# Using a Constellation of CubeSats to Conduct Thermospheric Science: The QB50 Mission

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### The Vision circa 2000



PC104



CubeSat 1kg/1L



**Bob Twiggs** 

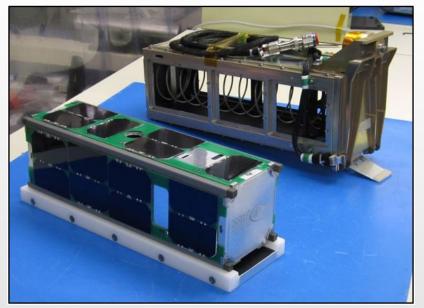
The Problem: How to launch these satellites?

# The solution



The PPOD
A containerized dispenser

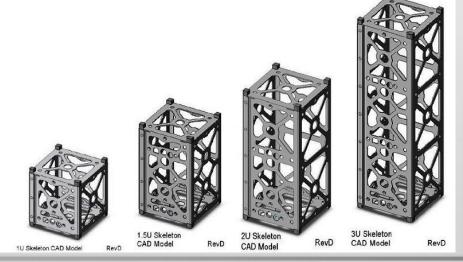
### For Reference







Density 1kg/L



## Key Events in CubeSat Evolution

2000 – Opal Nanosatellite Deployment of Picosatellites

~2000 – Bob Twiggs proposes CubeSat Standard

2003 – First PPOD deployment [Rokot-KM, 6 CubeSats]

2006 - First US CubeSat launch [Minotaur-1, GENESAT]

2007 – NSF CubeSat program created

2008 – First SpaceX PPOD deployment

2008 - NASA Announces CRS-1

2010 - NASA ELaNa Program created

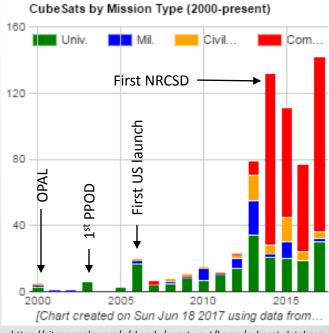
2012 - First ULA ABC deployment [11 CubeSats]

2014 – First Nanoracks ISS deployment [26 Doves]

2016 – ULA announces ABC on all future launches

2017 – 101 CubeSats Deployed from PSLV-XL

"In addition to the increase for CubeSat funding to \$10 million, about \$30 million in funding is slated for the Small Satellite Constellation initiative to investigate the use of small satellite constellations to observe the Earth." 3/31/16



https://sites.google.com/a/slu.edu/swartwout/home/cubesat-database

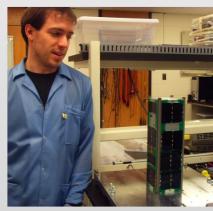


### The NSF CubeSat Program

- Program conceived in 2007
- First solicitation in 2008
- Supported 20 Cubesats

FY	Projects	Selected	%
2008	29	2	6.9%
2009	26	4	15%
2010	23	2	8.7%
2012	23	1	4.3%
2014	21	3	14%

### No competition in 3 years



Name	Investigators	Science Target			
RAX	SRI, U Michigan	Auroral turbulence			
DICE	ASTRA, Utah State	Stormtime E fields, plasma density			
CINEMA	UC Berkeley	Energetic particle inputs & neutral drivers			
CSSWE	U Colorado	Outer belt, solar energetic protons and electrons			
FIRE BIRD-I, -II	UNH, Montana State	Relativistic electron bursts			
FIREFLY	Siena College, GSFC	Terrestrial gamma ray flashes			
CADRE	U Michigan	Thermospheric composition & dynamics			
EXO-CUBE	Scientific Sol's, U Wisc., Cal Poly, GSFC	Exospheric structure & dynamics			
LAICE	U Illinois, VT	Gravity waves – IT coupling			
QBUS	U Colorado, Stanford, U Michigan, U Turabo	Thermospheric composition & dynamics			
ELFIN	UCLA, Aerospace Corp	Electron loss from radiation belt (NSF/NASA)			
IT-SPINS	Montana State, APL, SRI	1 <sup>st</sup> 2D images of O+ comp in the topside transition region			
ISX	Cal Poly, SRI	Ionospheric scintillations from equatorial spread-F			
Tryad	U of Auburn, U of AL- Huntsville	Terrestrial gamma ray flashes, triangulation			



