La revolución CubeSat y la exploración espacial

Andrés Marcos (anmarcos@ing.uc3m.es)

Aerospace Engineering department: https://aero.uc3m.es/

Master in Space Engineering (MISE): https://www.uc3m.es/master/space-engineering

13th November 2024

Brief Speaker CV

Andrés Marcos

Expert on application & transfer of robust control techniques to aerospace systems

Education (9 years): Aerospace Eng.: BSc'97 (St. Louis U., USA) , MSc'01 & PhD'04 (U. of Minnesota, USA)

Academic Experience (13 years): 2 yrs as Post-Doctoral RA (University Leicester, UK, 2004-2006)
7 yrs as Senior Lecturer (University of Bristol, UK, 2013-2020)
4 yrs as Distinguished Investigator / Chair of Excellence (Universidad Carlos III de Madrid, ES, 2021→)

Industrial Experience (12 years): 6 months as Industrial Research Fellow (Honeywell Labs, USA, 2003)
8 yrs from Senior Engineer to R&D Leader (Deimos Space, Spain, 2006-2013)
3 yrs as SME founder & scientific director (TASC Ltd, UK, 2020→2023)

Past projects

25+ years' experience leading aerospace control R&D

My PhD thesis was on aircraft FDI/FTC

Jan 2001-Feb 2004

I proposed & led first two EU coordination projects at Deimos Space (Industry)

Jul 2009-Oct 2012

Jan 2013-Jun 2016

With high-impact results

One of the ADDSAFE teams further consolidated their technique up to in-service deployment on Airbus A350 XWB

In VISION, several FDI/FTC techniques were pilot-flight tested first time in the World mine: Structured H_∞ Control

From TRL 3 → industry-developed, high-fidelity, nonlinear, simulators

To TRL 6/8 → flight tests: piloted & remotely operated

2008: Flight tests robust FDI designs on DLR's Advanced Technologies Testing Aircraft (ATTAS) in Munich.

2019: Flight tests of advanced controllers and wind observers in DLR's Environment for Autonomous GNC Landing Experiment (EAGLE) Vertical-TakeOff-and-Landing (VTOL) demonstrator in Bremen.

2016-2019: Flight and Aircraft-in-the-Loop tests of advanced FTC controllers in JAXA's Multi-Purpose Aviation Laboratory aircraft (MuPAL-α) in Tokyo.

Current position

"Beatriz Galindo" Distinguished Senior Investigator
Aerospace Engineering Department
Universidad Carlos III de Madrid (UC3M)

Personal 5-year talent-attraction award from Spanish Government to:

- Coordinate activities in academic-industry chair ST3LLAR
- Establish CubeSat development program at UC3M
- Develop advanced control & AI/ML techniques for aerospace systems

Director of UC3M's:

Master in Space Engineering, MISE

Center of Satellite Technology, CSAT

UC3M-SENER aerospace chair, ST3LLAR

CubeSat Program, ST3LLARsat

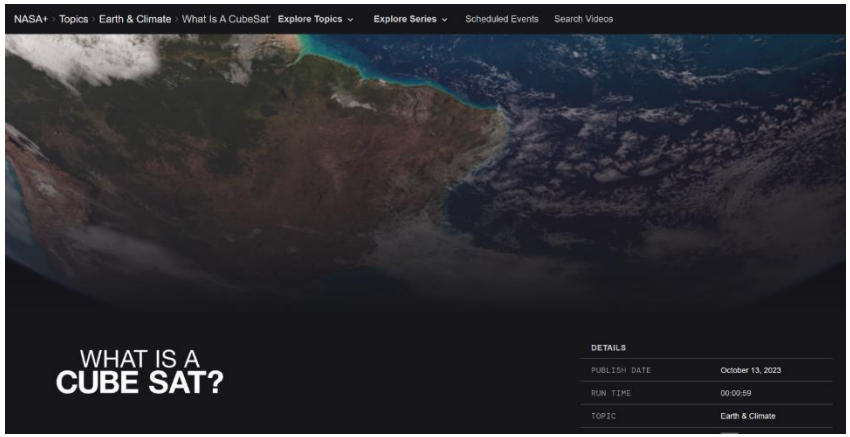
What is a CubeSat?

What is a CubeSat? Some nice videos

NASA – What is a CubeSat

https://www.youtube.com/watch?v=HZMiJ_Q47qk

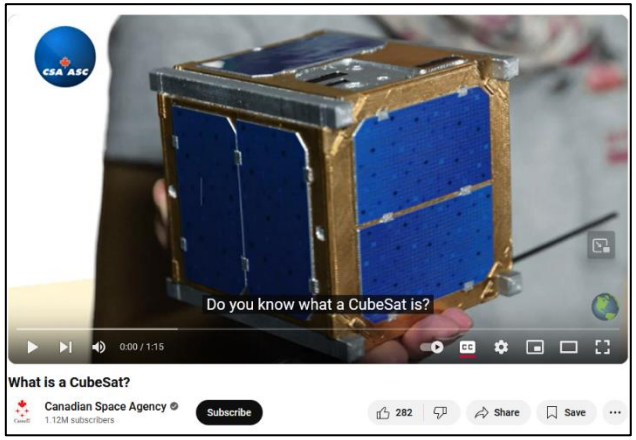
https://plus.nasa.gov/video/what-is-a-cubesat-2/



Canadian Space Agency (CSA) – What is a CubeSat?

https://www.youtube.com/watch?v=x7MmleXu7Dc

https://www.asc-csa.gc.ca/eng/multimedia/search/video/18450?search=cubesat



European Space Agency (ESA) Euronews – CubeSat, a satellite in a shoe box:

https://www.youtube.com/watch?v=w-7gkInt3JI

What is a CubeSat? Definitions

CubeSat

https://en.wikipedia.org/wiki/CubeSat

Article Talk

From Wikipedia, the free encyclopedia

A **CubeSat** is a class of small satellite with a form factor of 10 cm (3.9 in) cubes.[1] CubeSats have a mass of no more than 2 kg (4.4 lb) per unit,[2] and often use commercial off-the-shelf (COTS) components for their electronics and structure. CubeSats are deployed into orbit from the International Space Station, or launched as secondary payloads on a launch vehicle.[3] As of December 2023, more than 2,300 CubeSats have been launched.[4]

https://www.nanosats.eu/cubesat

What is a nanosatellite?

In mass-classification and in strict terms, a nanosatellite (nanosat, nano-satellite) is any satellite with mass from 1 kg to 10 kg. In this database, "nanosatellite" covers all CubeSats, PocketQubes, TubeSats, SunCubes, ThinSats and non-standard picosatellites, unless otherwise stated.

All are part of the same CubeSat revolution and modern electronics technology leap. Limiting to 1-10 kg would be confusing and troublesome. 1U CubeSat can be 0.8 kg, but also 1.3 kg. 6U can be less or more than 10 kg. Most masses are not public.

Upper limit in this database is 10 kg for non-standard types of nanosats and 27U CubeSat (30-40 kg). Lower limit is 1p PocketQubes and custom picosatellites over 100 g and SunCubes that can be less than 100 g.

What is a CubeSat? Classifications

https://en.wikipedia.org/wiki/Small_satellite

Group name[1]	Mass (kg)
Extra Heavy satellite	> 7,000
Heavy satellite	5,001 to 7,000
Large satellite	4,201 to 5,000
Intermediate satellite	2,501 to 4,200
Medium satellite	1,201 to 2,500
Small satellite	601 to 1,200
Mini satellite	201 to 600
Micro satellite	11 to 200
Nano satellite	1.1 to 10
Pico satellite	0.1 to 1
Femto satellite	<0.1

https://www.nanosats.eu/cubesat

Satellite mass classification

- Large satellites: >1000 kg
- Medium satellites: 500 to 1000 kg
- Small satellites: < 500 kg
  - Minisatellites: 100 to 500 kg
  - Microsatellites: 10 to 100 kg
  - Nanosatellites: 1 to 10 kg
  - Picosatellites: 100 g – 1 kg
  - Femtosatellites: 10 g – 100 g
  - Attosatellites: 1 g – 10 g
  - Zeptosatellites: 0.1 g – 1 g

- CubeSat sizes:
  - From 0.25U to 27U
  - From ~0.2 kg to ~40 kg

Small satellite (smallsat) is any satellite below 500 kg. This term should be used rarely, there can be large differences between sizes and capabilities.

A CubeSat is any picosat < nanosat < microsat of up to ~50kg / 27U

What is a CubeSat? Spanish 1st Pocket/Nano/Micro-Sats

A CubeSat is any picosat < nanosat < microsat of up to ~50kg / 27U

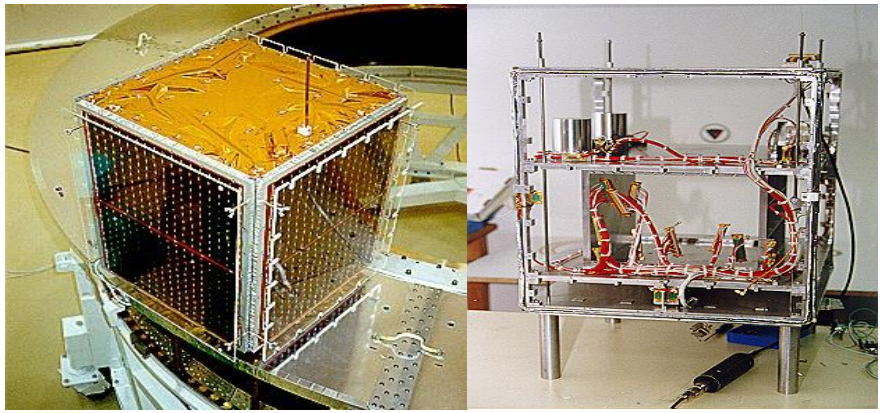
Polytechnic University of Madrid's 1st MicroSat: **UPM-SAT 1 (100U, 47Kg)**

Launched 7th July 1995: https://www.idr.upm.es/en/upmsat-1

UPM-SAT 1 is not a CubeSat: 45x45x55 cms / 47Kg

while a CubeSat is maximum of: **30x30x30 cms / 50Kg**

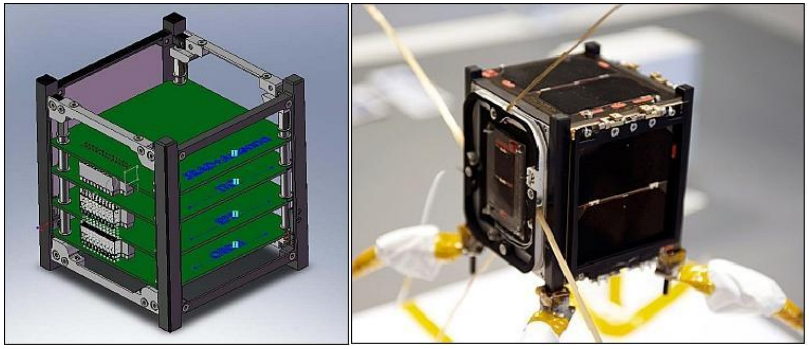
This might seem arbitrary, but it is driven by capacity of **CubeSat deployers** (currently only up to 27U).



