Small Satellite Trends, 2009-2013

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Aerospace focused on providing data-driven answers

- In summer 2014, Aerospace conducted an analysis of small satellites to understand historical trends and their impact on missions
  - *Develop an understanding of small satellites' potential contribution in future architectures*

- Aerospace collected data on all worldwide Earth-Orbiting small satellites launched 2009-2013 (244 total)
  - *All data came from public sources*
  - *Vendors were not contacted for validation or data completeness*
  - *Trends are representative, even without 100% data population*

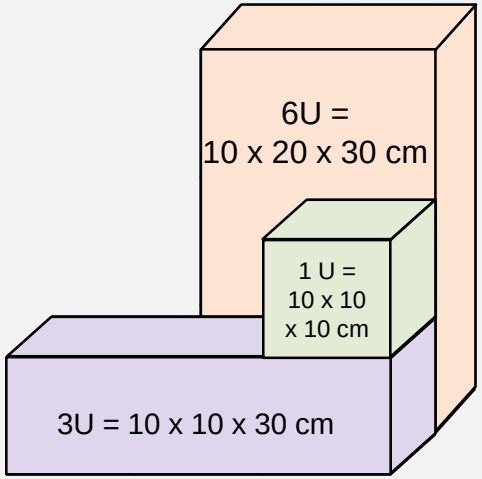
- Study initiated to provide data-driven answers to these types of questions:
  - *What types of missions are typically performed by spacecraft of different sizes?*
  - *Are satellites of one size more successful than another?*
  - *Are mission-focused satellites more successful than demonstration satellites?*
  - *What is a typical development schedule for commercial vs. university CubeSats?*
  - *What is the impact of developer experience on the probability of mission success?*
  - *How could these trends affect future architectures & mission profiles?*

Defined Small Satellites as <250 kg at launch

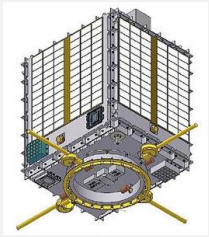
Small Satellites
Earth-orbiting, less than 250 kg wet mass

CubeSat
A small satellite conforming to a specifically defined form factor

e.g. SENSE
3U CubeSat
3.5 kg, 10 W



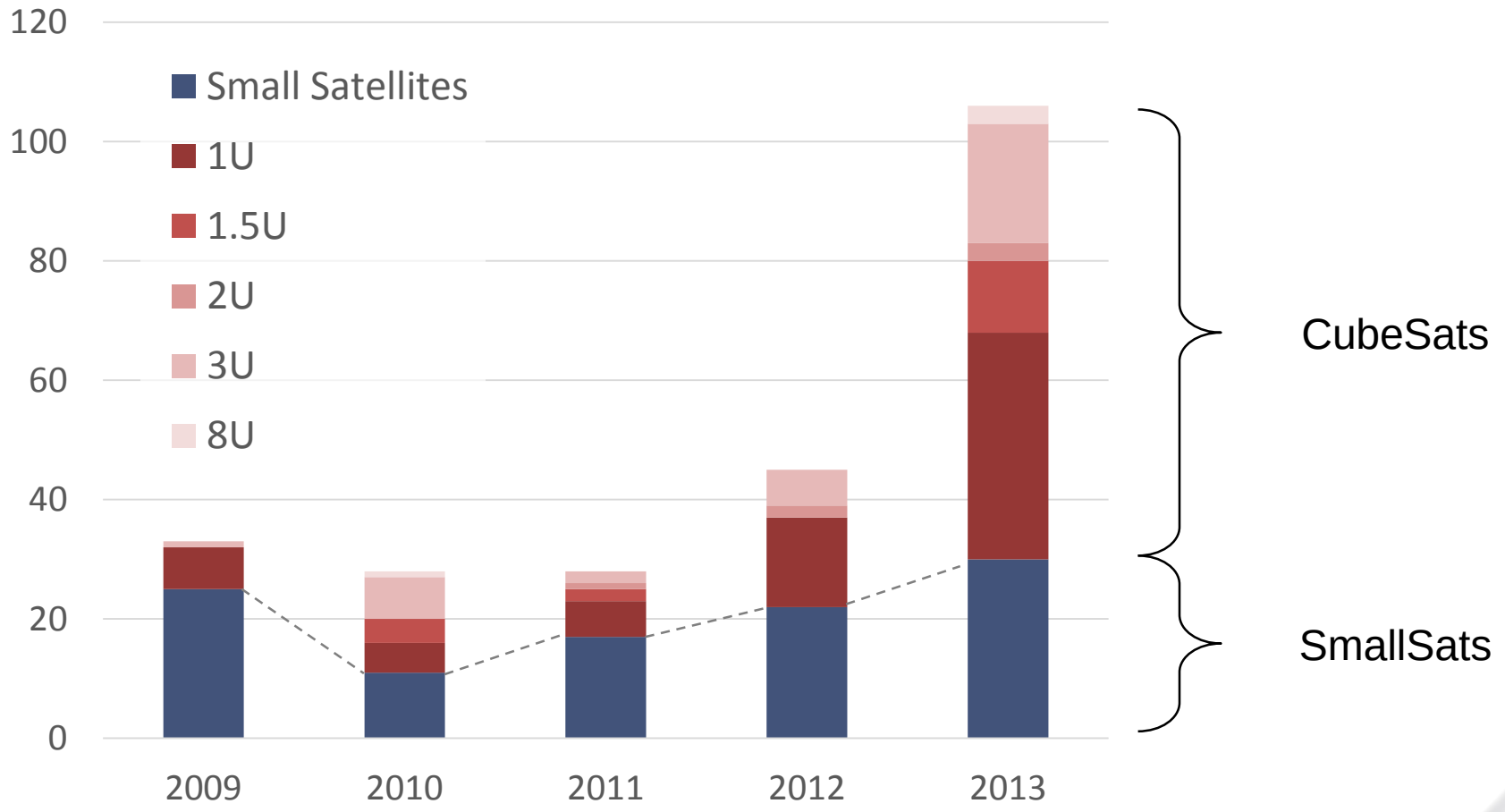
SmallSat
A small satellite not conforming to a CubeSat form factor