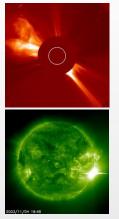


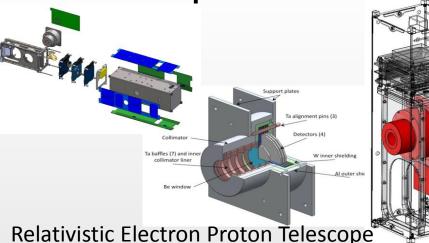
# Colorado Student Space Weather Experiment

### The Colorado Space Weather Experiment

### **Objectives**

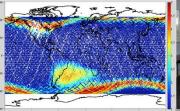
To understand the relationships between solar energetic particles (SEPs), flares, and coronal mass ejections (CMEs), and to characterize the variations of the Earth's radiation belt electrons.







- Funded by the NSF
- Launched in 2012, NROL-36
- 3mo primary mission, operated for 28mo
- Collected over 100MB of Science Data
- Coordinated in AES projects course
- Generated 19 peer reviewed publications



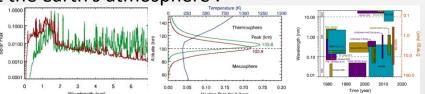




### The Miniature X-ray Solar Spectrometer

### **Objectives**

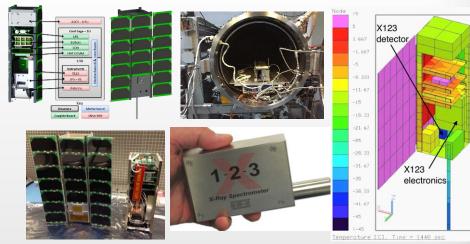
Observe the Sun, specifically the intensity of the soft X-ray spectrum from 0.4 keV (30 Å) to 30 keV (0.4 Å), with a resolution of 0.15 keV. These observations will be used to better understand how soft X-ray flares effect the earth's atmosphere .











- First NASA SMD CubeSat
- Launched Dec 6, 2015, OA-4 to ISS
- Deployed May 2016
- Achieved full success and still operating
- S/N 001 BCT XACT Demonstrated ~10 arcsec pointing
- Coordinated in AES projects course
- MinXSS-2 scheduled to launch 2Q17





### **QB50**

### An International Network of Double and Triple CubeSats

in a string-of-pearls configuration for multi-point, in-situ, long-duration exploration of the lower thermosphere (200-380 km), for re-entry research and for in-orbit demonstration of technologies and miniaturised sensors.





36 CubeSats built by 16 different countries \$9M EU investment 300 students involved from around the world Conducting lower thermosphere science

## Mid Latitude and High Latitude

28 CUBESATS FROM THE INTERNATIONAL SPACE STATION



**8 CUBESATS ON THE PSLV INDIAN ROCKET** 



PSLV Rocket from Satish

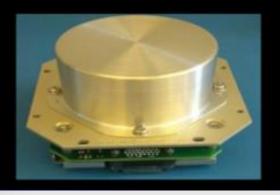
Dhawan Space Centre

PSLV launch scheduled June 23, 2017 [0359 GMT]
https://spaceflightnow.com/launch-schedule/



### QB50 Science Instruments

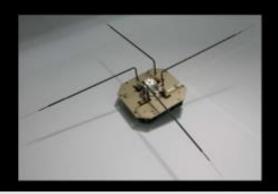
10 INMS – Ion/Neutral Mass Spectrometer



14 FiPEX – Flux Probe EXperiment



10 mNLP – multi Needle Langmuir Probe



- Designed for ionosphere thermosphere science
- Miniaturized to fit on a CubeSat [low SWaP]
- Development supported by the EU
- A suite of TRL-9 IT instruments

- INMS MSSL University College London
- FIPEX TU Dresden
- Langmuir Probe U Oslo

### **QBUS**

- US QB50 Consortium
  - Four Universities
  - ITM science expertise
  - Prior CubeSat experience
  - Over 100 students involved





