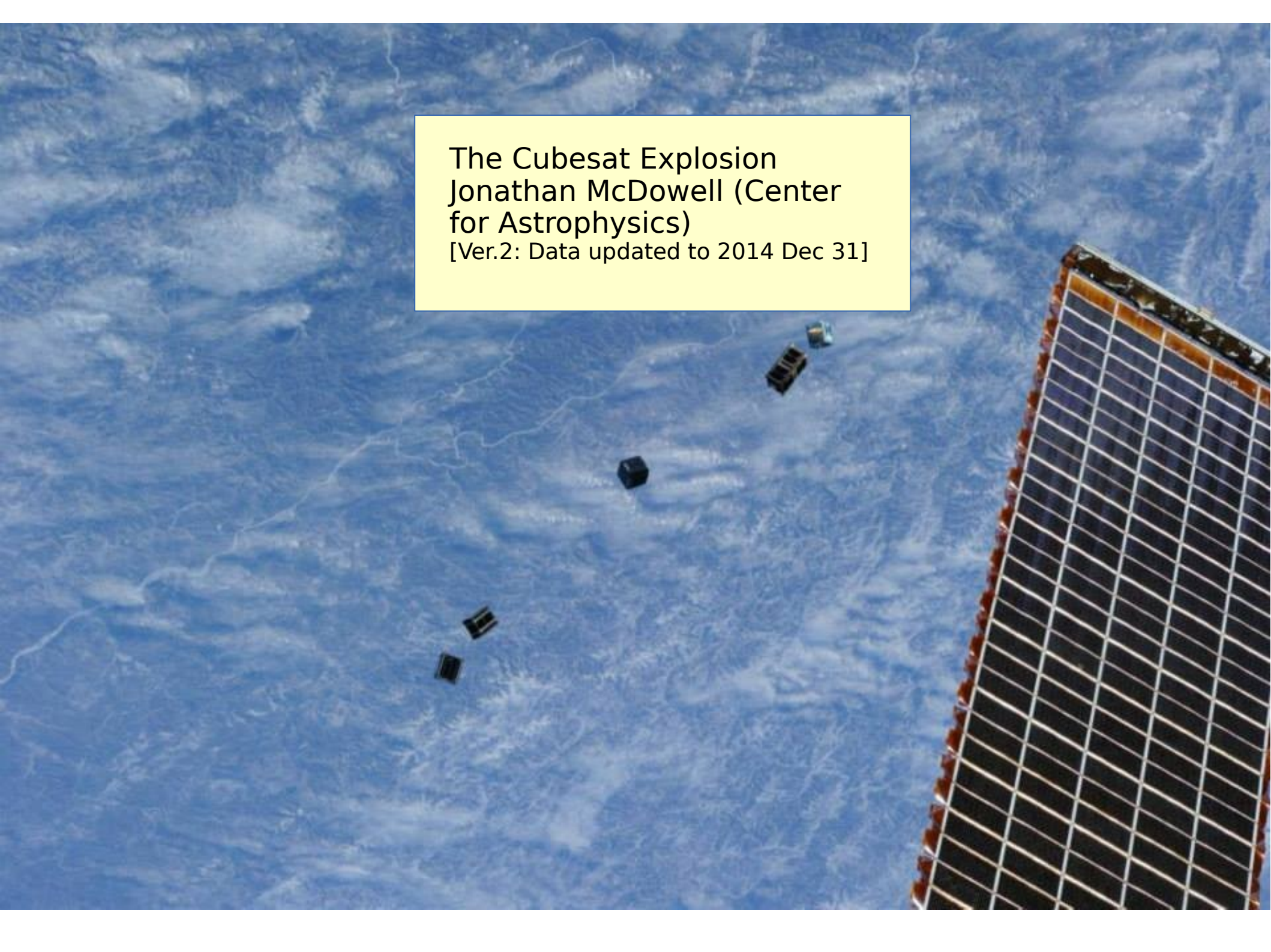


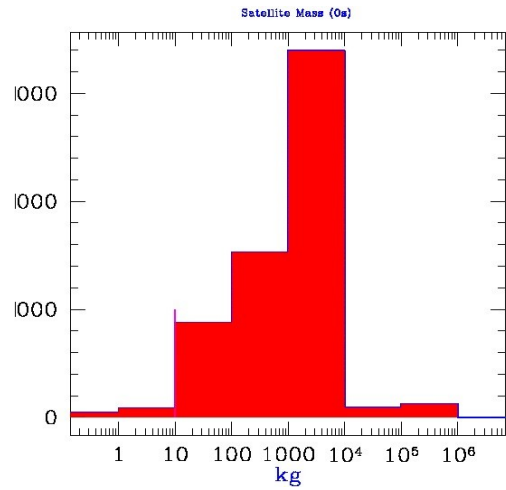
The Cubesat Explosion
Jonathan McDowell (Center
for Astrophysics)
[Ver.2: Data updated to 2014 Dec 31]



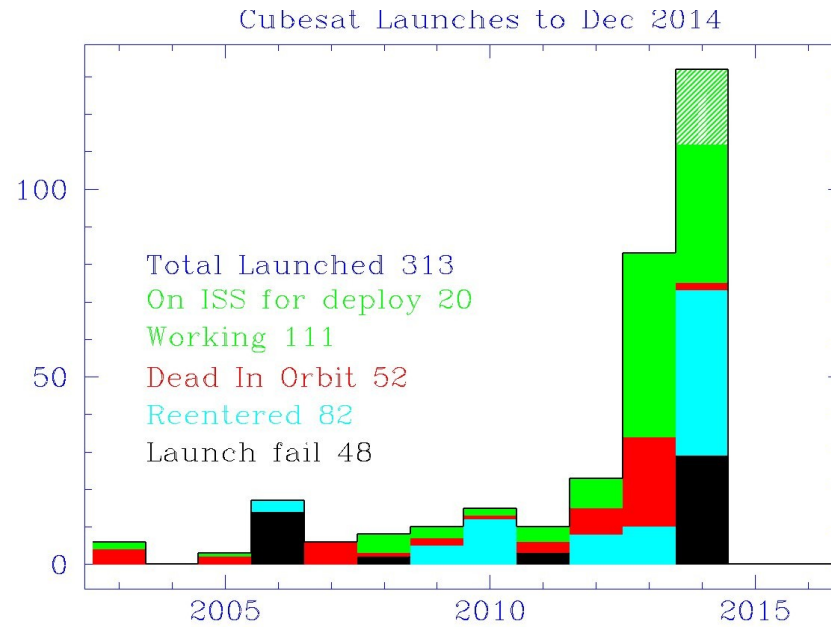
The Cubesat Explosion: STATISTICS 2014 Dec 31

