Small Satellite Reliability:
Updates through 2017

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Small Satellite Reliability Initiative (SSRI) TIM-3
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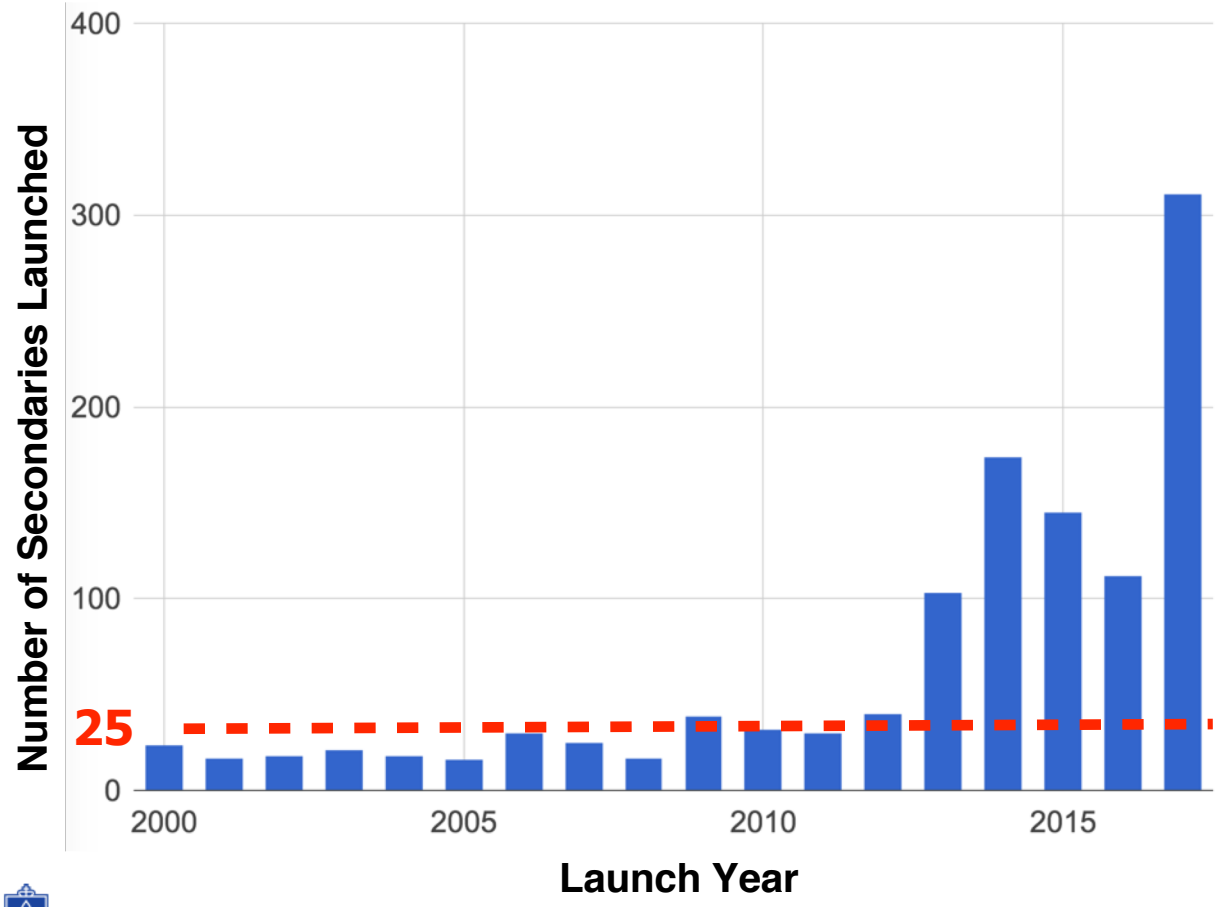
SAINT LOUIS UNIVERSITY
PARKS COLLEGE OF ENGINEERING,
AVIATION AND TECHNOLOGY

Outline: Getting excited about nomenclature!

- Census update
- Issue #1: Orbital clutter (and constellations)
- Issue #2: Our inadequate taxonomies
- Developers and mission success
- Issue #3: Low barriers to entry,
  High barriers to success
- Ongoing issues and future work

Remember when 25 was considered “a lot”?



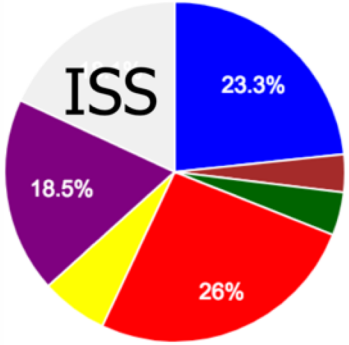
- You will be made to care!
- Toy, tool or debris cloud?
- Decisions are being made based on wild speculation about performance, cost and risk

“Where does he get these wonderful toys?”

