# La revolución CubeSat y la exploración espacial

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

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

**Universidad Carlos III de Madrid (UC3M)**

# Brief Speaker CV

**Andrés Marcos Esteban**
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## 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)

**Industrial Experience (11 years)**: 6 months as Industrial Research Fellow (Honeywell Labs, USA, 2003)
8 years from Senior Engineer to R&D Leader (Deimos Space, Spain, 2006-2013)
3 years as SME founder & scientific director (TASC Ltd, UK, 2020→2023)

**Academic Experience (15 years)**: 2 years as Post-Doctoral RA (University Leicester, UK, 2004-2006)
7 years as Senior Lecturer (University of Bristol, UK, 2013-2020)
5 years as Chair of Excellence (Universidad Carlos III de Madrid, ES, 2021-2026)
0.5+ years as Full professor (**Dept. of Aerospace Eng., UC3M**, 2026 → )

**Coordinator or Principal Investigator of 36 projects (~22M€ funding)**
**Published: 46 journals & 131 conference publications**

## 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 1st 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 $H_\infty$ 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-αircraft (MuPAL-α) in Tokyo.

# TRIVIA TIME

**NOW, before starting**, please answer the following questions

This is just to measure your current knowledge on CubeSats.

**After the presentations**, we will repeat the quiz

to gauge how much new knowledge you have acquired,

**And**

We will show the answers.

# TRIVIA TIME

**Q1.** What is the name of the first satellite sent up by humanity?

**Q2.** Name at least one company in Spain that makes CubeSats?

**Q3.** Name at least one Spanish University that has launched a CubeSat?

# TRIVIA TIME

## Q4. How much is the (typical) weight of a CubeSat?

A. < 1 Kg

B. 1-10 Kg

C. 10-50 Kg

D. >100 Kg

## Q5. How long can be the side of a CubeSat?

A. 5 cms

B. 10 cms

C. 30 cms

D. 80 cms

# TRIVIA TIME

## Q6. What is the (typical) orbit altitude for a CubeSat?

A. 10-100 Km

B. 100-300 Km

C. 300-600 Km

D. 600-900 Km

## Q7. What is the (typical) maximum travelling speed of a CubeSat?

A. 300 km/h

B. 3,0000 km/h

C. 30,000 km/h

D. 300,000 km/h

# TRIVIA TIME

## Q8. How many CubeSats have been launched into space?

A. <1,000

B. 1,000-3,000

C. 3,000-6,000

D. >6,000

## Q9. What is the success rate of a CubeSat program/launch?

A. < 30 %

B. 30-50 %

C. 50-70 %

D. > 70 %

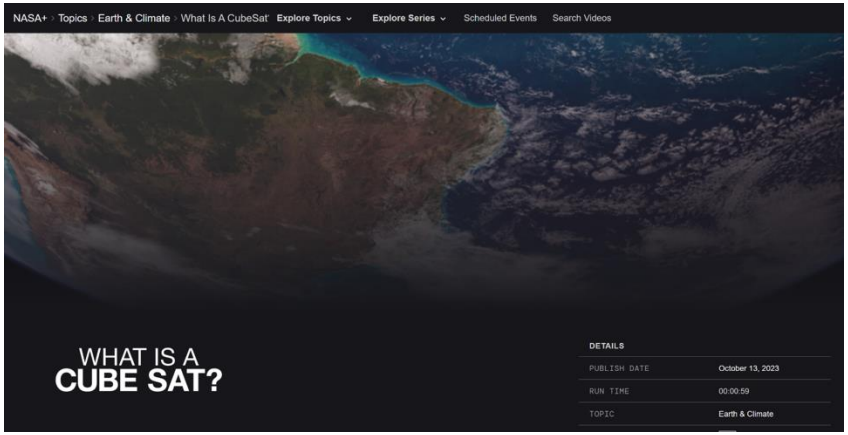
# What is a CubeSat?

# What is a CubeSat? Some nice videos

**NASA – What is a CubeSat** [59s]

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

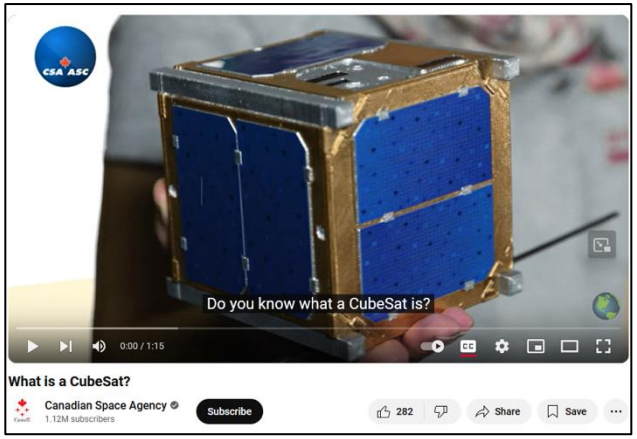
https://plus.nasa.gov/video/what-is-a-cubesat-2/




**Canadian Space Agency (CSA) – What is a CubeSat?** [1m15s]

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

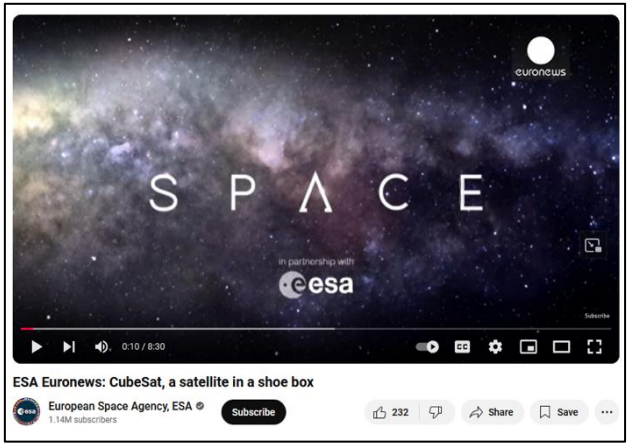
https://www.asc-csa.gc.ca/eng/multimedia/search/video/18450?search=cubesat




**European Space Agency (ESA) Euronews** [8m30s]

**– CubeSat, a satellite in a shoe box:**

https://www.youtube.com/watch?v=w-7gklnt3JI



# What is a CubeSat? Definitions *no exact agreement*

## 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]

## What is a nanosatellite?

https://www.nanosats.eu/cubesat

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 *no exact agreement*

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.

***my definition***

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

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

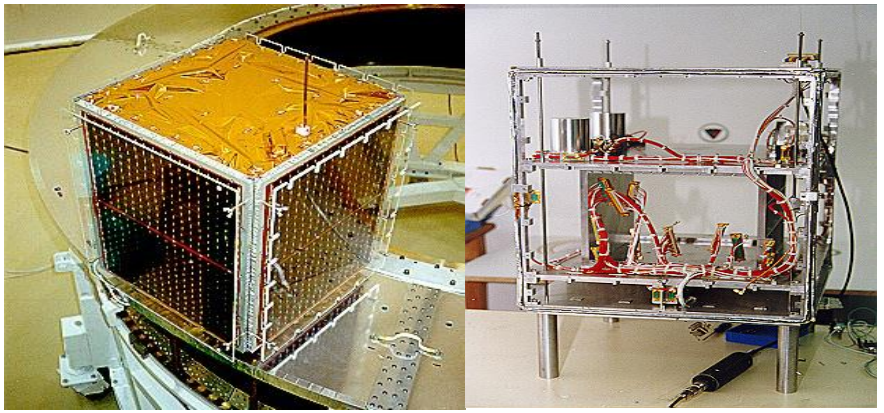
**A CubeSat is** any picosat < nanosat < microsat of up to ~50kg / 27U

**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**

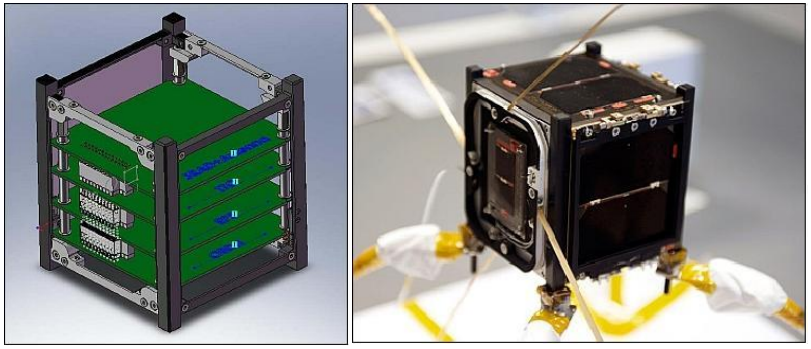
**The CubeSat definition might seem arbitrary,**
but it is driven by capacity of **CubeSat deployers** (currently up to 27U).



**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

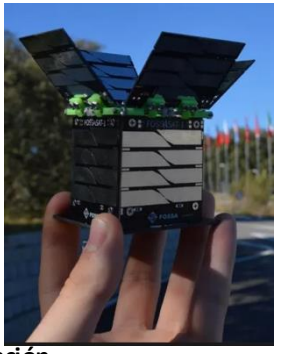


**FOSSA Systems**' 1st OS PocketQube:

**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)

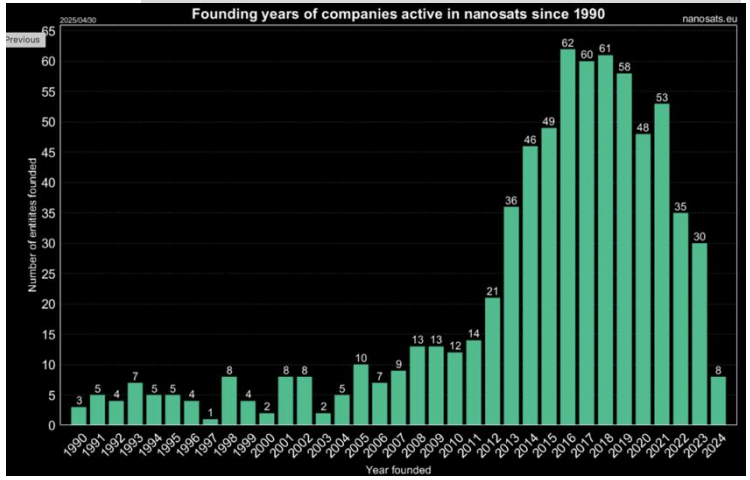
  to facilitate access to space for university students.

