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The Long-Threatened Flood of University-Class Spacecraft (and CubeSats) Has Come: Analyzing the Numbers

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ABSTRACT

We have covered the statistical history of university-class small satellites for nearly a decade, revisiting the numbers every two years. In every previous paper, we have promised/threatened that the number of university-class missions will increase, only to spend the next paper explaining why that flood has not happened – but is definitely going to happen next year. This year, at last, we can break the cycle: the flood of university-class spacecraft has come, in the form of CubeSats; more than 30 are known to be manifested for 2013, with equal (or greater) numbers for 2014.

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 nine years.[1-9] 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 2011 report by noting that that the year 2012 could be the third "watershed" year in the history of university-class missions, with a large number of (primarily international) CubeSats flying – and explaining why our 2009 report was incorrect in predicting a watershed in 2010. Finally, with this report, we break the cycle. With the launches in 2012 and 2013, we identify the following significant changes in university-class missions:

1) Independent schools are building more spacecraft than ever, and more independent schools than ever are flying multiple missions. Meanwhile, flagship missions are flat.

2) The failure rates for independent schools are down, and their adoption of "real" missions is up.
3) The CubeSat class is now the dominant category for university-class missions.

While some may see these trends and believe that CubeSats are here to stay, we see some potential causes for concern. As CubeSats become more popular – both among schools and industry – more attention/scrutiny is naturally given to them. Those who are not used to the high failure rates for university missions (above 25%) may begin to question why resources are being devoted to missions that don't always work. Similarly, the recent collision between NEE 01 Pegaso and a Russian upper stage further highlights the potential debris problem caused by all these new missions. Lastly, as we will discuss, we are not convinced that the ground infrastructure is ready to handle dozens of CubeSat launches per year: the processes for managing frequency coordination, tracking/deconfliction, launch integration and on-orbit interference will be strained by all these new missions.

Therefore, in this paper, we will first update our database of university-class missions, which now stands at 196 spacecraft manifested since 1970 (and 66 since 2009). 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.

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, although some have a mix of professional and educational missions – 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 2010, 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, those trends have reversed.

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 (PSSC) 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 nine years and has received only a handful of corrections, 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 1970 until the submission of this paper (June 2013) are listed in the Appendix, including the twenty-seven spacecraft that are on "official" manifests for the second half of 2013. 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.[10-13] 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 are given to the authors of reference 13 for their extensive archive describing satellite contacts

OBSERVATIONS

We extensively discussed the manifest in previous papers, so we will only comment on new results. In particular, we will focus our attention on the last 15 years, from 1999-2013.

Updated: First University-Class Mission

We must begin with a correction. From the very first paper, we have incorrectly identified UoSat-1 as the first university-class spacecraft. In fact, the first university-class spacecraft was Australis OSCAR 5, a 17-kg communications satellite built by students at the University of Melbourne and launched in 1970 (Figure 1).

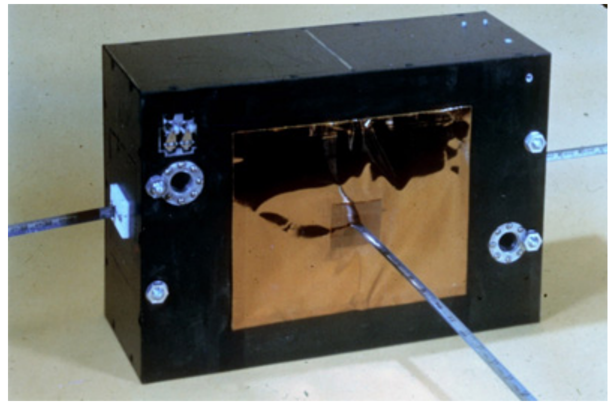

Figure 1. Australis OSCAR-5 (credit: AMSAT)

Thanks to Jan King, VK4GEY, for the notification.

Updated: Number crunching

First, as shown in Figure 2, the significant increase in manifests noted in previous years is a full-blown trend; the new "normal" for university-class flights is 25-30 per year. The flood has come. Credit must be given to the CubeSats; as shown in Figure 3, the smallest spacecraft account for the increase; the launch numbers for spacecraft above 10 kg is essentially flat.

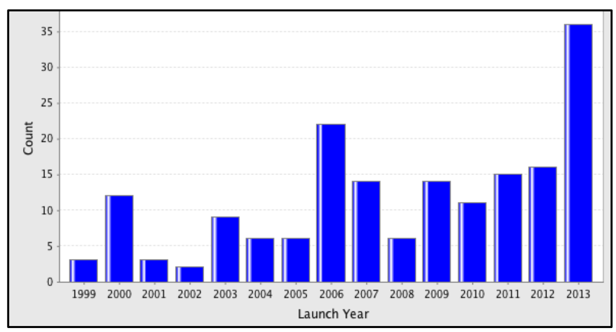

Figure 2: Manifested University-Class Spacecraft

For the first time this year, we can directly count the number of CubeSats. As shown in Figure 4, over the last 4 years, the fraction of CubeSats has grown to an overwhelming fraction.

