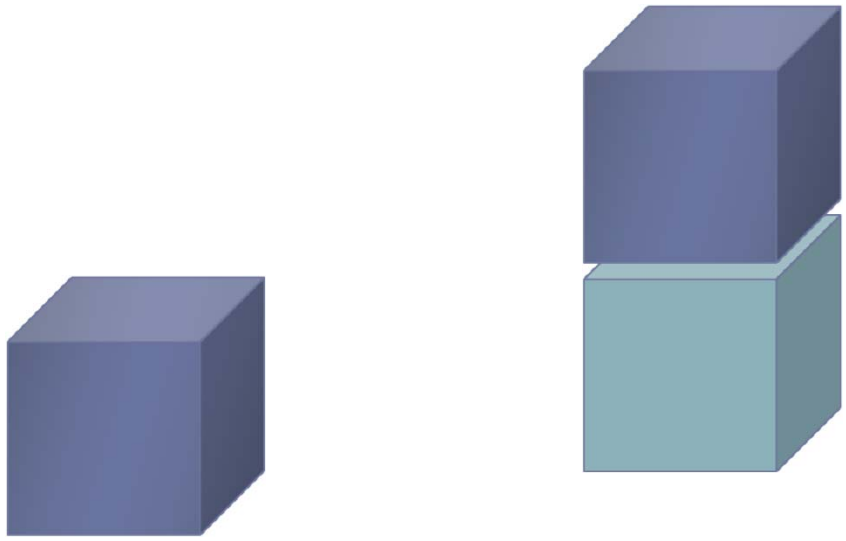


Achieving Science Goals with CubeSats

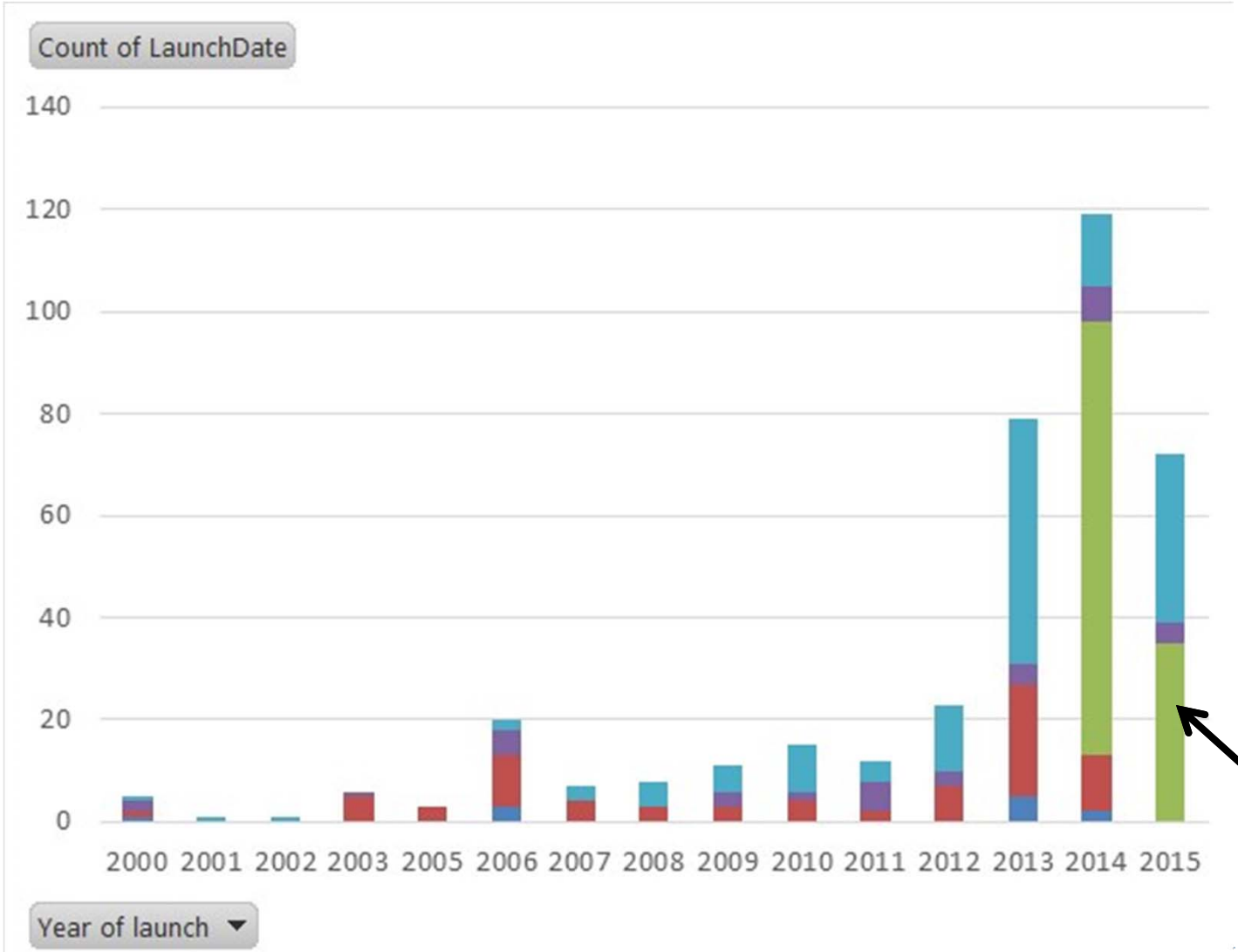
SSB Ad Hoc Committee Chair: Thomas H Zurbuchen, University of Michigan
Vice-chair: Bhavya Lal, IDA Science and Technology Policy Institute
Study director: Abigail Sheffer, Program Officer, SSB

