Aerospace Technologies for Earth Monitoring and Observation

Federico Toson   -   38th Cycle

Supervisor: Prof. Carlo Bettanini

Co-Supervisor: Prof. Giacomo Colombatti

Final Exam Admission - 11/09/2025

- Motivation: need for **innovative environmental monitoring** under climate change

- Development of **modular, low-cost sensing platforms** for Earth observation

- Multi-carrier approach: drones, balloons, satellites

- Focus on **different domains**: vegetation health, air pollution, light pollution, dynamics of UAV for Earth Observation

- Integration of **payload adaptability and flight dynamics analysis**

- Cross-platform calibration & data fusion for enhanced assessment
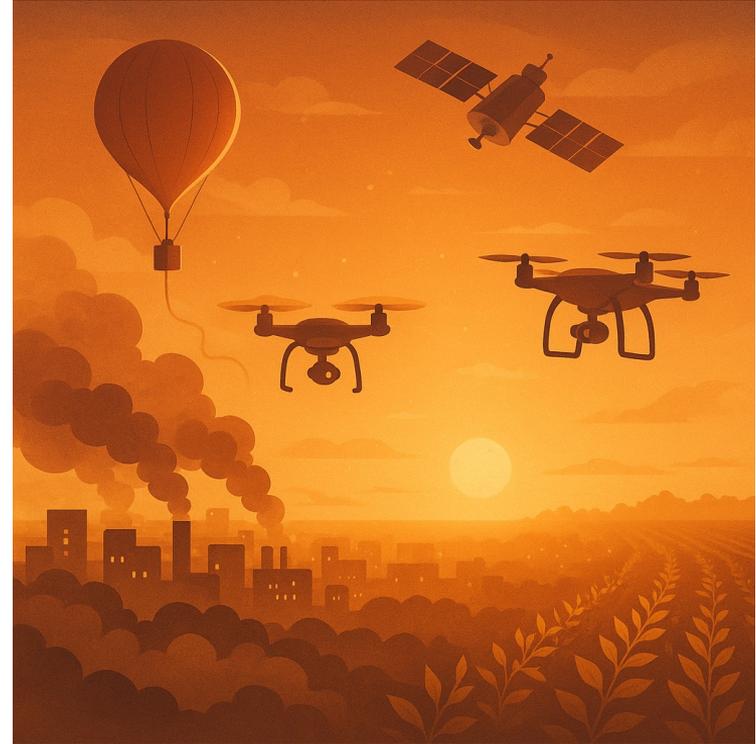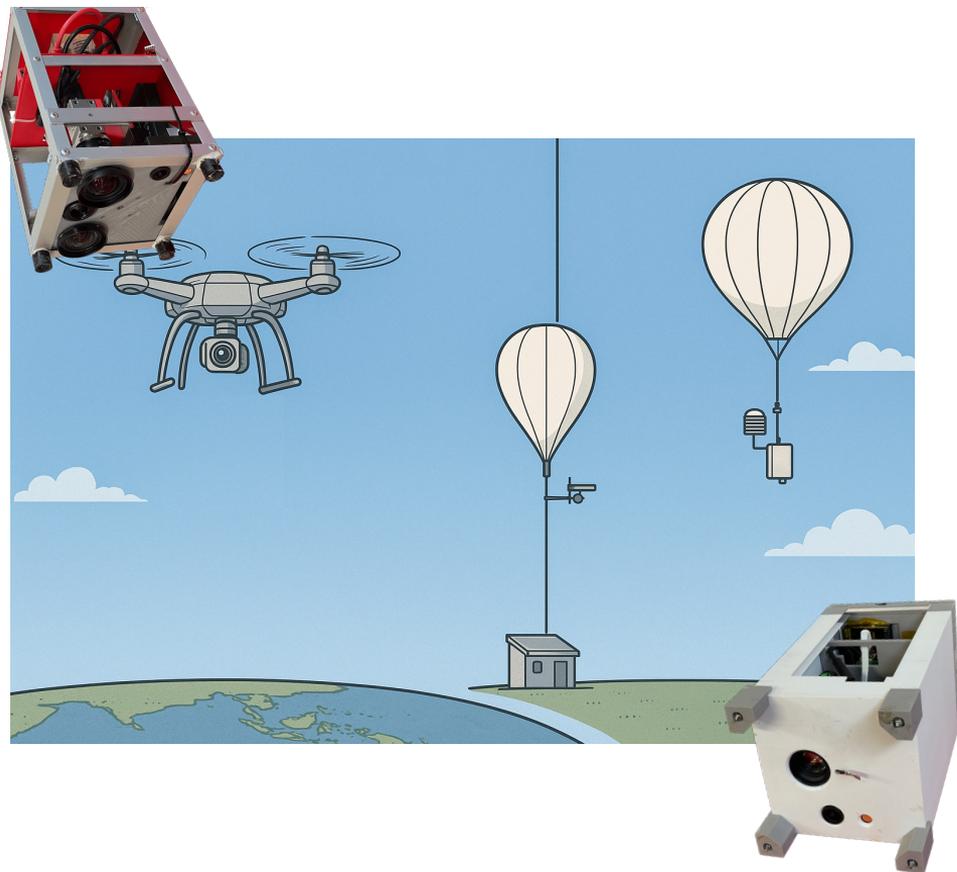
- Advance **flexible aerospace technologies** for sustainable monitoring