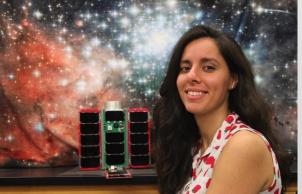














# QB50 QBUS – University of Colorado

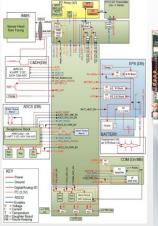


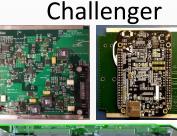


### Objectives

The QB50 project is an initiative born out of the European von Karman Institute that aims to deploy approximately fifty CubeSats into LEO in order to conduct multipoint, in-situ, measurements of the lower thermosphere.

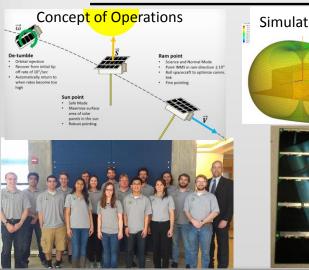


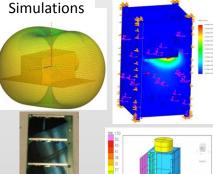


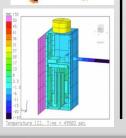




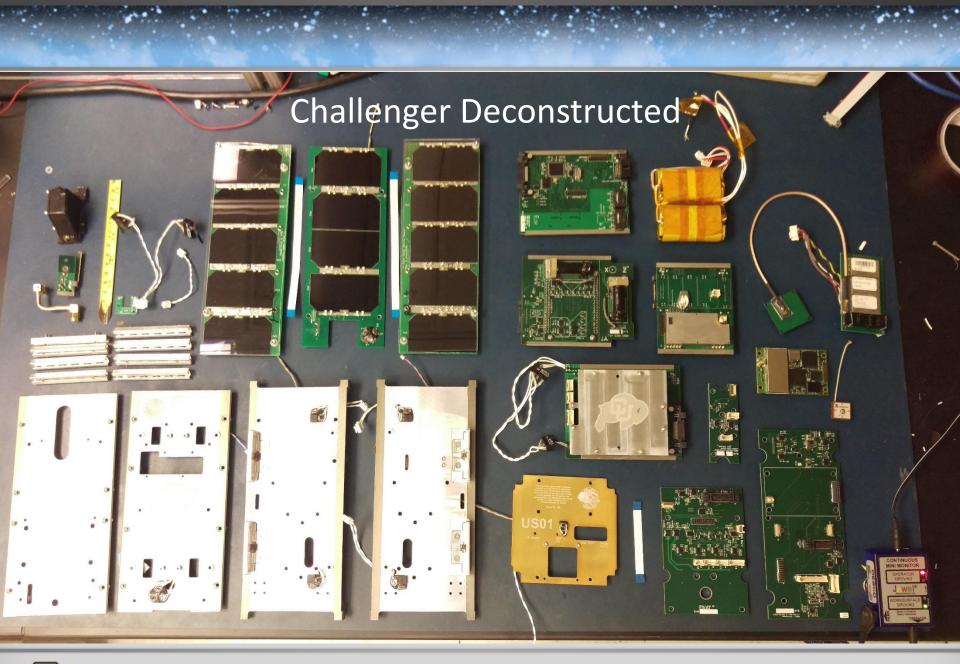




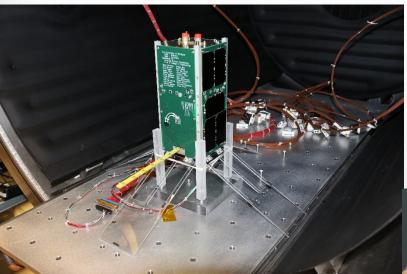




- Funded by NSF (\$180K)
- 2016-04-18 OA-7 launch
- 2016-05-25 ISS deployment
- 6-9mo orbital lifetime
- Builds on CSSWE and MinXSS Heritage
- New CU constructed ADCS system
- University College London constructed ion neutral mass spectrometer (INMS)
- Coordinated in AES projects course