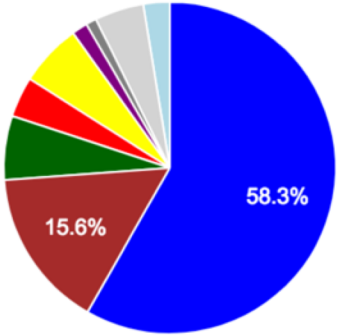
- Scour databases, ask lots of questions
  - Public: Gunter’s Space Page (international launch log)
  - Public: Jonathan’s Space Report (orbital elements)
  - Public: DK3WN Satblog (university/amateur operations)
  - Public: Union of Concerned Scientists (operational status)
  - Public: Program websites, conference presentations
  - Private: Personal communications
- Compile information into a central database
  - “Census” data, plus our own internal assessments
  - Web-accessible/searchable/plotable
- Try not to pull your hair out when India puts 100 CubeSats on the same launch

Global Participation in Secondary Spacecraft

Launch Provider (1169)



Builder (1169)

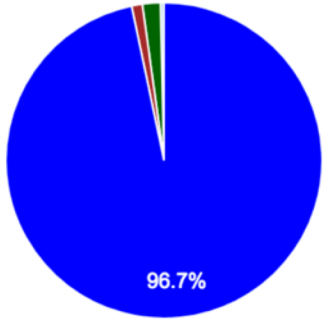


USA
Asia
Europe
China
India
Russia
Japan
Latin America
Africa

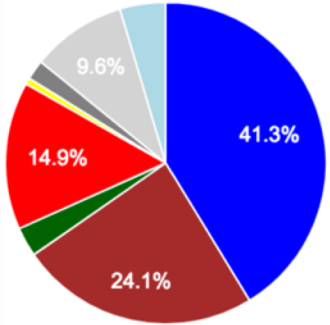
Not shown:
Europe (42)
Japan (48)
China (74)

Nations Using Each Launch Provider

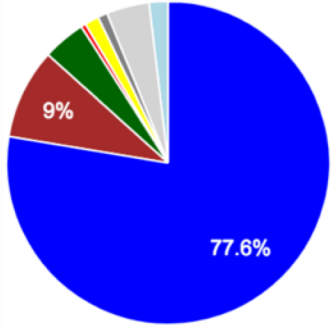
USA (273)



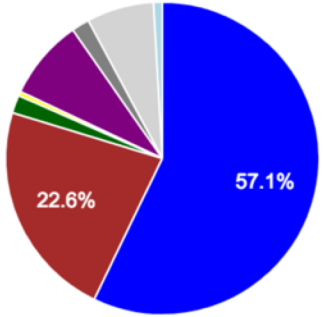
Russia (303)



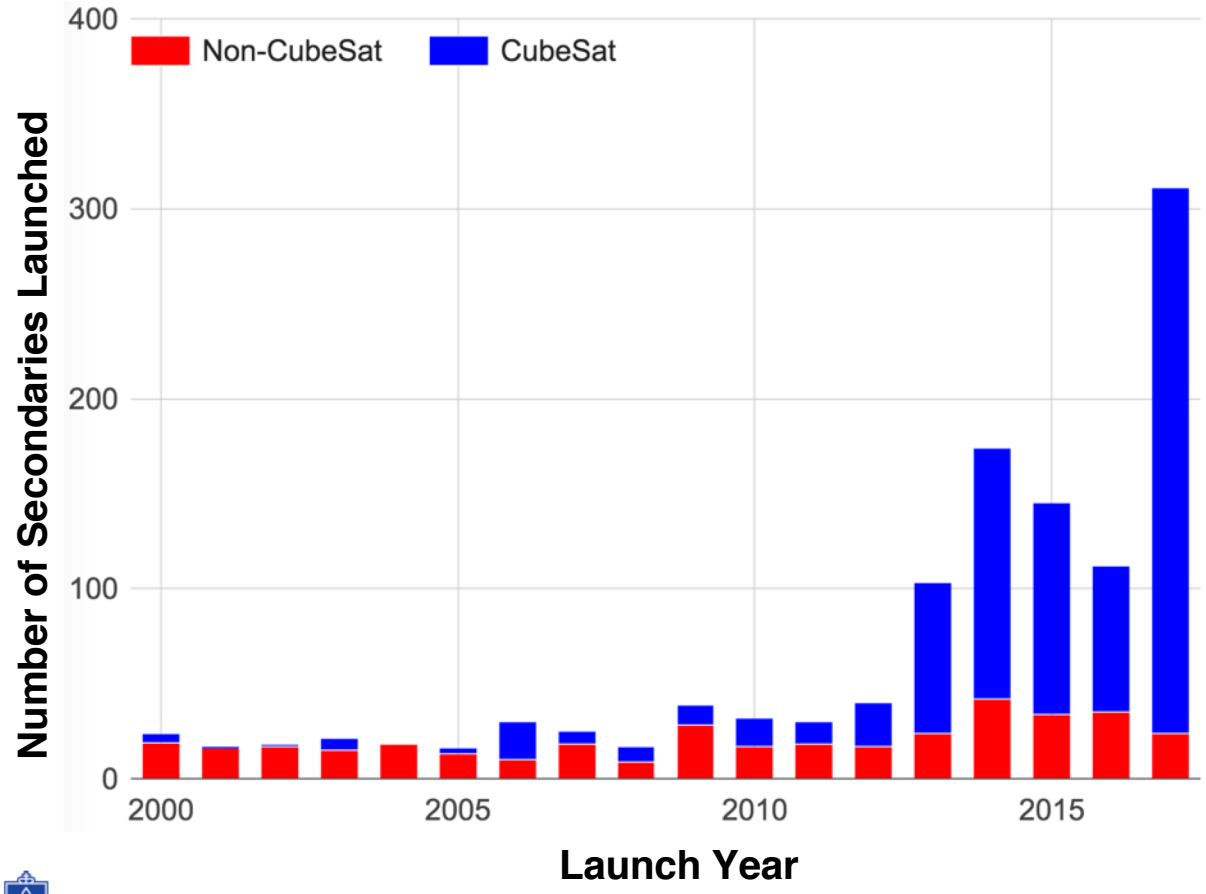
ISS (210)