- Validate a **modular, scalable sensing platform**

- Enable **precision agriculture, UAV flight dynamics, pollution analysis, and light mapping**

- Demonstrate scalability and application with other projects: PRIN, Light Pollution in Chile, E-FORESTER, J2050

- Enhance **accessibility** and foster **interdisciplinary collaboration**

| PHD STUDENT | Federico Toson | DATE | 10/09/25 | | First year |
| PHD THESIS | Aerospace Technologies for Earth Monitoring and Observation | ADMISSION TO | Final Exam Admission | | |

UNIVERSITÀ DEGLI STUDI DI PADOVA

CISAS G. COLOMBO

	WBS NUMBER	TASK TITLE	T1			T2			T3			T4		
			O	N	D	J	F	M	A	M	J	J	A	S
	1	Bibliographic Research												
	1.1	Today's technologies for Earth Observation												
	1.2	Precision agriculture strategies and indices												
	1.3	Earth observation via UAV												
	1.4	Earth Observation via Satellite												
	2	Earth Observation measurements know-how and technologies												
	2.1	Vegetation indices determination												
	2.2	Light Pollution sensor comparison												
	2.3	Hosting vehicles comparison												
	2.4	Cameras selection and comparison												
	2.5	Environmental measurements correlations												
	3	Prototypes development												
	3.1	Structure Design												
	3.2	3D printing and rapid prototiping												
	3.3	Manufacturing and Integration												
	3.4	Prototypes alternatives and interfaces												
	3.5	Electronics and software development												
	4	Field tests												
	4.1	Crops monitoring												
	4.2	Light pollution assessment												
	4.3	Flight dynamics analysis for data acquisition												
	4.4	Global device final testing												
	5	Data analysis and comparison												
	5.1	Vegetation Indices computation												
	5.2	Light pollution sources detection												
	5.3	Trajectory and dynamics studies												
	5.4	Satellite Data Comparison and correlation												