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).

Nanosats' companies: 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:

  **2U**: 10x10x20 cms

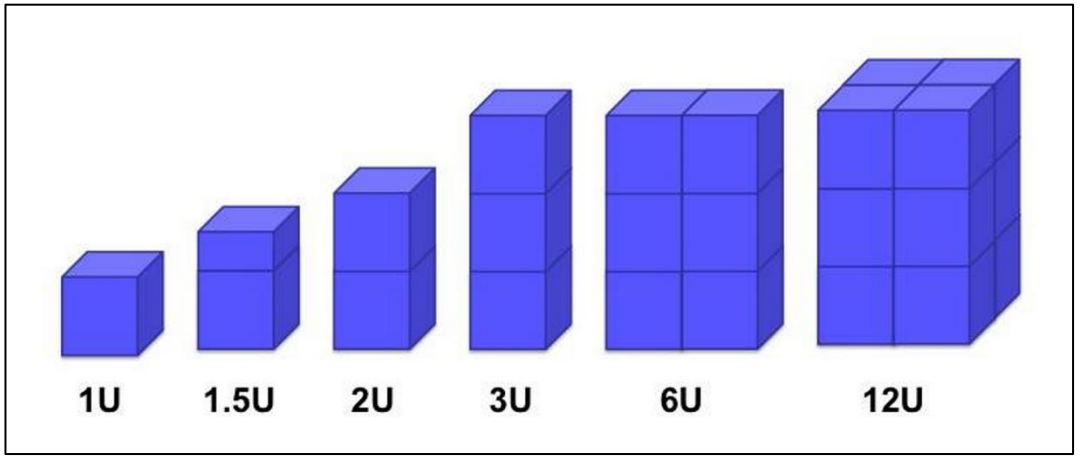
  **3U**: 10x10x30 cms

  **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:

  Distribuidor

  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)

- **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

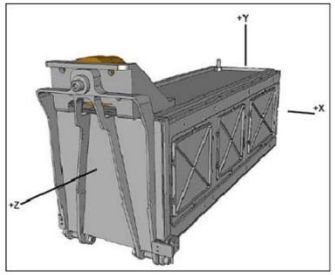



Figure 3: Illustration of the P-POD structure of the Mk III model (image credit: CalPoly)

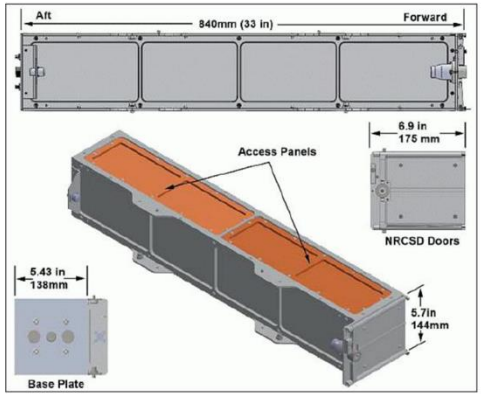
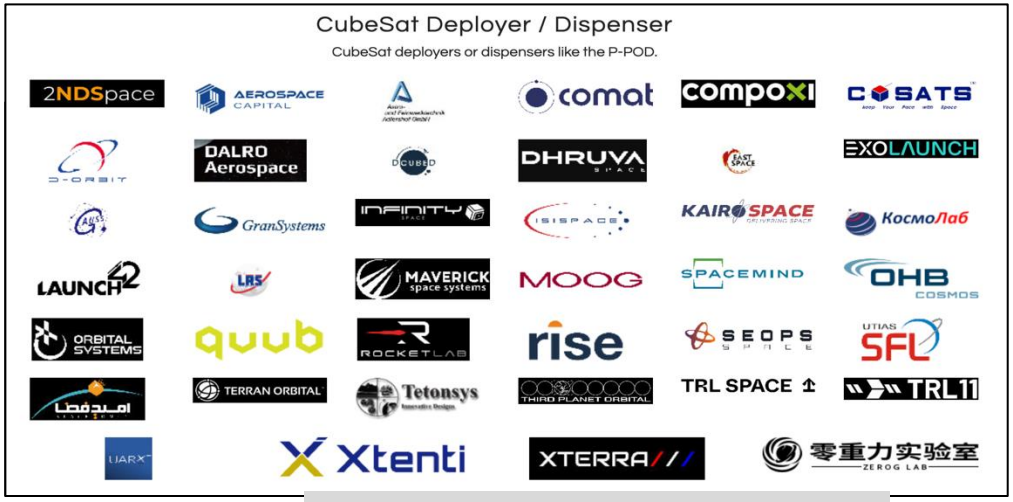



Figure 32: Illustration of the NRCSD configuration (image credit: NanoRacks)

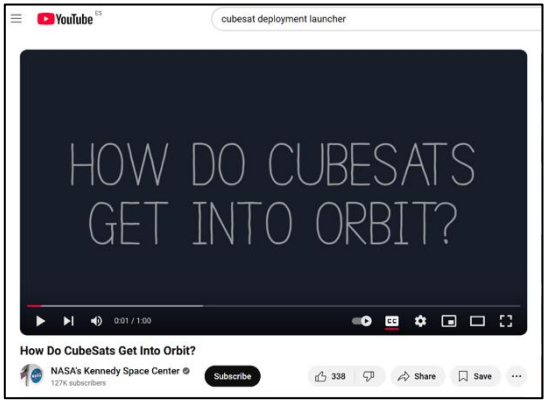



https://www.nanosats.eu/ecosystem#dispenser/

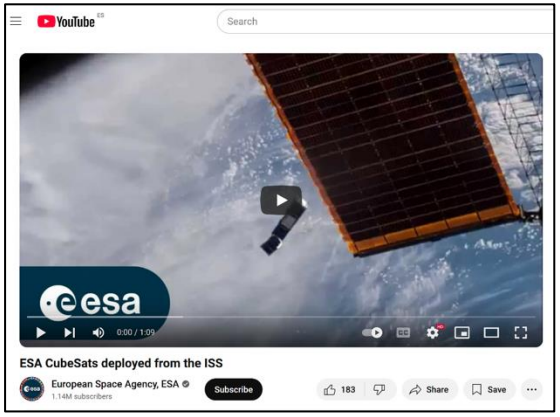
# What is a CubeSat? How are they launched?

- 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)

**NASA - How Do CubeSats Get Into Orbit?** [1m]
https://www.youtube.com/watch?v=pnRdlyIWl0k




**ESA CubeSats deployed from the ISS** [1m9s]
https://www.youtube.com/watch?v=-m4iNiNFFto



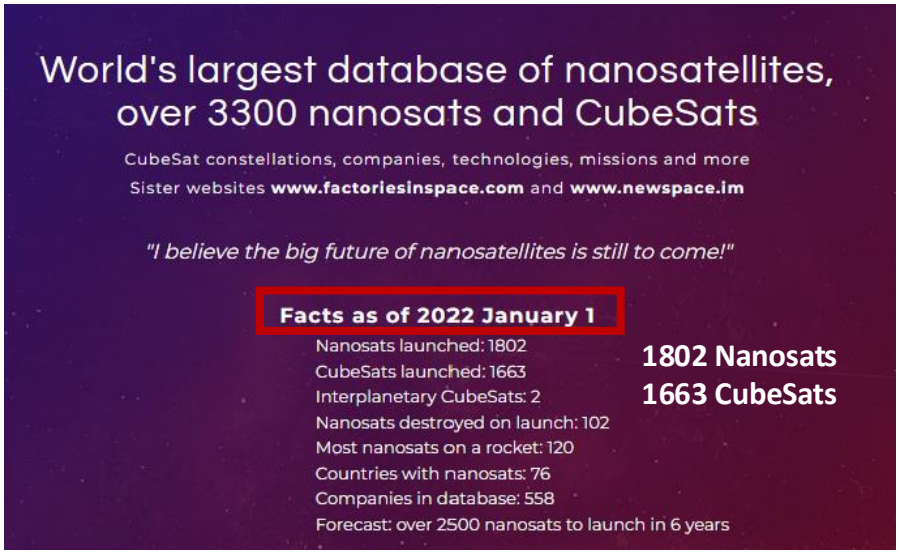

**CubeSat hits space station solar array 'mildly' after spacewalker deploys it** [2m28s]
https://www.youtube.com/watch?v=zfl42B3nWr0



# What is a CubeSat? How many are out there?

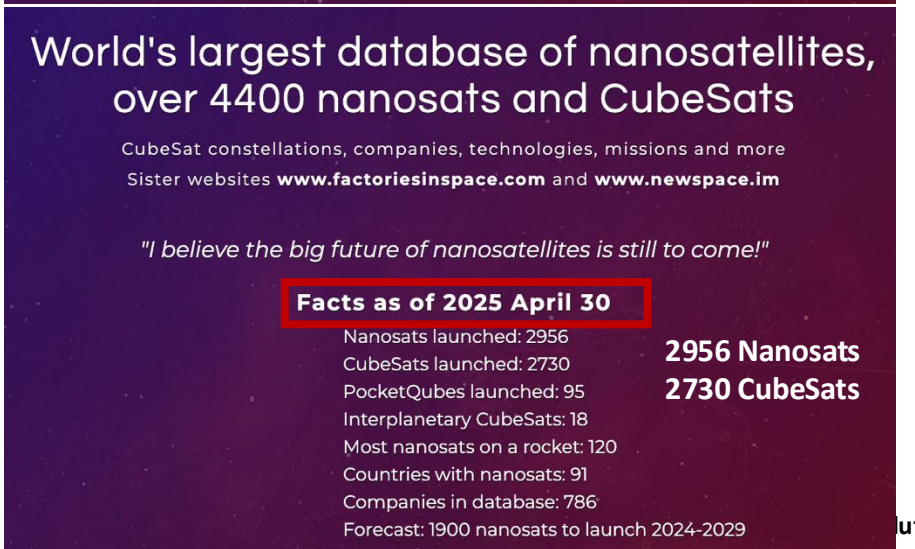
- Depending how you count, between **4,000-7,000** as of July 2026 (and since 1999)

