RAFAL KRZYSIAK

CONTACT INFORMATION

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EDUCATION

Ph.D.	Mechanical Engineering (GPA: 4.0)	University of California, Merced	*2022 - 2025*
M.S.	Mechanical Engineering (GPA: 4.0)	Northern Illinois University	*2019 - 2021*
B.S.	Mechanical Engineering (GPA: 3.8)	Northern Illinois University	*2017 - 2019*

SKILLS

Languages: Python, C/C++, MATLAB
Machine Learning & AI: TensorFlow, PyTorch, Scikit-learn, Pandas, NumPy, Explainable AI (XAI)
Robotics, Controls & Embedded Systems: ROS / ROS2, Gazebo, OpenCV, Control System Design, Raspberry Pi, Microcontrollers (Arduino, STM32)
CAD & Simulation (FEA): SolidWorks, Siemens NX, ANSYS (Thermal & Mechanical)
Drones & Avionics: Pixhawk (PX4/ArduPilot), QGroundControl, Mission Planner, VTOL & Fixed-Wing Design and implementation
Electronics: Altium Designer, PCB Design, Circuit Analysis
Operating Systems: Linux, Ubuntu, Command Line Interface (CLI), Shell Scripting

EXPERIENCE

Mechanical Engineer (Subcontract) NASA Jet Propulsion Laboratory, CA
Jan 2022 - Jan 2024

- Conducted FEA thermal and structural analysis on a JPL flight instrument for the International Space Station (ISS), verifying performance and survival under launch loads.
- Designed, built, and utilized a tunable laser spectrometer to quantify total water concentration of lunar regolith for NASA's Artemis program.
- Constructed a Level-II digital twin of a miniature tunable laser spectrometer to measure ISS water quality, verified via environmental chamber testing.

Mechanical Engineering Intern NASA Jet Propulsion Laboratory, CA
Summers 2018, 2019, 2024

- Applied 3D mechanical design and simulation software to improve designs of sensitive instruments for drone-based planetary science missions.
- Designed and laid out a power distribution circuit for a drone gas sensor and verified its performance.
- Integrated a methane gas sensor with robotic platforms using ROS.
- Collaborated with Chevron to upgrade and implement a robotic H2S sensor with wireless data collection.
- Provided mechanical substantiation for NASA's next-generation fire detection instrument in collaboration with NASA Armstrong Flight Research Center (AFRC).
- Conducted thermal analysis on radar technology for JPL's airborne program for planetary Earth science missions.

PROJECTS

Explainable AI (XAI) Research

- **XWFDT (Explainable Wildfire Digital Twin):** Developed a hybrid physics-ML digital twin integrating 3D wind, fire spread dynamics, and UAV-based multispectral sensing. Integrated XAI methods (GradCAM, LIME) to inform control strategies for prescribed burns.
- **Planetary Health Monitoring:** Advanced multi-task learning with Fractional Order SGD for land use classification, using Quantus-assessed explainability.
- **Health Monitoring:** Developed XCardio-Twin, an explainable framework to aid in monitoring and analysis of cardiovascular status using wearable IoT devices.

Scientific Machine Learning (SciML)

- **Methane Plume Detection & Quantification:** Developed a machine learning pipeline to detect and quantify methane plumes from hyperspectral imagery. The approach leverages fractional order image processing to enhance plume features, significantly improving model accuracy for environmental monitoring.
- **Miniature Tunable Laser Spectrometer:** Developed a level-II digital twin for the thermal analysis of a JPL flight instrument. Created a Physics-Informed Neural Network (PINN) to accurately model complex heat transfer on the electronics boards, enhancing predictive capabilities beyond traditional FEA.
- **PINN for 2D Heat Transfer:** Developed a Physics-Informed Neural Network to solve the 2D heat equation for both forward and inverse problems. The model integrates the governing PDE into the loss function for predictions from sparse sensor data, with performance validated experimentally on a custom-built thermal imaging lab platform.
- **PINN for 2D Fluid Dynamics:** Engineered a PINN to model complex 2D fluid dynamics governed by the Navier-Stokes equations. The model was developed as a high-speed surrogate to accelerate traditional CFD simulations for environmental applications, including methane plume dispersion and wildfire behavior modeling.

