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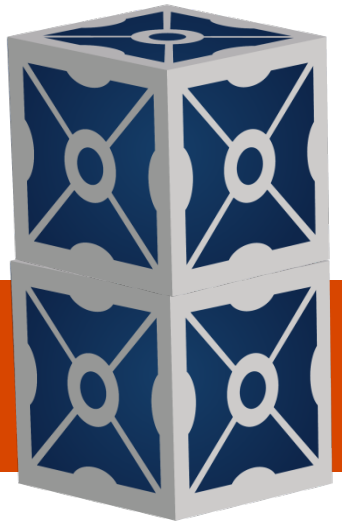

SPACE STUDIES BOARD

Achieving Science with CubeSats: Thinking Inside the Box

Robyn Millan
and the
Committee on Achieving Science Goals with Cubesats

Committee Chair: Thomas H. Zurbuchen, University of Michigan

Vice Chair: Bhavya Lal, IDA Science and Technology Policy Institute

Study Director: Abigail Sheffer, Program Officer, SSB

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Malcolm Macdonald, University of Strathclyde
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Edward L. Wright, University of California, Los Angeles
A. Thomas Young, Lockheed Martin Corporation [Retired]
Thomas H. Zurbuchen (Chair), University of Michigan

Can CubeSats support high priority science objectives?

Key Elements of Charge to Committee

Develop a **summary of status**, capability, availability, and accomplishments in the government, academic, and industrial sectors

Recommend **potential near-term investments** that could be made to improve the capabilities and usefulness of CubeSats for scientific return and to enable the science communities' use of CubeSats

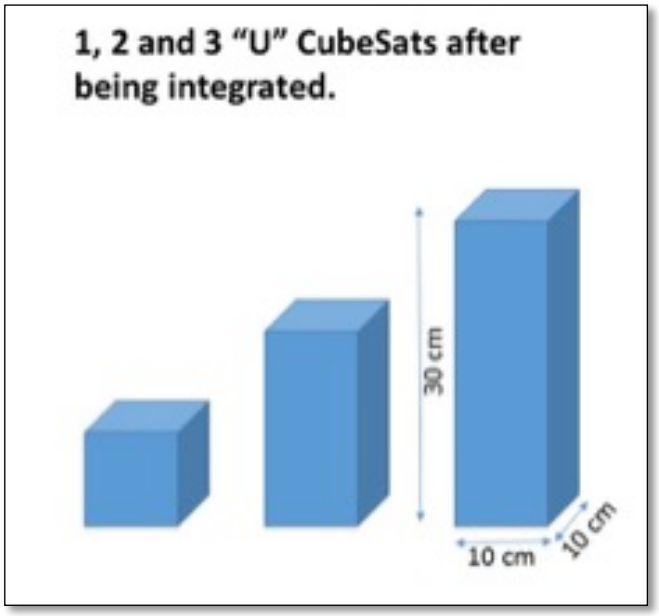
Identify a set of **sample priority science goals** that describe near-term science opportunities