University of Vigo's 1st NanoSat: **XaTcobeo (1U, <1Kg)**

Launched 13th Feb 2012: https://www.xatcobeo.com/

https://www.eoportal.org/satellite-missions/xatcobeo#xatcobeo-cubesat-mission

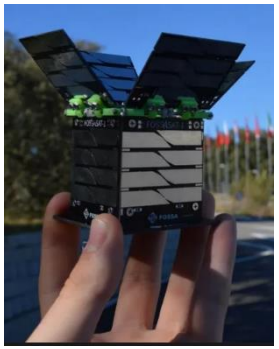


FOSSA Systems' 1st OS PocketQube:

FOSSAsat1 (0.5U, <0.5Kg)

Launched 6th Dec 2019

https://fossa.systems/our-history/



What is a CubeSat? Beginnings

- The CubeSat standard was **created in 1999 by**

  California Polytechnic State University, San Luis Obispo (prof. Jordi Puig-Suari)

  and **Stanford University's Space Systems Development Lab** (prof. Bob Twiggs)

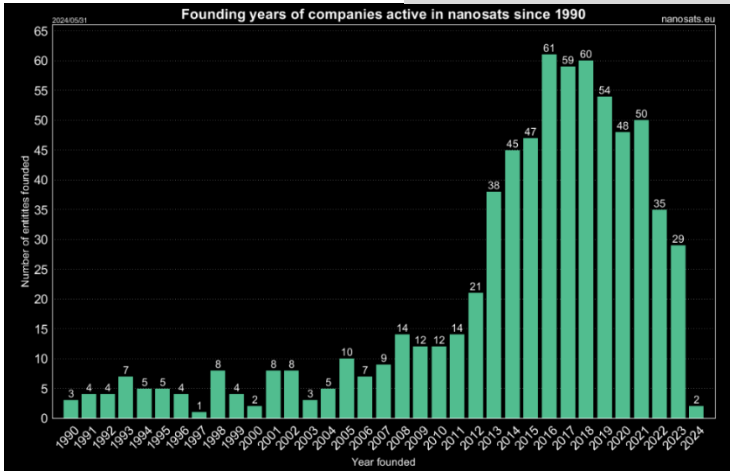
  to facilitate access to space for university students.

Aerospace / Mechanical engineer

Electronics engineer

- Since then, it has become a worldwide standard.
- CubeSat developers include not only universities and educational institutions, but also private firms and government organizations.
- The CubeSat-SmallSat segment is one of the fastest growing segments in the aerospace industry (NewSpace).

https://www.nanosats.eu/



What is a CubeSat? A Standard Description

- The CubeSat is a **standardized** satellite characterized by:
  - **Cube Modular Size: 10cmX10cmX10cm cube** (known as 1U)
  - **Mass per cube: of not more than 1.33 kg** (but sometimes defined as <2Kg)
  - **Functionalities: all basic functionalities for a research satellite**

    STR, EPS, OBC, SW/OBDH, TT&C + ADCS, THR, PAY + AIVT, MGT, BDGT, LAW

- **CubeSats are scalable**

  by grouping multiple 1U frames

  into larger configurations:

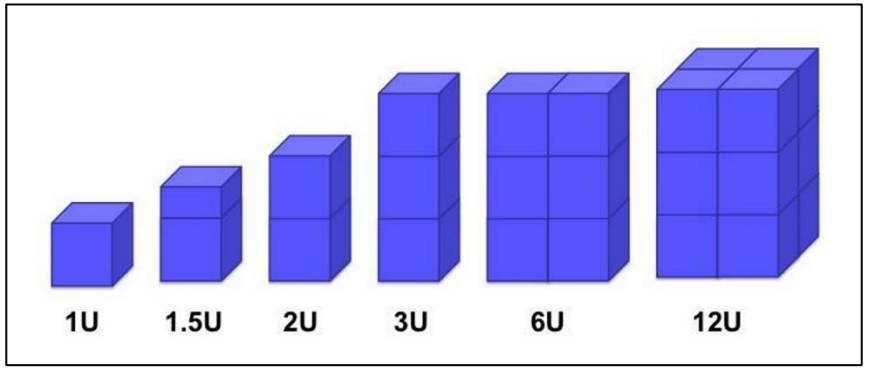
  3U: 10x10x30 cms

  6U: 10x20x30 cms

  12U: 20x20x30 cms

  27U: 30x30x30 cms

https://www.nasa.gov/what-are-smallsats-and-cubesats/



What is a CubeSat? How are they launched?

- Two ways:

  1. **Direct Launcher deployment:** Piggyback on launcher within a CubeSat Deployer
  2. **From ISS:** taken to ISS and released via CubeSat Deployer (or by hand, not often)

Distribuidor

- **CubeSats Deployers** are special containers designed to carry CubeSats:
  - **CalPoly's P-Pod**: up to 3U (i.e. 3x1U, 1x1U+1x2U, 1x3U)
  - **ISIS' ISIPOD**: tailored for 1U, 2U, or 3U
  - **NanoRacks CubeSat Deployer (NRCSD)**: for ISS, up to16U payloads

https://www.eoportal.org/other-space-activities/cubesat-concept#CubeSatDeployers.html.33

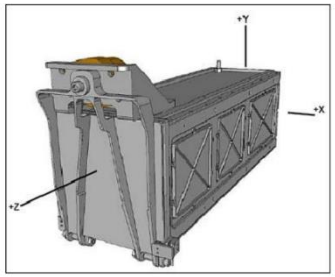


Figure 3: Illustration of the P-POD structure of the Mk III model (image credit: CalPoly)

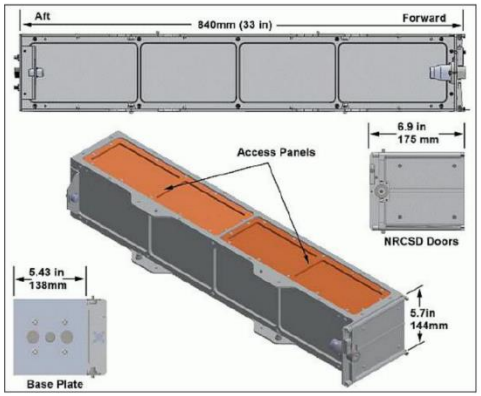
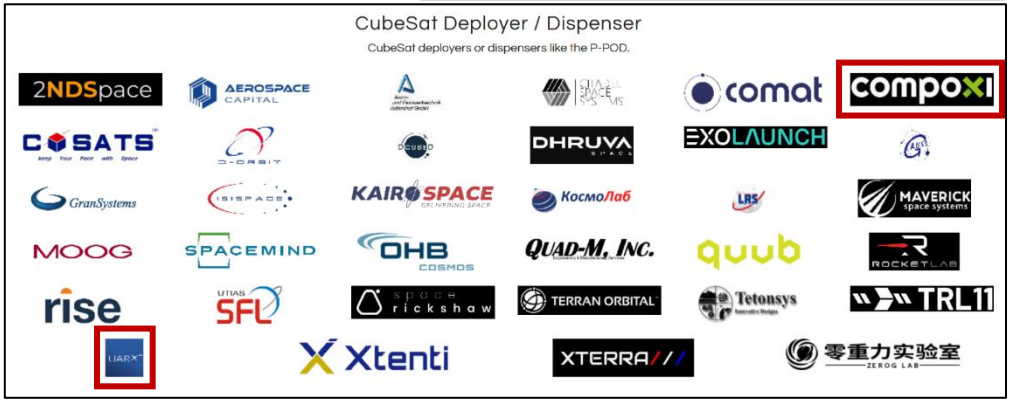


Figure 32: Illustration of the NRCSD configuration (image credit: NanoRacks)

https://www.nanosats.eu/ecosystem#dispenser/



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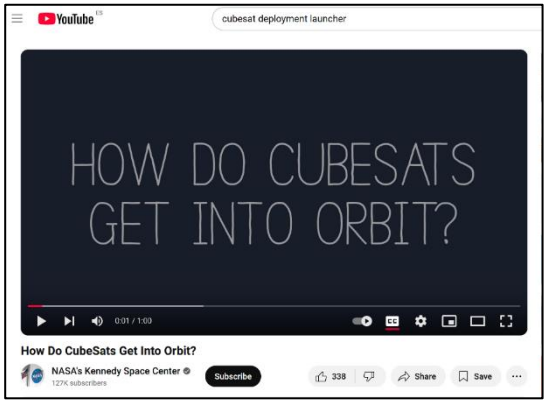
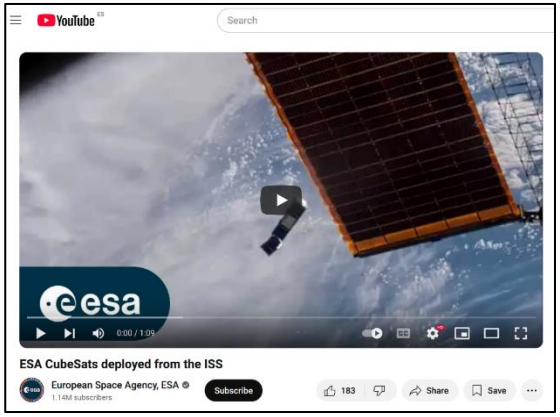
NASA - How Do CubeSats Get Into Orbit?
https://www.youtube.com/watch?v=pnRdlyIWI0k