Jonathan McDowell, Center for Astrophysics

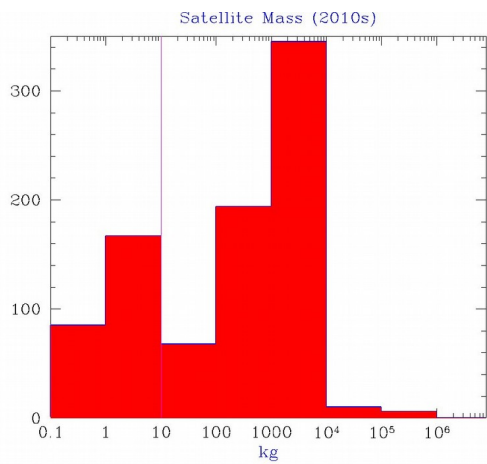
<http://planet4589.org>



Satellite masses
1960-2009



Total Launched 313
On ISS for deploy 20
Working 111
Dead In Orbit 52
Reentered 82
Launch fail 48



Satellite masses
2010-2014

	Orbited	Total Fail (no transmissions)
A: Academic/nonprofit	112	23?
B: Business/commercial	71	2
C: Civil govt. (e.g. NASA)	19	0
D: Defense/military	43	3+

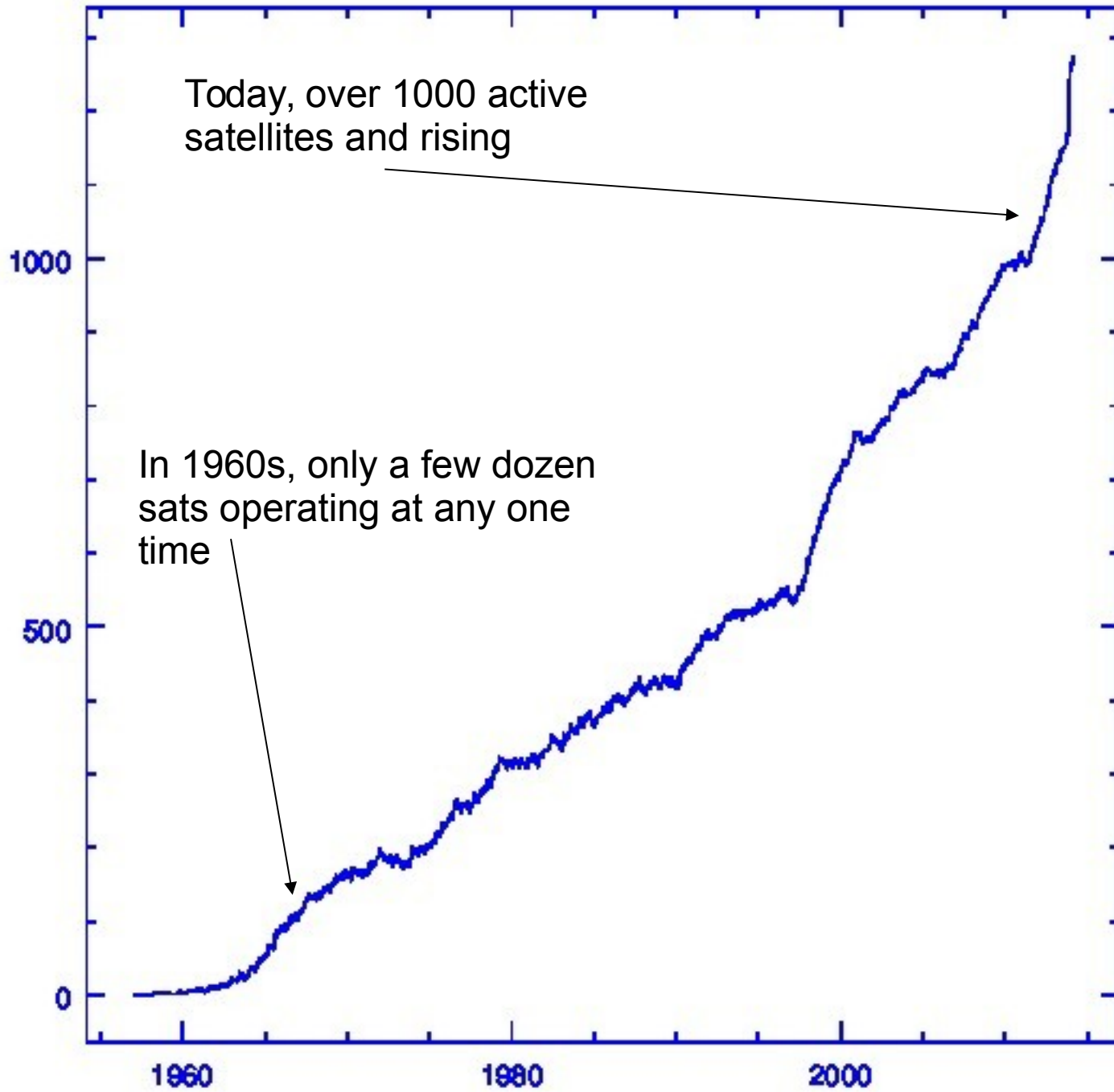
OPERATED > 2 YEARS: 25
(CUTE-I, XI-IV 11 years and going!)

