Alessandro Morselli

Assistant Professor (RTDa) · Politecnico di Milano

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Short Bio

Alessandro Morselli is an Assistant Professor working at the DART laboratory of Politecnico di Milano. He is co-founder of Nautilus - Navigation in Space, a university spin-off that aims at providing flight dynamics services for SmallSat missions. During his PhD he developed innovative methods for uncertainty propagation of resident space objects, in-orbit collision probability computation and tailored algorithms for orbit determination with the BIRALES sensor. Between 2015 and 2021 he worked as Flight Dynamics Engineer at ESOC, gaining a solid background on space operations. He was involved in routine, cruise and critical operations for various missions, like Exomars, BepiColombo, SolarOrbiter.
His main research interests are astrodynamics, trajectory optimization, autonomous guidance and control applications (with focus on interplanetary transfers and aerobreaking), and hardware-in-the-loop simulations.

Professional Experience

Politecnico di Milano *Milano*

Assistant Professor *03/2023 - present*

He is member of the Deep-space Astrodynamics Research and Technology (DART) group and he is working on the ERC-funded research project EXTREMA (Engineering Extremely Rare Events in Astrodynamics for Deep-Space Missions in Autonomy). He is in charge of designing, integrating, and testing an experimental apparatus to assess the closed-loop guidance for autonomous Cubesats navigating in deep space. He also contributes in the coordination of the FUTURE mission studies (Phases A-B), CubeNav project, and ERC PoC GUIDO.

Nautilus - Navigation in Space Srl *Bologna*

Guidance and Control Lead and Founder *07/2021 - present*

Nautilus is a joint spin-off company between Politecnico di Milano and University of Bologna. Nautilus is the first private company in Europe to supply Mission Analysis and Flight Dynamics (Orbit Determination and Control) full package services for deep space CubeSat missions. He leads the development of the Guidance and Control applications and coordinates the company activities in the area of spacecraft guidance and trajectory control. He is the reference person for the company branch in Milan.

Politecnico di Milano *Milano*

Post-Doc Researcher *04/2021 - 02/2023*

Projects: EXTREMA (Engineering Extremely Rare Events in Astrodynamics for Deep-Space Missions in Autonomy).
Supervisor: Prof. Francesco Topputo.

Deimos Space @ ESA/ESOC *Darmstadt*

Flight Dynamics Engineer *03/2015 - 03/2021*

He was part of the *Test & Validation Orbit* (TVO) team, which is responsible for checking and validating all orbit-related activities, ranging from *orbit determination* and *navigation*, to *manoeuvre planning* and *trajectory optimization*. He worked on both *interplanetary* and *Earth-observation* missions, where he

- provided operational support to flying missions, from launch and early operations (LEOP) to routine phases,
- coordinated with the simulation officers to define the scenarios for simulation campaigns to train the Flight Dynamics team before launch or critical operations, also generating the tracking data for the simulations and system tests,
- developed software to support flying and upcoming missions, to check that all required mission constraints were fulfilled and that consistent orbit, interface files and products were distributed to other actors (e.g., scientists, Flight Control Team, other FD teams).

He has actively supported the following interplanetary missions:

- *Exomars-TGO*: LEOP, cruise, *Mars Orbital Insertion* and EDL landing, *Aerobraking*, science phase
- *BepiColombo*: LEOP, cruise with *solar electric propulsion*, *Earth and Venus Swing-By* operations

- *SolarOrbiter*: LEOP, cruise, *Venus Swing-By* operations

and the following Earth orbiting missions:

- Sentinel-3A and Sentinel-3B: LEOP, orbit acquisition, handover to EUMETSAT
- Galileo: 2 LEOPs (Soyuz), orbit acquisition and fine positioning
- Swarm: routine operations, constellation maintenance, collision avoidance
- Cluster-II: science operations, constellation maintenance
- XMM and Integral: science operations, validation attitude pointings and scheduled on-board activities

He *led the development of the new TVO orbit propagator* to support both interplanetary and Earth-observation missions. He also contributed to the creation of tools for computing and checking mission constraints, manoeuvre constraints, and mission-relevant orbital events (visibility, conjunctions, occultations, …). He was the *TVO team coordinator* for the *Exomars-RSP* mission and was providing support as TVO officer for the upcoming *Euclid* and *Juice* missions.