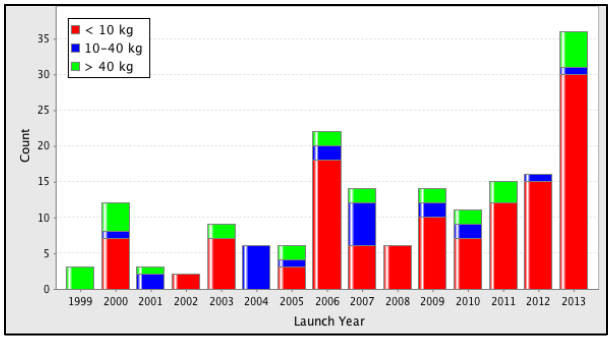

Figure 3: Spacecraft Launch Mass by Year

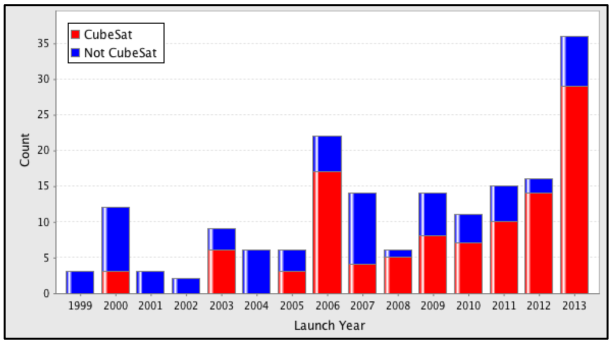

Figure 4: University-Class Spacecraft by CubeSat Category

Updated: Flagships vs. Independents

In 2011, we noted that the theme of the first decade had reversed: independents outnumber flagships by two or three-to-one in recent years (Figure 5). Flagship schools represented 54% of manifested spacecraft from 1970-2009, but now stand at just 40% of the launches from 1999-2013 (70 of 175), and only 20% of the manifests in 2012-2013!

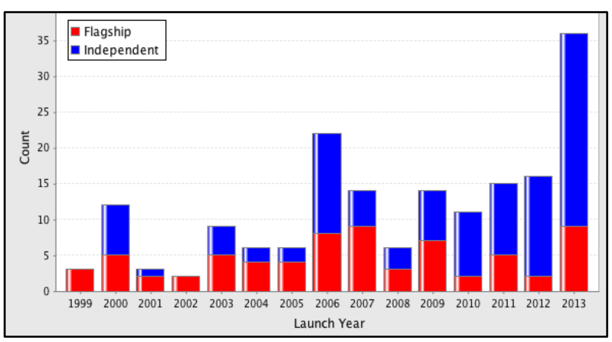

Figure 5: Flagship vs. Independent Missions

Credit is due to the CubeSat standard; the rise in independent school performance is directly linked to the increase in the number of CubeSats. However, the growth of CubeSats has led to a surprising trend: the sharp increase in independent schools with repeat missions (Figure 7). Only a few years, ago, we were lamenting that independent schools had few options for sustaining programs: today, 18 independent schools are considered to be active with multiple missions! (Active is defined as having at least one manifest in the past 4 years.) Meanwhile, there are only 9 active flagships with multiple missions (Figure 7). Programs such as Montana State University, the University of Michigan, Cal Poly, Kentucky Space and the University of Colorado have enjoyed launch rates of once every other year (or better). While the number of first-time programs with manifests seems to be holding at 8-10 per year, these newly-successful independents are actually providing a large share of the missions.

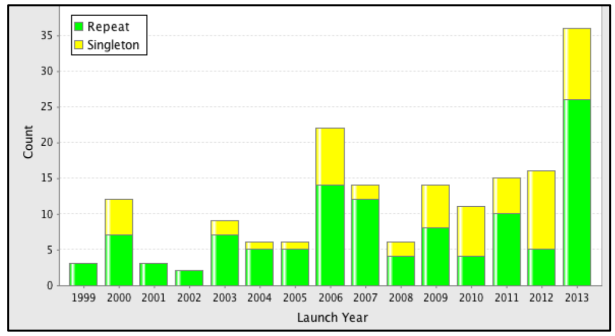

Figure 6: Repeat Missions vs. Single-Launch Programs

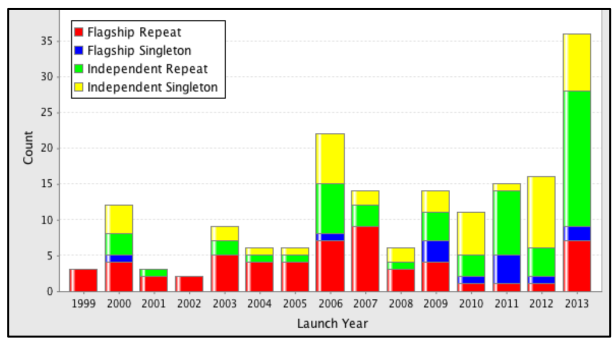

Figure 7: Comparison of Repeat Launches by Flagship Status

Twenty schools are providing first-time manifests in 2012-2013. If trends hold, half of these schools will not launch a second mission by 2018. We will be tracking their progress over the next few years. The complete list of schools with manifested hardware is in Table 1.