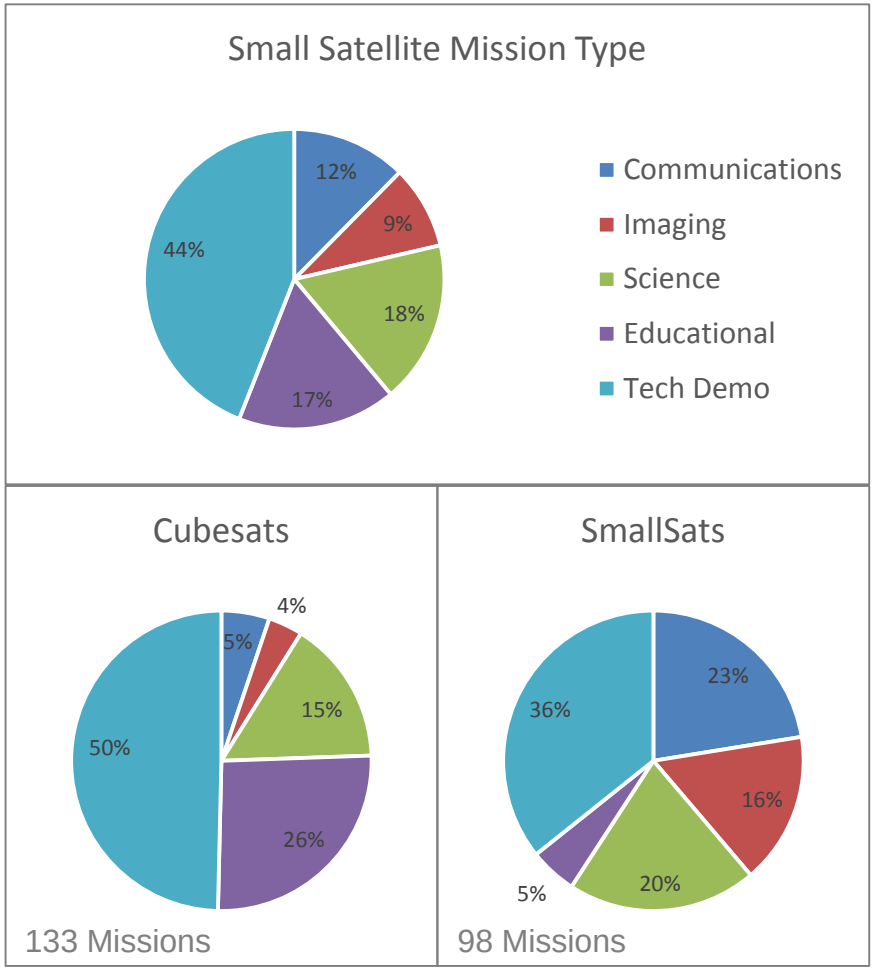
e.g. FalconSat-5
ESPA-class SmallSat
180 kg, 75 W

