“Revolutionizing the Outside…

…Through Innovation Inside”

(U) CubeSat Experiments (Q_bX)

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CubeSat Workshop – April 2009

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"Revolutionizing the Outside...

...Through Innovation Inside"

(U) Q_bX - Who We Are

- NRO Launch/Integration Support (OSL)
  Capt Derrick Showers
  Roderick Owens (U)
- University Consortium (U)
- Space Test Program (STP)
  Samantha Sims (U)
- DARPA
  Neil Fox (U)
- NASA
  Pete Klupar (AMES)
  Garrett Skrobot (KSC) (U)
- AF ORS
  Steve Buckley (U)

(U)
Q_bX Program Manager
Patrick Bournes (SSTLL)

Q_bX Technical Lead
Dave Williamson (AS&T)

Technical Advisors
David Hinkley (Aerospace)
Sigfried Jansen (Aerospace) (U)

(U)
Project A
Work Force Development

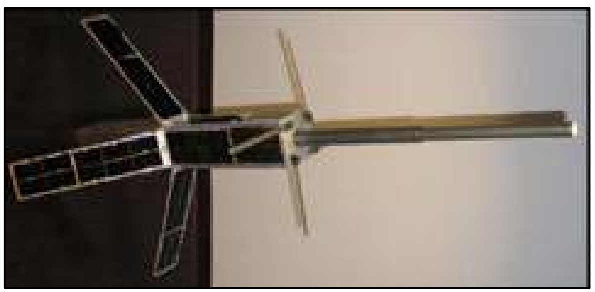
(U)
Project B
Technology Maturation

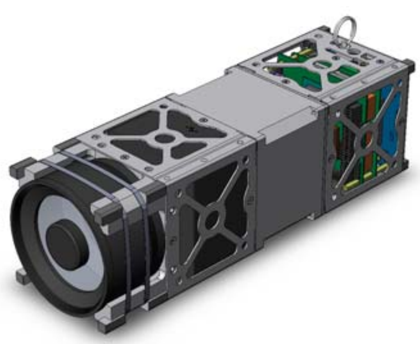
- Innovative Experiments Initiative (IEI)

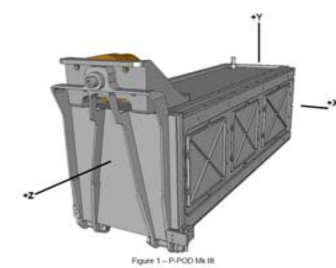
(U)

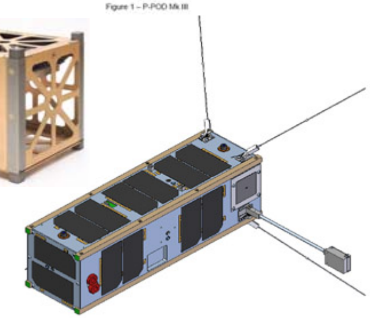
Q_bX – What it is

- NRO’s CubeSat program
- Monitor and enable CubeSat technologies for NRO missions
- Organize and facilitate innovation
- Enable launch opportunities









Why the NRO Needs Q_bX

- Advocate/Coordinate/Facilitate the rapidly growing interest in CubeSats:
  - e.g., AS&T/ATG, NRO/OSL, LANL, NASA, US Army SMDC, NSF, DARPA, ORS, AFRL, Others…
- Monitor, promote and be a harbinger of the world-wide Cubesat revolution:
  - Foreign Nations currently lead in CubeSat technology, launches, and subsystems
  - In the footsteps of the USSR's *Sputnik* (1957) and the US *Explorer 1* – **A new "space-race" has begun!!**
  - Do we lead the Cubesat revolution or do we become a victim of it?

Argentina	Australia	Brazil	Canada
China	Colombia	Denmark	Germany
India	Italy	Japan	Malaysia
Netherlands	Norway	Poland	Portugal
Romania	Saudi Arabia	South Africa	South Korea
Spain	Switzerland	Taiwan	Turkey
Ukraine	United Kingdom	US	…Others?

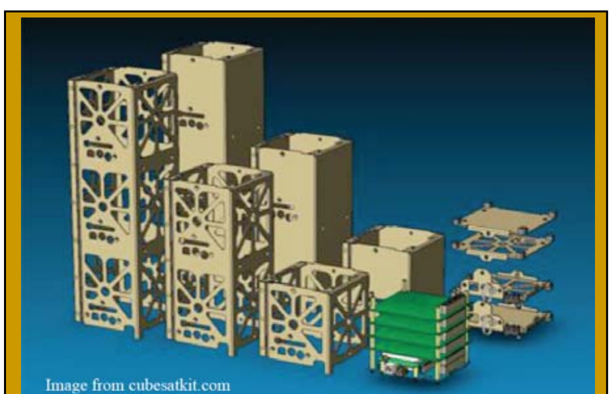
"Revolutionizing the Outside… …Through Innovation Inside"

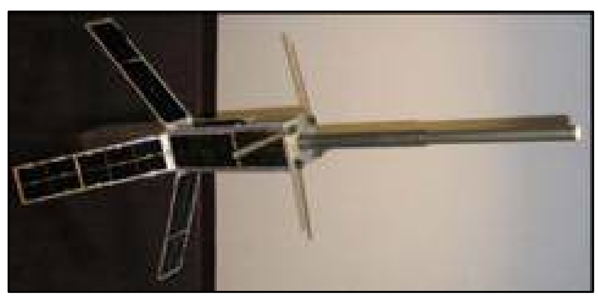
What are CubeSats?

- Proposed in 1999 by Stanford Prof. Bob Twiggs as a picosatellite standard:
  - 10 x 10 x 10cm, ~ 1 kg maximum mass; can be combined to create multiple "U" cubes (e.g., double, triple, etc…)
  - Larger formats are being considered (e.g., up to 10 x 20 x 30cm)
  - Standard mechanical interface requirements
  - Standard CubeSat deployer developed and flown (P-POD)
  - 46 CubeSats launched to date from various launch vehicles (including two spacecraft)
- Broad acceptance, large active developer list:
  - 53 U.S. companies; 50 U.S. universities, several high schools
  - 41 foreign universities on six continents
  - 32% of papers at '08 SmallSat Conference were CubeSat related

CUTE 1.7 + APD (Tokyo Tech. University)

CP4 (CalPoly) as seen from AeroCube-2 (Aerospace)





QuakeSat-1 (Stanford University and QuakeFinder, LLC)

CSTB1 (The Boeing Corporation)

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CubeSat Launches to Date (1 of 2)