Table 1: Spacefaring Universities (Flagships Highlighed in Yellow)

	School	Nation	First Launch	#
1	University of Melbourne	Australia	1/23/70	1
2	University of Surrey	UK	10/6/81	3

3	Weber State	USA	4/29/85	3
4	Technical University of Berlin	Germany	7/17/91	9
5	Korean Advanced Institute of Science and Technology	S. Korea	8/10/92	4
6	CNES Amateurs (?)	France	5/12/93	1
7	University of Bremen	Germany	2/3/94	1
8	Technion Institute of Technology	Israel	3/28/95	2
9	National University of Mexico	Mexico	3/28/95	2
10	Russian high school students	Russia	10/5/97	1
11	US Air Force Academy	USA	10/25/97	5
12	ESTEC	Europe	10/30/97	4
13	University of Alabama-Huntsville	USA	10/24/98	1
14	Naval Postgraduate School	USA	10/29/98	2
15	University of Stellenbosch	South Africa	2/23/99	2
16	Arizona State University	USA	1/27/00	2
17	Stanford University	USA	1/27/00	4
18	Santa Clara University	USA	2/10/00	3
19	Tsinghua University	China	6/28/00	1
20	University of Rome "La Sapienza"	Italy	9/26/00	7
21	King Abdulaziz City for Science & Technology	Saudi Arabia	9/26/00	11
22	Umeå University / Luleå University of Technology	Sweden	11/21/00	1
23	US Naval Academy	USA	9/30/01	6
24	UTIAS (University of Toronto)	Canada	6/30/03	2
25	Technical University of Denmark	Denmark	6/30/03	1
26	University of Aalborg	Denmark	6/30/03	3
27	Tokyo Institute of Technology	Japan	6/30/03	3
28	University of Tokyo	Japan	6/30/03	3
29	Universidade Norte do Paraná	Brazil	8/22/03	1
30	Mozhaiskiy Space Engineering Academy	Russia	9/27/03	2
31	New Mexico State University	USA	12/21/04	1
32	University of Würzburg	Germany	10/27/05	3
33	Norwegian Universities	Norway	10/27/05	2
34	Politecnico di Torino	Italy	7/26/06	2
35	Nihon University	Japan	7/26/06	2
36	Bauman Moscow State Technical University	Russia	7/26/06	2
37	Hankuk Aviation University	South Korea	7/26/06	1
38	Cal Poly San Luis Obispo	USA	7/26/06	6
39	Cornell University	USA	7/26/06	3
40	Montana State University	USA	7/26/06	6
41	University of Arizona	USA	7/26/06	2
42	University of Hawaii	USA	7/26/06	2
43	University of Illinois	USA	7/26/06	1
44	University of Kansas	USA	7/26/06	1
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	Colombia	4/17/07	1
48	University of Louisiana	USA	4/17/07	2
49	Fachhochschule Aachen	Germany	4/28/08	1
50	Technical University of Delft	Nether-lands	4/28/08	2
51	Kagawa University	Japan	1/23/09	1
52	Tohoku University	Japan	1/23/09	2
53	Tokyo Metropolitan College of Industrial Technology	Japan	1/23/09	1
54	Anna University	India	4/20/09	1
55	Texas A&M University	USA	7/15/09	1
56	University of Texas	USA	7/15/09	3
57	Ufa State Aviation Technical University	Russia	9/17/09	1
58	Ecole Polytechnique Fédérale de Lausanne	Switzer-land	9/23/09	1
59	Istanbul Technical University	Turkey	9/23/09	2
60	Kagoshima University	Japan	5/20/10	1
61	Soka University	Japan	5/20/10	1
62	University Space Engineering Consortium	Japan	5/20/10	1
63	Waseda University	Japan	5/20/10	1
64	Indian university consortium	India	7/12/10	1
65	Scuola universitaria della Svizzera italiana	Switzer-land	7/12/10	1
66	University of Michigan	USA	11/20/10	5
67	University of Southern California	USA	12/8/10	1
68	Kentucky Space	USA	3/4/11	2
69	University of Colorado at Boulder	USA	3/4/11	5
70	M.V. Lomonosov Moscow state university	Russia	4/20/11	1
71	Nanyang Technological University	Singapore	4/20/11	1
72	Indian Institute of Technology Kanpur	India	10/20/11	1
73	Auburn University	USA	10/28/11	1
74	Utah State	USA	10/28/11	2
75	Nanjing University	China	11/9/11	1
76	University of Montpellier II	France	2/13/12	1
77	Budapest University of Technology and Economics	Hungary	2/13/12	1
78	University of Bologna	Italy	2/13/12	1
79	Warsaw University of Technology	Poland	2/13/12	1
80	University of Bucharest	Romania	2/13/12	1
81	University of Vigo	Spain	2/13/12	1
82	Kyushu Institute of Technology (KIT)	Japan	5/17/12	1
83	Morehead State University	USA	9/13/12	1
84	FPT Technology Research	Vietnam	10/4/12	1

