

# Mauro Massari

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## Education

- 2005 **Ph.D. in Aerospace Engineering**, *Politecnico di Milano*, Milan, Italy.  
Thesis *"Trajectory Optimization for Spacecraft flying in Formation"*
- 2000 **M.Sc. in Aerospace Engineering**, *Politecnico di Milano*, Milan, Italy.  
Thesis *Autonomous navigation of a vehicle for space exploration with stereographic cameras*

## Professional Experiences

- 2008–present **Assistant Professor**, *Politecnico di Milano*, Department of Aerospace Science and Technology, Milan, Italy.  
Currently teaching a course of Payload Design.  
Responsible of Admission to the M.Sc. in Aeronautical and Space Engineering.
- 2005–2008 **Post-Doctoral Fellow**, *Politecnico di Milano*, Department of Aerospace Science and Technology, Milan, Italy.  
Research topic: *"Methods and techniques for the space qualification of a university microsatellite"*

## Didactic Activity

- 2015–2019 Advisor of 2 Ph.D. thesis in Aerospace Engineering at Politecnico di Milano.
- 2008–2019 Advisor or Co-Advisor of more than 80 M.Sc. thesis in Space Engineering at Politecnico di Milano.
- 2016–2019 Professor of the Payload Design course for the M.Sc. in Space Engineering at Politecnico di Milano.
- 2011–2015 Professor of the Space Engineering Design Synthesis module in the Space System Design course for the M.Sc. in Space Engineering at Politecnico di Milano.
- 2012–2015 Professor of the Introduction to Space Mission Analysis course for the B.Sc. in Aerospace Engineering at Politecnico di Milano.
- 2009–2011 Professor of the Orbital Mechanics module in the Fundamentals of Flight Mechanics course for the B.Sc. in Aerospace Engineering at Politecnico di Milano.
- 2008–2009 Professor of the Space System course for the B.Sc. in Aerospace Engineering at Politecnico di Milano.
- 2003–2008 Teaching Assistant in the Space System Design course for the M.Sc. in Space Engineering at Politecnico di Milano.

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## Research Activity

- Space Robotics In this Field various aspect has been faced including:
- the development of two prototypes of wheeled rover,
  - the development of a stereographic artificial vision system for the identification of the surrounding environment,
  - the study of algorithms for path planning and control,
  - the development of an artificial vision system for robot motion estimation,
  - the study of an artificial vision system for the characterization and classification of the surrounding environment,
  - the study of control systems for legged locomotion based on dynamical neural networks,
  - the realization of a prototype of a legged robot,
  - the study of a rover autonomous control system based on a multi-layer architecture in which stochastic techniques are used for planning and scheduling, behavioural algorithms and artificial neural networks are used for plan execution,
  - the study of control algorithm for space manipulators.
- Trajectory Optimization In this Field various aspect has been faced including:
- optimal trajectories for missions to asteroids (NEO) with low-thrust propulsion,
  - optimal control problem solution with direct transcription methods,
  - optimal control problem solution with a parallel multiple-shooting method associated with an interior point method for the solution of the resulting NLP problem.
- Spacecraft Formation Flying In this Field various aspect has been faced including:
- optimization of low thrust reconfiguration maneuvers for formations of satellites in circular and eccentric reference orbit
  - station keeping control of formation of satellites with a model predictive controller,
  - distributed coordination of reconfiguration maneuvers for swarms of satellites in formation.
  - SDRE control of station keeping and reconfiguration maneuvers.
- Space Surveillance and Tracking In this Field various aspect has been faced including:
- orbit determination of space debris using multibeam bistatic radar Sensor,
  - monitoring of space debris with optical telescopes,
  - relative pose estimation of uncooperative targets with high order Kalman filters.
- Uncertainty Propagation in Astrodynamics In this Field various aspect has been faced including:
- development of a software library for Taylor differential algebra (DA),
  - uncertainty propagation in orbital dynamics using Taylor differential algebra,
  - uncertainty propagation in orbital dynamics using massively parallel Montecarlo simulations on GPGPUs.