Download full report at: www.nap.edu/cubesats

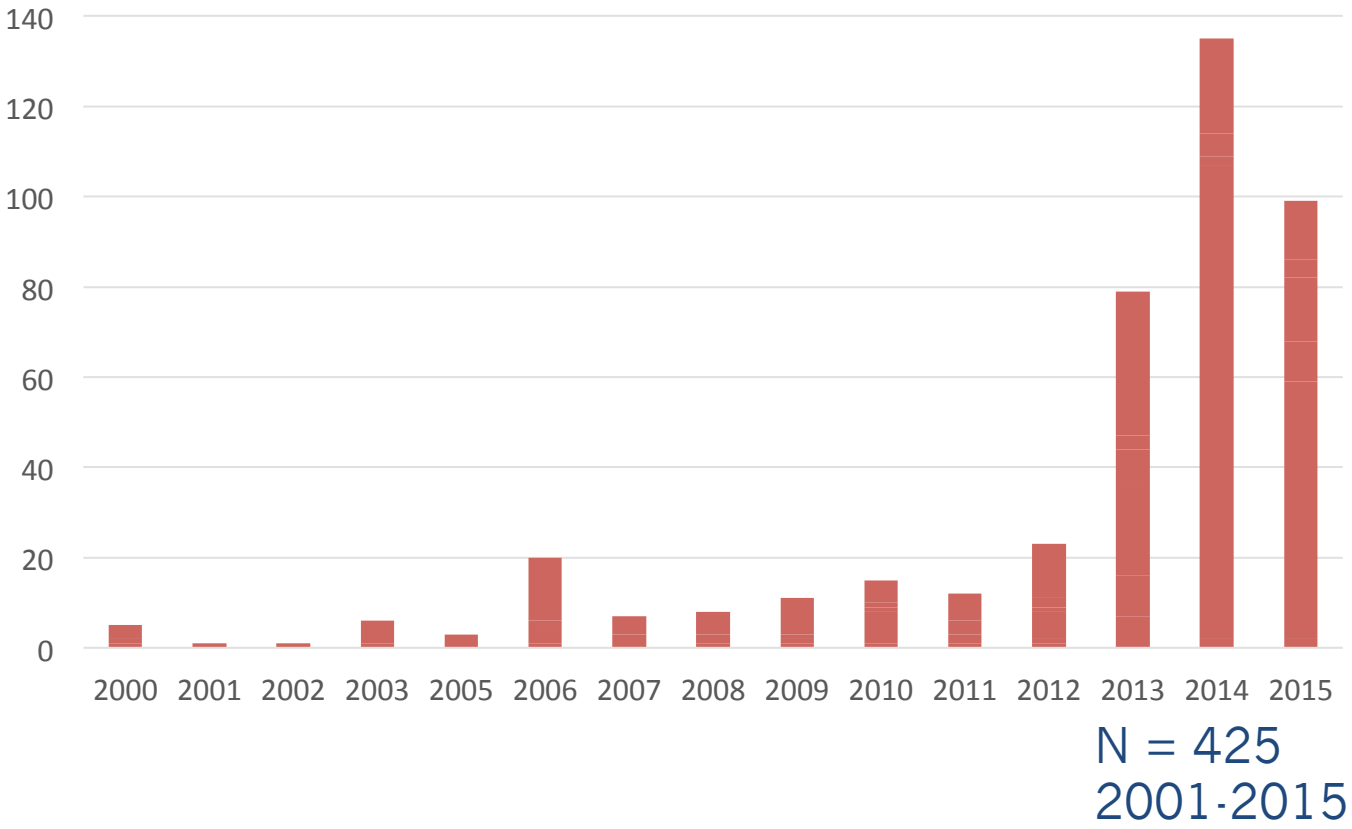
What is a CubeSat?

- A spacecraft sized in units, or U's, typically up to 12 U that is launched fully enclosed in a container

(a unit is defined as a volume of about 10 cm × 10 cm × 10 cm)