	Institute			
85	Fukuoka Institute of Technology	Japan	10/4/12	1
86	San Jose State University	USA	10/4/12	1
87	Technical University of Dresden	Germany	4/19/13	1
88	Samara Aerospace University	Russia	4/19/13	2
89	University of Tartu	Estonia	5/7/13	1
90	City University of New York	USA	6/30/13	1
91	Drexel University	USA	2013	1
92	Saint Louis University	USA	2013	2
93	Thomas Jefferson High School	USA	2013	1
94	University of Florida	USA	2013	1
95	University of Vermont	USA	2013	1
96	US Military Academy	USA	2013	1
97	Ventspils University	India	2013	1
98	Pontifical Catholic University of Peru	Peru	2013	1

We have long tracked the results of the Dnepr failure of 2006, which destroyed the spacecraft of eleven first-time schools, and predicted that the odds were against most of those schools mustering the resources for a second launch. Other than a few reflights of backup hardware, only five have continued to fly hardware (Bauman, Torino, Cal Poly, Montana State and Corneell).

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 31 spacecraft we have identified as failing prematurely since 1999 (Figure 8), almost half were never contacted on orbit, thereby precluding a detailed failure review.

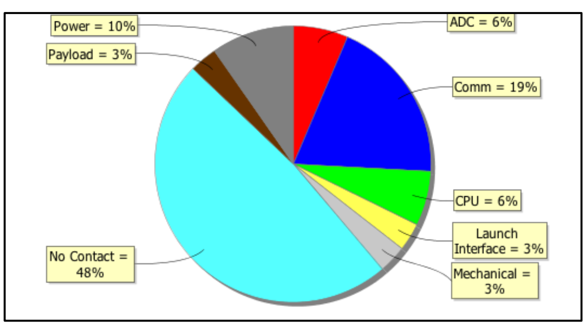

Figure 8: Failure Sources

In previous papers, we tracked mission lifetime as an indicator of success. With CubeSats, many modern missions have very short orbital and/or mission lifetimes, and the comparisons are not very useful. Instead, for the first time, we have assigned a mission success parameter to every spacecraft. As shown in Figure 9, missions are rated against their stated primary mission objectives. Missions that have demonstrated that their primary objectives were met are assigned a green status; spacecraft that accomplished some objectives are in yellow; spacecraft that are operational but have not returned science/technical data are orange; missions that were not able to perform normal two-way operations (or had that capability cut off in the first 30 days) are assigned the color red; and missions that did not deploy from the rocket (including launch failures) are in blue. Missions that have not flown are in gray.

Looking at Figure 9, it is striking that the proportions of missions in each category are fairly consistent from year to year.

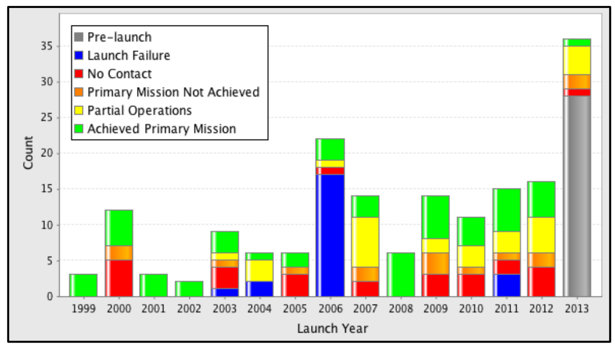

Figure 9: Mission Status

It is worth updating a statement from previous papers: only one of the 125 student-built spacecraft that made it to orbit is known to have had structural problems (jammed deployment mechanism). And only one of 125 student-built spacecraft is known to have had on-orbit thermal problems.* Granted, we must admit that student-built spacecraft do not last very long on orbit; 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

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

mission type (Figure 10) and then further subdivided by flagship and independent status (Figure 11). 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.