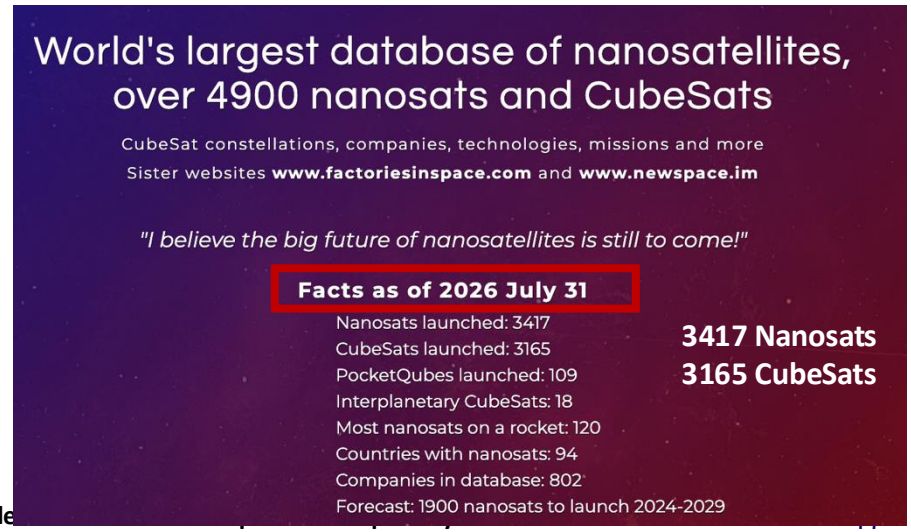
  https://www.nanosats.eu/





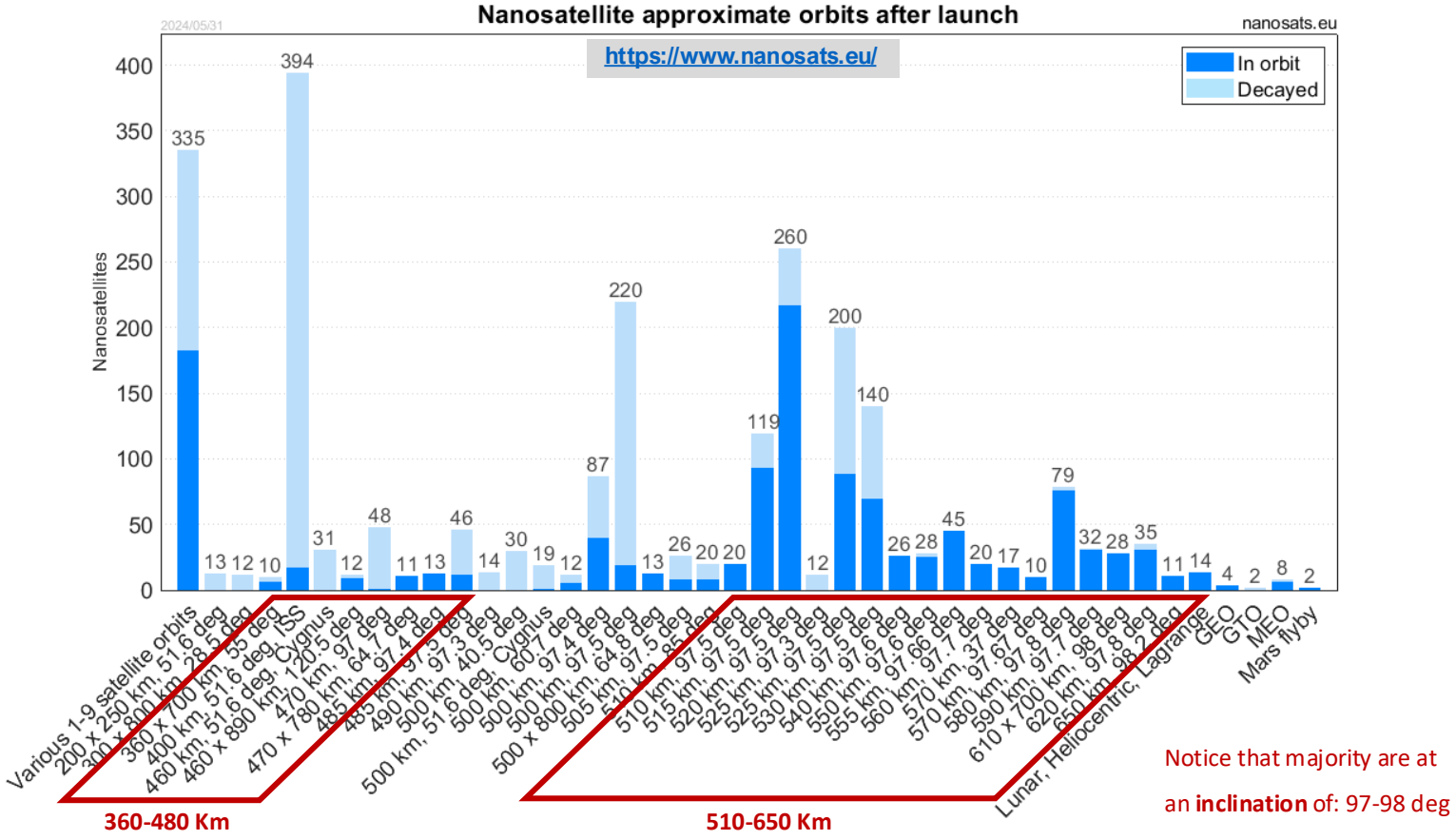




# What is a CubeSat? What are the typical orbits?

- Most CubeSats are deployed in mid of **Low-Earth-Orbit (LEO)**:
  - **Period** of 90-128 minutes (11-16 orbits a day) & **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.

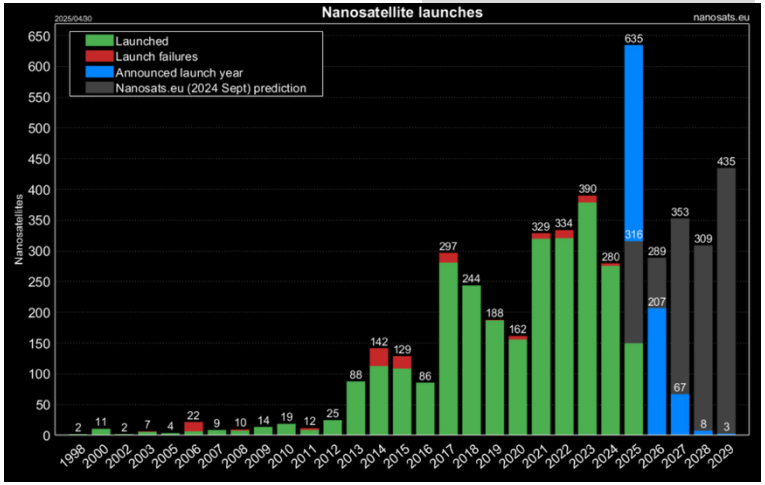
**References:**


A. Marcos, A. Ponche "**ST3LLARsat1 "BOIRA": Establishing the first student CubeSat program at UC3M**," EDULEARN'23, Palma (Spain), **2023**
https://library.iated.org/view/MARCOS2023ST3

M Betancourt "**Half of All First-Time CubeSat Projects End in Failure,"** Smithsonian's Air & Space Magazine, **2014**
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, **2018**
https://ntrs.nasa.gov/api/citations/20190002705/downloads/20190002705.pdf


https://www.nanosats.eu/



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

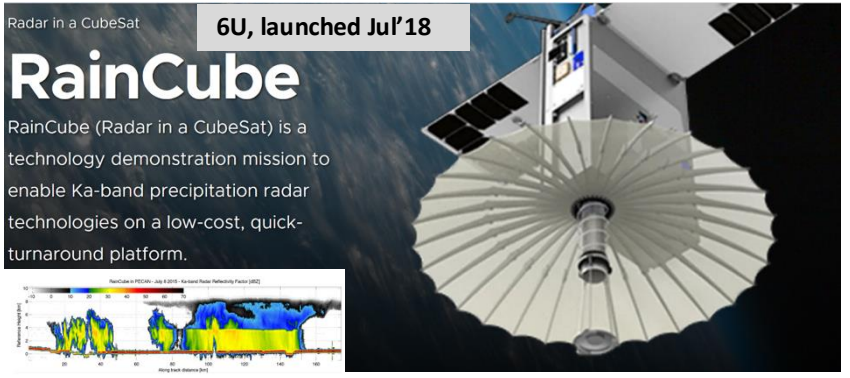
- **Almost anything**:
  - Earth monitoring
  - Telecommunications
  - Technology demonstration
  - Astrophysics
  - Commercial