Robotics & Autonomous Systems

- **Autonomous Aerial Mercury Detection Platform:** Engineered an integrated autonomous UAV and sensing platform for the in-situ detection of gaseous elemental mercury. The project involved designing a custom instrument payload and developing autonomous flight patterns for systematic environmental surveying and source localization.
- **CITRIS Aviation Prize (LEAPFROG UAV):** Co-developed a long-endurance, autonomous VTOL fixed-wing UAV for a 115-mile flight challenge. Integrated an edge-AI payload, multi-point ground control communication, and an emergency recovery system for environmental surveying missions.
- **Agricultural UAV/UGV Systems:** Developed a ROS2-based agricultural scout system with a UGV and UAV for autonomous remote sensing and crop monitoring.
- **Human-Robot Interaction:** Created a human-following robot using iRobot Create 2, ROS, and OpenCV.
- **Bipedal Humanoid Robot:** Designed and built a 17-DOF (servo-based) bipedal robot, developing the control system from the ground up. Implemented inverse kinematics and trajectory planning to generate a stable, dynamic walking gait.
- **Autonomous Tracked SLAM Robot:** Developed an autonomous tracked vehicle on the ROS2 framework. Integrated a 360-degree LiDAR to perform indoor SLAM for navigation and utilized a webcam with OpenCV for precise pose estimation via ArUco markers.
- **Vision-Based Drone Navigation:** Engineered a visual servoing system for a Tello drone to navigate complex indoor environments. The system processed the drone's live video feed using OpenCV to detect ArUco markers, enabling real-time pose estimation and autonomous, marker-based flight control.

- **Master's Thesis:** Developed information-based control methodologies for multi-robot teams in search and rescue missions, accounting for human prior knowledge.

Instrument Design & Analysis

- **UAVSAR Instrument Thermal Analysis:** Conducted thermal analysis for a JPL UAVSAR (Synthetic Aperture Radar) instrument pod. The analysis accounted for multiple operational scenarios, including solar loading during ground testing on a tarmac and the convective cooling effects during high-altitude flight.
- **Miniature Tunable Laser Spectrometer:** Conducted extensive thermal and structural analysis for a JPL flight instrument designed for the ISS. Modeled critical components using Finite Element Analysis (FEA) to predict instrument behavior and ensure operational reliability in the unique microgravity and thermal conditions of space.
- **Environmental Data CubeSat:** Engineered a 1U CubeSat for remote environmental and GPS data acquisition. The project involved the complete design lifecycle, including the integration of a solar panel-based power system, sensor payload selection, and overall systems analysis.
- **Smart Battery Management:** Developed a deep learning model for a self-aware smart battery system to modify mission plans and prevent battery-related failures.
- **Invasive Species Sampler:** Designed and manufactured an autonomous device for sampling spiny waterflea, including simulations and field testing.

PUBLICATIONS

1. R. Krzysiak and C. Yu, "Tiered IoT Device Strategy for Supraventricular Tachycardia Detection with Explainable AI and Patient Engagement", Abstract Submitted, AIMed, 2025.
2. S. Giri, D. Hollenbeck, R. Krzysiak and Y. Chen, "PHANTOM: Physics-informed Hyperspectral Adversarial Network for Transformer-Optimized Methane Detection", Submitted, American Control Conference (ACC 2026).
3. R. Krzysiak, J. Ramirez and Y. Chen, "Thermo-TwinX: A Glass-Box Approach to Intelligent Thermal Monitoring with Digital Twins", Submitted, International Conference on Mechanical and Electrical Engineering (ICMEE 2025).
4. R. Krzysiak, S. Giri and Y. Chen, "Optimal Methane Plume Extraction of Hyperspectral Imagery Using Fractional Order Matched Filter", Submitted, 2025.
5. F. Winiberg, M. Fradet, K. Schwarm, I. Sanders, M. Bryk, V. Cretu, R. Krzysiak, K. Mansour, N. Tallarida, J. Wallace, P. Dodd, A. Noell, and L. Christensen, "Tunable Laser Spectrometer for the Miniaturized Total Organic Carbon Analyzer", Acta Astronautica (Accepted).
6. D. Hollenbeck, R. Krzysiak, et al., "Developing An Optimal Mobile Measurement sUAS using Digital Twins and the Observability Gramian", ICCMA 2025 (Accepted).
7. R. Krzysiak, et al., "Modeling and Control of a Prescribed Fire with UAVs as Sensors and Actuators", ICCMA 2025 (Accepted).
8. S. Giri, R. Krzysiak, et al., "Aviris-Ng-Like Smart Virtual Remote Sensing via Spectra-Aware Physics Informed Gans", IDETC, 2025.
9. R. Krzysiak et al., "Advancing Multi-Task Learning With Fractional Order Sgd and Quantus-Assessed Explainability for Planetary Health Monitoring", IDETC, 2025.
10. R. Krzysiak et al., "Explainable Multi-task Learning for Improved Land Use Classification in Planetary Health Monitoring", DTPI, 2024.
11. F. Winiberg, M. Fradet, R. Krzysiak et al., "Design and Performance of Indium Seals for Size-Constrained Tunable Laser Spectrometers", Review of Scientific Instruments, 2024.

