Laura Titolo, Ph.D.

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https://lauratitolo.github.io/

I am a Principal Research Scientist at Code Metal working on applying formal methods to enhance the reliability of code transpilation techniques for edge computing and embedded systems applications. Prior to this role, I served as a Lead Research Scientist in the Safety-Critical Avionics Systems Branch at NASA Langley Research Center, and I was a member of the NASA Formal Methods Team. I earned my Ph.D. in Computer Science from the University of Udine (Italy), with part of my doctoral research conducted at the Technical University of Valencia (Spain). I hold a Bachelor's and a Master's degree in Computer Science from the University of Udine, both awarded with full marks and honors (summa cum laude).
My research focuses on the development and application of formal methods, particularly in the context of safety-critical systems. At NASA, I worked on advancing rigorous techniques for the verification and analysis of avionics software involving finite-precision computations. I was the technical lead and primary developer of PRECiSA, a static analyzer for round-off error estimations in floating-point programs, and ReFlow, an automatic code extractor that generates formally verified floating-point C implementations from real-valued specifications. I also contributed to the development of formal libraries for structured natural language requirements, hybrid systems verification, and temporal logic reasoning.
As part of the Formal Methods Team at NASA, I contributed to an in-depth formal analysis of the Compact Position Reporting (CPR) algorithm, a critical component of the Automatic Dependent Surveillance–Broadcast (ADS-B) protocol. I led the formal verification of the floating-point implementation of CPR, ensuring numerical accuracy and reliability. The proposed finite-precision C implementations of CPR are now the reference implementations in the international standard ED-102B/DO-260C.
I am an active member of the formal methods and programming languages research communities, and I have served on the program committees of several international conferences, including as program and general chair.

Employment History

Sep 2024 – now	**Principal Research Scientist.** Code Metal, Boston, MA, USA.
Jan 2024 – Sep 2024	**Lead Research Scientist.** NASA Langley Research Center/AMA Inc., Hampton, VA, USA.
June 2023 – Jan 2024	**Senior Research Scientist.** NASA Langley Research Center/AMA Inc., Hampton, VA, USA.
Sep 2019 – Jun 2023	**Senior Research Scientist.** NASA Langley Research Center/NIA, Hampton, VA, USA.
Sep 2017 – Sep 2019	**Research Scientist.** NASA Langley Research Center/NIA, Hampton, VA, USA.
Sep 2015 – Sep 2017	**Post Doctoral Researcher.** NASA Langley Research Center/NIA, Hampton, VA, USA.
Sep 2014 – Sep 2015	**Post Doctoral Researcher.** Department of Computer Science, University of Malaga, Spain.

Education

2010 – 2014 **Ph.D. Computer Science.** University of Udine, Italy.
Thesis title: *An Abstract Interpretation Framework for Diagnosis and Verification of Timed Concurrent Constraint Languages.*

Education (continued)

2008 – 2010 **M.Sc. Computer Science** University of Udine, Italy.
Thesis title: *A bottom-up goal-independent semantics for Timed Concurrent Constraint Programming*.

2005 – 2008 **B.Sc. Computer Science** University of Udine, Italy.
Thesis title: *Algebraic Semantics for CLP(FD)*.

2005 – 2010 **Scientific Track Diploma (equivalent to an honors postgraduate degree)** Scuola Normale Superiore Toppo Wassermann dell'Università degli Studi di Udine, Italy.
Highly selective program with parallel enrollment at the University of Udine, admitted through national-level competitive examination.

Research Publications

Journal Articles

1. A. Dutle, M. M. Moscato, **L. Titolo**, C. A. Muñoz, G. Anderson, and F. Bobot, "Formal analysis of the compact position reporting algorithm," *Formal Aspects of Computing*, vol. 33, no. 1, pp. 65–86, 2021. DOI: 10.1007/S00165-019-00504-0.
2. M. Comini, M. Gallardo, **L. Titolo**, and A. Villanueva, "A program analysis framework for tccp based on abstract interpretation," *Formal Aspects of Computing*, vol. 29, no. 3, pp. 531–557, 2017. DOI: 10.1007/S00165-016-0409-8.
3. M. Gallardo, L. Lavado, L. Panizo, and **L. Titolo**, "A constraint-based language for modelling intelligent environments," *Journal on Reliable Intelligent Environments*, vol. 3, no. 1, pp. 55–79, 2017. DOI: 10.1007/S40860-017-0040-3.
4. M. Comini, **L. Titolo**, and A. Villanueva, "Abstract diagnosis for tccp using a linear temporal logic," *Theory and Practice of Logic Programming*, vol. 14, no. 4-5, pp. 787–801, 2014. DOI: 10.1017/S1471068414000349.
5. **L. Titolo**, "An abstract interpretation framework for verification of timed concurrent constraint languages," *Theory and Practice of Logic Programming*, vol. 13, no. 4-5-Online-Supplement, 2013. URL: http://static.cambridge.org/resource/id/urn:cambridge.org:id:binary:20161018085635834-0697:S1471068413000112:tlp2013039.pdf.
6. M. Comini, **L. Titolo**, and A. Villanueva, "Abstract diagnosis for timed concurrent constraint programs," *Theory and Practice of Logic Programming*, vol. 11, no. 4-5, pp. 487–502, 2011. DOI: 10.1017/S1471068411000135.