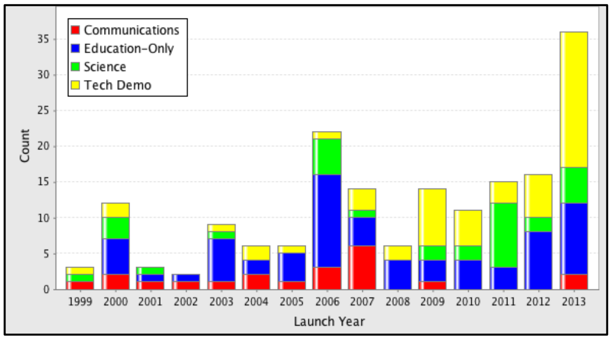

Figure 10: Mission Type by Year

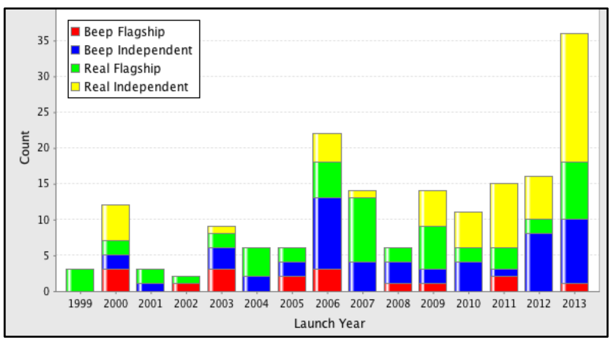

Figure 11: Mission Type by Year and University Classification

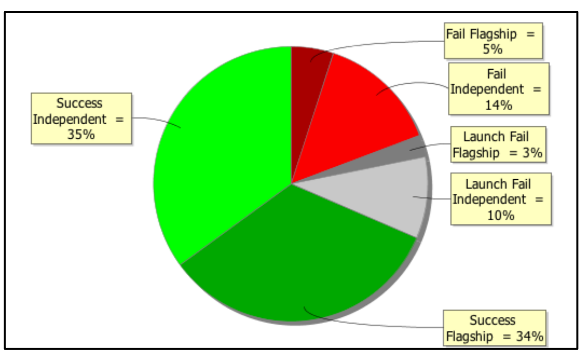

Figure 12: Success Rates by Flagship Category

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 (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).

CUBESATS

We have explored CubeSats in detail in previous papers.[7-9] We will not repeat that analysis here, rather, we will simply reprint two relevant figures from those studies. As seen in Figure 13, an incredibly large number of CubeSats are manifested to fly in 2013 – on the order of 80. Returning to Figure 4, we note that only 30 of those 80 are university-class missions! Therefore, we can confidently say that CubeSats have been adopted by the broader space industry. This is a staggering number of spacecraft.

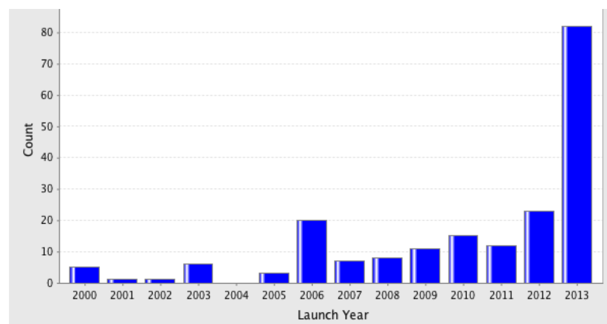

Figure 13: Manifested CubeSat-Class Missions

Some of the implications of the number of CubeSats manifested can be seen in Figure 14. This figure groups CubeSats according to the number deployed; note that increasingly, large numbers of CubeSats are being placed on the same launch.

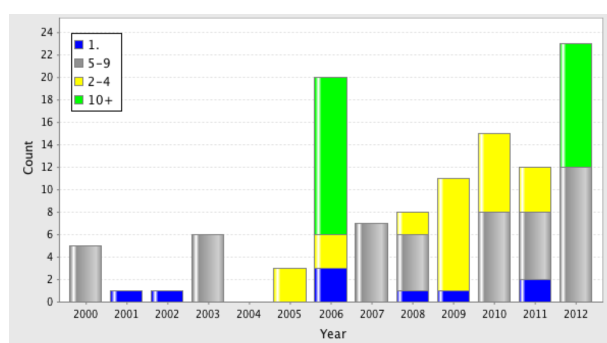

Figure 14: Number of CubeSats Manifested on One Launch

We see three implications:

1) Missions will lose on-orbit time due to tracking/deconfliction. It will take time to sort out Keplerian elements among 20 spacecraft.
2) CubeSats will be increasingly vulnerable to lauch failure, as a single launch vehicle problem can affect dozens of CubeSats.
3) The IARU, FCC and NOAA may not be able to keep up with the licensing requests, as so many missions need simultaneous (and last-minute) accommodations.

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. In fact, a group of independent schools have replaced the flagships as the leading integrators of university-class missions, with five or more missions fielded in the past four years! Digging a little deeper, we see that the driving trend in the past four 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 2011 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. When compiling the data, were quite surprised by the sheer number of CubeSats manifested in 2013, and we are concerned that IARU, FCC, NOAA, JSPOC and others will be quite surprised as well as they try to accommodate all these new space objects.

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. Four 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, especially as launches inevitably slip.

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

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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 2013, although we suspect that you could do just as well as the author did by using Google...

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APPENDIX: UNIVERSITY-CLASS MANIFEST

