PhD Aerospace Engineering UC3M
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Autonomous in-orbit formation flying of small satellites using aerodynamic forces

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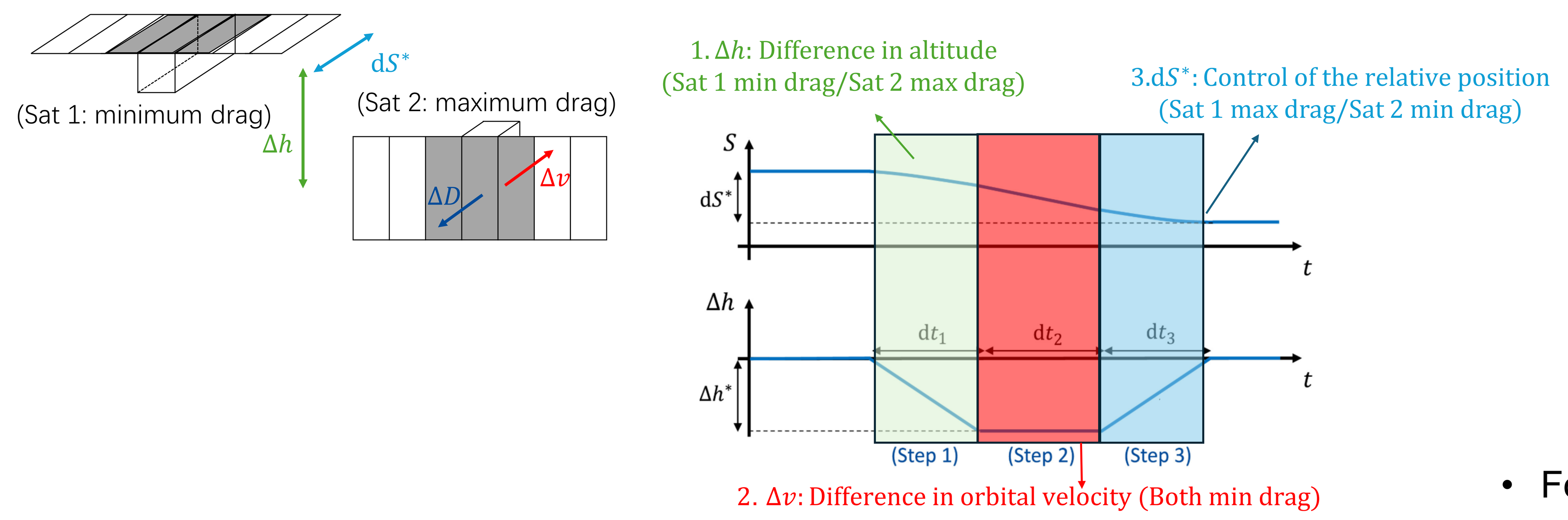
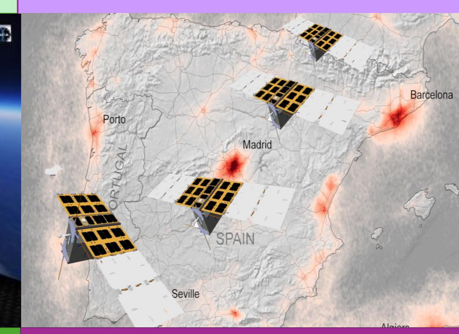
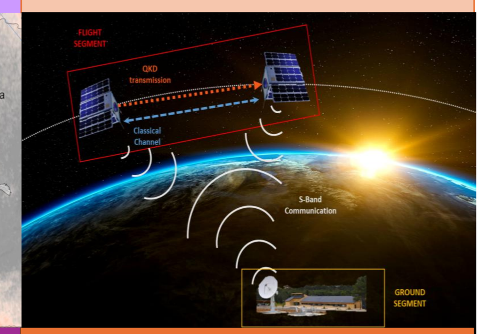
Motivation

ANSER (Advanced Nanosatellites Systems for Earth observation and Research) [1]

- Operate in **Low Earth Orbit (LEO)** at about 500 km of altitude.
- Adapt its orbit and formation using methods such as passive aerodynamics under **ground control**.

Differential drag (ratio of frontal area 21:1)



ANSER-Water Quality	ANSER ATmosphere	Quantum ANSER
		
Operational phase	**Critical Design Review**	**Conceptual phase**
3 x 3U CubeSats	4 x 6U CubeSats	2 x 16U CubeSats
In orbit since October 2023	Launch in 2028	Launch in 2030
Focused on water quality monitoring	Study air quality, climate change	Quantum technology demonstrator

- For future missions, the aim is to **control the formation autonomously.**

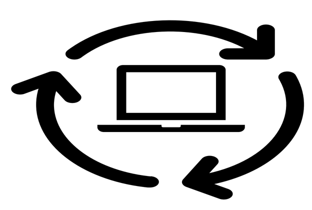
State of the Art

Mission	PRISMA [2]	CanX-4 & CanX-5 [3]	M2 [4]
Orbit	LEO	LEO	LEO
Features	Two nanosatellites: MANGO and TANGO	Two 3U nanosatellites	Two 6U CubeSatellites
Formation flying	Autonomous	Autonomous	Open loop (from the ground)
GNC	**Guidance**: Position and velocity of a relative trajectory. **Navigation**: On board navigation system includes two Phoenix-S GPS receivers and real-time orbit estimation software. **Control**: Use a Model Predictive Control (MPC).	**Guidance:** Along track (500 m-1000 m) or projected circular orbit (50 m-100 m). **Navigation:** GPS measurements and intersatellite link. **Control:** Drift Recovery And STation-Keeping algorithms (DRASTK) and use Pulse Width Modulation (PWM) technique.	**Guidance:** Along track (1.2 km-1.5 km). **Navigation:** GPS data. **Control:** Calculates position, velocity and drag coefficient from the downloaded GPS data, using a least-squares fit, and propagates the data (Runge-Kutta 9th) to generate the manoeuvres from the ground.
Type of control	High-Performance Green Propellant system, the cold gas micro-thrusters	Cold Gas Propulsion system	Differential drag