ESA CubeSats deployed from the ISS
https://www.youtube.com/watch?v=-m4iNiNFFto



CubeSat hits space station solar array 'mildly' after spacewalker deploys it
https://www.youtube.com/watch?v=zfl42B3nWr0

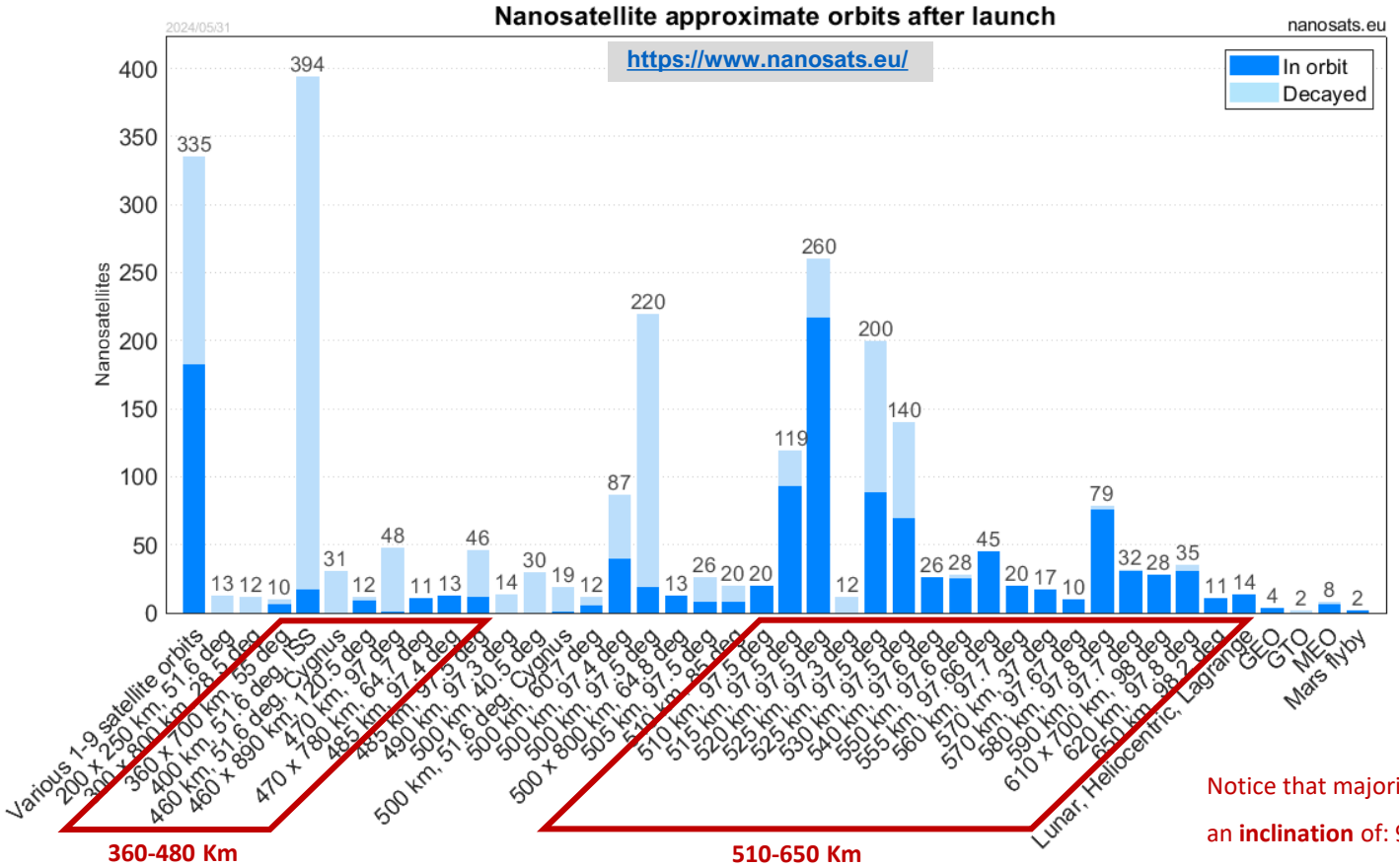
What is a CubeSat? How many are out there?

- Depending how you count, between **4,000-5,000** as of May 2024 (since 1999)

  https://www.nanosats.eu/

What is a CubeSat? What are the typical orbits?

- Most CubeSats are deployed in mid of **Low-Earth-Orbit (LEO)**:
  - **Period** of <128 minutes & **Eccentricity** of <0.25
  - **Mean altitude** of ~800 Km (maximum of 2,000 Km = 1/3 Earth radius)
  - **Mean orbital speed** to maintain a stable LEO orbit is about 7.8 km/s (~28,000 km/h)



Notice that majority are at an **inclination** of: 97-98 deg

What is a CubeSat? How difficult is it to do one?

Since 1999:

- Of an estimated 29,000 universities in the World, only ~200 have launched one.
- **~50% 1st time CubeSats fail** (to reach orbit, cancelled during development, do not respond).
- **It is a learning experience** (failure rate for 2nd attempt of a school/university is 20-25%).
- **Average time range** for developing a 1st CubeSat program is 5-7 years.

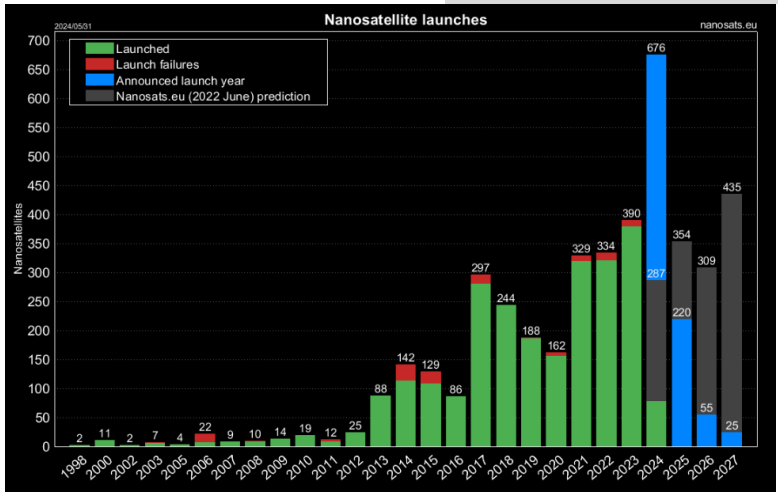
References:

A. Marcos, A. Ponche "**ST3LLARsat1 "BOIRA": Establishing the first student CubeSat program at UC3M**," EDULEARN'23, Palma (Spain)
https://library.iated.org/view/MARCOS2023ST3

M Betancourt "**Half of All First-Time CubeSat Projects End in Failure,**" Smithsonian's Air & Space Magazine
https://www.smithsonianmag.com/air-space-magazine/cubesats-are-great-even-if-they-die-you-180952745/

S.A. Jacklin "**Small-Satellite Mission Failure Rates**," NASA/TM-2018-220034
https://ntrs.nasa.gov/api/citations/20190002705/downloads/20190002705.pdf

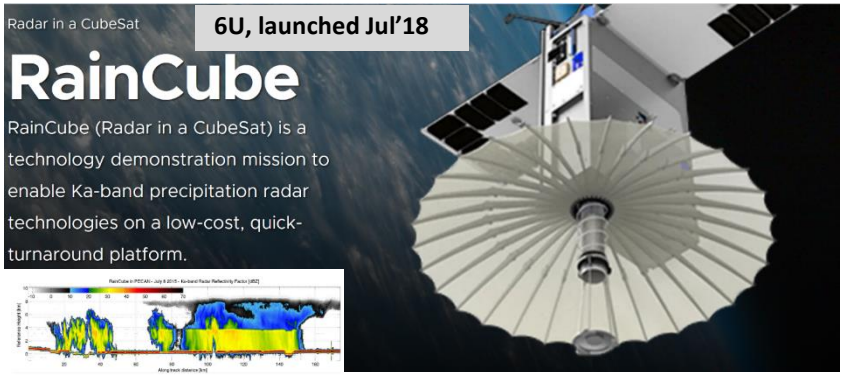
https://www.nanosats.eu/

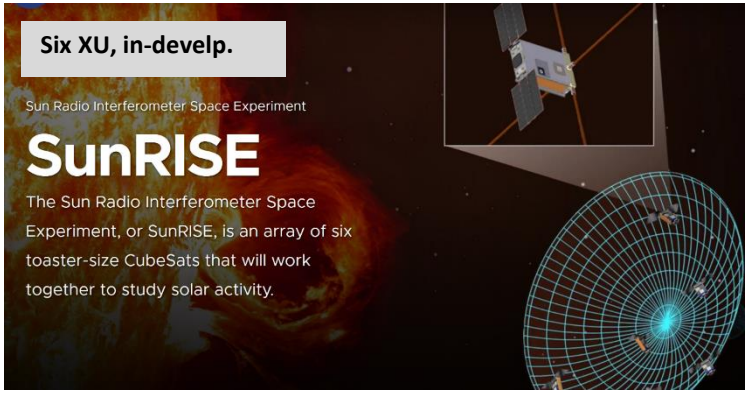


What is a CubeSat? What can we do with it?

