SSC09-XII-03

# The Promise of Innovation from University Space Systems: Are We Meeting It?

**Michael Swartwout**

***St. Louis University***

23rd Annual AIAA/USU Conference on Small Satellites

Logan, UT

13 August 2009


SAINT LOUIS UNIVERSITY
Parks College
Engineering. Aviation.

# Who Said It?



**"University-class spacecraft are …"**

- "… innovation-drivers in the staid, risk-adverse small satellite industry."

- "… not useful, except as a means for training students to be aerospace professionals."

They're both right. (Or wrong.)

# Are We "Innovators"?



- Short answer: yes, but not from the missions themselves
- Long answer
  - Read my paper (and **send me updates**)
  - Let's revisit the numbers
    - Reliability
    - Flagship vs. Independent
    - Mission utility
  - Only two innovations, but they're whoppers
    - The Small Satellite Industry
    - CubeSats

# Are We "In

- Short answ m the missions themselves
- Long answe
  - Read my p pdates)
  - Let's revisi
    - Reliability
    - Flagship
    - Mission u
  - Only two i whoppers
    - The Sma
    - CubeSats

| Launch | Launch ID | Launch Date | Mission | Primary Sponsor(s) | Nation | Mass (kg) | Mission Duration (months) | Status | Type | Multi | Flag? |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | 1 | 10/6/81 | UoSAT-1 (UO-9) | University of Surrey | UK | 52 | 96 | N | S | y | NF |
| 1984 | 2 | 3/1/84 | UoSAT-2 (UO-11) | University of Surrey | UK | 60 | 281 | N | C | y | NF |
| 1985 | 3 | 4/29/85 | NUSAT | Weber State, Utah State University | USA | 52 | 20 | N | T | y | NF |
| 1990 | 4 | 1/22/90 | WeberSAT (WO-18) | Weber State | USA | 16 | 96 | N | C | y | NF |
| 1991 | 5 | 7/17/91 | TUBSAT-A | Technical University of Berlin | Germany | 35 | 210 | N | C | y | F |
| 1992 | 6 | 8/10/92 | KITSAT-1 (KO-23) | Korean Advanced Institute of Science and Technology | Korea | 49 | 77 | N | T | y | F |
| 1993 | 7 | 5/12/93 | ARSENE | CNES Amateurs (?) | France | 154 | 4 | F | C | n | NF |
| | 8 | 10/26/93 | KITSAT-2 (KO-25) | Korean Advanced Institute of Science and Technology | Korea | 48 | 96 | N | C | y | F |
| 1994 | 9 | 1/25/94 | TUBSAT-B | Technical University of Berlin | Germany | 45 | 1 | F | T | y | F |
| | 10 | 3/2/94 | BremSat | University of Bremen | Germany | 63 | 11 | N | S | n | NF |
| 1995 | 11 | 8/28/95 | Techsat 1-A | Technion Institute of Technology | Israel | 50 | - | LF | C | y | F |
| | | | UNAMSAT-A | National University of Mexico | Mexico | 10 | - | LF | C | n | NF |
| 1996 | 12 | 5/9/96 | UNAMSAT-B (MO-30) | National University of Mexico | Mexico | 10 | 0 | F | C | n | NF |
| 1997 | 13 | 10/25/97 | Falcon Gold | US Air Force Academy | USA | 18 | 0.5 | N | T | y | F |
| | 14 | 10/30/97 | YES | ESA/ESTEC-led partnership | Europe | 187 | 0.1 | N | E | y | NF |
| | 15 | 11/3/97 | RS-17 | Russian high school students | Russia | 3 | 2 | N | E | n | NF |
| 1998 | 16 | 7/7/98 | TUBSAT-N | Technical University of Berlin | Germany | 8 | 46 | N | T | y | F |
| | | | TUBSAT-N1 | Technical University of Berlin | Germany | 3 | 20 | N | T | y | F |
| | 17 | 7/10/98 | Techsat 1-B (GO-32) | Technion Institute of Technology | Israel | 70 | 51 | N | S | y | F |
| | 18 | 10/30/98 | PANSAT (PO-34) | Naval Postgraduate School | USA | 70 | 60 | N | C | n | F |
| | | | SEDSAT (SO-33) | University of Alabama, Huntsville | USA | 41 | 33 | F | T | n | NF |
| 1999 | 19 | 2/23/99 | Sunsat (SO-35) | University of Stellenbosch | South Africa | 64 | 23 | N | C | y | F |
| | 20 | 5/27/99 | DLR-TUBSAT | Technical University of Berlin | Germany | 45 | 120 | N | S | y | F |
| | | | KITSAT-3 | Korean Advanced Institute of Science and Technology | Korea | 110 | 55 | N | T | y | F |
| 2000 | 21 | 1/27/00 | JAWSAT (WO-39) | Weber State, USAFA | USA | 191 | 1.0 | F | T | y | NF |
| | | | Falconsat 1 | US Air Force Academy | USA | 52 | 1.0 | F | E | y | F |
| | | | ASUsat 1 (AO-37) | Arizona State University | USA | 6 | 0.0 | F | E | y | NF |
| | | | Opal (OO-38) | Stanford University | USA | 23 | 29 | N | T | y | NF |
| | | 2/10/00 | JAK | Santa Clara University | USA | 0.2 | 0 | F | E | n | NF |
| | | 2/12/00 | Louise | Santa Clara University | USA | 0.5 | 0 | F | S | n | NF |
| | | | Thelma | Santa Clara University | USA | 0.5 | 0 | F | S | n | NF |
| | 22 | 6/28/00 | Tsinghua-1 | Tsinghua University | China | 49 | 30 | N | E | y | F |
| | 23 | 9/26/00 | TiungSAT-1 (MO-46) | ATSB | Malaysia | 50 | 39 | N | S | y | F |
| | | | Saudisat 1A (SO-41) | King Abdulaziz City for Science & Technology | Saudi Arabia | 10 | 36 | N | C | y | F |
| | | | Saudisat 1B (SO-42) | King Abdulaziz City for Science & Technology | Saudi Arabia | 10 | 27 | N | C | y | F |
| | | | UNISAT 1 | University of Rome "La Sapienza" | Italy | 12 | 24 | N | E | y | F |
| | 24 | 11/21/00 | Munin | Umeå University / Luleå University of Technology | Sweden | 6 | 3 | N | S | n | NF |
| 2001 | 25 | 9/30/01 | Sapphire (NO-45) | Stanford, USNA, Washington University | USA | 20 | 36 | N | E | y | NF |
| | | | PCSat 1 (NO-44) | US Naval Academy | USA | 12 | 94 | S | C | y | F |
| | 26 | 10/12/01 | Maroc-TUBSAT | Technical University of Berlin | Germany | 47 | 94 | A | S | y | F |
| 2002 | 27 | 12/20/02 | Saudisat 1C (SO-50) | King Abdulaziz City for Science & Technology | Saudi Arabia | 10 | 80 | A | C | y | F |
| | | | UNISAT 2 | University of Rome "La Sapienza" | Italy | 17 | 24 | N | E | y | F |
| 2003 | 28 | 6/30/03 | QuakeSat | Stanford University | USA | 3 | 61 | N | S | y | NF |
| | | | CUTE-1 (CO-55) | Tokyo Institute of Technology | Japan | 1 | 73 | S | E | y | F |
| | | | XI-IV (CO-57) | University of Tokyo | Japan | 1 | 73 | A | E | y | F |
| | | | CanX-1 | University of Toronto | Canada | 1 | 0 | F | E | y | F |
| | | | AAU Cubesat | University of Aalborg | Denmark | 1 | 3 | F | E | y | NF |
| | | | DTUsat | Technical University of Denmark | Denmark | 1 | 0 | F | E | n | NF |
| | 29 | 9/27/03 | STSAT-1 | Korean Advanced Institute of Science and Technology | Korea | 100 | 70 | A | T | y | F |
