

# SASWATA PAUL

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## RESEARCH INTERESTS

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My research interests primarily involve the design, development, and certification of safer flight systems by using the principles of formal methods, semantics, distributed and concurrent systems, autonomous systems, cyber-physical systems, and dynamic data-driven paradigms. Recently, I have been investigating the verification and assurance of machine-learning and artificial intelligence as applied in safety-critical digital aerospace systems.

## EDUCATIONAL QUALIFICATION

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<b>Ph.D. in Computer Science</b> <i>Rensselaer Polytechnic Institute, Troy, NY, USA</i>	<i>May 2022</i>
<b>M.S. in Computer Science</b> <i>Rensselaer Polytechnic Institute, Troy, NY, USA</i>	<i>Dec. 2018</i>
<b>B.Tech. in Computer Science &amp; Engineering</b> <i>National Institute of Technology, Agartala, Tripura, India</i>	<i>May 2015</i>

## WORK EXPERIENCE

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<b>Research Engineer</b> <i>GE Aerospace Research (Formerly GE Research)</i>	May 2022 - Present <i>Niskayuna, NY</i>
<ul style="list-style-type: none"><li>Principal Investigator (PI) for the FAA Certification of AI/ML program.</li><li>Developed Overarching Properties-based assurance arguments for AI/ML-based avionics systems.</li><li>Developed digital design review tools for DO-178C and ARP-4754 from the RACK curated database under the DARPA ARCOS Program.</li><li>Led the development of the RITE IDE for the RACK curated database under the DARPA ARCOS Program.</li><li>Designed an automated approach for the generation of assurance cases from the RACK curated database under the DARPA ARCOS Program.</li><li>Investigated DARPA hard problems on the assurance and certification of safety-critical cyber-physical systems.</li><li>Conducted research on using semantic technologies, formal tools, and software systems for the certification and assurance of safety-critical systems and authored several research papers, technical reports, and patents.</li><li>Contributed to proposals funded by DARPA, AFRL, and ARL.</li><li>Actively involved in the following projects: DARPA ARCOS, FAA Certification of AI/ML, ACE MBSE (funded by GE Aerospace), NASA V&amp;V, DARPA PEARLS.</li></ul>	
<b>Graduate Research Assistant</b> <i>Rensselaer Polytechnic Institute</i>	May 2017 - May 2022 <i>Troy, NY</i>
<ul style="list-style-type: none"><li>Developed the first machine-checked proof of eventual progress for the Synod consensus protocol.</li><li>Developed a failure-aware actor model for formal reasoning about distributed communication in airborne networks.</li><li>Developed a formal library in Athena tailored towards reasoning about distributed coordination protocols.</li><li>Developed a formally verified protocol for ensuring situational awareness in autonomous aircraft.</li><li>Designed a data-driven approach for the runtime verification of distributed systems using formal proofs.</li><li>Designed a provably-correct decentralized and autonomous air traffic management technique for Urban Air Mobility.</li><li>Developed a formally verified strategic conflict-aware flight planning algorithm.</li><li>Developed a data-driven approach for generating high-fidelity emergency trajectories for fixed-wing aircraft.</li></ul>	
<b>Research Intern</b> <i>GE Research</i>	Jun. 2020 - Aug. 2020, May 2021 - Jul. 2021 <i>Niskayuna, NY</i>
<ul style="list-style-type: none"><li>Worked on DARPA and NASA-funded programs with the High-Assurance Systems team.</li></ul>	

- Developed a formal data model for constructing Operational Risk Assessment artifacts (NASA V&V).
- Developed an approach for auto-generating assurance case fragments from the VERDICT toolchain (DARPA CASE).
- Proposed an approach to generate certification reports from the curated RACK database (DARPA ARCOS).
- Developed an SMT-based approach for strategic detection and elimination of aircraft conflicts for Urban Air Mobility.

