Mattia **Pugliatti**

Ph.D. Student · GNC & Mission design

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"You never fail until you stop trying"

Research interests

I am a curious, ambitious and creative researcher. My areas of interest are autonomous optical navigation, artificial intelligence, GNC, and small-bodies exploration. My career goal is to become a specialist in interplanetary missions and autonomous GNC design.

Experience

Ph.D. Student & Early Stage Researcher   *Milan, Italy*

POLITECNICO DI MILANO, *DART laboratory*   *Nov. 2019 - Present*

- Artificial intelligence for enhanced optical navigation techniques around small-bodies. Design and validation of autonomous GNC systems for interplanetary CubeSats.
- Mission analysis, image processing, and GNC design of the Milani mission. Team leader of the GNC group for the Milani mission.
- Marie Skłodowska Curie ESR13 of Stardust-R, the European Training Network on asteroids and space debris.

Visiting researcher   *Bremen, Germany*

DEUTSCHES FORSCHUNGSZENTRUM FÜR KÜNSTLICHE INTELLIGENZ, *DFKI*   *Feb. 2023 - May. 2023*

- Visiting researcher at the German center for artificial intelligence under the supervision of Dr. Marko Jankovic and Prof. Frank Kirchner.
- Visual digital twin of an analog crater facility for data-driven applications.
- Dataset generation with a Vicon-drone camera setup. Pose and visual labeling of the images with a digital twin.

Visiting researcher   *Tucson, Arizona, USA*

UNIVERSITY OF ARIZONA, *SSEL*   *Sept. 2021 - Jan. 2022*

- Visiting researcher at the Space System Engineering Laboratory under the supervision of professor Roberto Furfaro.
- Deep-learning and convolutional extreme learning machine methods for precise optical navigation in the proximity of a small-body.
- Recurrent neural networks and reinforcement learning for autonomous close-proximity operations.

GNC project engineer   *Madrid, Spain*

GMV, *SPS/GNC division - Interplanetary section*   *Sept. 2018 - Sept. 2019*

- GNC project engineer of the HERA mission, a technology demonstration mission to visit the Didymos binary system.
- Design and testing of the visual based navigation strategy for the proximity operation phases of the Hera mission for phases A and B1.
- Incremental testing and validation campaign using higher fidelity models: model-in-the-loop (with PANGU), software-in-the-loop and hardware-in-the-loop (responsible for the optical facility testbench and robotic facility simulations).

Visiting researcher   *Sagamihara, Japan*

JAXA, *Institute of Space and Astronautical Science*   *March. 2017 - Nov. 2017*

- Visiting researcher under the supervision of professor Yasuhiro Kawakatsu.
- Member of the trajectory design teams of EQUULEUS CubeSat and DESTINY smallsat missions.
- EQUULEUS: 6U CubeSat to be deployed during the maiden flight of the SLS to reach a NRHO about the L2 point of the Earth–Moon system. Team leader of the first-guess trajectory design group. Maintenance and implementation of a toolbox for the generation of large set of first-guess transfer trajectories in full-ephemeris model of the Sun–Earth–Moon system using SPICE and jPRO.
- DESTINY: Technology demonstration mission to investigate Phaethon asteroid. Trajectory design of the multiple lunar flyby phase with the application of a Moon-to-Moon database in the Earth–Moon CR3BP.

Internship   *Friedrichshafen, Germany*

AIRBUS DEFENCE AND SPACE, *Future programmes department*   *Jul. 2016 - Dec. 2016*

- Mission and spacecraft design of $NEOT\omega IST$, a low-cost impactor demonstration and characterization mission on Itokawa. Part of the NEOShield-2 project, supported by the European programme H2020.
- Focus on the flyby trajectory and formation flight design, high level assessment of a tracking strategy, and system engineering design of the flyby module.

Education

Delft University of Technology   *Delft, The Netherlands*

M.Sc. in Spaceflight   *Sep. 2015 - Mar. 2018*

- Specialization in space exploration, transfer orbit profile.
- Key courses: Mission Geometry and Orbit design, Planetary sciences, Astrodynamics I & II, Space Project, Microsatellite engineering.
- Thesis on the Extended Tisserand–Poincaré graph for multi-body trajectory design in the patched CR3BP model: Extension of the current theoretical framework in the CR3BP of the Tisserand parameter about the primary to a modified Tisserand parameter about the secondary, existing on a specific family of Poincaré sections.
- Generic formulation valid for any patched CR3BP model sharing the same body as primary and secondary, with applicability for EQUULEUS and DESTINY in the Sun–Earth–Moon system, and for capture trajectories in the Sun–Jupiter–Europa system.
- Final grade: 9.5/10 Cum Laude. Manuscript available at TU Delft repository.