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## Research Grants

The scientific activity has been performed also under the following research contracts:

### Principal Investigator

- Technology for Improving Re-Entry Predictions of European Upper Stages through Dedicated Observations, ESA Contract 4000114349/15/D/SR (Competitive call: ITT)

### Contributor

- Support to ISOC Processing software, ASI Contract.
- Studio di fattibilità per la realizzazione di un satellite geosincrono di osservazione della Terra – GEOSAR, ASI Contract
- Supporto alle Attività IADC e Validazione Pre-operativa per SST, ASI/INAF Contract
- Lunar CubeSats for Exploration (LUCÉ), ESA Contract 4000120225/17/NL/GLC/as (Competitive call: ITT)
- Assessment of onboard DA state estimation for spacecraft relative navigation. ESA Ariadna Contract No. IPL-PTE/LF/as/517.2016
- SpaceSHIP: Space Systems with Hybrid Propulsion, Regione Lombardia, Decree 5744 of 8/7/2015-2016, 2015 (Competitive call)
- Space Shepherd: Saving Human Lives through Satellite Imagery, Politecnico di Milano, 2014-2015 (Competitive call)
- Nonlinear Propagation of Uncertainties in Space Dynamics based on Taylor Differential Algebra, ESA Contract 4000109643/13/NL/MH (Competitive Call: ITT)
- Hybrid Propulsion Transfer Strategies. ESA Contract No. 4000105465/12/NL/AF (Competitive Call: ITT).
- Upgrade of the Uncertainty Propagation Module of STA. ESA Contract No. 4000102634.
- Assessment of Mission Design Including Utilization of Libration Points and Weak Stability Boundaries, ESA Contract 18147/04 (Competitive Call: Ariadna)
- Assessing the Accuracy of Interval Arithmetic Estimates in Space Flight Mechanics. ESA/ACT/Ariadna Contract No. 18851/05/NL/MV (Competitive Call: Ariadna)
- An Advanced Intelligent, Fault-tolerant System for Autonomy in Risky Environments. ESA Contract No. 18693/04/NL/MV (Competitive Call: ITI)
- Upgrade of Direct Interplanetary Trajectory Analysis Software (DITAN-2). ESA Contract, Subcontractor of Aurora B.V
- SIMONE: a NEO Space Mission Preparation Study. Subcontractor of QuinetiQ.

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## Publications

### Peer-Reviewed International Journal

- [1] D. Cutajar, A. Magro, J. Borg, K. Zarb Adami, G. Bianchi, C. Bortolotti, A. Cattani, F. Fiocchi, L. Lama, A. Maccaferri, A. Mattana, M. Morsiani, G. Naldi, F. Perini, G. Pupillo, M. Roma, S. Rusticelli, M. Schiaffino, P. Di Lizia, M. Losacco, M. Massari, M. Reali, and W. Villadei. A real-time space debris detection system for birales. *Journal of the British Interplanetary Society*, 71:102–108, 2019.
- [2] Francesco Cavenago, Pierluigi Di Lizia, Mauro Massari, and Alexander Wittig. On-board spacecraft relative pose estimation with high-order extended kalman filter. *Acta Aeronautica*, 158:55–67, 2019.