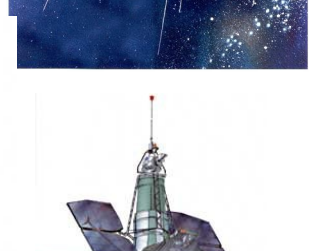
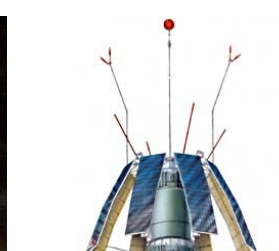
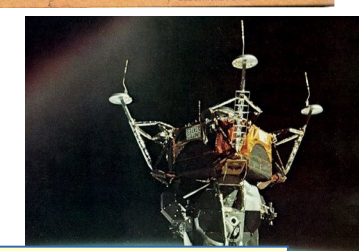
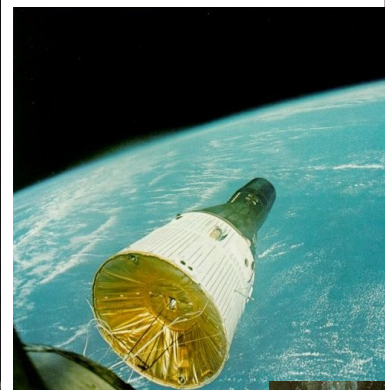
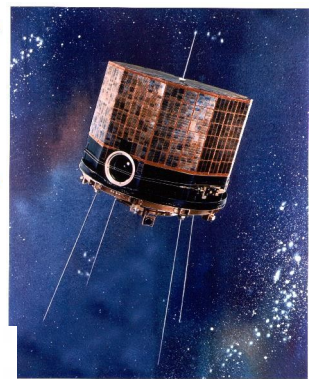
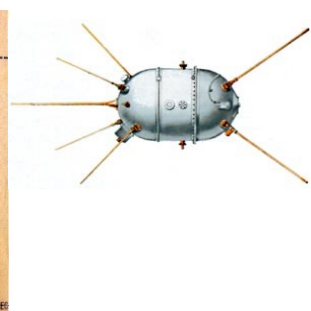
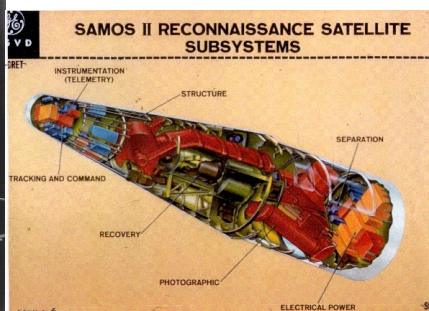
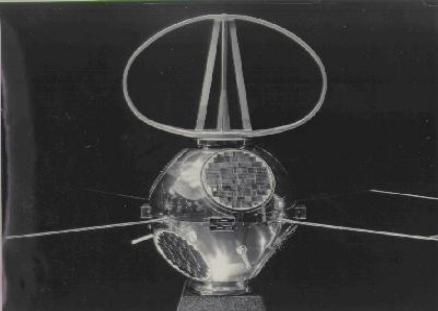
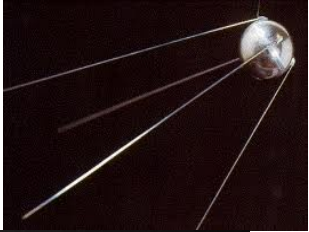
TOTAL 33 COUNTRIES:
USA 223 Japan 18 Germany 10

SCIENCE 31 (Bio 4, Astron 2) COM 32 IMG 106
TECH 143 CAL 1

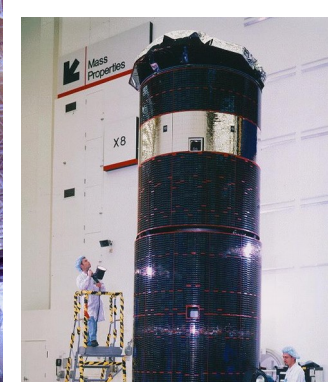
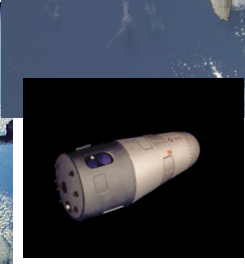
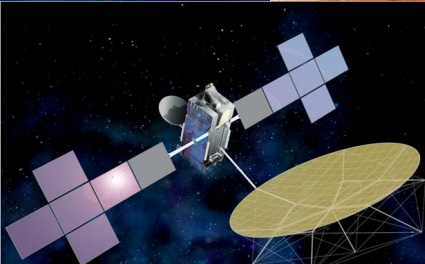
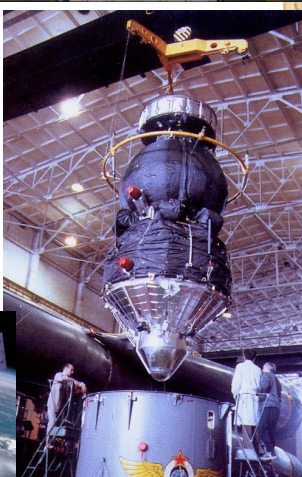
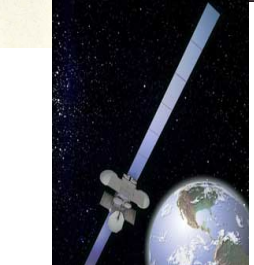
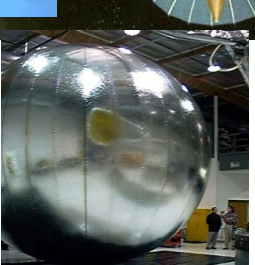
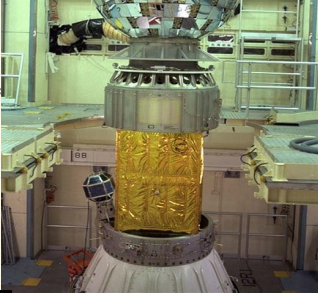
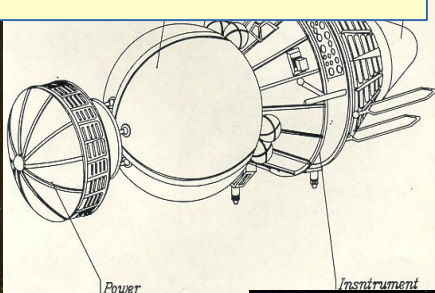
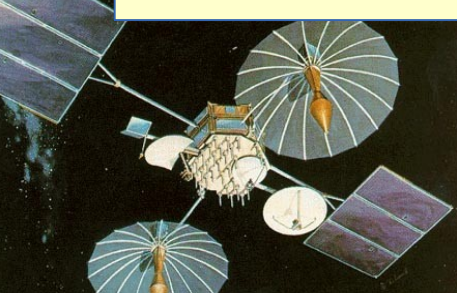
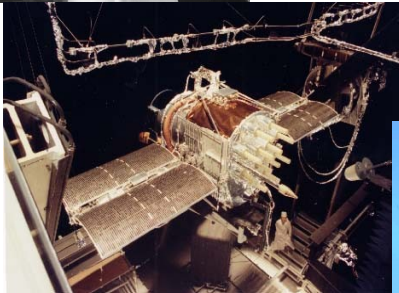