Conference Proceedings

1. **L. Titolo**, M. M. Moscato, M. A. Feliú, P. Masci, and C. A. Muñoz, "Rigorous floating-point round-off error analysis in precisa 4.0," in *Formal Methods - 26th International Symposium, FM 2024, Milan, Italy, September 9-13, 2024, Proceedings, Part II*, A. Platzer, K. Y. Rozier, M. Pradella, and M. Rossi, Eds., ser. Lecture Notes in Computer Science, vol. 14934, Springer, 2024, pp. 20–38. DOI: 10.1007/978-3-031-71177-0_2.
2. L. M. White, **L. Titolo**, J. T. Slagel, and C. A. Muñoz, "A temporal differential dynamic logic formal embedding," in *Proceedings of the 13th ACM SIGPLAN International Conference on Certified Programs and Proofs, CPP 2024, London, UK, January 15-16, 2024*, A. Timany, D. Traytel, B. Pientka, and S. Blazy, Eds., ACM, 2024, pp. 162–176. DOI: 10.1145/3636501.3636943.
3. N. B. F. Ferreira, M. M. Moscato, **L. Titolo**, and M. Ayala-Rincón, "A provably correct floating-point implementation of well clear avionics concepts," in *Formal Methods in Computer-Aided Design, FMCAD 2023, Ames, IA, USA, October 24-27, 2023*, A. Nadel and K. Y. Rozier, Eds., IEEE, 2023, pp. 237–246. DOI: 10.34727/2023/ISBN.978-3-85448-060-0_32.

4 E. Conrad, **L. Titolo**, D. Giannakopoulou, T. Pressburger, and A. Dutle, "A compositional proof framework for fretish requirements," in *CPP '22: 11th ACM SIGPLAN International Conference on Certified Programs and Proofs, Philadelphia, PA, USA, January 17 - 18, 2022*, A. Popescu and S. Zdancewic, Eds., ACM, 2022, pp. 68–81. DOI: 10.1145/3497775.3503685.

5 **L. Titolo**, M. M. Moscato, M. A. Feliú, and C. A. Muñoz, "Automatic generation of guard-stable floating-point code," in *Integrated Formal Methods - 16th International Conference, IFM 2020, Lugano, Switzerland, November 16-20, 2020, Proceedings*, B. Dongol and E. Troubitsyna, Eds., ser. Lecture Notes in Computer Science, vol. 12546, Springer, 2020, pp. 141–159. DOI: 10.1007/978-3-030-63461-2_8.

6 A. Dutle, C. A. Muñoz, E. Conrad, A. Goodloe, **L. Titolo**, I. Perez, S. Balachandran, D. Giannakopoulou, A. Mavridou, and T. Pressburger, "From requirements to autonomous flight: An overview of the monitoring ICAROUS project," in *Proceedings Second Workshop on Formal Methods for Autonomous Systems, FMAS 2020, Virtual, December 7, 2020*, M. Luckcuck and M. Farrell, Eds., ser. EPTCS, vol. 329, 2020, pp. 23–30. DOI: 10.4204/EPTCS.329.3.

7 M. M. Moscato, **L. Titolo**, M. A. Feliú, and C. A. Muñoz, "Provably correct floating-point implementation of a point-in-polygon algorithm," in *Formal Methods - The Next 30 Years - Third World Congress, FM 2019, Porto, Portugal, October 7-11, 2019, Proceedings*, M. H. ter Beek, A. McIver, and J. N. Oliveira, Eds., ser. Lecture Notes in Computer Science, vol. 11800, Springer, 2019, pp. 21–37. DOI: 10.1007/978-3-030-30942-8_3.

