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Attack of the CubeSats: A Statistical Look

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ABSTRACT

In previous conferences, we have presented a statistical history of university-class small satellites. Those studies need to be revised, because university-class spacecraft have reached a significant inflection point: in 2010-2011, we can identify a strong trend towards independent schools flying "real" CubeSat missions. For that trend, we must credit NASA and ESA for their sponsorship of competitively-selected CubeSat flights.

For this paper, we will revise previous studies in two ways:

1) Include the results of the past two years, which will show a continued upward trend in the number of university-class missions, a continued downward trend in the size of the spacecraft, and a not-so-continued dominance of the flagship universities. Have we hit a second turning point in the history of CubeSats, where they switch from novelties to actually-useful missions? (The preliminary answer: maybe.)

2) Expand the study to consider other small spacecraft mission types: specifically the professionally-built CubeSats. We will perform side-by-side comparison of the two.

The results will be used in a brave but ultimately naive attempt to predict the next few years in university-class and CubeSat-class flights: numbers, capabilities, and mix of participants.

INTRODUCTION

We have been documenting the history of university-class space missions for seven years.[1-7] The result of those studies can be broadly summarized as follows:

1) There sure are a lot of student-built satellites, and there will be even more next year.
2) University-class missions have had two watershed years: 1981, when the first university-class mission flew (UoSAT-1), and 2000, when a string of on-orbit failures nearly ended student satellite missions in the United States (and directly led to the introduction of the CubeSat standard).
3) The student launchspace is dominated by flagship universities, whose satellites are the most reliable and have the most significant missions. These flagships also fly a new spacecraft every few years.
4) By contrast, the "independent" schools tend to field spacecraft that fail more often, provide little-to-no value outside the school, and the overwhelming majority of independents only fly one spacecraft. Ever.
5) We're not sure what to make of these CubeSats, but they have the potential to upend the conclusions drawn from points #3 and #4 (while making point #1 more true than ever).

We concluded our 2009 report by noting that that the year 2010 could be the third "watershed" year in the history of university-class missions, with a large number of (primarily international) CubeSats flying. Well, in true aerospace fashion, there was a schedule slip, and 2011 has become the watershed year. In the two years since our last review, CubeSats have effectively taken over the university-class launchspace, burying the flagships in an avalanche of first-time independents – and unexpectedly carrying along a large number of professional programs into the CubeSat domain.

As in all previous years, we still confess that we have little-to-no idea what CubeSats mean for the long-term future of space missions: are they just a phase, another launch option, or a fundamental change in the way that space missions are pursued? Our opinions have indeed shifted: in 2004, we leaned towards short-term phase; today, we have more confidence that CubeSats are a long-term trend with revolutionary implications for some sectors of the space industry. And we have a lot more data to sift while forming those opinions.

Therefore, in this paper, we will first update our database of university-class missions, which now stands at 156 spacecraft since 1981. Using the most recent data, we will revisit our past claims about mission types, reliability, and the long-term viability of independent and flagship schools. In addition, given the significant role of CubeSats in the launchspace, we have compiled a database on all CubeSat-class spacecraft, and we will mine this data for insights into the state of the industry.

But first, as always, we need to define our terms: ***university-class*** satellites, ***flagship*** & ***independent*** schools, and ***CubeSat-class*** spacecraft.

Definitions

As discussed in previous papers, we narrowly define a ***university-class*** satellite as having three distinct features:

1. It is a functional spacecraft, rather than a payload instrument or component. To fit the definition, the device must operate in space with its own independent means of communications and command. However, self-contained objects that are attached to other vehicles are allowed under this definition (e.g. PCSat-2, Pehuensat-1).
2. Untrained personnel (i.e. students) performed a significant fraction of key design decisions, integration & testing, and flight operations.
3. The training of these people was as important as (if not more important) the nominal "mission" of the spacecraft itself.

Exclusion from the "university class" category does **not** imply a lack of educational value on a project's part; it simply indicates that other factors were more important than student education (e.g., schedule or on-orbit performance). Note also that many schools have "graduated" from university-class to professional programs, starting with the University of Surrey, who became SSTL, followed by schools such as the Technical University of Berlin, and the University of Toronto's Space Flight Laboratory (SFL).

Next, we define two broad categories of university-class programs: ***flagship*** and ***independent*** schools. A flagship university is designated by its government as a national center for spacecraft engineering research and development. Independent schools are all the rest.

By definition, flagships enjoy financial sponsorship, access to facilities and launch opportunities that the independent schools do not. Before 2009, these differences had a profound effect: generally speaking, flagship schools built bigger satellites with more "useful" payloads, and tended towards sustained programs with multiple launches over many years. By contrast, the satellites built by independent schools were three times more likely to fail, and for most of these programs, their first-ever spacecraft in orbit was also their last, i.e., the financial, administrative and student resources that were gathered together to built the first satellite are not available for the second. As we will see in the analysis section, below, some of these assumptions are starting to fail.

It is generally understood that a ***CubeSat-class*** spacecraft is one that adheres to the CubeSat/P-POD standard developed by Cal Poly and Stanford Universities (i.e., it fits inside the P-POD and follows the flight safety guidelines). However, for the purposes of this study, we also include the international analogs to the P-POD (Japan's T-POD and SFL's X-POD), the DoD analog (MEPSI) and the P-POD precursor (the picosats that flew inside Stanford's Opal spacecraft).[8]

Disclaimers

This information was compiled from online sources, past conference proceedings and author interviews with students and faculty at many universities, as noted in the references. The opinions expressed in this paper are just that, opinions, reflecting the author's experience as both student project manager and faculty advisor to university-class projects. The author accepts sole responsibility for any factual (or interpretative) errors found in this paper and welcomes any corrections. (The author has been cutting-and-pasting this disclaimer into every one of these papers for seven years and has yet to receive a single correction, so he is left to conclude that either (a) he is the greatest fact-checker ever or (b) nobody reads these papers and/or cares enough to send him updates.)

UNIVERSITY-CLASS MANIFEST, UPDATED

A list of university-class spacecraft launched from 1981 until the submission of this paper (June 2011) are split between Tables 1-3, including the twenty-three spacecraft that are on "official" manifests for the second half of 2011. Because the inclusion or omission of a spacecraft from this list may prove to be a contentious issue – not to mention the designation of whether a vehicle failed prematurely, it is worth repeating an explanation of the process for creating these tables.

First, using launch logs, the author's knowledge and several satellite databases, a list was created of all university-class small satellites that were placed on a rocket.[9-14] These remaining spacecraft were researched regarding mission duration, mass and mission categories, with information derived from published reports and project websites as indicated. A **T-class** (technology) mission flight-tests a component or subsystem that is new to the satellite industry (not just new to the university). An **S–class** (science) mission creates science data relevant to that particular field of study (including remote sensing). A **C-class** (communications) mission provides communications services to some part of the world (often in the Amateur radio service). While every university-class mission is by definition educational, those spacecraft listed as **E-class** (education) missions lack any of the other payloads and serve mainly to train students and improve the satellite-building capabilities of that particular school; typical E-class payloads are COTS imagers (low-resolution Earth imagery), on-board telemetry, and beacon communications. Finally, a spacecraft is indicated to have failed prematurely when its operational lifetime was significantly less than published reports predicted and/or if the university who created the spacecraft indicates that it failed.

This list of spacecraft is complete to the best of the author's ability. The caveats from previous versions of this work still apply: launch masses should be considered approximate, as should mission durations. Special thanks is given to the authors of reference 14 for their extensive archive describing satellite contacts.

