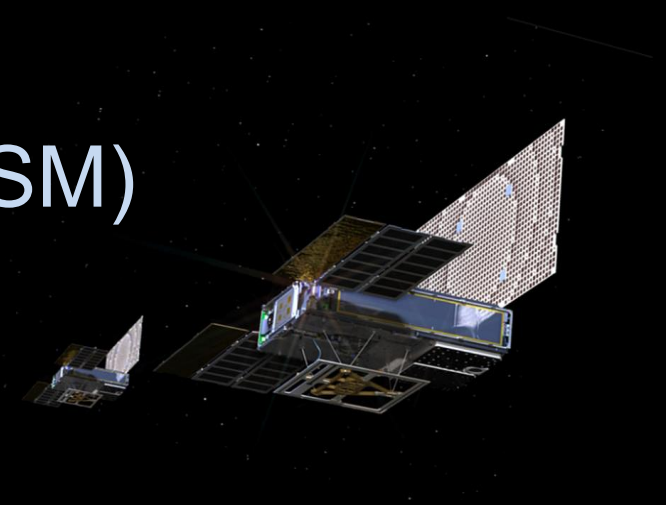


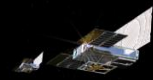
The Evolution of the CubeSat Spacecraft Platforms

AVT-336 Specialists' Meeting (RSM)

Craig D. Burkhard
NASA Ames Research Center
Moffett Field, CA, 94035 USA

Sasha V. Weston
Millennium Engineering and Integration Company
NASA Ames Research Center
Moffett Field, CA, 94035, USA

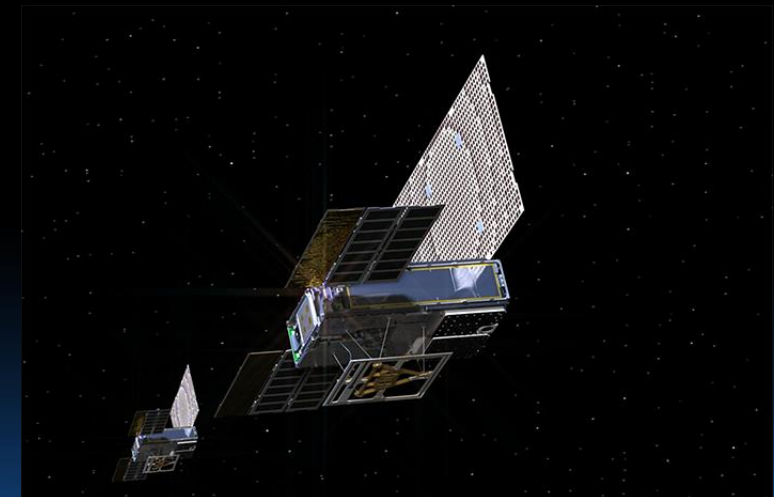
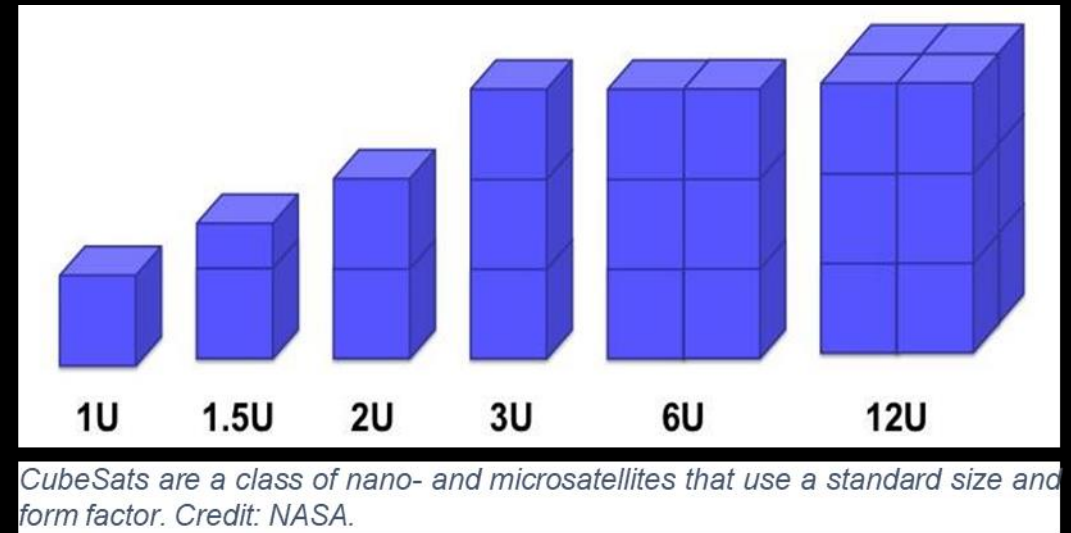