8 R. Salvia, **L. Titolo**, M. A. Feliú, M. M. Moscato, C. A. Muñoz, and Z. Rakamaric, "A mixed real and floating-point solver," in *NASA Formal Methods - 11th International Symposium, NFM 2019, Houston, TX, USA, May 7-9, 2019, Proceedings*, J. M. Badger and K. Y. Rozier, Eds., ser. Lecture Notes in Computer Science, vol. 11460, Springer, 2019, pp. 363–370. DOI: 10.1007/978-3-030-20652-9_25.

9 **L. Titolo**, M. A. Feliú, M. M. Moscato, and C. A. Muñoz, "An abstract interpretation framework for the round-off error analysis of floating-point programs," in *Verification, Model Checking, and Abstract Interpretation - 19th International Conference, VMCAI 2018, Los Angeles, CA, USA, January 7-9, 2018, Proceedings*, I. Dillig and J. Palsberg, Eds., ser. Lecture Notes in Computer Science, vol. 10747, Springer, 2018, pp. 516–537. DOI: 10.1007/978-3-319-73721-8_24.

10 **L. Titolo**, M. M. Moscato, C. A. Muñoz, A. Dutle, and F. Bobot, "A formally verified floating-point implementation of the compact position reporting algorithm," in *Formal Methods - 22nd International Symposium, FM 2018, Held as Part of the Federated Logic Conference, FloC 2018, Oxford, UK, July 15-17, 2018, Proceedings*, K. Havelund, J. Peleska, B. Roscoe, and E. P. de Vink, Eds., ser. Lecture Notes in Computer Science, vol. 10951, Springer, 2018, pp. 364–381. DOI: 10.1007/978-3-319-95582-7_22.

11 **L. Titolo**, C. A. Muñoz, M. A. Feliú, and M. M. Moscato, "Eliminating unstable tests in floating-point programs," in *Logic-Based Program Synthesis and Transformation - 28th International Symposium, LOPSTR 2018, Frankfurt/Main, Germany, September 4-6, 2018, Revised Selected Papers*, F. Mesnard and P. J. Stuckey, Eds., ser. Lecture Notes in Computer Science, vol. 11408, Springer, 2018, pp. 169–183. DOI: 10.1007/978-3-030-13838-7_10.

12 A. Dutle, M. M. Moscato, **L. Titolo**, and C. A. Muñoz, "A formal analysis of the compact position reporting algorithm," in *Verified Software. Theories, Tools, and Experiments - 9th International Conference, VSTTE 2017, Heidelberg, Germany, July 22-23, 2017, Revised Selected Papers*, A. Paskevich and T. Wies, Eds., ser. Lecture Notes in Computer Science, vol. 10712, Springer, 2017, pp. 19–34. DOI: 10.1007/978-3-319-72308-2_2.

13 M. M. Moscato, **L. Titolo**, A. Dutle, and C. A. Muñoz, "Automatic estimation of verified floating-point round-off errors via static analysis," in *Computer Safety, Reliability, and Security - 36th International Conference, SAFECOMP 2017, Trento, Italy, September 13-15, 2017, Proceedings*, S. Tonetta, E. Schoitsch, and F. Bitsch, Eds., ser. Lecture Notes in Computer Science, vol. 10488, Springer, 2017, pp. 213–229. DOI: 10.1007/978-3-319-66266-4_14.

14 M. Comini, M. Gallardo, **L. Titolo**, and A. Villanueva, "Abstract analysis of universal properties for tccp," in *Logic-Based Program Synthesis and Transformation - 25th International Symposium, LOPSTR 2015, Siena, Italy, July 13-15, 2015. Revised Selected Papers*, M. Falaschi, Ed., ser. Lecture Notes in Computer Science, vol. 9527, Springer, 2015, pp. 163–178. DOI: 10.1007/978-3-319-27436-2_10.

15 D. Adalid, M. Gallardo, and **L. Titolo**, "Modeling hybrid systems in the concurrent constraint paradigm," in *Proceedings XIV Jornadas sobre Programación y Lenguajes, PROLE 2014, Cadiz, Spain, September 16-19, 2014*, S. Escobar, Ed., ser. EPTCS, vol. 173, 2014, pp. 1–15. DOI: 10.4204/EPTCS.173.1.

16 M. Comini, **L. Titolo**, and A. Villanueva, "Towards an effective decision procedure for LTL formulas with constraints," in *23rd Workshop on Logic-based methods in Programming Environments (WLPE 2013)*, vol. abs/1308.4171, 2013. arXiv: 1308.4171. URL: http://arxiv.org/abs/1308.4171.