**Graduate Teaching Assistant**  
Rensselaer Polytechnic Institute

Aug. 2016 - May 2017, Aug. 2020 - Dec. 2020  
Troy, NY

- Conducted practical labs, held office hours, proctored exams, and graded assignments and exams for courses such as Computer Science I, Principles of Software, and Programming Languages.

**Summer Intern**  
Society for Natural Language Technology & Research

May 2014 - Jul. 2014  
Kolkata, India

- Developed an Android application for generating the shortest/cheapest bus route between two given destinations.

## NOTABLE AWARDS

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- *Best Paper Award*, Certification and DO-178C session, at the 42nd AIAA/IEEE DASC, Barcelona, Spain, Oct. 2023.
- *Robert McNaughton Prize* for outstanding achievements, Rensselaer Polytechnic Institute, May, 2022.
- *Best Paper Award*, Software Development track, at the 40th AIAA/IEEE DASC, San Antonio, TX, Oct. 2021.
- Finalist for *Best Student Paper Award* at the 38th AIAA/IEEE DASC, San Diego, CA, Sep. 2019.
- Topper of the Computer Science department at NIT Agartala in the 8th semester of B.Tech., May 2015.
- Secured 1st position in inter-college coding competition at NIT Agartala, 2013.
- Secured 2nd position at Holy Cross School Agartala in Indian School Certificate examination, 2011.
- Secured 4th position at Holy Cross School Agartala in Indian Certificate of Secondary Education examination, 2009.

## PROFESSIONAL SERVICE

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### Conference Chair

- Session Chair, Communications, Navigation, and Surveillance and Information Networks (CNS) track, AIAA/IEEE Digital Avionics Systems Conference (DASC), 2024.

### Reviewer

- Reviewer, International Workshop on Formal Methods for Blockchain (FMBC), 2024.
- Reviewer, Formal Methods in Computer-Aided Design (FMCAD), 2023.
- Reviewer, IEEE International Symposium on Software Reliability Engineering (ISSRE), 2023.
- Reviewer, International Conference on Autonomous Agents and Multi-agent Systems (AAMAS), 2019.
- Reviewer, IEEE International Conference on Cluster Computing (CLUSTER), 2019.
- Reviewer, International Conference on Big Data (BigData), 2017.
- Reviewer, International Conference on Utility and Cloud Computing (UCC), 2017.

### Mentoring

- Udayan Mandal, Summer Intern, GE Research, 2023.
- Elkin Cruz, Undergraduate Researcher, Rensselaer Polytechnic Institute, 2020.
- Alexandra ZYTEK, Undergraduate Researcher, Rensselaer Polytechnic Institute, 2018.
- Frederick Hole, Undergraduate Researcher, Rensselaer Polytechnic Institute, 2018.

### Other

- Conducted workshops for high school students for "STEM Day" at the Worldwide Computing Laboratory, Rensselaer Polytechnic Institute, in 2018 and 2019

## RESEARCH GRANTS

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1. Principal Investigator (PI): “Safety Assurance in Complex Aerospace Digital Systems that include AI/ML”. Federal Aviation Administration (FAA) Grant No.: 692M15-22-T-00012 (Grant Amount: \$1,145,794.00).

## PUBLICATIONS

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### Peer-Reviewed Journal Publications

