The Cubesat Explosion
Jonathan McDowell
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The Cubesat Explosion: STATISTICS 2014 JUNE
Jonathan McDowell, Center for Astrophysics

Satellite masses 1960-2009

Satellite masses 2010-2014

Orbited  TotalFail
(no transmissions)
A: Academic/nonprofit 108 23?
B: Business/commercial 40 2
C: Civil govt. (e.g. NASA) 17 0
D: Defense/military 41 3+

OPERATED > 2 YEARS: 38
(CUTE-I, XI-IV 11 years and going!)

TOTAL 29 COUNTRIES:
USA 130  Japan 19  Germany 10

SCIENCE 22 (Bio 4, Astron 2) COM 23 IMG 41
TECH 119 CAL 1

http://planet4589.org
In 1960s, only a few dozen sats operating at any one time

Today, over 1000 active satellites and rising
Satellites come in many shapes and sizes...
In the 1950s there were some 1-10 kg sats but in later decades trend was to satellites in the 1000 to 10000 kg range.

No nanosats or picosats (left of magenta line, 0.1-10 kg)
In the 2010s a dramatic shift to lower satellite masses

Each Shuttle about 100 tonnes in orbit

Wow! Nanosats!
Cubesats: 1 kg, 10 cm (2 lb, 4 in for the metric impaired)
Standard kit for universities to make students build sats in engineering courses
Can also make '3U' cuboids 30 x 10 cm; '6U' cuboids 30 x 20 cm coming soon

Aalborg U. 2003

Univ. of Tokyo, 2003

Cubesat deploy from ISS, 2012

Triple-cube Quakesat, Stanford 2003
All the Cubesats 1: 2003-2010  [Photo credit to satellite owners, many via Gunter Krebs' excellent space.skyrocket.de page, which see for detailed credits]
All the Cubesats 2: 2010-2013
All the Cubesats 3: More 2013 Cubesats
LAUNCHED: 226
19 failed to reach orbit
1 aboard ISS waiting to deploy

ORBITED 206 (includes 5 Pocket Qub 0.1-0.5 kg)

<table>
<thead>
<tr>
<th>Category</th>
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<th>TotalFail</th>
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<td>41</td>
<td>3+ (unknown others?)</td>
</tr>
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It's hard to define success/fail – many cubesats have vague and minimal goals, others v ambitious (tether deploy, etc). The 'TotalFail' above means that a reliable signal from the satellite was never detected.
Even with this minimal success criterion, 20 percent of the student built sats fail. Categories B,C,D tend to be built by professional aerospace companies and fail less often.

STILL IN ORBIT 156
STILL WORKING 117
OPERATED > 2 YEARS: 38 (CUTE-I, XI-IV 11 years and going!)
### CUBESAT STATISTICS 2014 JUNE – BY COUNTRY

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</tr>
<tr>
<td>Denmark</td>
<td>5</td>
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**Others:**
- **N America**: Canada 2
- **S America**: Argentina 2, Chile 2, Peru 3, Ecuador 2, Colombia 1
- **Europe**: Spain 3, Netherlands 3, Italy 2, Norway 2, UK 2, Switzerland 2, Lithuania 2, Estonia 1, France 1, Poland 1, Hungary 1, Romania 1
- **Asia**: Korea 3, Turkey 2, Vietnam 2, India 1, Pakistan 1, Singapore 1
- **Africa**: South Africa 1

**NOTE:** Russia 0 (ZERO! - also surprising)

**Total 29 Countries**
Cubesats for Science

2003 QUAKESAT (Stanford) VLF from earthquakes
2006 KuteSat (Kansas/Lawrence) Radiation dose [Launch fail]
2006 ICECube-1 (Cornell) Ionosphere scintillation [Launch fail]
2006 MEROPe (Montana State) Radiation belts [Launch fail]
2010 RAX (Michigan) Radio from aurora
2011 Exp 1 Prime (Montana State) Radiation belts [Launch fail]
2011 DICE-1/2 (Utah State) E/B fields in ionosphere
2011 RAX-2 (Michigan) Radio from aurora
2011 HRBE (Montana State) Radiation belts
2012 Goliat (Bucharest) Radiation, meteoroids
2012 CSSWE (Colorado) Space weather
2012 CINEMA (Berkeley) Ionosphere, ring current
2013 SOMP (Dresden) Atomic oxygen
2013 Firefly (GSFC/Siena) Lightning/TGFs
2013 KHUSAT-1,2 (Kyung Hee U) Ionosphere, ring current
2013 FIREBIRD A,B (Montana State) Electron microbursts
2013 CUNYSAT (Medgar Evers,CUNY) Ionosphere with GPS [Fail]

Astronomy:
2008 AAUSAT-II (Aalborg) GRBs
2012 CXBN (Morehead State) Hard X-ray Background [Fail]

Life Sciences:
2006 Genesat-1 (NASA Ames)
2009 Pharmasat (NASA Ames)
2010 O/OREOS (NASA Ames)
2014 SporeSat (NASA Ames)