Launch Date	Mission Name	Organization	Mission Country	Launch Vehicle	Country of Launch	Success Score	Comment
1/26/00	PICOSAT1 (aka. MEPSI-1) (2 sc)	Aerospace/AFRL/DARPA	US	JAWSAT/OPAL SC	US		
9/7/01	PICOSAT1.1(aka. MEPSI-2) (2 sc)	Aerospace/AFRL/DARPA	US	Minotaur 1/MightySat2.1 SC	US (Vandenburg)		
12/2/02	MEPSI-3 (2 sc)	Aerospace/AFRL/DARPA	US	Space Shuttle (STS-113)	US (Cape)		
6/30/03	CUTE-1	Tokyo Inst. Of Technology	Japan	Rockot	Russia (Plesetsk)		
6/30/03	DTUsat-1	Tech. U. of Denmark	Denmark	Rockot	Russia (Plesetsk)		
6/30/03	AAUsat	Alborg U.	Denmark	Rockot	Russia (Plesetsk)		
6/30/03	QuakeSat	QuakeSat, LLC/Stanford	US	Rockot	Russia (Plesetsk)		
6/30/03	CanX-1	U. of Toronto	Canada	Rockot	Russia (Plesetsk)		
6/30/03	CUBESAT XI-IV	U. of Tokyo	Japan	Rockot	Russia (Plesetsk)		
10/27/05	CUBESAT XI-V	U. of Tokyo	Japan	Kosmos-3M	Russia (Plesetsk)		
10/27/05	NCUBE-2	Norwegian U. of S&T	Norway	Kosmos-3M	Russia (Plesetsk)		
10/27/05	UWE-1	U. of Wurzburg	Germany	Kosmos-3M	Russia (Plesetsk)		
2/21/06	CUTE-1.7+APD	Tokyo Inst. Of Technology	Japan	M-V-8	Japan (Kagoshima)		
7/26/06	SACRED	U. of Arizona	US	DNEPR	Russia	N/A	Launch Failure
7/26/06	ION	U. of Illinois	US	DNEPR	Russia	N/A	Launch Failure
7/26/06	RINCON	U. of Arizona	US	DNEPR	Russia	N/A	Launch Failure
7/26/06	ICE Cube 1	Cornell U.	US	DNEPR	Russia	N/A	Launch Failure
7/26/06	ICE Cube 2	Cornell U.	US	DNEPR	Russia	N/A	Launch Failure
7/26/06	KUTESat	U. of Kansas	US	DNEPR	Russia	N/A	Launch Failure
7/26/06	nCube-1	Norwegian U. of S&T	Norway	DNEPR	Russia	N/A	Launch Failure
7/26/06	HAUSAT 1	Hankuk Aviation U.	S. Korea	DNEPR	Russia	N/A	Launch Failure
7/26/06	SEEDS	Nihon U.	Japan	DNEPR	Russia	N/A	Launch Failure
7/26/06	CP1	CalPoly	US	DNEPR	Russia	N/A	Launch Failure
7/26/06	CP2	CalPoly	US	DNEPR	Russia	N/A	Launch Failure
7/26/06	AeroCube-1	Aerospace	US	DNEPR	Russia	N/A	Launch Failure
7/26/06	MEROPE	Montana State	US	DNEPR	Russia	N/A	Launch Failure
7/26/06	Voyager	U. of Hawaii	US	DNEPR	Russia	N/A	Launch Failure
9/22/06	HIT-SAT	Hokkaido Inst. of Tech.	Japan	M-V	Japan (Kagoshima)		
12/9/06	MEPSI 2A/2B (2 sc)	Aerospace	US	Space Shuttle (STS-116)	US (Cape)		
12/11/06	GeneSat-1	NASA Ames	US	Minotaur 1	US (Wallops)		
4/17/07	CSTB1	Boeing	US	DNEPR	Russia		
4/17/07	AeroCube-2	Aerospace	US	DNEPR	Russia		
4/17/07	CP3	CalPoly	US	DNEPR	Russia		
4/17/07	CP4	CalPoly	US	DNEPR	Russia		
4/17/07	Libertad-1	U. Sergio Arboleda	Columbia	DNEPR	Russia		
4/17/07	CAPE1	U. of Louisiana	US	DNEPR	Russia		
4/17/07	MAST (3 sc)	Tethers Unlimited/Stanford	US	DNEPR	Russia		

"Revolutionizing the Outside... ...Through Innovation Inside"

CubeSat Launches to Date (2 of 2)

Launch Date	Mission Name	Organization	Mission Country	Launch Vehicle	Country of Launch	Success Score	Comment
28-Apr-08	CanX-2	U. of Toronto	Canada	PSLV	India (Sri Harikota)		
28-Apr-08	CanX-6	U. of Toronto	Canada	PSLV	India (Sri Harikota)		
28-Apr-08	Delfi-C3	Delft U. of Tech.	Netherlands	PSLV	India (Sri Harikota)		
28-Apr-08	CUTE-1.7+APD2	Tokyo Inst. Of Technology	Japan	PSLV	India (Sri Harikota)		
28-Apr-08	AAUSat-2	Alborg U.	Denmark	PSLV	India (Sri Harikota)		
28-Apr-08	Compass-1	Fachhoch Aachen	Germany	PSLV	India (Sri Harikota)		
28-Apr-08	SEEDS-2	Nihon U.	Japan	PSLV	India (Sri Harikota)		
3-Aug-08	PreSat	NASA Ames	US	Falcon 1	US (Kwajalein)	N/A	Launch Failure
3-Aug-08	NanoSail-D	NASA Marshall	US	Falcon 1	US (Kwajalein)	N/A	Launch Failure
14-Sep-08	PharmaSat	NASA Ames	US	Minotaur I	US		
14-Sep-08	CubeSat Tech Demo	NASA Wallops	US	Minotaur I	US		
1-Dec-08	OUFTI-1	University of Liege	Belguim	Vega	ESA		
1-Dec-08	SwissCube	Ecole Plytech Fed Lausanne	Switzerland	Vega	ESA		
1-Dec-08	Xatcobeo	U. ov Vigo; INTA	Spain	Vega	ESA		
1-Dec-08	UNICubeSAT	U. of Rome	Italy	Vega	ESA		
1-Dec-08	Robusta	U. of Montpellier 2	France	Vega	ESA		
1-Dec-08	AtmoCube	U. of Trieste	Italy	Vega	ESA		
1-Dec-08	e-st@r	Politecnico di Torino	Italy	Vega	ESA		
1-Dec-08	Goliat	U. of Bucharest	Romania	Vega	ESA		
1-Dec-08	PW-Sat	Warshaw U. of Technology	Poland	Vega	ESA		
1-Dec-09	ASP-1	NASA Ames	US	Minotaur IV (STP-S26)	US (Kodiak)		
1-Dec-09	Radio Aurora Explorer	NSF	US	Minotaur IV (STP-S26)	US (Kodiak)		

To Be Updated

Why CubeSats?

- Keeps-up with Moore's Law
- Is a world-wide phenomena in which **the US is NOT leading**, but must
- Developers are enthusiastic innovators
- Users are enthusiastic supporters
- Cheapest, quickest, best way to perform specific functions in space:

•Challenging ("world's first") experiments
•Preliminary demonstration of parts/components
•Supplementation of large-scale satellites
•Systems that can be implemented/expanded in groups
•Systems that are needed quickly
•Development of space experts

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Standardization, Modularity, and Expandability

- *Key AS&T concepts –*
  - Advanced *Systems* and Technology,
  - Doing things faster better, cheaper,
  - Increase the pace of innovation,
  - Lead the world in this revolutionary space technology,
  - Different acquisition model for faster product development
- *Enable rapid product development through-*
  - Common interfaces
  - Standardized testing
  - Assured launches
- *"Containerize" access to space-*
  - Any rocket, anywhere in the world (Atlas–Centaurs, ESPA, Minotaurs, Delta, Space-X, Commercial, Stripe, Pegasus, foreign launches(?))

