SI-2024 Introduction to CubeSat and Satellite Communication

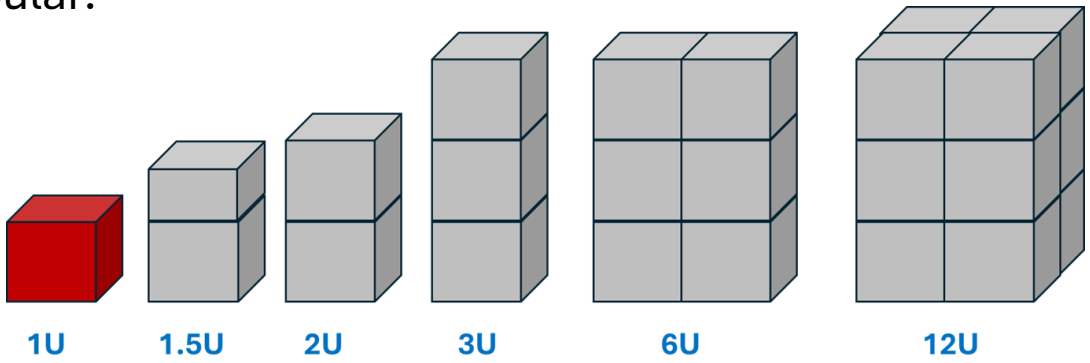
CubeSat: Basic Concepts and Processes

25th June 2024

SiliconTech

What are CubeSats

- A *small satellite* is generally considered to be any satellite that weighs less than *300 kg (1,100 lb*)
- A **1U CubeSat is a 10 cm cube** with a mass of approximately **1 to 1.33 kg**.
- Over the years, larger sizes as multiple of the standard unit has become popular:



Why CubeSats

- Standardized size allows for modular mass production resulting in significantly lower cost of production
- Small size and weight significantly lowers launch cost
- Standard design specification maintained by CubeSat Design Specification (CDS) at https://cubesat.org

1U CubeSat CP1 (left)
3U CubeSat CP10 (right) [Cal Poly]

1U Standard
Dimensions:
10x10x10cm
4”x4”x4”

3U Standard
Dimensions:
10x10x30cm
4”x4”x12”

A Little Background

- CubeSats began as a collaborative effort in 1999 between Jordi Puig-Suari, a professor at California Polytechnic State University (Cal Poly), and Bob Twiggs, a professor at Stanford University's Space Systems Development Laboratory (SSDL)
- Original intent of the project was to provide affordable access to space for the university science community
- But it's not just big universities; smaller universities, high schools, middle schools, and elementary schools have also been able to start their own CubeSat program.
- In addition to educational institutes, government agencies and small commercial agencies now above access to space at a fraction of the cost compared to small satellites.