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



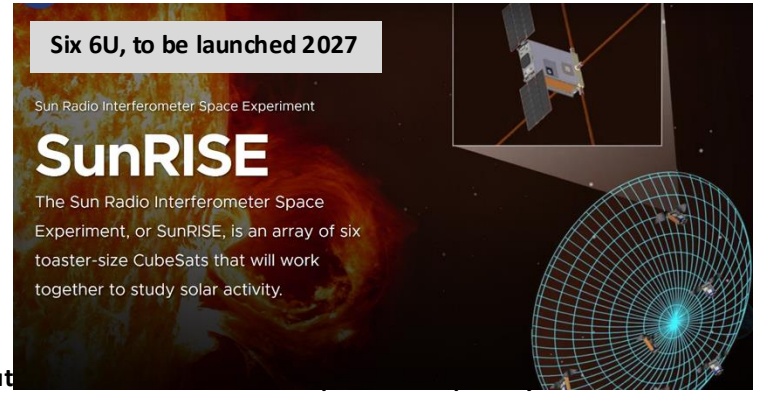






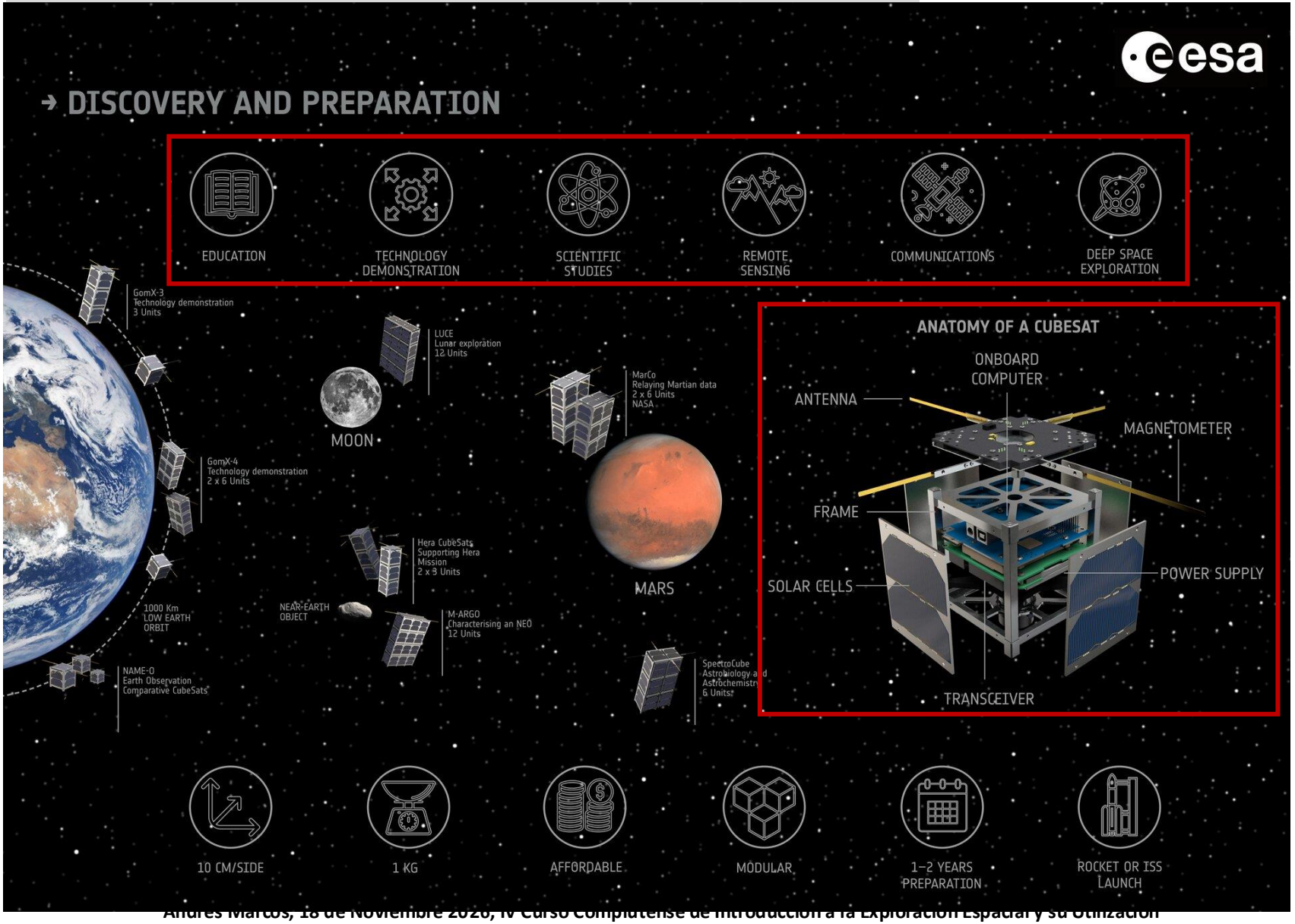






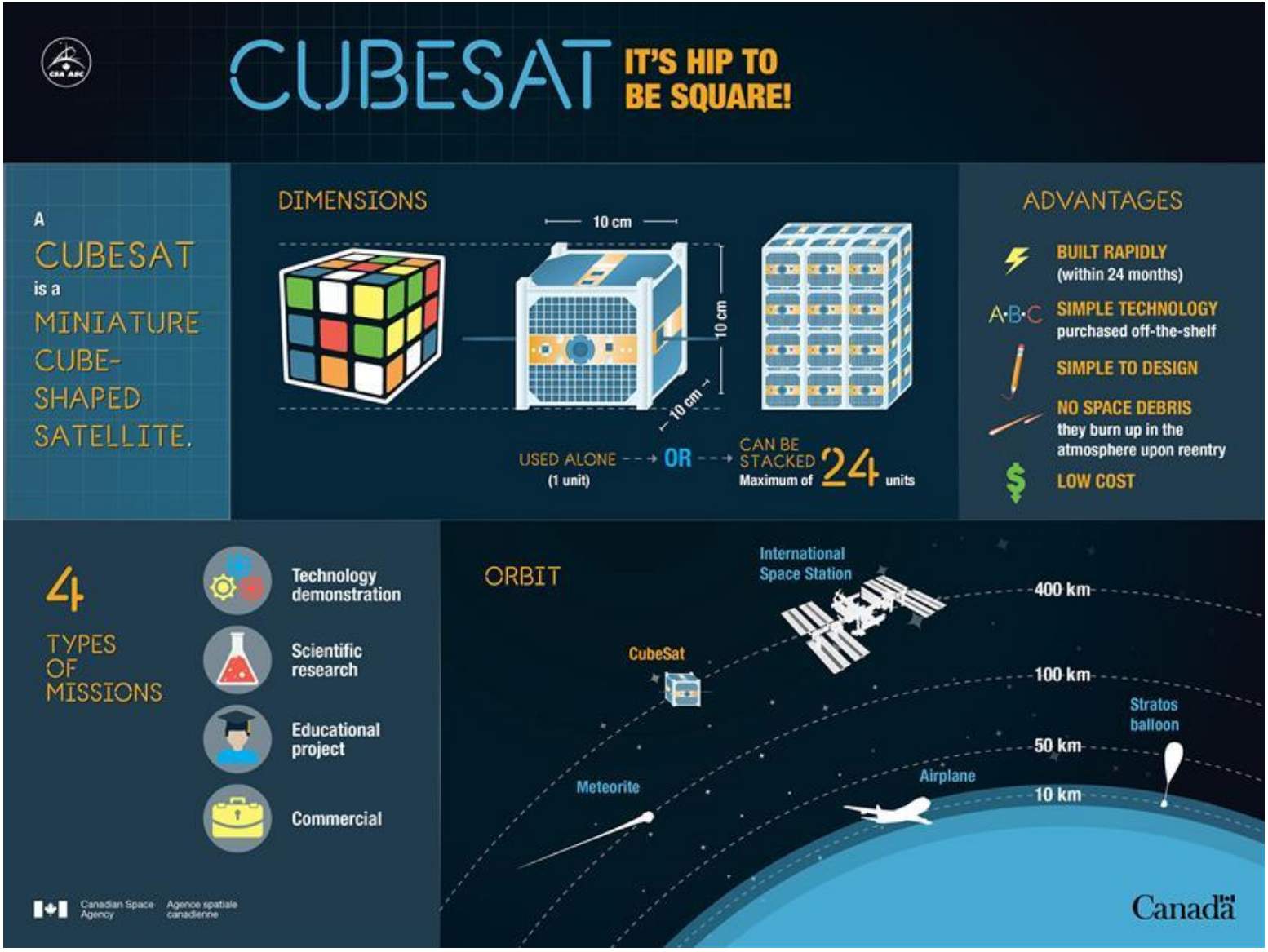
# What is a CubeSat? A Visual Summary - ESA

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



# Example - UC3M's ST3LLARsat1 "Boira"

**1st student CubeSat program at UC3M**

**Start Date:** September 2022 (expected launch 2026-27)

**Required Skills**: Multidisciplinary (aero, telecom, signals, SW, HW …)

**Director**: UC3M / Aero – Dr. Andrés Marcos

**First mission**: **ST3LLARsat1 "BOIRA"**

**"Boira"** means fog in two of Spain's official languages: Galician & Catalonian

## ST3LLARsat1 BOIRA: Project Goals

St3llar MiSE

**EDUCATIONAL**

1st **UC3M** CubeSat student programme

To provide students with **hands-on experience in a real space project**

**SCIENTIFIC**

Aim is to **design, build, launch and operate a 2U CubeSat**

**to monitor climate change** by measuring local atmospheric moisture

**TECHNOLOGICAL**

IOD of

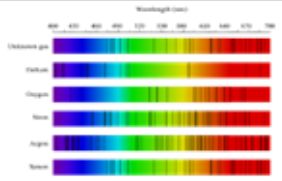
1. **All the operating equipment** (except payload) fitting in about **1U**
2. **A weather-observing scientific instrument** fitting in about **1U**
3. An in-house **state-of-art compact communication antenna**
4. An in-house OBC software for **advanced AOCS/ADCS algorithms**