- Literature review

- Prototype definition: **ATEMO**

- Design and MAIT

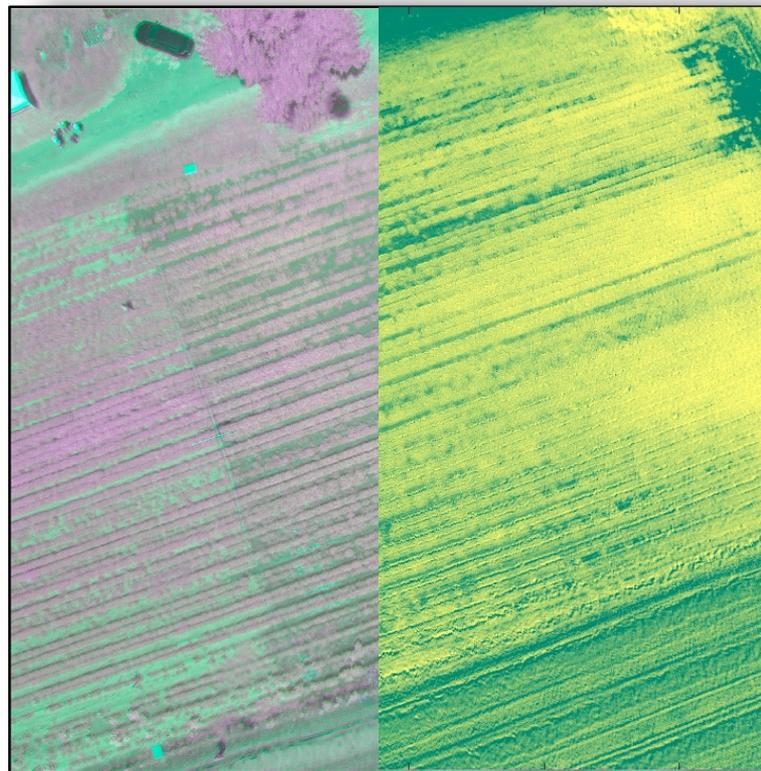- 3D printed structure first iterations

- Sensor & instrument selection
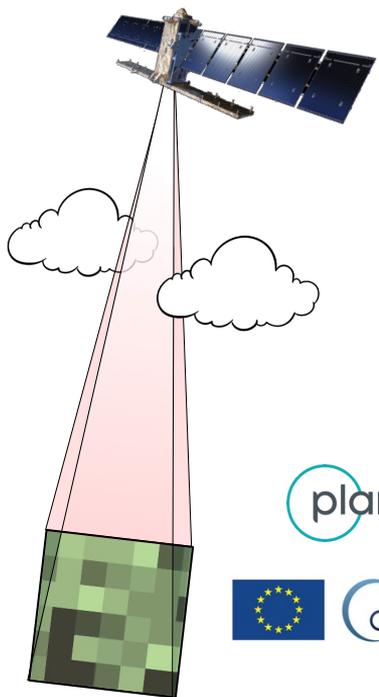
$$NDVI = \frac{NIR - Red}{NIR + Red}$$

BLUE GREEN RED NIR
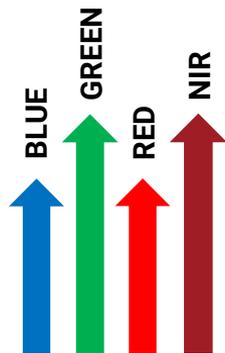
Stressed Leaf

Tests on **vegetation indices / plant health;** Field campaigns – **PRIN "Rewatering**

PHD STUDENT | Federico T | DATE | 10/09/25 | DATE | 10/09/25

chnologies for Earth Monitoring and Observation | Aerospace | ADMISSION TO | ies for Earth Monitoring And Observation | ADMISSION TO | Final Exam Admission

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Second year

WBS NUMBER	TASK TITLE	% OF TASK COMPLETE	T1	T2	T3	T4		T1			T2			T3			T4		
								O	N	D	J	F	M	A	M	J	J	A	S
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- **System improvement**: adaptable & modular design

- Use of **3D printing / fast prototyping** → replacement of aluminium parts

- Verification of **analytical techniques** (spectral, cameras, filters)

- Extensive **platform testing**

- Field tests on **vineyards & soya fields**

- Platforms: **drones + tethered balloons**

- **Stratospheric launch (Pisa, 2024)**

  - ATEMO validated in extreme environment
  - Data comparison with satellites
 - Study of balloon–payload dynamics

PHD STUDENT | DATE | Federico Toson | | DATE | 10/09/25

PHD THESIS | ADMISSION TO | Observation | Aerospace Technologies for Earth Monitoring and Observation | Final Exam Admission | ADMISSION TO | Final Exam Admission

Università degli Studi di Padova

Third year

WBS TASK NUMBER / % TASK COMPLETE	TASK TITLE	T1	T2	T3	T4	T1	T2	T3		T1		T2		T3		T4	
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- All **GANTT milestones completed** on time

- Field campaigns with UAVs & stratospheric balloons → robust dataset

- **Platform performance optimization** under real conditions

- Development of **multi-platform calibration & data fusion**

- **Publications** in international journals & conferences
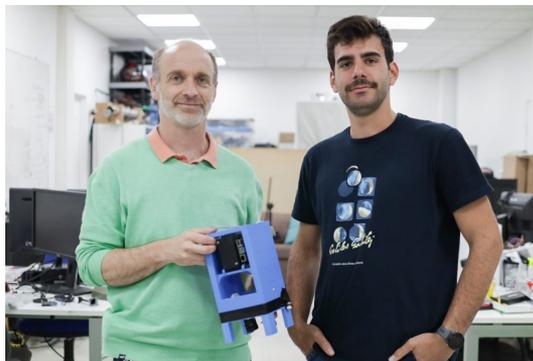
- **Iterative design & validation** of modular lightweight ATEMO structure