1. B. Meng, A. Viswanathan, **S. Paul**, W. Smith, A. Moitra, K. Siu, and M. Durling. “Attack-Defense Tree-based Analysis and Optimal Defense Synthesis for System Design”, *Innovations in Systems & Software Engineering: A NASA Journal*, Accepted Feb. 2024. (To appear)
2. **S. Paul**, E. Cruz, A. Dutta, A. Bhaumik, E. Blasch, G. A. Agha, S. Patterson, F. Kopsaftopoulos, C. Varela. “Formal Verification of Safety-Critical Aerospace Systems”, *IEEE Aerospace and Electronic Systems Magazine*, Apr. 2023. <https://doi.org/10.1109/MAES.2023.3238378>
3. **S. Paul**, S. Patterson, F. Kopsaftopoulos, and C. A. Varela. “Towards Formal Correctness Envelopes for Dynamic Data-Driven Aerospace Systems”, *Handbook Dyn. Data-Driven App. Syst.*, Accepted Nov. 2022. (To appear)
4. **S. Paul**, G. A. Agha, S. Patterson, and C. A. Varela. “Eventual Consensus in Synod: Verification using a Failure-Aware Actor Model”, *Innovations in Systems & Software Engineering: A NASA Journal*, Jul. 2022. <https://doi.org/10.1007/s11334-022-00463-5>
5. B. Meng, D. Larraz, K. Siu, A. Moitra, J. Interrante, W. Smith, **S. Paul**, D. Prince, H. Herencia-Zapana, M. F. Arif, M. Yahyazadeh, V. T. Valapil, M. Durling, C. Tinelli, and O. Chowdhury. “VERDICT: A Language and Framework for Engineering Cyber-Resilient and Safe System”, *Systems*, Mar. 2021. <https://doi.org/10.3390/systems9010018>

### Peer-Reviewed Conference/Workshop Publications

1. **S. Paul**, B. Meng, and C. Alexander. “SMT-Based Aircraft CONflict Detection and Resolution”, In *Proc. of the 16th NASA Formal Methods Symp.*. Accepted Feb. 2024. (To appear)
2. R. Lorch, B. Meng, K. Siu, A. Moitra, M. Durling, **S. Paul**, S. C. Varanasi, and C. McMillan. “Formal Methods in Requirements Engineering: Survey and Future Directions”, In *Proc. of the International Conference on Formal Methods in Software Engineering*. Accepted Jan. 2024. (To appear)
3. B. Meng, J. Debnath, S. Varanasi, E. Manolios, M. Durling, **S. Paul**, D. Prince, S. Alsabagah, R. Haadsma, C. McMillan, C. Zhang, and T. Oates. “Towards a Correct-by-Construction Design of Integrated Modular Avionics”, In *Proc. of the 23rd Conf. on Formal Meth. in Comp. Aided Design*, Oct. 2023. [https://doi.org/10.34727/2023/isbn.978-3-85448-060-0\\_30](https://doi.org/10.34727/2023/isbn.978-3-85448-060-0_30)
4. **S. Paul**, D. Prince, N. Iyer, M. Durling, N. Visnevski, B. Meng, S. Varanasi, K. Siu, C. McMillan, and M. Meiners. “Towards the Certification of Neural Networks using Overarching Properties: An Avionics Case Study”, In *Proc. of the 42nd AIAA/IEEE Digit. Avionics Syst. Conf.*, Oct. 2023. <https://doi.org/10.1109/DASC58513.2023.10311280>
5. **S. Paul**, C. Alexander, M. Durling, K. Siu, D. Prince, B. Meng, S. Varanasi, and D. Stuart. “Automated DO-178C Compliance Summary Through Evidence Curation”, In *Proc. of the 42nd AIAA/IEEE Digit. Avionics Syst. Conf.*, Oct. 2023. <https://doi.org/10.1109/DASC58513.2023.10311159>
6. P. Zhou, **S. Paul**, A. Dutta, C. Varela, F. Kopsaftopoulos. “On Formal Verification of Data-Driven Flight Awareness: Leveraging the Cramér-Rao Lower Bound of Stochastic Functional Time Series Models”, In *Proc. of the DDDAS Conference*, Oct. 2022. [https://doi.org/10.1007/978-3-031-52670-1\\_5](https://doi.org/10.1007/978-3-031-52670-1_5)
7. **S. Paul**, S. Patterson, and C. A. Varela. “Formal Guarantees of Timely Progress for Distributed Knowledge Propagation”, *Proc. of the 3rd Workshop on Formal Methods for Auton. Syst.*, Oct. 2021. <https://doi.org/10.4204/EPTCS.348.5>
8. V. T. Valapil, H. Herencia-Zapana, M. Durling, K. Armstrong, **S. Paul**, S. Borgyos, A. Moitra, and W. Premerlani. “Towards Formalization of a Data Model for Operational Risk Assessment”, *Proc. of the 40th AIAA/IEEE Digit. Avionics Syst. Conf.*, Oct. 2021. <https://doi.org/10.1109/DASC52595.2021.9594289>
9. B. Meng, **S. Paul**, A. Moitra, K. Siu, and M. Durling. “Automating the Assembly of Security Assurance Case Fragments”, *Proc. of the 40th Int. Conf. on Comp. Safety, Reliability, and Security*, Sep. 2021. [https://doi.org/10.1007/978-3-030-83903-1\\_7](https://doi.org/10.1007/978-3-030-83903-1_7)
10. **S. Paul**, G. A. Agha, S. Patterson, and C. A. Varela. “Verification of Eventual Consensus in Synod Using a Failure-Aware Actor Model”, *Proc. of the 13th NASA Formal Methods Symp.*, May 2021. [https://doi.org/10.1007/978-3-030-76384-8\\_16](https://doi.org/10.1007/978-3-030-76384-8_16)
11. **S. Paul**, S. Patterson, and C. A. Varela. “Collaborative Situational Awareness for Conflict-Aware Flight Planning”, In *Proc. of the 39th AIAA/IEEE Digit. Avionics Syst. Conf.*, Oct. 2020. <https://doi.org/10.1109/DASC50938.2020.9256620>