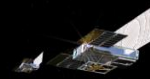
Introduction



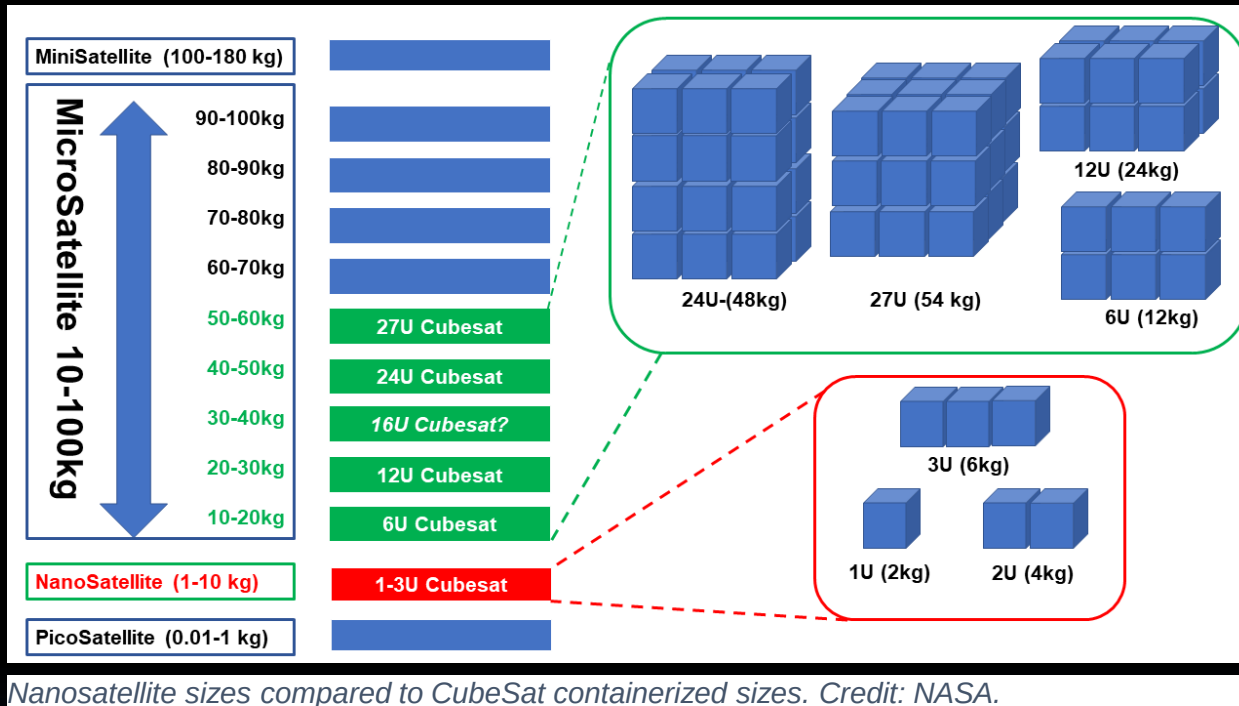
- CubeSats have experienced growth in the past 10 years both mission complexity and physical size to accommodate more robust requirements
- MarCO was the first step to bridge the gap between CubeSats and deep space, and now more CubeSat missions are being designed for beyond LEO environments
- This paper focuses on 1U – 12U CubeSats and picosatellites
- Data for this paper was collected from the *Nanosats Database using records between January 2010 - April 2021. Further references are provided for the various missions discussed.
- The graphs presented herein show all 1U-6U CubeSat missions that were successfully launched, excluding 12U and picosatellites



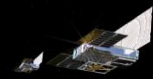
An artist's rendering of the twin Mars Cube One (MarCO) spacecraft as they fly through deep space. Credit: NASA/JPL-Caltech.