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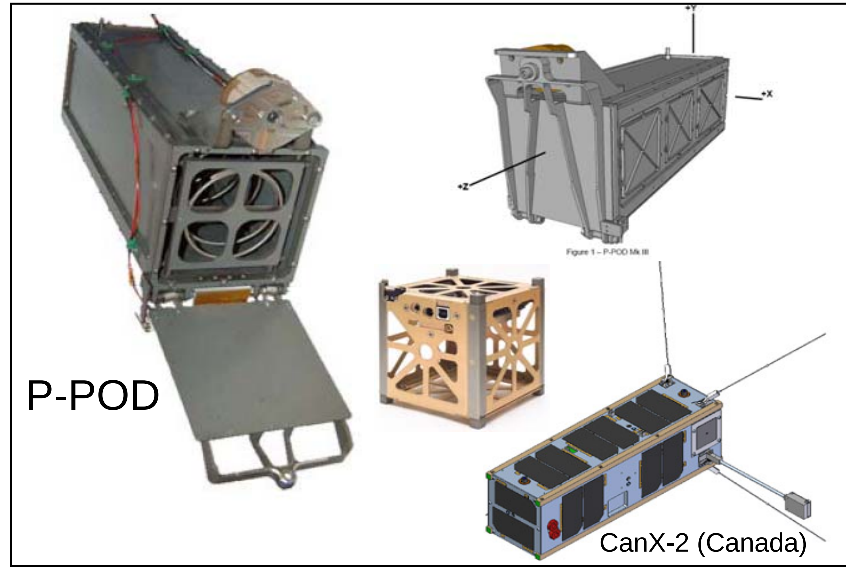
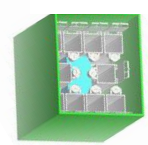
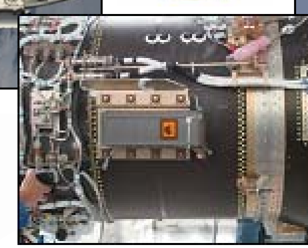
CubeSats Provide - "Containerization" and Standard Interfaces







A Revolution in <u>World-Wide</u> Transport

A Revolution in <u>Space</u> Transport

"Revolutionizing the Outside..."

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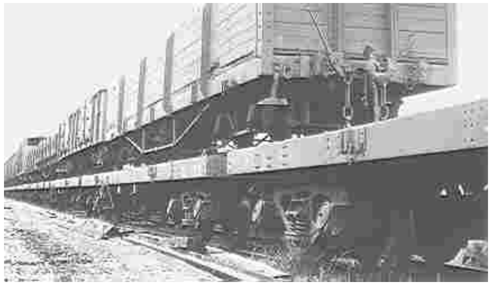
History Lesson 2 - Australian Railroads
A study in what happens if we do not standardize (1 of 4)



Riding Piggy-back to solve the different gauge problems.

- From - http://www.infrastructure.gov.au/rail/trains/history.aspx

"Even before a single rail was laid, and for many years to come, the battle of the choice of railway gauge (distance between the rails) was fiercely fought. The British Parliament recognized the importance of a uniform railway gauge, and passed the Railway Gauge Act of 1846, which prohibits the use of any gauge apart from the standard gauge of 4' 8 1/2" (1435mm). All colonies including Australia were expected to adopt this uniform gauge. Accordingly, on 19th February 1850, an Act was passed in South Australia authorizing the construction of the Adelaide to Port Adelaide Railway to the standard gauge of 4' 8 1/2".

The Sydney Railway Company Engineer from Ireland was able to persuade the authorities that the Irish Broad Gauge of 5'3" was superior. A Bill was passed on 27th June 1852 that the gauge of the NSW Railways be changed to 5'3". Consequently, both the Victorian and South Australian Colonies amended their choice of gauge to match the choice of NSW. On 20th January 1853, Victoria specified 5'3" in the Melbourne to Hobson's Bay Railway Act. South Australia followed with an alteration to their introductory Railway Act as well.

"The Irish Engineer was soon in dispute with the Company and resigned. His position was eventually taken by an engineer from Scotland, who came with vast experience in building standard gauge railways in both Britain and on the Continent. He immediately recommended that for reasons of economy and convenience, the gauge be changed again back to the standard gauge of 4' 8 1/2". Victoria and South Australia immediately protested, as they had already ordered broad gauge locomotives and rolling stock. The NSW engineer refused to change his position, so **as a result of an impasse on the choice of gauges, the problem would plague Australian railways for the next 120 years."**

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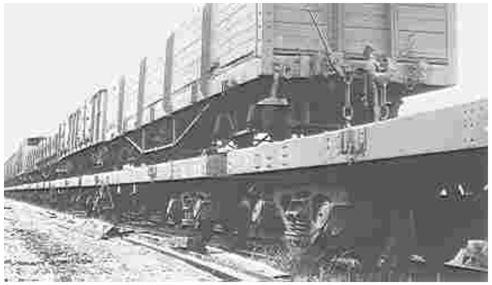
History Lesson 2 - Australian Railroads (Cont)
A study in what happens if we do not standardize (2 of 4)



Riding Piggy-back to solve the different gauge problems.

From: http://www.cultureandrecreation.gov.au/articles/railways/

"Rail gauge incompatibility

When railway construction began in Australia in the 1850s, the engineers favoured the gauge system they were most familiar with: the emerging standard gauge (rails 1,425 millimeters apart) from England and Europe or the broad gauge (rails 1,590 millimeters apart) from Ireland.

A third system of a narrow gauge (rails 1050mm apart) was chosen for Queensland, Tasmania and Western Australia. The narrow gauge system was also used in other states for industries such as timber cutting and mining. The narrow gauges had advantages when working in the mountains as less earth had to be cut out of the side of hills to build the lines.

Despite initial attempts to work together for a uniform approach, ***the colonies were driven by economic and political pressures to develop their own systems.***

When train lines were expanded to travel between states, the lines, equipment and operating practices were incompatible. Passengers and freight would often have to be transferred from one train to another at state borders. ***In 1917, a person wanting to travel from Perth to Brisbane on an east-to-west crossing of the continent had to change trains six times. "***

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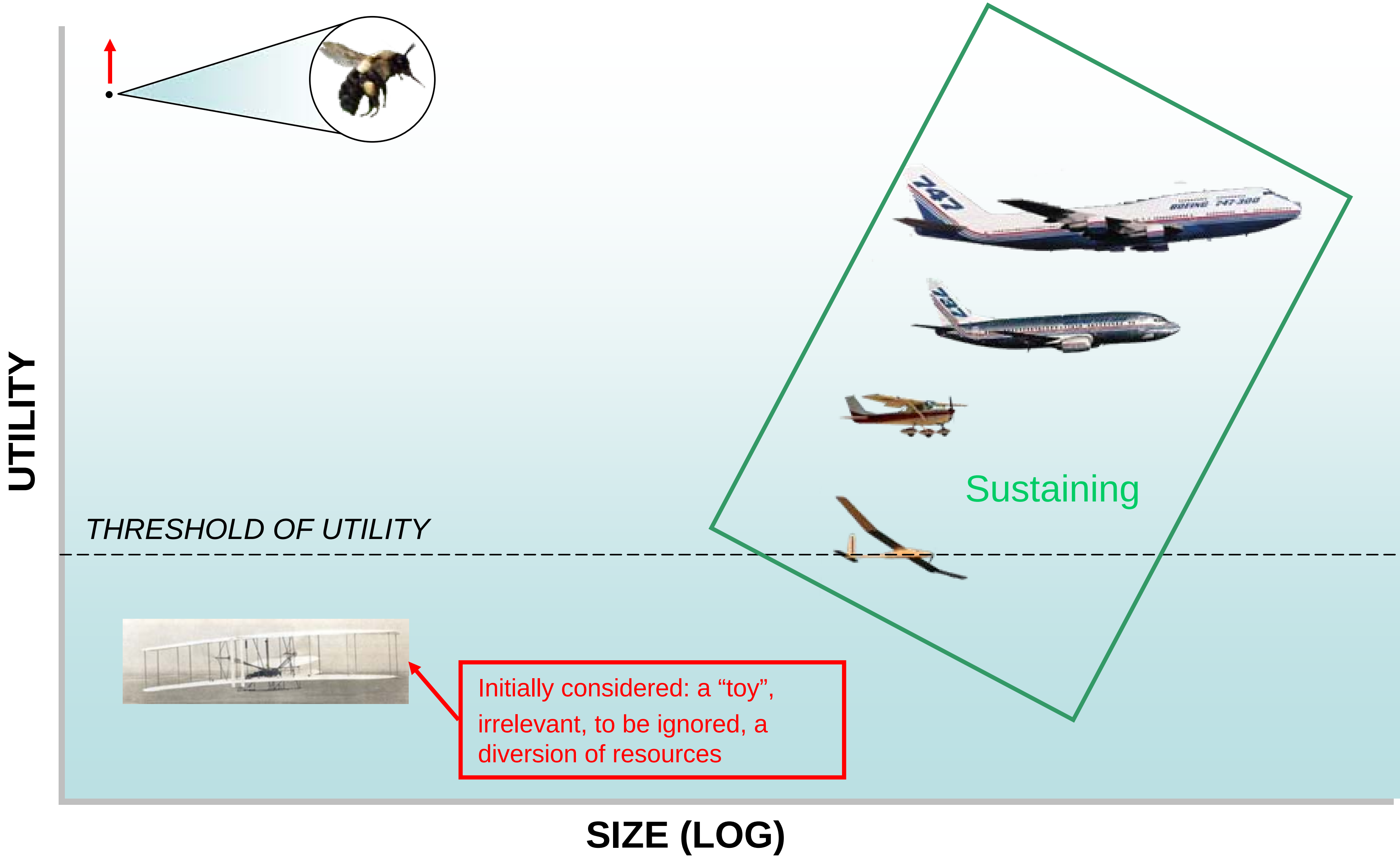
History Lesson 2 - Australian Railroads (Cont)
A study in what happens if we do not standardize (3 of 4)