12. B. Meng, A. Moitra, A. W. Crapo, **S. Paul**, K. Siu, M. Durling, D. Prince, H. Herencia-Zapana. "Towards Developing Formalized Assurance Cases", In *Proc. of the 39th AIAA/IEEE Digit. Avionics Syst. Conf.*, Oct. 2020. <https://doi.org/10.1109/DASC50938.2020.9256740>
13. **S. Paul**, F. Kopsaftopoulos, S. Patterson, and C. A. Varela. "Dynamic Data-Driven Formal Progress Envelopes for Distributed Algorithms", In *Proc. of InfoSymbiotics/DDDAS2020*, Oct. 2020. [https://doi.org/10.1007/978-3-030-61725-7\\_29](https://doi.org/10.1007/978-3-030-61725-7_29)
14. E. Cruz-Camacho, **S. Paul**, F. Kopsaftopoulos, and C. A. Varela. "Towards Provably Correct Probabilistic Flight Systems", In *Proc. of InfoSymbiotics/DDDAS2020*, Oct. 2020. [https://doi.org/10.1007/978-3-030-61725-7\\_28](https://doi.org/10.1007/978-3-030-61725-7_28)
15. **S. Paul**, S. Patterson, and C. A. Varela. "Conflict-Aware Flight Planning for Avoiding Near Mid-Air Collisions", In *Proc. of the 38th AIAA/IEEE Digit. Avionics Syst. Conf.*, San Diego, CA, USA, Sep. 2019. <https://doi.org/10.1109/DASC43569.2019.9081658>
16. **S. Paul**, F. Hole, A. ZYTEK, and C. A. Varela. "Wind-Aware Trajectory planning for Fixed-Wing Aircraft in Loss of Thrust Emergencies", In *Proc. of the 37th AIAA/IEEE Digit. Avionics Syst. Conf.*, London, England, Sep. 2018. <https://doi.org/10.1109/DASC.2018.8569842>
17. **S. Paul**, F. Hole, A. ZYTEK, and C. A. Varela. "Flight Trajectory Planning for Fixed-Wing Aircraft in Loss of Thrust Emergencies", In *InfoSymbiotics/DDDAS workshop*, Cambridge, Massachusetts, Aug. 2017. <https://doi.org/10.48550/arXiv.1711.00716>

## Other Publications

1. **S. Paul**, D. Prince, N. Iyer, M. Durling, N. Visnevski, and B. Meng. "Assurance of Machine Learning-Based Aerospace Systems: Towards an Overarching Properties-Driven Approach", Tech. Report, *United States Department of Transportation*, Sep. 2023.
2. **S. Paul**, "Formal Verification of Decentralized Coordination in Autonomous Multi-Agent Aerospace Systems", PhD Dissertation, *Rensselaer Polytechnic Institute*, Troy, NY, May 2022.
3. **S. Paul**, "Emergency Trajectory Planning for Fixed-Wing Aircraft", Master's Thesis, *Rensselaer Polytechnic Institute*, Troy, NY, Dec. 2018.

