Rylan Noah Malarchick

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Research Objective

Junior pursuing BS/MS Engineering Physics at Embry-Riddle Aeronautical University. Researching hardware-aware quantum systems software (compilers + pulse optimization) with the goal of developing deployment-ready quantum compilers. Preparing for PhD in quantum computing (Fall 2029).

Education

Embry-Riddle Aeronautical University Daytona Beach, FL

BS/MS Engineering Physics (Accelerated), Spacecraft Instrumentation Track, Comp. Math Minor ***Expected May 2027***

Relevant Coursework

Mathematics: Calculus II/III, Differential Equations & Matrix Methods, Linear Algebra, Numerical Analysis I, Mathematical Methods for Engineers & Physics I/II, High Performance Scientific Computing, Boundary Value Problems (graduate)
Physics: Physics I/II/III Laboratory, Modern Physics, Modern Physics Laboratory
Computing: Intro Computing for Engineers, Digital Circuit Design, Signals & Systems, Microprocessor Systems, Numerical Methods for Engineers & Scientists (EP 501, graduate)

Research Experience

NASA Goddard Space Flight Center May 2025 – Aug 2025

OSTEM Intern – Atmospheric Remote Sensing *Greenbelt, MD*

- Developed ML framework for cloud base height retrieval from 1,426 NASA ER-2 airborne observations across 5 research flights (3 used for final analysis), engineering 38 atmospheric features (10 ERA5 base + 28 physics-derived)
- Achieved $R^2 = 0.744$ with MAE = 117.4m using rigorous per-flight cross-validation; gradient boosting outperformed CNNs ($R^2 = 0.320$) by 123%
- Engineered preprocessing pipeline for HDF5 data with temporal interpolation and radiometric correction
- Discovered catastrophic domain shift (R^2 = -15.4) in leave-one-flight-out cross-validation; developed few-shot adaptation recovering $R^2 = 0.57$–0.85 with only 50 target-domain samples
- First author on preprint: *"Atmospheric Features Outperform Images for Cloud Base Height Retrieval"* (pending arXiv submission, awaiting NASA approval)
- GitHub: github.com/rylanmalarchick/CloudMLPublic

Project Experience

QubitPulseOpt – Quantum Optimal Control Simulation | *QuTiP, Python, GRAPE* Oct 2025 – Present

- Developed Python framework using QuTiP for quantum gate optimization via GRAPE (Gradient Ascent Pulse Engineering), achieving 99.14% X-gate fidelity in 20ns simulations (77× error reduction vs. fixed-amplitude Gaussian baseline pulses)
- Implemented Lindblad master equation for realistic noise modeling including T_1/T_2 decoherence effects on transmon qubits
- Developed hardware-representative workflow via API connectivity to IQM Garnet 20-qubit superconducting processor for calibration retrieval (gate fidelities, coherence times, qubit connectivity)
- Engineered library with strict standards (RAII, zero-warning builds, CI/CD pipeline), 864 unit tests, 74% code coverage (85% on critical modules)
- Preprint published: arXiv:2511.12799 – *"GRAPE Pulse Optimization for Quantum Gates with Hardware-Representative Noise"*
- Future integration: End-to-end compilation pipeline with quantum-circuit-optimizer for circuits-to-pulses workflow
- GitHub: github.com/rylanmalarchick/QubitPulseOpt

High-Performance Variational Quantum Eigensolver | *PennyLane, JAX, OpenMPI* Oct 2025 – Jan 2026

- Implemented hybrid quantum-classical VQE in PennyLane/JAX to compute H_2 molecular ground state energy across 100 bond lengths, achieving near-exact accuracy (-1.137 Ha at equilibrium)

- Achieved **117× speedup** via 4-phase optimization pipeline on ERAU Vega HPC cluster (4× NVIDIA H100 GPUs, 192 AMD EPYC cores): JIT compilation, GPU acceleration, multi-GPU scaling, MPI parallelization
- Reduced H_2 potential energy surface computation from 593.95s to 5.04s, enabling practical interactive exploration of quantum chemistry problems
- Preprint published: arXiv:2601.09951 (with A. Steed): *"Parallelizing the Variational Quantum Eigensolver: From JIT Compilation to Multi-GPU Scaling"*
- GitHub: github.com/rylanmalarchick/QuantumVQE

Quantum Circuit Optimizer | *C++17, CMake* – **Complete** Dec 2025
- Production-quality C++ quantum compiler with OpenQASM 3.0 parser, DAG-based IR, 4 optimization passes (gate cancellation, commutation, rotation merging, constant folding), and SABRE routing algorithm
- Supports multiple hardware topologies (linear, grid, heavy-hex); 340 unit tests with comprehensive coverage
- Designed for cross-layer fidelity analysis with QubitPulseOpt integration
- GitHub: github.com/rylanmalarchick/quantum-circuit-optimizer