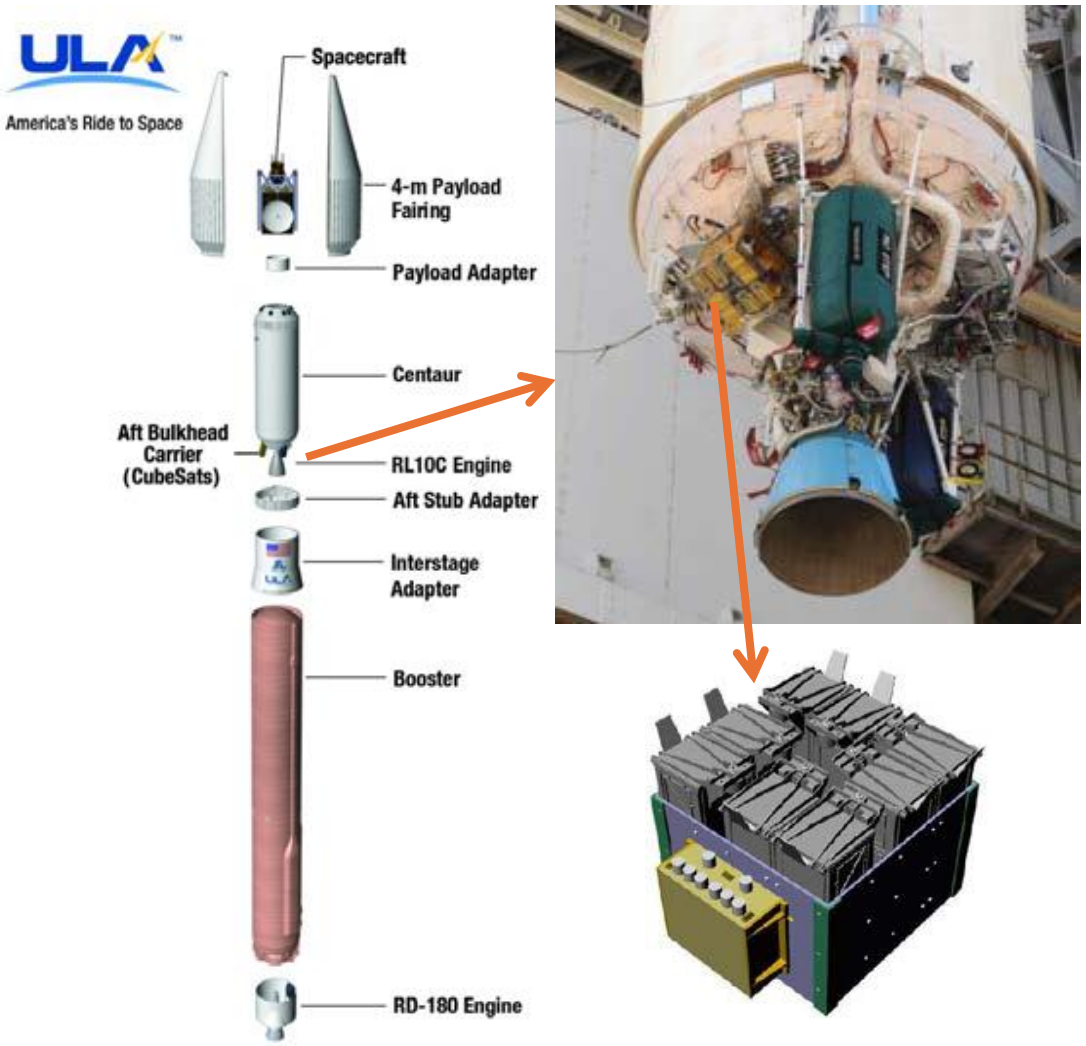
University student taking measurements of a 2U CubeSat (CP9). [Cal Poly]"

CubeSat Dispenser System

- The dispenser, which is the interface between the CubeSat and the launch vehicle (LV).
- The dispenser provides attachment to a launch vehicle (or rocket), protects the CubeSat during launch, and releases it into space at the appropriate time.
- The first dispenser for CubeSats was the Poly-Picosatellite Orbital Deployer (P-POD). It was developed by Cal Poly, San Luis Obispo.
- Now there are numerous dispensers available.

Poly-Picosatellite Orbital Deployer (P-POD) Developed by Cal Poly, San Luis Obispo. [Cal Poly]

Rockets (Launch Vehicles)



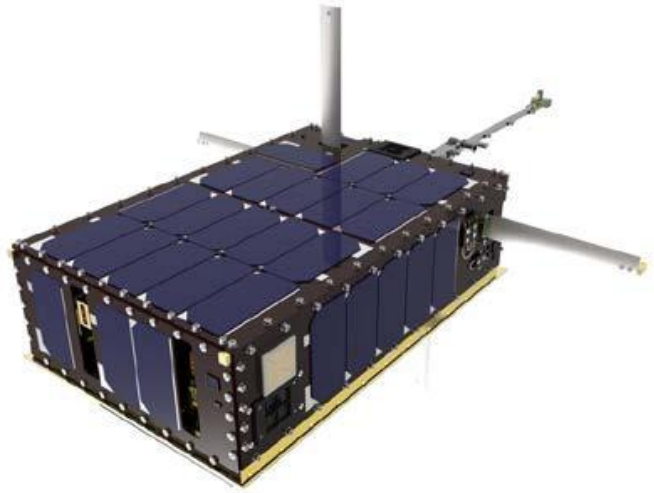
ULA launch vehicle with a NPSCul-Lite housing eight 3U P-PODs and attached to the LV via an Aft Bulkhead Carrier (ABC) plate.