# QBUS - University of Michigan

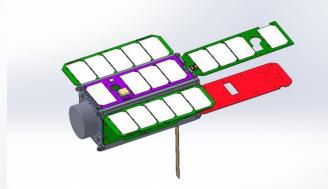


- PI Aaron Ridley
- Two CubeSats
  - Columbia and Atlantis
- Dart configuration
- Flying TU Dresden FIPEX [0, 02] probe

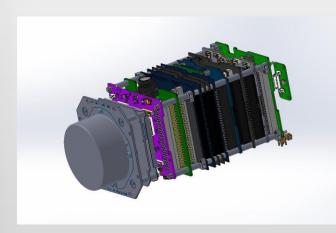


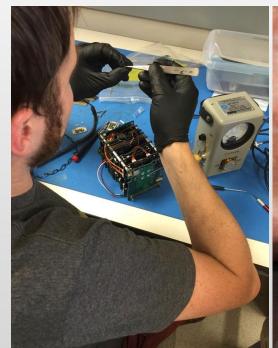
# QBUS - Stanford

- PI Sigrid Close
- One CubeSats
  - Discovery
- Using U Stellenbach (Q50 ADCS)
- Flying UCL INMS











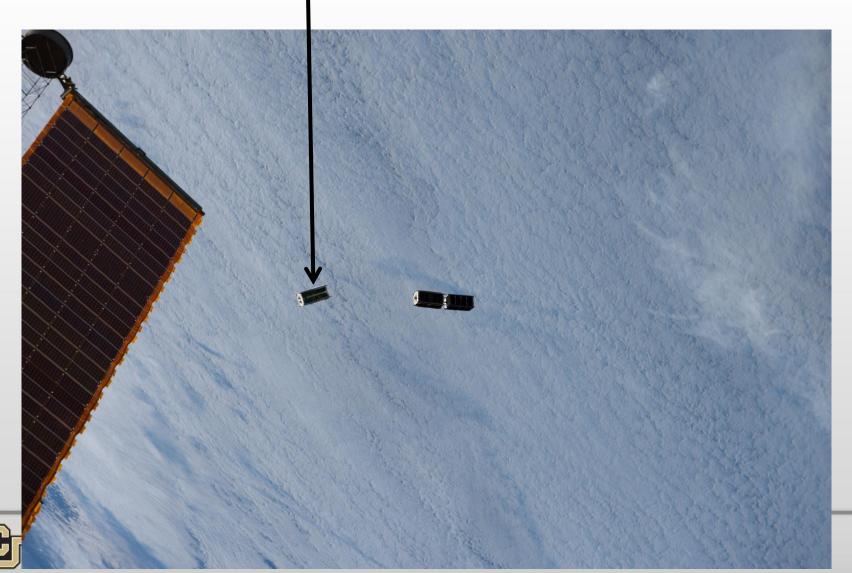




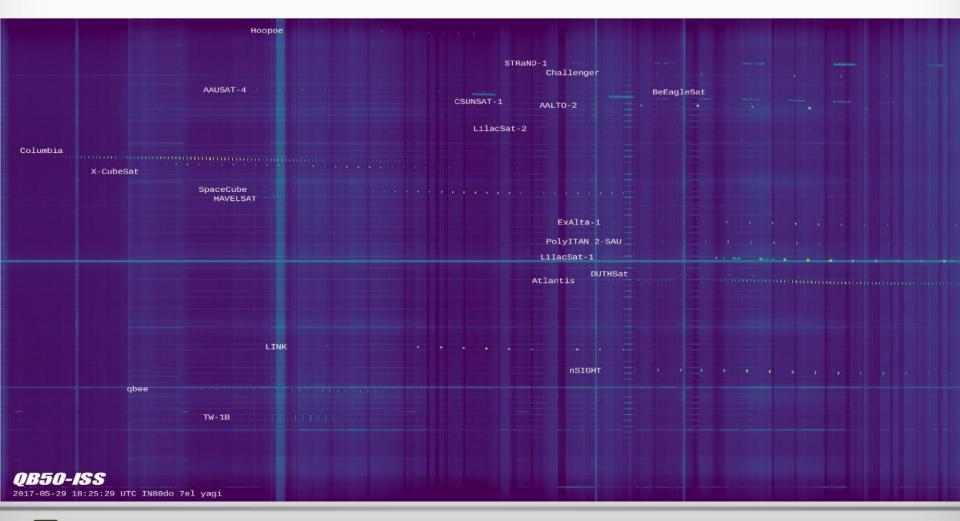
# 28 Satellites on OA-7 launch

QB50 ID	Satellite Name	Satellite Callsign	Country	Launch	Deployment batch	Deployment order	Position in the pod (1=first out)	Deployment date/time (UTC)	Size	QB50 sensor
DE02	SOMP2	ON02DE	Germany	ISS	1	1	1	16/05/17, 08:25	2U	FIPEX
TR02	HAVELSAT	ON02TR	Turkey	ISS	1	1	2	16/05/17, 08:25	2U	mNLP
US04	Columbia	ON04US	USA	ISS	1	1	3	16/05/17, 08:25	2U	FIPEX
TW01	PHOENIX	ON01TW	Taiwan	ISS	1	2	1	17/05/17, 01:45	2U	INMS
FR01	X-CubeSat	ON01FR	France	ISS	1	2	2	17/05/17, 01:45	2U	FIPEX
SE01	qbee	ON01SE	Sweeden	ISS	1	2	3	17/05/17, 01:45	2U	FIPEX
AZ01	ZA-AEROSAT	ON01AZ	South Africa	ISS	1	3	1	18/05/17, 01:00	2U	FIPEX
KR01	LINK	ON01KR	South Korea	ISS	1	3	2	18/05/17, 01:00	2U	INMS
GR02	UPSat	ON02GR	Greece	ISS	1	4	1	18/05/17, 08:25	2U	mNLP