Name	Launch Cntry	Launch Date	Mission Type	Mission Status	Contractor
Australis OSCAR 5	AUS	1/23/70	C	5	University of Melbourne
OSCAR 9 (UoSAT 1)	UK	10/6/81	S	5	University of Surrey
OSCAR 11 (UoSAT 2)	UK	3/1/84	C	5	University of Surrey
NUSAT 1	US	4/29/85	T	5	Weber State
OSCAR 18 (WEBERSAT)	US	1/22/90	C	5	Weber State
TUBSAT A	GER	7/17/91	C	5	Technical University of Berlin
OSCAR 23 (KITSAT 1)	SKOR	8/10/92	T	5	Korean Advanced Institute of Science and Technology
ARASENE	FR	5/12/93	C	5	CNES Amateurs (?)
KITSAT B	SKOR	9/26/93	C	5	Korean Advanced Institute of Science and Technology
TUBSAT B	GER	1/25/94	T	5	Technical University of Berlin
BREMSAT	GER	2/3/94	S	5	University of Bremen
Techsat 1 (Gurwin 1 Oscar (29))	ISRL	3/28/95	C	1	Technion Institute of Technology
UNAMSAT A	MEX	3/28/95	C	1	National University of Mexico
UNAMSAT B	MEX	9/5/96	C	2	National University of Mexico
SPUTNIK JR	CIS	10/5/97	E	5	Russian high school students
Falcon Gold	US	10/25/97	T	5	US Air Force Academy
TEAMSAT	ESA	10/30/97	E	4	ESTEC
TUBSAT N	GER	7/7/98	T	4	Technical University of Berlin
TUBSAT N1	GER	7/7/98	T	5	Technical University of Berlin
TECHSAT 1B	ISRA	7/10/98	S	5	Technion Institute of Technology
SEDSAT 1	US	10/24/98	T	2	University of Alabama-Huntsville
PAN SAT	US	10/29/98	C	5	Naval Postgraduate School
SUNSAT	SAFR	2/23/99	C	5	University of Stellenbosch
KITSAT 3	SKOR	5/26/99	T	5	Korean Advanced Institute of Science and Technology
TUBSAT	GER	5/26/99	S	5	Technical University of Berlin
ASUSAT	US	1/27/00	E	3	Arizona State University
FALCONSAT	US	1/27/00	E	3	US Air Force Academy
JAWSAT	US	1/27/00	T	2	Weber State
OPAL	US	1/27/00	T	5	Stanford University
PICOSAT 3 (JAK)	US	2/10/00	E	2	Santa Clara University
PICOSAT 4 (Thelma)	US	2/12/00	S	2	Santa Clara University
PICOSAT 5 (Louise)	US	2/12/00	S	2	Santa Clara University
TZINGHUA 1	PRC	6/28/00	E	5	Tsinghua University
SAUDISAT 1A	SAUD	9/26/00	C	5	King Abdulaziz City for Science & Technology
SAUDISAT 1B	SAUD	9/26/00	C	2	King Abdulaziz City for Science & Technology
UNISAT	IT	9/26/00	E	5	University of Rome "La Sapienza"
MUNIN	SWED	11/21/00	S	5	Umeå University / Luleå University of Technology
PCSAT	US	9/30/01	C	5	US Naval Academy
SAPPHIRE	US	9/30/01	E	5	Stanford University
MAROC TUBSAT	GER	12/10/01	S	5	Technical University of Berlin
SAUDISAT 1C	SAUD	12/20/02	C	5	King Abdulaziz City for Science & Technology
UNISAT 2	IT	12/20/02	E	5	University of Rome "La Sapienza"
AAU CUBESAT 1	DEN	6/30/03	E	2	University of Aalborg
CANX-1	CA	6/30/03	E	2	UTIAS (University of Toronto)
CUBESAT XI-IV (CO-57)	JPN	6/30/03	E	4	University of Tokyo
CUTE-1 (CO-55)	JPN	6/30/03	E	3	Tokyo Institute of Technology
DTUSAT 1	DEN	6/30/03	E	2	Technical University of Denmark
QUAKESAT 1	US	6/30/03	S	5	Stanford University