Dinamica Srl *Milan*

Senior Project Engineer *09/2014 - 03/2015*

His main assignment was a project to develop a software tool to perform non-linear propagation of uncertainties in space dynamics, under ESA contract. He contributed to the development of the Differential Algebra computational engine and of the software framework, besides writing documentation and reports. He took part at the intermediate and final project review in ESTEC.

Carlo Gavazzi Space - OHB Italia *Milan*

Junior Thermal Engineer *03/2011 - 10/2011*

He worked on the design and qualification of a satellite thermal control systems using Loop Heat Pipes and thermo-electric coolers. He designed and carried out thermal and mechanical testing campaigns on shaking tables, thermal vacuum chambers, and climate chambers.
He oversaw the functional and qualification tests of mechanical ground support equipment for Galileo satellites.

Education

Politecnico di Milano *Milan*

PhD - Aerospace Engineering *10/2011 - 12/2014*

- Thesis: *"High Order Methods for Space Situational Awareness"*
- Advisor: Prof. Franco Bernelli-Zazzera

The thesis work dealt with differential algebra applications to the space debris problem, ranging from measurements to orbit conjunctions management. The main achievements are:

- an orbit determination algorithm tailored for the Northern Cross multi-beam receiver, including the assessment of its performances
- efficient Monte Carlo methods for computing the collision probability between resident space objects, exploiting the high order expansions of the relative distance
- an approach to design fuel-optimal avoidance manoeuvres that fulfil mission constraints, using multi-objective optimization techniques.

Politecnico di Milano *Milan*

MSc - Space Engineering *09/2008 - 04/2011*

- Thesis: *"The space debris problem: collision risk assessment for perturbed orbits via rigorous global optimization"*
- Advisor: Prof. Franco Bernelli Zazzera

The thesis work focused on a new method to identify the Minimum Orbital Intersection Distance for perturbed orbits. A global optimizer (based on Taylor Models and Interval Arithmetic) is used to determine the minimum geometrical distance over a certain time frame between two orbits whose evolution is modelled with analytical and semi-analytical orbit theories (e.g., SGP4).

Politecnico di Milano *Milan*

BSc - Aerospace Engineering *09/2005 - 07/2008*

- Thesis: *"Development of a software simulator for the guidance, navigation, and control of a planetary rover: analysis and implementation of the artificial vision module"*
- Advisor: Prof. Michéle Lavagna

This work consisted in the implementation of a software module for a planetary rover simulator. Images of the planetary landscape were extracted from the simulator and then processed with computer vision algorithms to obtain depth maps and identify obstacles (e.g., rocks).

Publications

Peer-reviewed journal articles

Morselli, A.C., **Morselli, A.**, Giordano, C., Topputo, F., "Convex Trajectory Optimization Using Thrust Regularization". Journal of Guidance Control and Dynamics, 47 (2), 2024, 339-346.
DOI: 10.2514/1.G007646

Morselli, A., Armellin, R., Di Lizia, P., and Bernelli-Zazzera, F., "A high order method for orbital conjunctions analysis: Monte Carlo collision probability computation". Advances in Space Research, 55 (1), 2015, 311-333.
DOI: 10.1016/j.asr.2014.09.003

Morselli, A., Armellin, R., Di Lizia, P., and Bernelli-Zazzera, F., "A high order method for orbital conjunctions analysis: Sensitivity to initial uncertainties". Advances in Space Research, 53(3), 2014, 490-508.
DOI: 10.1016/j.asr.2013.11.038

Di Lizia, P., Armellin, R., **Morselli, A.**, and Bernelli-Zazzera, F., "High order optimal feedback control of space trajectories with bounded control". Acta Astronautica, 94(1), 2014, 383-394.
DOI: 10.1016/j.actaastro.2013.02.011