Table 1: University-Class Spacecraft Launched From 1981 to 2003

Launch	Launch ID	Launch Date	Mission	Primary School(s)	Nation	Mass (kg)	Mission Duration (months)	Status	Type
1981	1	10/6/81	UoSAT-1 (UO-9)	University of Surrey	UK	52	96	N	S
1984	2	3/1/84	UoSAT-2 (UO-11)	University of Surrey	UK	60	281	N	C
1985	3	4/29/85	NUSAT	Weber State, Utah State University	USA	52	20	N	T
1990	4	1/22/90	WeberSAT (WO-18)	Weber State	USA	16	96	N	C
1991	5	7/17/91	TUBSAT-A	Technical University of Berlin	Germany	35	188	N	C
1992	6	8/10/92	KITSAT-1 (KO-23)	Korean Advanced Institute of Science and Technology	Korea	49	77	N	T
1993	7	5/12/93	ARSENE	CNES Amateurs (?)	France	154	4	F	C
	8	10/26/93	KITSAT-2 (KO-25)	Korean Advanced Institute of Science and Technology	Korea	48	96	N	C
1994	9	1/25/94	TUBSAT-B	Technical University of Berlin	Germany	45	1	F	T
	10	3/2/94	BremSat	University of Bremen	Germany	63	11	N	S
1995	**11**	**8/28/95**	Techsat 1-A	Technion Institute of Technology	Israel	50	-	LF	C
			UNAMSAT-A	National University of Mexico	Mexico	10	-	LF	C
1996	12	5/9/96	UNAMSAT-B (MO-30)	National University of Mexico	Mexico	10	0	F	C
1997	13	10/25/97	Falcon Gold	US Air Force Academy	USA	18	0.5	N	T
	14	10/30/97	YES	ESA/ESTEC-led partnership	Europe	187	0.1	N	E
	15	11/3/97	RS-17	Russian high school students	Russia	3	2	N	E
1998	**16**	**7/7/98**	TUBSAT-N	Technical University of Berlin	Germany	8	46	N	T
			TUBSAT-N1	Technical University of Berlin	Germany	3	20	N	T
	17	7/10/98	Techsat 1-B (GO-32)	Technion Institute of Technology	Israel	70	51	N	S
	18	**10/30/98**	PANSAT (PO-34)	Naval Postgraduate School	USA	70	60	N	C
			SEDSAT (SO-33)	University of Alabama, Huntsville	USA	41	33	F	T
1999	19	2/23/99	Sunsat (SO-35)	University of Stellenbosch	South Africa	64	23	N	C
	20	**5/27/99**	DLR-TUBSAT	Technical University of Berlin	Germany	45	120	N	S
			KITSAT-3	Korean Advanced Institute of Science and Technology	Korea	110	55	N	T
2000	**21**	**1/27/00**	JAWSAT (WO-39)	Weber State, USAFA	USA	191	1.0	F	T
			Falconsat 1	US Air Force Academy	USA	52	1.0	F	E
			ASUsat 1 (AO-37)	Arizona State University	USA	6	0.0	F	E
			Opal (OO-38)	Stanford University	USA	23	29	N	T
		2/10/00	JAK	Santa Clara University	USA	0.2	0	F	E
		2/12/00	Louise	Santa Clara University	USA	0.5	0	F	S
			Thelma	Santa Clara University	USA	0.5	0	F	S
	22	6/28/00	Tsinghua-1	Tsinghua University	China	49	30	N	E
	23	**9/26/00**	TiungSAT-1 (MO-46)	ATSB	Malaysia	50	39	N	S
			Saudisat 1A (SO-41)	King Abdulaziz City for Science & Technology	Saudi Arabia	10	36	N	C
			Saudisat 1B (SO-42)	King Abdulaziz City for Science & Technology	Saudi Arabia	10	27	N	C
			UNISAT 1	University of Rome "La Sapienza"	Italy	12	24	N	E
	24	11/21/00	Munin	Umeå University / Luleå University of Technology	Sweden	6	3	N	S
2001	**25**	**9/30/01**	Sapphire (NO-45)	Stanford, USNA, Washington University	USA	20	36	N	E
			PCSat 1 (NO-44)	US Naval Academy	USA	12	116	S	C
	26	10/12/01	Maroc-TUBSAT	Technical University of Berlin	Germany	47	104	N	S
2002	**27**	**12/20/02**	Saudisat 1C (SO-50)	King Abdulaziz City for Science & Technology	Saudi Arabia	10	101	A	C
			UNISAT 2	University of Rome "La Sapienza"	Italy	17	24	N	E
2003	**28**	**6/30/03**	QuakeSat	Stanford University	USA	3	61	N	S
			CUTE-1 (CO-55)	Tokyo Institute of Technology	Japan	1	95	S	E
			XI-IV (CO-57)	University of Tokyo	Japan	1	95	A	E
			CanX-1	University of Toronto	Canada	1	0	F	E
			AAU Cubesat	University of Aalborg	Denmark	1	3	F	E
			DTUsat	Technical University of Denmark	Denmark	1	0	F	E
	29	**9/27/03**	STSAT-1	Korean Advanced Institute of Science and Technology	Korea	100	19	N	T
			Mozhayets 4 (RS-22)	Mozhaisky military academy	Russia	64	78	N	C