## SELECTED RESEARCH PROJECTS

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### · Safety Assurance in Complex Aerospace Digital Systems that include AI/ML

**Organization:** GE Aerospace Research

**Funding Agency:** Federal Aviation Administration (FAA)

**Involvement Period:** July 2022 - present

**Description:** This goal of this project is to investigate the certification challenges for AI/ML-based components used in digital aerospace systems. The project aims to use Overarching Properties as the foundation to create an alternate means of compliance for such intelligent aerospace systems which cannot be certified using existing standards.

### · Rapid Assurance Curation Kit (RACK)

**Organization:** GE Aerospace Research

**Funding Agency:** Defense Advanced Research Projects Agency (DARPA)

**Involvement Period:** July 2022 - present

**Description:** RACK is a specialized data-curation platform being developed under the DARPA Automated Rapid Certification Of Software (ARCOS) program. RACK can be used for curating evidence generated during a software development life cycle and generate assurance arguments for the certification of safety-critical software systems.

### · PrOof Engineering for SYSTEm ARchitecture Design Model (OYSTER)

**Organization:** GE Research

**Funding Agency:** Defense Advanced Research Projects Agency (DARPA)

**Involvement Period:** July 2022 - July 2023

**Description:** The goal of OYSTER is to develop innovative theories and prototype tools that combine Machine Learning-(ML), Satisfiability Modulo Theories (SMT) and model checking to improve formal proof construction, evolution, and repair for system architecture design models.

### · Analysis of Safety-Critical Systems Using Formal Methods-Based Runtime Evaluation (ASSURE)

**Organization:** Rensselaer Polytechnic Institute

**Funding Agency:** Air Force Office of Scientific Research (AFOSR) and National Science Foundation (NSF)

**Involvement Period:** August 2017 - May 2022

**Description:** The failure or malfunction of safety-critical aerospace, healthcare, power generation, and transportation systems can have catastrophic consequences for human beings and the environment. The ASSURE project aims to employ formal methods-based techniques for the verification of safety-critical systems and their correctness properties.

· **Evaluation of Verification & Validation Tools in a Unmanned Aircraft Systems**

**Organization:** GE Research

**Funding Agency:** National Aeronautics and Space Administration (NASA)

**Involvement Period:** May 2021 - Jul. 2021

**Description:** The goal of this project is to evaluate Validation & Verification (V&V) tools on a runtime safety assurance (RTSA ) system. The project uses formal tools such as FRET, Advocate, AGREE, CoCoSim, and ASSERT developed by NASA, DARPA, Virginia Tech and GE.

· **Verification Evidence & Resilient Design in anticipation of Cybersecurity Threats (VERDICT)**

**Organization:** GE Research

**Funding Agency:** Defense Advanced Research Projects Agency (DARPA)

**Involvement Period:** Jun. 2020 - Aug. 2020

**Description:** The goal of this project is to develop the necessary design, analysis and verification tools to allow system engineers to design-in cyber resiliency and manage tradeoffs as they do other nonfunctional properties when designing complex embedded computing systems.

· **The PILOTS Programming Language**

**Organization:** Rensselaer Polytechnic Institute

**Funding Agency:** Air Force Office of Scientific Research (AFOSR) and National Science Foundation (NSF)

**Involvement Period:** Dec. 2016 - Aug. 2018

**Description:** PILOTS is a ProgrammIng Language for spatiO-Temporal data Streaming applications, especially designed to be used for building applications that run on moving objects such as airplanes, cars, and so on. The unique language features in PILOTS are first-class support for data selection, data interpolation, fault detection and recovery, and declarative machine learning.