1. *"the colonies were driven by economic and political pressures to develop their own railroad systems."*
2. *In 1852 an Irish Railroad Engineer convinced the NSW parliament that his railroad gauge was a better technical solution than the common gauge standard*
3. *"as a result of an impasse on the choice of gauges, the problem would plague Australian railways for the next 120 years."*
4. *"In 1917, a person wanting to travel from Perth to Brisbane on an east-to-west crossing of the continent had to change trains six times."*

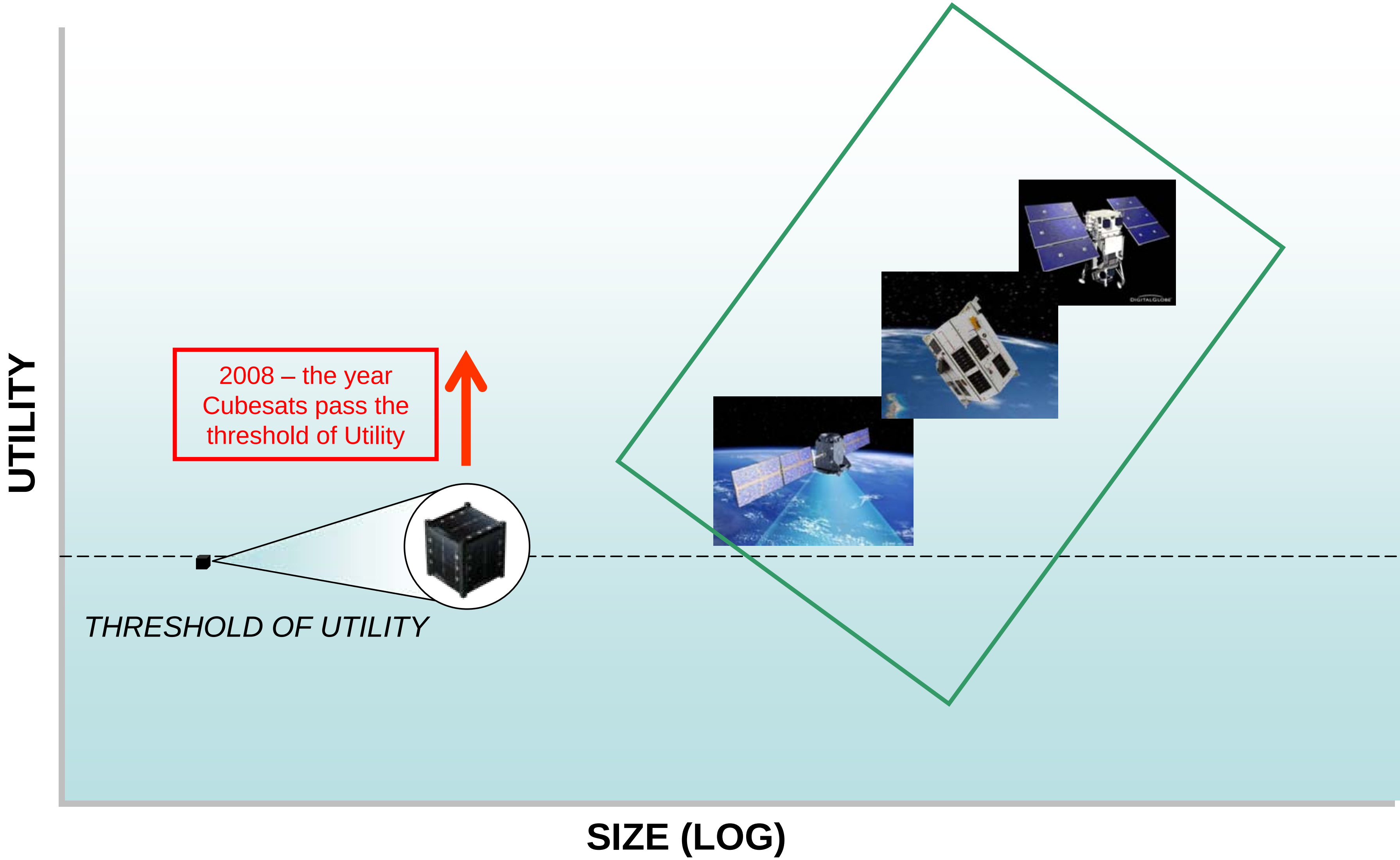
History Lesson 2 - Australian Railroads (Cont)
A study in what happens if we do not standardize (4 of 4)

1. *The Organizations shown have the authority and financial means develop their own Cubesat standards.*
2. *There is already talk of organizations wanting to change the standard to meet individual design preferences*
3. *The organizations have a choice-*
    1. *Are we the 21st century equivalent of the Irish railroad engineer or*
    2. *Do we accept that there is considerable value in the common standard (CAL-Poly P-Pod)?*
4. *It is the intent of the QbX program to stay with the common Cal-Poly P-Pod standard.*

Utility – Can Cubesats be useful?
Air-Breather Analogy



Utility – Can Cubesats be useful? Satellite Comparison



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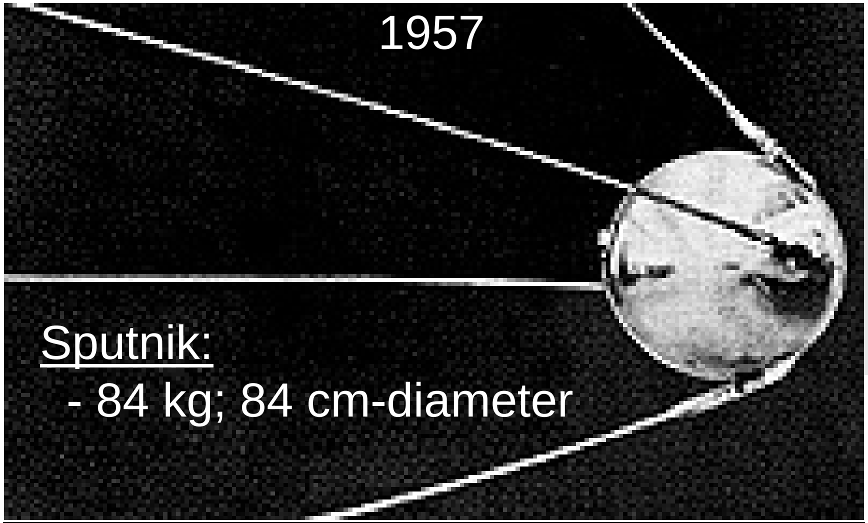
CubeSats Unleash – The Power of Tomorrow