12. R. Krzysiak et al., "Human prior knowledge estimation from movement cues for information-based control of mobile robots during search", ACM Transactions on Human-Robot Interaction (THRI), 2024.
13. R. Krzysiak et al., "Thermally conductive-radiative driven digital twin of miniature tunable laser spectrometer in micro-gravity", Submitted to Journal of Applied Thermal Engineering, 2023.
14. D. Hollenbeck, D. An, R. Krzysiak et al., "Towards Cognitive Battery Monitoring on Hybrid VTOL Fixed-Wing sUAS with Maximized Safe Endurance", ICCMA, 2023.
15. D. An, R. Krzysiak et al., "A Proximal Point Sensing System for Mapping Soil Moisture Using A Miniaturized Spectrometer", ICCMA, 2023.
16. R. Krzysiak, et al., "XCardio-Twin: An Explainable Framework to Aid in Monitoring and Analysis of Cardiovascular Status", DTPI, 2023.
17. D. An, R. Krzysiak, et al., "Long Endurance Site-Specific Management of Biochar Applications Using Unmanned Aircraft Vehicle and Unmanned Ground Vehicle", IFAC-PapersOnLine 56.2 (2023): 8908-8913.
18. D. An, R. Krzysiak, et al., "Battery-health-aware UAV mission planning using a cognitive battery management system", 2023 International Conference on Unmanned Aircraft Systems (ICUAS). IEEE, 2023.
19. R. Krzysiak et al., "XAI – The future of wearable Internet of Things", IEEE/ASME MESA conference, 2022.
20. R. Krzysiak, "Human-aware information-theoretic control of robotic swarms", Master's Thesis, Northern Illinois University, 2021.
21. R. Krzysiak and S. Butail, "Information based control of robots in search and rescue missions with human prior knowledge", IEEE Transactions on Human-Machine Systems, 2021.

TEACHING & MENTORSHIP EXPERIENCE

Teaching Assistant University of California, Merced
2022, 2024

· Taught labs and discussion courses for Electrical Circuits, Statics, and Drones. Graded quizzes, assignments, and exams.

Teaching Assistant Northern Illinois University
2018 - 2019

· Graded assignments, projects, and exams for Mechanism Design and Analysis. Consulted with student teams on project designs.

Graduate Assistant Northern Illinois University
2020 - 2021

· National Science Foundation, Great Journeys Assistantship.

Mentorship

· **UCM AIAA Graduate Mentor (2022 - Present):** Advise undergraduate students in the American Institute of Aeronautics and Astronautics chapter.
· **UC Merced MesaLab Mentor (2022 - Present):** Guide underrepresented minority students in conducting research.
· **UC Merced Cube Sat Mentor (2025 - Present):** Mentor undergraduate students in satellite design, development, and mission planning for small satellite projects.

LEADERSHIP & PROFESSIONAL ACTIVITIES

Mars Rover Team Vice President (2018 - 2019) & **Secretary** (2019)

Member, Pi Tau Sigma (The International Mechanical Engineering Honor Society)

Outreach, Northern Illinois University STEMFEST & Honors Outreach Program