Committee Membership

Thomas H. Zurbuchen (Chair), University of Michigan
Bhavya Lal, (Vice Chair), IDA Science and Technology Policy Institute

Julie Castillo-Rogez, Jet Propulsion Laboratory, Caltech
Andrew Clegg, Google, Inc.
Paulo Lozano, Massachusetts Institute of Technology
Malcolm Macdonald, University of Strathclyde
Robyn Millan, Dartmouth College
Charles D. Norton, Jet Propulsion Laboratory, Caltech
William H. Swartz, Johns Hopkins University
Alan M. Title, Lockheed Martin Space Technology Advanced R&D Labs
Thomas N. Woods, University of Colorado Boulder
Edward L. Wright, University of California, Los Angeles
A. Thomas Young, Lockheed Martin Corporation [Retired]

CubeSat Launch by Application



Technology

Science

Imaging

Educational

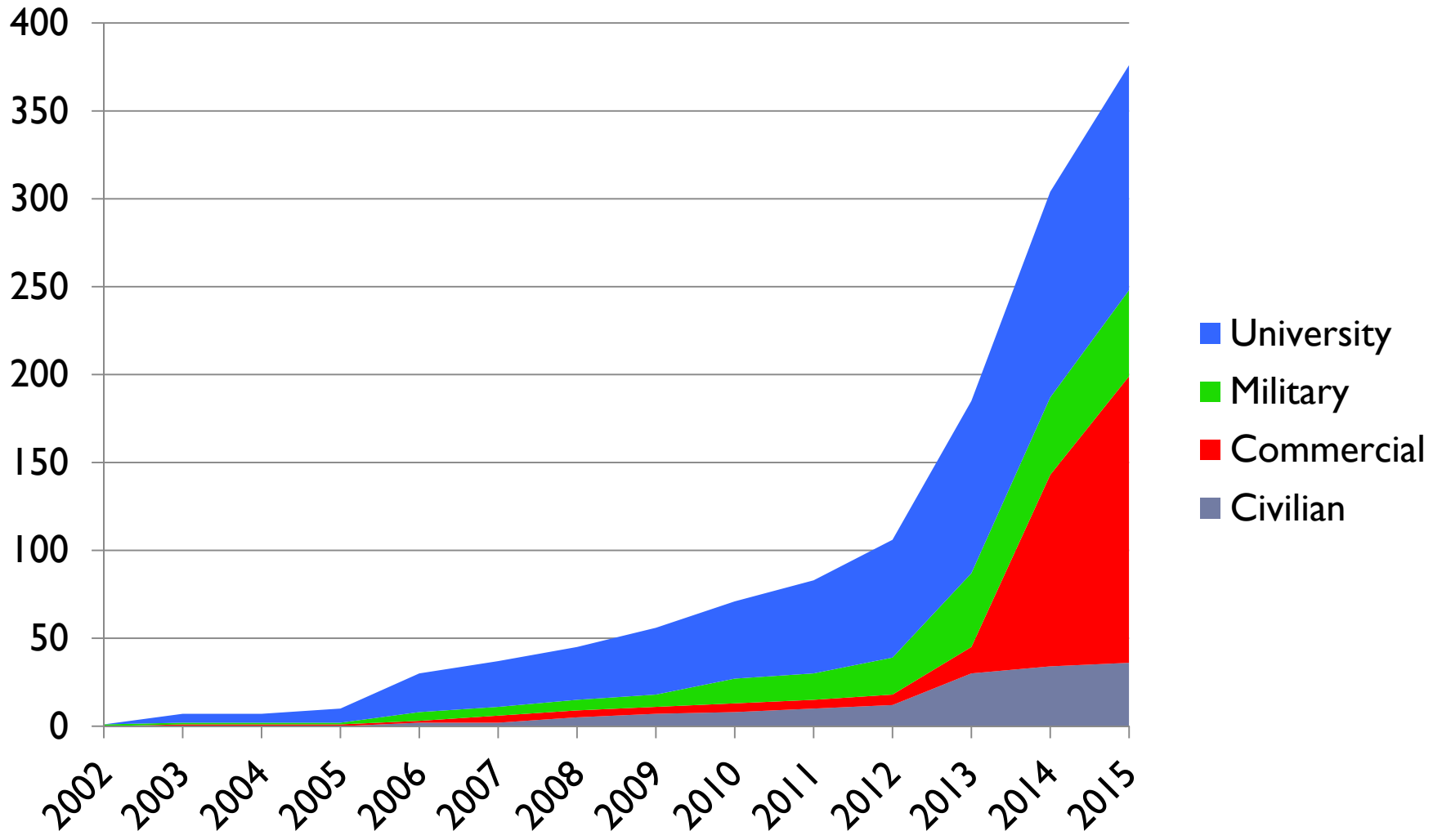
Communication

~50 CubeSats lost in launch failures

Slide 3

b1 Should this include data through 2015? SInce we have it already? It is in the report
blal, 10/14/2015

CubeSats: Cumulative Increase by Sector



Key Elements of Charge

- Review the current state of scientific potential and technological promise of CubeSats
- Review the potential of CubeSats as a platform for obtaining high-priority science data
  - From recent decadal reviews
  - Science priorities in 2014 NASA Science plan
- Provide a set of recommendations on how to assure scientific return on future federal agency support of CubeSat programs

Committee Actions

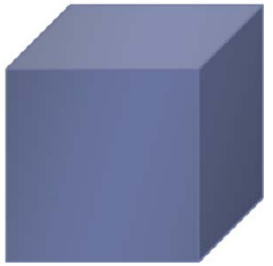
- Develop summary of status, capability, availability and accomplishments in government, academic and industrial sectors
- Recommend any potential near-term investments that could be made to