Active Satellites 1957-2013



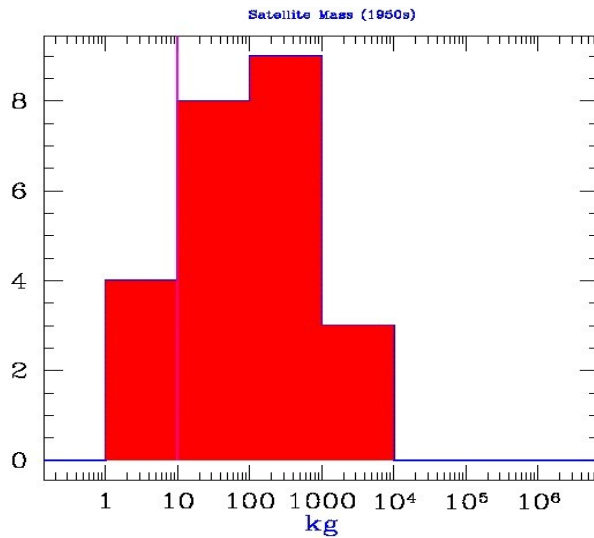


Satellites come in many shapes and sizes...

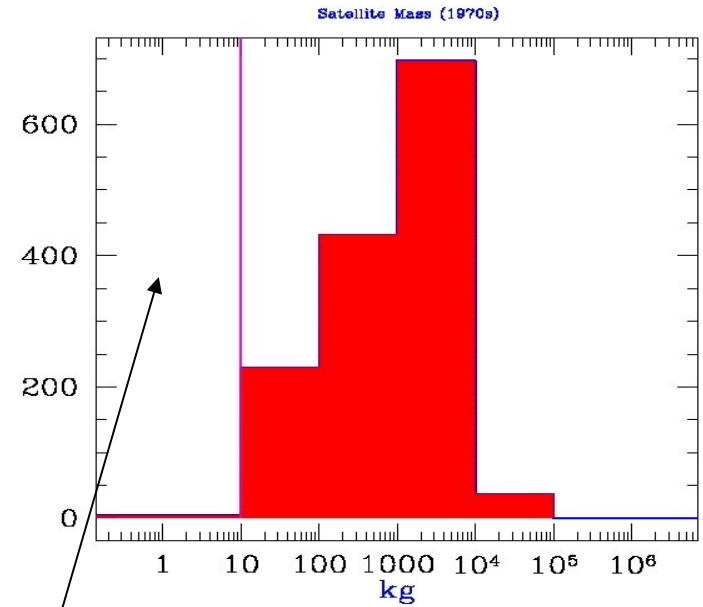


In the 1950s there were some 1-10 kg sats but in later decades trend was to satellites in the 1000 to 10000 kg range

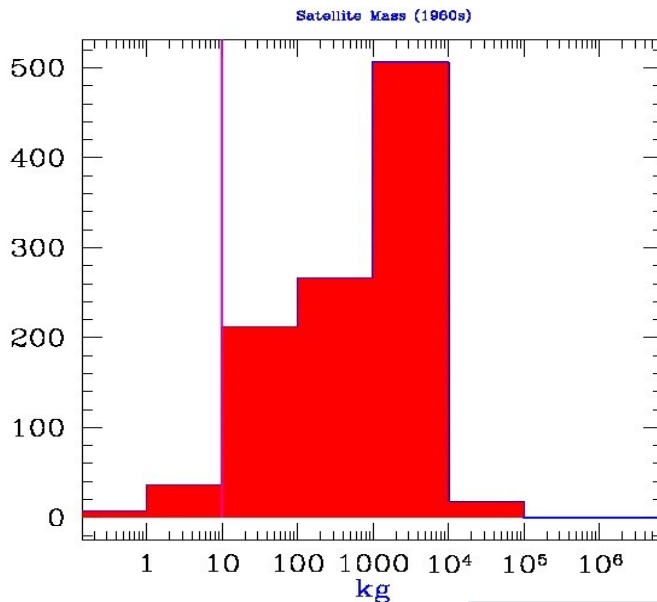
1950s



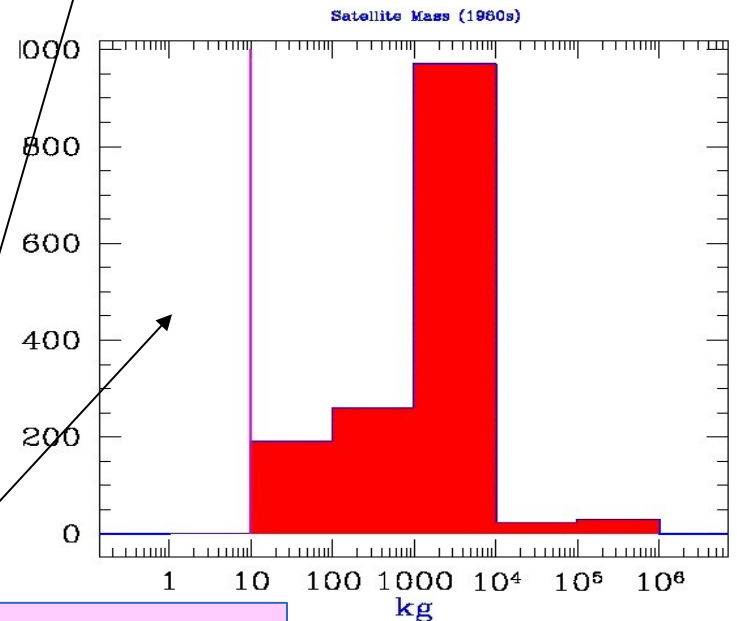
1970s



1960s



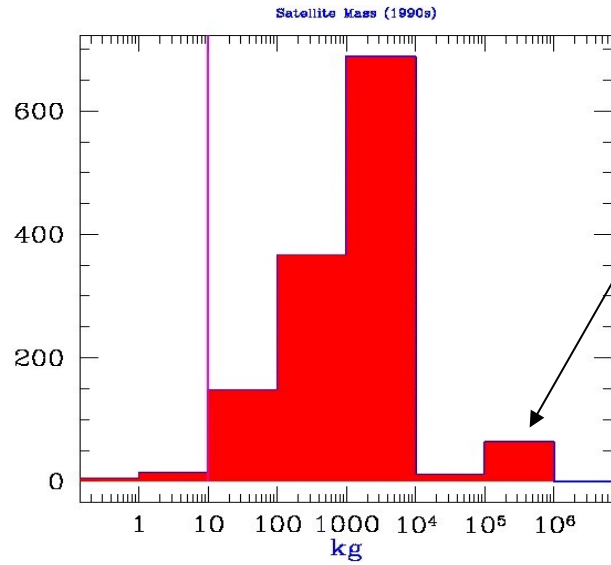
1980s



No nanosats or picosats
(left of magenta line, 0.1-10 kg)