UNOSAT 1	BRAZ	8/22/03	E	1	Universidade Norte do Paraná
KAISTSAT 4 / STSAT-1	SKOR	9/27/03	T	5	Korean Advanced Institute of Science and Technology
MOZHAYETS 4	CIS	9/27/03	C	5	Mozhaiskiy Space Engineering Academy
SAUDICOMSAT 1	SAUD	6/29/04	C	4	King Abdulaziz City for Science & Technology
SAUDICOMSAT 2	SAUD	6/29/04	C	4	King Abdulaziz City for Science & Technology
SAUDISAT 2	SAUD	6/29/04	T	4	King Abdulaziz City for Science & Technology
UNISAT 3	IT	6/29/04	T	5	University of Rome "La Sapienza"
3CS: Ralphie	US	12/21/04	E	1	New Mexico State University
3CS: Sparkie	US	12/21/04	E	1	Arizona State University
PCSat 2	US	8/3/05	T	5	US Naval Academy
CUBESAT XI-V (CO-58)	JPN	10/27/05	E	5	University of Tokyo
Mozhayets 5	CIS	10/27/05	E	2	Mozhaiskiy Space Engineering Academy
Ncube 2	NOR	10/27/05	E	2	Norweigan Universities
SSETI-EXPRESS	ESA	10/27/05	C	2	ESTEC
UWE-1	GER	10/27/05	E	3	University of Würzburg
CUTE 1.7	JPN	2/21/06	C	2	Tokyo Institute of Technology
FalconSat 2	US	3/24/06	S	1	US Air Force Academy
Baumanets 1	CIS	7/26/06	E	1	Bauman Moscow State Technical University
CP 1 (K7RR-Sat)	US	7/26/06	E	1	Cal Poly San Luis Obispo
CP 2	US	7/26/06	E	1	Cal Poly San Luis Obispo
HAUSAT 1	SKOR	7/26/06	E	1	Hankuk Aviation University
ICECube 1	US	7/26/06	S	1	Cornell University
ICECube 2	US	7/26/06	S	1	Cornell University
ION	US	7/26/06	S	1	University of Illinois
KUTESat Pathfinder	US	7/26/06	E	1	University of Kansas
Mea Huaka'I (Voyager)	US	7/26/06	E	1	University of Hawaii
MEROPE	US	7/26/06	S	1	Montana State University
Ncube 1	NOR	7/26/06	E	1	Norweigan Universities
PicPot	IT	7/26/06	E	1	Politecnico di Torino
Rincon 1	US	7/26/06	E	1	University of Arizona
SACRED	US	7/26/06	E	1	University of Arizona
SEEDS	US	7/26/06	E	1	Nihon University
Unisat 4	CIS	7/26/06	E	1	University of Rome "La Sapienza"
HITSAT (HO-59)	JPN	9/22/06	E	4	Hokkaido Institute of Technology
ANDE FCAL SPHERE 2	US	12/10/06	T	5	US Naval Academy
MARSCOM	US	12/20/06	C	5	US Naval Academy
RAFT (NO 60)	US	12/20/06	C	5	US Naval Academy
PEHUENSAT 1	ARGN	1/10/07	C	5	National University of Comahue
FALCONSAT 3	US	3/9/07	S	4	US Air Force Academy
MIDSTAR 1	US	3/9/07	T	4	US Naval Academy
CAPE 1	US	4/17/07	E	3	University of Louisiana
CP3	US	4/17/07	E	2	Cal Poly San Luis Obispo
CP4	US	4/17/07	E	3	Cal Poly San Luis Obispo
LIBERTAD 1	COL	4/17/07	E	5	University of Sergio Arboleda
SAUDICOMSAT 3	SAUD	4/17/07	C	4	King Abdulaziz City for Science & Technology
SAUDICOMSAT 4	SAUD	4/17/07	C	4	King Abdulaziz City for Science & Technology
SAUDICOMSAT 5	SAUD	4/17/07	C	4	King Abdulaziz City for Science & Technology
SAUDICOMSAT 6	SAUD	4/17/07	C	4	King Abdulaziz City for Science & Technology
SAUDICOMSAT 7	SAUD	4/17/07	C	4	King Abdulaziz City for Science & Technology
YES2/FLOYD	ESA	9/25/07	T	5	ESTEC
YES2/FOTINO	ESA	9/25/07	T	2	ESTEC

AAUSAT 2	DEN	4/28/08	E	5	University of Aalborg
CANX 2	CA	4/28/08	T	5	UTIAS (University of Toronto)
COMPASS 1	GER	4/28/08	E	5	Fachhochschule Aachen
CUTE-1.7+APD II	JPN	4/28/08	E	5	Tokyo Institute of Technology
DELFI C3 (DO-64)	NETH	4/28/08	T	5	Technical University of Delft
SEEDS 2 (CO-66)	JPN	4/28/08	E	5	Nihon University
KKS-1 (KISEKI)	JPN	1/23/09	T	3	Tokyo Metropolitan College of Industrial Technology
PRISM (HITOMI)	JPN	1/23/09	T	5	University of Tokyo
SPRITE-SAT (RISING)	JPN	1/23/09	S	3	Tohoku University
STARS (KUKAI)	JPN	1/23/09	T	3	Kagawa University
ANUSAT	IND	4/20/09	C	5	Anna University
CP 6	US	5/19/09	E	5	Cal Poly San Luis Obispo
BEVO 1	US	7/15/09	T	4	University of Texas
DRAGONSAT 2 (AggieSat 2)	US	7/15/09	T	2	Texas A&M University
SUMBANDILA	SAFR	9/17/09	T	5	University of Stellenbosch
UGATUSAT	CIS	9/17/09	T	2	Ufa State Aviation Technical University
BEESAT	GER	9/23/09	T	5	Technical University of Berlin
ITu-pSAT 1	TURK	9/23/09	E	5	Istanbul Technical University
SWISSCUBE (SwissCube 1)	SWTZ	9/23/09	S	4	Ecole Polytechnique Fédérale de Lausanne
UWE-2	GER	9/23/09	E	2	University of Würzburg
HAYATO (K-SAT)	JPN	5/20/10	T	2	Kagoshima University
NEGAI-STAR (Negai-Boshi)	JPN	5/20/10	E	5	Soka University
UNITEC-1	JPN	5/20/10	T	3	University Space Engineering Consortium
WASEDA-SAT2	JPN	5/20/10	E	2	Waseda University
STUDSAT	IND	7/12/10	E	2	Indian university consortium
TISAT 1	SWIT	7/12/10	E	5	Scuola universitaria della Svizzera italiana
FALCONSAT 5 (USA 221)	US	11/20/10	S	4	US Air Force Academy
FAST 1 (USA 222)	US	11/20/10	T	4	University of Texas
FAST 2 (USA 228)	US	11/20/10	T	4	University of Texas
RAX 1 (USA 218)	US	11/20/10	S	5	University of Michigan
Mayflower-Caerus	US	12/8/10	T	5	University of Southern California
E1P (Explorer 1 Prime)	US	3/4/11	S	1	Montana State University
Hermes	US	3/4/11	T	1	University of Colorado at Boulder
KySat 1	US	3/4/11	E	1	Kentucky Space
XSAT	STCT	4/20/11	S	4	Nanyang Technological University
YOUTHSAT	IND	4/20/11	S	4	M.V. Lomonosov Moscow state university
EDUSAT	IT	8/17/11	E	4	University of Rome "La Sapienza"
JUGNU	IND	10/20/11	E	5	Indian Institute of Technology Kanpur
AubieSat1 (AO-71)	US	10/28/11	S	3	Auburn University
DICE 1 (DICE X)	US	10/28/11	S	5	Utah State
DICE 2 (DICE Y)	US	10/28/11	S	5	Utah State
HRBE (Explorer-1 PRIME)	US	10/28/11	S	5	University of Michigan
M-Cubed (w/HRBE)	US	10/28/11	T	2	Montana State University
RAX 2	US	10/28/11	S	5	University of Michigan
RAX2	US	10/28/11	S	5	University of Michigan
TX 1	PRC	11/9/11	T	2	Nanjing University
ALMASAT-1	IT	2/13/12	E	2	University of Bologna
e-st@r	IT	2/13/12	T	2	Politecnico di Torino
Goliat	ROM	2/13/12	E	3	University of Bucharest
MaSat 1 (MO-72)	HUN	2/13/12	E	5	Budapest University of Technology and Economics
PW-Sat 1	POL	2/13/12	T	4	Warsaw University of Technology