- **High flexibility & adaptability** across operational scenarios

- **experimental tests** in Italy & abroad

- Calibration procedures in dedicated laboratories

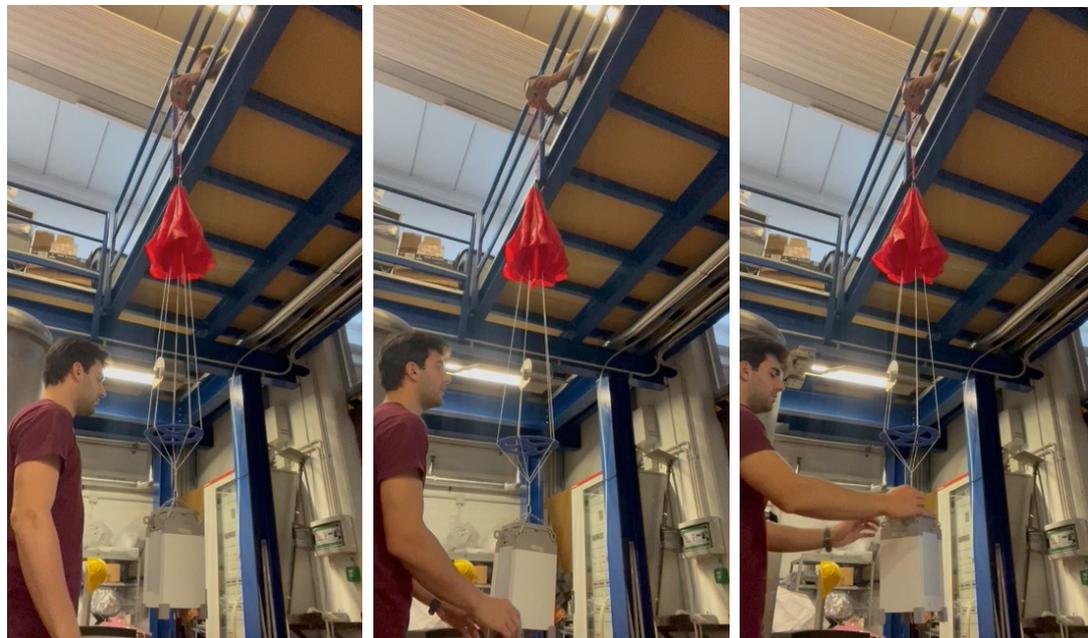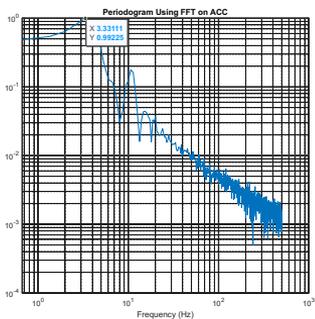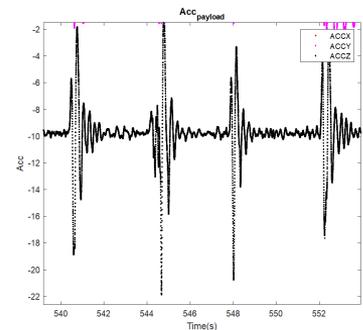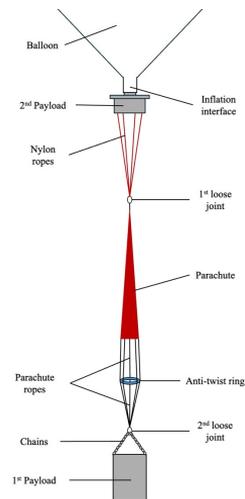- Focus on **flight dynamics**: pendular, torsional, longitudinal oscillations