Politecnico di Milano   *Milan, Italy*

B.Sc. in Aerospace Engineering   *Sep. 2012 - Sep. 2015*

- Key courses: Fundamental of Space Missions, Applied Numerical Analysis, Theoretical Mechanics, Automatic Control.
- Final grade: 106/110.

Publications

2023

J8 **"Onboard State Estimation Around Didymos with Recurrent Neural Networks and Segmentation Maps"**, **M. Pugliatti**, A. Scorsoglio, R. Furfaro, F. Topputo. IEEE Transactions on Aerospace and Electronic Systems, 2023, doi:10.1109/TAES.2023.3288506

J7 **"The vision-based guidance, navigation, and control system of Hera's Milani Cubesat"**, **M. Pugliatti**, F. Piccolo, A. Rizza, V. Franzese, F. Topputo. Acta Astronautica, 2023, Volume 210, Pages 14–28, doi:10.1016/j.actaastro.2023.04.047, preprint

2022

J6 **"Small-Body Segmentation Based on Morphological Features with a U-Shaped Network Architecture"**, **M. Pugliatti**, M. Maestrini. Journal of Spacecraft and Rockets, 2022, Volume 59, Issue 6, Pages 1821–1835, doi: 10.2514/1.A35447, preprint

J5 **"Data-Driven Image Processing for Onboard Optical Navigation Around a Binary Asteroid"**, **M. Pugliatti**, V. Franzese, F. Topputo. Journal of Spacecraft and Rockets, 2022, Volume 59, Issue 3, Pages 943–959, doi: 10.2514/1.A35213,preprint

J4 **"CubeSat landing simulations on small bodies using blender"**, P. Peñarroya, **M. Pugliatti**, F. Ferrari, S. Centuori, F. Topputo, M. Vetrisano, M. Sanjurjo-Rivo. Advances in Space Research, 2022, ISSN 0273-1177, doi:10.1016/j.asr.2022.07.044, preprint

J3 **"Image Processing Robustness Assessment of Small-Body Shapes"**, C. Buonagura, **M. Pugliatti**, F. Topputo. The Journal of the Astronautical Sciences, 2022, Volume 69, Issue 6, Pages 1744–1765, doi:10.1007/s40295-022-00348-6, preprint

2021

J2 **"Preliminary mission profile of Hera's Milani CubeSat"**, F. Ferrari, V. Franzese, **M. Pugliatti**, C. Giordano, F. Topputo. Advances in Space Research, 2021, Volume 67, Issue 6, Pages 2010–2029, doi:10.1016/j.asr.2020.12.034, preprint

J1 **"Trajectory Options for Hera's Milani CubeSat Around (65803) Didymos"**, F. Ferrari, V. Franzese, **M. Pugliatti**, C. Giordano, F. Topputo. The Journal of the Astronautical Sciences, 2021, Volume 68, Issue 4, Pages 973–994, doi:10.1007/s40295-021-00282-z, preprint

Conferences

*C24** **"The image processing of Milani: challenges after DART impact"**, M. Pugliatti, C. Giordano, F. Topputo, ESA-GNC conference, Sopot, Poland, June 2023

C23 **"The CubeSat Mission FUTURE: a Preliminary Analysis to Validate the On-board Autonomous Orbit Determination"**, C. Buonagura, S. Borgia, **M. Pugliatti**, A. Morselli, F. Topputo, F. Corradino, P. Visconti, L. Deva, A. Fedele, G. Leccese, S. Natalucci, ESA-GNC conference, Sopot, Poland, June 2023

C22 **"The Hera Milani CubeSat mission"**, C. Giordano, F. Ferrari, V. Franzese, **M. Pugliatti**, F. Piccolo, A. Rizza, T. Kohout, F. Dirri, A. Longobardo, C. Gisellu, E. Palomba, M. Cardi, F. Perez-Lissi, P. Martino, I. Carnelli, 5th COSPAR Symposium, 2023, Singapore, Apr 2023

*C21** **"The Design Pipeline of the Milani Mission: Overview and Challenges After DART Impact"**, M. Pugliatti, F. Topputo, StardustR Final Conference, Noordwijk, The Netherlands, Nov 2022

*C20** **"Enhanced Vision-Based Algorithms about Small Bodies: Lessons learned from the Stardust-R experience"**, M. Pugliatti, F. Topputo, StardustR Final Conference, Noordwijk, The Netherlands, Nov 2022

*C19** **"Robust boulder identification under varying illumination conditions"**, M. Pugliatti, F. Topputo, Space Imaging Workshop, Atlanta, Georgia, Oct 2022

C18 **"Hardware-In-the-loop Simulation Framework for CubeSats Proximity Operations: Application to the Milani Mission"**, A. Rizza, F. Piccolo, **M. Pugliatti**, P. Panicucci, F. Topputo, 73rd International Astronautical Congress, Paris, France, Oct 2022