| | | | Mozhayets 4 (RS-22) | Mozhaisky military academy | Russia | 64 | 70 | A | C | y | F |
| 2004 | 30 | 4/18/04 | Naxing-1 (NS-1) | Tsinghua University | China | 25 | 64 | A | T | y | F |
| | 31 | 6/29/04 | SaudiSat 2 | King Abdulaziz City for Science & Technology | Saudi Arabia | 15 | 61 | A | S | y | F |
| | | | SaudiComsat-1 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 61 | A | C | y | F |
| | | | SaudiComsat-2 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 61 | A | C | y | F |
| | | | UNISAT 3 | University of Rome "La Sapienza" | Italy | 12 | 61 | A | E | y | F |
| | 32 | 12/21/04 | 3CS: Sparky | ASU/NMSU/CU Boulder | USA | 16 | - | LF | E | y | NF |
| | | | 3CS: Ralphie | ASU/NMSU/CU Boulder | USA | 16 | - | LF | E | y | NF |
| 2005 | 33 | 8/3/05 | PCSat 2 | US Naval Academy | USA | 12 | 13 | N | C | y | F |
| | 34 | 10/27/05 | XI-V (CO-58) | University of Tokyo | Japan | 1 | 45 | S | E | y | F |
| | | | Mozhayets 5 | Mozhaisky military academy | Russia | 64 | 0 | F | E | y | F |
| | | | UWE-1 | University of Wurzburg | Germany | 1 | 1 | F | E | y | NF |
| | | | Ncube II | Norwegian Universities | Norway | 1 | 0 | F | E | n | NF |
| | | | SSETI Express (XO-53) | European Universities | Europe | 62 | 0 | F | C | y | NF |
| 2006 | 35 | 2/21/06 | CUTE-1.7 (CO-56) | Tokyo Institute of Technology | Japan | 10 | 1 | F | C | y | F |
| | 36 | 3/24/06 | Falconsat 2 | US Air Force Academy | USA | 20 | - | LF | S | y | F |
| | 37 | 7/26/06 | UNISAT 4 | University of Rome "La Sapienza" | Italy | 12 | - | LF | E | y | F |
| | | | Ncube | Norwegian Universities | Norway | 1 | - | LF | E | n | NF |
| | | | KUTESat | University of Kansas | USA | 1 | - | LF | E | n | NF |
| | | | CP2 | Cal Poly San Luis Obispo | USA | 1 | - | LF | E | y | NF |
| | | | CP1 | Cal Poly San Luis Obispo | USA | 1 | - | LF | E | y | NF |
| | | | ION | University of Illinois | USA | 2 | - | LF | T | n | NF |
| | | | ICE CUBE1 | Cornell University | USA | 1 | - | LF | T | n | NF |
| | | | ICE CUBE2 | Cornell University | USA | 1 | - | LF | T | n | NF |
| | | | PiCPoT | Politecnico di Torino, Italy | Italy | 2.5 | - | LF | E | y | NF |
| | | | SEEDS | Nihon University | Japan | 1 | - | LF | E | n | NF |
| | | | SACRED | University of Arizona | USA | 1 | - | LF | E | n | NF |
| | | | Rincon | University of Arizona | USA | 1 | - | LF | E | n | NF |
| | | | MEROPE | Montana State University | USA | 1 | - | LF | S | n | NF |
| | | | HAUSAT-1 | Hankuk Aviation University | S. Korea | 1 | - | LF | E | n | F |
| | | | Baumanets 1 | Bauman Moscow State Technical University | Russia | 92 | - | LF | E | n | F |
| | 38 | 9/22/06 | HITSat (HO-59) | Hokkaido Institute of Technology | Japan | 2.7 | 5 | N | C | n | NF |
| | 39 | 12/21/06 | RAFT-1 (NO-60) | US Naval Academy | USA | 1 | 5 | N | C | y | F |
| | | | MARScom | US Naval Academy | USA | 1 | 5 | N | C | y | F |
| | | | ANDE (NO-61) | US Naval Academy | USA | 75 | 12 | N | C | y | F |
| 2007 | 40 | 1/10/07 | LAPAN-Tubsat | Technical University of Berlin | Germany | 56 | 31 | A | C | y | F |
| | | | PEHUENSAT-1 (PO-63) | National University of Comahue | Argentina | 6 | 3 | N | C | n | NF |
| | 41 | 3/9/07 | Falconsat 3 | US Air Force Academy | USA | 54 | 29 | A | S | y | F |
| | | | MidSTAR-1 | US Naval Academy | USA | 120 | 29 | A | T | y | F |
| | 42 | 4/17/07 | Saudi ComSat-3 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 28 | A | C | y | F |
| | | | Saudi ComSat-4 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 28 | A | C | y | F |
| | | | Saudi ComSat-5 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 28 | A | C | y | F |
| | | | Saudi ComSat-6 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 28 | A | C | y | F |
| | | | Saudi ComSat-7 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 28 | A | C | y | F |
| | | | CP4 | Cal Poly San Luis Obispo | USA | 1 | 5 | N | E | y | NF |
| | | | CP3 | Cal Poly San Luis Obispo | USA | 1 | 5 | N | E | y | NF |
| | | | Libertad-1 | University of Sergio Arboleda | Columbia | 1 | 1 | N | E | n | NF |
| | | | CAPE-1 | University of Louisiana | USA | 1 | 5 | N | E | n | NF |
| | 43 | 9/25/07 | YES2/Floyd | ESA-led partnership | Europe | 30 | 0 | N | T | y | NF |
| | | | Yes2/Fotino | ESA-led partnership | Europe | 6 | 0 | F | T | y | NF |
| 2008 | 44 | 4/28/08 | Cute 1.7 + APD II (CO-65) | Tokyo Institute of Technology | Japan | 2 | 15 | A | E | y | F |
| | | | CanX 2 | University of Toronto | Canada | 2 | 15 | A | T | y | F |
| | | | AAU-CubeSat II | University of Aalborg | Denmark | 1 | 15 | A | T | y | NF |
| | | | SEEDS 2 (CO-66) | Nihon University | Japan | 1 | 15 | A | E | n | NF |
| | | | COMPASS 1 | Fachhochschule Aachen | Germany | 1 | 15 | S | E | n | NF |
| | | | Delfi-C3 (DO-64) | Technical University of Delft | Netherlands | 3 | 15 | S | T | n | F |
| 2009 | 45 | 1/23/09 | SpriteSat (Raijin) | Tohoku University | Japan | 50 | 0 | F | S | n | NF |
| | | | PRiSM | University of Tokyo | Japan | 8 | 7 | A | T | y | F |
| | | | KKS 1 | Tokyo Metropolitan College of Industrial Technology | Japan | 3 | 0 | F | T | n | NF |
| | | | STARS 1 | Kagawa University | Japan | 8 | 0 | F | T | n | NF |
| | 46 | 4/20/09 | ANUSAT | Anna University | India | 38 | 4 | A | C | n | F |
| | 47 | 5/19/09 | CP6 | Cal Poly San Luis Obispo | USA | 1 | 3 | A | E | y | NF |
| | 48 | 7/15/09 | BEVO-1 | University of Texas | USA | 5 | 1 | S | T | y | NF |
| | | | AggieSat2 | Texas A&M University | USA | 3.2 | 1 | S | T | n | NF |
| | 49 | 8/20/09 | SumbandilaSat | University of Stellenbosch | South Africa | 80 | n/a | - | T | y | F |
| | | | UGATUSAT | Ufa State Aviation Technical University | Russia | 30 | n/a | - | T | n | F |
| | 50 | 9/5/09 | UWE-2 | University of Wurzburg | Germany | 1 | n/a | - | E | y | NF |
| | | | SwissCube-1 | Ecole Polytechnique Fédérale de Lausanne | Switzerland | 1 | n/a | - | S | n | F |
| | | | BeeSat | Technical University of Berlin | Germany | 1 | n/a | - | T | y | F |
| | | | ITU-pSat | Istanbul Technical University | Turkey | 1 | n/a | - | E | n | F |