Table 2: University-Class Spacecraft Launched (or Manifested) From 2004 to 2010

Launch	Launch ID	Launch Date	Mission	Primary School(s)	Nation	Mass (kg)	Mission Duration (months)	Status	Type
2004	**30**	**6/29/04**	SaudiSat 2	King Abdulaziz City for Science & Technology	Saudi Arabia	15	83	A	S
			SaudiComsat-1	King Abdulaziz City for Science & Technology	Saudi Arabia	12	83	A	C
			SaudiComsat-2	King Abdulaziz City for Science & Technology	Saudi Arabia	12	83	A	C
			UNISAT 3	University of Rome "La Sapienza"	Italy	12	83	A	T
	31	**12/21/04**	3CS: Sparky	ASU/NMSU/CU Boulder	USA	16	-	LF	E
			3CS: Ralphie	ASU/NMSU/CU Boulder	USA	16	-	LF	E
2005	32	8/3/05	PCSat 2	US Naval Academy	USA	12	13	N	C
	33	**10/27/05**	XI-V (CO-58)	University of Tokyo	Japan	1	67	S	E
			Mozhayets 5	Mozhaisky military academy	Russia	64	0	F	E
			UWE-1	University of Würzburg	Germany	1	1	F	E
			Ncube II	Norwegian Universities	Norway	1	0	F	E
			SSETI Express (XO-53)	European Universities	Europe	62	0	F	C
2006	34	2/21/06	CUTE-1.7 (CO-56)	Tokyo Institute of Technology	Japan	10	1	F	C
	35	3/24/06	Falconsat 2	US Air Force Academy	USA	20	-	LF	S
	36	**7/26/06**	UNISAT 4	University of Rome "La Sapienza"	Italy	12	-	LF	E
			Ncube	Norwegian Universites	Norway	1	-	LF	E
			KUTESat	University of Kansas	USA	1	-	LF	E
			CP2	Cal Poly San Luis Obispo	USA	1	-	LF	E
			CP1	Cal Poly San Luis Obispo	USA	1	-	LF	E
			ION	University of Illinois	USA	2	-	LF	T
			ICE CUBE1	Cornell University	USA	1	-	LF	T
			ICE CUBE2	Cornell University	USA	1	-	LF	T
			PiCPoT	Politecnico di Torino, Italy	Italy	2.5	-	LF	E
			SEEDS	Nihon University	Japan	1	-	LF	E
			SACRED	University of Arizona	USA	1	-	LF	E
			Rincon	University of Arizona	USA	1	-	LF	E
			MEROPE	Montana State University	USA	1	-	LF	S
			HAUSAT-1	Hankuk Aviation University	S. Korea	1	-	LF	E
			Baumanets 1	Bauman Moscow State Technical University	Russia	92	-	LF	E
	37	9/22/06	HITSat (HO-59)	Hokkaido Institute of Technology	Japan	2.7	5	N	C
	38	**12/21/06**	RAFT-1 (NO-60)	US Naval Academy	USA	1	5	N	C
			MARScom	US Naval Academy	USA	1	5	N	C
			ANDE (NO-61)	US Naval Academy	USA	75	12	N	C
2007	39	1/10/07	PEHUENSAT-1 (PO-63)	National University of Comahue	Argentina	6	3	N	C
	40	**3/9/07**	Falconsat 3	US Air Force Academy	USA	54	51	A	S
			MidSTAR-1	US Naval Academy	USA	120	25	N	T
	41	**4/17/07**	Saudi ComSat-3	King Abdulaziz City for Science & Technology	Saudi Arabia	12	49	A	C
			Saudi ComSat-4	King Abdulaziz City for Science & Technology	Saudi Arabia	12	49	A	C
			Saudi ComSat-5	King Abdulaziz City for Science & Technology	Saudi Arabia	12	49	A	C
			Saudi ComSat-6	King Abdulaziz City for Science & Technology	Saudi Arabia	12	49	A	C
			Saudi ComSat-7	King Abdulaziz City for Science & Technology	Saudi Arabia	12	49	A	C
			CP4	Cal Poly San Luis Obispo	USA	1	5	N	E
			CP3	Cal Poly San Luis Obispo	USA	1	5	N	E
			Libertad-1	University of Sergio Arboleda	Columbia	1	1	N	E
			CAPE-1	University of Louisiana	USA	1	5	N	E
	42	**9/25/07**	YES2/Floyd	ESA-led partnership	Europe	30	0	N	T
			Yes2/Fotino	ESA-led partnership	Europe	6	0	F	T
2008	**43**	**4/28/08**	Cute 1.7 + APD II (CO-65)	Tokyo Institute of Technology	Japan	2	37	A	E
			CanX 2	University of Toronto	Canada	2	37	A	T
			AAU-CubeSat II	University of Aalborg	Denmark	1	37	S	T
			SEEDS 2 (CO-66)	Nihon University	Japan	1	37	A	E
			COMPASS 1	Fachhochschule Aachen	Germany	1	37	S	E
			Delfi-C3 (DO-64)	Technical University of Delft	Netherlands	3	37	S	T
2009	**44**	**1/23/09**	SpriteSat (Raijin)	Tohoku University	Japan	50	0	F	S
			PRISM	University of Tokyo	Japan	8	28	A	T
			KKS 1	Tokyo Metropolitan College of Industrial Technology	Japan	3	0	F	T
			STARS 1	Kagawa University	Japan	8	0	F	T
	45	4/20/09	ANUSAT	Anna University	India	38	25	A	C
	46	5/19/09	CP6	Cal Poly San Luis Obispo	USA	1	4	N	E
	47	**7/15/09**	BEVO-1	University of Texas	USA	5	0	F	T
			AggieSat2	Texas A&M University	USA	3.2	8	F	T
	48	**9/17/09**	SumbandilaSat (SO-67)	University of Stellenbosch	South Africa	81	12	N	T
			UGATUSAT (RS 28)	Ufa State Aviation Technical University	Russia	35	0	F	T
	49	**9/23/09**	UWE-2	University of Würzburg	Germany	1	1	F	E
			SwissCube-1	Ecole Polytechnique Fédérale de Lausanne	Switzerland	1	20	A	S
			BeeSat	Technical University of Berlin	Germany	1	20	A	T
			ITU-pSat	Istanbul Technical University	Turkey	1	20	A	E
2010	**50**	**5/20/10**	UNITEC 1	University Space Engineering Consortium	Japan	16	0	F	T
			Waseda-SAT2	Waseda University	Japan	1.2	0	F	E
			Negai*	Soka University	Japan	1	3	N	E
			K-Sat	Kagoshima University	Japan	1.5	0	F	S
	51	**7/12/10**	STUDSAT	Indian university consortium	India	1	1	F	E
			Tisat 1	Scuola universitaria della Svizzera italiana	Switzerland	1	11	A	E
	52	**9/30/10**	FASTRAC-A	University of Texas	USA	15	8	A	T
			FASTRAC-B	University of Texas	USA	15	8	A	T
			RAX	University of Michigan	USA	3	7	N	S
			FalconSat-5	US Air Force Academy	USA	100	8	A	S
	53	12/8/10	Caerus	University of Southern California	USA	1.67	0	N	E

Table 3: University-Class Spacecraft Launched (or Manifested) In 2011

Launch	Launch ID	Launch Date	Mission	Primary School(s)	Nation	Mass (kg)	Mission Duration (months)	Status	Type
2011	**54**	**3/4/11**	Explorer-1 Prime	Montana State University	USA	1	-	LF	S
			KySat-1	Kentucky Space	USA	1	-	LF	E
			Hermes	Colorado	USA	1	-	LF	T
	55	**4/20/11**	YouthSat	M.V. Lomonosov Moscow state university	Russia	92	1	A	S
			X-Sat	Nanyang Technological University	Singapore	105	1	A	S
	56	6/20/11	EDUSAT	University of Rome "La Sapienza"	Italy	10	n/a	-	E
	57	8/25/11	Baumanets 2	Bauman Moscow State Technical University	Russia	40	n/a	-	T
	58	**10/25/11**	RAX 2	University of Michigan	USA	3	n/a	-	S
			COVE/Mcubed	University of Michigan	USA	3	n/a	-	T
			DICE 1	Utah State	USA	2	n/a	-	S
			DICE 2	Utah State	USA	2	n/a	-	S
			Explorer-1 Prime F2	Montana State University	USA	1	n/a	-	S
	59	**10/31/11**	Almasat-1	University of Bologna	Italy	12.5	n/a	-	E
			AtmoCube	Trieste University	Italy	1	n/a	-	S
			e-st@r	Politecnico di Torino, Italy	Italy	1	n/a	-	T
			Goliat	University of Bucharest	Romania	1	n/a	-	E
			OUFTI 1	Université de Liège	Belgium	1	n/a	-	T
			PW-Sat 1	Warsaw University of Technology	Poland	1	n/a	-	T
			ROBUSTA	University of Montpellier II	France	1	n/a	-	E
			UWE-3	University of Würzburg	Germany	1	n/a	-	E
			UNICubeSat	University of Rome "La Sapienza"	Italy	1	n/a	-	T
			XaTcobeo	University of Vigo	Spain	1	n/a	-	T
	60	11/1/11	Horyu-2	Kyushu University	Japan	6	n/a	-	T
	61	**12/31/11**	SRMSAT	SRM University	India	10	n/a	-	E
			Jugnu	Indian Institute of Technology Kanpur	India	4	n/a	-	S
			Venta	Ventspils University	India	10	n/a	-	C
	62		InnoSat	ATSB	Malaysia	4	n/a	-	T
			CubeSAT	ATSB	Malaysia	4	n/a	-	T

OBSERVATIONS

We extensively discussed the manifest in previous papers, so we will only comment on new results.

Updated: Number crunching

First, as shown in Figure 1, the significant increase in manifests noted in previous years is a full-blown trend; the new "normal" for university-class flights is 10-15 per year. Credit must be given to the CubeSats; as shown in Figure 2 (and especially in Figure 3), the smallest spacecraft account for the increase. We speculated in 2007 and again in 2009 that, with the backlog of first-generation CubeSats cleared, we might see a dropoff in CubeSat missions. This has not happened; in fact, the 2012 manifest has almost 30 NASA-sponsored CubeSats!

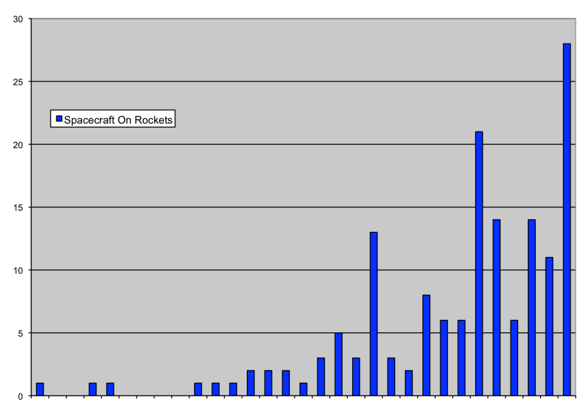

Figure 1: Manifested University-Class Spacecraft

Updated: Flagships vs. Independents

In the past two years, the flagship trend has reversed: independents outnumber flagships two-to-one in 2010 and 2011 (Figure 4). That reversal appears to strengthen in 2012. Flagship schools represented 54% of manifested spacecraft through the end of 2009, and now stand at just 46% (73 of 156). No longer do a few schools dominate the manifest (Figure 6): 36 schools fielded their first satellite in the years 2009-2011!