Russian cosmonaut preparing to launch a 1U CubeSat that he is holding in his hand. [NASA]

U.S. Launch Vehicles Used for CubeSat Launches.

Development Process Overview

- A CubeSat can be designed, built, tested, and delivered in as little as 9 months, but typically takes 18 to 24 months to complete. Once your CubeSat is ready to be delivered, the typical time to launch is anywhere from a few months to a few years.

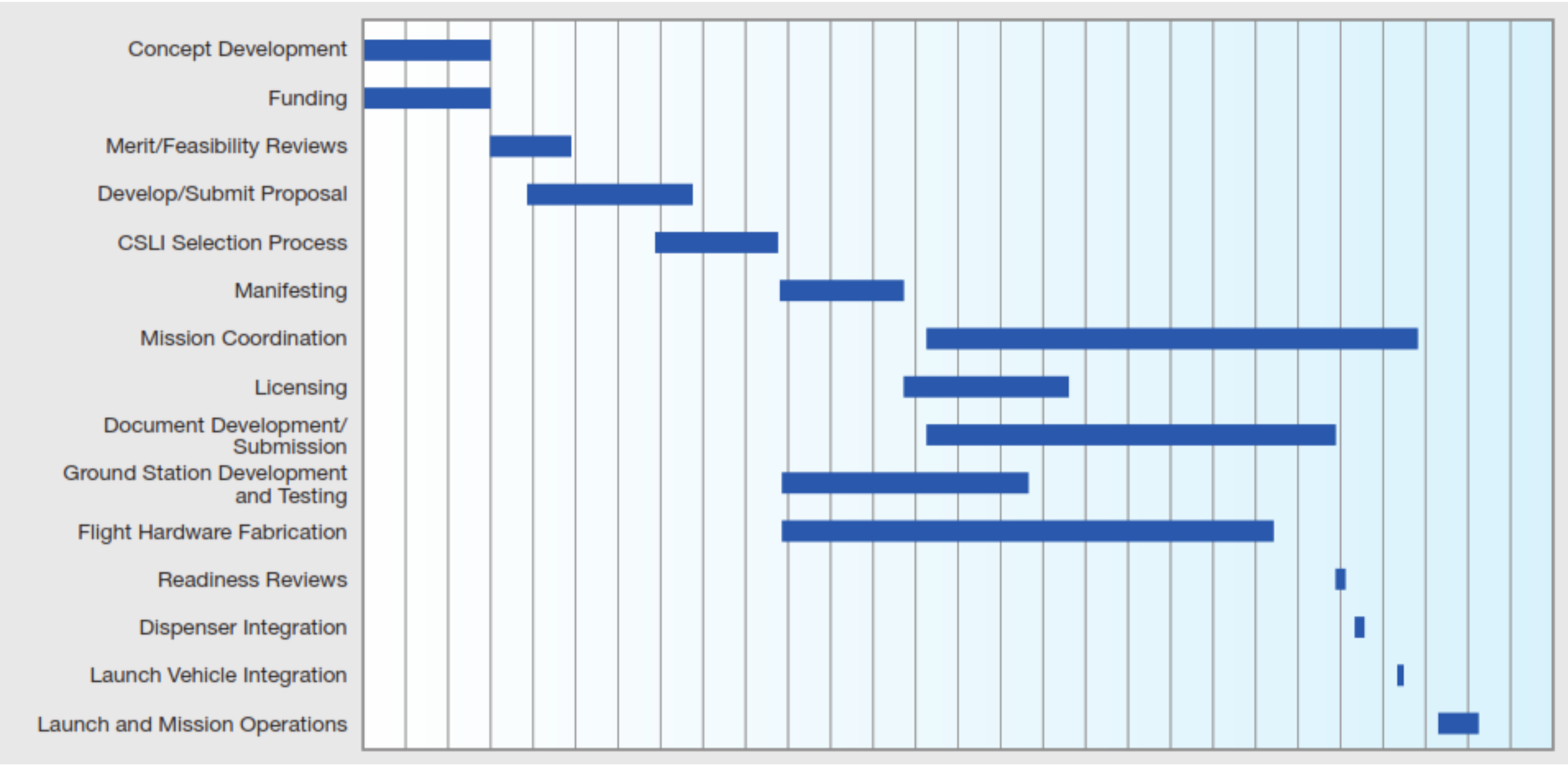


Example of a 6U CubeSat (Dellingr CubeSat) [NASA]

- Typical Development Cycle:

1. Concept Development (1–6 months)
2. Securing Funding (1–12 months)
3. Merit and Feasibility Reviews (1–2 months)
4. CubeSat Design (1–6 months)
5. Development and Submittal of Proposal in Response to CSLI Call (3–4 months)
6. Selection and Manifesting (1–36 months)
7. Mission Coordination (9–18 months)
8. Licensing (4–6 months)
9. Flight-Specific Documentation Development and Submittal (10–12 months)
10. Ground Station Design, Development, and Testing (2–12 months)
11. CubeSat Hardware Fabrication and Testing (2–12 months)
12. Mission Readiness Reviews (half-day)
13. CubeSat to Dispenser Integration and Testing (1 day)
14. Dispenser to Launch Vehicle Integration (1 day)
15. Launch (1 day)
16. Mission Operations (variable, up to 20 years)

Development Process Overview (Typical Schedule)



Concept Development (1-6 Months)

- ❑ Mission Goal: What do you want your CubeSat to do ?
- ❑ First, take care of bare minimum payload: communication, power management and on board computer.