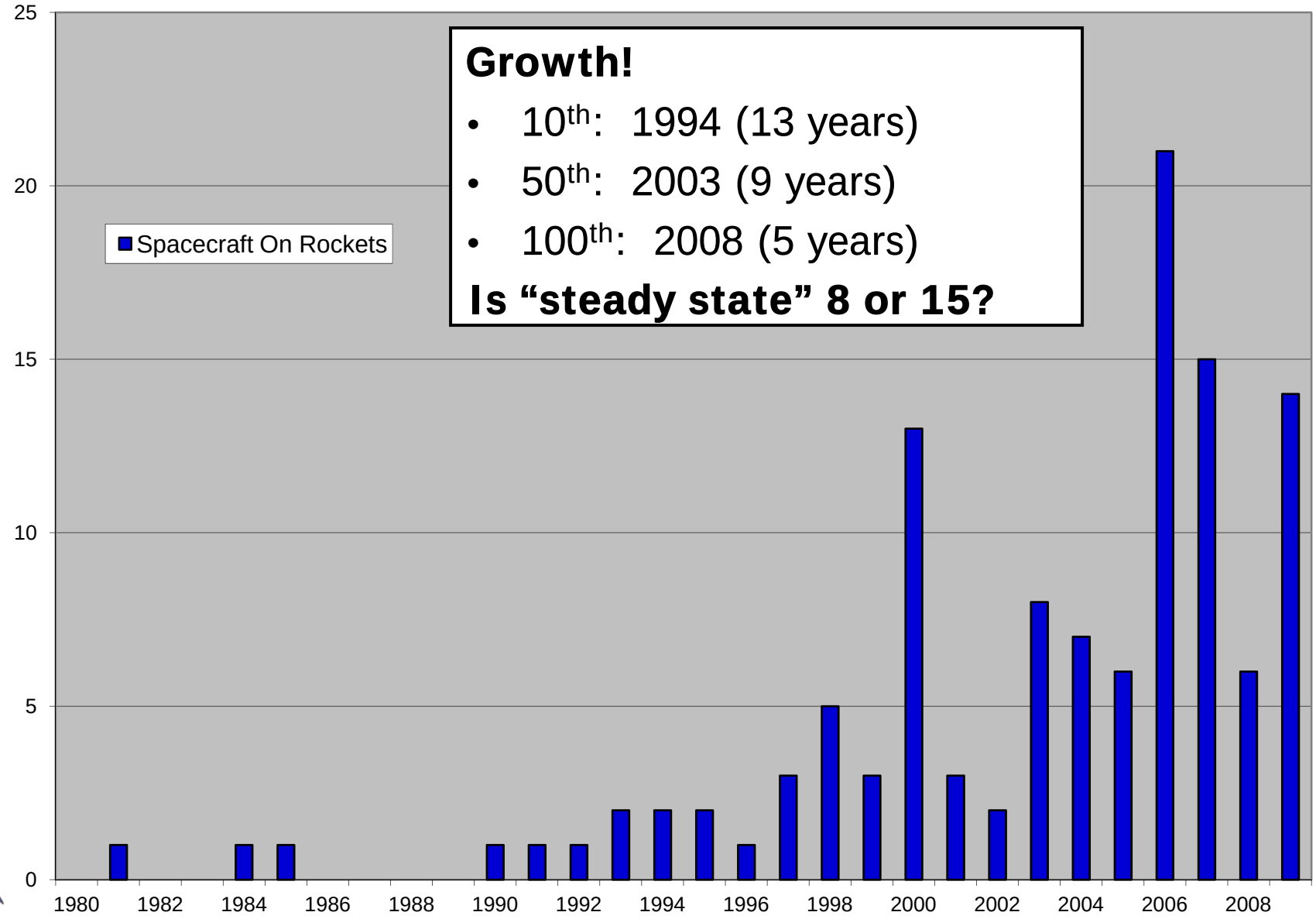
# *"University-Class Satellite"*



- Working definition
  - Self-contained device with independent communications, command & control
  - Untrained personnel (*i.e. students*) have key roles in design, fabrication, integration and operations
  - Training is at least as important as the rest of the mission
- Excluded (by definition)
  - Many, many satellites with strong university participation (especially as science PI)
  - Most Amateur satellites
- Exclusion does not imply lack of educational value!

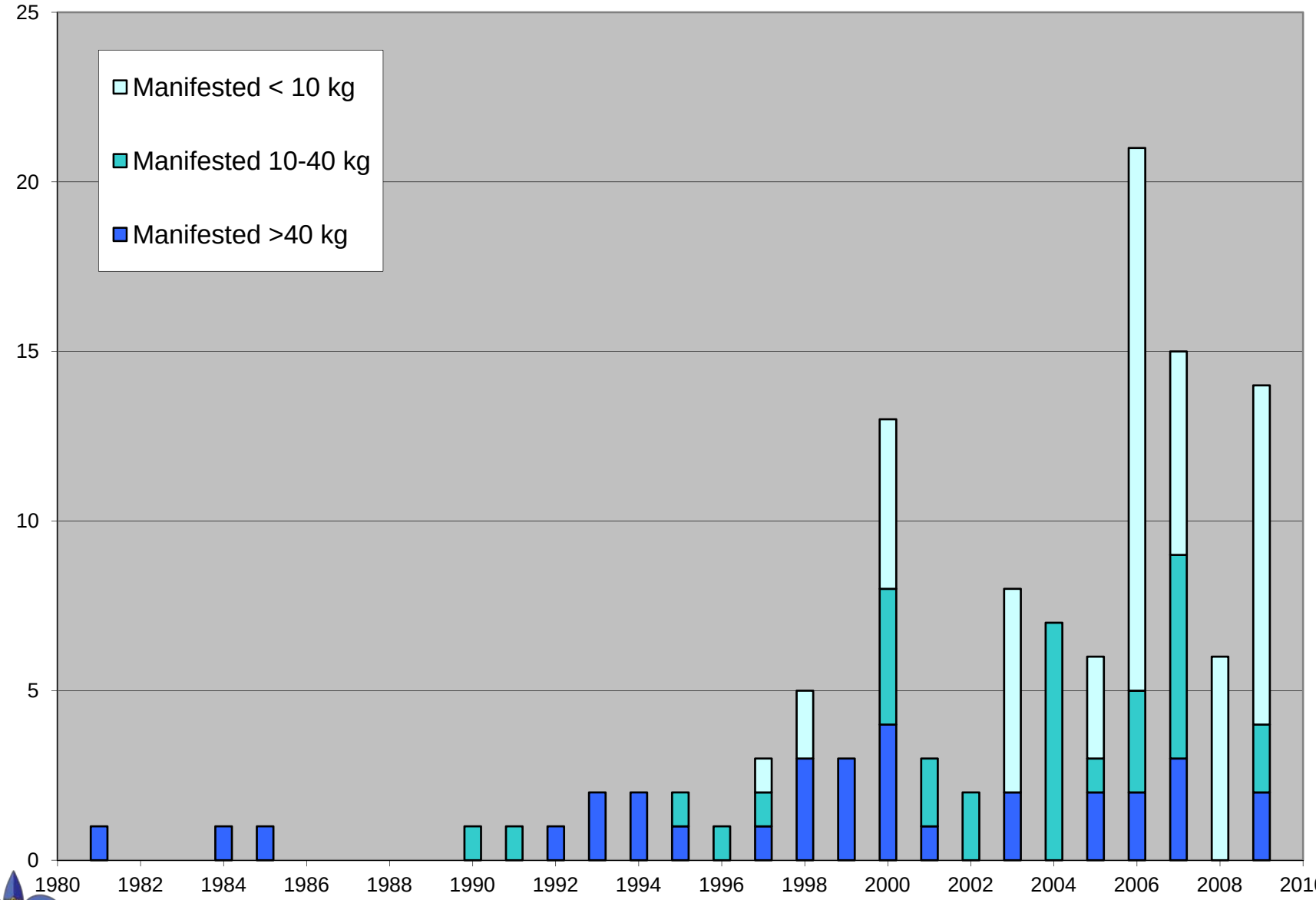
# The Numbers




Growth!
• 10th: 1994 (13 years)
• 50th: 2003 (9 years)
• 100th: 2008 (5 years)
Is “steady state” 8 or 15?
Spacecraft On Rockets
25
20
15
10
5
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008

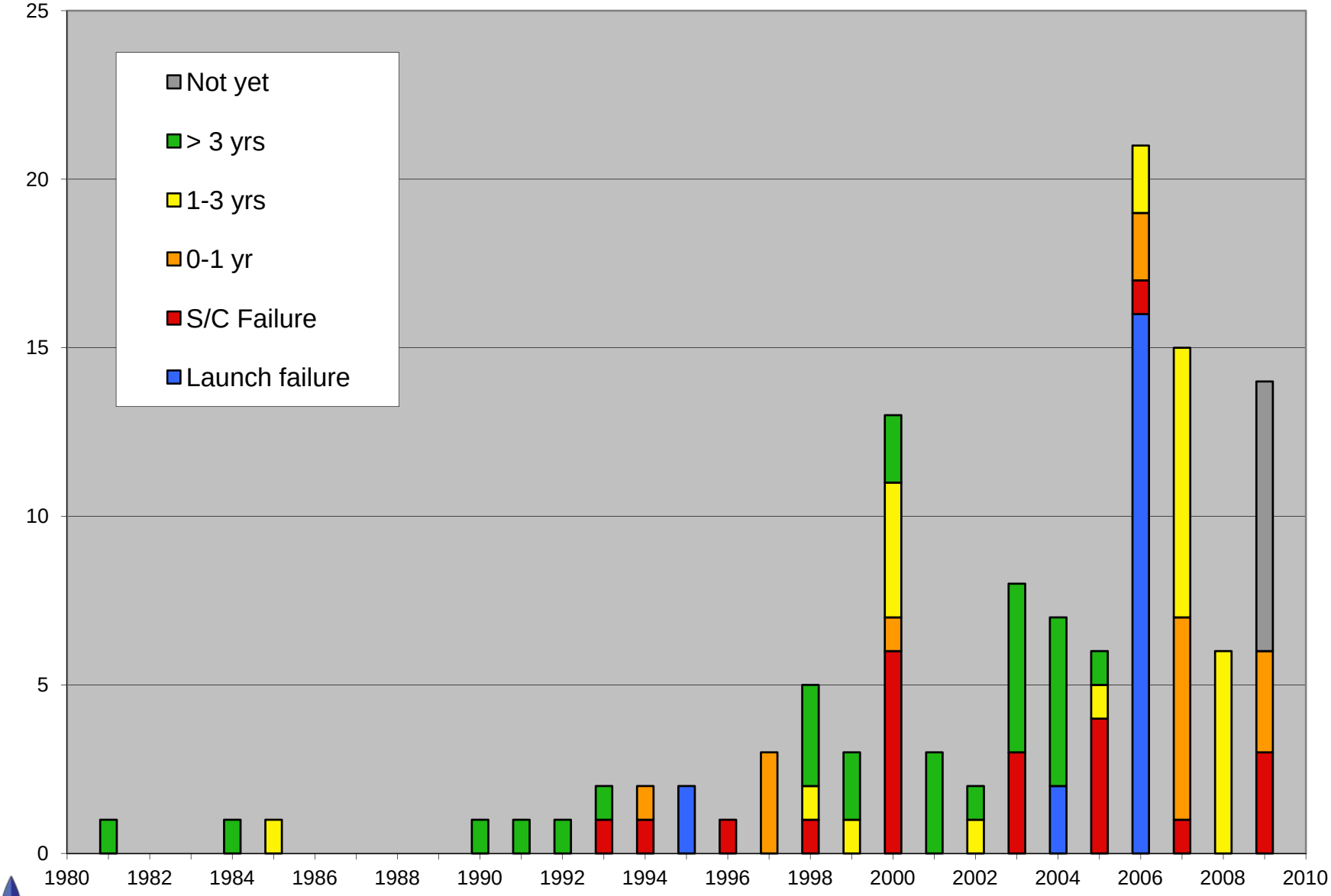
# It's Not Just CubeSats! *[Okay, it's mostly CubeSats]*