LED 1

LED 2

LED 3

Federico Toson   Photo credits Henriette Hartmann   Aerospace Technologies for Earth Monitoring and Observation.   12/20
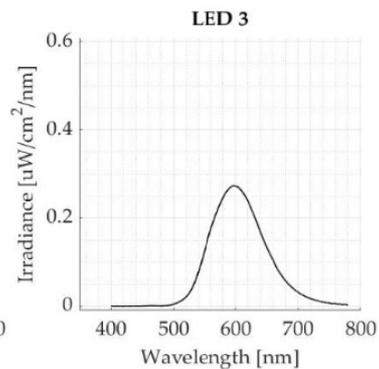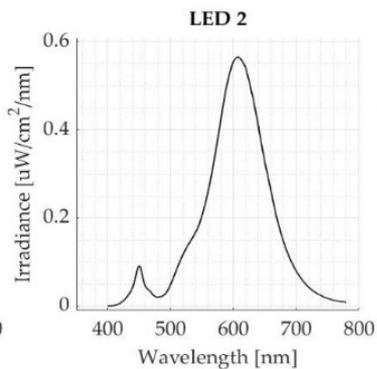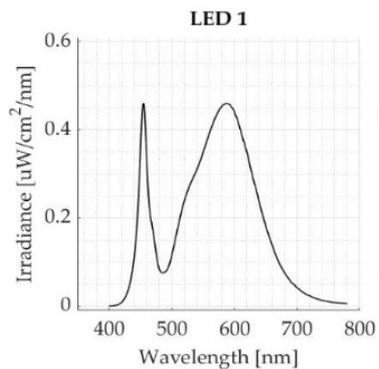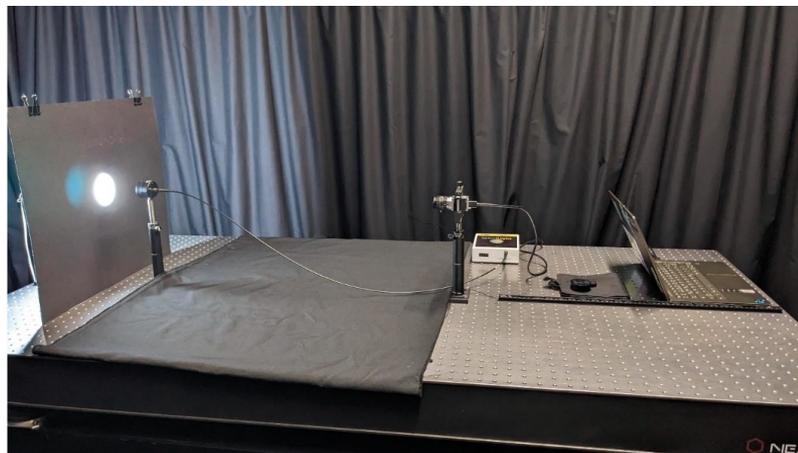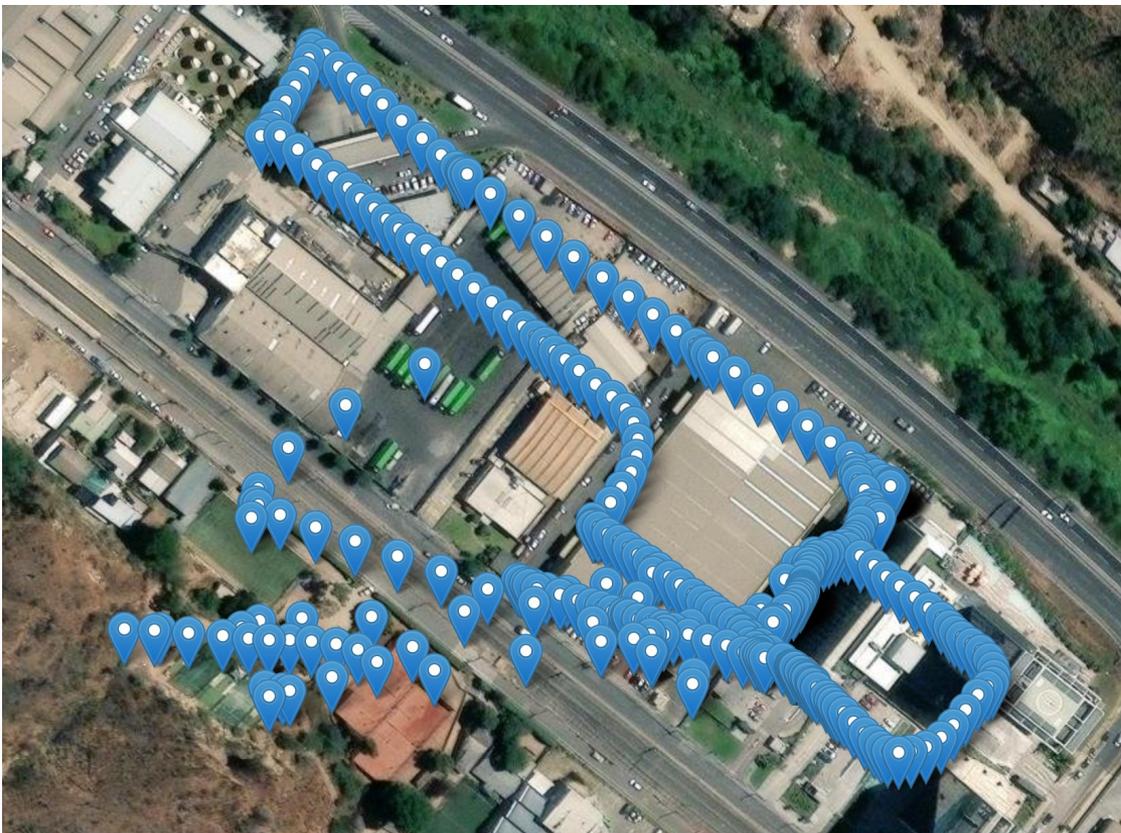
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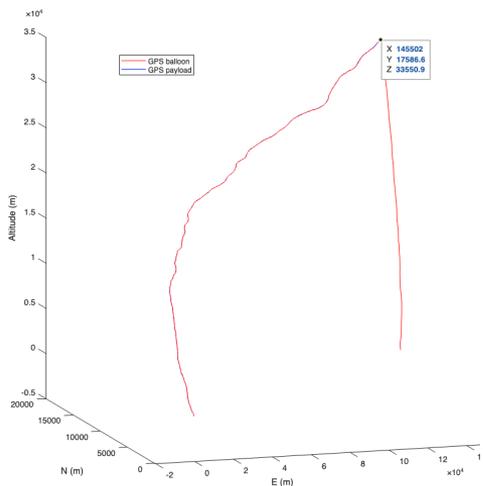
Model analysis