  - A) improve the capabilities that have a high impact and return
  - B) enable the science communities' use of CubeSats
- Identify a set of sample priority science goals that describe near-term science opportunities

Work Plan

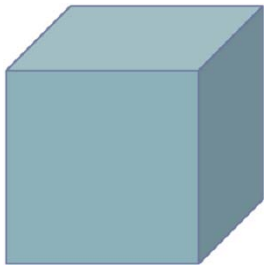
- Ad Hoc Committee has ~ 15 scientists and engineers
- Initial information gathering symposium of 1-3 days, and other input processes such as town hall meetings at conferences
- Meet as a committee to further gather input and synthesize what is learned about
  - Status of CubeSats in research, innovation, and education
  - Funding sources, programs, etc.
  - Enabling technologies, etc.
  - Developments in industry
  - Evolutionary path of CubeSats, etc.
  - Limitations, barriers of this technology, etc.
  - Policy challenges
- Anticipated completion Spring of 2016

Approach

- First two meetings focused on collecting data
  - CubeSat launches, successes etc.
  - Publication numbers, characteristics, etc.
  - Policy issues
  - Best science ideas for CubeSats today
  - Type of science addressed by CubeSats

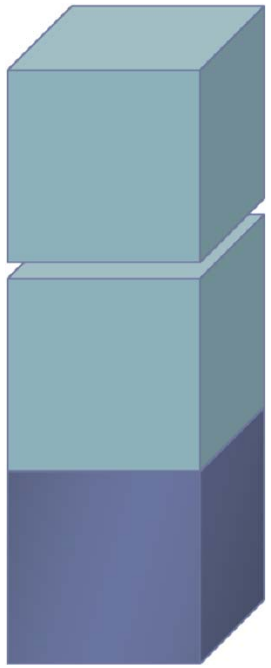


- Then, integration towards findings, conclusions and recommendations



Meetings Held To Date

- Meeting #1: June 20-21, 2015 in DC
  - NSF, NASA, DOD, USGS, NOAA statements
  - Policy issues: debris and communications
- Meeting #2: September 2-3, 2015 in Irvine
  - Community symposium
  - Science focus
  - Committee-only meeting on September 4
- Meeting #3: October 22-23, 2015
  - Focus on integration, recommendation
- Meeting #2a: October 28, 2015 with CBPSS
  - Microgravity Research on CubeSats
- Meeting #4: October 30, 2015
  - Policy focus