## ST3LLARsat1
## 2U structure & internal config

@ BDR (March'23) @ FDR (Feb'24) @ Jun'25



## ST3LLARsat1 science: measure water vapor (WV)

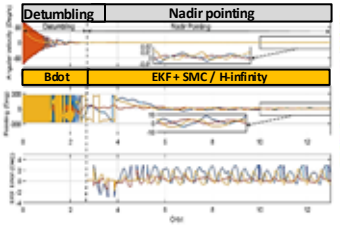


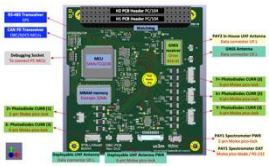



## ST3LLARsat1 in-house technologies:

Compact antenna Advanced ADCS OBC & ADCS PBCs



***Sept'22**: Official start of the 1st UC3M student CubeSat program*

**Phase 1:** [Sept'22 – Jun'23] **Feasibility** & **ESA-FYS-DB BDR**

**Phase 2:** [Sept'23 – Jun'24] **ESA-FYS-DB FDR**

**Phase 3-A/B:** [Sept'24 – Jun'25 / Jun'25 – Jun'26] **Consolidation** & Prelim-AIVT activities

**Phase 4:** [Sept'26 – Jun'27] **AIVT activities (STM vibration & TVAC)**

**Phase 5:** [Sept'27 – **Dec'28**] End of AIVT activities & launch preparation

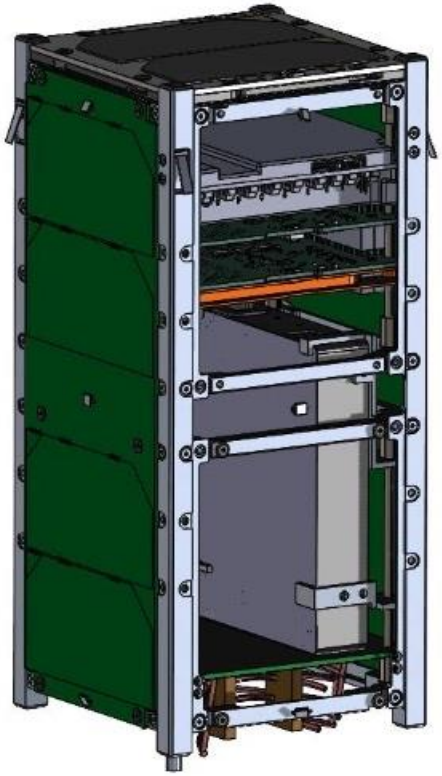
**Dec'22: Selected by ESA for pilot FYS! DB**
**1st CubeSat from a University in Madrid!!**

esa FLY YOUR SATELLITE!

**Nov'26: Selected by ESA / EU-Horizon for launch opportunity**
**In IOD "Ready-to-Fly" program**

# Example - UC3M's ST3LLARsat1 "Boira"

**ST3LLARsat1: 2U configuration**



| Mass (Kg) w/ 20% margin | 2.083 |
|---|---|

**Structure**: 2U SpaceMind SM-02 *

**Solar cells (16)**: 1x SpaceMind-SP1X *
3x SpaceMind-SP2X *
1x Endurosat-SP1Z (part of Deply.Ant) *

**Deployable UHF antenna**: Endurosat 1U *

**PCDU+Battery**: Endurosat EPS-1 *

**OBC-PCB**: MCU SAMV71Q21B-AAB

- **GNSS Antenna**: Molex 206640-0001
- **GNSS Receiver**: Skytraq Orion B16C1 *
- **RF transceiver**: Semtech SX1276 *
- **Coarse Sun Sensor**: 13x OSRAM SFH 2401 *

**ADCS-PCB**: same MCU as OBC-PCB

- **3-axis gyro**: MEMS ADIS 16500 (never flown)
- **Magnetometer**: PNI RM3100 *
- **Magnetorquers**: 2x CubeSpace rods CR0002 *
  1x CubeSpace Coil *

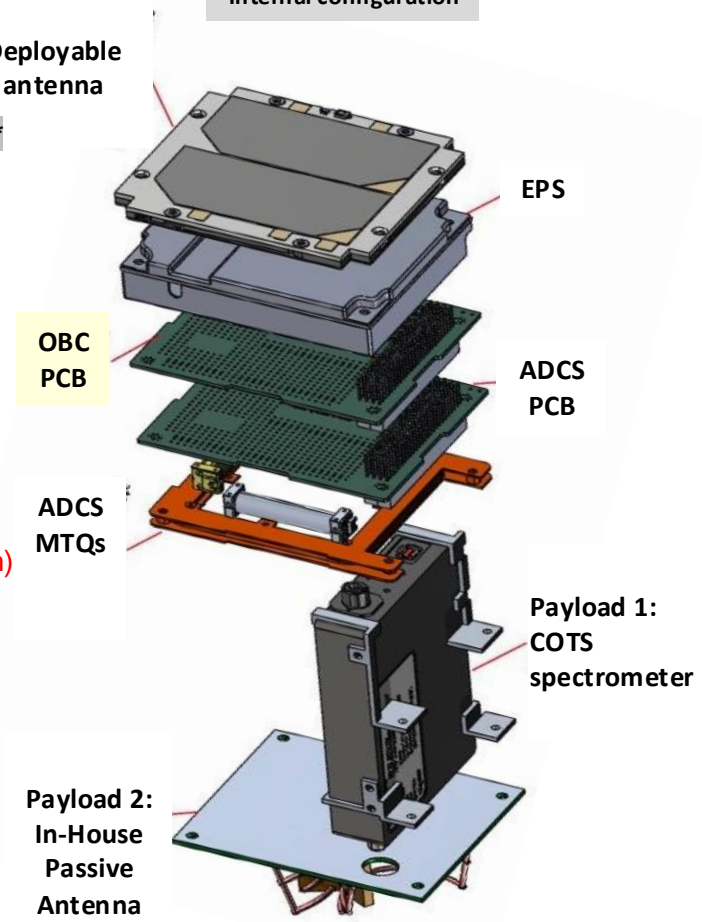
**Payload1**: Avantes AvaSpec-Nexos Spectrometer *

**Payload2**: **In-House** non-deployable UHF antenna

**OBSW**: freeRTOS / C & C++

| In-House | Procured | In-process | * Flight-heritage |
|---|---|---|---|

**ST3LLARsat1: Internal configuration**



# CubeSat Programmes

# CubeSat Programmes: First & Institutional

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



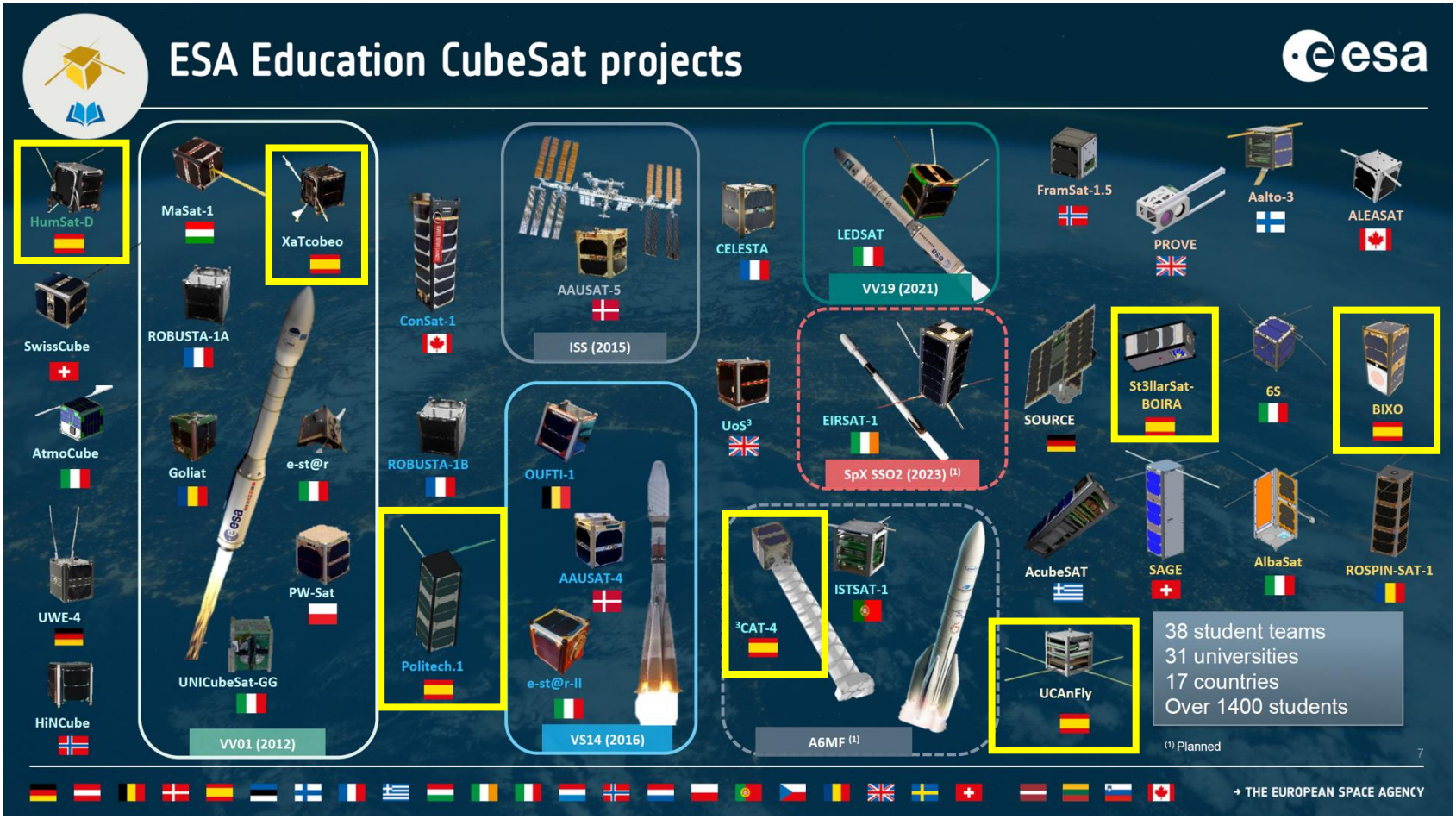

**NASA** https://www.nasa.gov/directorates/heo/home/CubeSats_initiative




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



# CubeSat Programmes: ESA Education – FYS program




**UVigo:** XaTcobeo (1U, Feb'12), HumSat-D (1U, Nov'13), BIXO (2U, started Nov'20 / expected 2027)

**UPC**: ³CAT-4 (1U, started in 2017 / Jul'24), PoCat-LEKTRON (2x0.5U, started in 2024)

**UCadiz**: UCAnFLy (1U, started in 2018 / expected 2026)

**UC3M**: ST3LLARsat1 "BOIRA" (2U, started Sept'22 / expected Dec'28) *** ESA/EU Launch Opportunity awarded Nov'2026) ***