$f_{pendulum}$	0.31 ± 0.20 Hz
$f_{longitudinal}$	3.47 ± 0.20 Hz
$f_{torsional}$	0.20 ± 0.20 Hz

Flight results

$f_{pendulum}$	0.314 ± 0.015 Hz
$f_{longitudinal}$	3.15 ± 0.15 Hz
$f_{torsional}$	0.08 Hz ± 0.15 Hz
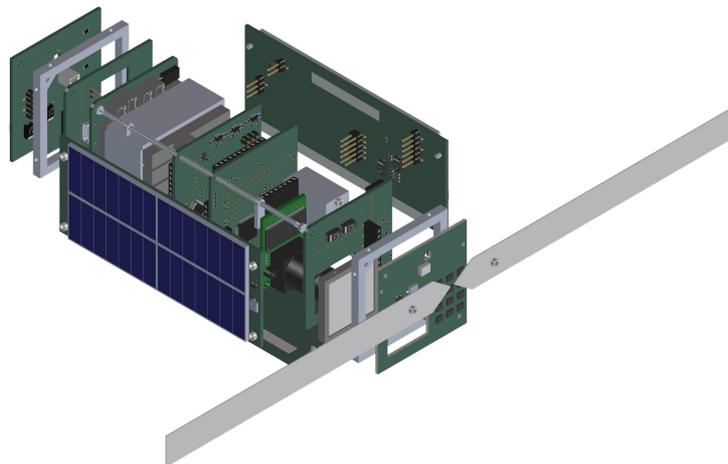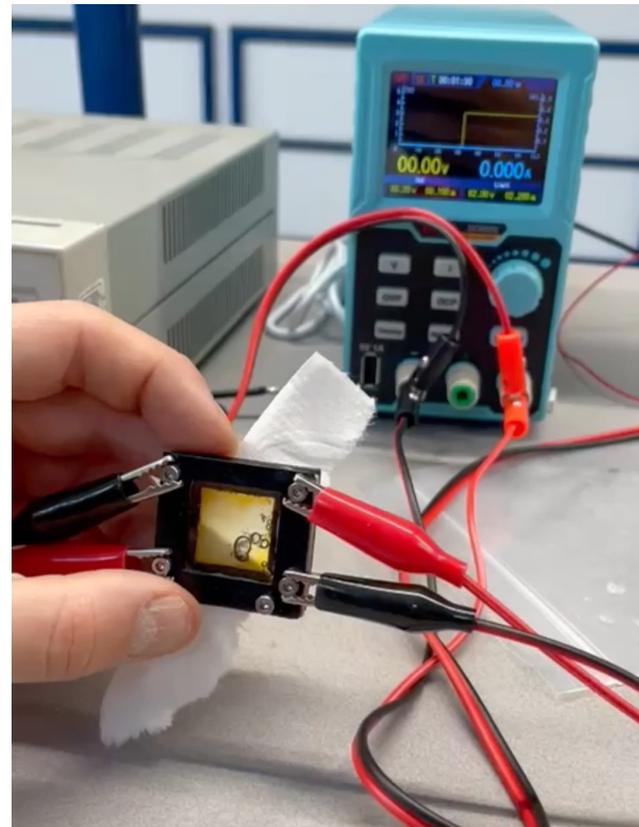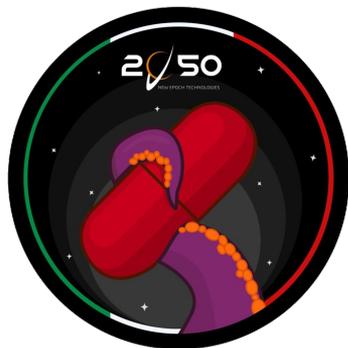
- **DAFNAE & TESAF**: Crops monitoring study *(Summer 2023, Summer 2024)*