CubeSat Platforms Overview

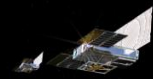


- In 1999, a collaboration between California Polytechnic State University (Cal Poly) in San Luis Obispo and Stanford University in Stanford, California developed a small educational platform called a CubeSat
- CubeSats are now a common form of small spacecraft that can weigh only a few kilograms (up to 30 kg) and are based on a form factor of a 10 cm square cube, or unit (U)
- Ordinarily, a CubeSat was composed of a single cube, a 1U, and it is now common to combine multiple cubes to form, for instance, 3U or 6U
- CubeSat dimensions expected to officially further increase to 16U, 24U, and 27U



This chapter provides an overview of the standardized process for obtaining a complete smallsat bus

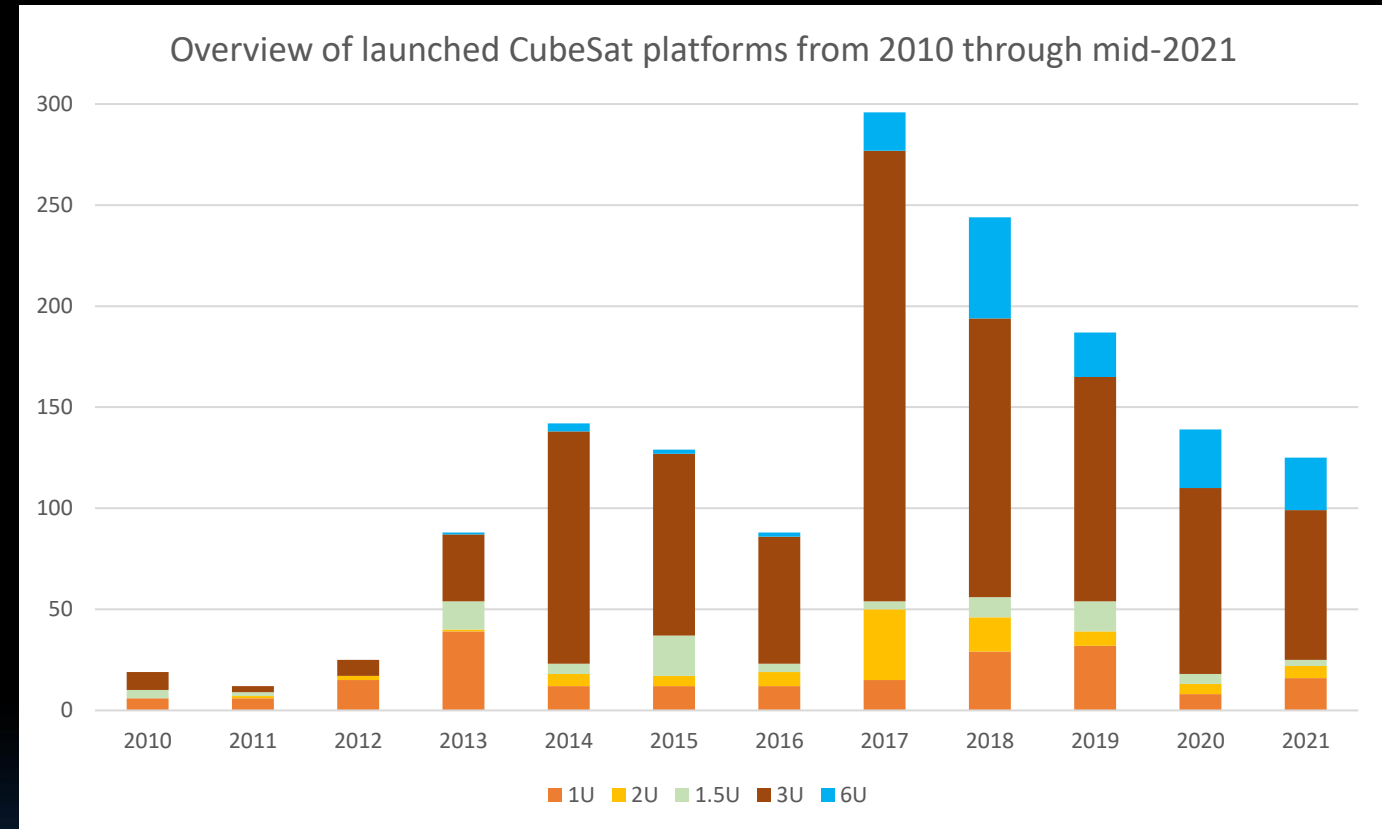
- There is an abundance of modular platforms upon which a payload can be hosted and ready to fly in a comparatively short amount of time
- Two options have emerged from the SmallSat bus market in the last decade:
 - Turnkey bus solutions from CubeSat vendors, with a sufficiently diverse portfolio of systems and services, who offer package “deals” that can be based around the customer’s requirements;
 - COTS bus solutions where the customer obtains a ready-made platform and work their own integration, testing, and operation
- Provides an Includes various commercial canisterized and non-canisterized SmallSat options, common types of science missions for type of SmallSat (picosat, nanosat, microsat,& minisat), recent and upcoming trends