Armellin, R., **Morselli, A.**, Di Lizia, P., and Lavagna, M., "Rigorous computation of orbital conjunctions". Advances in Space Research, 50(5), 2012, 527-538.
DOI: 10.1016/j.asr.2012.05.011

Book chapters

Morselli, A., Armellin, R., Di Lizia, P., Bernelli-Zazzera, F., "Rigorous global optimization for collision risk assessment on perturbed orbits". In: Fasano G., Pintér J. (eds) Space Engineering. Springer Optimization and Its Applications, vol 114., pp 237-267, Springer, Cham.
DOI: 10.1007/978-3-319-41508-6_9

Di Domenico G., Andreis E., Morelli A. C., Merisio G., Franzese V., Giordano C., **Morselli, A.**, Panicucci P., Ferrari F., Topputo F., "The ERC-Funded EXTREMA Project: Achieving Self-Driving Interplanetary CubeSats". In: Fasano G., Pintér J. (eds) Space Engineering. Springer Optimization and Its Applications, vol 200., pp 167-199, Springer, Cham.
DOI: 10.1007/978-3-031-24812-2_6

PhD Thesis

Morselli, A., "High order methods for Space Situational Awareness", Politecnico di Milano, December 2014

Papers in Conference Proceedings

Morelli, A.C., **Morselli, A.**, Perico, D., Topputo, F., "The EXTREMA Autonomous Guidance Algorithm for Low-Thrust Interplanetary Spacecraft", 74th International Astronautical Congress 2023 (IAC), Baku, Azerbaijan (2023)

Morelli, A.C., **Morselli, A.**, Giordano, C., Topputo, F., "Combined Convex And Direct Shooting Optimization For Low-Thrust Trajectory Generation With Analytical Thrust Profile", 33rd AAS/AIAA Space Flight Mechanics Meeting, Austin, TX (2023)

Muylle, J., **Morselli, A.**, Lombardo, M., Locarini, A., Gomez-Casajus, L., Maggi, M., Zannoni, M., Topputo, F., Cottini, V., Ciabuschi, S., Natalucci, S., "CUBENAV: A Flight Dynamics Tool to Support Guidance and Navigation Operations of Deep-Space CubeSats", 12th International Conference on Guidance, Navigation & Control Systems (GNC) and 9th International Conference on Astrodynamics Tools and Techniques (ICATT), Sopot, Poland (2023)

Buonagura, C., Borgia, S., Pugliatti, M., **Morselli, A.**, Topputo, F., Corradino, F., Visconti, P., Deva, L., Fedele, A., Leccese, G., Natalucci, S. "The CubeSat Mission FUTURE: A Preliminary Analysis to Validate the On-Board Autonomous Orbit Determination", 12th International Conference on Guidance, Navigation & Control Systems (GNC) and 9th International Conference on Astrodynamics Tools and Techniques (ICATT), Sopot, Poland (2023)

Morselli, A., Morelli, A.C., Topputo, F., "ETHILE: a thruster-in-the-loop facility to enable autonomous guidance and control of autonomous interplanetary CubeSats", 73rd International Astronautical Congress 2022 (IAC), Paris, France (2022)

Morselli, A., Di Domenico, G., Andreis, E., Morelli, A.C., Merisio, G., Franzese, V., Giordano, C., Panicucci, P., Ferrari, F., Topputo, F., "The EXTREMA Orbital Simulation Hub: a Facility for GNC Testing of Autonomous Interplanetary CubeSat", Small Satellites Systems and Services - 4S Symposium, Vilamoura, Portugal (2022)

Di Domenico, G., Andreis, E., Morelli, A.C., Merisio, G., Franzese, V., Giordano, C., **Morselli, A.**, Panicucci, P., Ferrari, F., Topputo, F., "Toward Self-Driving Interplanetary CubeSats: the ERC-Funded Project EXTREMA", 72nd International Astronautical Congress 2021 (IAC), Dubai, UAE (2021)