# Not a Great Year for Mission Success





# What Breaks?



22 of 93 orbited spacecraft "failed"

## What Breaks?

- Radiation: 1*
- Launch interface: 1
- Launch thermal: 1
- Communications: 4½
- CPU lockup: 2
- Power: 4½
- DOA: 8*

## What Doesn't Break?

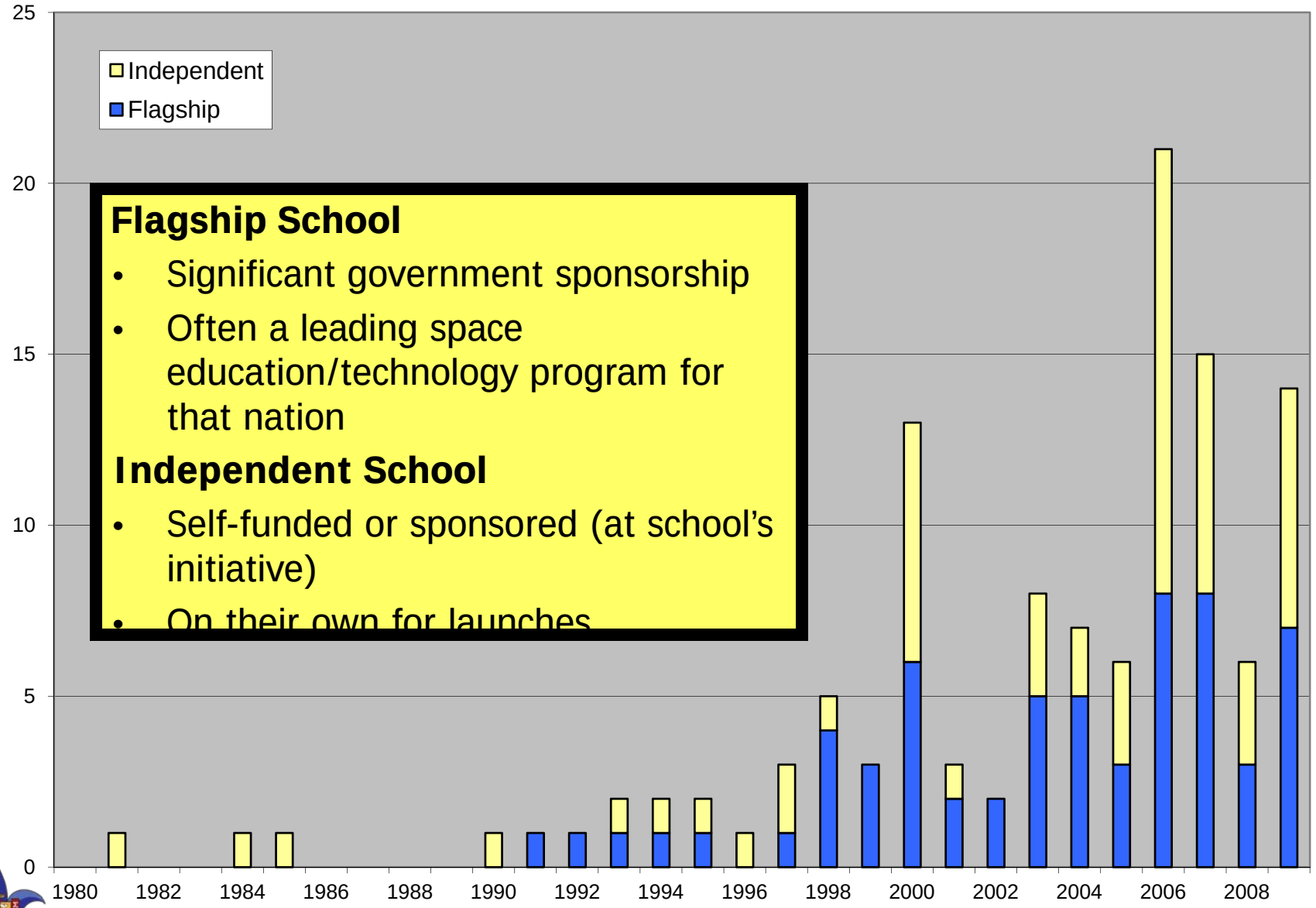
- Structures
- Thermal*
- Commercial Electronics in Radiation Environment*

**Lifetime reduction**

Perhaps we should worry more about **system-level functional testing** and less (?) about the **space environment**...

# It Still Helps to Be Somebody






**Flagship School**

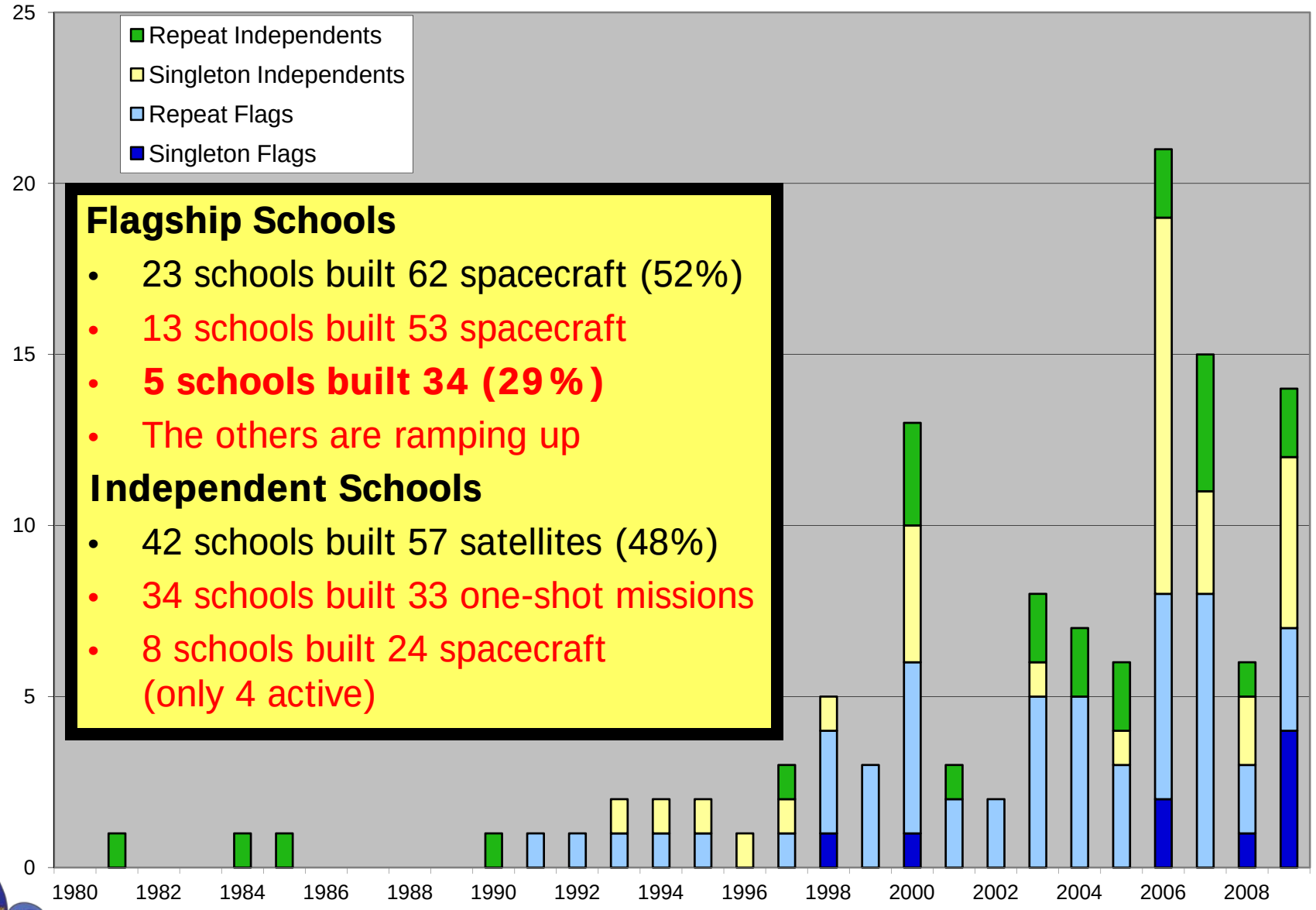
- Significant government sponsorship
- Often a leading space education/technology program for that nation