- [3] Mauro Massari, Pierluigi Di Lizia, and Mirco Rasotto. Nonlinear uncertainty propagation in astrodynamics using differential algebra and graphics processing units. *Journal of Aerospace Information Systems*, 14:493–503, 2017.
- [4] Francesco Cavenago, Lorenzo Voli, and Mauro Massari. Adaptive hybrid system framework for unified impedance and admittance control. *Journal of Intelligent & Robotic Systems*, 91:569–581, 2018.
- [5] Paolo Massioni and Mauro Massari. Convex optimisation approach to constrained fuel optimal control of spacecraft in close relative motion. *Advances in Space Research*, 61:2366–2376, 2018.
- [6] M. Massari and A. Wittig. Optimization of multiple-rendezvous low-thrust missions on general-purpose graphics processing units. *Journal of Aerospace Information Systems*, 13:80–92, 2016.
- [7] A. G. Castiglioni, M. B. Bigdeli, C. Palamini, D. Martinoia, L. Frezza, B. Matassini, D. Pizzocri, and M. Massari. Spaceship earth. space-driven technologies and systems for sustainability on ground. *Acta Astronautica*, 115:195–205, 2015.
- [8] Mauro Massari and M. Zamaro. Application of sdre technique to orbital and attitude control of spacecraft formation flying. *Acta Astronautica*, 94:409–420, 2014.
- [9] M. Massari, F. Bernelli Zazzera, and S. Canavesi. Nonlinear control of formation flying with state constraints. *Journal of Guidance Control and Dynamics*, 35:1919–1925, 2012.
- [10] M. Massari and F. Bernelli Zazzera. Optimization of low-thrust reconfiguration maneuvers for spacecraft flying in formation. *Journal of Guidance Control and Dynamics*, 32:1629–1638, 2009.
- [11] M. Ceriotti, M. Vasile, G. Giardini, and M. Massari. Approach to model interest for a planetary rover through dezert-smarandache theory. *Journal of Aerospace Computing, Information, and Communication*, 6:92–108, 2009.
- [12] M. Massari, G. Sangiovanni, and F. Bernelli Zazzera. N.e.me.sys: a planetary legged rover controlled with dynamical artificial neural networks. *Intelligent Automation and Soft Computing*, 14:263–278, 2008.
- [13] M. Massari. Optimization of relative orbit transfer with low thrust propulsion. *International Journal of Mechanics and Control*, 8:9–22, 2007.

### Book Chapters

- [14] S. Speretta, A. Cervone, P. Sundaramoorthy, R. Noomen, S. Mestry, A. Cipriano, F. Topputo, J. Biggs, P. Di Lizia, M. Massari, K. Mani, D. Dei Tos, S. Ceccherini, V. Franzese, A. Ivanov, D. Labate, L. Tommasi, A. Jochemsen, J. Gailis, R. Furfaro, V. Reddy, J. Vennekens, and R. Walker. *LUMIO: an Autonomous CubeSat for Lunar Exploration*, pages 103–134. Springer, Cham, 2019.
- [15] Topputo Francesco and Massari Mauro. *Modeling and Optimization of Hybrid Transfers to Near-Earth Objects*, pages 425–442. Springer, 2016.

### International Conferences

- [16] Mauro Massari, Francesco Cavenago, and Marco Canafoglia. Virtual model control for planetary hexapod robot walking on rough terrain. In *2019 IEEE Aerospace Conference*, pages 1–10. IEEE, 2019.