Overall Symposium Participation

- ~125 participants not including the committee
- 60 poster submissions

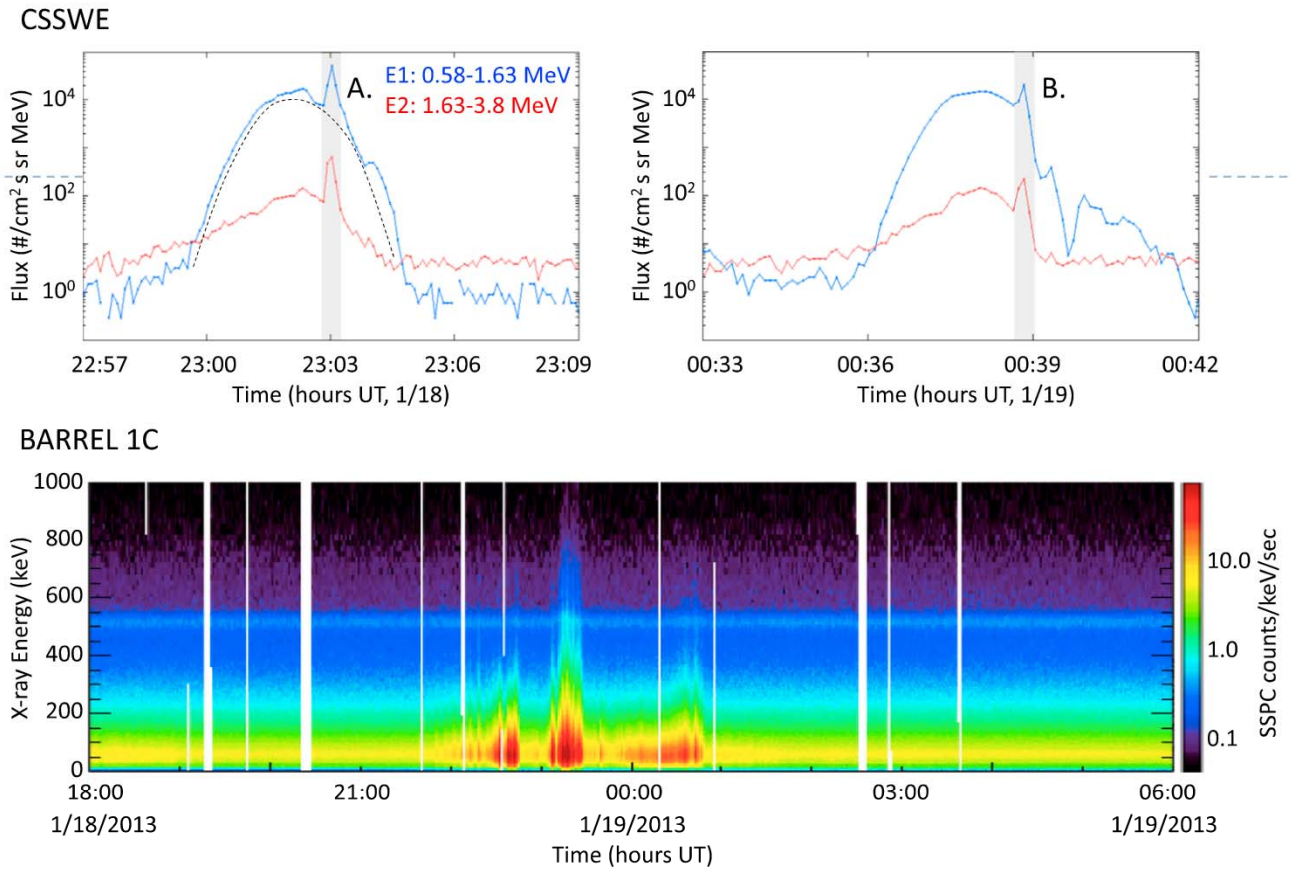
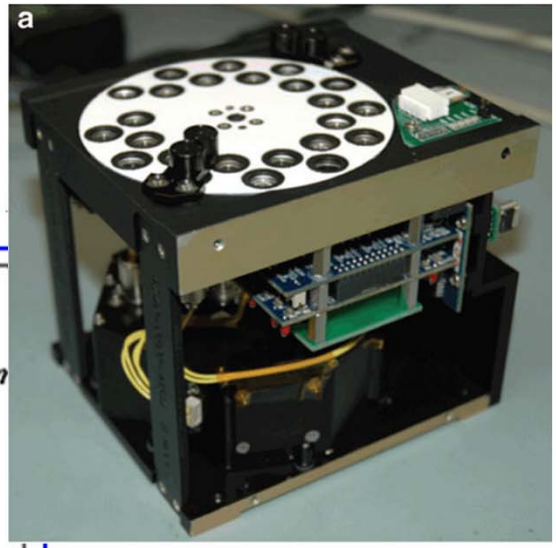
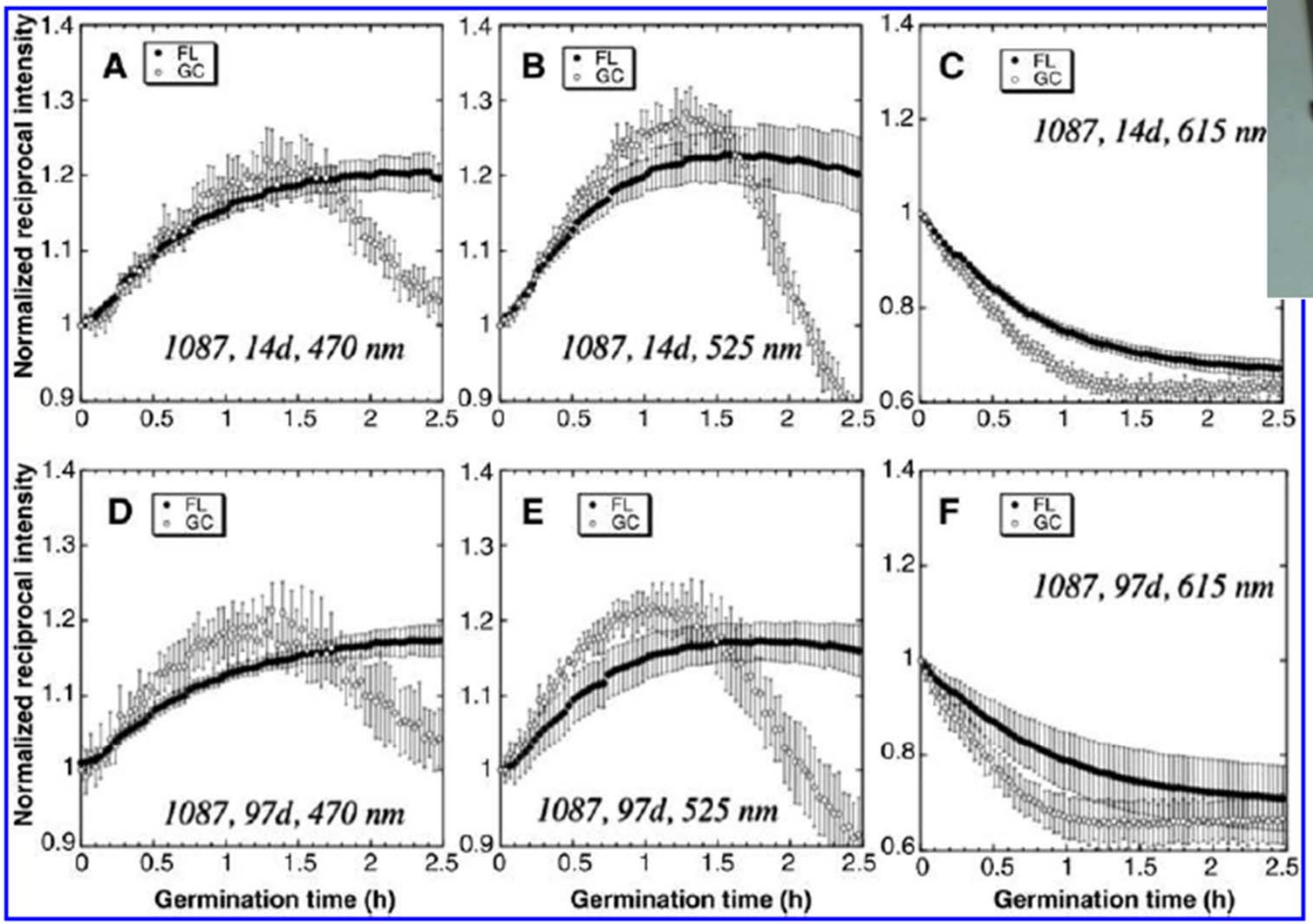