Still, it's not all great news. Only 12 of 53 independent schools to have fielded a spacecraft have repeated (up from 9 in 2009), while 14 of 29 flagships have repeated, which is actually down significantly due to an influx of first-time flagshps. The complete list of schools with manifested hardware is in Table 4.

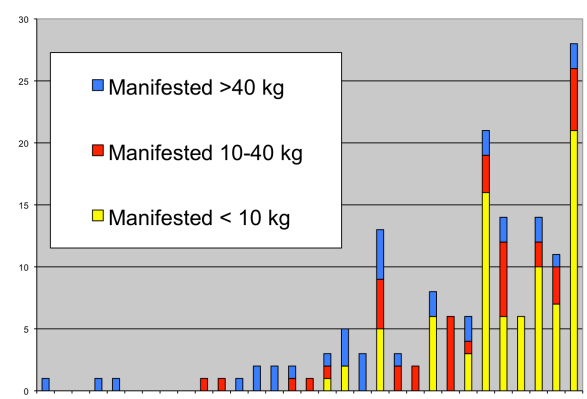

Figure 2: Spacecraft Launch Mass by Year

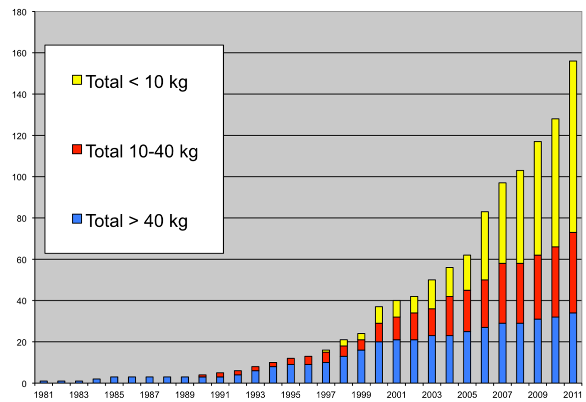

Figure 3: Aggregate Totals of Spacecraft Launched per Year Categorized by Mass

Table 4: Spacefaring Universities (Flagships Highlighed in Yellow)

	School	Nation	First Launch	#
1	University of Surrey	UK	10/6/81	2
2	Weber State	USA	4/29/85	3
3	Utah State	USA	4/29/85	3
4	Technical University of Berlin	Germany	7/17/91	7
5	Korean Advanced Institute of Science and Technology	Korea	8/10/92	4
6	CNES Amateurs (?)	France	5/12/93	1
7	University of Bremen	Germany	3/2/94	1
8	Technion Institute of Technology	Israel	8/28/95	2
9	National University of Mexico	Mexico	8/28/95	2
10	US Air Force Academy	USA	10/25/97	6
11	Russian high school students	Russia	11/3/97	1
12	Naval Postgraduate School	USA	10/30/98	1
13	University of Alabama, Huntsville	USA	10/30/98	1
14	University of Stellenbosch	South Africa	2/23/99	2
15	Arizona State University	USA	1/27/00	3
16	Stanford University	USA	1/27/00	3
17	Santa Clara University	USA	2/10/00	3
18	Tsinghua University	China	6/28/00	1
19	ATSB	Malaysia	9/26/00	3
20	King Abdulaziz City for Science & Technology	Saudi Arabia	9/26/00	1 1
21	University of Rome "La Sapienza"	Italy	9/26/00	6
22	Umeå University / Luleå University of Technology	Sweden	11/21/00	1
23	US Naval Academy	USA	9/30/01	6
24	Tokyo Institute of Technology	Japan	6/30/03	3
25	University of Tokyo	Japan	6/30/03	3
26	University of Toronto	Canada	6/30/03	2
27	University of Aalborg	Denmark	6/30/03	2
28	Mozhaisky Military Academy	Russia	9/27/03	2
29	Technical University of Denmark	Denmark	6/30/03	1
30	New Mexico State University	USA	12/21/04	1
31	CU Boulder	USA	12/21/04	1
32	University of Würzburg	Germany	10/27/05	3
33	Norwegian Universites	Norway	10/27/05	2
34	European Universities	Europe	10/30/97	4
35	University of Kansas	USA	7/26/06	1
36	Cal Poly San Luis Obispo	USA	7/26/06	5
37	University of Illinois	USA	7/26/06	1
38	Cornell University	USA	7/26/06	2
39	Politecnico di Torino, Italy	Italy	7/26/06	2
40	Nihon University	Japan	7/26/06	2
41	University of Arizona	USA	7/26/06	2
42	Montana State University	USA	7/26/06	3
43	Hankuk Aviation University	S. Korea	7/26/06	1
44	Bauman Moscow State Technical University	Russia	7/26/06	2
45	Hokkaido Institute of Technology	Japan	9/22/06	1
46	National University of Comahue	Argentina	1/10/07	1
47	University of Sergio Arboleda	Columbia	4/17/07	1
48	University of Louisiana	USA	4/17/07	1
49	Fachhochschule Aachen	Germany	4/28/08	1
50	Technical University of Delft	Netherlan ds	4/28/08	1
51	Tohoku University	Japan	1/23/09	1
52	Tokyo Metropolitan College of Industrial Technology	Japan	1/23/09	1
53	Kagawa University	Japan	1/23/09	1
54	Anna University	India	4/20/09	1
55	Ecole Polytechnique Fédérale de Lausanne	Switzerla nd	9/23/09	1
56	Istanbul Technical University	Turkey	9/23/09	1
57	Ufa State Aviation Technical University	Russia	9/17/09	1
58	University of Texas	USA	7/15/09	3
59	Texas A&M University	USA	7/15/09	1
60	University Space Engineering Consortium	Japan	5/20/10	1
61	Waseda University	Japan	5/20/10	1

62	Soka University	Japan	5/20/10	1
63	Kagoshima University	Japan	5/20/10	1
64	Indian university consortium	India	7/12/10	1
65	Scuola universitaria della Svizzera italiana	Switzerland	7/12/10	1
66	University of Michigan	USA	9/30/10	3
67	Trieste University	Italy	10/31/11	1
68	University of Bucharest	Romania	10/31/11	1
69	Warsaw University of Technology	Poland	10/31/11	1
70	University of Montpellier II	France	10/31/11	1
71	University of Vigo	Spain	10/31/11	1
72	University of Southern California	USA	12/8/10	1
73	Kentucky Space	USA	3/4/11	1
74	Colorado	USA	3/4/11	1
75	M.V. Lomonosov Moscow state university	Russia	4/20/11	1
76	Nanyang Technological University	Singapore	4/20/11	1
77	University of Bologna	Italy	10/31/11	1
78	Université de Liège	Belgium	10/31/11	1
79	Kyushu University	Japan	11/1/11	1
80	SRM University	India	12/31/11	1
81	Indian Institute of Technology Kanpur	India	12/31/11	1
82	Ventspils University	India	12/31/11	1

In previous papers, we noted that the Dnepr failure of 2006 destroyed the spacecraft of ten first-time schools, and predicted that the odds were against most of those schools mustering the resources for a second launch. The good news is that half of those schools have flown another mission (or are manifested in 2011), with one more school (Nihon) flying a copy of the lost CubeSat, but only Cal Poly has flown new hardware since the Dnepr loss – all of them CubeSats.