- ❑ Funding agency/source will drive some mission goals e.g. environmental monitoring, etc.
- ❑ Look for low-hanging goals that has never been done before. Will add lot of value for the project.

Securing Funding (1-12 Months)

- ❑ Launching the satellite is by far the biggest cost.
- ❑ Look for govt. funding related to space science and technology.
- ❑ Crowdfunding is a viable option.

Merit and Feasibility Review (1-2 Months)

- As part of most funding proposals, you will be required to perform a merit review and a feasibility review.
- These reviews help assure mission stakeholders (and everyone else involved in the mission) that your team or organization can fulfill your obligations and completing a successful and worthwhile mission..

CubeSat Design (Varies)

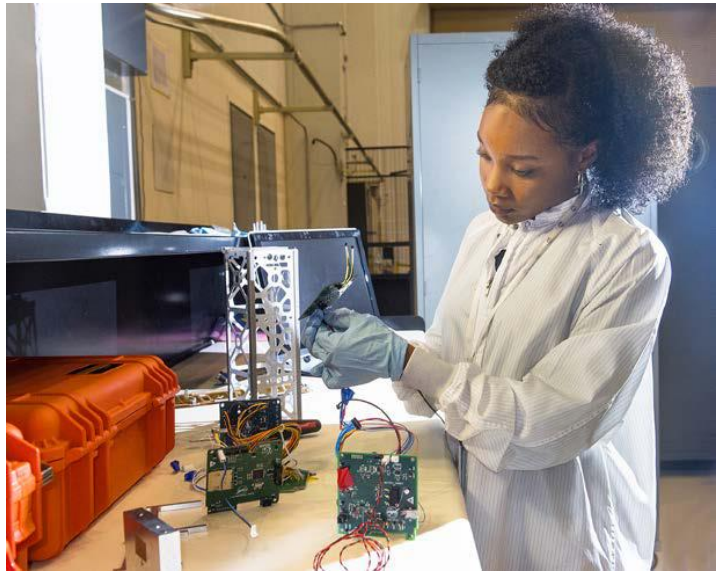
- Carefully research what goes in the payload. Some elements can add to your design significantly. For e.g. adding an imager requires a NOAA certification which is a lengthy process.
- Some general advice:
  - Keep it simple. Anything complexity adds to design time and risk.
  - Keep important components in the exterior for better serviceability.
  - Always keep 5-10% margin (where possible) from the specification.
  - Add redundancy on mission critical elements e.g. burnwires.
  - Use familiar and popular components to avoid last minute surprises.
  - Use UL listed batteries
  - Use high-melting point materials.
  - Try to emulate the launch and orbit conditions as closely as possible e.g. environmental testing, resistance to shock and vibration