CubeSat launches have skyrocketed in recent years …



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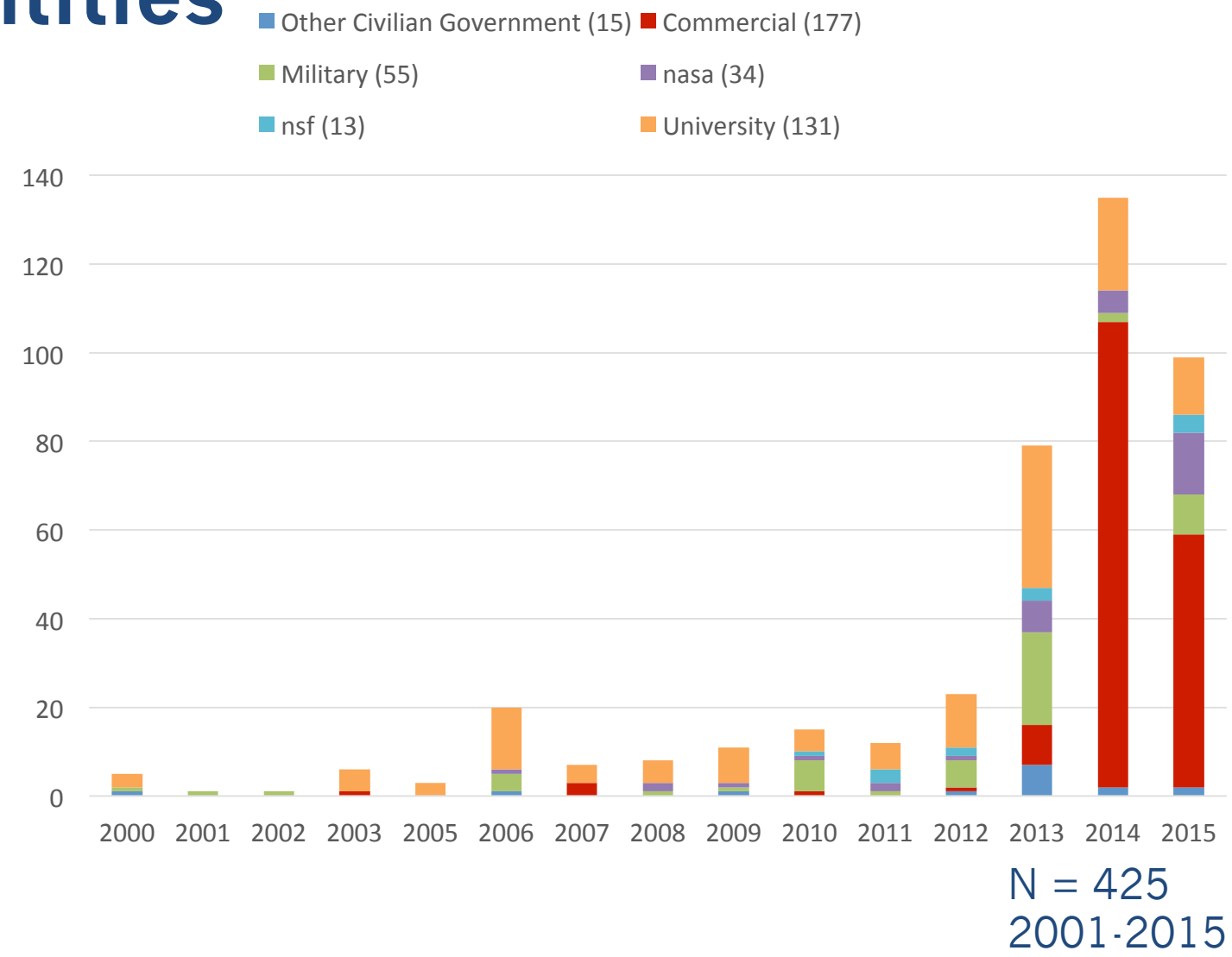
…lately dominated by commercial entities



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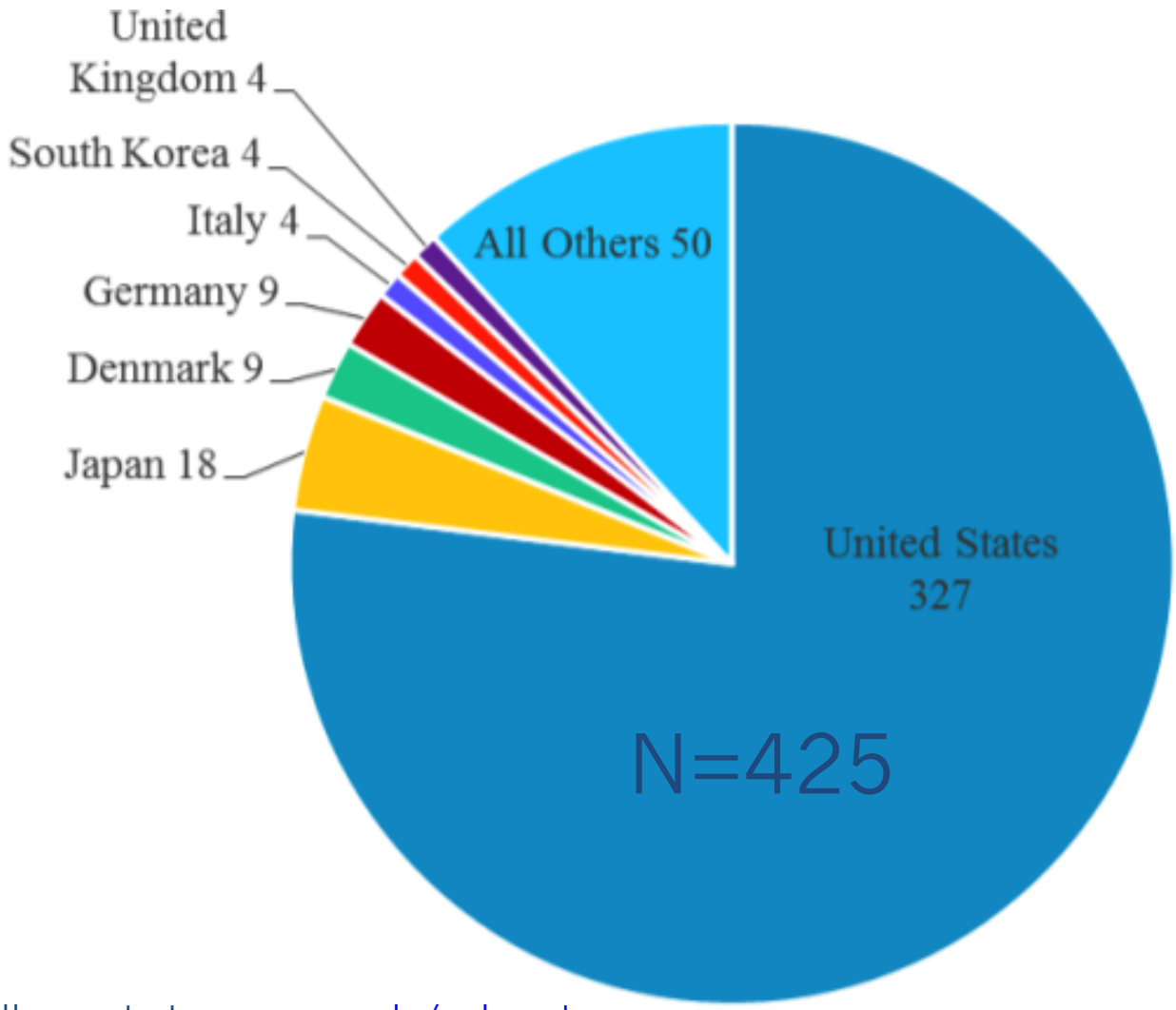
36 Countries have Launched CubeSats – United States Dominates