- [17] M. Losacco, P. Di Lizia, M. Massari, G. Bianchi, G. Pupillo, A. Mattana, G. Naldi, C. Bortolotti, M. Roma, M. Schiaffino, F. Perini, L. Lama, A. Magro, D. Cutajar, J. Borg, W. Villadei, and M. Reali. The multibeam radar sensor birales: Performance assessment for space surveillance and tracking. In *2019 IEEE Aerospace Conference*, pages 1–13, 2019.
- [18] Francesco Cavenago, Alessandro M. Giordano, Garching Bei Munchen, and Mauro Massari. An approach to contact detection and isolation for free-floating space robots based on momentum monitoring. In *2019 IEEE Aerospace Conference*, pages 1–9. IEEE, 2019.
- [19] M. Massari, P. Astori, and F. Cavenago. Semi-active damping system characterization for landing in microgravity. In *2019 IEEE Aerospace Conference*, pages 1–8, 2019.
- [20] A. Scorsoglio, R. Furfaro, R. Linares, and M. Massari. Actor-critic reinforcement learning approach to relative motion guidance in near-rectilinear orbit. In *29th AAS/AIAA Space Flight Mechanics Meeting*, pages 1–20, 2019.
- [21] M. Massari and P. Massioni. Fuel-optimal convex trajectory optimization of rendezvous on elliptical orbits. In *29th AAS/AIAA Space Flight Mechanics Meeting*, pages 1–9, 2019.
- [22] F. Cavenago and M. Massari. Collision detection and isolation for free-floating space robots. In *69th International Astronautical Congress (IAC 2018)*, pages 1–8. International Astronautical Federation, IAF, 2018.
- [23] F. Topputo, M. Massari, J. Biggs, P. Di Lizia, D. Dei Tos, K. Mani, S. Ceccherini, V. Franzese, A. Cervone, P. Sundaramoorthy, S. Speretta, S. Mestry, R. Noomen, A. Ivanov, D. Labate, A. Jochemsen, R. Furfaro, V. Reddy, K. Jacquinet, R. Walker, J. Vennekens, A. Cipriano, and D. Koschny. Lumio: Charazterizing lunar meteoroid impacts with a cubesat. In *69th International Astronautical Congress (IAC 2018)*, pages 1–11. International Astronautical Federation, IAF, 2018.
- [24] D. A. Santeramo, M. Massari, P. Di Lizia, C. Marzo, and L. Muolo. Polimi optical sensor for space surveillance and tracking. In *69th International Astronautical Congress (IAC 2018)*, pages 1–6. International Astronautical Federation, IAF, 2018.
- [25] M. Losacco, P. Di Lizia, M. Massari, A. Mattana, F. Perini, M. Schiano, C. Bortolotti, M. Roma, G. Naldi, G. Pupillo, G. Bianchi, L. Lama, D. Cutajar, A. Magro, C. Portelli, M. Reali, and W. Villadei. The multibeam radar sensor birales: Performance assessment for space surveillance and tracking. In *69th International Astronautical Congress (IAC 2018)*, pages 1–9, 2018.
- [26] D. Cutajar, A. Magro, J. Borg, K. Zarb Adami, G. Bianchi, C. Bortolotti, A. Cattani, F. Fiocchi, L. Lama, A. Maccaferri, A. Mattana, M. Morsiani, G. Naldi, F. Perini, G. Pupillo, M. Roma, S. Rusticelli, M. Schiaffino, P. Di Lizia, M. Losacco, M. Massari, M. Reali, and W. Villadei. A real-time space debris detection system for birales. In *69th International Astronautical Congress (IAC 2018)*, pages 1–9, 2018.
- [27] P. Sundaramoorthy, F. Topputo, M. Massari, J. Biggs, P. Di Lizia, D. Dei Tos, K. Mani, S. Ceccherini, V. Franzese, A. Cervone, S. Speretta, S. Mestry, R. Noomen, A. Ivanov, D. Labate, A. Jochemsen, R. Furfaro, V. Reddy, K. Jacquinet, R. Walker, J. Vennekens, A. Cipriano, S. Pepper, and M. van de Poel. System design of lumio: a cubesat at earth-moon l2 for observing lunar meteoroid impacts. In *69th International Astronautical Congress (IAC 2018)*, pages 1–8. International Astronautical Federation, IAF, 2018.