C17 **"Deep learning for Navigation of Small Satellites about Asteroids: an introduction to the DeepNav Project"**, C. Buonagura, **M. Pugliatti**, F. Topputo, V. Franzese, F. Topputo, A. Zeqaj, M. Zannoni, M. Varile, I. Bloise, F. Fontana, F. Rossi, L. Feruglio, M. Cardone, AII conference, Reggio Calabria, Italy, Sept 2022

*C16** **"Object Recognition Algorithms for the Didymos Binary System"**, M. Pugliatti, F. Piccolo, F. Topputo, AII conference, Reggio Calabria, Italy, Sept 2022

C15 **"Mission analysis and navigation assessment for Hera's Milani CubeSat"**, C. Bottiglieri, F. Piccolo, A. Rizza, **M. Pugliatti**, V. Franzese, C. Giordano, F. Ferrari, F. Topputo, 4S Symposium, Vilamoura, Portugal, May 2022

C14 **"Procedural minor body generator tool for data-driven optical navigation methods"**, C. Buonagura, **M. Pugliatti**, F. Topputo, CEAS, Berlin, Germany, May 2022

*C13** **"Toward verification and validation of the Milani Image Processing Pipeline in the hardware-in-the-loop testbench TinyV3RSE"**, F. Piccolo, **M. Pugliatti**, P. Panicucci, F. Topputo, AAS-GNC, Breckenridge, Colorado, Feb 2022

*C12** **"Design of the On-Board Image Processing of the Milani Mission"**, M. Pugliatti, F. Piccolo, A. Rizza, V. Franzese, C. Bottiglieri, C. Giordano, F. Ferrari, F. Topputo, AAS-GNC, Breckenridge, Colorado, Feb 2022

C11 **"Improvements and applications of the DART vision-based navigation test-bench TINYV3RSE"**, P. Panicucci, **M. Pugliatti**, V. Franzese, F. Topputo, AAS-GNC, Breckenridge, Colorado, Feb 2022

*C10** "**The Milani mission: overview and architecture of the optical-based GNC system**", **M. Pugliatti**, A. Rizza, F. Piccolo, V. Franzese, C. Giordano, C. Bottiglieri, F. Ferrari, F. Topputo, AIAA-SciTech, San Diego, California, Jan 2022

*C9** "**TINYV3RSE: The DART Vision-Based Navigation Test-bench**", **M. Pugliatti**, P. Panicucci, V. Franzese, F. Topputo, AIAA-SciTech, San Diego, California, Jan 2022

2021

C8 "**Trajectory design and orbit determination of Hera's Milani CubeSat**", C. Bottiglieri, F. Piccolo, A. Rizza, C. Giordano, **M. Pugliatti**, V. Franzese, F. Ferrari, F. Topputo, Astrodynamic Specialist Conference, Big Sky [Virtual], California, Aug 2021

C7 "**The Hera Milani CubeSat Mission**", F. Topputo, F. Ferrari, V. Franzese, **M. Pugliatti**, C. Giordano, A. Rizza, D. Calvi, G. Ammirante, F. Stesina, A. Esposito, S. Corpino, P. Visconti, R. Diaz de Cerio Goenaga, F. Corradino, A. Santoni, M. Cardi, T. Kohout, F. Perez-Lissi, P. Martino, I. Carnelli, 7th IAA Planetary Defense Conference, Vienna, Austria, Apr 2021

C6 "**Using Blender As Contact Dynamics Engine For Cubesat Landing Simulations Within Impact Crater On Dimorphos**", P. Peñarroya, **M. Pugliatti**, S. Centuori, F. Topputo, 7th IAA Planetary Defense Conference, Vienna, Austria, Apr 2021

*C5** "**Navigation about irregular bodies through segmentation maps**", **M. Pugliatti**, F. Topputo, 31st Space Flight Mechanics Meeting, Charlotte [Virtual], North Carolina, Feb 2021

*C4** "**Onboard Small-Body semantic segmentation based on morphological features with U-Net**", **M. Pugliatti**, M. Maestrini, P. di Lizia, F. Topputo, 31st Space Flight Mechanics Meeting, Charlotte [Virtual], North Carolina, Feb 2021.