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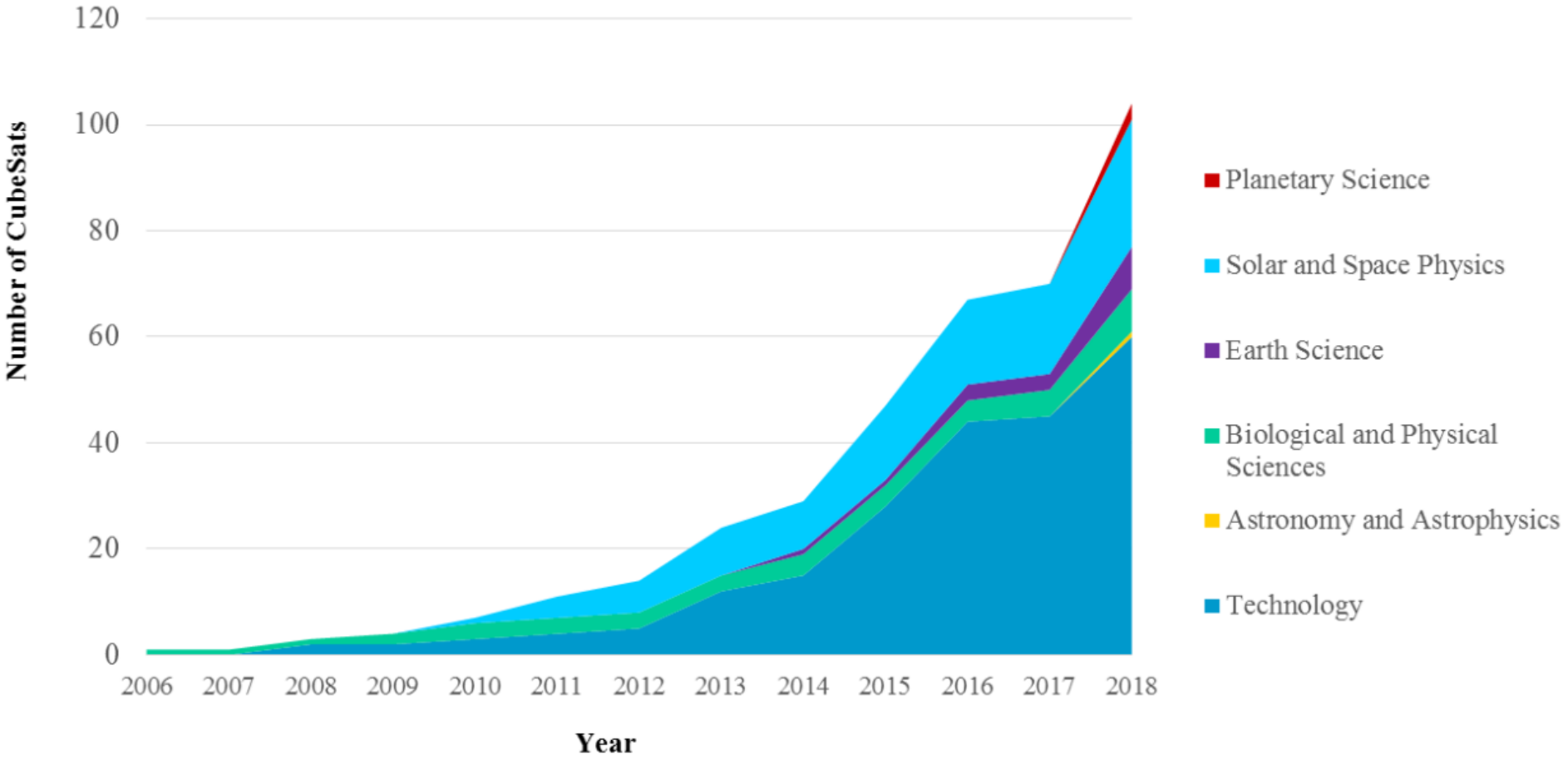
NASA/NSF CubeSats: >100 launched or about to be launched (72 missions)