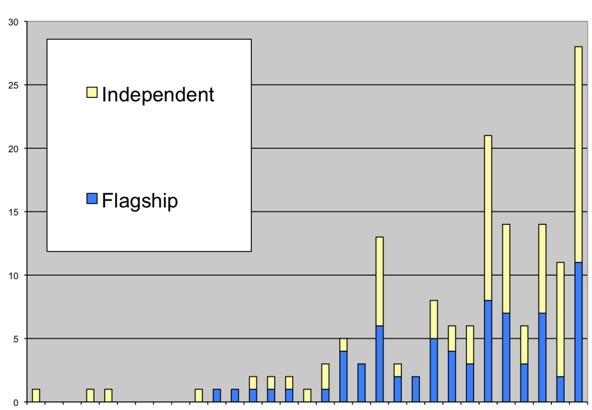

Figure 4: Flagship vs. Independent Missions

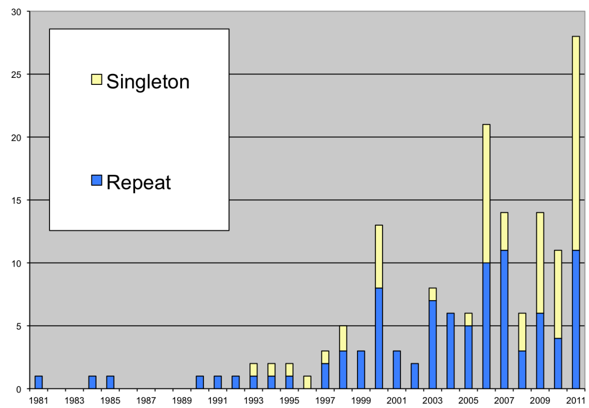

Figure 5: Repeat Missions vs. Single-Launch Programs

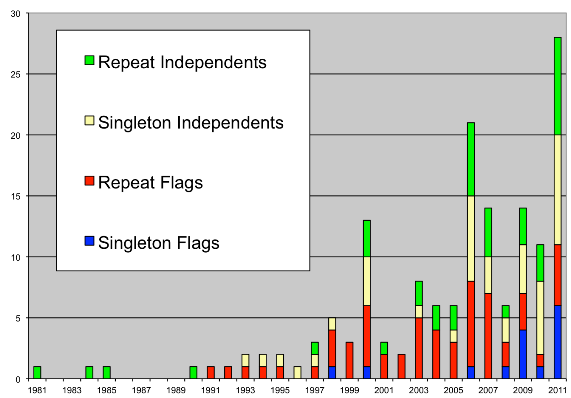

Figure 6: Comparison of Repeat Launches by Flagship Status

Updated: What Breaks First?

Whether out of embarrassment, proprietary concerns, or simply a lack of interest, university-class missions do not publish failure reports. The following information is the author's best guess based on news articles and the few published failure reports and has been revised since the last paper. Of the 30 spacecraft we have identified as failing prematurely (Figure 7), the failures can be attributed to (or guessed to be) the following:

- **Radiation:** 1 (TUBSAT-B). Killed by the Van Allen Belts due to its orbit altitude of 1250 km.
- **Structure/launch interface:** 3 (Mozhayets 5, BEVO 1, AggieSat-2). Mozhayets 5 failed to separate from the launch vehicle; the other two spacecraft were launched as a unit and failed to disconnect from one another.
- **Thermal:** 1 (UNAMSAT-B); cold prelaunch thermal conditions led to an inability to contact the spacecraft immediately after launch, leading to more thermally-induced battery probems.

- **Communications:** 7½ (Arsene, SEDsat [partial], JAWSAT, Cute-1.7, UWE-1, STUDSAT, UNITEC-1, K-SAT). These spacecraft were operational for a short time, losing either their transmitters or receivers (or both) unexpectedly. Bad wiring is suspected in some cases.
- **Power:** 5½ (SEDSat [partial], ASUSat-1, FalconSAT-1, AAU CubeSat-I, SSETI-Express, UGATUSAT). The reasons vary, but all of these vehicles had problems, typically with the connection between batteries and solar arrays.
- **CPU:** 2 (SpriteSat, STARS-1). Both of these spacecraft encountered unexpected CPU lockups within days of launch; as of the writing of this paper, they have not been recovered.
- **Unknown:** 10 (JAK, Louise, Thelma, CanX-1, DTUsat, NCube II, YES2/Fotino, KKS 1, Waseda-SAT2, UWE-2). These eight spacecraft were confirmed to have released, but contact was never made. Bad communications or bad power is suspected.

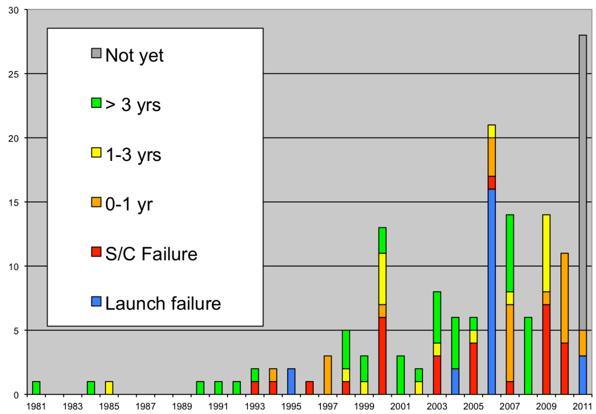

Figure 7: Spacecraft Lifetime by Launch Year

It is worth updating a statement from previous papers: only one of the 91 student-built spacecraft that made it to orbit is known to have had structural problems (jammed deployment mechanism). And only one of 91 student-built spacecraft is known to have had on-orbit thermal problems.* Granted, as we revisit Figure 7, we must admit that student-built spacecraft do not last very long on orbit (an average of 40 months with a median of 24 months, with the average dropping by more than 12 months if the first six spacecraft from the 1980s and 1990s are omitted); inadequate thermal design and inattention to COTS electronics doubtlessly contribute to those reduced lifetimes. Again, while no one should discount the importance of sound structural & thermal analysis/testing, nor should students ignore the risks of COTS electronics, the flight history still indicates that more time needs to be devoted to system-level functional testing rather than these three issues.

Updated: Mission Type

In the previous paper, we identified the growth of E-Class missions among independents in this decade. That trend reversed as seen in the chart of launch manifest by mission type (Figure 8) and then further subdivided by flagship and independent status (Figure 9). There is a significant increase in the number of independent schools carrying "real" missions; as will be noted below, this trend can be credited to the selection process used by NASA and ESA to fly university-class CubeSats.

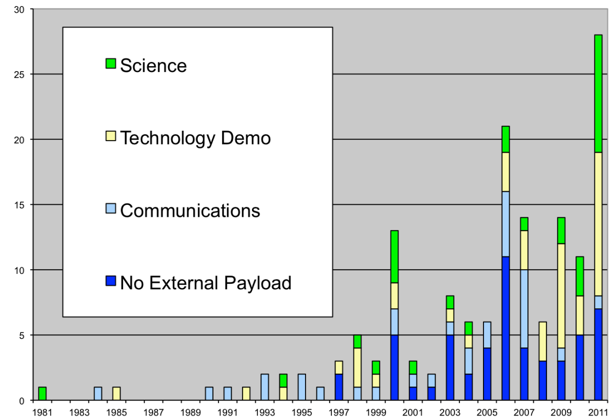

Figure 8: Mission Type by Year

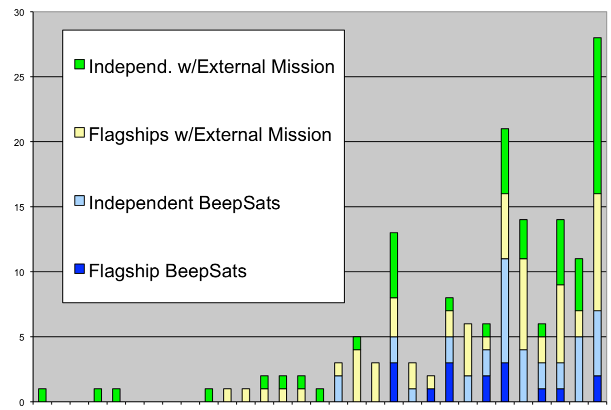

Figure 9: Mission Type by Year and University Classification

Final Scorecard: Flagship vs. Independents

This point has been discussed in detail in previous papers, but it is worth repeating with the new data. Due to their government/industry support, flagship schools tend to build more satellites per school (29 flags have built 73 spacecraft), their satellites are less likely to fail

* It also must be noted that 10 spacecraft have unknown root causes of failure, and structural and/or thermal problems cannot be ruled out.