FalconSat images from https://directory.eoportal.org/web/eoportal/satellite-missions/f/falconsat-5, courtesy of USAFA
SENSE images from https://directory.eoportal.org/web/eoportal/satellite-missions/s/sense. Artists' concept courtesy of USAF/SMC, space vehicle integration picture courtesy of USAF.

Rapid growth observed in the small satellite community

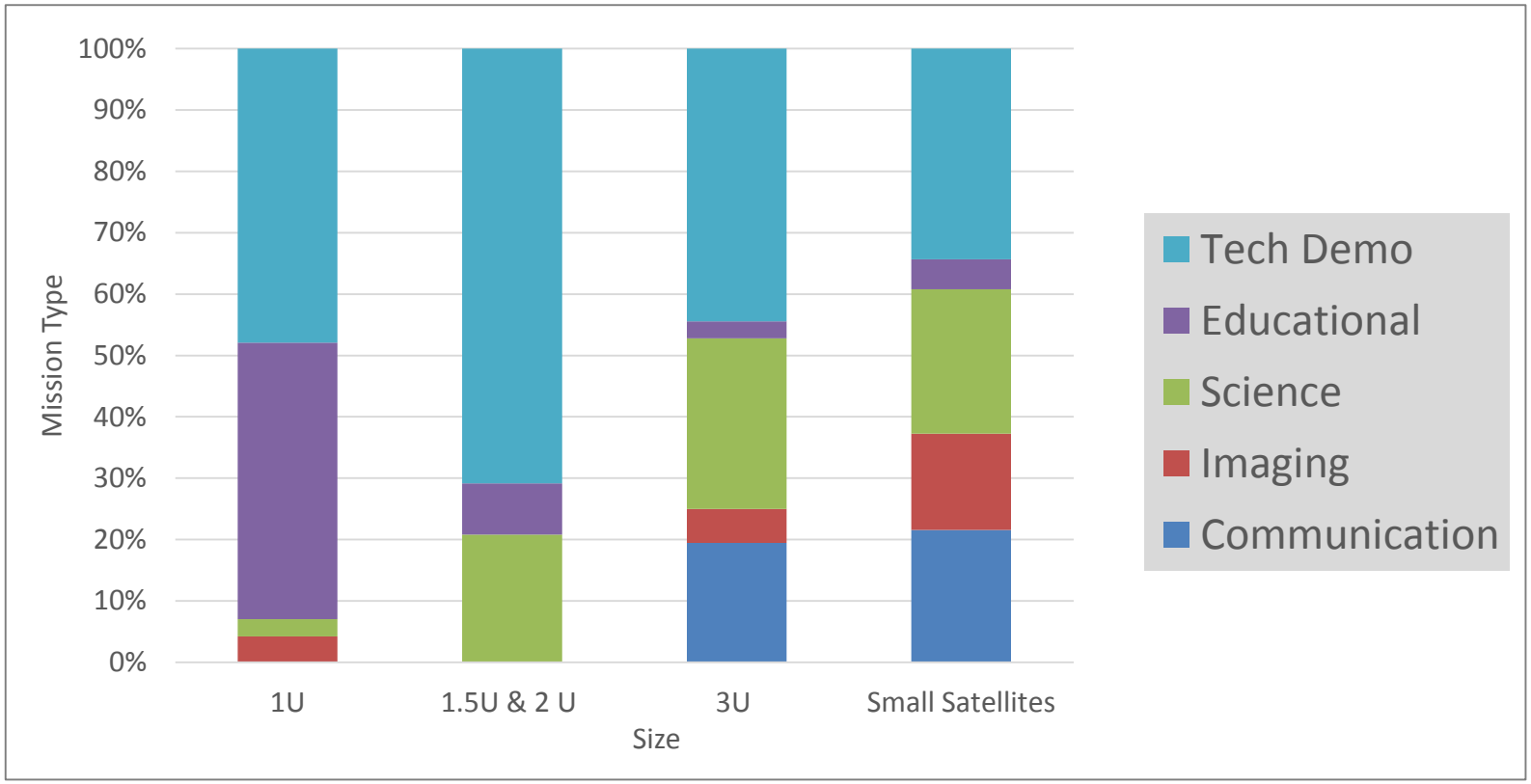


Small satellites perform a diverse set of missions



- **Communications** missions provide communications services, such as real-time connectivity, data store and forward
- **Imaging** missions focus on earth observing remote sensing
- **Mission/Science** perform data gathering missions, such as earth or space environmental monitoring
- **Educational** missions' primary purpose is to teach students about subsystem topics and systems engineering