**Independent School**

- Self-funded or sponsored (at school's initiative)
- On their own for launches

# Repeat Business: Same Old, Same Old






**Flagship Schools**

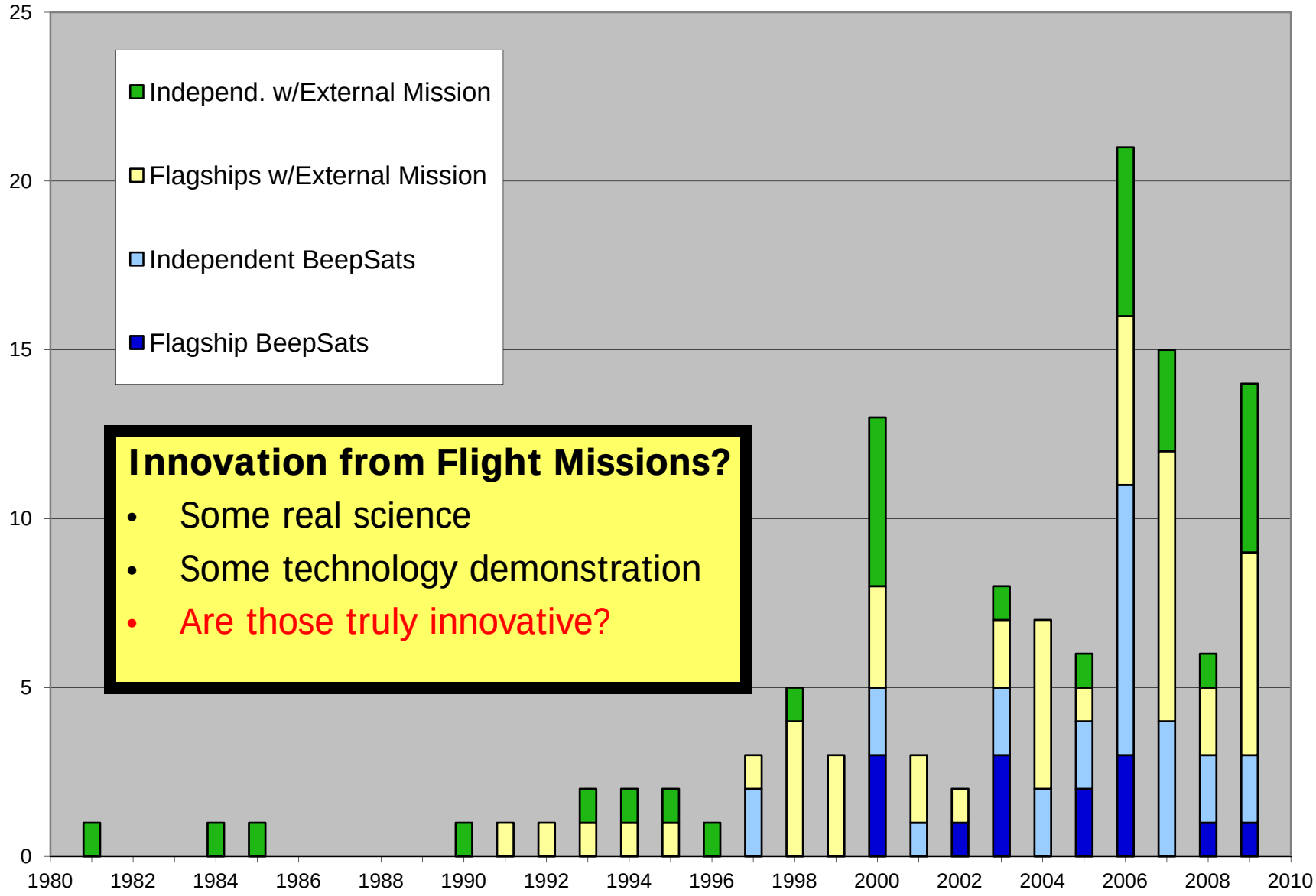
- 23 schools built 62 spacecraft (52%)
- 13 schools built 53 spacecraft
- **5 schools built 34 (29%)**
- The others are ramping up

**Independent Schools**

- 42 schools built 57 satellites (48%)
- 34 schools built 33 one-shot missions
- 8 schools built 24 spacecraft (only 4 active)

# Beyond the Beep?





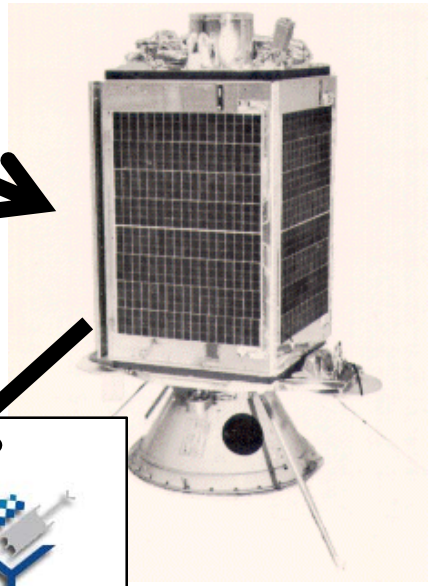
# To Grossly Oversimplify



- Flagship schools
  - Build “real” missions that work (90% success)
  - Use CubeSats as stepping-stones
  - Sustain programs around a larger (20-100 kg) bus
  - Move up the “value chain” and out of the university class
- Independent schools
  - Build one satellite that might work (58%), then fly no more (80%)
  - Build CubeSats and, if sustained, it’s a series of E-class CubeSats