1957

Sputnik:
- 84 kg; 84 cm-diameter

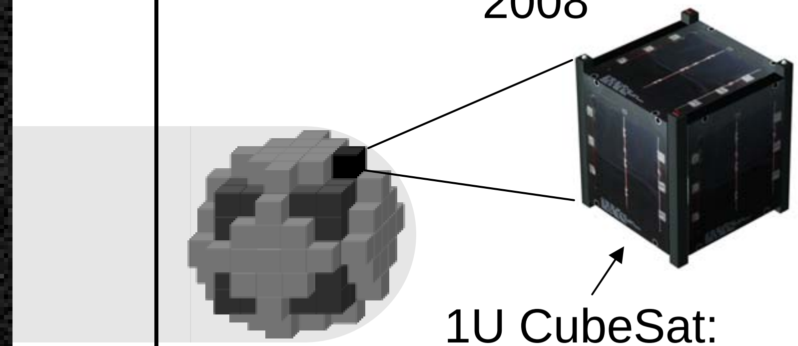
System Contents:
- Single frequency transmitter
- Custom non-standard interface

This is the technology that evolved into satellite systems as we know today.

Approximately 212 CubeSats can fit in the volume of 1 Sputnik, while each CubeSat is orders of magnitude more capable!!

This is the technology that will evolve into satellite systems we will know …tomorrow.

2008



1U CubeSat:
- 1 kg; 10 cm-cube

System Contents (1U):

- Variable frequency half-duplex uplink/downlink; 2 W; >100 kbps rate
- Beacon for tracking and tagging
- GPS; 3-axis ADCS; sun sensors
- Magnetometer; temperature sensors
- > 2 GB flash memory
- 200 – 500 MHz processor; 300 MIPS
- Rechargeable power-system; both fixed and deployable solar panels
- Deployable from multiple platforms (including host SC)
- Designed with standard interfaces

Miniature Imaging Spacecraft (MISC)

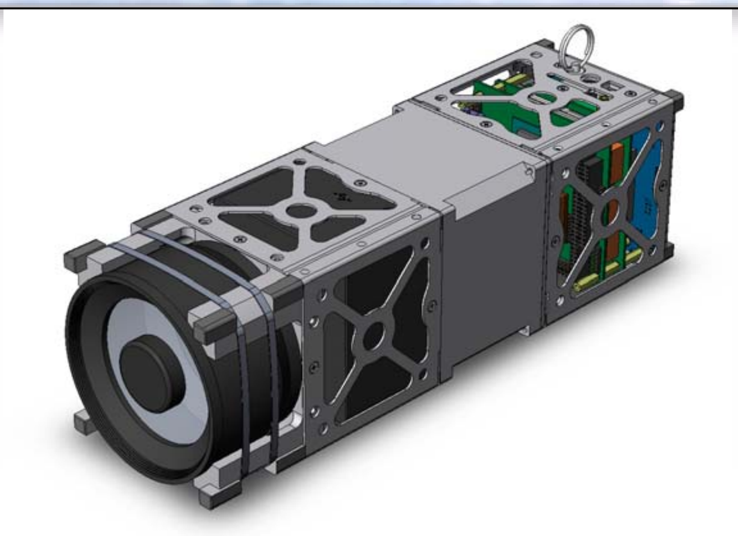
Pumpkin Inc.

OBJECTIVE

- MISC is a platform for rapid development cycles for small sensor (e.g. optical and EM) missions. The first MISC iteration creates an operationally responsive, agile, versatile & disposable imaging spacecraft from COTS components for short, high-impact NRO missions. Inexpensive to assemble, launch and operate, MISC and its ground station software can also provide a low-cost platform for operational training.

DESCRIPTION

- The MISC project combines these COTS components: spacecraft bus, ADACS, “solid cat” 3.5” catadioptric telescope and repackaged interline CCD sensor module.



EXPECTED PERFORMANCE

- 10x10x35cm, 4kg nanosatellite
- 11MP RGB sensor, 0.2º pointing accuracy w/3-axis ADACS
- 36x24km ground image, 11m GSD@ 600km LEO

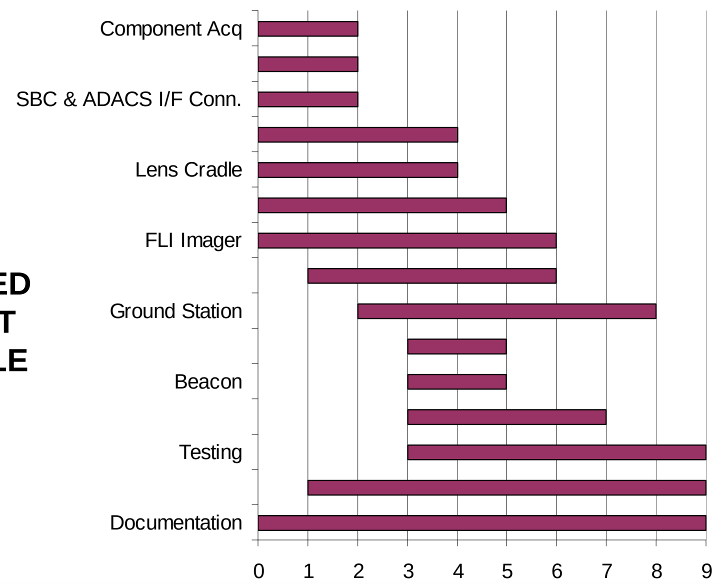
COMPARISON TO THE STATE OF THE ART

- Highly responsive, very low cost, disposable
- Use of COTS leverages rapid development cycles
- Single MISC: Ideal experimental testbed for scenario / operations / technology development
- MISC constellation: Persistent surveillance, arrays

TRL

- MISC at beginning of DII effort: TRL 3
- MISC at end of DII effort: TRL 6

PROPOSED PROJECT SCHEDULE



"Revolutionizing the Outside..."

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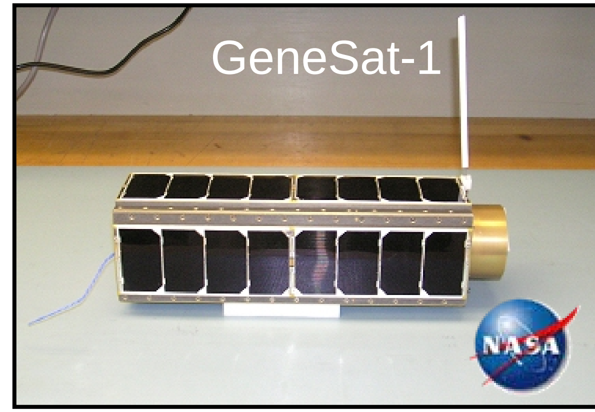
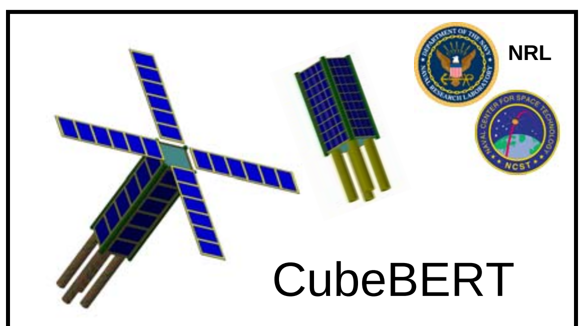
US Government Partners