Figure 1. (top) Measurements from the CSSWE CubeSat and (bottom) BARREL balloon 1C during a precipitation event on 18–19 January 2013. CSSWE measures two precipitation bands (labeled A and B and indicated by the shaded grey regions) on two consecutive passes through the outer belt. The dashed black line suggests the background trapped and bounce loss cone flux upon which the precipitation bands are superimposed. (bottom) X-ray spectra from balloon 1C are shown from 18:00 UT 18 January through 06:00 UT 19 January. During this time, three main precipitation events are measured by the balloon, the second two showing X-rays of energies >0.5 MeV. No background subtraction has been applied here to either the BARREL or CSSWE measurements.

Blum et al., 2013





Nicholson et al., 2011

FIG. 4. SESLO data, *B. subtilis ykoUykoV* mutant strain WN1087 spores. Flight (FL; filled circles) and ground control (GC; open circles) data for SESLO bioblock module 1, activated at Day 14 post-launch (top row **A–C**) and bioblock module 2 activated at Day 97 post-launch (bottom row **D–F**). Data were taken at 470 nm (A, D), 525 nm (B, E), and 615 nm (C, F). Data points are averages ± standard deviations ($n=4$ for B/FL; $n=5$ for E/FL; $n=6$ for all others).

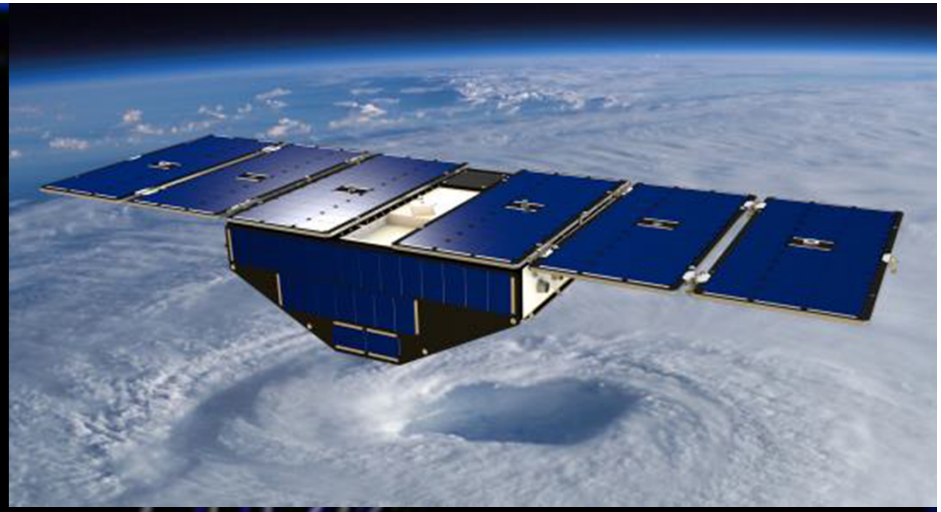
Policy-Centered Meeting

- Goal - Understand the key policy issues/challenges that could throttle the development of science-focused CubeSats
  - Focus on orbital debris, spectrum, and ITAR issues specific to CubeSats
- Invited government and industry leaders to explore policy issues
  - Domestic and international challenges and solutions
  - Role of the private sector
- Opening keynote address by Tom Kalil (OSTP). All relevant government agencies participated – DOD (OSD and JSpOC), NASA, FAA, FCC, and NOAA
  - Also participating: private sector (AGI) and universities (USRA); attendees included other private actors

Issues Considered

- NSF Geophysics was first program to support CubeSats. What is the NSF CubeSat function now?
- Proliferation of CubeSat programs at NASA
  - Broad and fast innovation vs. Coordination
  - Cultural issues – why do small sats matter in a big sat world?
- (Re)-emergence of U-class missions: Venture Class
  - New types of missions are possible now based on CubeSat technology
- Potential chokepoints for the development of science CubeSats
  - Debris, spectrum, or launch constraints

CYGNSS



GPS satellites

CYGNSS Observatories

Upcoming

- Closed committee conference calls to discuss and finalize recommendations
- Meeting #5: January 16-17, 2016 ISSI forum
  - International focus
- Meeting #6, tentative: January 28-29, 2016
  - Focus on completion of report

- We are on schedule for a timely delivery in March-April time-frame

Questions, Comments?