- [28] Stefano Speretta, Francesco Topputo, James Biggs, Pierluigi Di Lizia, Mauro Massari, Karthik Mani, Diogene Dei Tos, Simone Ceccherini, Vittorio Franzese, Angelo Cervone, Prem Sundaramoorthy, Ron Noomen, Samiksha Mestry, Ana do Carmo Cipriano, Anton Ivanov, Demetrio Labate, Leonardo Tommasi, Arnoud Jochemsen, J Gailis, Roberto Furfaro, Vishnu Reddy, Johan Vennekens, and Roger Walker. Lumio: achieving autonomous operations for lunar exploration with a cubesat. In *SpaceOps 2018 Conference and Exhibition*, pages 1–11. American Institute of Aeronautics and Astronautics, 2018.
- [29] D. Dei Tos, F. Topputo, M. Massari, J. Biggs, and A. Cipriano. On the sophisticated orbit design of the lunar meteoroid impacts observer cubesat. In *69th International Astronautical Congress (IAC 2018)*, pages 1–13. International Astronautical Federation, IAF, 2018.
- [30] F. Topputo, M. Massari, J. Biggs, P. Di Lizia, D. Dei Tos, K. Mani, S. Ceccherini, V. Franzese, A. Cervone, P. Sundaramoorthy, S. Speretta, S. Mestry, R. Noomen, A. Ivanov, D. Labate, A. Jochemsen, R. Furfaro, V. Reddy, K. Jacquinet, R. Walker, J. Vennekens, and A. Cipriano. Lumio: a cubesat at earth-moon l2. In *4S Symposium*, pages 1–15, 2018.
- [31] Matteo Losacco, Pierluigi Di Lizia, Mauro Massari, Andrea Mattana, Federico Perini, Marco Schiaffino, Claudio Bortolotti, Mauro Roma, Giovanni Naldi, Giuseppe Pupillo, Germano Bianchi, Denis Cutajar, Alessio Magro, Claudio Portelli, Marco Reali, and Walter Villadei. Orbit determination of resident space objects with the multibeam radar sensor birales. In *Space Flight Mechanics Meeting - AIAA SciTech 2018*, pages 1–20. American Institute of Aeronautics and Astronautics, 2018.
- [32] Francesco Cavenago, Pierluigi Di Lizia, Mauro Massari, Simone Servadio, and Alexander Wittig. Da-based nonlinear filters for spacecraft relative state estimation. In *Space Flight Mechanics Meeting - AIAA SciTech 2018*, pages 1–17. American Institute of Aeronautics and Astronautics, 2018.
- [33] Mauro Massari, Pierluigi Di Lizia, Francesco Cavenago, and Alexander Wittig. Differential algebra software library with automatic code generation for space embedded applications. In *AIAA Information Systems-AIAA Infotech @ Aerospace - AIAA SciTech 2018*, pages 1–12. American Institute of Aeronautics and Astronautics, 2018.
- [34] G. Bianchi, C. Bortolotti, A. Cattani, F. Focchi, A. Maccaferri, A. Mattana, M. Morsiani, G. Naldi, F. Perini, A. Porfido, G. Pupillo, M. Roma, S. Rusticelli, M. Schiaffino, E. Urru, P. Di Lizia, M. Losacco, M. Massari, J. Borg, D. Cutajar, A. Magro, M. Reali, and W. Villadei. A new approach to leo space debris survey: the italian multibeam bi-static radar ‘birales’. In *1st IAA Conference on Space Situational Awareness (ICSSA)*, pages 1–18, 2017.
- [35] Francesco Cavenago, Pierluigi Di-Lizia, Mauro Massari, and Alexander Wittig. On-board da-based state estimation algorithm for spacecraft relative navigation. In *7th European Conference for Aerospace Sciences (EUCASS 2017)*, pages 1–14, 2017.
- [36] Pierluigi Di Lizia, Mauro Massari, Matteo Losacco, G. Bianchi, A. Mattana, G. Pupillo, C. Bortolotti, M. Roma, Alessandro Morselli, Roberto Armellin, A. Magro, D. Cutajar, C. Portelli, and M. Reali. Performance assessment of the multibeam radar sensor birales for space surveillance and tracking. In *7th European Conference on Space Debris, ESA/ESOC*, pages 1–13. ESA, 2017.
- [37] Gianinnetto Marco, Aiello Martina, Marchesi Andrea, Topputo Francesco, Massari Mauro, Lombardi Riccardo, Banda Francesco, and Tebaldini Stefano. Obia ship detection with multispectral and sar images: A simulation for copernicus security applications. In

*2016 International Geoscience and Remote Sensing Symposium (IGARSS 2016)*, pages 1229–1232, New York, NY, 2016. IEEE.