India (217)



Not All Secondaries are CubeSats *(but most are)*



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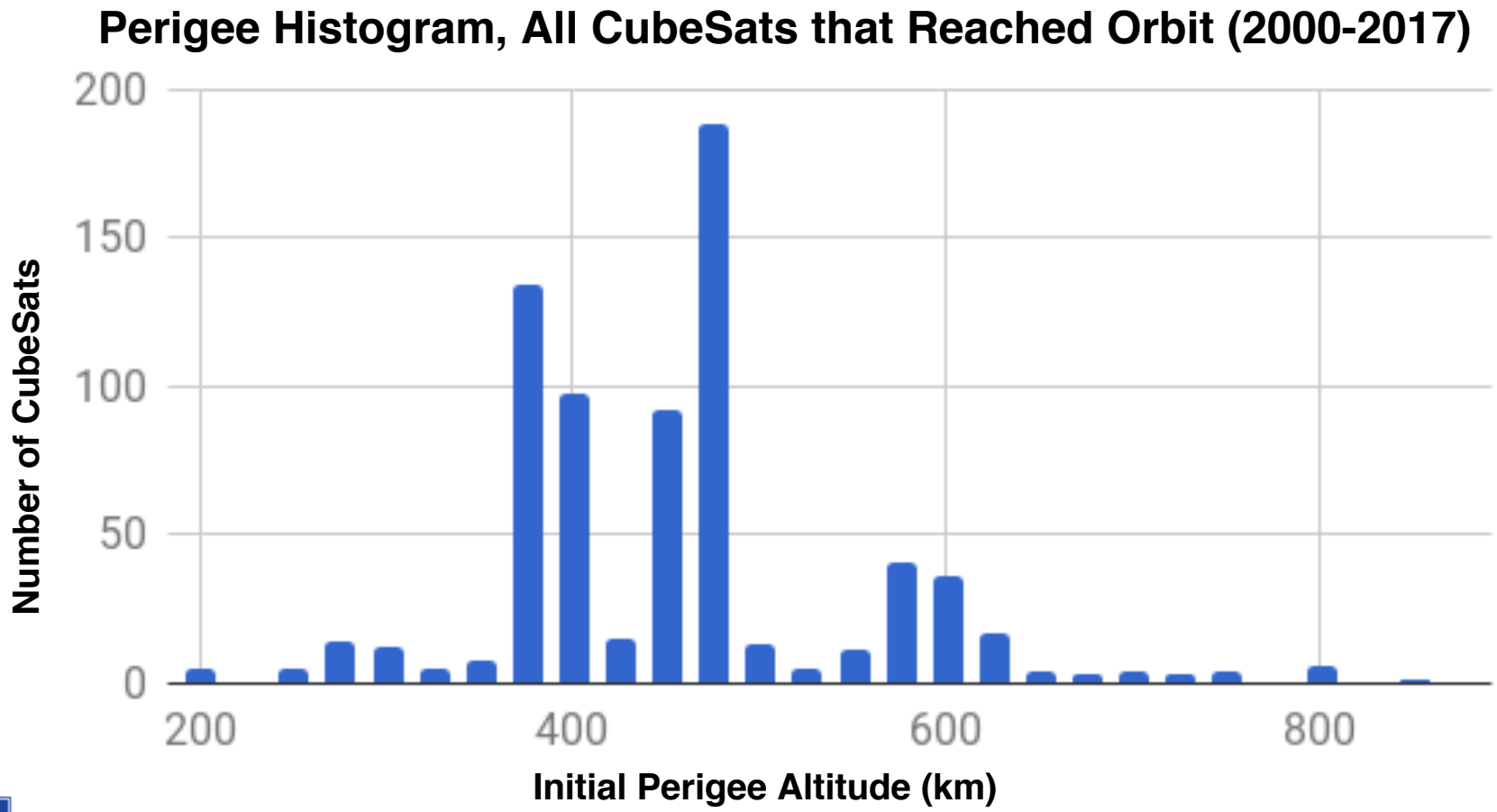
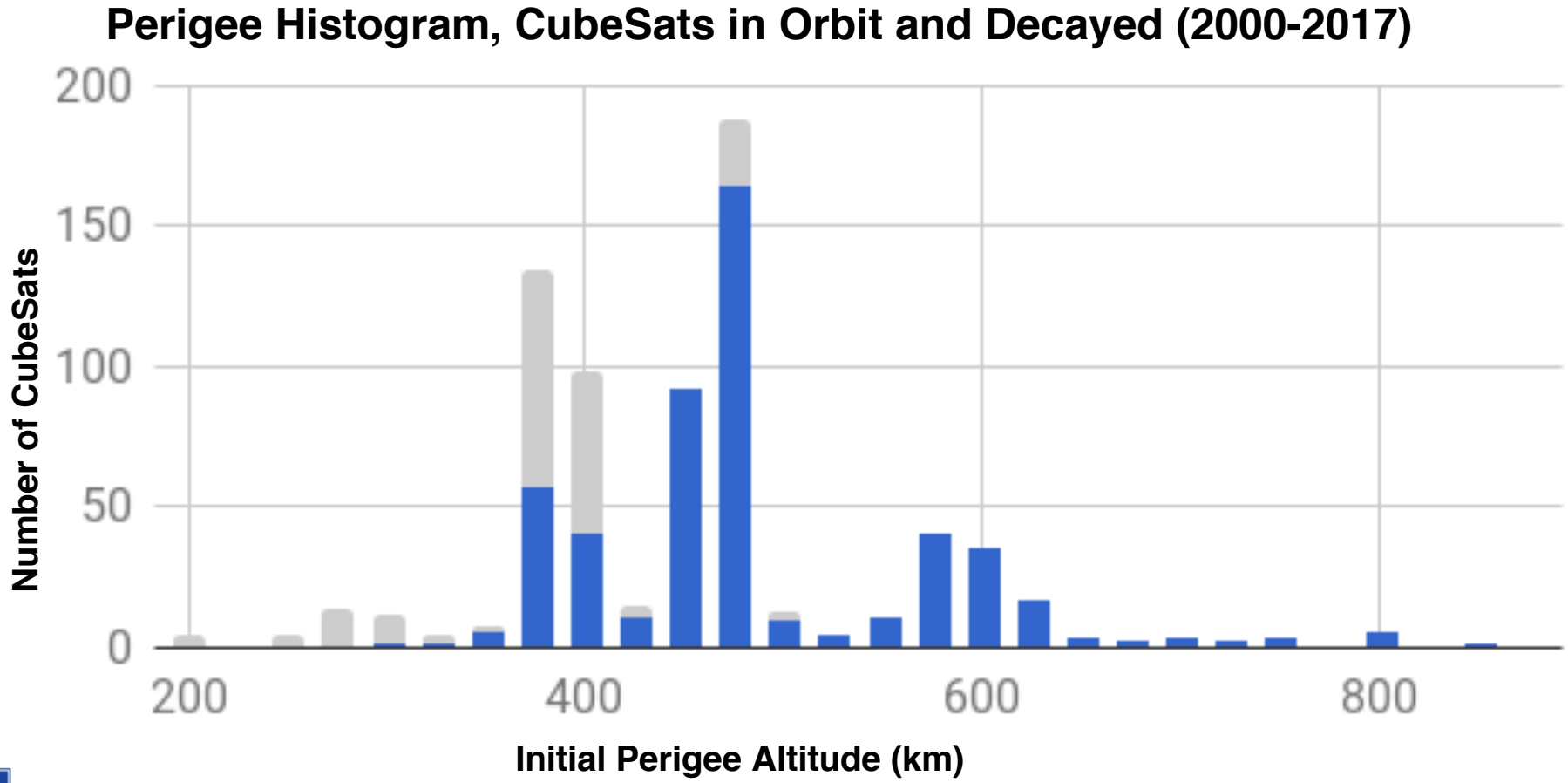
Issue 1: Darkening the Skies With CubeSats?