- **Technology Demonstration** missions are intended to demonstrate new components or subsystems, such as a new reaction wheel or propulsion system that lacked space flight heritage

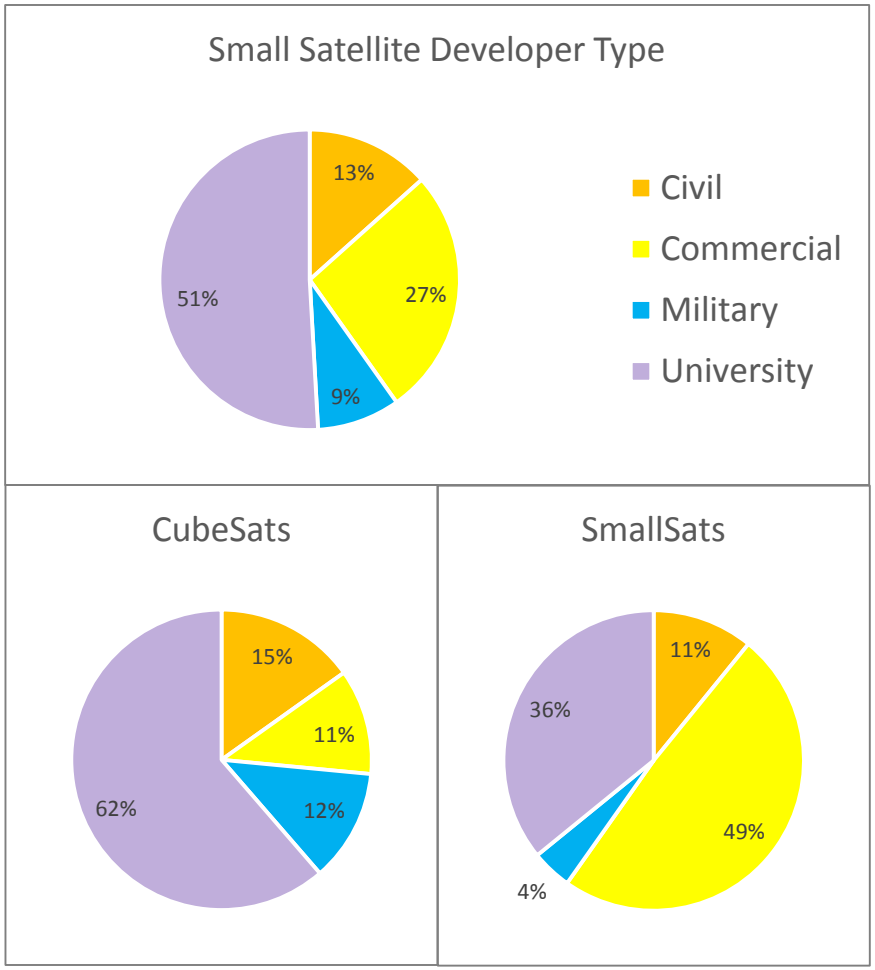
3U CubeSats can provide mission utility



Similar missions are being performed with
3U CubeSats and SmallSats, implying that

viable missions are being performed with **3U CubeSats**

Small Satellites are developed by a diverse set of integrators



- **Civil** includes US and foreign civil organizations
- **Commercial** includes for-profit commercial entities
- **Military** organizations are government funded for defense purposes
- **University** are academic organizations
- Categorized by the organization responsible for spacecraft manufacturing and/or integration