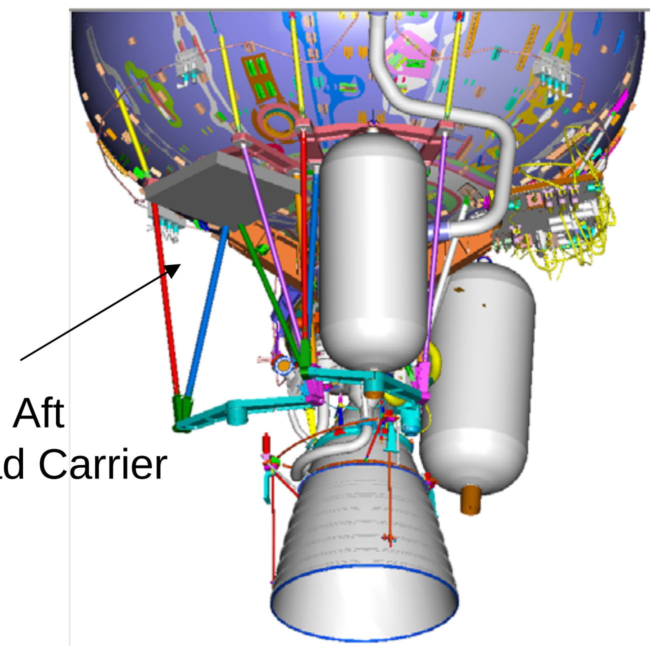
- DARPA
- SMC/STP
- NSF
- NRL
- US Army SMDC
- NASA Ames
- NASA KSC
- DOE
- ORS
- AFRL
- Many universities



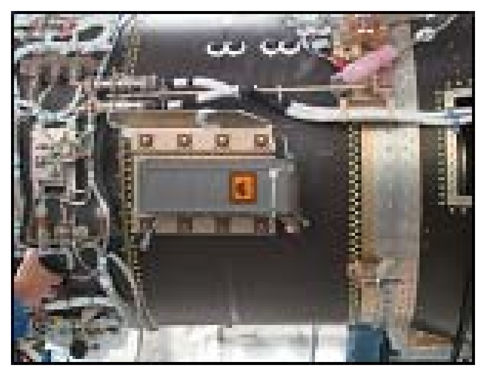


Enable Access To Space for CubeSats

- Actively working with:
  - NRO/OSL SP³ on ABC
  - SMC/STP SP³ on ESPA
  - ORS P-POD access



Centaur Aft Bulkhead Carrier (ABC)



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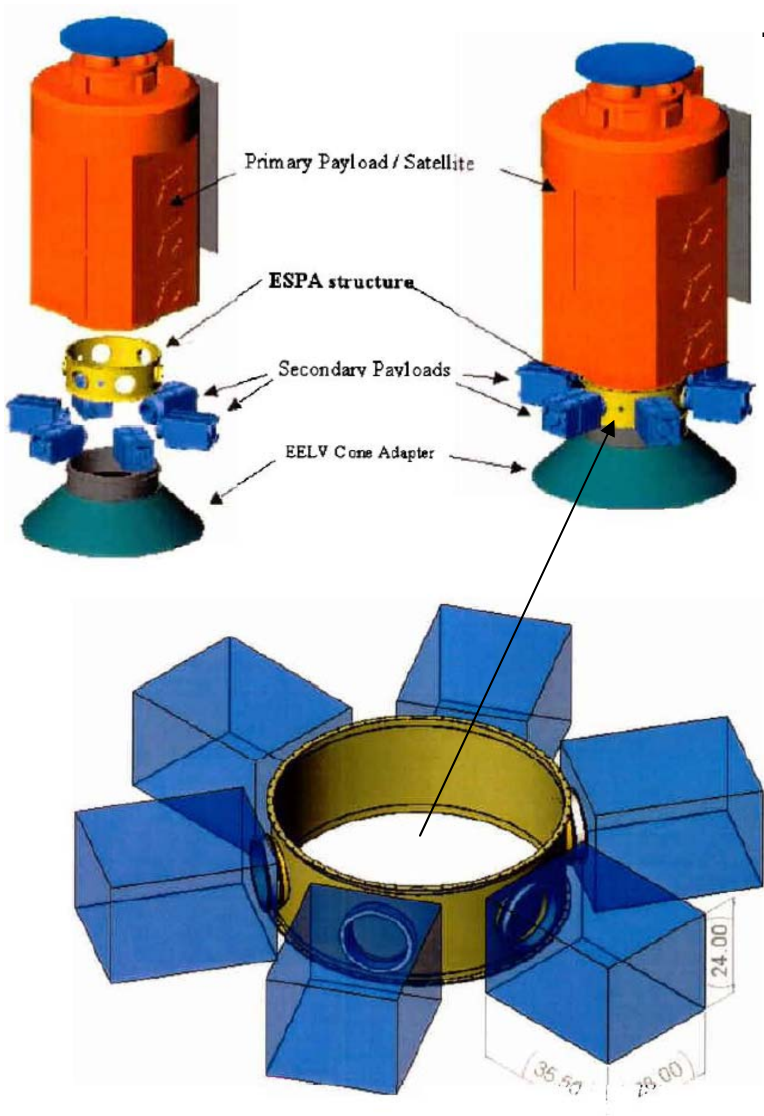
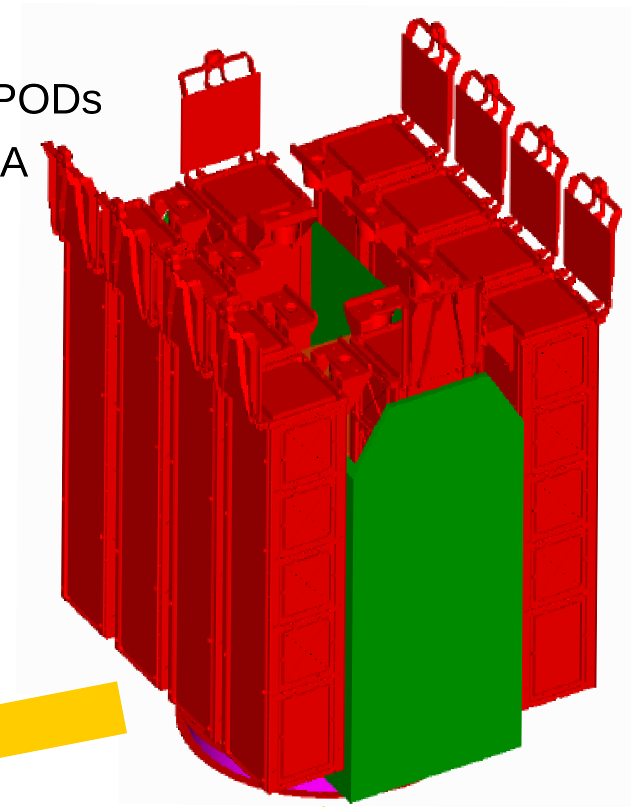
NPSCuL – ESPA Multi-CubeSat Dispenser

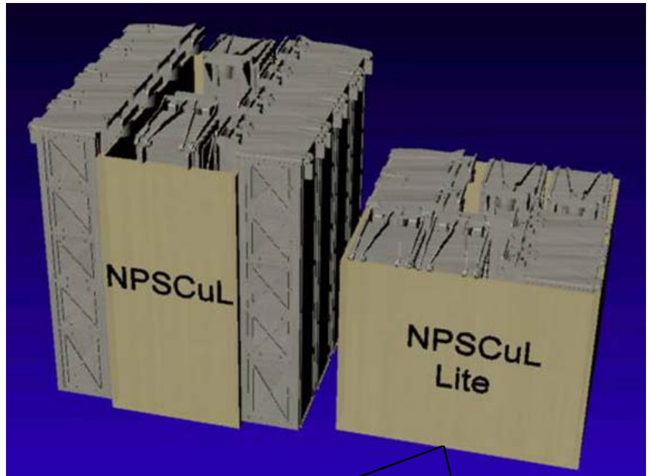


NPSCuL:

- Enables 10/5U P-PODs
- Designed for ESPA



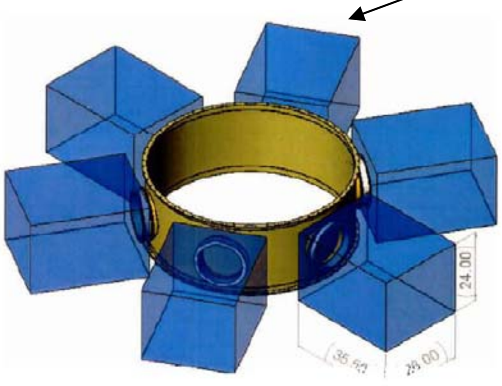
SP³ – ESPA/ABC Interchangeable CubeSat Active Ballast System



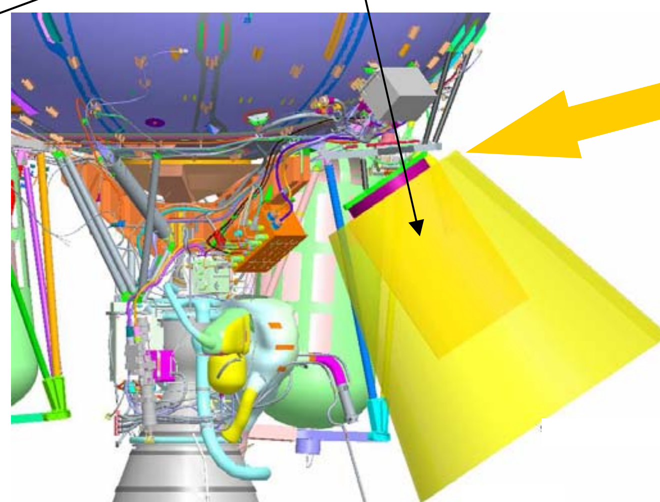
<u>NPSCuL Lite:</u>

- Enables 8/3U P-PODs

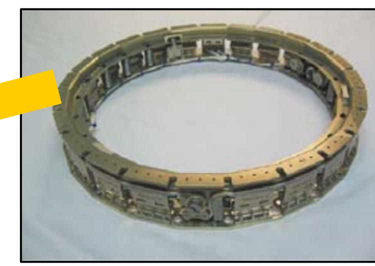
Either



ESPA

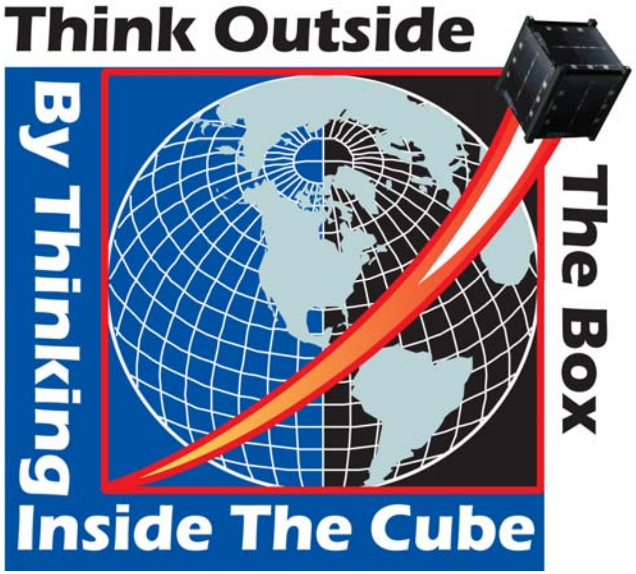


ABC



"Revolutionizing the Outside...
...Through Innovation Inside"

Innovative Experiments Initiative (IEI)



- Enable extremely small experiments in the range of less than 1 kg up to ~5 kg
- Lead innovative space-based experiments beyond the currently prevailing large satellite paradigm
- Benefit large satellites by providing experiment platforms for rapid space validation of technologies
- Monitor, enable, and leverage the growing domestic US expertise in CubeSat technologies and subsystems
- Foster the next generation of space professionals – A new generation who will have a different view of space

"Revolutionizing the Outside... ...Through Innovation Inside"

IEI - FY08 Statistics

- BAA/GSSA released 23 May 2008
- Proposals received 1 July 2008
- 10 awarded efforts at $150K each
- Prior Known US University CubeSat developers ~ 41
  - Known University developers participating in IEI ~ 13
  - New University developers participating in IEI ~ 9
- Prior Known US Industry CubeSat developers ~ 15
  - Known Industry developers participating in IEI ~ 10
  - New Industry developers participating in IEI ~ 38
- Number of unique registered IEI participants to date = 70
  - US developer community currently participating in IEI = **68%**
- Number of complete proposals received = 102

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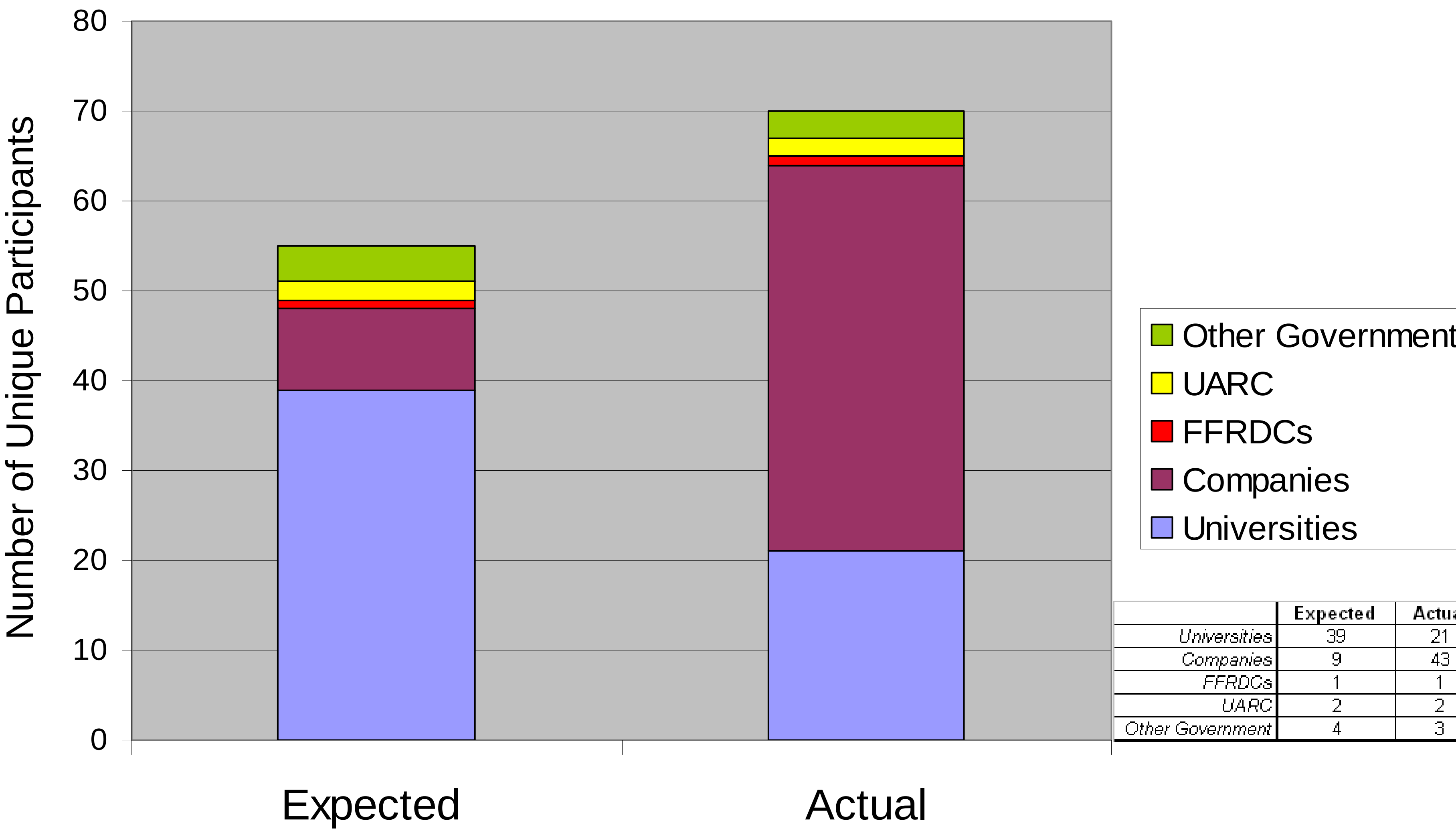
IEI - FY08 Statistics