Darkening the Skies With CubeSats?



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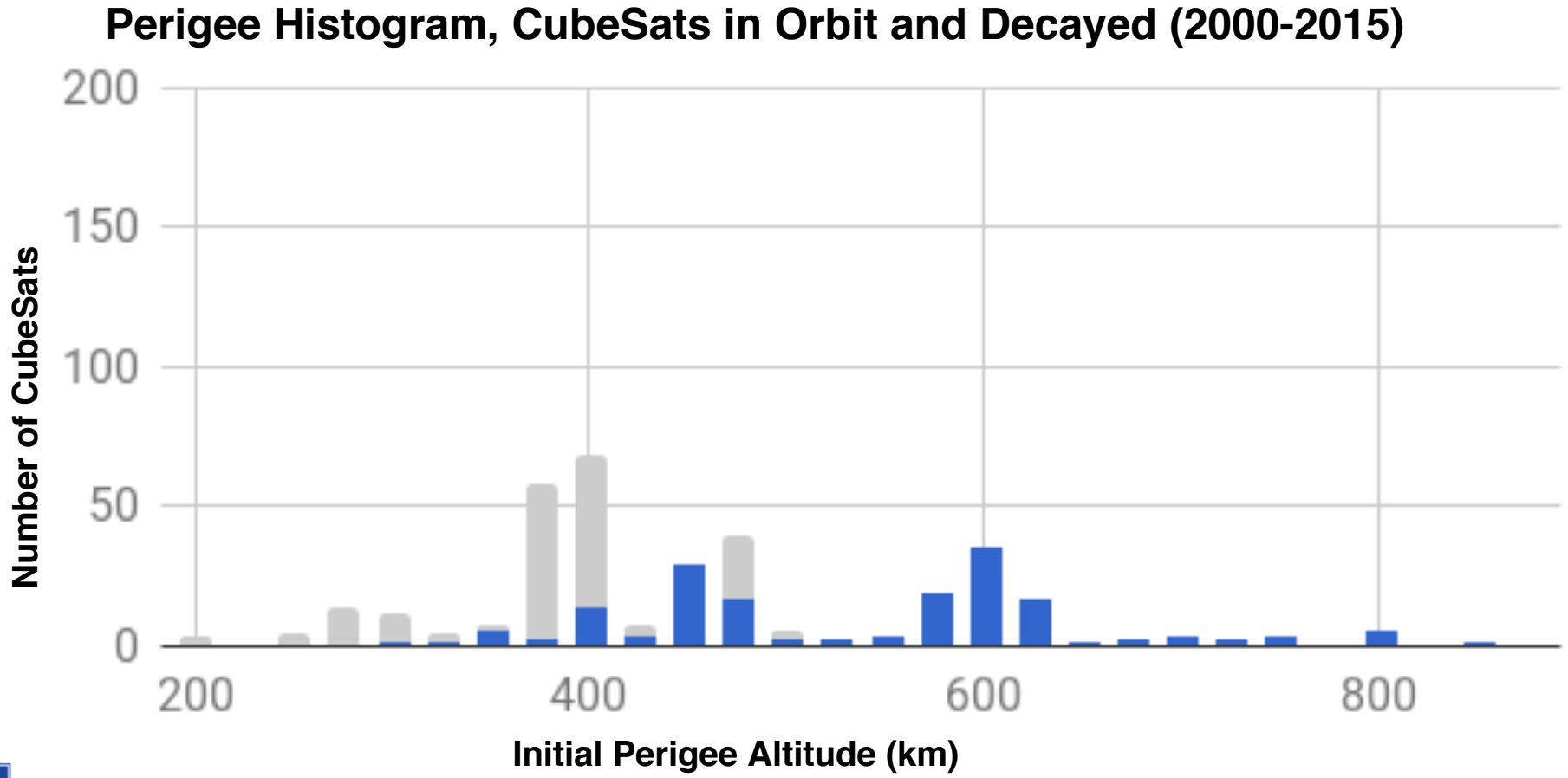
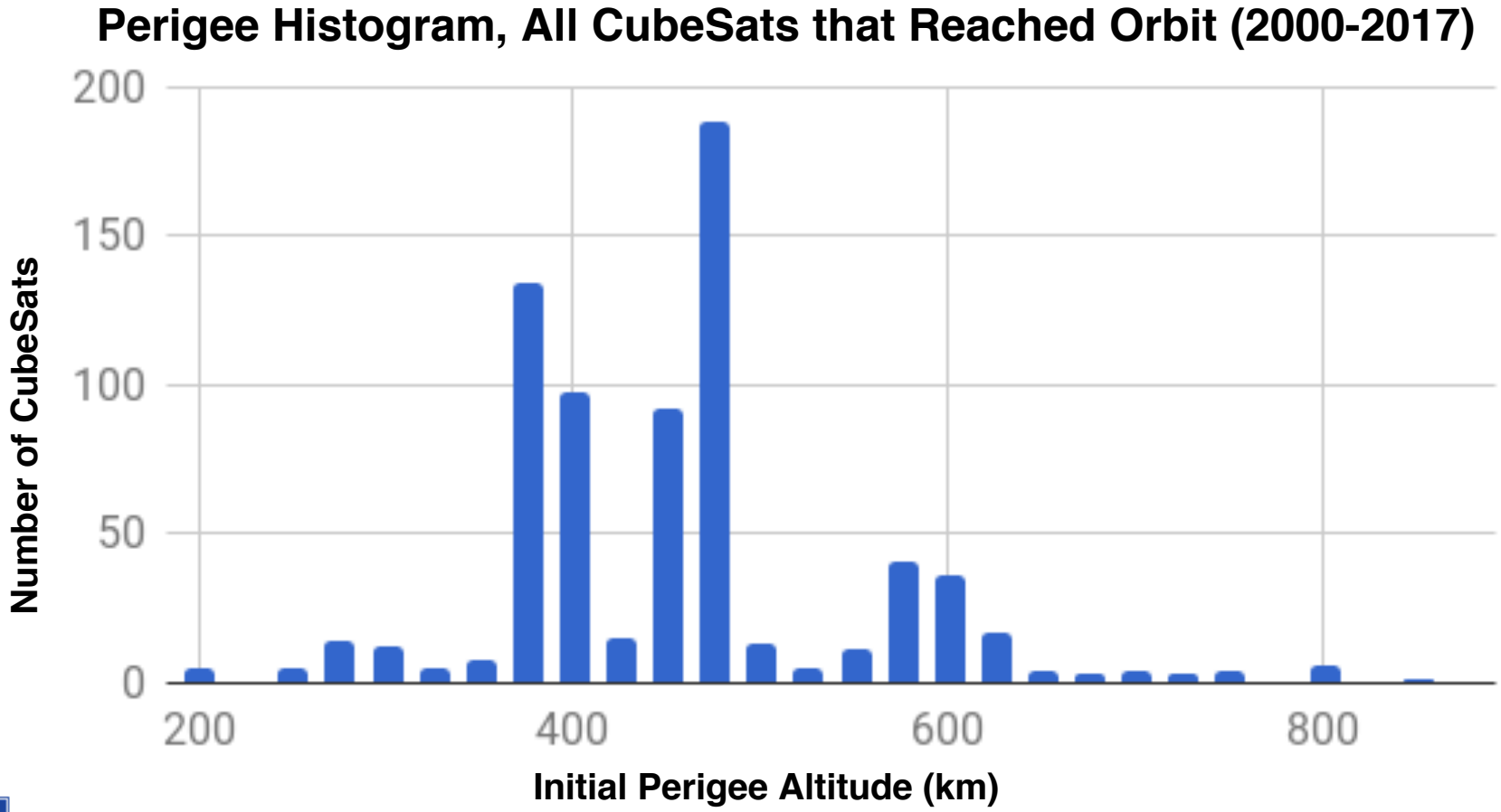


Who is Responsible for This?