# Innovation #1: This Industry

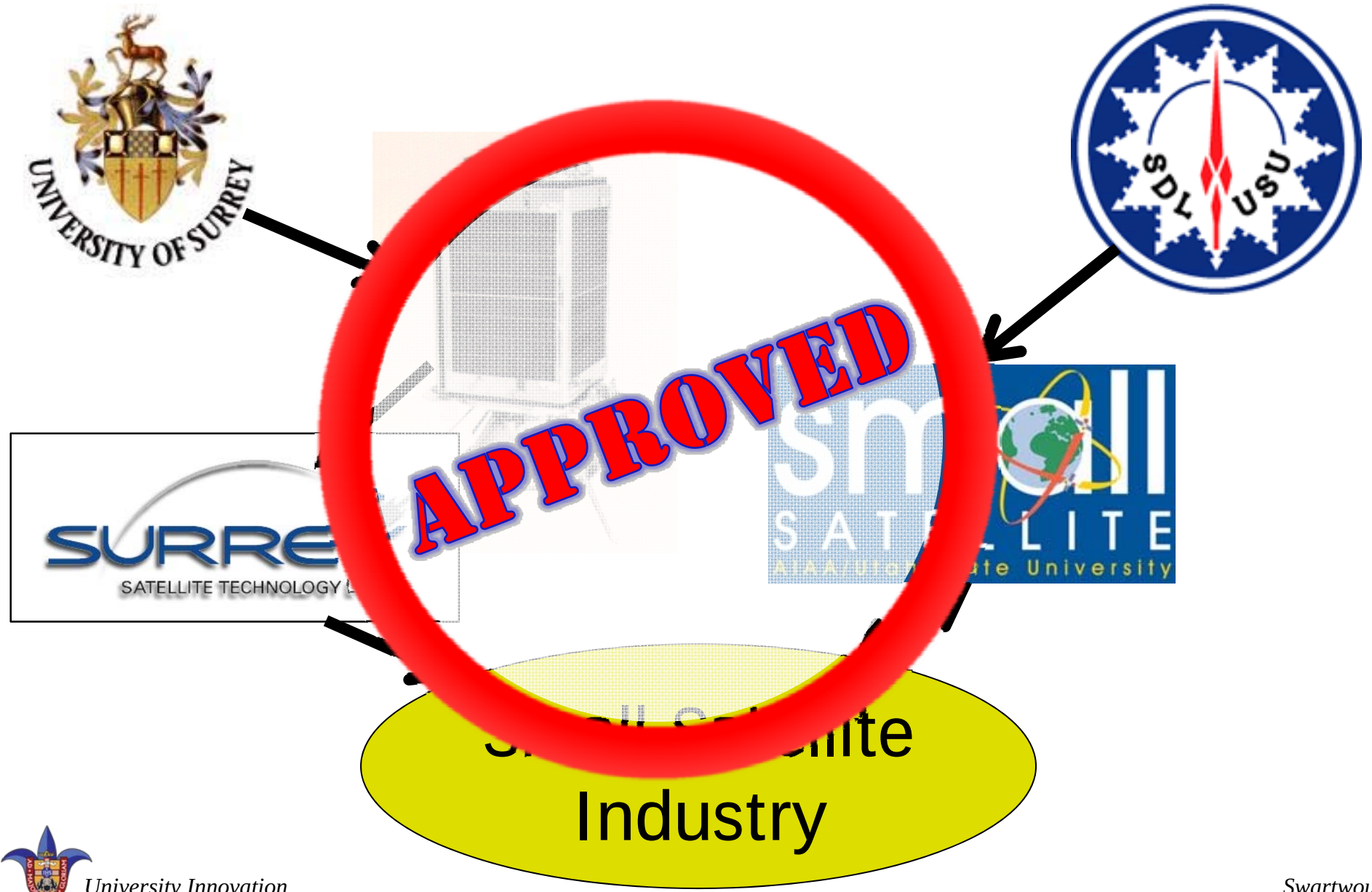




Small Satellite Industry

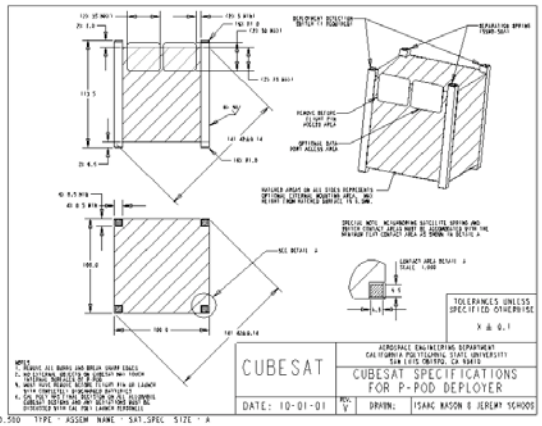
# Innovation #1: This Industry

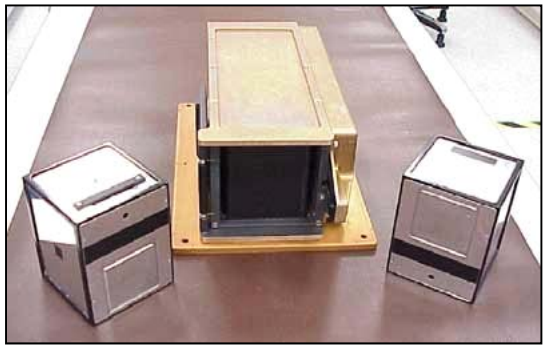


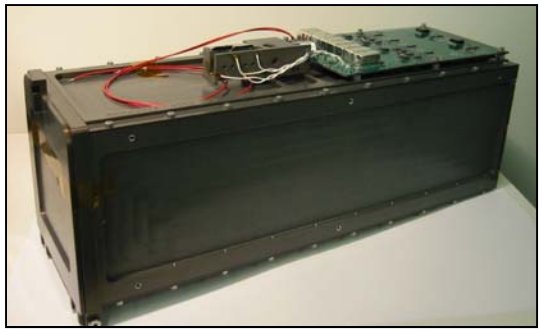


# Revolution #2 (?): CubeSats





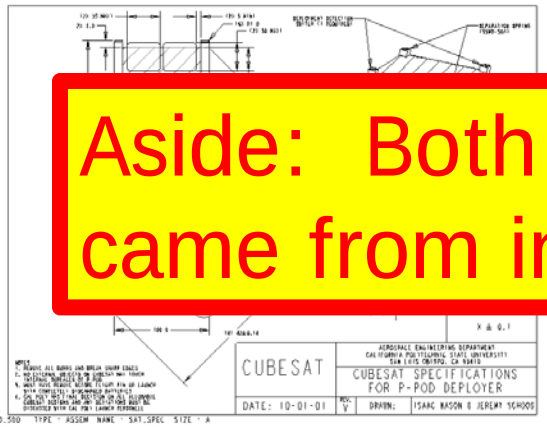





- Twiggs (Stanford) and Puig-Suari (Cal Poly) defined a standard for carrying 10 cm, 1 kg cubes into space
- *[The real innovation was the P-POD]*
- Timeline
  - 1999 concept definition
  - 2003 first flight
  - 2009 41st university flight
- Look around at the number of non-university CubeSat programs (~12 flights)

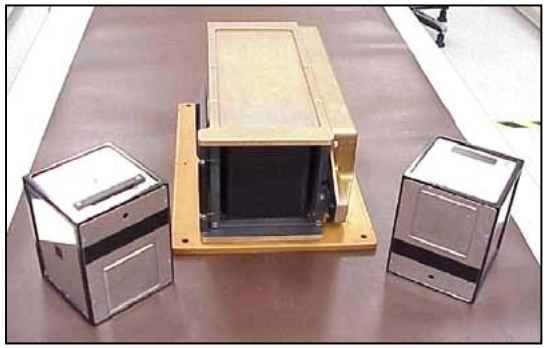
# Revolution #2 (?): CubeSats

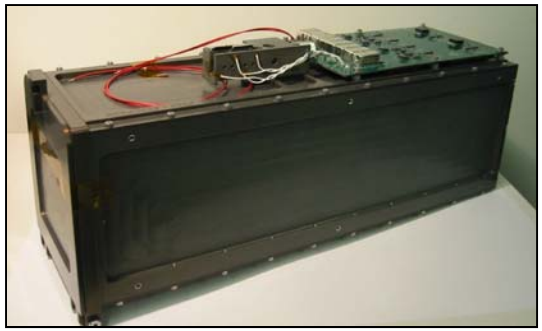





Aside: Both revolutions came from independents...

- Twiggs (Stanford) and Puig-Suari ed a standard for 1 kg cubes into space
- *[The real in ation was th -POD]*
- Timeline
  - 1999 oncept definition
  - 2003 rst flight
  - 2009 1 versity flight
- Look ar nd at the number f non-unive ity CubeSat programs (~1





APPROVED

# The Counter-Argument



- What about the other 100 spacecraft?
- What about the 100 spacecraft that haven't launched (and may never launch)?

- University Nanosat Program
  - 10 years, 27 schools
  - One flight (plus three in pipeline)
  - Four other flights by Nanosat schools


ATTENTION
ELECTROSTATIC SENSITIVE AREA
FOLLOW PROPER ESD PROCEDURES AT ALL TIMES

# What Have We Learned?



- University-class spacecraft are not going away
  - CubeSat growth continues
  - As some programs “graduate”, new ones appear
- Bifurcation has grown stronger
  - Flagships building reliable sci/tech missions
  - Independents building less reliable E-class CubeSats
- Innovation happens, unexpectedly
  - Surrey did not intend to kick-start an industry
  - Twiggs & Puig-Suari did not intend to spur a new industry
  - Flagships don’t innovate (probably on purpose)

SSC09-XII-03

# The Promise of Innovation from University Space Systems: Are We Meeting It?

**Michael Swartwout**

***St. Louis University***

23rd Annual AIAA/USU Conference on Small Satellites

Logan, UT

13 August 2009


SAINT LOUIS UNIVERSITY
Parks College
Engineering. Aviation.