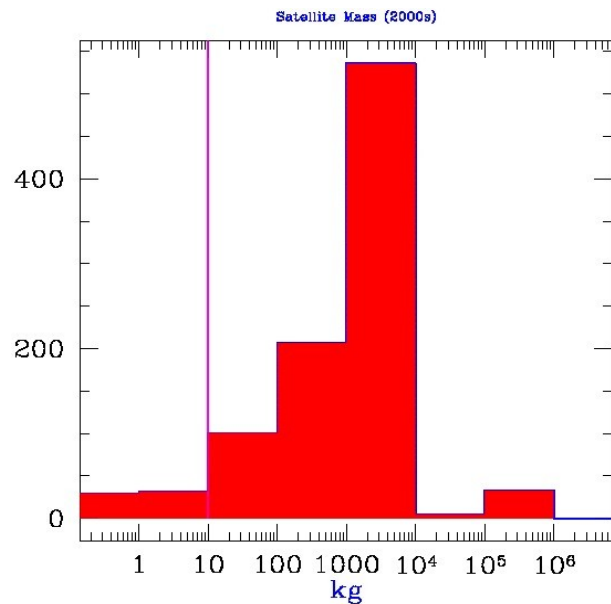
In the 2010s a dramatic shift to lower satellite masses

1990s

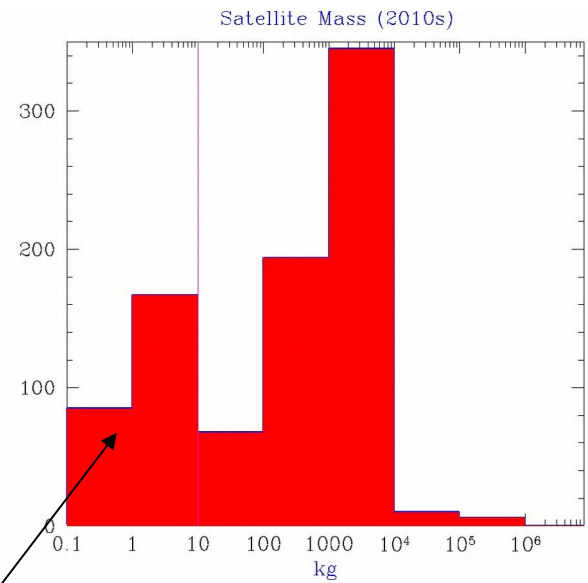


Each Shuttle about 100 tonnes in orbit

2000s

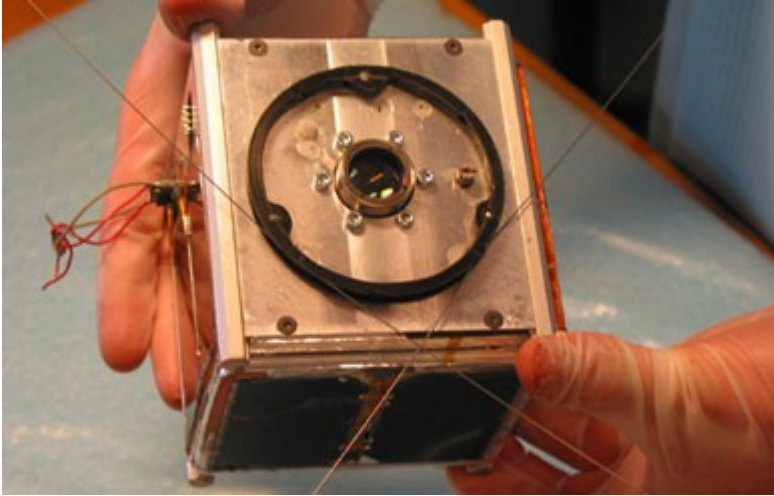


2010s

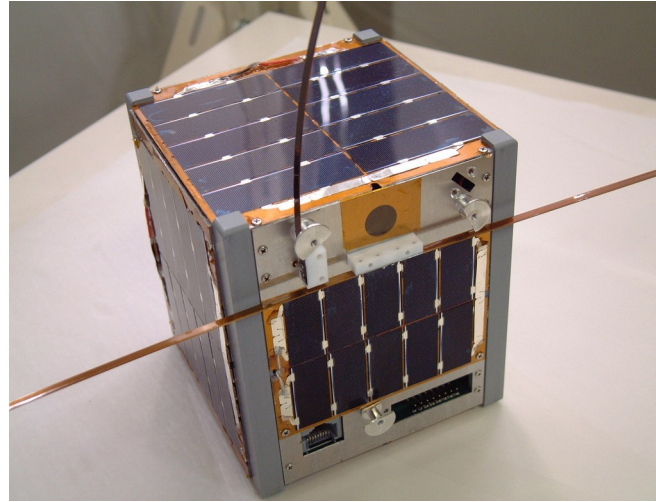


Wow! Nanosats!