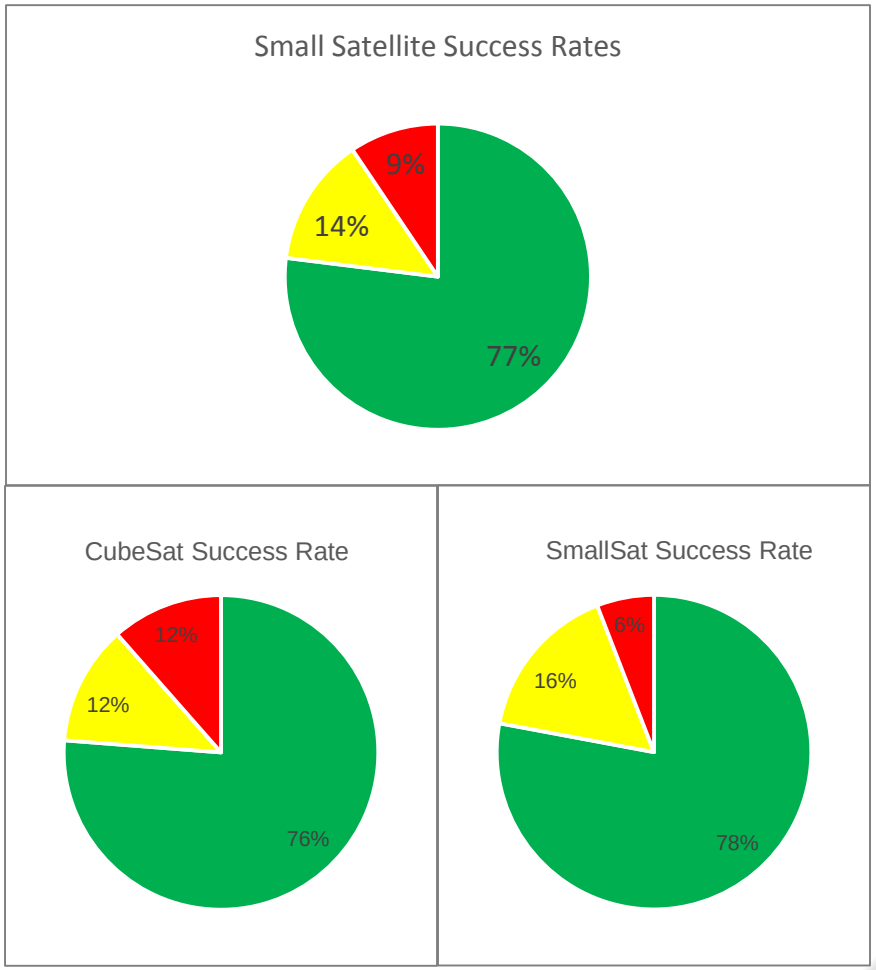
Most non-university CubeSats are built in two years or less

Developer	Average CubeSat Development Time (Years)	% of CubeSats Built in Two Years Or Less
Commercial	1.7	100%
Military	1.6	92%
University	3.8	21%

Small satellites are 84% successful

- Success is defined as:
  - ***Full (Green)****: achieved desired mission performance over its intended design life*
  - ***Partial (Yellow)****: achieved desired mission performance but subsequently suffered an early mission-ending failure, OR achieved some level of degraded (but still useful) performance over its intended design life*
  - ***Spacecraft Failure (Red)****: complete mission failure – no successful contact after deployment*
  - ***Launch Vehicle Failure****: rocket did not successfully place the satellite into orbit*
    **Not included in analysis*