# University-Class Missions, 1981-2003

Saint Louis University
Parks College
Engineering. Aviation.

| Launch | Launch ID | Launch Date | Mission | Primary School(s) | Nation | Mass (kg) | Mission Duration (months) | Status | Type | Multi | Flag? |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1981** | 1 | 10/6/81 | UoSAT-1 (UO-9) | University of Surrey | UK | 52 | 96 | N | S | y | NF |
| **1984** | 2 | 3/1/84 | UoSAT-2 (UO-11) | University of Surrey | UK | 60 | 281 | N | C | y | NF |
| **1985** | 3 | 4/29/85 | NUSAT | Weber State, Utah State University | USA | 52 | 20 | N | T | y | NF |
| **1990** | 4 | 1/22/90 | WeberSAT (WO-18) | Weber State | USA | 16 | 96 | N | C | y | NF |
| **1991** | 5 | 7/17/91 | TUBSAT-A | Technical University of Berlin | Germany | 35 | 210 | N | C | y | F |
| **1992** | 6 | 8/10/92 | KITSAT-1 (KO-23) | Korean Advanced Institute of Science and Technology | Korea | 49 | 77 | N | T | y | F |
| **1993** | 7 | 5/12/93 | ARSENE | CNES Amateurs (?) | France | 154 | 4 | F | C | n | NF |
| | 8 | 10/26/93 | KITSAT-2 (KO-25) | Korean Advanced Institute of Science and Technology | Korea | 48 | 96 | N | C | y | F |
| **1994** | 9 | 1/25/94 | TUBSAT-B | Technical University of Berlin | Germany | 45 | 1 | F | T | y | F |
| | 10 | 3/2/94 | BremSat | University of Bremen | Germany | 63 | 11 | N | S | n | NF |
| **1995** | **11** | **8/28/95** | Techsat 1-A | Technion Institute of Technology | Israel | 50 | - | LF | C | y | F |
| | | | UNAMSAT-A | National University of Mexico | Mexico | 10 | - | LF | C | n | NF |
| **1996** | 12 | 5/9/96 | UNAMSAT-B (MO-30) | National University of Mexico | Mexico | 10 | 0 | F | C | n | NF |
| **1997** | 13 | 10/25/97 | Falcon Gold | US Air Force Academy | USA | 18 | 0.5 | N | T | y | F |
| | 14 | 10/30/97 | YES | ESA/ESTEC-led partnership | Europe | 187 | 0.1 | N | E | y | NF |
| | 15 | 11/3/97 | RS-17 | Russian high school students | Russia | 3 | 2 | N | E | n | NF |
| **1998** | **16** | **7/7/98** | TUBSAT-N | Technical University of Berlin | Germany | 8 | 46 | N | T | y | F |
| | | | TUBSAT-N1 | Technical University of Berlin | Germany | 3 | 20 | N | T | y | F |
| | 17 | 7/10/98 | Techsat 1-B (GO-32) | Technion Institute of Technology | Israel | 70 | 51 | N | S | y | F |
| | **18** | **10/30/98** | PANSAT (PO-34) | Naval Postgraduate School | USA | 70 | 60 | N | C | n | F |
| | | | SEDSAT (SO-33) | University of Alabama, Huntsville | USA | 41 | 33 | F | T | n | NF |
| **1999** | 19 | 2/23/99 | Sunsat (SO-35) | University of Stellenbosch | South Africa | 64 | 23 | N | C | y | F |
| | **20** | **5/27/99** | DLR-TUBSAT | Technical University of Berlin | Germany | 45 | 120 | N | S | y | F |
| | | | KITSAT-3 | Korean Advanced Institute of Science and Technology | Korea | 110 | 55 | N | T | y | F |
| **2000** | **21** | **1/27/00** | JAWSAT (WO-39) | Weber State, USAFA | USA | 191 | 1.0 | F | T | y | NF |
| | | | Falconsat 1 | US Air Force Academy | USA | 52 | 1.0 | F | E | y | F |
| | | | ASUsat 1 (AO-37) | Arizona State University | USA | 6 | 0.0 | F | E | y | NF |
| | | | Opal (OO-38) | Stanford University | USA | 23 | 29 | N | T | y | NF |
| | | 2/10/00 | JAK | Santa Clara University | USA | 0.2 | 0 | F | E | n | NF |
| | | **2/12/00** | Louise | Santa Clara University | USA | 0.5 | 0 | F | S | n | NF |
| | | | Thelma | Santa Clara University | USA | 0.5 | 0 | F | S | n | NF |
| | 22 | 6/28/00 | Tsinghua-1 | Tsinghua University | China | 49 | 30 | N | E | y | F |
| | **23** | **9/26/00** | TiungSAT-1 (MO-46) | ATSB | Malaysia | 50 | 39 | N | S | n | F |
| | | | Saudisat 1A (SO-41) | King Abdulaziz City for Science & Technology | Saudi Arabia | 10 | 36 | N | C | y | F |
| | | | Saudisat 1B (SO-42) | King Abdulaziz City for Science & Technology | Saudi Arabia | 10 | 27 | N | C | y | F |
| | | | UNISAT 1 | University of Rome "La Sapienza" | Italy | 12 | 24 | N | E | y | F |
| | 24 | 11/21/00 | Munin | Umeå University / Luleå University of Technology | Sweden | 6 | 3 | N | S | n | NF |
| **2001** | **25** | **9/30/01** | Sapphire (NO-45) | Stanford, USNA, Washington University | USA | 20 | 36 | N | E | y | NF |
| | | | PCSat 1 (NO-44) | US Naval Academy | USA | 12 | 94 | S | C | y | F |
| | 26 | 10/12/01 | Maroc-TUBSAT | Technical University of Berlin | Germany | 47 | 94 | A | S | y | F |
| **2002** | **27** | **12/20/02** | Saudisat 1C (SO-50) | King Abdulaziz City for Science & Technology | Saudi Arabia | 10 | 80 | A | C | y | F |
| | | | UNISAT 2 | University of Rome "La Sapienza" | Italy | 17 | 24 | N | E | y | F |
| **2003** | **28** | **6/30/03** | QuakeSat | Stanford University | USA | 3 | 61 | N | S | y | NF |
| | | | CUTE-1 (CO-55) | Tokyo Institute of Technology | Japan | 1 | 73 | S | E | y | F |
| | | | XI-IV (CO-57) | University of Tokyo | Japan | 1 | 73 | A | E | y | F |
| | | | CanX-1 | University of Toronto | Canada | 1 | 0 | F | E | y | F |
| | | | AAU Cubesat | University of Aalborg | Denmark | 1 | 3 | F | E | y | NF |
| | | | DTUsat | Technical University of Denmark | Denmark | 1 | 0 | F | E | n | NF |
| | **29** | **9/27/03** | STSAT-1 | Korean Advanced Institute of Science and Technology | Korea | 100 | 70 | A | T | y | F |
| | | | Mozhayets 4 (RS-22) | Mozhaisky military academy | Russia | 64 | 70 | A | C | y | F |