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 20cm coming soon



Aalborg U. 2003



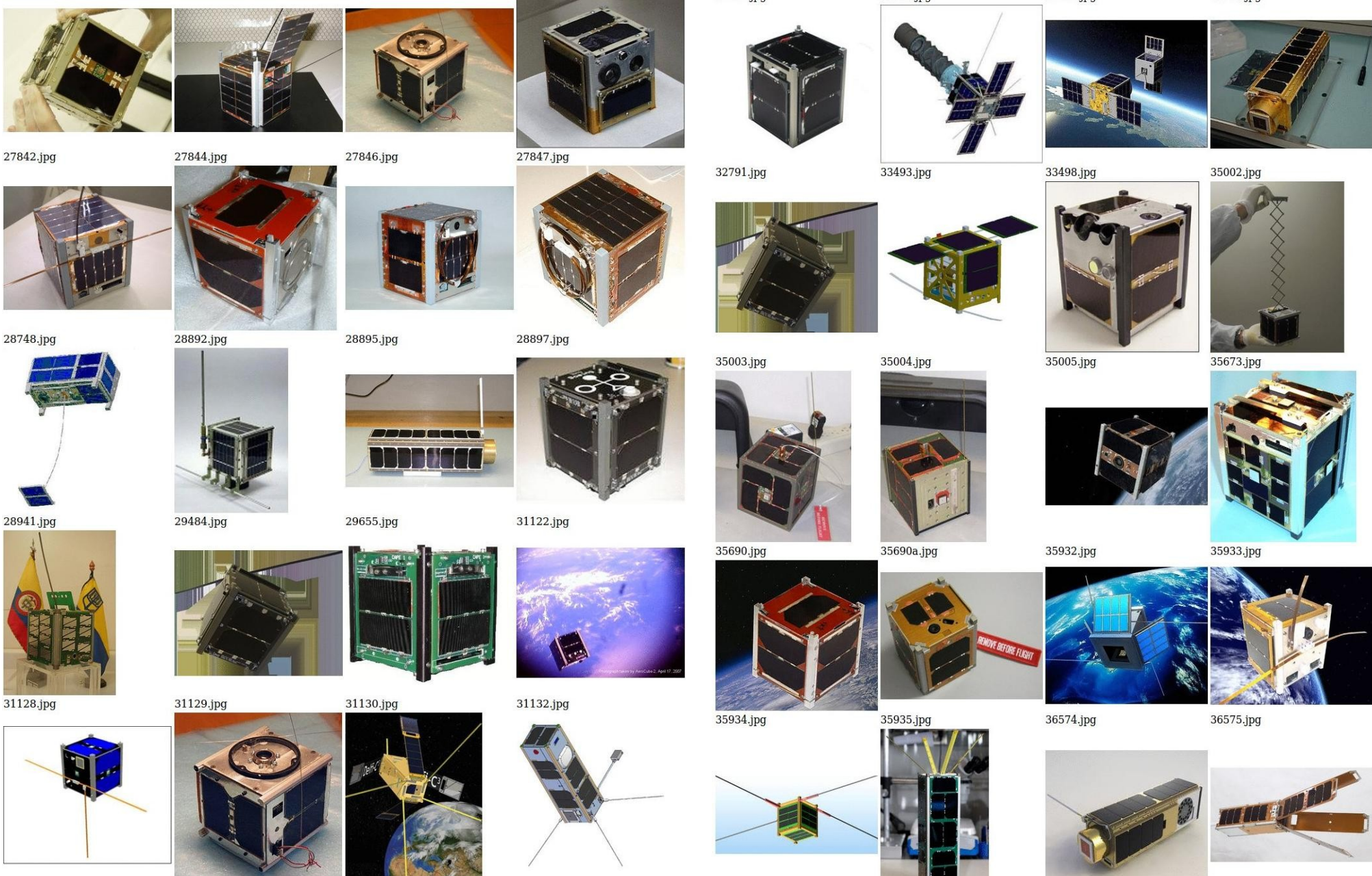
Univ. of Tokyo, 2003



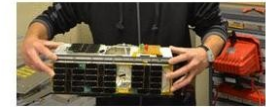
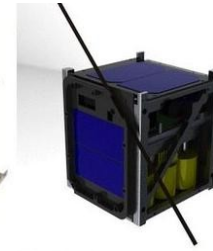
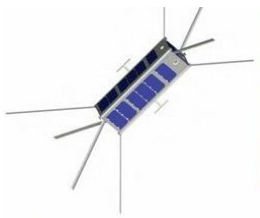
Cubesat deploy from ISS,
2012



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]



37246.jpg

37247.jpg

37249.jpg

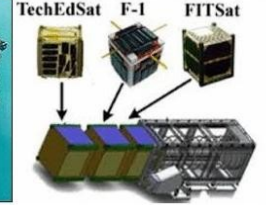
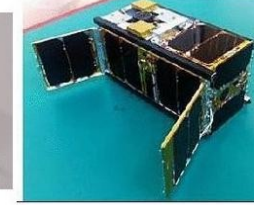
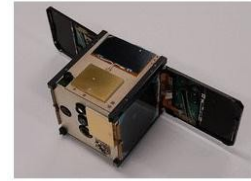
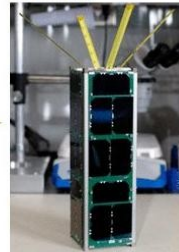
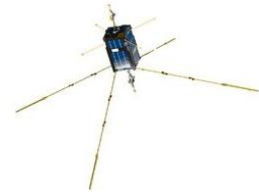
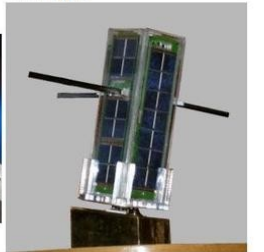
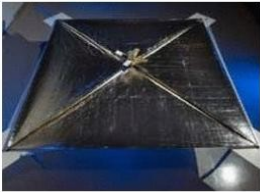
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38765.jpg



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37839.jpg

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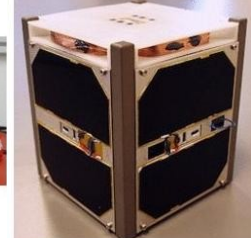
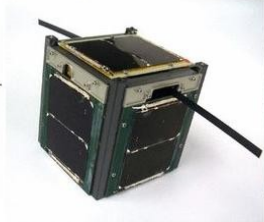
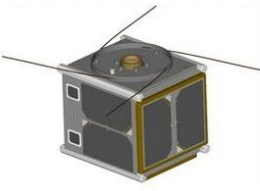
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38769.jpg

38852.jpg

38854.jpg

38856.jpg



37854.jpg

37855.jpg

38079.jpg

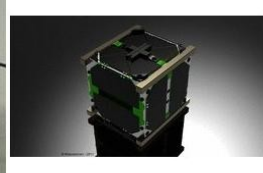
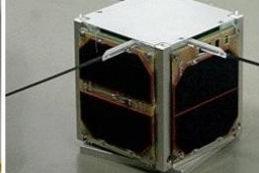
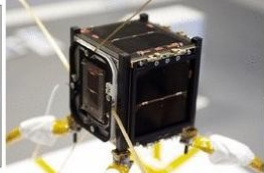
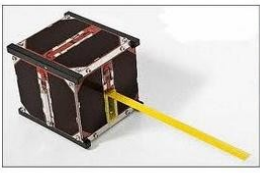
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39132.jpg