FR05	SpaceCube	ON05FR	France	ISS	1	4	2	18/05/17, 08:25	2U	FIPEX
IL01	Ноорое	ON01IL	Israel	ISS	1	4	3	18/05/17, 08:25	2U	mNLP
US01	Challenger	ON01US	USA	ISS	2	5	1	25/05/17, 5:25	2U	INMS
CN03	NJUST-1	ON03CN	China	ISS	2	5	2	25/05/17, 5:25	2U	FIPEX
AU02	UNSW-EC0	ON02AU	Australia	ISS	2	5	3	25/05/17, 5:25	2U	INMS
GR01	DUTHSat	ON01GR	Greece	ISS	2	6	1	25/05/17, 08:45	2U	mNLP
CN02	LilacSat-1	ON02CN	China	ISS	2	6	2	25/05/17, 08:45	2U	INMS
AZ02	nSIGHT	ON02AZ	South Africa	ISS	2	6	3	25/05/17, 08:45	2U	FIPEX
ES01	QBITO	ON01ES	Spain	ISS	2	7	1	25/05/17, 11:55	2U	INMS
FI01	Aalto-2	ON01FI	Finland	ISS	2	7	2	25/05/17, 11:55	2U	mNLP
AU01	SUSat	ON01AU	Australia	ISS	2	7	3	25/05/17, 11:55	2U	INMS
KR03	SNUSAT-1b	ON03KR	Korea	ISS	2	8	1*	25/05/17, 23:40	2U	FIPEX
AU03	i-INSPIRE II	ON03AU	Australia	ISS	2	9	1	26/05/17, 04:00	2U	mNLP
UA01	KPI-SAU-1	ON01UA/QBUA01	Ukraine	ISS	2	9	2	26/05/17, 04:00	2U	FIPEX
KR02	SNUSAT-1	ON02KR	Korea	ISS	2	9	3	26/05/17, 04:00	2U	FIPEX
CA03	ExAlta-1	ON03CA	Canada	ISS	2	10	1*	26/05/17, 08:55	3U	mNLP
CN04	Ao Xiang-1	ON04CN	China	ISS	2	11	1	26/05/17, 12:15	2U	INMS
TR01	BEEAGLESAT	ON01TR	Turkey	ISS	2	11	2	26/05/17, 12:15	2U	mNLP
US02	Atlantis	ON02US	USA	ISS	2	11	3	26/05/17, 12:15	2U	FIPEX