(7 of 59 to reach orbit – about 11%) and more likely to carry a real mission (57 of 73, or 78%). By stark contrast, independent schools tend to build only one spacecraft, ever (53 independents have launched 83 spacecraft), their failure rates are much higher (23 of 51 to reach orbit, or 45%), and less likely to carry a real mission (37 of 83 are BeepSats, or 44%). Independents tend to build CubeSats (nearly three-quarters, or 60 of 83).

Of 55 launches carrying student-built spacecraft to date, only five have failed, but one of them was the 2006 Dnepr carrying 15 university-class missions. Unfortunately, independent schools have borne the brunt of the failures, with 18 spacecraft lost, or more than 20% of all independent-built spacecraft placed on rockets. Flagships have had an easier time of it, losing only 5 (7%). This is a trend worth following, especially as years continue, to see whether the 2006 loss was a statistical anomaly.

CUBESATS

Especially in the proceedings of this conference, it seems silly to define the CubeSat, but on the off chance that someone reads this paper 20 years from now, we will briefly recap: in 2000, Profs. Bob Twiggs of Stanford and Jordi Puig-Suari of Cal Poly defined a new set of standards to integrate & fly very small student-built spacecraft. The CubeSat standard was to allow three 10x10x10 cm cubes to fit into a single spring-actuated ejector system; the intent was to define a spacecraft size and mission scope such that students could build and fly a spacecraft within their academic lifetimes. Standard sizes and performance specifications were also intended to encourage collaboration among schools. The first CubeSats were launched in 2003, and eight years later (a blink of the eye in aerospace time), nearly seventy have already flown.

Using the same sources as before,[1-7] and the same methods as before, we have updated the database to include all CubeSats. (The list is in the Appendix.) And, as before, certain trends immediately emerge. As seen in Figure 10, there is a steady increase in manifested CubeSats from 2005 through 2011, with an astonishing (to this author) 97 CubeSat-class missions fielded in 10 years. As noted above, the estimated manifest for 2012 is at least 25 (and could be as high as 50). Viewing the same data by form factor (Figure 11), we note that the P-POD standard is dominating the manifest; in fact, the MEPSI standard was dropped in favor of the P-POD. Similarly, one can observe that the 1U class is the dominant choice.

If we examine the manifest according to the type of developer (i.e., university, commercial, civil or military), we can observe the difficulty in establishing any trends (Figure 12). In 2009-2010 it seemed apparent that military and NASA programs were poised to crowd out the universities by snapping up all available capacity.

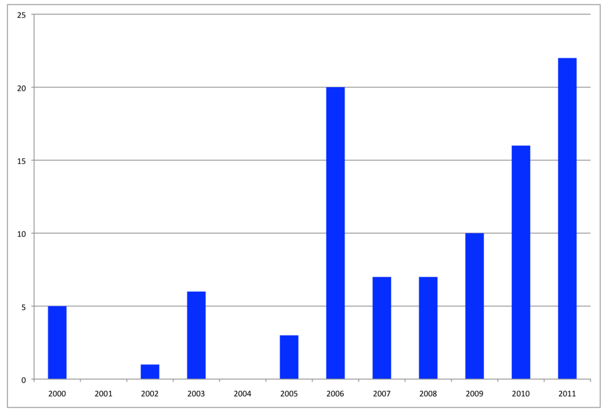

Figure 10: Manifested CubeSat-Class Missions

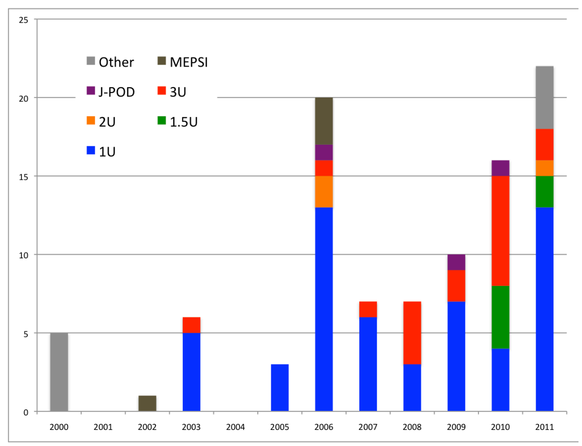

Figure 11: CubeSat Form Factor by Year

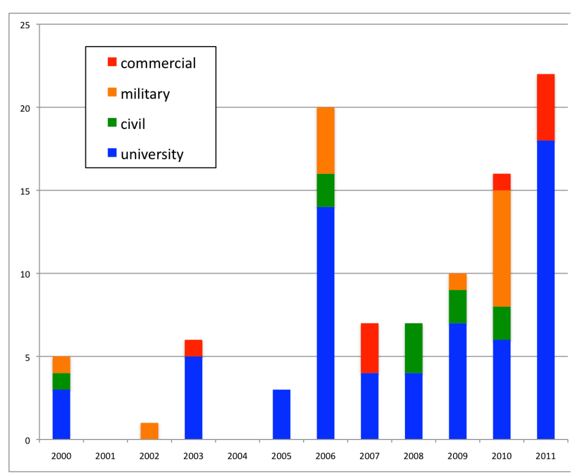

Figure 12: Mission Developer by Year

Instead, capacity grew, and a lot of new independent schools started providing 1U CubeSats. In fact, as shown in Figure 13, it is fair generalization to say that universities provide 1U CubeSats: 49 of 54 1Us are university-built, and 49 of 64 university missions are 1U. Similarly, professional programs build bigger spacecraft (1.5U, 2U or 3U): 17 of 27 larger CubeSat-class spacecraft are industry-built (and 17 of the 33 industry-built CubeSat-class missions).

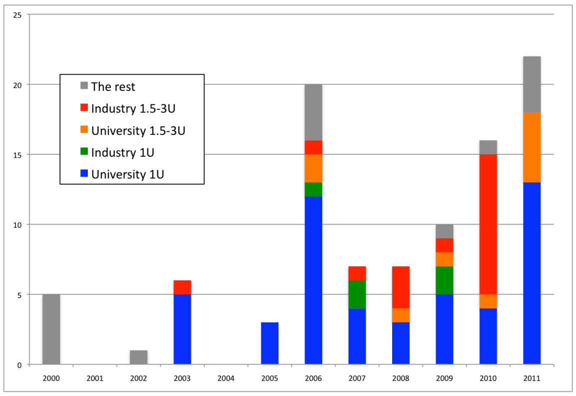

Figure 13: CubeSat Form Factor by Developer Category and Manifest Year

From that data and the previous discussion on university-class Beepsats, one might believe that the 3U form factor is necessary to support a "real" mission, and the 1U is only good for a Beepsat. However, considering Figure 14, it is very fascinating to note that the university programs are moving away from the E-Class mission towards "real" science and technology demonstrations.