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Science Impact and Potential

- Scientific contributions and potential of CubeSats in the context of the Decadal Surveys
  - Review of publications to assess impact
  - Unique role of CubeSats in each science discipline

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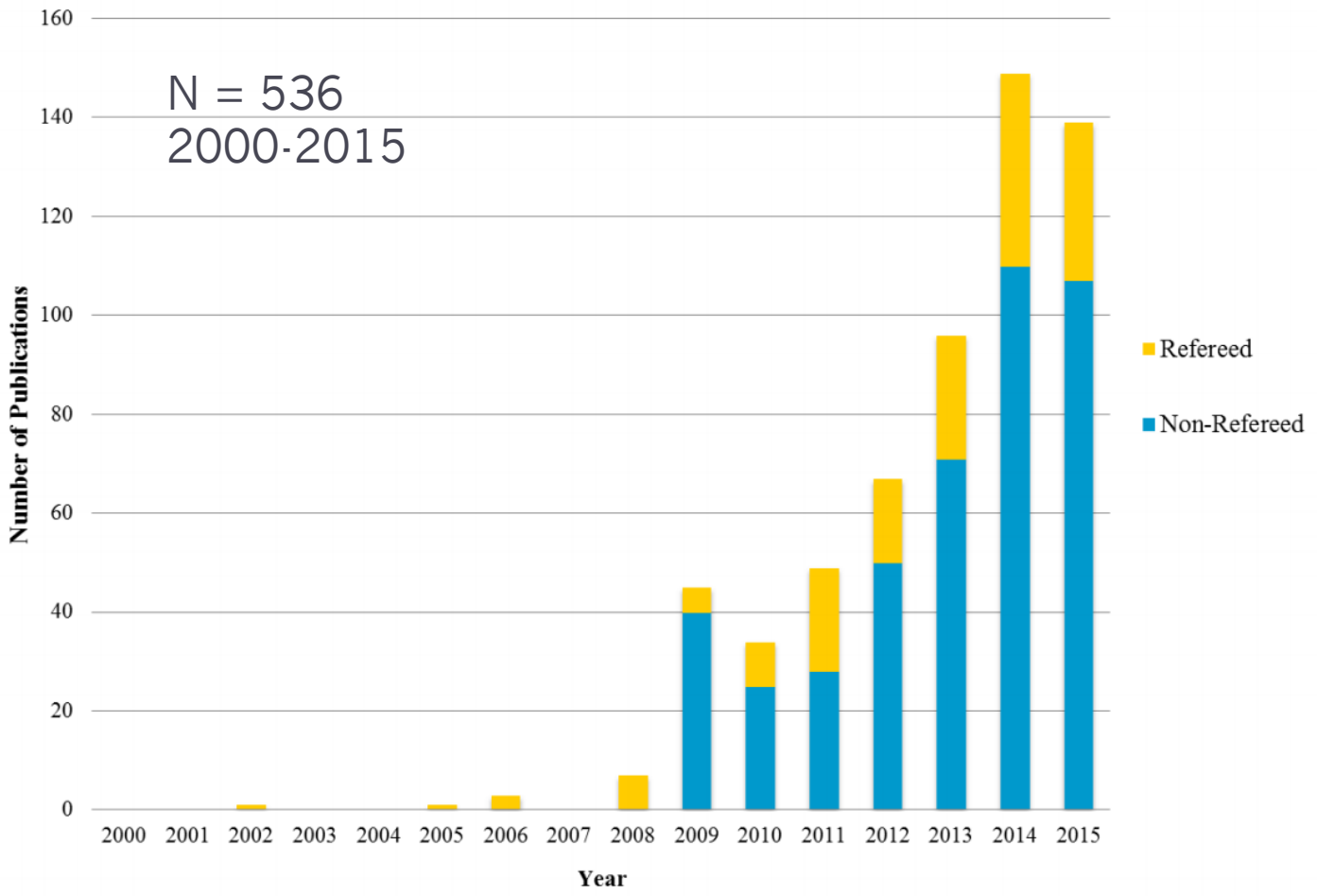
CubeSat-based Science already Underway



