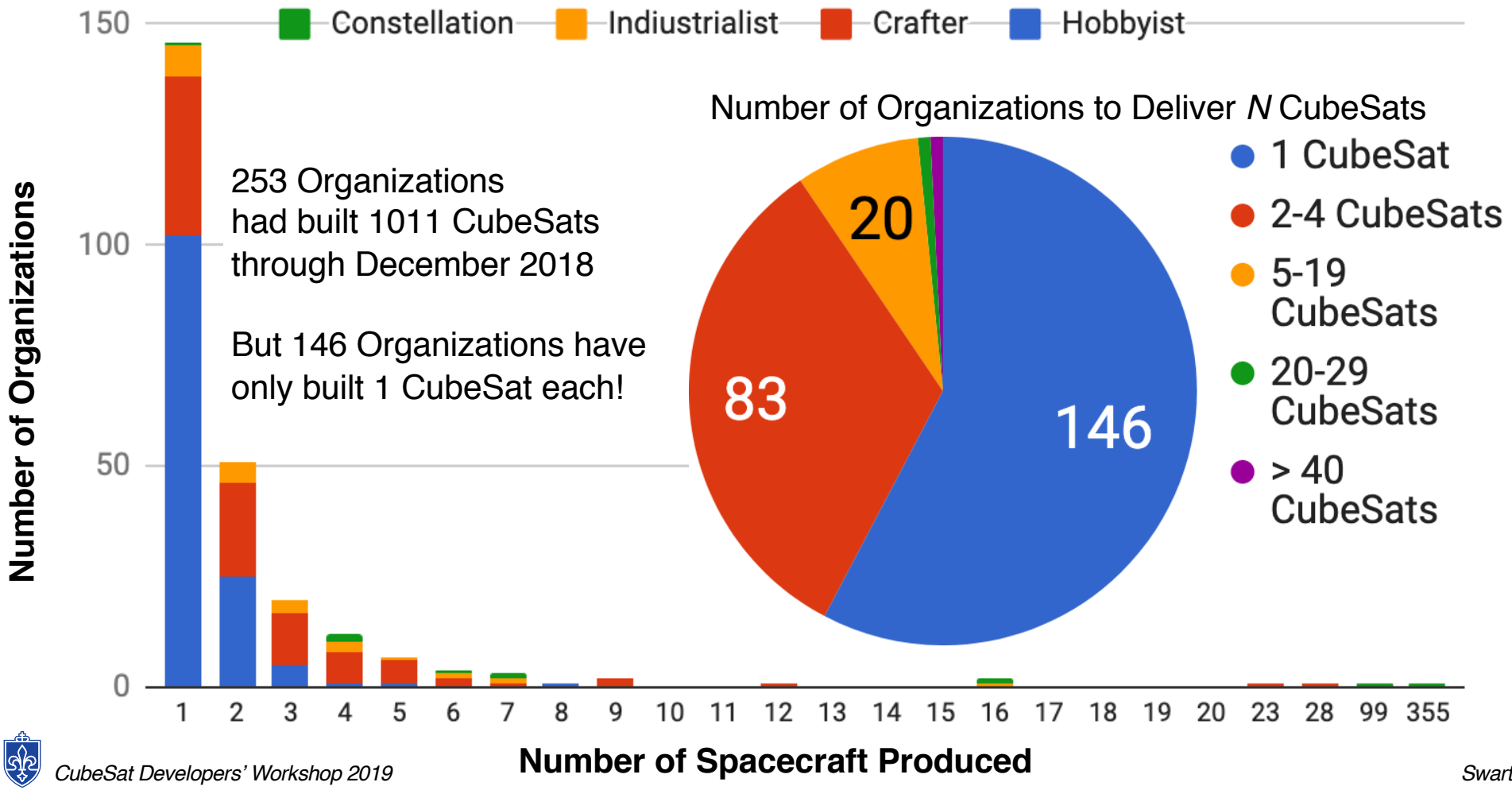
2010-2014
79 missions

2015-2018
86* missions

What's Going On?

- **Industrialists**: You get what you pay for!
- **Crafters**: Failures appear to be a result of ambitious technology infusion *(i.e., acceptable losses)*
- **Hobbyists**:
  - Ad hoc procedures for design, integration, test
  - Lack of time spent on integration & test
  - Workmanship (?)
  - Uncaptured best practices?

Hobbyists: It's Hard to Improve, When You Don't Repeat!



The Plural of "Anecdote" is not "Data", but …

- Possible reasons for DOA
  - **Compressed development schedule leads to uncaught mistakes** (software errors, mechanisms binding, inadequate power budget, non-robust startup sequences)
  - Shock loads expose workmanship flaws (few hobbyists test for shock)
  - Underpowered RF system
  - Two or more recoverable errors "team up"
  - SEEs
- Sources of early failure
  - Environmental wear (thermal cycling, radiation effects)
  - Low margins (battery depth-of-discharge)
  - Long-term software instability

It's Not All Bad News …

- Those that survive the first 90 days tend to stick around
  - PCSat (2001), XI-IV (2003), XI-V (2005)
  - Think of it as post-launch "burn-in" and end-to-end functional testing (!?!)
- Common characteristics of success
  - Process, process, process!
  - Development schedule with significant functional testing and margin
  - Organizational robustness to staff turnover and mission failure
- Common features for on-orbit success: operational robustness
  - "Bulletproof" power-rich safe mode
  - Hard reset from the ground (bypassing flight software)
  - Flight software uploads
  - Lack of time-critical operational events

Acknowledgements

- Data Sources
  - Public: Gunter's Space Page (international launch log)
  - Public: Jonathan's Space Report (orbital elements)
  - Public: DK3WN Satblog (university/amateur operations)
  - Public: Union of Concerned Scientists (operational status)
  - Public: Program websites, conference presentations
  - Public: Bryan Klofas (communications/operational status)
  - Private: Personal communications (***hint, hint***)
- NASA NEPP (NNX17AJ46G and 80NSSC18K0637)
- Student research team: Samantha Carlowicz, Scott Elliott, Connor Highlander, Andie Kaess, Tinevimbo Ndlovu, Cody Powers, Patrick Sullivan, Adam Walker, Sean Walsh

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