- **Almost anything**:
  - Earth monitoring
  - Telecommunications
  - Technology demonstration
  - Astrophysics
  - Commercial

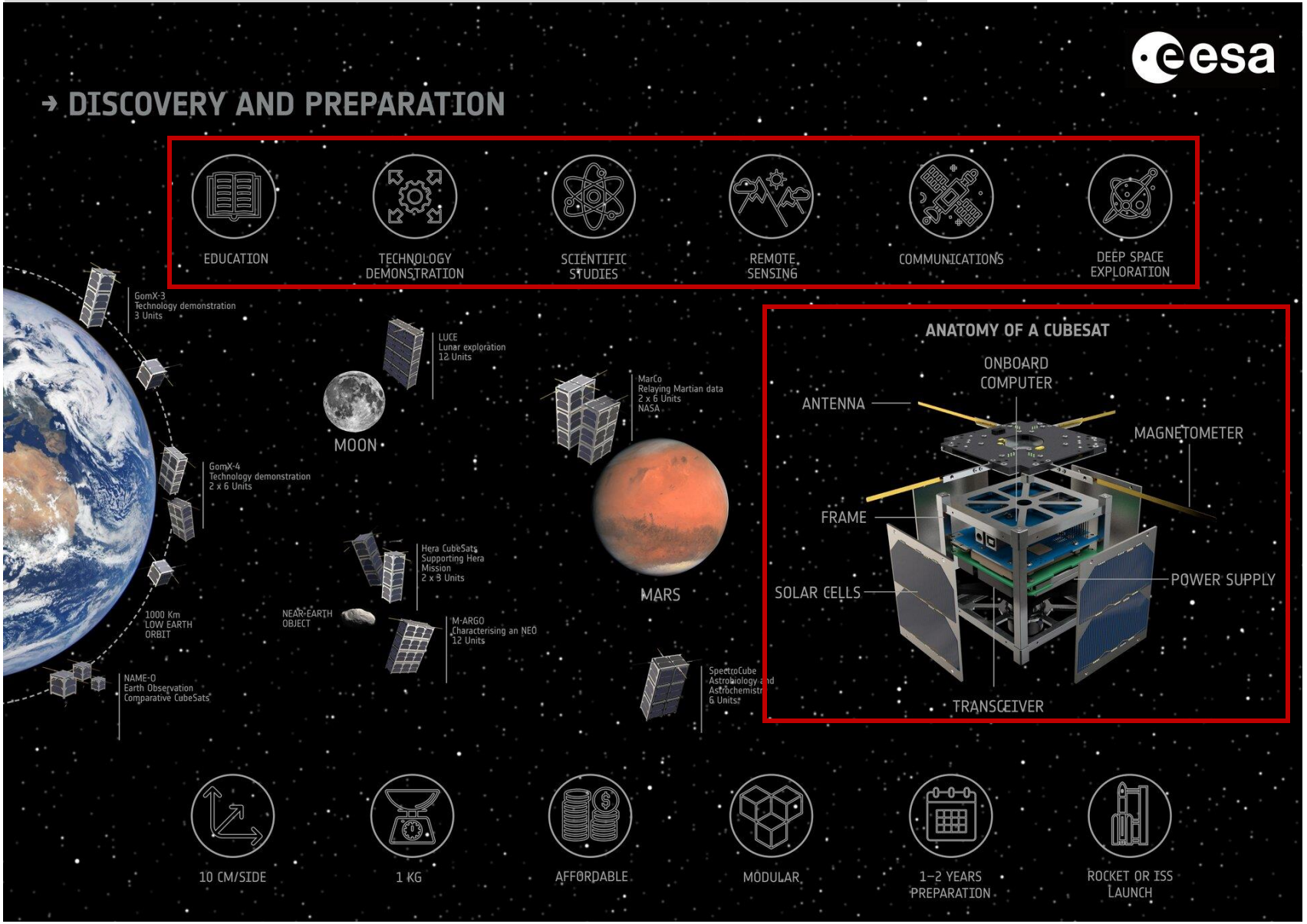
https://www.jpl.nasa.gov/missions/?mission_type=CubeSat/SmallSat





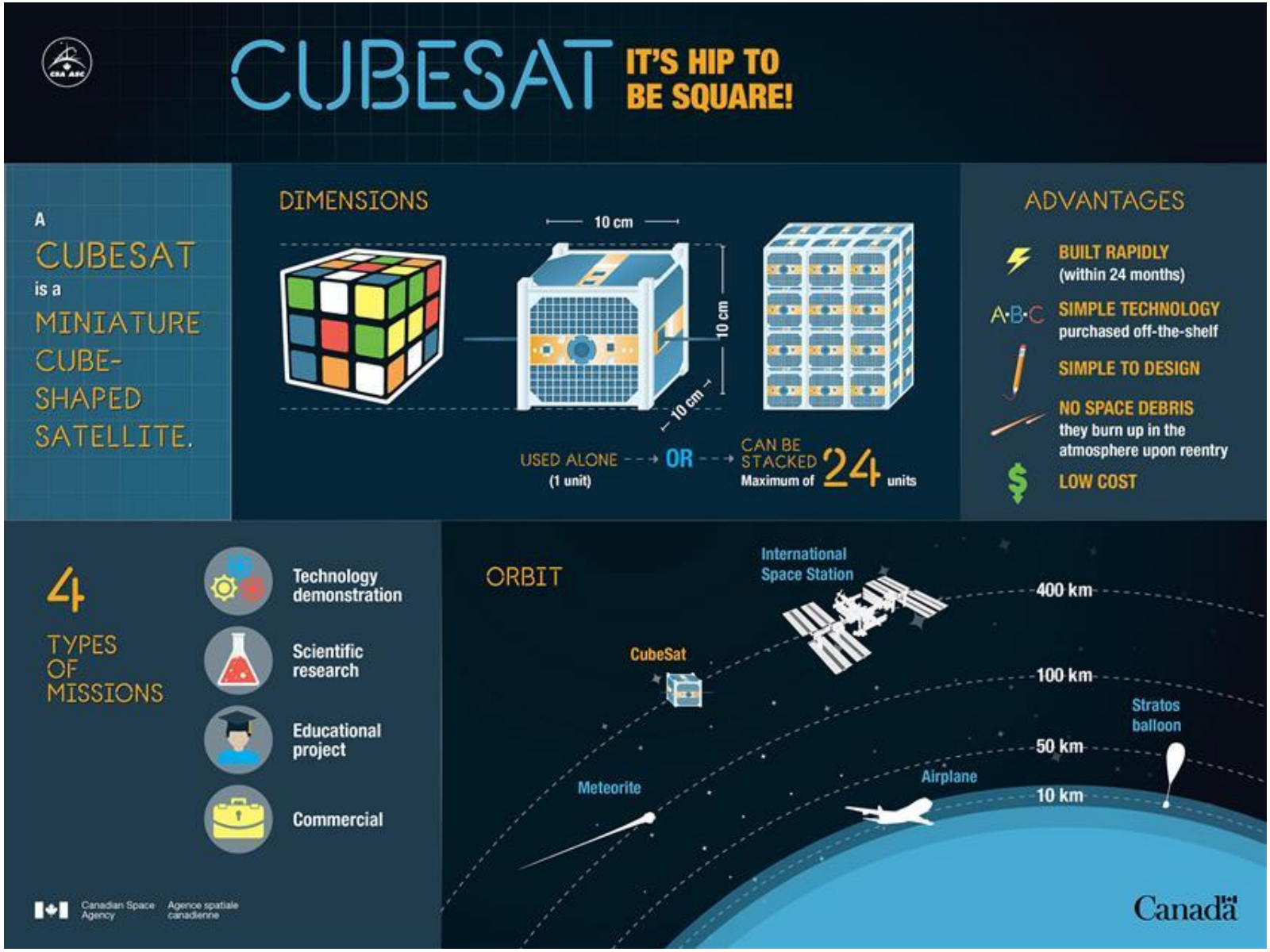
What is a CubeSat? A Visual Summary - ESA

https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/CubeSats



What is a CubeSat? A Visual Summary - CSA

https://www.asc-csa.gc.ca/eng/multimedia/search/image/7097?search=cubesat



CubeSat Programmes

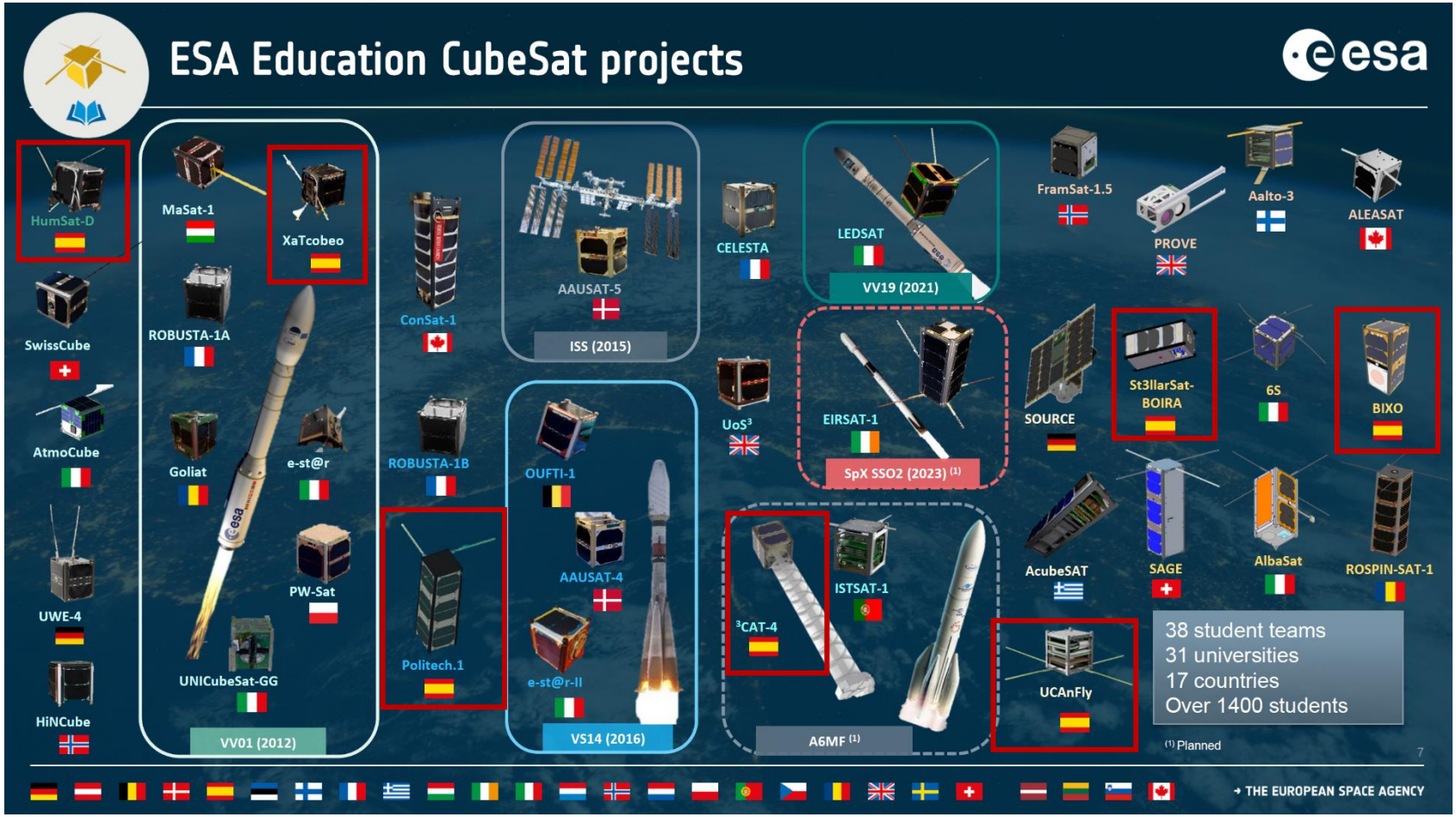
CubeSat Programmes: First & Institutional

The Original Idea, CalPoly https://www.cubesat.org/

NASA https://www.nasa.gov/directorates/heo/home/CubeSats_initiative

ESA https://www.esa.int/Education/CubeSats_-_Fly_Your_Satellite/About_Fly_Your_Satellite!