- 25% of the papers (160 of 536) in refereed journals
- 75% of refereed papers in engineering disciplines

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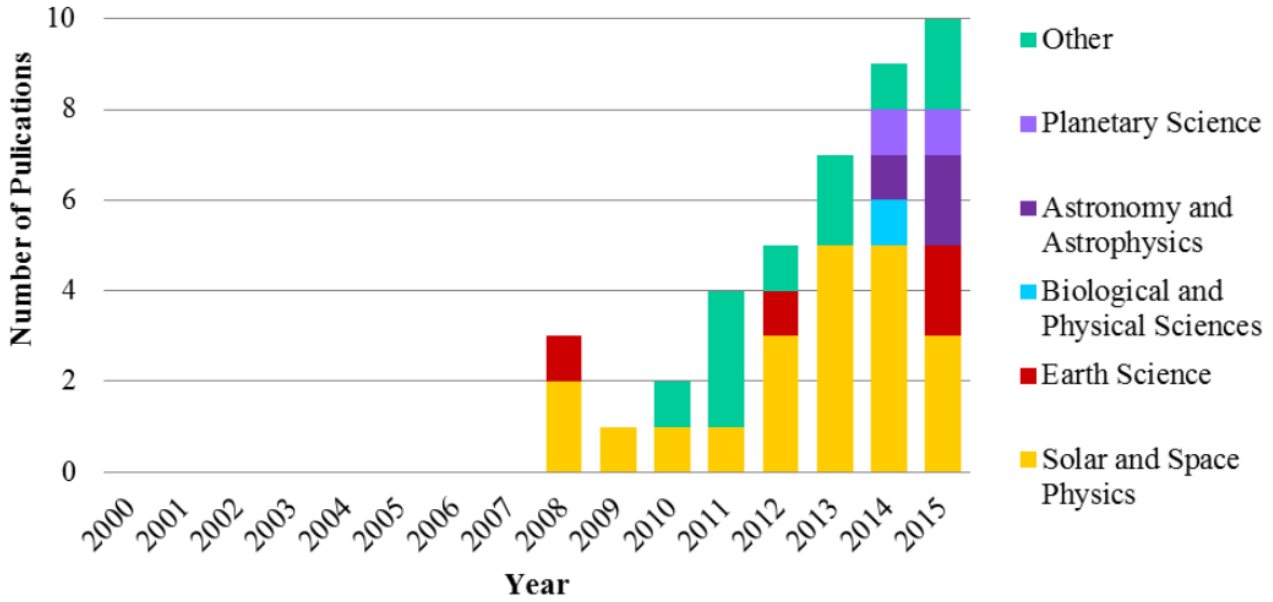
Solar and Space Physics