Honors and Awards

2023 **NASA Langley Mentoring Award**, a recognition of mentorship and appreciation of [my] efforts above and beyond expectations and to share knowledge and insight by mentoring others with great ability, veracity, and integrity.

2022 **NASA Group Achievement Award** for outstanding contributions verifying the Compact Position Reporting Algorithm to support safety of Automatic Dependent Surveillance-Broadcast in National Airspace System.

2021 **Contributor to the international ADS-B standard**. Technical contributions to the revision of the Automatic Dependent Surveillance–Broadcast (ADS-B) aviation standard (Jan 6 2021).

2019 **National Institute of Aerospace Best Paper Award** for "A Formally Verified Floating-Point Implementation of the Compact Position Reporting Algorithm".

Professional Service

Steering Committee

ACM SIGPLAN International Workshop on the State Of the Art in Program Analysis (SOAP).

Conference Organization

2025 **NFM 2025 General Chair** - 17th International NASA Formal Methods Symposium.

LOPSTR 2025 Program Chair - 35th International Symposium on Logic-Based Program Synthesis and Transformation.

2023 **FMICS 2023 Program Chair** - 28th International Conference on Formal Methods for Industrial Critical Systems.

2022 **SOAP 2022 Program Chair** - 11th ACM SIGPLAN International Workshop on the State Of the Art in Program Analysis.

2021 **NFM 2021 Program Chair** - 13th International NASA Formal Methods Symposium.

Editorial Roles

2023 Guest Editor for the International Journal on Software Tools for Technology Transfer - Selected extended papers of FMICS 2023 (to appear).

Editor for the Proceedings of Formal Methods for Industrial Critical Systems - 28th International Conference, FMICS 2023, Antwerp, Belgium, September 20-22, 2023, vol. 14290, Lecture Notes in Computer Science, Springer, 2023, ISBN: 978-3-031-43680-2, https://link.springer.com/book/10.1007/978-3-031-43681-9.

Professional Service (continued)

- 2021 Guest Editor for the Journal on Innovations in Systems and Software Engineering (STTT), Volume 19 (2023) - Selected extended papers of NFM 2021, https://doi.org/10.1007/s11334-023-00544-z
- 2022 Editor for the Proceedings of SOAP '22: 11th ACM SIGPLAN International Workshop on the State Of the Art in Program Analysis, San Diego, CA, USA, 14 June 2022, ACM, 2022, ISBN: 978-1-4503-9274-7, https://dl.acm.org/doi/proceedings/10.1145/3520313.
- 2021 Editor for the Proceedings of NASA Formal Methods - 13th International Symposium, NFM 2021, Virtual Event, May 24-28, 2021, Proceedings, vol. 12673, Lecture Notes in Computer Science, Springer, 2021, ISBN: 978-3-030-76383-1, https://link.springer.com/book/10.1007/978-3-030-76384-8.

Program Committee Participation

- 2026 **POPL 2026** - 53rd ACM SIGPLAN Symposium on Principles of Programming Languages
- 2025 **PADL 2025** - 27th International Symposium on Practical Aspects of Declarative Languages
- **FMICS 2025** - 30th International Conference on Formal Methods for Industrial Critical Systems
- **VSTTE 2025** - 17th International Conference on Verified Software: Theories, Tools, and Experiments
- **CPP 2025** - 14th ACM SIGPLAN International Conference on Certified Programs and Proofs
- 2024 **NSAD 2024** - 10th International Workshop on Numerical and Symbolic Abstract Domains
- **FMICS 2024** - 29th International Conference in Formal Methods for Industrial Critical Systems
- **ARITH 2024** - 31st IEEE International Symposium on Computer Arithmetic
- **LOPSTR 2024** - 34th International Symposium on Logic-based Program Synthesis and Transformation
- 2023 **ARITH 2023** - 30th IEEE International Symposium on Computer Arithmetic
- **LOPSTR 2023** - 33rd International Symposium on Logic-based Program Synthesis and Transformation
- **SAS 2023** - 30th International Symposium Static Analysis Symposium
- **NFM 2023** - 15th NASA Formal Methods Symposium
- 2022 **VMCAI 2022** - 23rd International Conference on Verification, Model Checking, and Abstract Interpretation
- **SAS 2022** - 29th International Symposium Static Analysis Symposium (SAS 2022)
- **LOPSTR 2022** - 32th International Symposium on Logic-Based Program Synthesis and Transformation
- **CPP 2022** - 11th ACM SIGPLAN International Conference on Certified Programs and Proofs
- **CAV 2022** - 34th International Conference on Computer Aided Verification
- 2021 **SOAP 2021** - 10th ACM SIGPLAN International Workshop on the State Of the Art in Program Analysis
- **DETECT 2021** - Workshop on Modeling, Verification and Testing of Dependable Critical Systems
- **ESEC-FSE 2021** - ACM Joint European Software Engineering Conference and Symposium on the Foundations of Software Engineering - Demonstratio Track (ESEC-FSE 2021)
- **FMAS 2021** - 3rd Workshop on Formal Methods for Autonomous Systems
- 2020 **NFM 2020** - 12th International NASA Formal Methods Symposium
- **FMAS 2020** - 2nd Workshop on Formal Methods for Autonomous Systems