Mission Coordination (9-18 Months)

- Mission coordination will begin about 18 months before the scheduled launch date.
- It will start with a “kickoff” meeting between all of the developers on the mission and the mission integrator.
- The mission typically represents your CubeSat plus any other co-manifested CubeSats, the dispensers, the launch, and the deployment.
- CubeSat missions involve, at the very least, a CubeSat developer and an LV provider.

Regulatory Licensing (4-6 Months)

- All CubeSats must go through a licensing process in order to transmit radio signals and a separate process to license the use of an imaging instrument such as a camera.
- Regulatory licensing can be a lengthy process. Before submitting any application, there should be a clear understanding of all regulatory compliance requirement and apply for them ASAP.
- Radio licensing for a RF transmission is almost a must for most payloads. But most CubeSats use a Amateur Band e.g. 433MHz. But the operator needs to have an amateur radio (HAM) license.
- The second license you may have to obtain is based on whether your CubeSat includes an imager, or camera.



- This process can be lengthy, and the Wireless Planning and Coordination (WPC) wing will need to see your license from NOAA before it will finish processing your RF license..

Ground Station Design, Development and Testing (2-12 Months)

- The ground station should be built early in the timeline and should be in sync with CubeSat development.
- Thorough testing is critical to successful mission.
- There are lot of CubeSats in the 433MHz band using LoRa or FSK modulation that cane be used to test ground station.

CubeSat Hardware Fabrication and Testing (4-6 Months)

- Standard payloads (PMU, SDR, Solar Panels, etc.) are available from commercial vendors.
- The decision to buy or make depends on mission goal e.g. cost, design experience, etc.
- Keep sufficient margin between launch date and estimated completion.
- If possible, built multiple units preferably in parallel to mitigate any last minute issues with the unit.
- Keep excellent record during the development process, taking as many pictures as possible.
- Two types of testing are done: development testing and verification testing.
- Verification testing typically includes vibration and thermal vacuum tests, and in some cases shock, EMI/EMC, and static load tests, to ICD-prescribed levels.
- Day In The Life (DITL) testing is also required to show that electrical inhibits and timers will function correctly

Mission Readiness Reviews (Half Day)