CubeSat Programmes: ESA Education – FYS program



Uvigo: XaTcobeo (1U, Feb'2012), HumSat-D (1U, Nov'2013), BIXO (expected 2024)

UPC: 3CAT-4 (1U, Jul'24)

UCadiz: UCAnFLy (1U, expected 2025)

UValencia: Polytech.1 (3U, cancelled)

UC3M: ST3LLARsat1 "BOIRA" (2U, expected 2026)

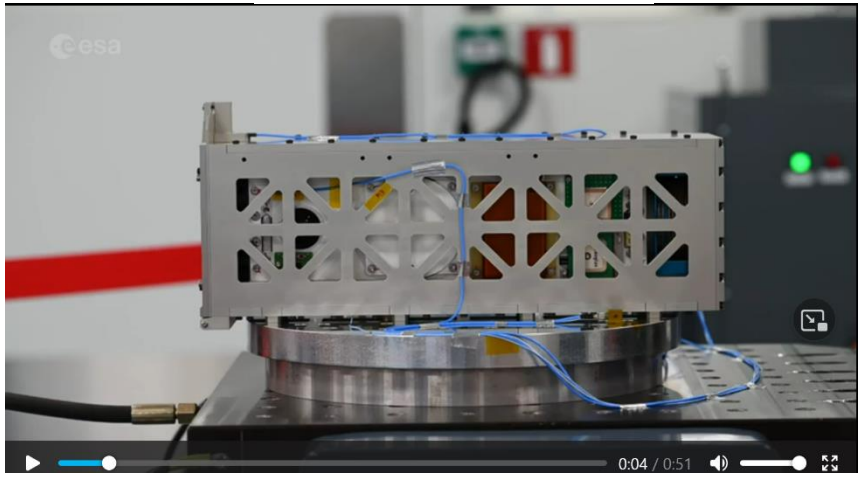
CubeSat Programmes: ESA Education – FYS program

https://www.esa.int/Education/CubeSats_-_Fly_Your_Satellite/CubeSat_Support_Facility

The CubeSat Support Facility (CSF) is an assembly integration and testing facility for CubeSats, located at the ESA Education Training Centre, based at the ESEC-Galaxia facility in Transinne, Belgium. Its purpose: offer training and test facilities for university students that are part, or aiming to be part, of ESA's educational CubeSat initiatives such as 'Fly Your Satellite!'.

The CSF is primarily used by teams participating in ESA Academy's Fly Your Satellite! CubeSat Programme, but in the near future there will be additional innovative courses offered to help university students to learn about environmental testing with hands-on activities and lectures from experts.

SOURCE CubeSat



CubeSat Programmes: Universities

From the "Resources" at NASA SSRO Knowledge Base: https://s3vi.ndc.nasa.gov/ssri-kb/topics/4/

	School	Nation	First Launch	Total
1	University of Melbourne	Australia	1/23/1970	1
2	University of Surrey	UK	10/6/1981	4
3	Weber State	USA	4/29/1985	3
4	Technical University of Berlin	Germany	7/17/1991	15
5	Korean Advanced Institute of Science and Technology	South Korea	8/10/1992	4
6	University of Bremen	Germany	2/3/1994	1
7	National University of Mexico	Mexico	3/28/1995	2
8	Technion Institute of Technology	Israel	3/28/1995	2
9	Universidad Politécnica de Madrid	Spain	7/7/1995	2
10	Russian high school students	Russia	10/5/1997	1
11	US Air Force Academy	USA	10/25/1997	6
12	ESTEC	Europe	10/30/1997	4
13	LASP	US	2/26/1998	4
14	University of Alabama-Huntsville	USA	10/24/1998	2
15	Naval Postgraduate School	USA	10/29/1998	2
16	University of Stellenbosch	South Africa	2/23/1999	2
17	Arizona State University	USA	1/27/2000	2
18	Stanford University	USA	1/27/2000	3
19	Santa Clara University	USA	2/10/2000	3
20	Tsinghua University	China	6/28/2000	4
21	King Abdulaziz City for Science & Technology	Saudi Arabia	9/26/2000	11
22	University of Rome "La Sapienza"	Italy	9/26/2000	10
23	Umeå University / Luleå University of Technology	Sweden	11/21/2000	1
24	US Naval Academy	USA	9/30/2001	8
25	Aalborg University	Denmark	6/30/2003	5
26	Technical University of Denmark	Denmark	6/30/2003	2
27	Tokyo Institute of Technology	Japan	6/30/2003	5
28	University of Tokyo	Japan	6/30/2003	8
29	UTIAS (University of Toronto)	Canada	6/30/2003	4
30	Universidade Norte do Paraná	Brazil	8/22/2003	1
31	Mozhaiskiy Space Engineering Academy	Russia	9/27/2003	2
32	New Mexico State University	USA	12/21/2004	1
33	Norweigan Universities	Norway	10/27/2005	2
34	University of Würzburg	Germany	10/27/2005	4
35	Bauman Moscow State Technical University	Russia	7/26/2006	2
36	Cal Poly	USA	7/26/2006	14
37	Cornell University	USA	7/26/2006	5
38	Hankuk Aviation University	South Korea	7/26/2006	1
39	Montana State University	USA	7/26/2006	9
40	Nihon University	Japan	7/26/2006	4
41	Politecnico di Torino	Italy	7/26/2006	3
42	University of Arizona	USA	7/26/2006	2
43	University of Hawaii	USA	7/26/2006	3
44	University of Illinois	USA	7/26/2006	4
45	University of Kansas	USA	7/26/2006	1
63	University Space Engineering Consortium	Japan	5/20/2010	1
64	Waseda University	Japan	5/20/2010	2
65	Indian university consortium	India	7/12/2010	1
66	Scuola universitaria della Svizzera italiana	Switzerland	7/12/2010	1
67	University of Michigan	USA	11/20/2010	7
68	University of Southern California	USA	12/8/2010	1
69	Colorado Space Grant Consortium	USA	3/4/2011	3
70	Kentucky Space	USA	3/4/2011	7
71	M.V. Lomonosov Moscow state university	Russia	4/20/2011	1
72	Nanyang Technological University	Singapore	4/20/2011	8
73	Indian Institute of Technology Kanpur	India	10/12/2011	1
74	Auburn University	USA	10/28/2011	1
75	Utah State University	USA	10/28/2011	2
76	Budapest University of Technology and Economics	Hungary	2/13/2012	1
77	University of Bologna	Italy	2/13/2012	1
78	University of Bucharest	Romania	2/13/2012	1
79	University of Montpellier II	France	2/13/2012	2
80	University of Vigo	Spain	2/13/2012	3
130	College of Engineering, Pune	India	6/22/2016	1
131	Sathyabama University	India	6/22/2016	1
132	Shaanxi Engineering Laboratory	China	6/25/2016	1
133	Universidad Politécnica de Cataluña	Spain	8/15/2016	2
134	IIT Bombay	India	9/26/2016	1
135	Escola Municipal Presidente Tancredo de Almeida Neves	Brazil	12/9/2016	1
190	New Mexico Institute of Mining and Technology	US	12/16/2018	1
191	West Virginia University	US	12/16/2018	1
192	North Idaho STEM Charter Academy	US	12/16/2018	1
193	Space Kidz	INDI	1/24/2019	1

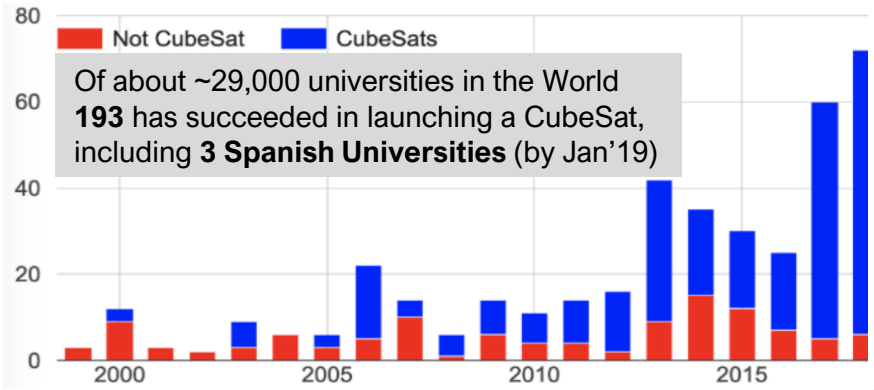


Figure 1: Count of University-class missions launched each year since 1999

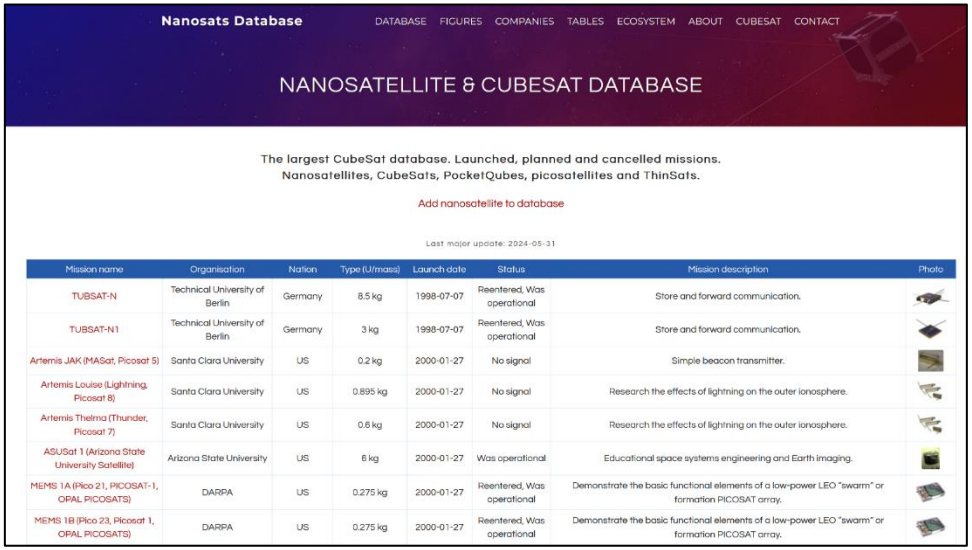
CubeSat Programmes: Databases

- Several databases available listing all missions/platforms:

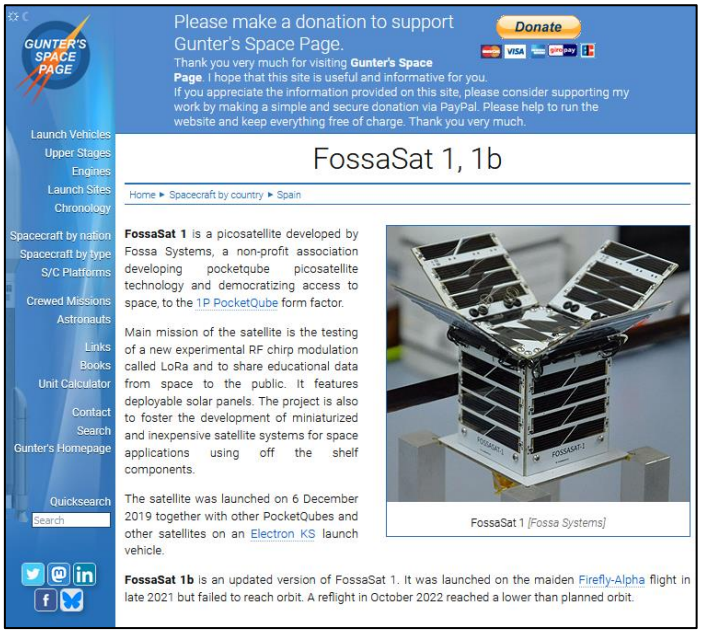
https://www.nanosats.eu/

https://space.skyrocket.de/ (Gunter's Space Page)

https://www.eoportal.org/

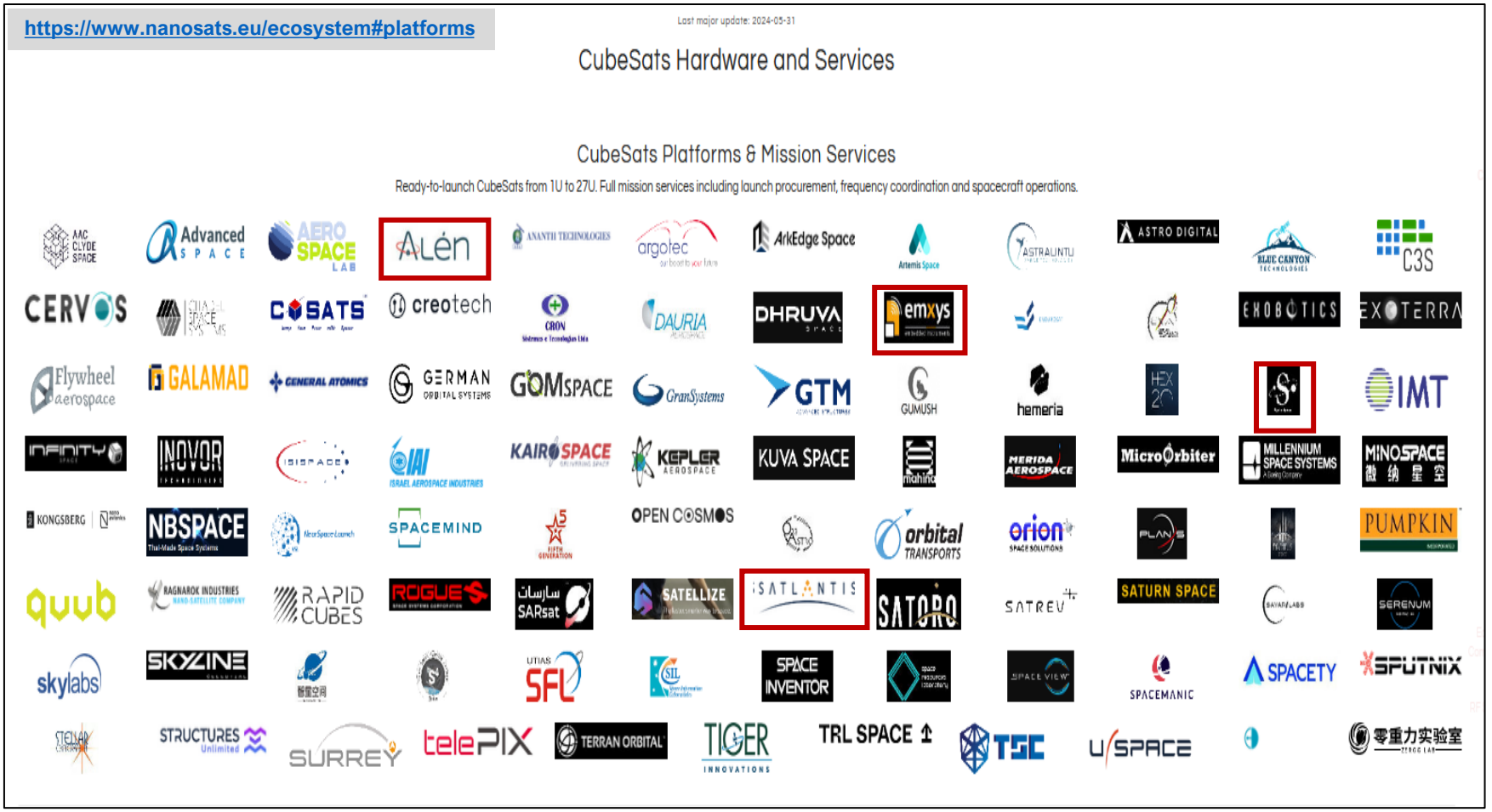


Mission name	Organisation	Nation	Type (U/mass)	Launch date	Status	Mission description	Photo
TUBSAT-N	Technical University of Berlin	Germany	8.5 kg	1998-07-07	Reentered, Was operational	Store and forward communication.	
TUBSAT-N1	Technical University of Berlin	Germany	3 kg	1998-07-07	Reentered, Was operational	Store and forward communication.	
Artemis JAK (MASat, Picosat 5)	Santa Clara University	US	0.2 kg	2000-01-27	No signal	Simple beacon transmitter.	
Artemis Louise (Lightning, Picosat 8)	Santa Clara University	US	0.895 kg	2000-01-27	No signal	Research the effects of lightning on the outer ionosphere.	
Artemis Thelma (Thunder, Picosat 7)	Santa Clara University	US	0.6 kg	2000-01-27	No signal	Research the effects of lightning on the outer ionosphere.	
ASUSat 1 (Arizona State University Satellite)	Arizona State University	US	6 kg	2000-01-27	Was operational	Educational space systems engineering and Earth imaging.	
MEMS 1A (Pico 21, PICOSAT-1, OPAL PICOSATS)	DARPA	US	0.275 kg	2000-01-27	Reentered, Was operational	Demonstrate the basic functional elements of a low-power LEO "swarm" or formation PICOSAT array.	
MEMS 1B (Pico 23, Picosat 1, OPAL PICOSATS)	DARPA	US	0.275 kg	2000-01-27	Reentered, Was operational	Demonstrate the basic functional elements of a low-power LEO "swarm" or formation PICOSAT array.	



CubeSat Programmes: Platforms & Mission Services

https://www.nanosats.eu/ecosystem#platforms



Platforms: Alen Space, EMXYS, Hydra Space, SATLANTIS

Subsystems: Aistech, Alter Tech., Anteral, Arquimea, Balamis, BHDynamics, Comet Ingeniería, Compoxi, DHV Tech., FOSSA Systems, IENAI Space, Karten Space, Kreios Space, Prosix Eng., Radian Systems, Sateliot, SLIMOp Space, UARX, VALAR, Xiroi

CubeSat Basics

CubeSat Basics: Design Specification Documents

Always, always, always read & refer to the CubeSat spec-docs.