	Expected	Actual
Universities	39	21
Companies	9	43
FFRDCs	1	1
UARC	2	2
Other Government	4	3

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IEI - FY08 University Participants

Auburn University
University of Alabama
Tuskegee University
Arizona State University
University of Arizona
Boston University
Cal Poly State University
San Jose Sate University
Stanford University
University of California Irvine
University of California Santa Barbara
University of Chicago
University of Colorado - Boulder
Florida Institute of Technology
Embry-Riddle Aeronautical University
University of Hawaii
University of Illinois
Purdue University
Taylor University
SUNY Geneseo
Iowa State University
University of Central Florida (New!)
University of Florida (New!)
University of Southern California (New!)
US Naval Postgraduate School

University of Kansas
University of Louisiana
US Naval Academy
Dartmouth College
Michigan Technological University
Washington University - St. Louis
Montana State University
Cornell University
Polytechnic University – NYC
North Carolina State University
University of North Dakota
University of Oklahoma
University of Texas - Austin
Texas Christian University
Texas A&M
Utah State University
George Mason University
University of Washington
George Washington University
Morehead State University (New!)
University of Alaska Fairbanks (New!)
University of Kentucky (New!)
University of New Mexico (New!)
Santa Clara University (New!)
University of Arkansas (New!)

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IEI - FY08 Industry Participants

The Aerospace Corporation
QuakeFinder, LLC
Tethers Unlimited
Globaltec R&D Center
Global Imaging
Kentucky Science & Tech Corporation
Boeing
Pumpkin, Inc.
Johns Hopkins Applied Physics Lab
AeroAstro, Inc (New!)
Aerojet (New!)
Astronautical Development, LLC (New!)
Azure Summit Technology, Inc (New!)
BAE Systems (New!)
Booz Allen Hamilton (New!)
Bridger Photonics Inc (New!)
Brimrose Tech Corporation, Inc (New!)
Busek Co. Inc (New!)
Cal Poly Corporation
CU Aerospace LLC (New!)
Design_Net Engineering, LLC (New!)
Digital Fusion Solutions, Inc (New!)
Innovative Technology Systems (New!)
Interorbital Systems (New!)
Design & Dev Eng Services Corp (New!)
Planning Systems Incorporated (New!)

ITT Corporation (New!)
NASA/JPL-Ames
KOR Electronics (New!)
L-3 Communications (New!)
L3 Corporation (New!)
LinQuest Corporation (New!)
Los Alamos National Laboratory
Michigan Aerospace Corp (New!)
Microcosm, Inc (New!)
MicroSat Systems, Inc (New!)
Nanohmics Inc (New!)
Naval Research Laboratory
Northrop Grumman (New!)
QinetiQ North America (New!)
Rincon Research Corp (New!)
Science Applications Int Corp (New!)
Space Dynamics Laboratory (New!)
SRI International
Texas Eng Experiment Station (New!)
Charles Stark Draper Lab
Foster-Miller Inc (New!)
Miltec Corp (New!)
Alliant Tech Systems (New!)
ATK Space Systems (New!)
Malin Space Science Systems (New!)
Vulcan Wireless Inc (New!)
Optimal Synthesis (New!)

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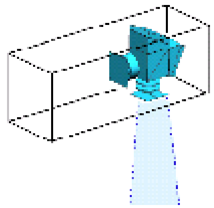
Think Outside The Box By Thinking Inside The Cube

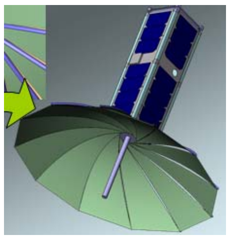
IEI – Funded Efforts



Hyperspectral Imager

Hinge

Gravity Gradient Boom



19dB Deployable Antenna

H-1 Beacon Module

QbX

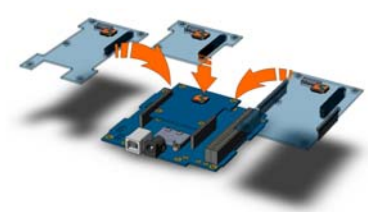
IEI

Optimal Ground Scheduling For CubeSats

•H-1 UHF/VHF Radio Module

Rate Adaptable, Constant Power Downlink

PnP Attitude Control



C&DH Module

Structureless Antenna

CubeSat Technology Needs

- **Secondary Dispensers**
  1) NPS-CUL Lite - NRO/OSL and NPS collaboration, Multiple (up to 8) P-Pods, Compatible with Atlas Centaur ABC/ ESPA rings
  2) NASA/Ames and ORS collaboration on Minotaur, Multiple (up to 8) P-Pods
- **Stearable solar arrays**
  - Rotation of arrays about one axis
  - To enable 40 W average power over 24 hr period
  - Accelerated de-orbit at mission end
- **Propulsion –** Electric and Cold Gas
- **Flexible Power System**
  - Can handle 1 to 12 strings of solar cells
  - Works in partial illumination
- **Space qualified GPS**
  - CubeSat form factor
  - Low-power FPGA based
  - Rad-tolerant
- **Actuators and Mechanisms**

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...Through Innovation Inside"

Q_bX – Summary

1. The CubeSat phenomenon may be a disruptive technology - a revolution that can either be lead or followed
2. Keeps up with Moore's law
3. CubeSats may enable users to buy and fly Satellites in weeks – some are talking of entire satellite buses being bought online and delivered by FEDEX
4. Takes advantage of 16,000kg excess launch capacity over the next 5 years
5. Expect many CubeSats to be launched/year – rapid growth in launches /year
6. Exceptional workforce development tool - outreach, training, recruitment
7. Many in the space community NRO, ORS, AFRL, NASA, DARPA, DOE, SMC, NPS, NRL - are supporters (or interested observers) of the Cubesat concept
8. Expectation management is necessary

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Q_bX – Takeaways

1. QbX is the NRO's CubeSat office

2. P-PODS are the containerization of space

3. A distributed CubeSat technology development and launch capability across multiple organizations is a good thing.

4. We should all be protective of the ***Cal Poly P-Pod Standard***. ***This is critical to the whole CubeSat effort.*** - *(Please remember what damage a single railroad engineer did to an entire nation, creating disruption that lasted over a century, because he broke the railroad gauge standard.)*