39134.jpg



38081.jpg

38082.jpg

38083.jpg

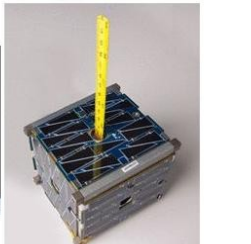
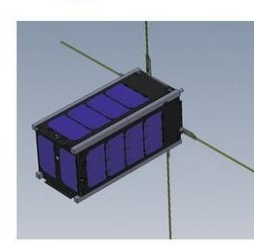
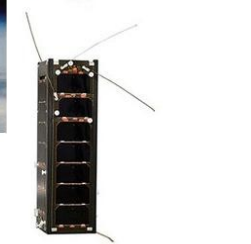
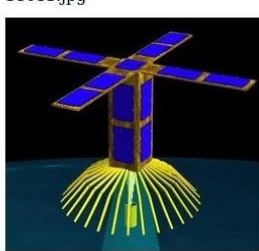
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39151.jpg



38085.jpg

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38761.jpg

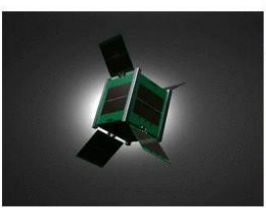
39152.inr

39153.inr

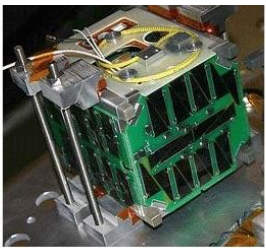
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39381.inr

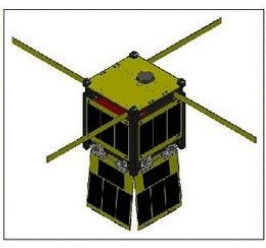
All the Cubesats 2: 2010-2013



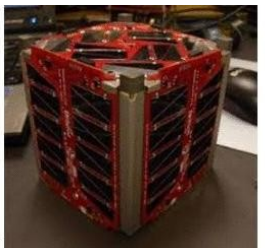
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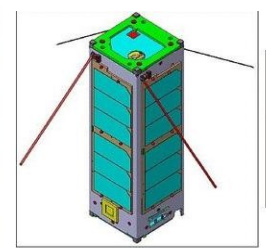
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39384.jpg



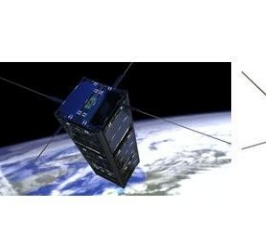
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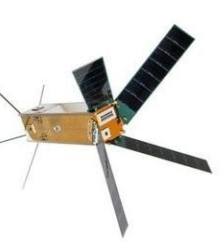
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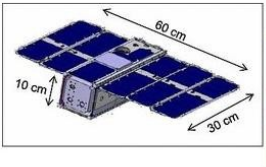
39424.jpg



39427.jpg



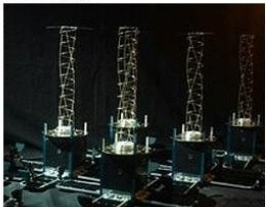
39428.jpg



39388.jpg



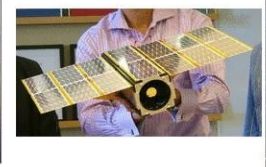
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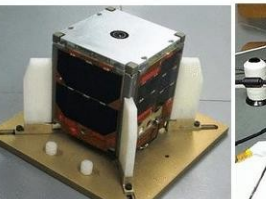
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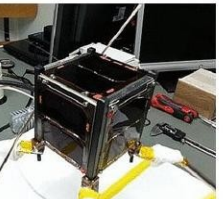
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39430.jpg



39432.jpg



39433.jpg



39395.jpg



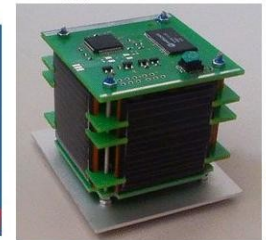
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39400.jpg



39402.jpg



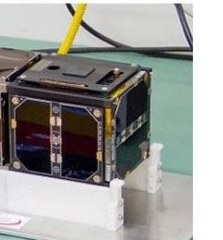
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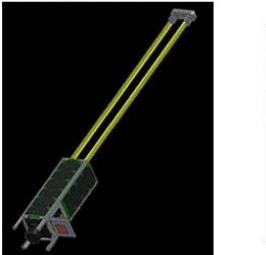
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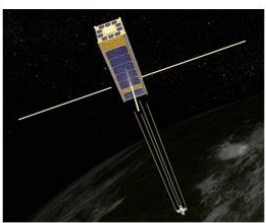
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39438.jpg



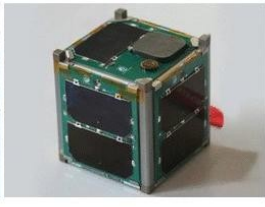
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39404.jpg



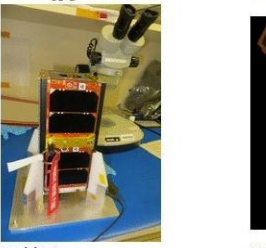
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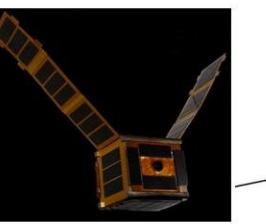
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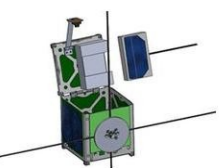
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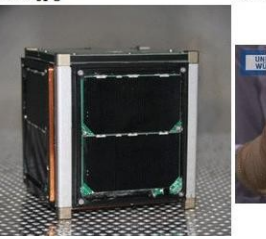
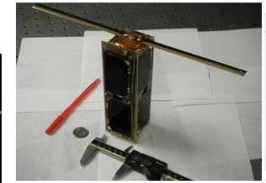
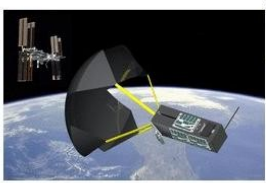
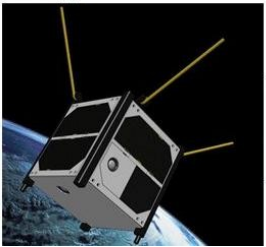
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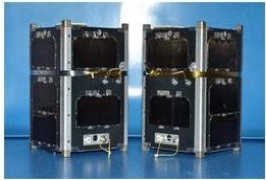
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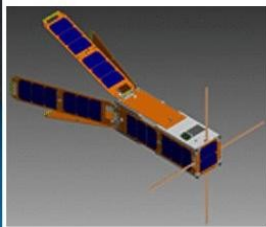
All the Cubesats 3: More 2013 Cubesats