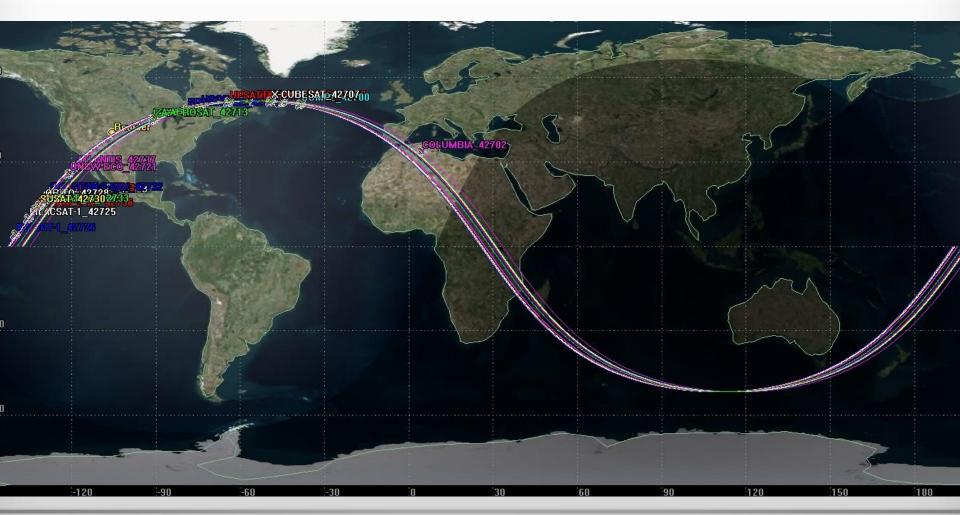
# US04 – Columbia being deployed



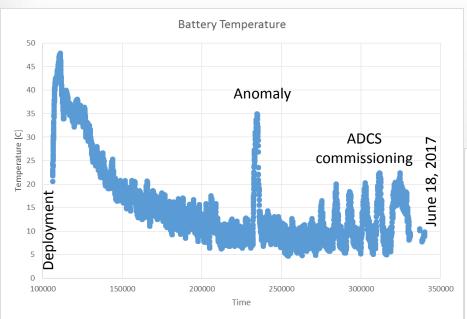
# QB50 Spectrum



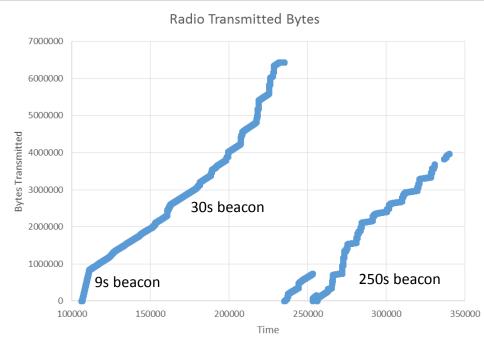
# QB50 Constellation at 11:23 Today



# Challenger Data

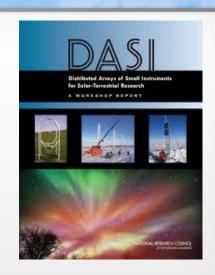


### Currently in commissioning mode



### QB50 Status and Plans

- First CubeSat science constellation
- Providing distributed IT measurements
- DASI in space
- Challenger, Columbia & Atlantis in commissioning
- Discovery to launch soon
- Orbital lifetime ~ 1 year
- Science opportunities
  - Science Phase 1 Aug thru Sept 2017
  - Science Phase 2 Jan thru Mar 2018



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NASA HQ PHOTO O @na.

@QB50Challenger



Tweets & replies

Dr Chris Bridges @DrChrisBridges - Jun 13

nateurs showing very real passion / skills in R&D #CubeSat missions for

@QB50Mission - thanks Davide for sharing! 73sl @AmsatUK #hamradio

QB50-CubeSat Mission

and lower thermosphere where the

@ Belgium

QB50 will explore scientifically the middle

space weather effects take place with in-

Contact: Scott Palo palo@Colorado.edu