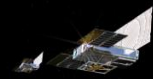


Evolution of CubeSat Platforms



- Initial CubeSat adoption was by the university science and engineering community. It is the reason many universities now offer aerospace engineering programs
- Quickly, 1U – 3U CubeSat platform range was utilized by all space enthusiasts
- 2014: the CubeSat form factor expanded to include the 1U, 1.5U, 2U, 3U, and 6U platforms
- 2016: introduced the 12U platform
- Demand for larger CubeSats is increasing as they offer more capability for more complex science and technology demonstrations

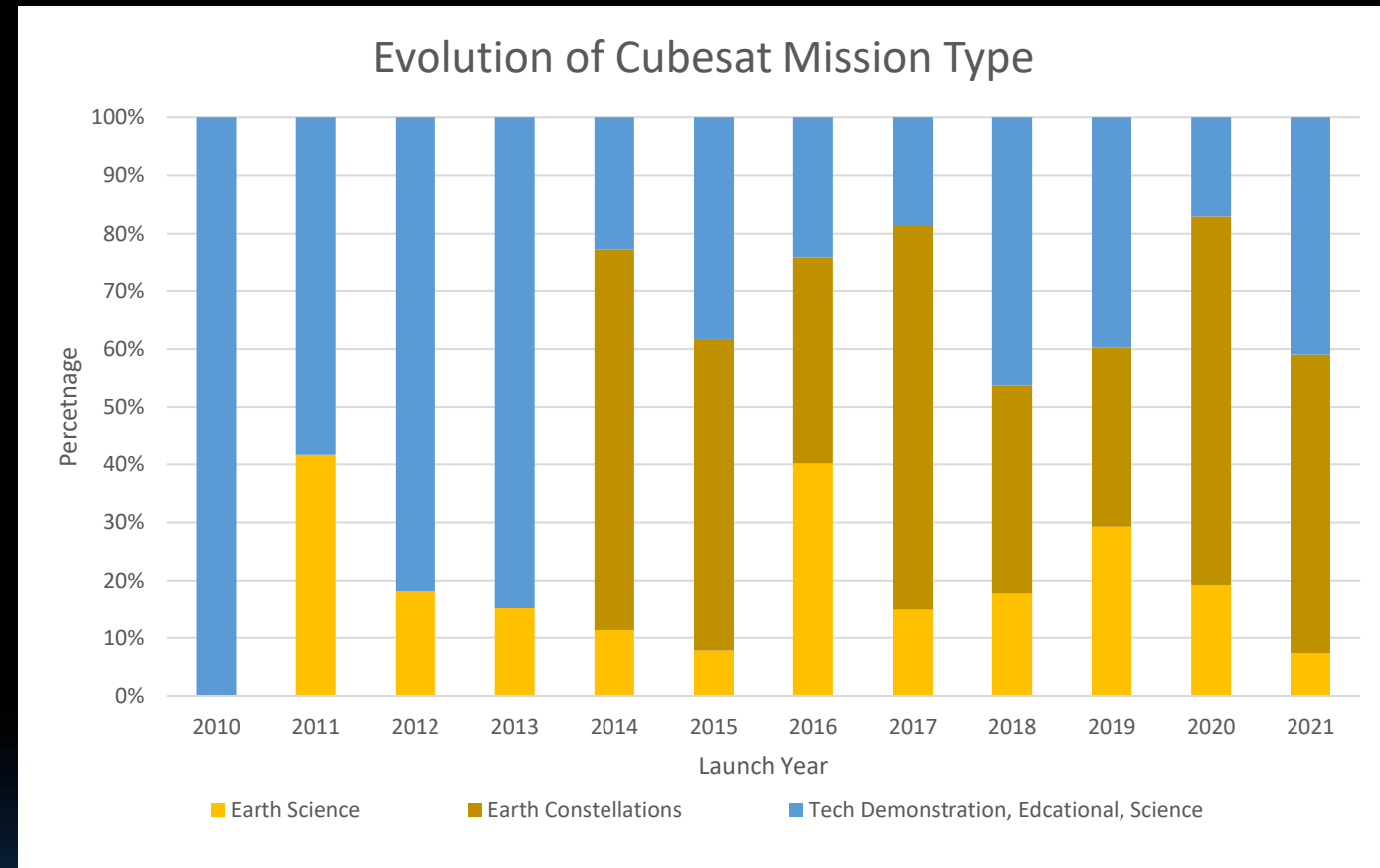


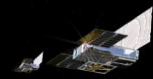


Evolution of CubeSat Missions



- CubeSat missions are becoming more sophisticated which requires higher performance technology
- A rise in LEO constellations that collect atmospheric data, offer Internet of Things (IoT) capability, and remote sensing
 - 2014: first launch of Planet Labs' Doves 3U constellation (93 launched throughout the year)
 - 2017: 46 LEMUR spacecraft launched; 140 Doves launched
 - 2021: 140 LEMUR 3U spacecraft are operational; >200 operational Doves
- Design CubeSat missions beyond LEO environments, such as geostationary and geotransfer orbits (GEO and GTO), lunar, and deep space.
 - 2019: two 12U spacecraft (TDO-3 and TDO-4) in GTO