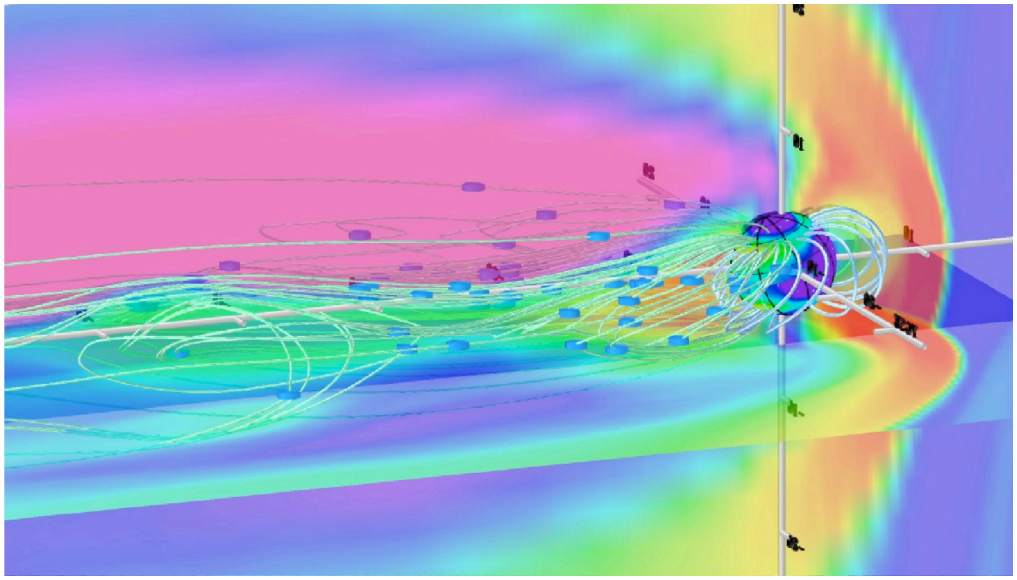
- CubeSats have already proven their scientific value
  - Majority of refereed science publications are in space physics
  - largely driven by the NSF CubeSat program
- DRIVE initiative
  - CubeSats "diversify" by providing stand-alone, unique measurements and measurements that augment larger facilities; "venture forward" by driving technology development; and "educate".

N = 41
2000-2015



Solar and Space Physics Opportunities

- Augmenting larger facilities
  - CSSWE works with Van Allen
  - RAX works with PFSIR
- New kinds of measurements
  - Hazardous orbits not accessible to traditional large observatories to probe the atmospheric boundary region
  - Filling a niche or gap (MinXSS)
  - Multipoint measurements to understand coupled Sun-Earth system
- Technology development
  - Demonstration of spacecraft and instrument innovations



"Instrumenting Space" through Distributed Architectures

- Investment required in pointing, high rate communication, sensor technology, and propulsion

