Formation Flying of the ANSER Cluster of **CubeSats using Differential Drag Control**

I. Castro-Fernández, C. Arza-González, V. Prieto-Laso, N. Pardina-Popp, C. Campuzano-Corrales and S. Rodríguez-Bustabad

Presenter:

Iván Castro-Fernández

Instituto Nacional de Técnica Aeroespacial (INTA), Spain



CubeSat Developers Workshop 2025

(Apr 2025)



Instituto Nacional Aeroespacial

Contents

- Motivation
- Methodology
- In-Orbit Results
- Conclusions

Motivation of Formation-Flying Control (FFC) in Clusters

FFC in clusters of CubeSats

<u>Why</u> flying in formation with CubeSats?

- <u>Joint/colaborative</u> operation between small satellites
- Large payloads distributed among several CubeSats

How to fly in formation with CubeSats?

Propulsion system → Challenging in CubeSats due to volume and mass constraints

<u>Aerodynamic forces</u> \rightarrow Free and effective in LEO;



FFC in the ANSER® programme at INTA



FFC Methodology in the ANSER Mission

Key elements of the ANSER FFC

Deployable flaps:

- Ratio between max. and min. areas of 21:1
- This leads to high maneuverability
- Deployment FLW1 (85%) and FLW2 (100%)

Complete ADCS:

- Commercial solution by CubeSpace
- 3-axis control (0.1º accuracy)
- It allows for <u>pitch control</u> of the satellites





FFC methodology

- Using <u>differential</u> aerodynamic forces of <u>Drag & Lift</u> to control the <u>relative position</u> between the FLW1 and FLW2
- <u>Differential drag</u> \rightarrow In-plane maneuvers
- <u>Differential lift</u> → Out-of-plane maneuvers (not tested yet)

Differential drag ΔD

- 1) Difference in altitude Δh
- 2) Difference in orbital velocity Δv
- **3)** Control of the relative position ΔS



In-orbit change of attitude for FFC (FLW2)



FFC modes

- Mode 0: uncontrolled formation-flying
- Mode 1: high/low rate of descent

- Mode 2: constant differential altitude
- Mode 3: station-keeping



In-Orbit Results

Formation flying results



FFC Modes:

- Mode 0: uncontrolled formation-flying
- Mode 1: high/low rate of descent
- Mode 2: constant differential altitude
- Mode 3: station-keeping

Remarks:

- Differential drag maneuvers are <u>responsive</u> and <u>effective</u>
- The separation between satellites was reduced <u>from +10000 km to 100 km</u>
- <u>Station-keeping</u> 100 < S < 200 km during the last period

Formation flying results: station-keeping



Identification of the aerodynamic model



Drag coefficient

$C_D = \frac{2B^*m}{\rho_0 A}$

Remarks:

- Aerodynamic model $C_D(\theta)$ was experimentally identified
- Statistically similar coefficients for both FLWs

Conclusions

Conclusions and Future Works

Conclusions:

- Differential <u>aerodynamic forces</u> (drag and lift) are <u>powerful</u> and <u>natural</u> resources for FFC of CubeSats in LEO
- Two key elements: high ratio of cross-sectional areas (21:1) and 3-axis attitude control
- The ANSER mission has achieved its formation-flying goals

Future works:

- FFC between the FLWs and the recently launched LDR-S → Start using <u>differential lift</u>
- <u>Autonomous</u> (onboard) <u>FFC</u> for future missions (ANSER-AT and Q-ANSER)

Acknowledgements

The small-satellite constellation programme (ANSER) has been self-funded by the Spanish Institute of Aerospace Technology (INTA). The launch was funded by the European Commission through its programme IOD/IOV.



ANSER TEAM







Thank you for your attention!

Dr. Iván Castro-Fernández

E-mail: icasfer@inta.es





Backup slides

Flaps deployment



Formation flying results: COE



.

Current situation between the FLWs and the LDR-S



Next steps:

- Formation-flying control in the along-track direction (<u>ISL</u> comms between LDR-S and FLWs in the <u>two orbit crossings</u>)
- Attempt orbital plane change with differential lift (h < 450 km)

Operación científica (espectrómetro CINCLUS)

Transición tierra-agua

Espectros de agua



Comentarios:

- Espectrómetro CINCLUS validado: espectros esperados para tierra y agua
- X: Longitud de onda (380 850 nm)
- Y: Tiempo o distancia (110 tomas)
- Se barren ${\sim}35~{\rm km}$ en dirección along-track



Photos with the nadir camera from space

Iberian peninsula



Anular eclipse (14 – Oct – 2024)