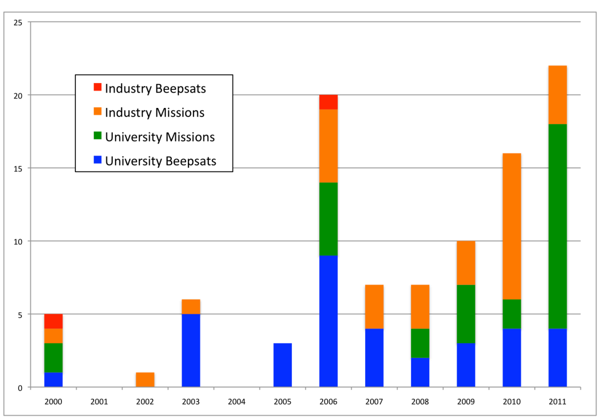

Figure 14: Subdivision of BeepSat and "Real" Mission by Developer and Manifest Year

In 2009, we looked at the data and were fairly convinced that the CubeSat launchspace was about to be overrun by 3Us built by industry, and what few university-class CubeSats that were launched would be European-built. Instead, as already noted, universities were able to keep up with the new launch capacity, as well as attempt real missions on a 1U. Also, as shown in Figure 15, after a few lean years in the late part of the last decade, the United States is fielding more CubeSats than the rest of the world put together.

What happened?

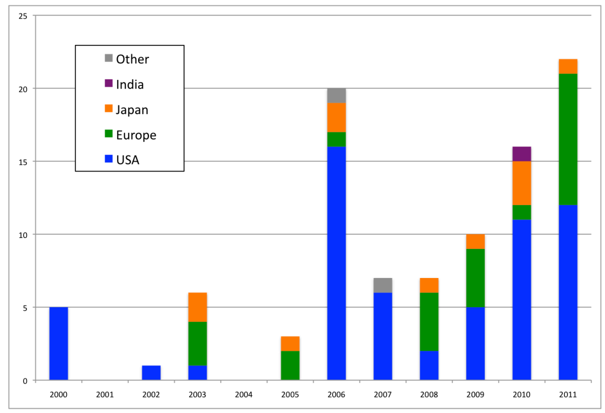

Figure 15: Mission Developer by Nation/Region and Manifest Year

We believe that three things happened.

1) Various agencies in the Defense Department experienced success with early CubeSats (e.g. the Aerospace Corporation's Aerocube series, and Boeing's CSTB-1), and decided to choose the P-POD over the MEPSI ejection system.
2) Europe accepted the CubeSat as an excellent education and training system such that they sponsored a competitive program to select university CubeSats to fly on the maiden voyage of the Vega rocket.
3) NASA experienced its own success with the GeneSat family of CubeSats, and observed the actions of the DoD and ESA. Then in a stunning (but most welcome) reversal, NASA created the Educational Launch of Nanosatellites (ELaNa) program, where nearly every expendable rocket launched by NASA going to LEO is carrying P-PODs.

"Stunning"? Yes. After all, it was only 5 years ago that then-Administrator Mike Griffin stood up before this very conference and told the students in the audience that it was not NASA's job to broker launches for their spacecraft; and instead of pursuing these university-class missions, they should be pursuing internships in industry (which was the only place to get real experience).[15] And, now, in 2011, NASA has made it their business to broker launches for student satellites – dozens of them!

Similarly, it was only 7 years ago that the Director of Advanced Systems and Technology at NRO told the audience of this conference that his agency had no interest in CubeSats. And, now, in 2011 the NRO Colony program is one of the largest funding sources for CubeSat technology development.

CONCLUSION

As shown in the data, the last two years have been very different in the university-class launchspace. The long-established trends of multiple-mission flagships and single-mission, low-reliability independents are changing; not only are the independents starting to dominate the field, but they are doing so with "real" missions. Digging a little deeper, we see that the driving trend in the past two years is the explosive growth in mission-capable 1U CubeSats fielded by first-time independent schools.

While we can certainly credit the continuous improvements in miniature technology and the development of "off-the-shelf" CubeSat components, we believe that the real credit for the growth in university-class missions, paradoxically, belongs to government agencies (the DoD, ESA, NSF and NASA). These agencies embraced the CubeSat standard in its early phases; each one made it easier for the next agency to adopt the standard and further bolster its performance. This has culminated in the NASA ELaNa program, which might launch several dozen university-class CubeSats in the next 12-24 months.

Another fascinating observation is that the universities' dependence on E-Class (BeepSat) missions went away the moment that competitively-selected sponsored launches became available; NASA and ESA appear to have no problem filling their available slots with a large number of new missions.

Also, as noted in our 2009 paper, flagships tend to move up the "value chain" from CubeSat-class beginner spacecraft to larger, more capable systems that can fly "real" sponsored payloads. Now that the number of CubeSat launch slots in a given year absolutely dwarfs the slots for 50-100 kg spacecraft, it will be interesting to see whether that trend reverses. We suspect that we will see a lot more flagship 3Us in the next two years.

Finally, it would not be a complete paper on university-class missions without some less-cheerful news. The differential failure rates between flagship spacecraft and independents does not seem to be changing (as demonstrated by the flurry of recent failures among independent missions). We would expect that 5-10 of the upcoming independent-built ELaNa missions in 2011-2012 will experience on-orbit failure. It is not clear how such failures – if they occur – would affect the future of the program. Will it be a repeat of the Class of 2000 experience, where university-class flights in the U.S. were set back almost 10 years? Or will there be enough success stories to warrant a relaxed approach to mission failure among university missions?

On the subject of CubeSats, we still wonder whether these steeply-increasing launch numbers can be sustained, or if we will reach overcapacity in launches. Two years ago, we suspected that industry was going to crowd out the university when it came to launch slots. Today, we are cautiously optimistic that there will be enough capacity for everyone.

As usual, we await the next two years with great anticipation.

REFERENCES

Much work in university-class spacecraft is not published – especially for missions that flew in the 20th century. Meanwhile, most of the 21st-century university "publishing" comes from ephemeral web pages. All websites cited were active as of June 2009, although we suspect that you could do just as well as the author did by using Google...

1. M. A. Swartwout, "University-Class Satellites: From Marginal Utility to 'Disruptive' Research Platforms," Proceedings of the 18th Annual AIAA/USU Conference on Small Satellites, Logan, UT, 9-12 August, 2004, Paper SSC04-II-05.
2. M. A. Swartwout, "Twenty (plus) Years of University-Class Spacecraft: A Review of What Was, An Understanding of What Is, And a Look at What Should Be Next," Proceedings of the 20th Annual AIAA/USU Conference on Small Satellites, Logan, UT, 14 August 2006, Paper SSC06-I-03.
3. M. A. Swartwout, "Beyond the Beep: Student-Built Satellites with Educational and 'Real' Missions," 21st Annual AIAA/USU Conference on Small Satellites, Logan, UT, 15 August 2007, Paper SSC07-XI-10.
4. M. A. Swartwout, "The first one hundred university-class spacecraft 1981-2008," IEEE Aerospace and Electronic Systems Magazine, vol. 24, no. 3, 2009.
5. M. A. Swartwout, "Student-Built Gossamer Spacecraft: Why Aren't There More (Yet)?", Proceedings of the 50th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Palm Springs, CA, 4 - 7 May 2009, Paper AIAA-2009-2158-359.