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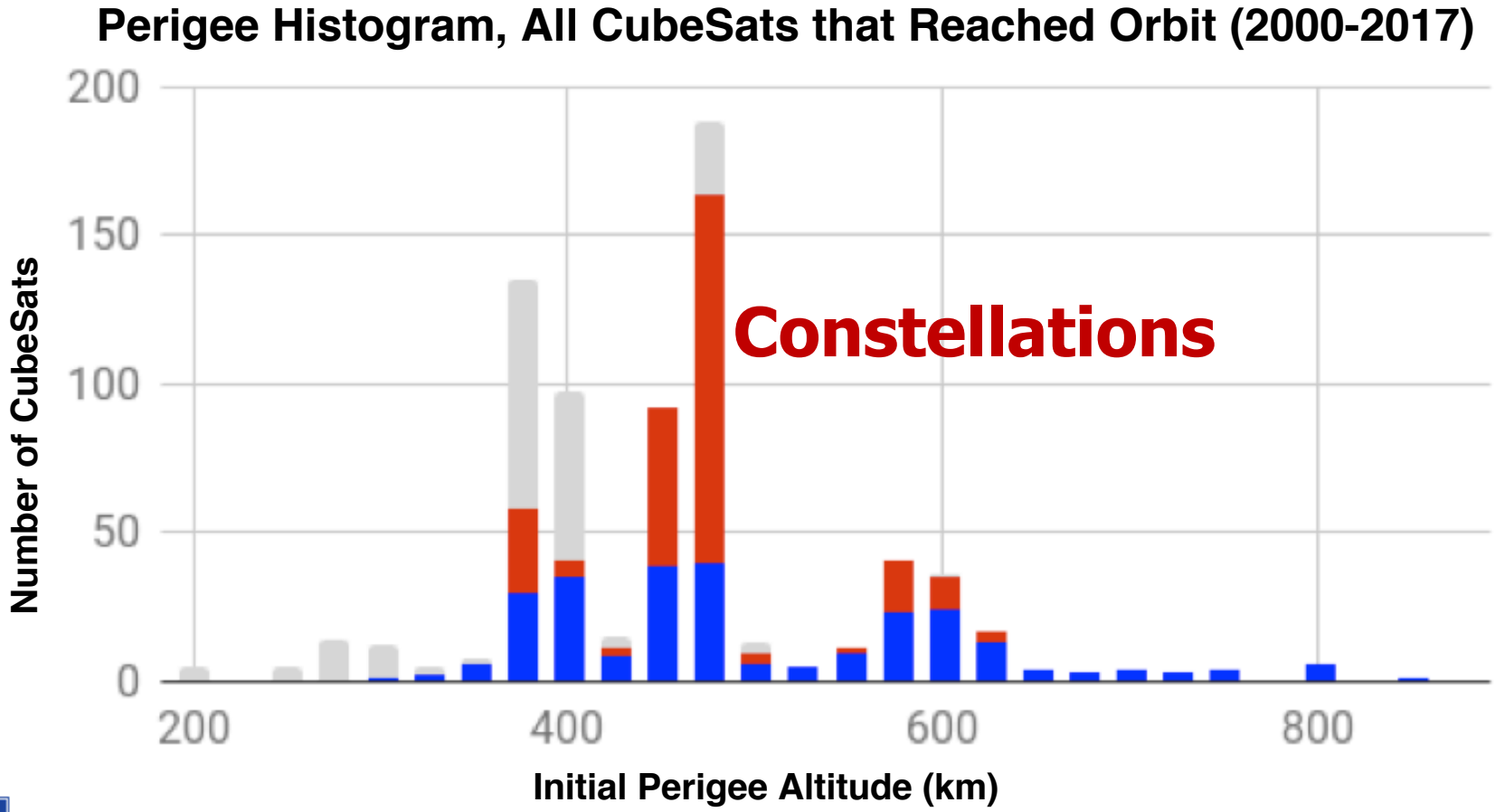

Issue 2: Small satellites are not just small(er) satellites

Different constraints lead to a different design approach

- Launch availability – these missions expect to operate in multiple orbit altitudes, inclinations
- There is a competitive advantage to short development cycles
  - The rocket will not wait for you
  - You need something to show off when chasing the next contract
  - Staff training and turnover
- Low cost, but your customer still wants results
  - Higher margins (i.e. lower performance)
  - Managed expectations
- It is possible to spend $10 million on a CubeSat with similar performance to a $1 million CubeSat (and similar odds of success)

NASA Mission Classifications *(NPR 8705.4)*

Characterization	Class A	Class B	Class C	Class D
Priority *(Criticality to Agency Strategic Plan)*	High priority	High priority	Medium priority	Low priority
National significance	Very high	High	Medium	Low to medium
Complexity	Very high to high	High to medium	Medium to low	Medium to low
Launch constraints	Critical	Medium	Few	Few to none
In-Flight Maintenance	N/A	Not feasible or difficult	May be feasible	May be feasible and planned
Alternative Research Opportunities or Re-flight Opportunities	No alternative or re-flight opportunities	Few or no alternative or re-flight opportunities	Some or few alternative or re-flight opportunities	Significant alternative or re-flight opportunities
Examples	HST, Cassini, JIMO, JWST	MER, MRO, Discovery payloads, ISS Facility Class Payloads, Attached ISS payloads	ESSP, Explorer Payloads, MIDEX, ISS complex subrack payloads	SPARTAN, GAS Can, technology demonstrators, simple ISS, express middeck and subrack payloads, SMEX

Secondaries: They're All Class D! (?!)

Characterization	Class A	Class B	Class C	Class D
Priority *(Criticality to Agency Strategic Plan)*	High priority	High priority	Medium priority	Low priority
National significance	Very high	High	Medium	Low to medium
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New Taxonomy: Will We Know It When We See It?