Losacco, M., Romano, M., Di Lizia, P., Colombo, C., Armellin, R., **Morselli, A.**, Sanchez Pérez, J. M., "Advanced Monte Carlo sampling techniques for orbital conjunctions analysis and Near-Earth Objects impact probability computation". 1st NEO, Debris Detection Conference, Darmstadt, Germany, (2019)

Di Lizia, P., Massari, M., Losacco, M., Bianchi, G., Mattana, A., Pupillo, G., Bortolotti, C., Roma, M., **Morselli, A.**, Armellin, R., Magro, A., Cutajar, D., Portelli, C., Reali, M., "Performance assessment of the multibeam radar sensor Birales for Space Surveillance and Tracking", 7th European Conference on Space Debris, ESA/ESOC, Darmstadt, Germany (2017)

Rasotto, M., **Morselli, A.**, Wittig, A., Massari, M., Di Lizia, P., Armellin, R., Valles, C., Ortega, G., "Differential algebra space toolbox for nonlinear uncertainty propagation in space dynamics.", 6th International Conference on Astrodynamics Tools, Techniques (ICATT), Darmstadt, Germany, (2016)

Morselli, A. et al., "A new high sensitivity radar sensor for space debris detection and accurate orbit determination", 2015 IEEE Metrology for Aerospace (MetroAeroSpace), Benevento, (2015), pp. 562-567, DOI: 10.1109/MetroAeroSpace.2015.7180719

Morselli, A., Armellin, R., Di Lizia, P., Bernelli Zazzera, F., Salerno, E., Bianchi, G., Montebugnoli, S., Magro, A., Zarb Adami, K., "Orbit determination of space debris using a bi-static radar configuration with a multiple-beam receiver", 65th International Astronautical Congress 2014 (IAC), Toronto, Canada (2014)

Morselli, A., Armellin, R., Di Lizia, P., Bernelli-Zazzera, F., "Collision avoidance maneuver design based on multi-objective optimization.". 24th AAS/AIAA Space Flight Mechanics Meeting, Santa Fe, NM, USA (2014)

Morselli, A., Armellin, R., Di Lizia, P., Bernelli-Zazzera, F., "Computation of collision probabilities based on special perturbations and high order methods". 6th European Conference on Space Debris (ESA SP-723), ESOC, Darmstadt, Germany (2013)

Di Lizia, P., Armellin, R., **Morselli, A.**, Bernelli Zazzera, F., "High order optimal feedback control of low-thrust orbital transfers with saturating actuators". 1st IAA Conference on Dynamics, Control of Space Systems (DyCoSS), Porto, Portugal (2012)

Lavagna, M., Armellin, R., **Morselli, A.**, Serpelloni, E., "ASTREA: a Mars Lagrangian Point Base to Serve Asteroids Belt Cycling Missions", Global Space Exploration Conference (GLEX), Washington D.C., USA (2012)

Armellin, R., Di Lizia, P., **Morselli, A.**, Lavagna, M., "An orbital conjunction algorithm based on Taylor Models", 22nd AAS/AIAA Space Flight Mechanics Meeting, Charleston, SC, USA (2012)

Morselli, A., Armellin, R., Di Lizia, P., Bernelli Zazzera, F., "Computing collision probability using Differential Algebra and Advanced Monte Carlo Methods", 63rd International Astronautical Congress (IAC), Naples, Italy (2012)

Armellin, R., Di Lizia, P., **Morselli, A.**, Valli, M., Lavagna, M., Bernelli Zazzera, F., Berz, M., "High order algorithms for the management of uncertainties with applications in Space Situational Awareness". 5th International Conference on Astrodynamics Tools, Techniques (ICATT), Noordwijk, The Netherlands (2012)

Morselli, A., Armellin, R., Di Lizia, P., Bernelli Zazzera, F., "Collision risk assessment for perturbed orbits via rigorous global optimization", 62nd International Astronautical Congress (IAC), Cape Town, South Africa (2012)

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