6. M. A. Swartwout, "The Promise of Innovation from University Space Systems: Are We Meeting It?" 23rd Annual AIAA/USU Conference on Small Satellites, Logan, UT, 13 August 2009, Paper SSC09-XII-03.
7. M. A. Swartwout, "A Brief History of Rideshares (and Attack of The CubeSats)," Proceedings of the 2011 IEEE Aerospace Conference, Big Sky, MT, 8 March 2011, Paper 1518.
8. Cutler, J. and G. Hutchins, "OPAL: Smaller, Simpler, and Just Plain Luckier," Proceedings of the 14th AIAA/USU Conference on Small Satellites, Logan, UT, September 2000, Paper SSC04-VII-04.
9. SSTL, "Small Satellites Home Page," http://centaur.sstl.co.uk/SSHP/micro/index.html, June 2011
10. SSTL, "Nanosatellites," http://centaur.sstl.co.uk/SSHP/nano/index.html, June 2011
11. G. Krebs, "Gunter's Space Page," http://www.skyrocket.de/space/space.html, June 2011
12. AMSAT, "Satellite Status Page," http://www.amsat.org/amsat-new/satellites/status.php, June 2011.
13. Union of Concerned Scientists Satellite Database, http://www.ucsusa.org/nuclear_weapons_and_global_security/space_weapons/technical_issues/ucs-satellite-database.html, June 2011.
14. Rupprecht, Mike, "Amateurfunk", http:// www.dk3wn.info, June 2011.
15. Bauman, J. "NASA chief justifies cuts during session at USU," Deseret Morning News, August 15, 2006. Cited from online version on 6 June 2009: http://www.deseretnews.com/article/1,5143,645193239,00.html?pg=2

APPENDIX: CUBESAT MANIFEST

Name	**Launch Date**	**Mass**	**Launch Vehicle**	**Class**	**Subtype**	**Beep?**
PICOSAT 1&2	01/27/00	1	Minotaur 1	mil	Opal	n
Jak	01/27/00	0.2	Minotaur 1	uni	Opal	y
Thelma	01/27/00	1	Minotaur 1	uni	Opal	n
Louise	01/27/00	1	Minotaur 1	uni	Opal	n
Stensat	01/27/00	0.2	Minotaur 1	civ	Opal	y
MEPSI	11/24/02	2	Shuttle	mil	M	n
DTUSAT	06/30/03	1	Rokot	uni	1U	y
CUTE-1	06/30/03	1	Rokot	uni	1U	y
QUAKESAT	06/30/03	3	Rokot	$$$	3U	n
AAU CUBESAT	06/30/03	1	Rokot	uni	1U	y
CANX-1	06/30/03	1	Rokot	uni	1U	y
CUBESAT XI-IV	06/30/03	1	Rokot	uni	1U	y
Ncube 2	10/27/05	1	Kosmos	uni	1U	y
UWE-1	10/27/05	1	Kosmos	uni	1U	y
CUBESAT XI-V	10/27/05	1	Kosmos	uni	1U	y
CUTE 1.7	02/21/06	3	M-V	uni	2U	n
CP 1 (K7RR-Sat)	07/26/06	1	Dnepr	uni	1U	y
CP 2	07/26/06	1	Dnepr	uni	1U	y
HAUSAT 1	07/26/06	1	Dnepr	uni	1U	y
ICECube 1	07/26/06	1	Dnepr	uni	1U	n
ICECube 2	07/26/06	1	Dnepr	uni	1U	n
ION	07/26/06	2	Dnepr	uni	2U	n
KUTESat	07/26/06	1	Dnepr	uni	1U	y
Mea Huaka'i	07/26/06	1	Dnepr	uni	1U	y
MEROPE	07/26/06	1	Dnepr	uni	1U	n
Ncube 1	07/26/06	1	Dnepr	uni	1U	y
Rincon 1	07/26/06	1	Dnepr	uni	1U	y
SACRED	07/26/06	1	Dnepr	uni	1U	y
SEEDS	07/26/06	1	Dnepr	uni	1U	y
AeroCube 1	07/26/06	1	Dnepr	mil	1U	y
HITSAT	09/22/06	1	M-V	civ	J	n
CP3	12/10/06	2	Shuttle	mil	M	n
LIBERTAD 1	12/10/06	5	Shuttle	mil	M	n
MARSCOM	12/10/06	5	Shuttle	mil	M	n
GENESAT	12/16/06	4	Minotaur 1	civ	3U	n
CSTB 1	04/17/07	1	Dnepr	$$$	1U	n
MAST	04/17/07	3	Dnepr	$$$	3U	n
LIBERTAD 1	04/17/07	1	Dnepr	uni	1U	y
CP3	04/17/07	1	Dnepr	uni	1U	y
CAPE 1	04/17/07	1	Dnepr	uni	1U	y
CP4	04/17/07	1	Dnepr	uni	1U	y
AEROCUBE 2	04/17/07	1	Dnepr	$$$	1U	n
PreSat	02/08/08	4	Falcon-1	civ	3U	n
Nanosail D	02/08/08	4	Falcon-1	civ	3U	n

COMPASS 1	04/28/08	1	PSLV	uni	1U	y
AAUSAT 2	04/28/08	1	PSLV	uni	1U	n
DELFI C3	04/28/08	3	PSLV	uni	3U	n
CANX-2	04/28/08	3.5	PSLV	civ	3U	n
SEEDS 2	04/28/08	1	PSLV	uni	1U	y
KKS-1 (KISEKI)	01/23/09	3	H-IIA 202	uni	J	n
PHARMASAT	05/19/09	5	Minotaur 1	civ	3U	n
CP6	05/19/09	1	Minotaur 1	uni	1U	y
HAWKSAT 1	05/19/09	1	Minotaur 1	civ	1U	n
AEROCUBE 3	05/19/09	1	Minotaur 1	mil	1U	n
DRAGONSAT	07/15/09	5	Shuttle	uni	3U	n
SWISSCUBE	09/23/09	1	PSLV CA	uni	1U	n
BEESAT	09/23/09	1	PSLV	uni	1U	n
UWE-2	09/23/09	1	PSLV	uni	1U	y
ITUPSAT 1	09/23/09	1	PSLV	uni	1U	y
HAYATO (K-SAT)	05/20/10	1	H-IIA 202	uni	1U	n
WASEDA-SAT2	05/20/10	1	H-IIA 202	uni	J	y
NEGAI	05/20/10	1	H-IIA 202	uni	1U	y
STUDSAT	07/12/10	1	PSLV CA	uni	1U	y
TISAT 1	07/12/10	1	PSLV CA	uni	1U	y
NanosailD2	11/20/10	4	Minotaur-4	civ	3U	n
RAX	11/20/10	3	Minotaur-4	uni	3U	n
O/OREOS	11/20/10	5	Minotaur-4	civ	3U	n
QBX2	12/08/10	5	Falcon-9	mil	3U	n
SMDC ONE	12/08/10	4	Falcon-9	mil	3U	n
Perseus 003	12/08/10	1.5	Falcon-9	mil	1.5U	n
Perseus 001	12/08/10	1.5	Falcon-9	mil	1.5U	n
QBX1	12/08/10	5	Falcon-9	mil	3U	n
Perseus 002	12/08/10	1.5	Falcon-9	mil	1.5U	n
Perseus 000	12/08/10	1.5	Falcon-9	mil	1.5U	n
Mayflower	12/08/10	5	Falcon-9	$$$	3U	n
Explorer 1 Prime	03/04/11	1	Taurus	uni	1U	n
KySat	03/04/11	1	Taurus	uni	1U	y
Hermes	03/04/11	1	Taurus	uni	1U	n
PQ-Gemini++ 1	06/20/11	0.12	Dnepr	$$$	0.5U	n
PQ-Gemini++ 2	06/20/11	0.12	Dnepr	$$$	0.5U	n
PQ-Gemini++ 3	06/20/11	0.12	Dnepr	$$$	0.5U	n
PQ-Gemini++ 4	06/20/11	0.12	Dnepr	$$$	0.5U	n
COVE/Mcubed	10/25/11	3	Delta	uni	2U	n
DICE 1	10/25/11	3	Delta	uni	1.5U	n
DICE 2	10/25/11	3	Delta	uni	1.5U	n
Explorer 1 Prime2	10/25/11	1	Delta	uni	1U	n
RAX 2	10/25/11	3	Delta	uni	3U	n
AtmoCube	10/31/11	1	Vega	uni	1U	n
e-st@r	10/31/11	1	Vega	uni	1U	n
Goliat	10/31/11	1	Vega	uni	1U	y
OUFTI 1	10/31/11	1	Vega	uni	1U	n

PW-Sat 1	10/31/11	1	Vega	uni	1U	n
ROBUSTA	10/31/11	1	Vega	uni	1U	y
UNICubeSat	10/31/11	1	Vega	uni	1U	n
UWE-3	10/31/11	1	Vega	uni	1U	y
XaTcobeo	10/31/11	1	Vega	uni	1U	n
Jugnu	12/31/11	4	PSLV	uni	3U	n