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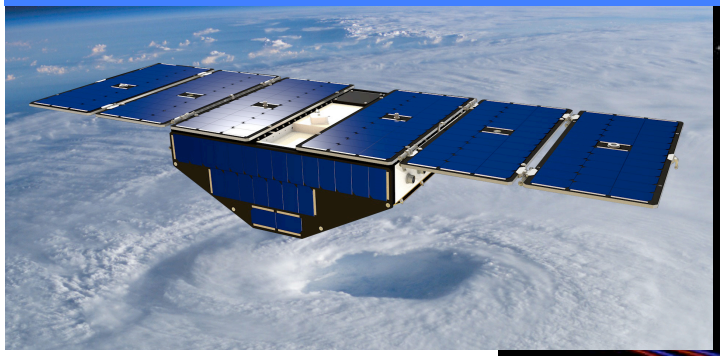
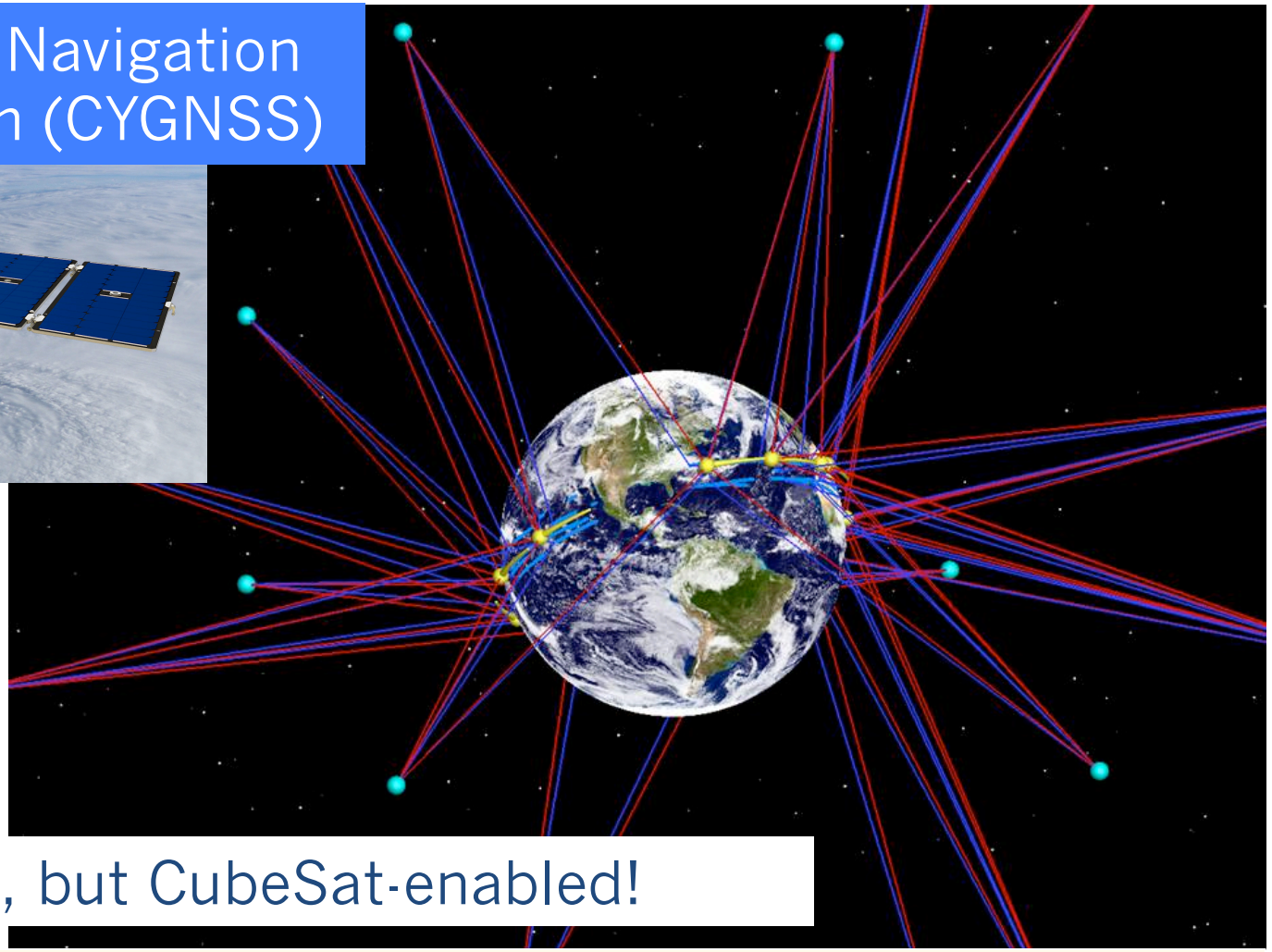
Example: Constellations/Swarms

Cyclone Global Navigation Satellite System (CYGNSS)





Not CubeSats, but CubeSat-enabled!

…NASA should develop the capability to implement large-scale constellation missions taking advantage of CubeSats or CubeSat-derived technology and a philosophy of evolutionary development.

What CubeSats Enable

- **Conclusion:** CubeSats have already produced high-value science, as demonstrated by peer-reviewed publications in high-impact journals.
- **Conclusion:** Although all science disciplines benefit from innovative CubeSat missions, CubeSats cannot address all science objectives and are not a low-cost substitute for all platforms. Some activities such as those needing large apertures, high power instruments, or very high precision pointing most likely will always require larger platforms because of fundamental and practical constraints of small spacecraft.
- CubeSats are a specific tool in the suite of options for conducting science.

Report Makes 8 Recommendations

- Future of the NSF and NASA programs
- Use of CubeSats as training tools
- Constellations, technology development, and leveraging private sector capabilities
- Recommendations and best practices regarding policy challenges

For full details, see www.nap.edu/cubesats

Summary: High Value Science

CubeSats are a specific tool in the suite of options for conducting science.

- CubeSats as targeted investigations
- augment the capabilities of large missions and ground-based facilities.
- enable new kinds of measurements (e.g. distributed, low altitude)
- enable technologies that benefit larger missions

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