- [38] M. Rasotto, G. Di Mauro, M. Massari, P. Di Lizia, R. Armellin, Q. Funke, and T. Flohrer. Optimization of observation strategy to improve re-entry prediction of objects in heo. In *17th Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS 2016)*, pages 1309–1323, Red Hook, NY, 2016. Curran Associates.
- [39] A. Zuanetti, F. Topputo, and M. Massari. Integrated monitoring of refugees in the mediterranean sea with small satellite constellations. In *67th International Astronautical Congress (IAC 2016)*, pages 1–9. International Astronautical Federation, IAF, 2016.
- [40] M. Rasotto, A. Morselli, A. Wittig, M. Massari, P. Di Lizia, R. Armellin, C. Y. Valles, and G. Ortega. Differential algebra space toolbox for nonlinear uncertainty propagation in space dynamics. In *6th International Conference on Astrodynamics Tools and Techniques (ICATT)*, pages 1–11, 2016.
- [41] G. Di Mauro, M. Rasotto, M. Massari, P. Di Lizia, R. Armellin, Q. Funke, and T. Flohrer. Design of optimal observation strategy for re-entry prediction improvement of gtos upper stage. In *6th International Conference on Astrodynamics Tools and Techniques (ICATT)*, pages 1–8, 2016.
- [42] M. Massari, P. Di Lizia, and M. Rasotto. Nonlinear uncertainty propagation in astrodynamics: Comparing taylor differential algebra with monte-carlo on gpus. In *Spaceflight Mechanics 2016*, pages 2373–2388, San Diego, CA, 2016. Univelt.
- [43] F. Topputo, D. A. Dei Tos, D. Filippetto, A. Rivolta, M. Massari, A. Rocchi, P. Di Lizia, J. L. Gonzalo, H. Urrutxua, C. Bombardelli, V. Pesce, A. Colagrossi, and D. Pastor Moreno. Gtoc8: Results and methods of polimi-upm. In *Spaceflight Mechanics 2016*, pages 4301–4308, San Diego, CA, 2016. Univelt.
- [44] F. Topputo, M. Massari, R. Lombardi, M. Gianinetto, A. Marchesi, M. Aiello, S. Tebaldini, and F. Banda. Space shepherd: using space assets to monitor, track, and search-and-rescue illegal immigrants in the mediterranean sea. In *66th International Astronautical Congress (IAC 2015) - Space The Gateway for Mankind's Future*, pages 11422–11431, Red Hook, NY, 2015. Curran Associates.
- [45] F. Topputo, M. Massari, R. Lombardi, M. Gianinetto, A. Marchesi, M. Aiello, S. Tebaldini, and F. Banda. Space shepherd: Search and rescue of illegal immigrants in the mediterranean sea through satellite imagery. In *Remote Sensing - Understanding the earth for a safer world: IGARSS 2015*, pages 4852–4855, New York, NY, 2015. IEEE.
- [46] M. Massari and A. Wittig. Massively parallel optimization of target sequences for multiple-rendezvous low-thrust missions on gpus. In *Spaceflight Mechanics 2015*, pages 1841–1853, San Diego, CA, 2015. Univelt.
- [47] F. L. Consonni, B. Buffa, D. A. Dianda, F. Manelli, M. Molinelli, D. Pizzocri, and M. Massari. Greenspace: Towards a systematic, global and innovative evaluation of the environmental impact of space activities for a safe and sustainable space environment. In *65th International Astronautical Congress 2014 (IAC 2014)*, pages 9474–9484, Red Hook, NY, 2014. Curran Associates.
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- [67] R. Armellin, M. Massari, and A. Ercoli Finzi. Optimal formation flying reconfiguration and station keeping maneuvers using low thrust propulsion. In *18th International Symposium on Space Flight Dynamics (ESA SP-548)*, pages 429–434, Noordwijk, 2004. ESA.
- [68] M. Massari, G. Giardini, and F. Bernelli Zazzera. Artificial vision system for movement determination of an autonomous planetary exploration rover based on discrete optical flow and stereo geometry. In *Dynamics and Control of Systems and Structures in Space (DCSSS) 6th Conference*, pages 143–152, 2004.
- [69] M. Massari, F. Bernelli Zazzera, and M. Vasile. Trajectory optimization for a mission to neos, using low-thrust propulsion and gravity assist. In *Spaceflight mechanics 2003*, pages 317–329, San Diego, CA, 2003. Univelt.
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