# University-Class Missions, 2004-2008

Saint Louis University
Parks College
Engineering. Aviation.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2004 | 30 | 4/18/04 | Naxing-1 (NS-1) | Tsinghua University | China | 25 | 64 | A | T | y | F |
| | 31 | 6/29/04 | SaudiSat 2 | King Abdulaziz City for Science & Technology | Saudi Arabia | 15 | 61 | A | S | y | F |
| | | | SaudiComsat-1 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 61 | A | C | y | F |
| | | | SaudiComsat-2 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 61 | A | C | y | F |
| | | | UNISAT 3 | University of Rome "La Sapienza" | Italy | 12 | 61 | A | T | y | F |
| | 32 | 12/21/04 | 3CS: Sparky | ASU/NMSU/CU Boulder | USA | 16 | - | LF | E | y | NF |
| | | | 3CS: Ralphie | ASU/NMSU/CU Boulder | USA | 16 | - | LF | E | y | NF |
| 2005 | 33 | 8/3/05 | PCSat 2 | US Naval Academy | USA | 12 | 13 | N | C | y | F |
| | 34 | 10/27/05 | XI-V (CO-58) | University of Tokyo | Japan | 1 | 45 | S | E | y | F |
| | | | Mozhayets 5 | Mozhaisky military academy | Russia | 64 | 0 | F | E | y | F |
| | | | UWE-1 | University of Würzburg | Germany | 1 | 1 | F | E | y | NF |
| | | | Ncube II | Norwegian Universities | Norway | 1 | 0 | F | E | n | NF |
| | | | SSETI Express (XO-53) | European Universities | Europe | 62 | 0 | F | C | y | NF |
| 2006 | 35 | 2/21/06 | CUTE-1.7 (CO-56) | Tokyo Institute of Technology | Japan | 10 | 1 | F | C | y | F |
| | 36 | 3/24/06 | Falconsat 2 | US Air Force Academy | USA | 20 | - | LF | S | y | F |
| | 37 | 7/26/06 | UNISAT 4 | University of Rome "La Sapienza" | Italy | 12 | - | LF | E | y | F |
| | | | Ncube | Norwegian Universites | Norway | 1 | - | LF | E | n | NF |
| | | | KUTESat | University of Kansas | USA | 1 | - | LF | E | n | NF |
| | | | CP2 | Cal Poly San Luis Obispo | USA | 1 | - | LF | E | y | NF |
| | | | CP1 | Cal Poly San Luis Obispo | USA | 1 | - | LF | E | y | NF |
| | | | ION | University of Illinois | USA | 2 | - | LF | T | n | NF |
| | | | ICE CUBE1 | Cornell University | USA | 1 | - | LF | T | n | NF |
| | | | ICE CUBE2 | Cornell University | USA | 1 | - | LF | T | n | NF |
| | | | PiCPoT | Politecnico di Torino, Italy | Italy | 2.5 | - | LF | E | n | NF |
| | | | SEEDS | Nihon University | Japan | 1 | - | LF | E | n | NF |
| | | | SACRED | University of Arizona | USA | 1 | - | LF | E | n | NF |
| | | | Rincon | University of Arizona | USA | 1 | - | LF | E | n | NF |
| | | | MEROPE | Montana State University | USA | 1 | - | LF | S | n | NF |
| | | | HAUSAT-1 | Hankuk Aviation University | S. Korea | 1 | - | LF | E | n | F |
| | | | Baumanets 1 | Bauman Moscow State Technical University | Russia | 92 | - | LF | E | n | F |
| | 38 | 9/22/06 | HITSat (HO-59) | Hokkaido Institute of Technology | Japan | 2.7 | 5 | N | C | n | NF |
| | 39 | 12/21/06 | RAFT-1 (NO-60) | US Naval Academy | USA | 1 | 5 | N | C | y | F |
| | | | MARScom | US Naval Academy | USA | 1 | 5 | N | C | y | F |
| | | | ANDE (NO-61) | US Naval Academy | USA | 75 | 12 | N | C | y | F |
| 2007 | 40 | 1/10/07 | LAPAN-Tubsat | Technical University of Berlin | Germany | 56 | 31 | A | C | y | F |
| | | | PEHUENSAT-1 (PO-63) | National University of Comahue | Argentina | 6 | 3 | N | C | n | NF |
| | 41 | 3/9/07 | Falconsat 3 | US Air Force Academy | USA | 54 | 29 | A | S | y | F |
| | | | MidSTAR-1 | US Naval Academy | USA | 120 | 29 | A | T | y | F |
| | 42 | 4/17/07 | Saudi ComSat-3 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 28 | A | C | y | F |
| | | | Saudi ComSat-4 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 28 | A | C | y | F |
| | | | Saudi ComSat-5 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 28 | A | C | y | F |
| | | | Saudi ComSat-6 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 28 | A | C | y | F |
| | | | Saudi ComSat-7 | King Abdulaziz City for Science & Technology | Saudi Arabia | 12 | 28 | A | C | y | F |
| | | | CP4 | Cal Poly San Luis Obispo | USA | 1 | 5 | N | E | y | NF |
| | | | CP3 | Cal Poly San Luis Obispo | USA | 1 | 5 | N | E | y | NF |
| | | | Libertad-1 | University of Sergio Arboleda | Columbia | 1 | 1 | N | E | n | NF |
| | | | CAPE-1 | University of Louisiana | USA | 1 | 5 | N | E | n | NF |
| | 43 | 9/25/07 | YES2/Floyd | ESA-led partnership | Europe | 30 | 0 | N | T | y | NF |
| | | | Yes2/Fotino | ESA-led partnership | Europe | 6 | 0 | F | T | y | NF |
| 2008 | 44 | 4/28/08 | Cute 1.7 + APD II (CO-65) | Tokyo Institute of Technology | Japan | 2 | 15 | A | E | y | F |
| | | | CanX 2 | University of Toronto | Canada | 2 | 15 | A | T | y | F |
| | | | AAU-CubeSat II | University of Aalborg | Denmark | 1 | 15 | A | T | y | NF |
| | | | SEEDS 2 (CO-66) | Nihon University | Japan | 1 | 15 | A | E | n | NF |
| | | | COMPASS 1 | Fachhochschule Aachen | Germany | 1 | 15 | S | E | n | NF |
| | | | Delfi-C3 (DO-64) | Technical University of Delft | Netherlands | 3 | 15 | S | T | n | F |

*Swartwout*

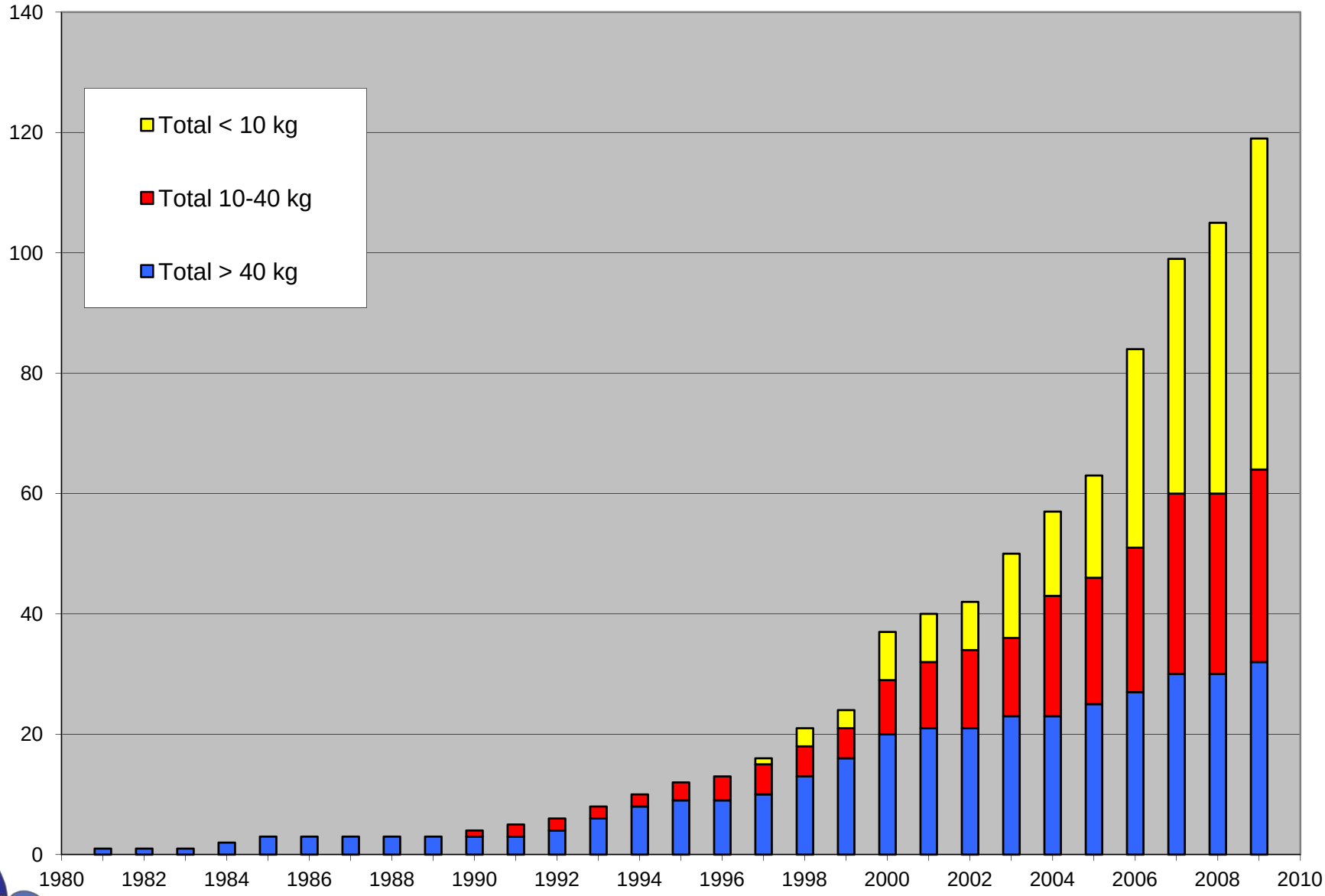
# University-Class Missions, 2009



| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2009** | **45** | **1/23/09** | SpriteSat (Raijin) | Tohoku University | Japan | 50 | 0 | F | S | n | NF |
| | | | PRISM | University of Tokyo | Japan | 8 | 7 | A | T | y | F |
| | | | KKS 1 | Tokyo Metropolitan College of Industrial Technology | Japan | 3 | 0 | F | T | n | NF |
| | | | STARS 1 | Kagawa University | Japan | 8 | 0 | F | T | n | NF |
| | 46 | 4/20/09 | ANUSAT | Anna University | India | 38 | 4 | A | C | n | F |
| | 47 | 5/19/09 | CP6 | Cal Poly San Luis Obispo | USA | 1 | 3 | A | E | y | NF |
| | **48** | **7/15/09** | BEVO-1 | University of Texas | USA | 5 | 1 | S | T | n | NF |
| | | | AggieSat2 | Texas A&M University | USA | 3.2 | 1 | S | T | n | NF |
| | **49** | **8/20/09** | SumbandilaSat | University of Stellenbosch | South Africa | 80 | n/a | - | T | y | F |
| | | | UGATUSAT | Ufa State Aviation Technical University | Russia | 30 | n/a | - | T | n | F |
| | **50** | **9/5/09** | UWE-2 | University of Würzburg | Germany | 1 | n/a | - | E | y | NF |
| | | | SwissCube-1 | Ecole Polytechnique Fédérale de Lausanne | Switzerland | 1 | n/a | - | S | n | F |
| | | | BeeSat | Technical University of Berlin | Germany | 1 | n/a | - | T | y | F |
| | | | ITU-pSat | Istanbul Technical University | Turkey | 1 | n/a | - | E | n | F |

# Sum Total of University-Class Spacecraft





# Launch rate and operational totals