- The most well-known and detailed are:
  - **CalPoly's**:

    DesignSpecification_CalPoly_rev13_final.pdf

    DesignSpecification_CalPoly_rev14_July2020.pdf

    CubesatInterfaceFitProcedure_CalPoly_rev02W_2020.pdf

  - **NASA's 101**:

    DesignSpecification_Cubesat101_NASA2017.pdf

  - **ESA** (https://emits.sso.esa.int > emits-doc > ESTEC >):

    AO8352_AD1_IOD_CubeSat_ECSS_Eng_Tailoring_Iss1_Rev1-2.pdf

    IOD_CubeSat_ECSS_Eng_Tailoring_Iss1_Rev3-2.pdf (24/11/2016)

See also other docs at: https://www.cubesat.org/cubesatinfo

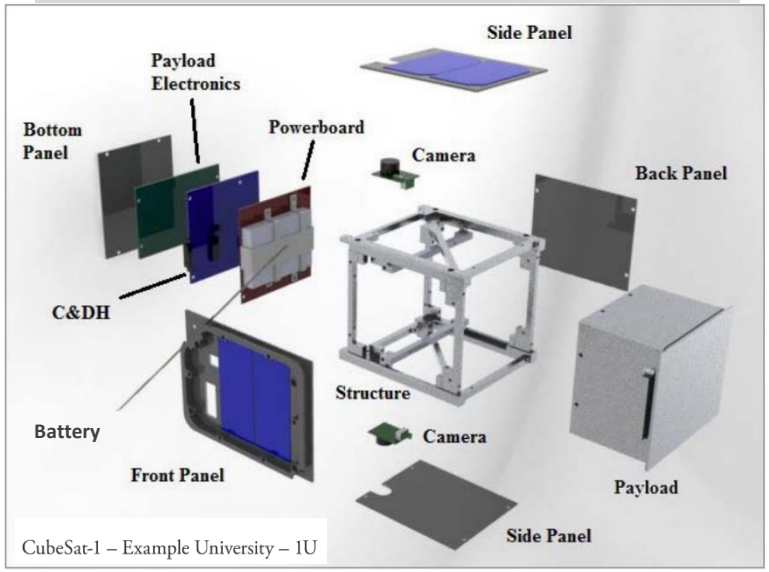
CubeSat Basics: Functionalities

- **Functionalities: all basic functionalities of a standard satellite**
  STR, EPS, OBC, SW/OBDH, TT&C + ADCS, THR, PAY + AIVT, MGT, BDGT, LAW

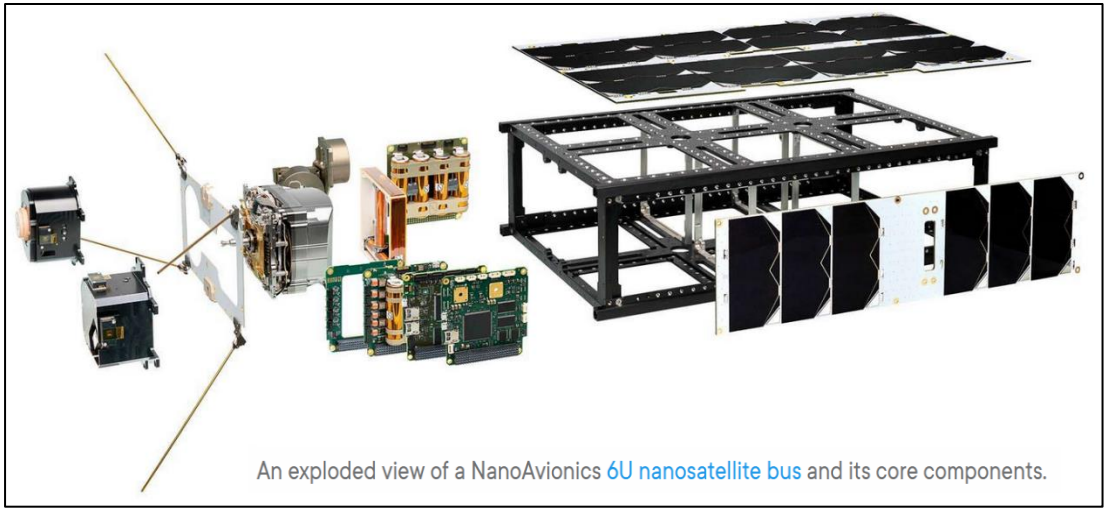
STR – structure
EPS – power (battery, solar panels, powerboard)
OBC – onboard computer
SW/OBDH – software / onboard data handling
TT&C – telecommunication

ADCS – attitude determination & control system
THR – thermal
PAY – payload (science and/or technology)
AIVT – assembly, integration, validation, and testing
MGT, BDGT, LAW – management, budget, regulations

https://www.nasa.gov/wp-content/uploads/2017/03/nasa_csli_cubesat_101_508.pdf



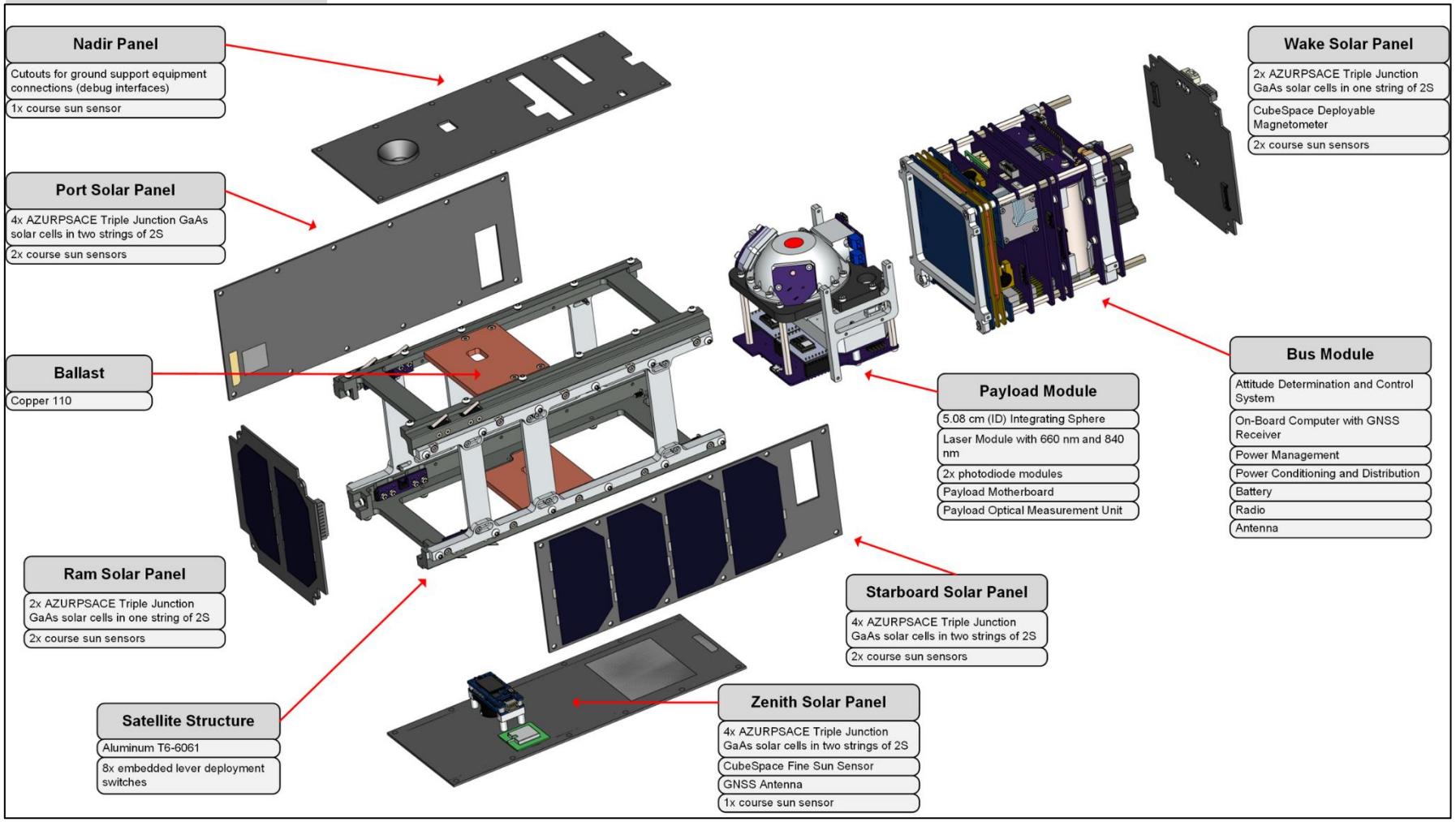
https://nanoavionics.com/blog/cubesat-101-the-comprehensive-guide-to-understanding-satellite-technology/


An exploded view of a NanoAvionics 6U nanosatellite bus and its core components.

CubeSat Basics: Subsystems

- **Functionalities: all basic functionalities of a standard satellite**
  STR, EPS, OBC, SW/OBDH, TT&C + ADCS, THR, PAY + AIVT, MGT, BDGT, LAW

https://www.orcasat.ca/design



CubeSat Basics: Team Roles

- **Functionalities: all basic functionalities of a standard satellite**
  STR, EPS, OBC, SW/OBDH, TT&C + ADCS, THR, PAY + AIVT, MGT, BDGT, LAW

Kiril A. Dontchev, Kartik Ghorakavi, Cameron E. Haag, Thomas M. Liu., Rafael Ramos, "**M-Cubed: University of Michigan Multipurpose MiniSatellite with Optical Imager Payload**," 1999 ASEE Annual Conference

http://www-personal.umich.edu/~mjregan/MCubed/Pages/Documents/M-CubedAIAAPaper.pdf

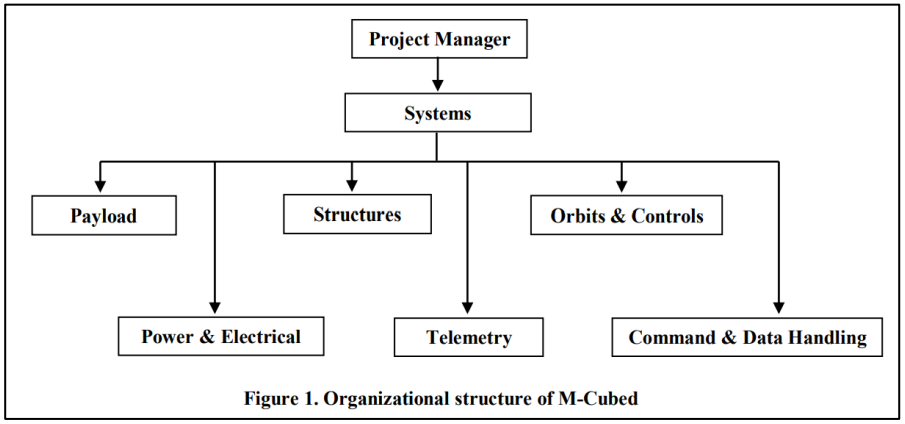


Figure 1. Organizational structure of M-Cubed

Bruce C. Chesley, Michael J. Caylor, "**Developing an Integrated Curriculum for Small Satellite Engineering**" 1999 ASEE Annual Conference

https://s3vi.ndc.nasa.gov/ssri-kb/static/resources/developing-an-integrated-curriculum-for-small-satellite-engineering.pdf