**UValencia**: Polytech.1 (3U, cancelled)

# CubeSat Programmes: ESA Education – FYS program

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

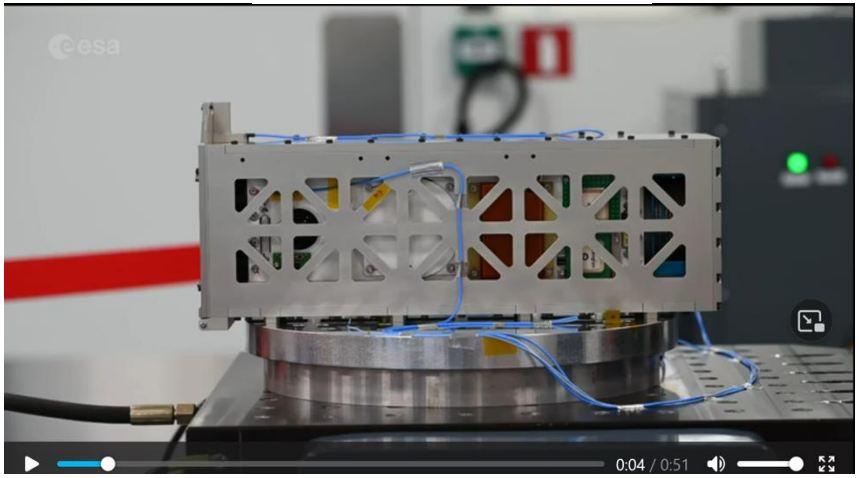



The CubeSat Support Facility (CSF) is an assembly integration and testing facility for CubeSats, located at the ESA Education Training Centre, based at the ESEC-Galaxia facility in Transinne, Belgium. Its purpose: offer training and test facilities for university students that are part, or aiming to 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 |

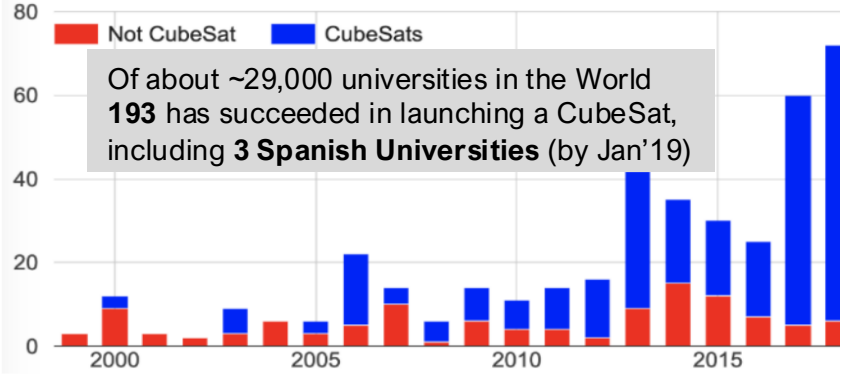



**Figure 1: Count of University-class missions launched each year since 1999**

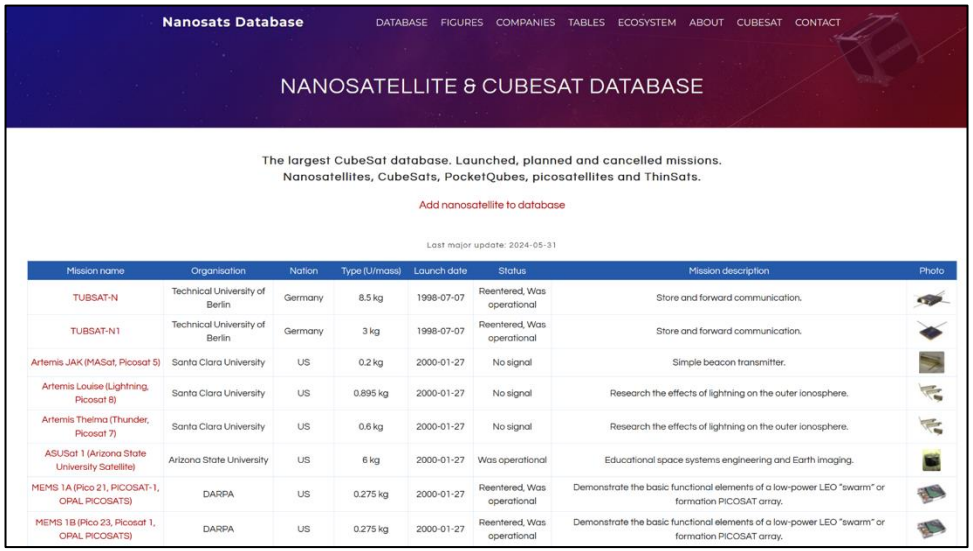
# CubeSat Programmes: Databases

- 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. | |




**FossaSat 1** is a picosatellite developed by Fossa Systems, a non-profit association developing pocketqube picosatellite technology and democratizing access to space, to the 1P PocketQube form factor.

Main mission of the satellite is the testing of a new experimental RF chirp modulation called LoRa and to share educational data from space to the public. It features deployable solar panels. The project is also to foster the development of miniaturized and inexpensive satellite systems for space applications using off the shelf components.

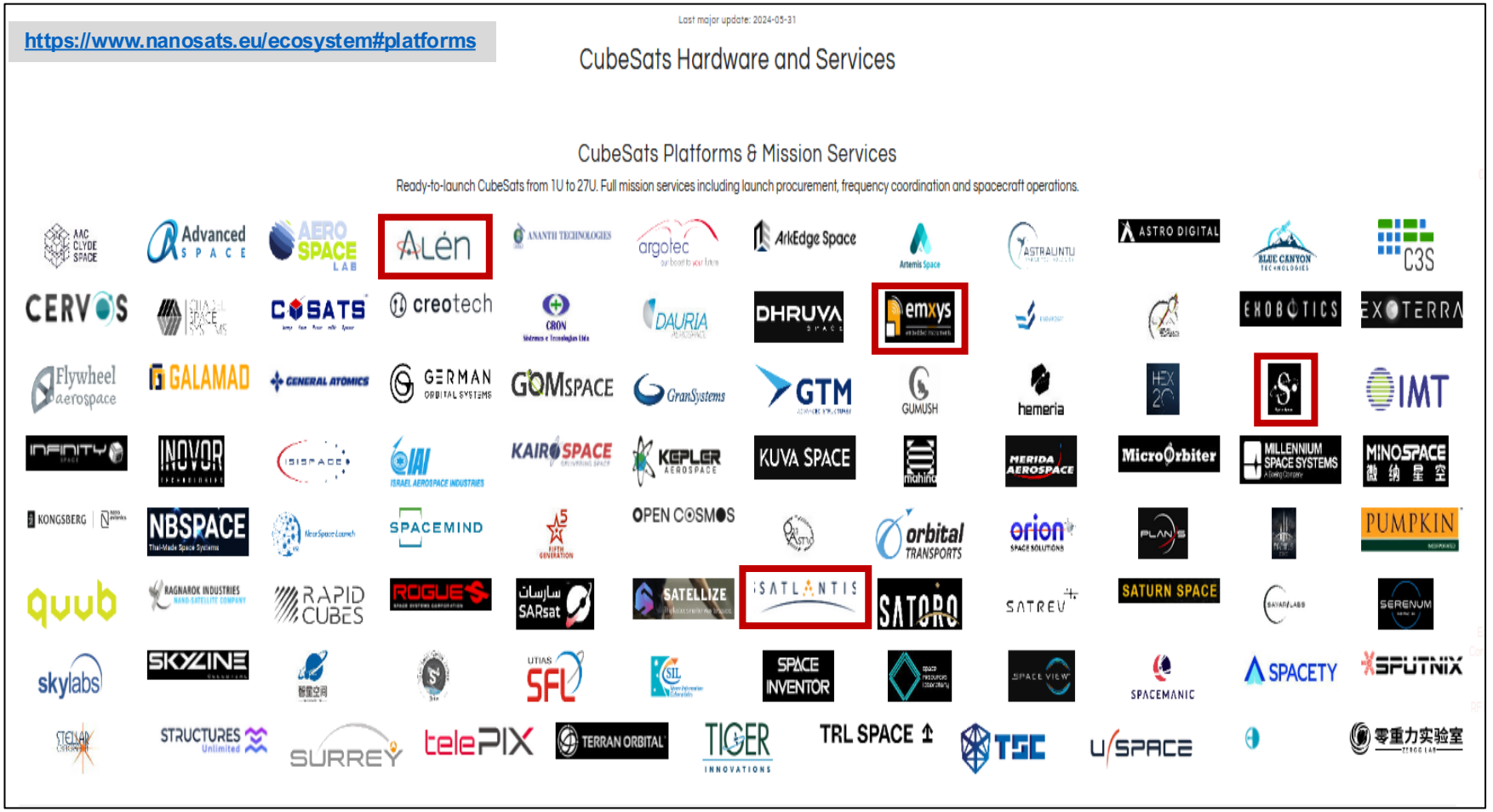
The satellite was launched on 6 December 2019 together with other PocketQubes and other satellites on an Electron KS launch vehicle.