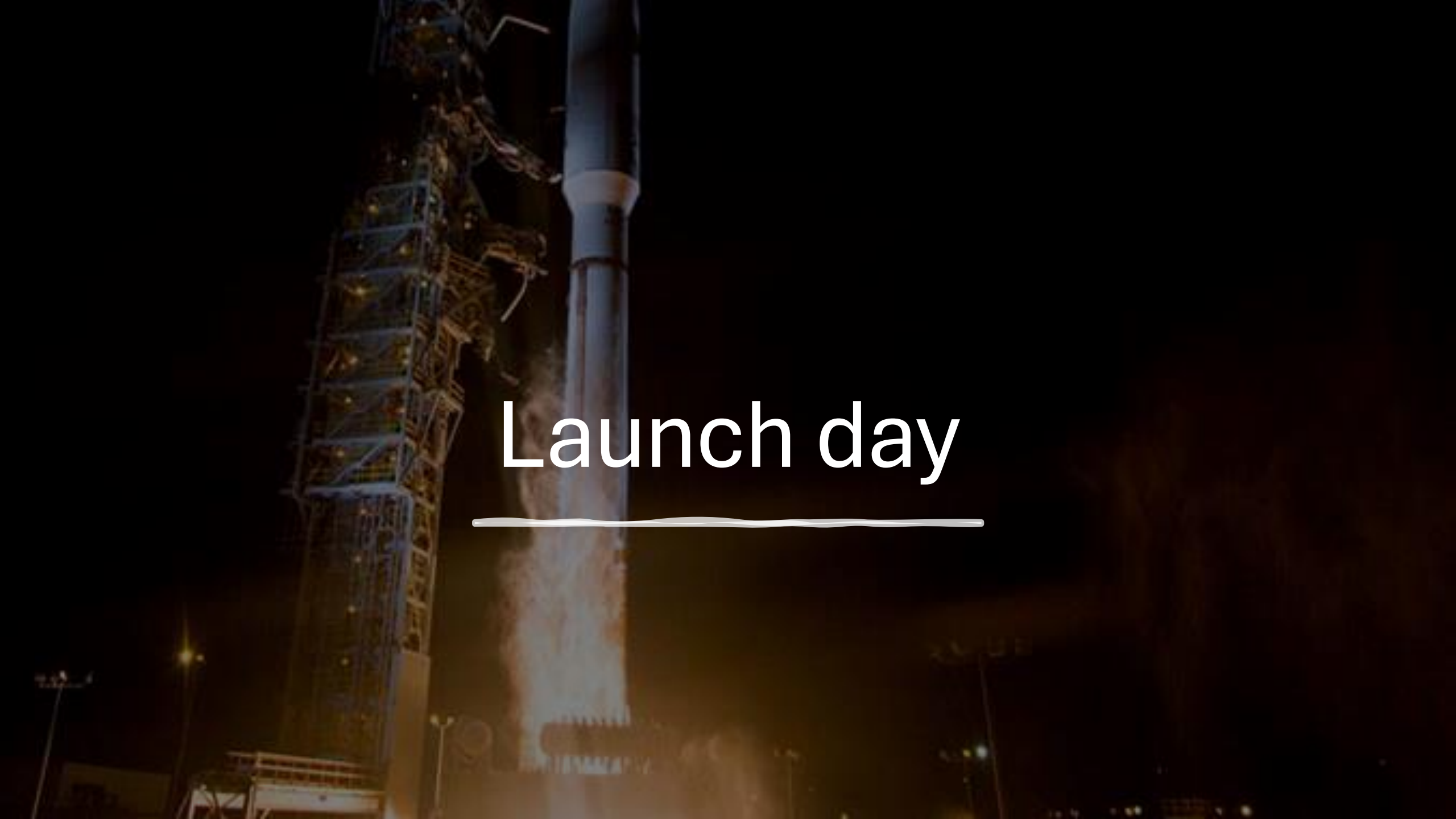
- ❑ Usually, a review presented to the launch integrators and/or funding agency to convince them of the mission readiness of the program.

CubeSat-to-Dispenser Integration and Testing (2 Days)

- ❑ After the CubeSat design is complete, this test is done with the integrator to test the integrated system to make sure the system survives launch.

Dispenser to Launch Vehicle Integration (1 Day)

- ❑ This is where the system is handed to the launch organization (NASA, SpaceX, ISRO, etc.) to attach the dispenser to the rocket.


Launch day

Mission Operation (Variable, up to 20years)

- Initial part of the mission can be the most exciting as well as frustrating.
- By this time, the ground station team should have plenty experience in tracking similar satellites.
- After the CubeSat is ejected into the orbit, the launch provider will provide the state vectors that can be converted to a standard two-line element (TLE) format.

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1 42704U 98067LM  17304.55488591  .00021073  00000-0  25707-3 0  9994
2 42704  51.6386  74.8642 0001580  42.1764 317.9350 15.60423680 26110
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