- Don't use these:
  - Cost: Too difficult to capture
  - Mass/size: Cannot differentiate between 3Us
- **Nature of the mission**
  - Schedule
  - Risk posture
- **The approach towards mission assurance**
  - Best practices
  - Testing
  - Risk posture, again

Attempt #1: The mindset of the developer

- **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")

2017: The Year of the Constellation

Organization	First Launch	Launched to Date	Launched in 2017	Mission
Planet	4/19/2013	319	140	Whole-Earth Imaging
Spire	11/19/2013	71	46	Meteorology, AIS
Sky and Space Global	6/23/2017	3	3	Narrowband Communications
Cicero	6/23/2017	4	4	Radio Occultation (atmospheric physics)
QB50	6/19/2014	37	35	Upper-atmosphere physics using global assortment of home-built spacecraft
Corvus	7/14/2017	4	4	Agricultural Mapping

We are witnessing either

- The commercial validation of the CubeSat platform for ad-hoc constellations
- The beginning of the great CubeSat dot-com bubble!

None of These Things are Quite Like the Others …

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  - Building for fun & future profit
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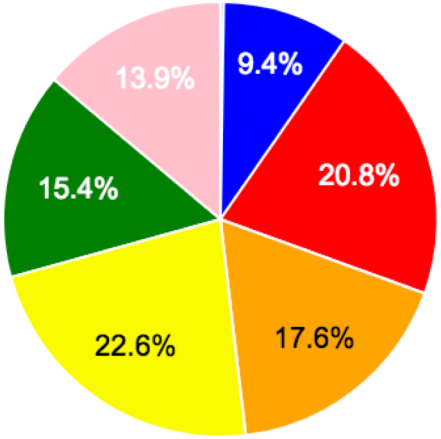
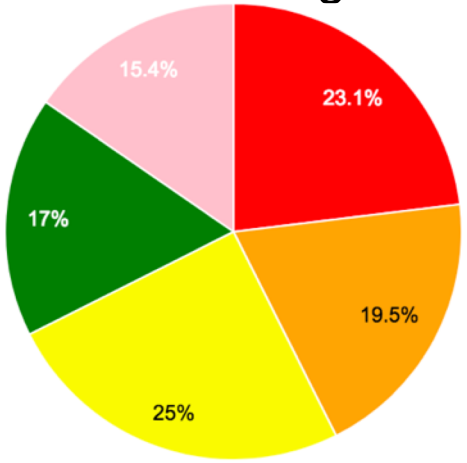
CubeSat Mission Status, 2000-2017 (No constellations)

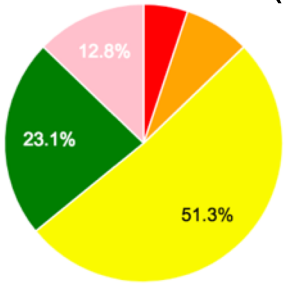
All Missions (403)



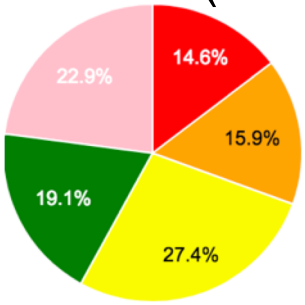
All missions reaching orbit (364)



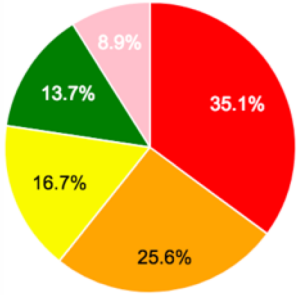
Industrialists (39)



Crafters (157)



Hobbyists (168)