ROBUSTA	FR	2/13/12	T	2	University of Montpellier II
UniCubeSat-GGs	IT	2/13/12	T	4	University of Rome "La Sapienza"
XaTcobeo	SPN	2/13/12	E	5	University of Vigo
HORYU 2	JPN	5/17/12	E	4	Kyushu Institute of Technology (KIT)
CP5	US	9/13/12	E	4	Cal Poly San Luis Obispo
CSSWE	US	9/13/12	S	5	University of Colorado at Boulder
CXBN	US	9/13/12	S	3	Morehead State University
F1	VNM	10/4/12	E	2	FPT Technology Research Institute
FITSAT-1 (NIWAKA)	JPN	10/4/12	T	5	Fukuoka Institute of Technology
Raiko	JPN	10/4/12	E	5	Tohoku University
TechEdSat	US	10/4/12	T	4	San Jose State University
AAUSAT 3	DEN	2/25/13	E	5	University of Aalborg
STRAND-1	UK	2/25/13	T	3	University of Surrey
AIST 2	CIS	4/19/13	T	4	Samara Aerospace University
BeeSat 2	GER	4/19/13	T	4	Technical University of Berlin
BeeSat 3	GER	4/19/13	T	2	Technical University of Berlin
SOMP	GER	4/19/13	E	4	Technical University of Dresden
TURKSAT 3USAT	TURK	4/26/13	C	3	Istanbul Technical University
ESTCube-1	EST	5/7/13	T	4	University of Tartu
All-Star-THEIA	US	2013	S	0	University of Colorado at Boulder
CUNYSat-1	US	2013	E	0	City University of New York
FIREBIRD 2	US	2013	S	0	Montana State University
Hermes 2	US	2013	E	0	University of Colorado at Boulder
Black Knight	US	2013	E	0	US Military Academy
CAPE 2	US	2013	E	0	University of Louisiana
COPPER	US	2013	T	0	Saint Louis University
DragonSat	US	2013	T	0	Drexel University
Ho'oponopono-2	US	2013	C	0	University of Hawaii
KYSat 2	US	2013	T	0	Kentucky Space
Lunar Lander	US	2013	T	0	University of Vermont
NPS-SCAT	US	2013	T	0	Naval Postgraduate School
SwampSat	US	2013	E	0	University of Florida
TJSat	US	2013	E	0	Thomas Jefferson High School
FIREBIRD 1	US	2013	S	0	Montana State University
M-Cubed-2	US	2013	T	0	University of Michigan
CUSat	US	2013	T	0	Cornell University
Dande	US	2013	S	0	University of Colorado at Boulder
SNAPS	US	2013	T	0	Stanford University
AIST	CIS	2013	T	0	Samara Aerospace University
Baumenets 2	CIS	2013	T	0	Bauman Moscow State Technical University
Delfi-n3Xt	NETH	2013	T	0	Technical University of Delft
PUCP-SAT 1	PER	2013	E	0	Pontifical Catholic University of Peru
UniSat 5	IT	2013	T	0	University of Rome "La Sapienza"
UWE 3	GER	2013	E	0	University of Würzburg
Venta 1	LAT	2013	T	0	Ventspils University
Argus	US	2013	S	0	Saint Louis University
PrintSat	US	2013	T	0	Montana State University