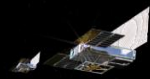
Notable CubeSat Missions 2010-2021



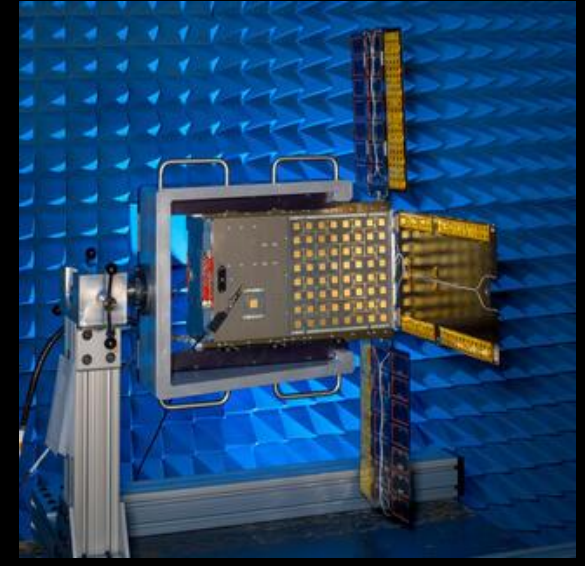
Spacecraft	Volume	Launch Year	Mission Type
Technology Educational Satellite, TechEdSat-n (TESn), spacecraft	1U, 3U, 6U	2012-2021	Educational & Technology Demonstration
LEMUR constellation	3U	2014-2021	Earth Science
Prometheus spacecraft	1.5U	2013-2021	Technology Demonstration
AeroCube spacecraft	1U, 1.5U, 0.5U, 3U	2012-2020	Technology Demonstration
FIREBIRD-2 spacecraft	1.5U	2013, 2015	Educational, Heliophysics
CanX (Canadian Advanced Nanospace eXperiments) spacecraft	1U –3U	2008, 2013, 2014, and 2016	Education, Technology Demonstration, Heliophysics, Earth Science
SporeSat	3U	2015	Biological
AX-1 (Aoxiang Zhixing)	12U	2016	Earth Science, Technology Demonstration
ASTERIA (ExoplanetSat, Arcsecond Space Telescope Enabling Research in Astrophysics)	6U	2017	Heliophysics
HaloSat	6U	2018	Astrophysics
TDO-3 and -4 (Technology Demonstration Orbiter)	12U	2019	Technology Demonstration, Educational Activities, Earth Science
NetSat-1-4	3U	2020	Technology Demonstration
13 Artemis payloads	6U	2021*	Technology Demonstration, Heliophysics, Lunar Science

A highlight on a few dozen CubeSat missions launched between 2010 and – 2021* with more attention on the scientific demonstrations

*To be launched late-2021



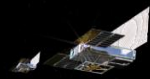
- There are several upcoming CubeSat missions designed for GTO, GEO, lunar, and heliocentric orbits
 - SpectroCube
 - GTOSat
 - Artemis I 6U payloads
 - The Aerodynamic Deorbit Experiment
- More CubeSat constellations
 - Sateliot IoT nanosatellite constellation
 - TROPICS mission
- Increase in larger-CubeSat constellations (6U and 12U)
 - Omnispace: 200 operational 12U spacecraft by end-2022
 - Horizon Technologies: AMBER CubeSat constellation
 - SatRevolution: REC 6U CubeSat constellation



BioSentinel Electromagnetic Compatibility Test. Credit: NASA.



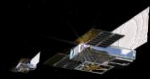
TROPICS constellation. Credit: Massachusetts Institute of Technology/Lincoln Laboratory and NASA.



Conclusions



- The size of the CubeSat platform is expanding
- CubeSat missions are becoming both more complicated and scientific in nature
 - CubeSat development advancement for more harsh environments as well as expanding launch opportunities for CubeSats and SmallSats
 - Greater data processing and transmission capacity, propulsion systems, optical communications, spacecraft autonomy, spacecraft navigation, collapsible/foldable telescopes, thin film solar cells, and inflatable antennas
- Groups of interconnected CubeSats in LEO and Lunar orbit have very useful applications (scientific, technology demonstrations)
- CubeSat constellations will likely grow in number as they can significantly improve our understanding of the space environment with their ability to capture simultaneous, multipoint measurements with identical instruments across a large area
 - The combination of high spatial and temporal resolution from nanosatellite constellations and improved technology (sensor quality) may begin to replace the era of large satellites with smaller and cheaper nanosatellites
- There will also be an improved coordination between spacecraft for inter-satellite navigation and communication which will benefit future complex CubeSat science missions



Thank you



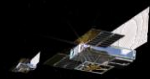
Visit the Small Spacecraft Systems Virtual Institute's Web portal to view entire SoA report online

<https://www.nasa.gov/smallsat-institute/sst-soa-2020>

Reach out to the Small Spacecraft Systems Virtual Institute for further comments and questions

agency-smallsat-institute@mail.nasa.gov

- Learn more about the Small Spacecraft Systems Virtual Institute: www.nasa.gov/smallsat-institute



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