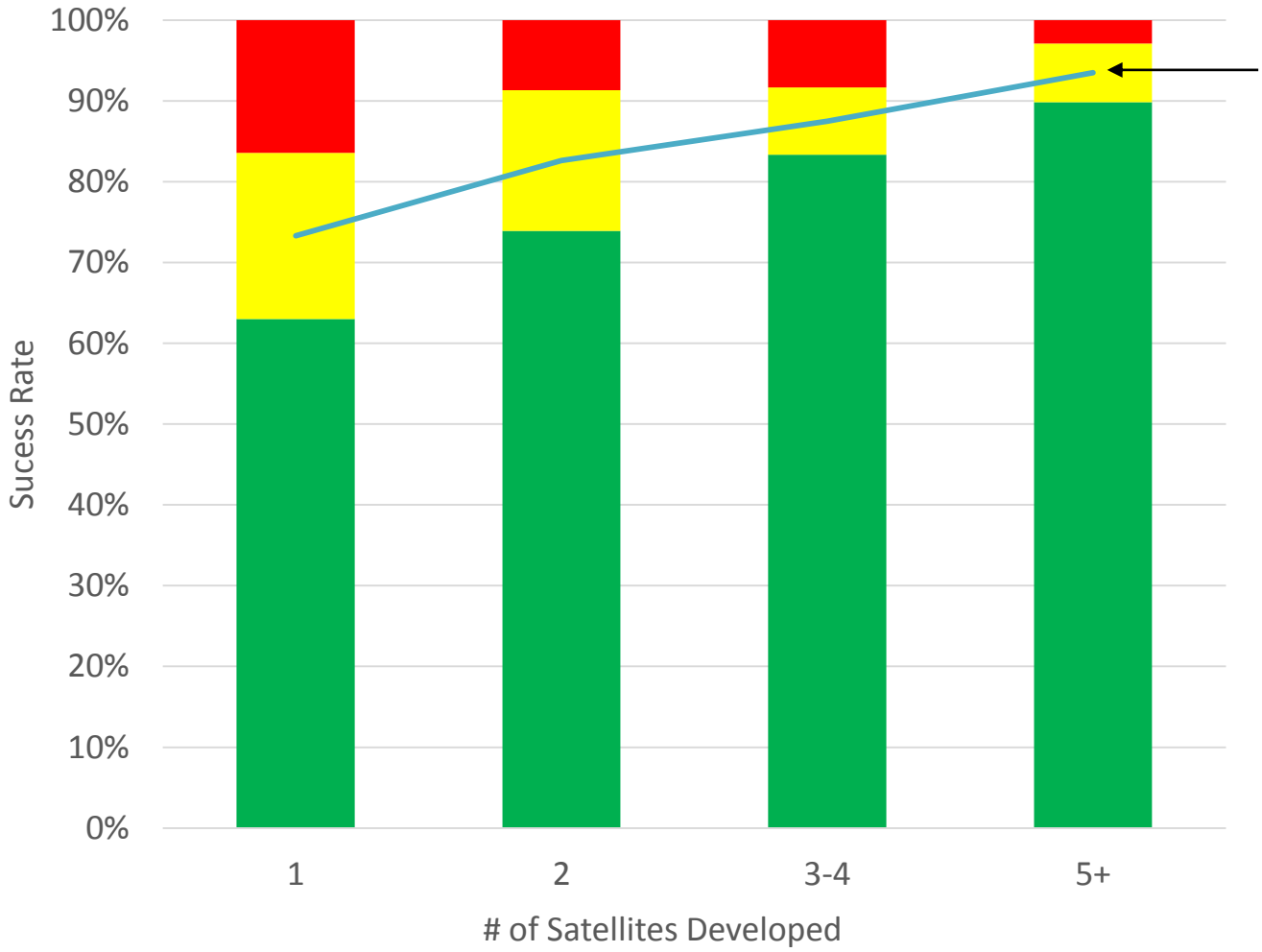
The overall success metric of Small Satellites is **84%**, with no appreciable difference between CubeSats & SmallSats