2020

*C3** "**Small-Body shape recognition with Convolutional Neural Network and comparison with explicit features based methods**", **M. Pugliatti**, F. Topputo, Astrodynamic Specialist Conference, Lake Tahoe [Virtual], California, Aug 2020

2017

C2 "**NEOTωIST–Design Study of a Kinetic Impactor Demonstration Mission Featuring NEO Spin Change and Observer Sub-spacecraft**", K. Engel, **M. Pugliatti**, L. Drube, J.L. Cano, S. Eggl, D, Hestroffer, A. Falke, U. Johann, A. Harris, Planetary Defence Conference 2017, Tokyo, Japan, Aug 2017

2016
C1 "**NEOTωIST-An Asteroid Impactor Mission Featuring Sub-spacecraft for Enhanced Mission Capability**", K. Engel, **M. Pugliatti**, L. Drube, J.L. Cano, S. Eggl, D, Hestroffer, A. Falke, U. Johann, A. Harris, 67th International Astronautical Congress, Guadalajara, Mexico, Aug 2016

Datasets

D2 "**The image processing of Milani: challenges after DART impact**", (2023), doi:10.5281/zenodo.7962714. A dataset that accompanies the results presented at the ESA-GNC conference in 2023, Sopot, Poland for the work "The Design Pipeline of the Milani Mission: Overview and Challenges After DART Impact". The dataset can be used for phase angle regression from images of the Didymos system

D1   **"DOORS: Dataset fOr bOuldeRs Segmentation"**, (2022), doi:10.5281/zenodo.7107409. A dataset that accompanies the results presented at the ESA-GNC conference in 2023, Sopot, Poland for the work "Robust boulder identification under varying illumination conditions". The dataset can be used for several image-processing tasks related to small bodies and boulders such as regression, semantic segmentation, and classification

Supervision of M.Sc. thesis

All thesis are available at POLITesi

Name	AY	Title
Davide Gravina	2022-2023	*[provisional] Star-tracker calibration and validation.*
Fabio Piazza	2022-2023	*[provisional] Traditional horizon-based image processing enhanced by AI*
Marco Galeazzi	2022-2023	*[provisional] PINN for gravity modeling of binary systems.*
Andrea Gallina	2022-2023	*[provisional] PINN for stationkeeping in Halo orbits*
Giuseppe Addario	2021-2022	*Low-thrust spacecraft transfers using physics-informed neural networks*
Leonardo Gubello	2021-2022	*Image processing with traditional and artificial intelligence techniques for ship detection*
Lorenzo Beccari	2020-2021	*Image processing techniques for vision-based navigation around small bodies*
Francesco Carrasso	2020-2021	*A convolutional neural network model as image processing in cislunar environment*
Damien Morin	2020-2021	*Optimization of payload operations for a CubeSat in a double asteroid environment*
Marzio Agistri	2020-2021	*Star tracker measurement filtering via UF/EKF with recursive pre-filtering of IMU reading*
Marco Pavoni	2019-2020	*Small bodies centroiding via image processing and convolutional neural network*
Carmine Buonagura	2019-2020	*Image processing robustness assessment with procedural generated minor bodies shapes*

Projects contributions

- **COSMICA**: Validation and Verification for optical-based navigation algorithms with Hardware-in-the-loop facilities
- **SPARKS**: Technology demonstration missions for swarms. OSIP-funded.
- **STARNAV**: Vision-based navigation algorithms with Star-trackers.
- **DeepNAV**: Deep-learning methods for feature tracking algorithms around small bodies.
- **FUTURE**: CubeSat autonomous demonstration mission for autonomous optical navigation algorithms.

Space missions contributions

- **MILANI**: Mission analysis and GNC design and analysis, with a particular focus on autonomous OpNav techniques. Team leader of the GNC group. Designer of the image processing software. (2+ years of experience, from proposal to phase C)
- **HERA**: Testing of the visual-based navigation strategy. Model-in-the-loop, software-in-the-loop, hardware-in-the-loop with engineering camera model, optical laboratory and robotic facility. (1 year of experience, phases A and B1)
- **EQUULEUS**: Mission analysis and trajectory design in a high-fidelity multi-body system. (9 months of experience, phase A)
- **DESTINY+**: Mission analysis and trajectory design in a patched conics dynamic. (9 months of experience, phase A)
- **NEOTωIST**: Mission and spacecraft design, flyby trajectory and formation flight design, high level assessment of a tracking strategy and system engineering of the flyby module. (5 months of experience, phase 0)

Honors & Awards

Rocca fellowship *Boston-Milan*

May 2022

- Scholarship provided to fund 6-12 months of research stays at MIT for 5-6 Politecnico di Milano Ph.D. students every year. Progetto Roberto Rocca.
- A grant provided with the aim to increase the exchange of ideas between Massachusetts Institute of Technology and Politecnico di Milano.

Technical skills

- Programming languages and software: Python, Matlab, Simulink, STK, jPRO, C++, LaTeX.
- Operative systems: Linux, Microsoft, MacOS.
- Others: Blender, PANGU, Git, SPENVIS, Excel, Word, Power point.
- Teamwork: Problem solving, extensive experience in international teams (7+ years), fit for leadership positions, at ease with pressure.

Languages and personal interests

- Italian (Mother tongue), English (Advanced, TOEFL: 114/120 Nov 2017), Spanish & German (basic).
- I love backpacking, travelling around the world, exploring disparate cultures and tasting the most extravagant foods.