Objectives

Autonomous Formation Flying Control (FFC) requires the CubeSats to communicate with one another via the **Inter-Satellite Link (ISL)** and the implementation of **Guidance, Navigation and Control (GNC)** algorithms that enable the on-board control loop to be closed.

FFC COMPUTER



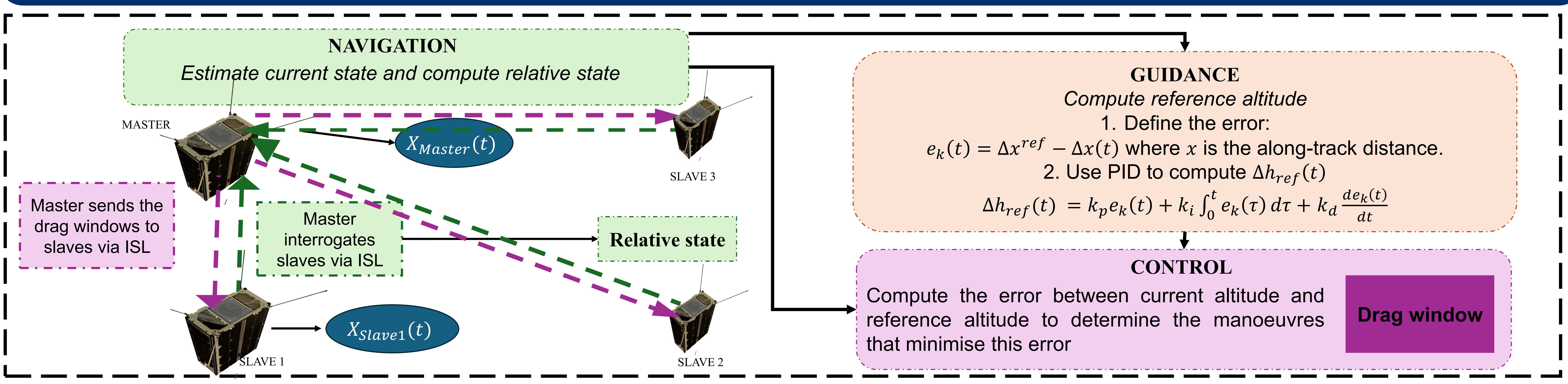
Guidance: Provides reference state information; for example, for station-keeping, target values for radial, along-track and across-track separation between the satellites are established.

Navigation: Estimates the current state.

Control: Calculates the manoeuvres that minimise the error between the reference state and the current state, providing an output of the differential angle of attack between satellites.

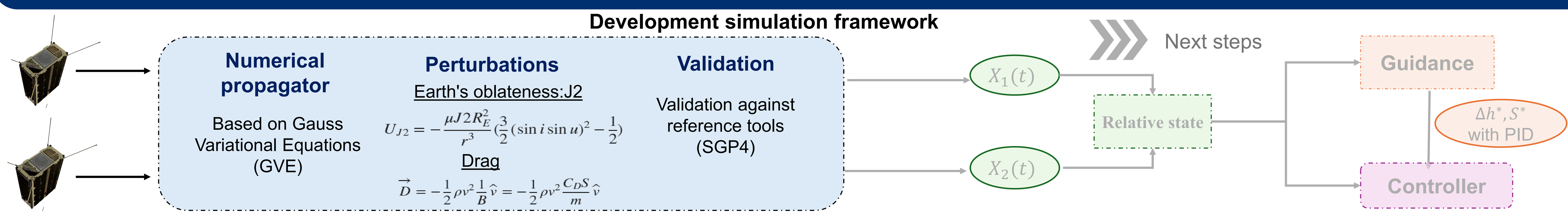
This means that, in order to maintain their position, the satellites are arranged in a **train-like configuration**, with the ground-based operator specifying the order and along-track distance among satellites.

Methodology



Preliminary Research

Development simulation framework



References

[1] Castro-Fernández et al. (2026). *Formation flying of the ANSER cluster using differential-drag control.* Acta Astronautica.

[2] Gill, E., Montenbruck, O., D'Amico, S., & Persson, S. (2006). *Autonomous satellite formation flying for the PRISMA technology demonstration mission.* Paper presented at the 16th AAS/AIAA Space Flight Mechanics Conference, Tampa, FL, United States.

[3] European Space Agency (ESA). (2012, May 29). *CanX-4 and 5 (Canadian Advanced Nanospace eXperiment-4 & 5)*. eoPortal. Retrieved December 17, 2024, from https://www.eoportal.org/satellite-missions/canx-4-5#formation-flying-control-algorithm

[4] Brown et al. (s.f.). *Formation flying and change detection for the UNSW Canberra Space 'M2' low Earth orbit formation flying CubeSat mission.*

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