- **University of Pisa:** Stratospheric balloon launches *(October 2024, December 2025)*

- **University of Chile**: Light Pollution research *(November 2024)*

- **AMU (Poland)**: E-FORESTER project *(June 2025)*

- **S3 Company (Cyprus):** E-FORESTER project *(summer 2025)*

- **Veneto Region and innovative industrial cluster projects:** SATSDIFACTION, SATCO, AMOS

- Paper collection thesis

Launch of an Innovative Air Pollutant Sampler up to 27,000 Metres Using a Stratospheric Balloon

Federico Toson[1] · Mauro Pulice[1] · Marco Furiato[1] · Matilde Pavan[1] · Simone Sandon[1] · Dumitrita Sandu[1] · Giovanni Righi[1]

Development and Preliminary Testing of the ATEMO Multi-Purpose Sensing Platform

Federico Toson[1] · Alessio Aboudan[1] · Carlo Bettanini[1,2] · Giacomo Colombatti[1,2] · Irene Terlizzi[1] · Sebastiano Chiodini[1,2] · Lorenzo Olivieri[1,2] · Giovanni Trevisanuto[3]

Characterisation of the flight chain for sounding balloon missions

Publisher: IEEE   Cite This   PDF

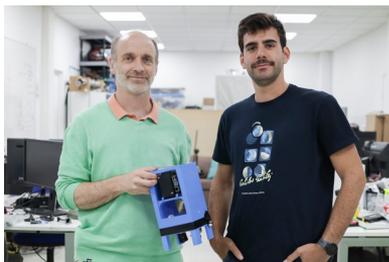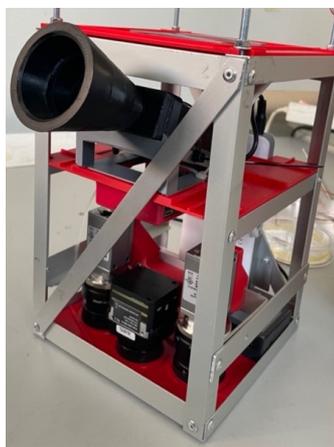Federico Toson ; Carlo Bettanini   All Authors

20 March 2025
The J2050 student PocketQube for space debris investigation and optical observation technology development

Federico Toson, Giacomo Porcarelli, Greta Rosa, Lorenzo Olivieri, Giacomo Colombatti

- Flight Chain Dynamics Validation and Balloon Ascent Modeling: From Pre-Launch Characterization to Real Flight Data Comparison (submitted to ACTA Astronautica)

- Light Pollution work to be concluded and submitted to different Journals and conferences

- ATEMO platform proved effective as a **modular, multi-carrier sensing architecture** for environmental monitoring

- Experimental campaigns validated **flight dynamics models** and confirmed system performance in operational conditions

- Integration of **multi-platform calibration and data fusion** enhanced data accuracy and reliability

- Research bridged **aerospace engineering methodologies with environmental sensing requirements**

- Foundation laid for **development of autonomous mission planning and advanced sensor integration**

- Established strong interdisciplinary and institutional collaborations, supporting **future scalable aerospace applications**

Aerospace Technologies for Earth Monitoring and Observation.

Thank you for your attention

Federico Toson   -   38th Cycle

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