**FossaSat 1b** is an updated version of FossaSat 1. It was launched on the maiden Firefly-Alpha flight in late 2021 but failed to reach orbit. A reflight in October 2022 reached a lower than planned orbit.



# 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

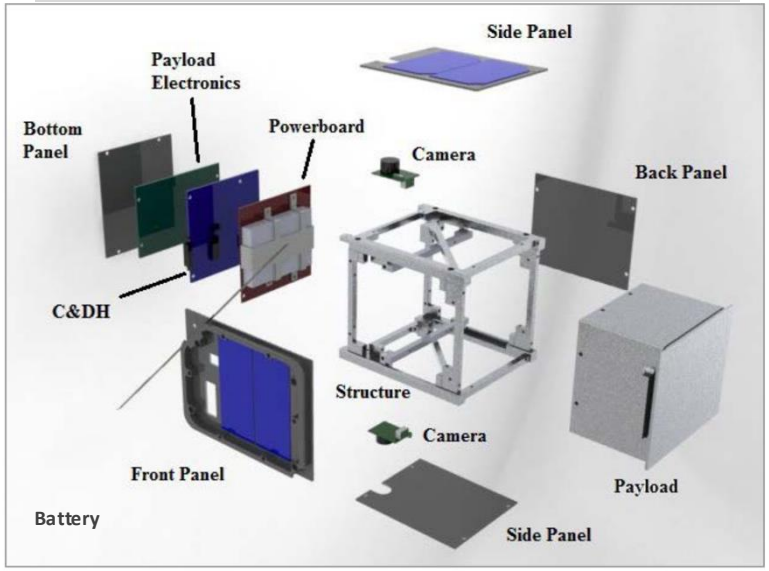
# CubeSat Basics: Functionalities

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

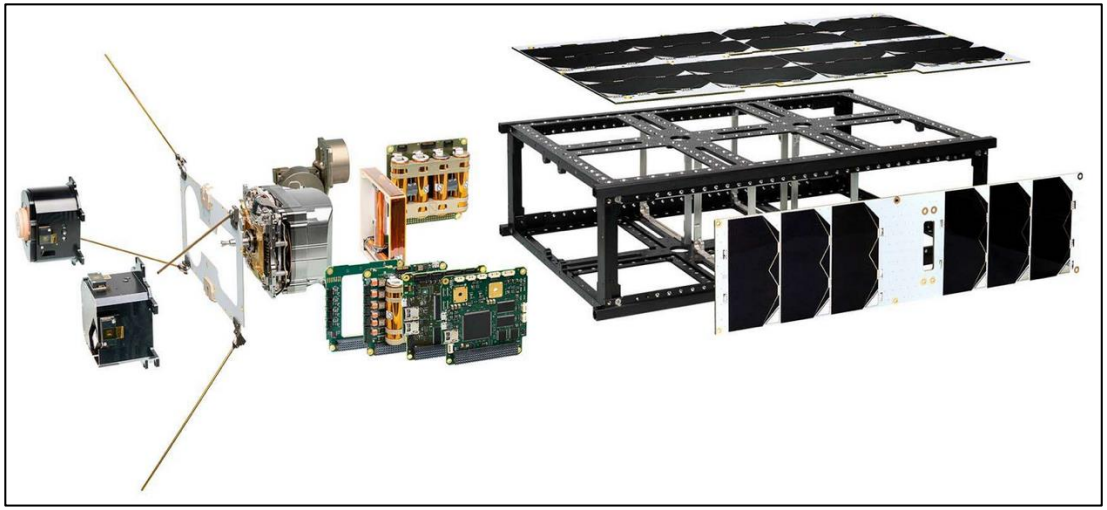
**STR** – structure
**EPS** – power (battery, solar panels, powerboard)
**OBC** – onboard computer
**SW/OBDH** – software / onboard data handling
**TT&C** – telecommunication

**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/

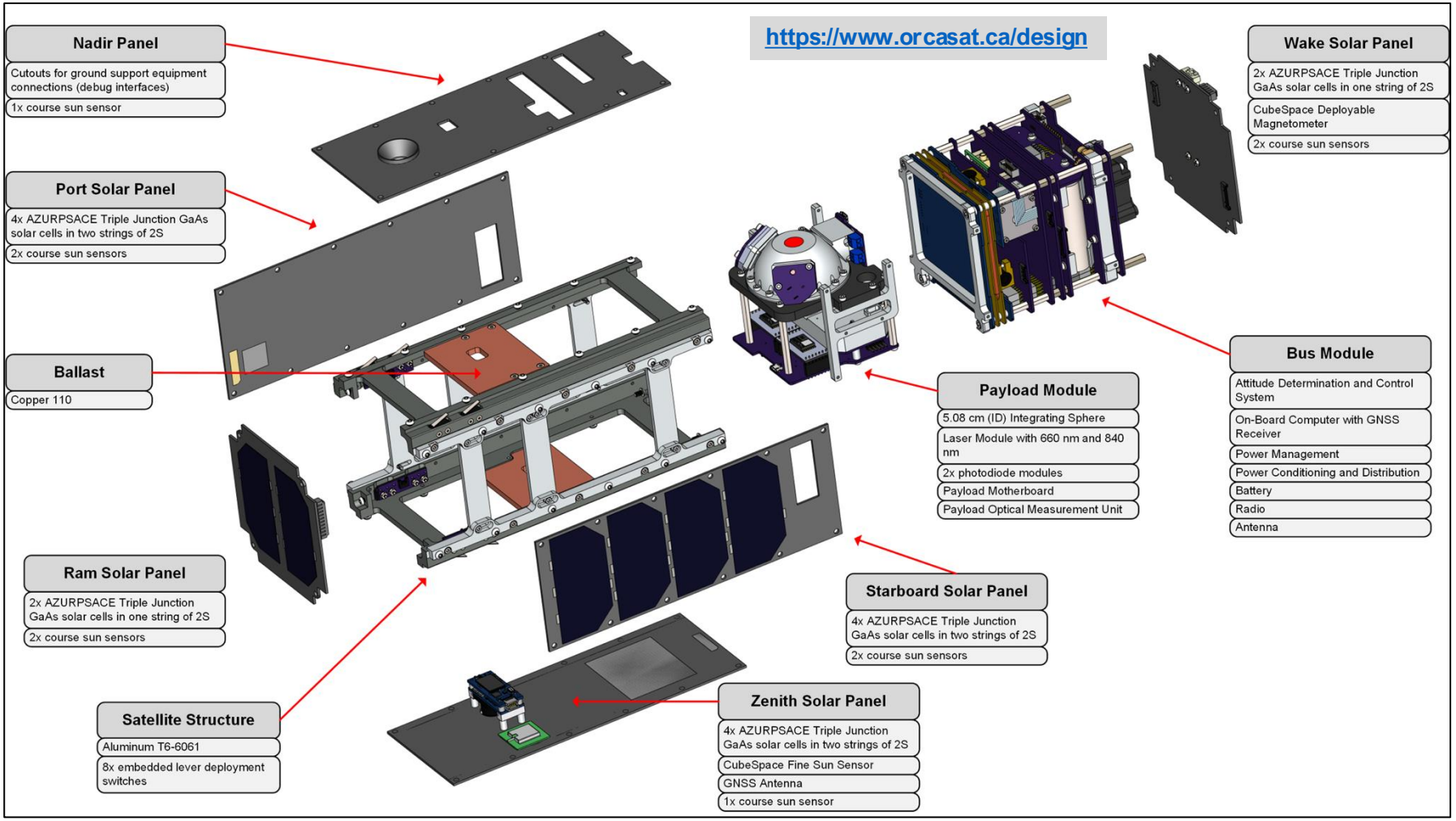


An exploded view of a NanoAvionics 6U nanosatellite bus and its core components.

CubeSat-1 – Example University – 1U

# 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**



# 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

https://www.researchgate.net/publication/240615366_M-Cubed_University_of_Michigan_Multipurpose_MiniSatellite_with_Optical_Imager_Payload