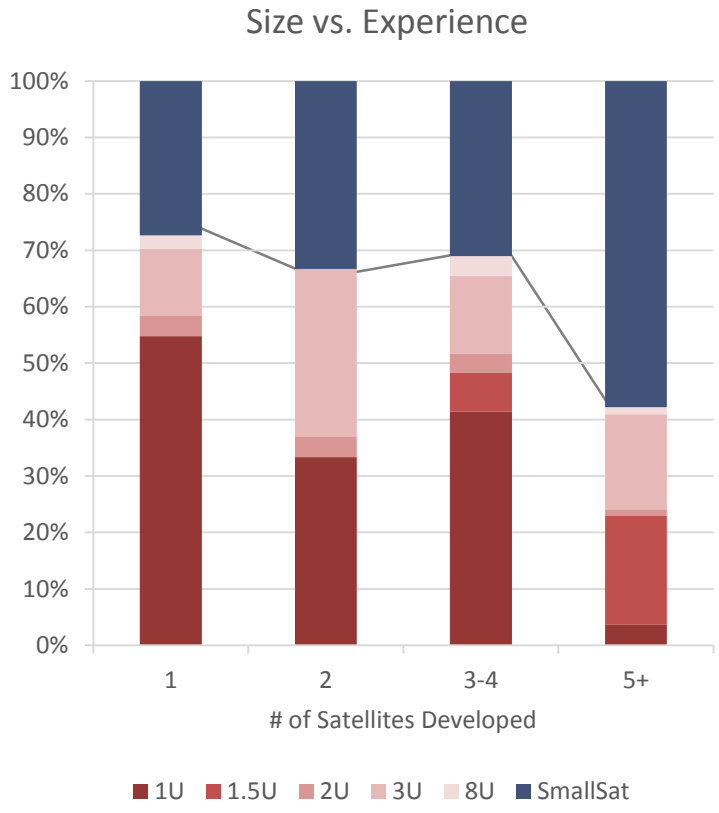
*As defined by: 100% Full + 50% partial

Public data is available for 194 of the 244 missions.

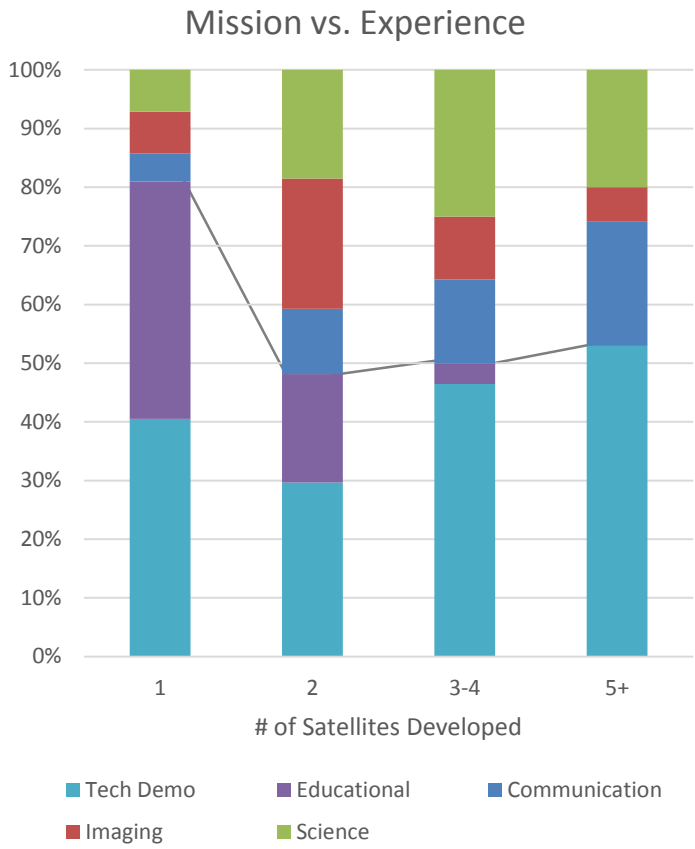
Success rate increases with experience



Experienced developers build more capable, complex vehicles



Increasing Size & Complexity



Impact of Experience:

Developers with more experience choose to build more **complex**, more **capable** vehicles, with **higher success** rates

Cost is hard to find from public sources

- Using only public data sources, reliable cost figures were difficult to find
  - *Most cost values were high level costs quoted in news stories*
  - *Scope of cost figures were not well defined*
    - Includes space segment, ground segment, and launch vehicle or rideshare accommodation?
    - Includes full program lifecycle (development, integration, and operation)?
  - *No independent verification of cost performed*

- Limited insight into costs prevented development of meaningful conclusions
  - *Additional data will be required*

- **Cooperative collaboration with mission developers may be required to collect normalized system-level costs**

Key Findings

- **Rapid growth** has been observed in the small satellite industry
- Mission-focused spacecraft become increasingly viable at form factors **as small as a 3U** CubeSat
- Typical development time for commercial/government developed CubeSats is **18-24 months,** and universities typically take twice as long
- The probability of **mission success** is significantly higher for organizations that have previously developed at **least two** satellites
- Developers with more experience choose to build more **complex**, more **capable** vehicles, with **higher success** rates

To verify accuracy of your data in our database please contact:

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