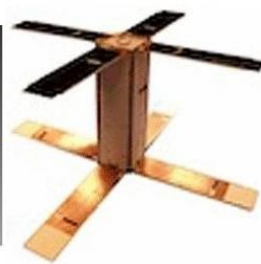
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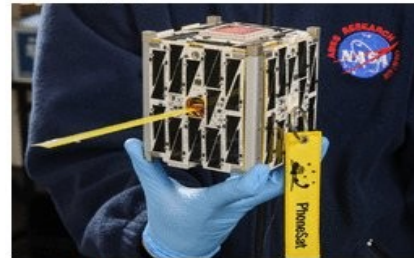
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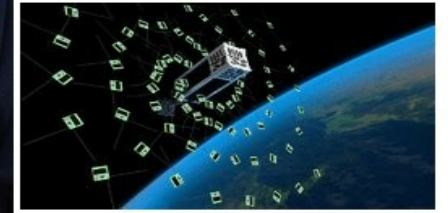
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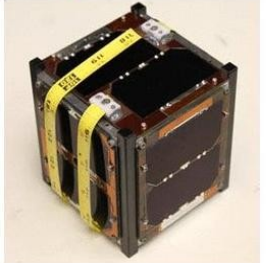
39468.jpg



39684.jpg



39685.jpg



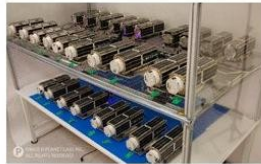
39469.jpg



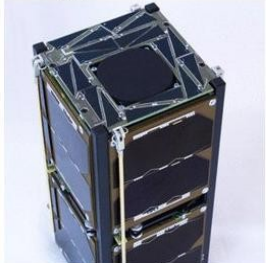
39471.jpg



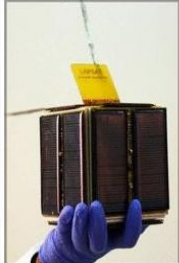
39474.jpg



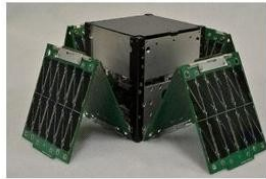
39512.jpg



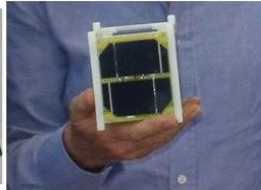
39567.jpg



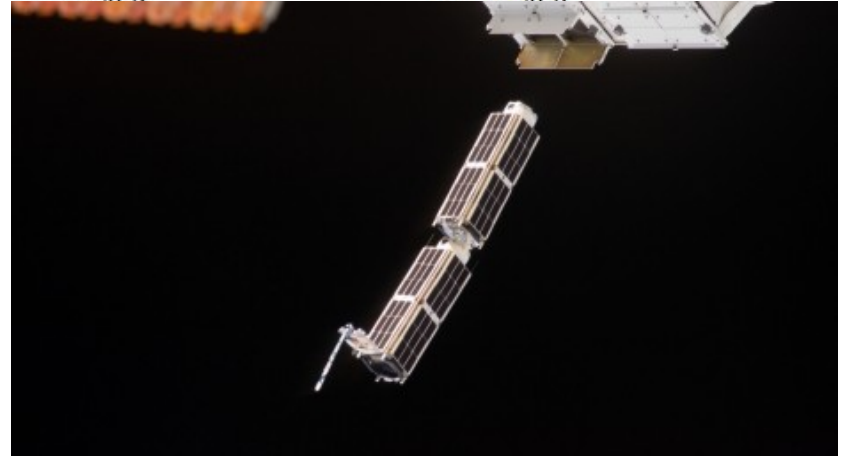
39568.jpg



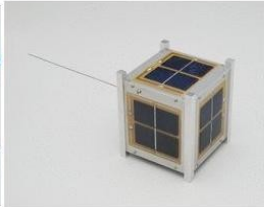
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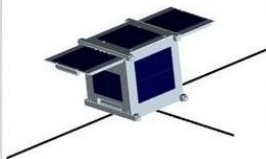
39570.jpg



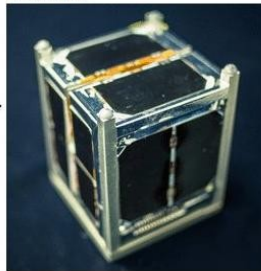
39571.jpg



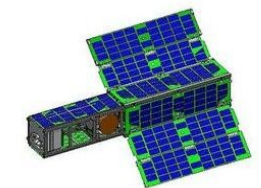
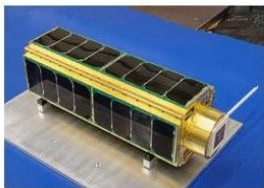
39573.jpg



39575.jpg



39577.jpg



All the Cubesats 4: 2013-2014

CUBESAT STATISTICS 2014 Dec 31

LAUNCHED: 313

48 failed to reach orbit

20 aboard ISS waiting to deploy

DEPLOYED 245 (includes 5 Pocket Qub 0.1-0.5 kg)

	Orbited	TotalFail
A: Academic/nonprofit	112	23?
B: Business/commercial	71	2
C: Civil govt. (e.g. NASA)	19	0
D: Defense/military	43	3+ (unknown others?)

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 163

STILL WORKING 111

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

CUBESAT STATISTICS 2014 DEC 31 – BY COUNTRY LAUNCHED 313 (including failures to orbit)

USA	223				
JAPAN	18				
GERMANY	10				
DENMARK	6 (surprising!)				

By continent:

N AMERICA 225
Canada 2

S AMERICA 11:

Argentina 2, Peru 4, Ecuador 2, Colombia 1, Uruguay 1, Brazil 1

EUROPE 27+16 = 43

Spain 3, Netherlands 4, Italy 3, Norway 3, UK 2, Belgium 2,
Switzerland 2, Lithuania 2, Estonia 1, France 1, Poland 1, Hungary 1,
Romania 1, Ukraine 1

ASIA 14 + 18 = 32

Korea 4, Turkey 2, Vietnam 2, India 1, Pakistan 1, Singapore 3, Israel 1

AFRICA 1

South Africa 1

NOTE: Russia 0 (ZERO! - also surprising)

TOTAL 33 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]
2014 NanoSatBR (Brazil-INPE) Radiation belts
2014 QB50P1/P2 (Von Karman Inst) Atmosphere
2014 MicroMas (MIT) Atmosphere

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)