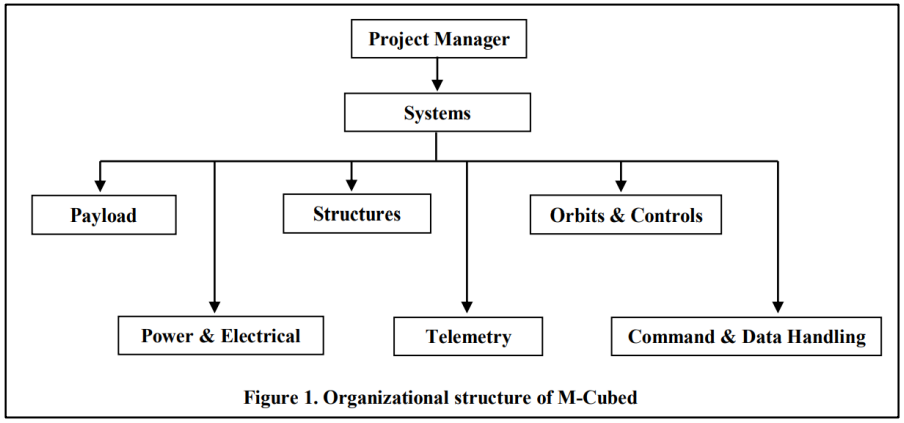


Figure 1. Organizational structure of M-Cubed

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

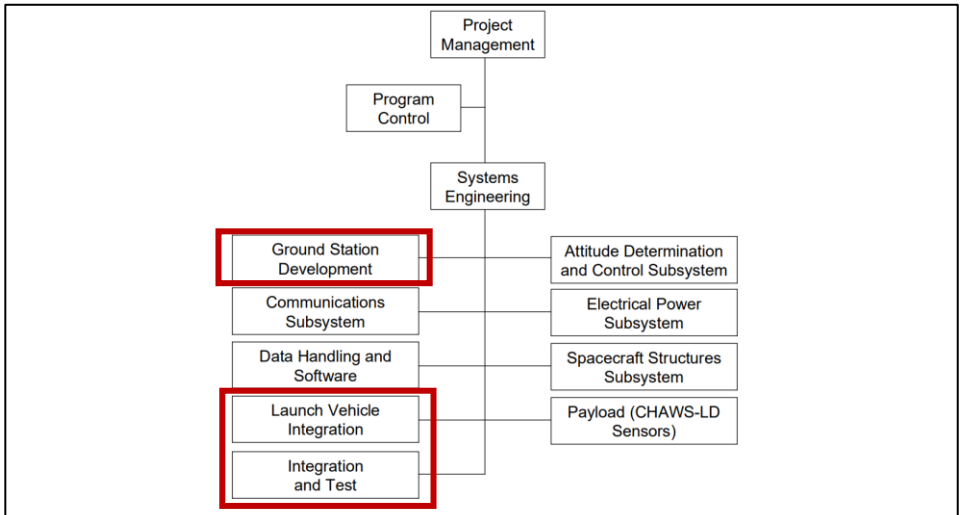


**Fig. 3. Small Satellite Student Team Organization.** Each team contains students and at least one faculty mentor. The program control function includes scheduling, budgeting, contracting, and configuration management.

# 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

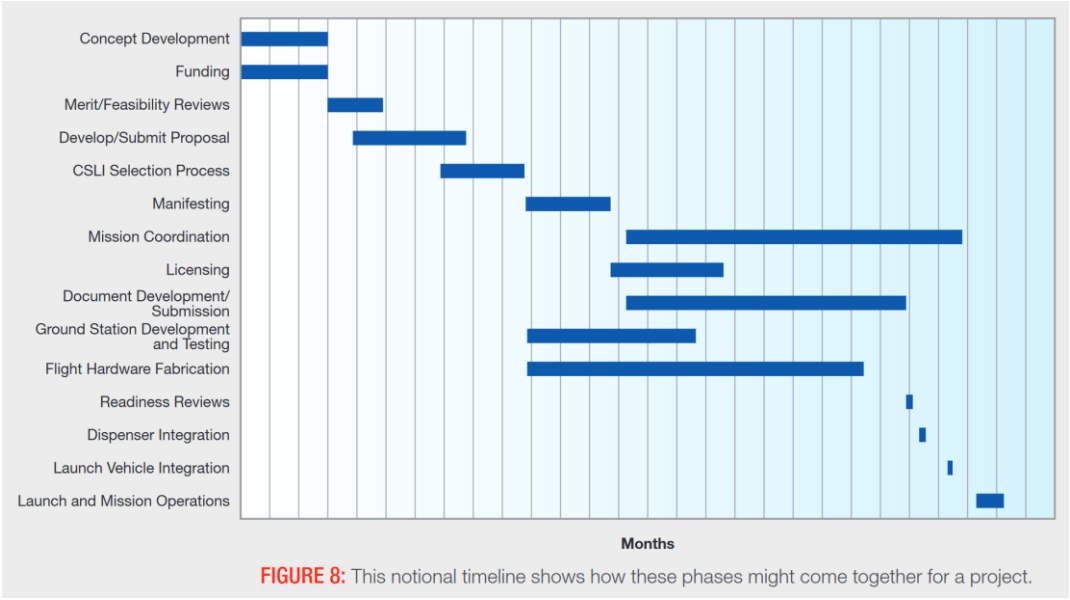



FIGURE 8: This notional timeline shows how these phases might come together for a project.

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

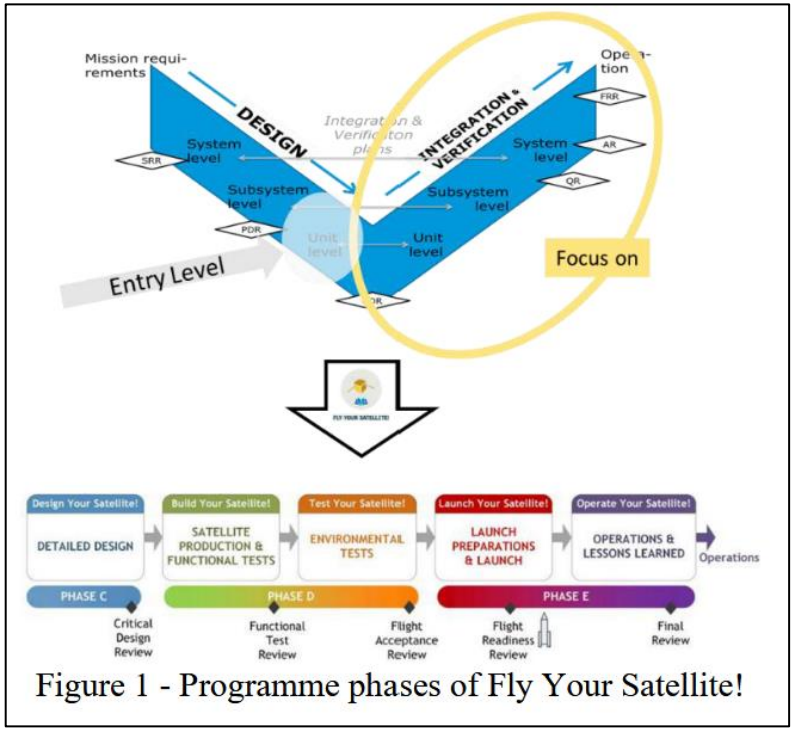



Figure 1 - Programme phases of Fly Your Satellite!




FIGURE 9: Common costs associated with developing a CubeSat.

# 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



# TRIVIA TIME

**Before starting**, please answer the following questions

This is just to measure your current knowledge on CubeSats.

**NOW, after the presentations**, we will repeat the quiz

to gauge how much new knowledge you have acquired,

**And**

We will show the answers.

# TRIVIA TIME

**Q1.** What is the name of the first satellite sent up by humanity?

**Q2.** Name at least one company in Spain that makes CubeSats?

**Q3.** Name at least one Spanish University that has launched a CubeSat?

# TRIVIA TIME

## Q4. How much is the (typical) weight of a CubeSat?

A. < 1 Kg

B. 1-10 Kg

C. 10-50 Kg

D. >100 Kg

## Q5. How long can be the side of a CubeSat?

A. 5 cms

B. 10 cms

C. 30 cms

D. 80 cms

# TRIVIA TIME

## Q6. What is the (typical) orbit altitude for a CubeSat?

A. 10-100 Km

B. 100-300 Km

C. 300-600 Km

D. 600-900 Km

## Q7. What is the (typical) maximum travelling speed of a CubeSat?

A. 300 km/h

B. 3,0000 km/h

C. 30,000 km/h

D. 300,000 km/h

# TRIVIA TIME

## Q8. How many CubeSats have been launched into space?

A. <1,000

B. 1,000-3,000

C. 3,000-6,000

D. >6,000

## Q9. What is the success rate of a CubeSat program/launch?

A. < 30 %

B. 30-50 %

C. 50-70 %

D. > 70 %

# TRIVIA TIME

**Before starting**, please answer the following questions

This is just to measure your current knowledge on CubeSats.

**After the presentations**, we will repeat the quiz

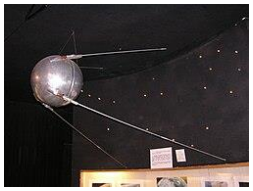
to gauge how much new knowledge you have acquired,

**And NOW**

**we will show the answers**.

# TRIVIA TIME: ANSWER

## Q1. What is the name of the first satellite sent up by humanity?



https://en.wikipedia.org/wiki/Sputnik_1

**Sputnik,19**: Launched by Soviet Union on the 4th October 1957

It was a metal sphere of 58 cm in diameter and 83Kg

Lasted 22 days and burnt on re-entry on 4th January 1958

## Q2. Name at least one company in Spain that makes CubeSats?

**Platforms**: Alen Space, EMXYS, Hydra Space, SATLANTIS

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

## Q3. Name at least one Spanish University that has launched a CubeSat?

**Launched**: Universidad de Vigo, UPM, UPC

**Ongoing**: UC3M, Universidad de Cadiz, Universidad de La Laguna

# TRIVIA TIME : ANSWER

## Q4. How much is the (typical) weight of a CubeSat?

A. < 1 Kg
B. 1-10 Kg
C. 10-50 Kg
D. >100 Kg



## Q5. How long can be the side of a CubeSat?

A. 5 cms
B. 10 cms
C. 30 cms
D. 80 cms



# TRIVIA TIME : ANSWER

## Q6. What is the (typical) orbit altitude for a CubeSat?

A. 10-100 Km

B. 100-300 Km

C. 300-600 Km ★

D. 600-900 Km

## Q7. What is the (typical) maximum travelling speed of a CubeSat?

A. 300 km/h

B. 3,0000 km/h

C. 30,000 km/h ★

D. 300,000 km/h

# TRIVIA TIME : ANSWER

## Q8. How many CubeSats have been launched into space?

A. <1,000

B. 1,000-3,000

C. 3,000-6,000 ★

D. >6,000

## Q9. What is the success rate of a 1st CubeSat program/launch?

A. < 30 %

B. 30-50 % ★

C. 50-70 %

D. > 70 %