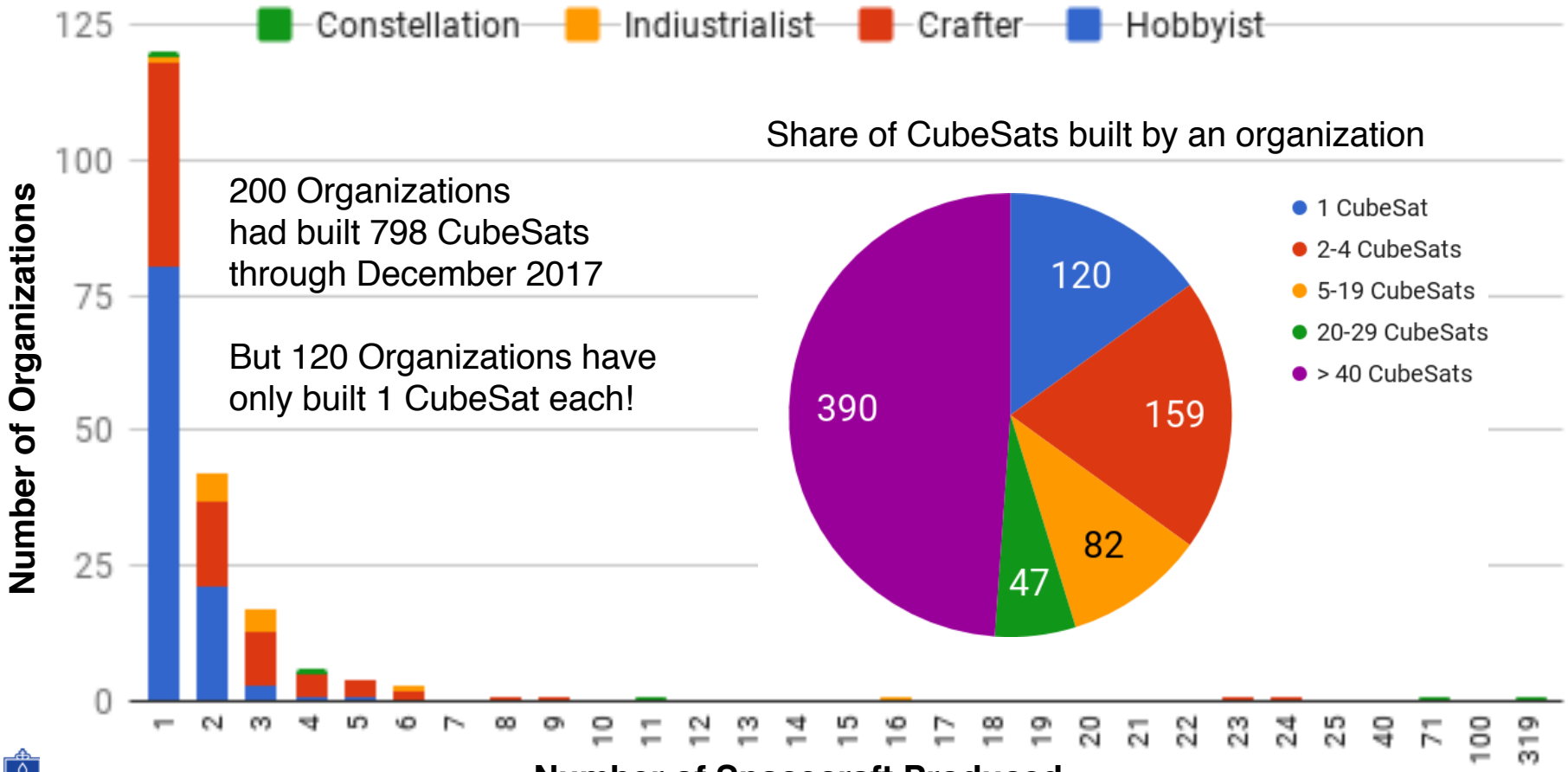


Why the discrepancy?

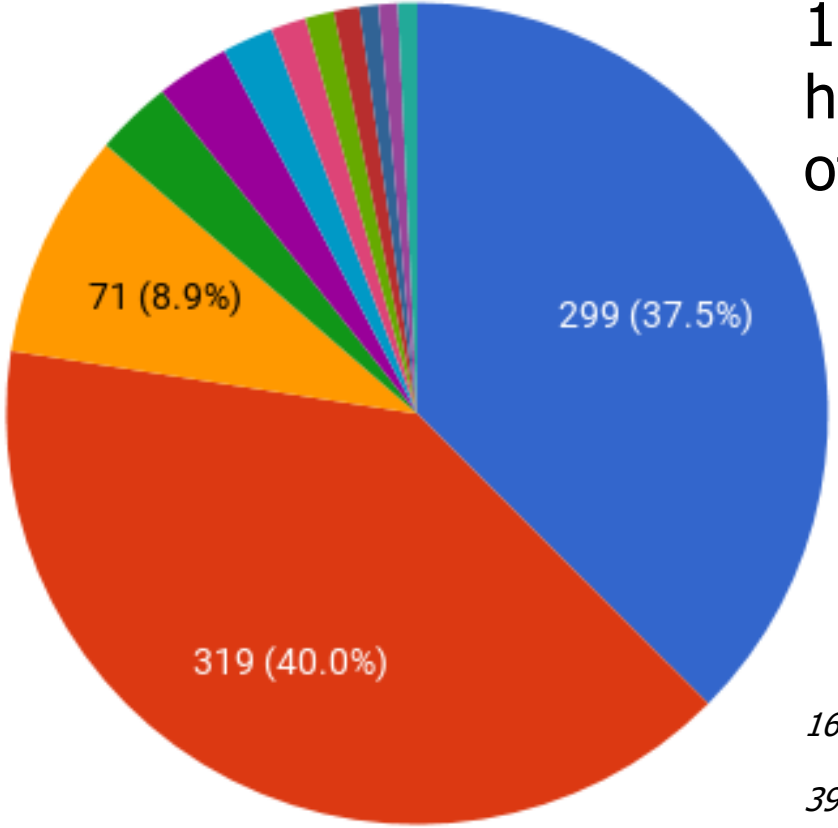
[Disclaimer: No, I don't have that data … no one does.]

- **Industrial**: You get what you pay for!
- **Crafter**: Failures appear to be a result of ambitious technology infusion *(i.e., acceptable losses)*
- **Hobbyist**:
  - 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!



Crafters/Constellations: Repetition = Success



11 Organizations have flown 62.5% of the CubeSats

16 Organizations have flown 65%

39 Organizations have flown 75%

Implications and Future Work

- Secondary spacecraft occupy a different part of the risk-cost-performance spectrum
  - Shorter missions (both in-development and on-orbit)
  - Much smaller budgets
  - Elevated risk acceptance
  - Very large numbers on each launch (heterogeneous and constellations)
- Mission success tracks well with I&T processes and risk tolerance
- The Hobby/Crafter/Industrial/Constellation taxonomy is useful, but needs expansion
  - New mission domains (interplanetary)
  - Increased mission profile (front-line science, commercial comm)
- Needed steps: more data, more data, expand taxonomy, more data

Acknowledgements

- Census 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
- Support
  - AFOSR / UNP (original work)
  - NASA NEPP (NNX17AJ46G and 80NSSC18K0637)

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