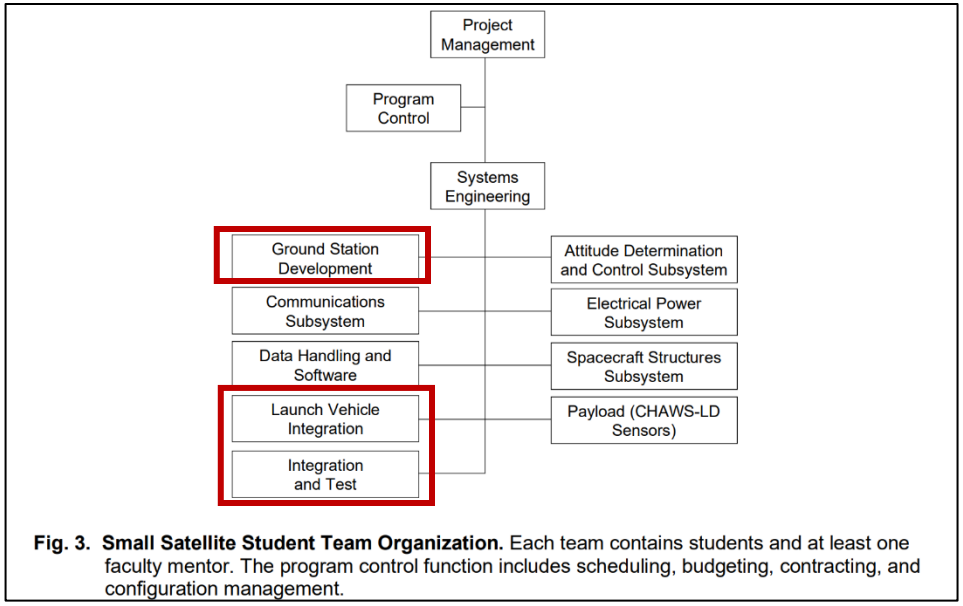


Fig. 3. Small Satellite Student Team Organization. Each team contains students and at least one faculty mentor. The program control function includes scheduling, budgeting, contracting, and configuration management.

CubeSat Basics: Typical Development Process

- **Functionalities: all basic functionalities of a standard satellite**
  STR, EPS, OBC, SW/OBDH, TT&C + ADCS, THR, PAY + AIVT, MGT, BDGT, LAW

NASA CubeSat 101: Basic Concepts and Processess for First-Time CubeSat Developers

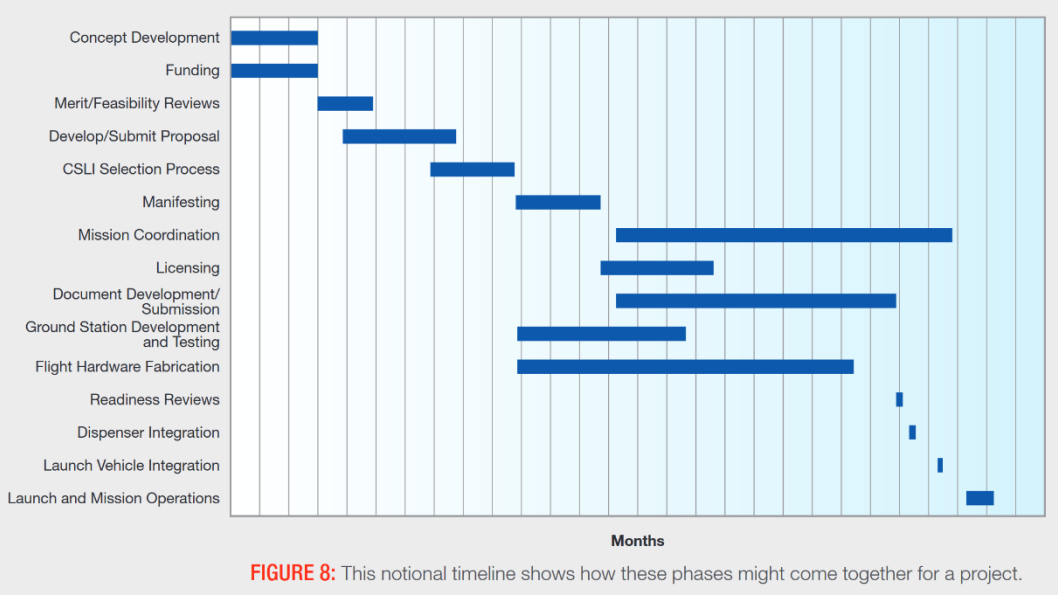


FIGURE 8: This notional timeline shows how these phases might come together for a project.

FIGURE 9: Common costs associated with developing a CubeSat.

https://www.esa.int/Education/CubeSats_-_Fly_Your_Satellite/Current_programme_Phases

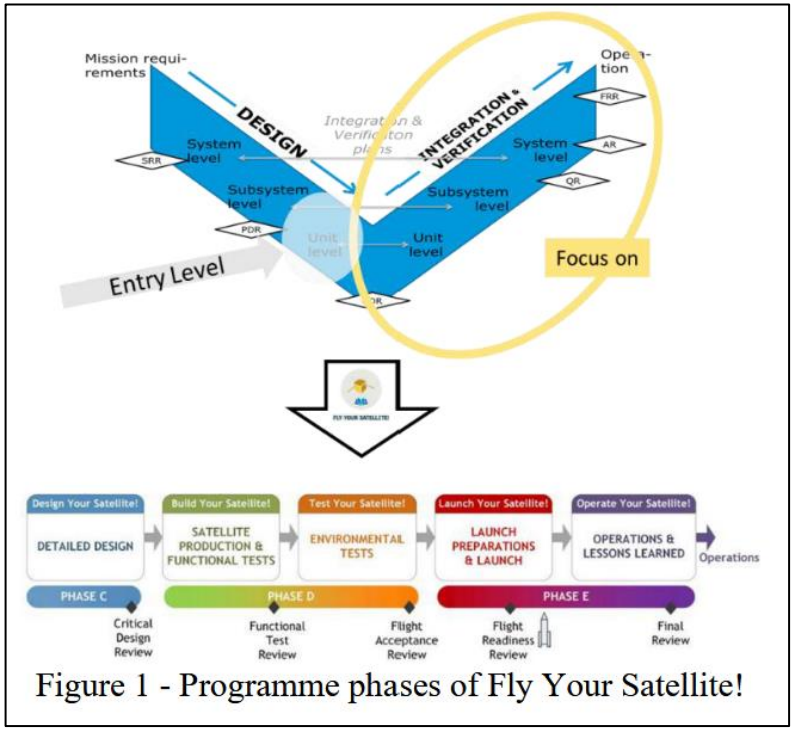


Figure 1 - Programme phases of Fly Your Satellite!

CubeSat Basics: General Advice

- **Functionalities: all basic functionalities of a standard satellite**
  STR, EPS, OBC, SW/OBDH, TT&C + ADCS, THR, PAY + AIVT, MGT, BDGT, LAW

NASA CubeSat 101: Basic Concepts and Processess for First-Time CubeSat Developers

> FREE ADVICE

KEEP EXCELLENT RECORDS OF EVERYTHING YOU DO. It is incredibly important to keep great records of the work your team has been doing. These records should be in the form of photographic evidence and thorough documentation. This is especially important for student organizations that will be losing senior team members as they graduate. Keeping records helps continuity within the project; you'll avoid "reinventing the wheel" over and over again.

> FREE ADVICE

KEEP IT SIMPLE. Keep the design as simple as possible. CDS requirements are on the conservative side. The CDS prohibits pyrotechnics, and discourages a host of other cool stuff. Some violations would be unacceptable, but some may be waived or approved on a mission-by-mission basis. You will, however, be eligible for more launches if you adhere to these specifications. Things like a propulsion system may make the launch provider or their primary payload nervous, and some just choose not to carry CubeSats that have them. So CSLI may still select your CubeSat for launch but it may take longer to find a willing launch provider to give you a ride.

> FREE ADVICE

FLEXIBILITY IS KEY. Keep your mission as flexible as possible. CSLI may select your CubeSat mission because it has some great science goals, but that doesn't guarantee you'll get a launch right away. If you need special considerations like a very specific orbit or specific launch date, finding a launch could be tricky. Do your best to keep your requirements for launch as flexible as possible.

> FREE ADVICE

DEVELOPMENT TESTING. "Test like you fly" is a common mantra for CubeSat developers and applies to more than just final environmental testing. During electronic development, use evaluation and development kits and **breadboard** components before fabricating boards. Once the printed circuit boards (PCBs) are produced, test as many expected functions as possible before interfacing it with other systems. Keep the scope small with testing and add components systematically, testing them along the way. Never assume that boards or subsystems that work well during standalone testing will work well when integrated with other boards or subsystems.

During mechanical development, it is useful to do thermal and vibration tests on individual subsystems prior to integrating all components. This often catches design issues early on and reduces over-test on the overall system.

DID YOU KNOW?

What's the IARU?

The International Amateur Radio Union (IARU) is an international agency run by volunteers who are based in countries around the world, who coordinate what group will be allowed to use which radio frequencies in the amateur band. As you can imagine, lots of people are transmitting for various reasons all day, everyday. To avoid transmissions interfering with each other by using the same frequency, IARU keeps track of which amateur frequencies are available and assigns the unused bands upon request. That's why the FCC requires CubeSat developers to contact the IARU for an amateur frequency assignment before an RF license can be processed.

For an amateur license, the FCC will need the following:

- IARU coordination letter
- Satellite orbital debris mitigation compliance document (discussed in *Chapter 6*)
- **SpaceCap notice**: the SpaceCap software can be downloaded from *http://www.itu.int*)
- Prelaunch notification letter with general mission and satellite information

CubeSat Basics: And to finish 1st part of the class …

University of Victoria (Canada) – ORCASat Final Assembly:

https://www.orcasat.ca/updates/final-assembly-time-lapse

RG SAT – Building a CubeSat for less than $1000
Part 1 -- It should be possible

https://www.youtube.com/watch?v=m8TSiKHZbC8