Professional Service (continued)

- **DETECT 2020** - Workshop on Modeling, Verification and Testing of Dependable Critical Systems
- **NSV 2020** - 13th International Workshop on Numerical Software Verification (NSV 2020)

2019
- **NSV 2019** - 12th International Workshop on Numerical Software Verification

2018
- **TNC 2018** - 1st International Workshop on Trusted Numerical Computations Workshop
- **NSV 2018** - 11th International Workshop on Numerical Software Verification (NSV 2018), hosted by the Federated Logic Conference
- **NFM 2018** - 10th International NASA Formal Methods Symposium (NFM 2018)

2015
- **CILC 2015** - 30th Italian Conference on Computational Logic

Journal Reviewing Activity

- International Journal on Software Tools for Technology Transfer (Springer)
- ACM Journal of Computing Surveys
- Journal of Software: Practice and Experience (Wiley)
- Journal of Computers and Electrical Engineering (Elsevier)
- Journal of Automated Reasoning (Springer)
- Journal of Logical and Algebraic Methods in Programming (Elsevier)

PhD/MSc Thesis Evaluation Jury

2023
- Thiago Mendoça Ferreira Ramos, University of Brasilia, Brasil

2021
- Maxime Jacquemin, CEA List, France
- Dorra Ben Khalifa, University of Perpignan, France

Seminars and Invited Talks

2024
- "Taming Floating-point Errors in Avionics Applications at NASA". Talk at the Lipari Summer School on Abstract Interpretation, Italy.

2023
- "Taming Floating-point Errors in Avionics Applications". Invited talk at the University of Kent, UK.
- "ReFlow: from real number specifications to floating-point implementations". Invited Lightweight talk, DOE/NSF Workshop on Correctness in Scientific Computing, Orlando, Florida, USA.
- "ReFlow: from real number specifications to floating-point implementations". Invited Talk, Challenges of Software Verification Symposium 2023, Ca' Foscari University, Venice, Italy.

2022
- "Floating-point round-off error analysis of safety-critical avionics software". Seminar at the Technical University of Valencia, Spain.
- "Floating-point round-off error analysis of safety-critical avionics software". Invited Talk, Challenges of Software Verification Symposium 2022, Ca' Foscari University, Venice, Italy.
- "Taming Numerical Errors in Aerospace Applications". AIAA Hampton Roads Section 2022-2023 Technical Talk Series, NASA Langley, USA.
- "Taming Numerical Errors in Aerospace Applications". NASA Research Directory Tech 2022 Talk, NASA Langley, USA.

Seminars and Invited Talks (continued)

2017
- "An Abstract Interpretation Framework for the Round-Off Error Analysis of Floating-Point Programs". Invited talk at Dagstuhl Seminar 17352 on Analysis and Synthesis of Floating-point Programs, Germany.
- "A Static Analysis Framework for the Estimation of Verified Floating-Point Round-Off Errors". Invited talk at the French Alternative Energies and Atomic Energy Commission (CEA), Paris, France.

2014
- "Abstract Diagnosis for tccp using a Linear Temporal Logic". Talk at the University of the Basque Country, San Sebastian, Spain.
- "An Abstract Interpretation Framework for Verification of Timed Concurrent Constraint Languages". Talk at IMDEA Software Institute, Madrid, Spain.

2011
- ''Abstract Diagnosis for Timed Concurrent Constraint programs". Talk at the University of Siena, Italy.

Languages

Italian	Native
English	Fluent
Spanish	Fluent
French	Intermediate
Russian	Basic