CUDA Quantum Simulator | *CUDA, C++17, cuBLAS* – **Core Complete** Dec 2025
- GPU-accelerated quantum state vector simulator with optimized CUDA kernels for single-qubit gates (X, Y, Z, H, Rx, Ry, Rz) and two-qubit gates (CNOT, CZ, SWAP, Toffoli)
- RAII memory management via `CudaMemory<T>` wrapper; density matrix simulation with Lindblad noise models (depolarizing, amplitude/phase damping)
- 9 test suites passing; MIT license with SPDX headers on all 31 source files
- Simulates up to 29 qubits on single RTX 4070 GPU (12GB VRAM); validated against Qiskit Aer statevector simulator
- GitHub: github.com/rylanmalarchick/cuda-quantum-simulator

LLVM Loop Unroll Analyzer | *LLVM 18, C++, Scalar Evolution* Dec 2025
- Developed custom LLVM pass analyzing loop structures and identifying unroll opportunities using Scalar Evolution for trip count analysis
- Implemented using LLVM 18 New Pass Manager for modern pass infrastructure compatibility
- Reports loop nesting depth, bounds analysis, and unroll recommendations with metadata attachment
- Foundation for understanding compiler infrastructure; bridges classical compiler optimization with quantum circuit compilation
- GitHub: github.com/rylanmalarchick/llvm-unroll-analyzer

AIRHOUND – UAV Pursuit System | *YOLOv8, ROS2, NVIDIA Jetson* Sept 2024 – Present
- Principal Investigator and perception lead on team of 7 developing autonomous UAV perception system for detect and pursuit of target drones
- Led and co-authored SPARK grant proposal to secure project funding
- Training and optimizing computer vision models (YOLOv8, RF-DETR) for real-time UAV tracking on NVIDIA Jetson Orin NX edge computing platform
- Accepted for presentation at SPIE Defense & Commercial Sensing 2026 (April 28, 2026); manuscript due April 8, 2026
- GitHub: github.com/eppl-erau-db/AIRHOUND

Research Code Principles | *Documentation, Python* – **Complete** Dec 2025
- Open-source framework for building production-grade research software with AI coding agents; 5 core principles for correctness-first scientific code
- Comprehensive style guides for C++, Python, CMake, and testing; AI agent prompting strategies for research-quality output
- Includes OpenCode Context Manager tool: vector-based semantic search for documentation retrieval, reducing token usage by 60-70% in AI coding sessions
- GitHub: github.com/rylanmalarchick/research-code-principles

quantSim – Quantitative Trading System | *Python, LightGBM, Docker* Nov 2025 – Present
- End-to-end quantitative swing-trading system with daily market data ingestion (Yahoo Finance), feature engineering, and ML-based signal generation using LightGBM
- Automated pipeline: SQLite storage, backtesting engine for strategy evaluation, and paper trading execution via Alpaca API
- Containerized deployment with Docker; scheduled execution via cron/anacron
- GitHub: github.com/rylanmalarchick/quantSim

Publications

Preprints:
Malarchick, R., Steed, A. (2026). "Parallelizing the Variational Quantum Eigensolver: From JIT Compilation to Multi-GPU Scaling." *arXiv:2601.09951.* [Link]

Malarchick, R. (2025). "GRAPE Pulse Optimization for Quantum Gates with Hardware-Representative Noise." *arXiv:2511.12799.* [Link]

Pending arXiv Submission:
Malarchick, R., et al. (2025). "Atmospheric Features Outperform Images for Cloud Base Height Retrieval." *Pending arXiv submission (awaiting NASA approval).* NASA GSFC collaboration.

Conference Presentations:
AIRHOUND: UAV Pursuit-Evasion System – Accepted for presentation at *SPIE Defense + Commercial Sensing 2026* (April 28, 2026); manuscript due April 8, 2026.

Technical Skills

Programming Languages: Python, C/C++, MATLAB, Bash/Shell
Compilers: LLVM (custom passes, Scalar Evolution, New Pass Manager), OpenQASM 3.0, DAG-based IR, circuit optimization, qubit routing
Quantum Computing: PennyLane, QuTiP, Qiskit, JAX, Catalyst, GRAPE optimization, Lindblad master equation, quantum simulation, VQE
High-Performance Computing: CUDA, OpenMPI (mpi4py), GPU acceleration (NVIDIA H100, RTX 4070), JIT compilation, HPC clusters (PBS)
Machine Learning: PyTorch, TensorFlow, scikit-learn (XGBoost, LightGBM, GBDT), NumPy, Pandas
Robotics & Embedded: ROS2, PX4, NVIDIA Jetson, CUDA
Hardware: FPGAs (Verilog, Vivado), Arduino, Pixhawk flight controllers
Developer Tools: Git/GitHub, Docker, Linux/Unix, CI/CD (GitHub Actions), pytest, CMake, Nsight Systems
Data Formats: HDF5, NetCDF, ERA5 reanalysis data

Awards & Honors

Goldwater Scholarship Campus Finalist (2025)
USTFCCCA Academic All-American (2024, 2025) – Cross Country
136th at 2025 NCAA Division II Cross Country National Championships
ERAU Dean's List
ERAU Athletic Scholarship

Athletics

NCAA Division II Cross Country and Track & Field (Aug 2023 – Present)
Events: 5000m, 10000m, Cross Country
136th at 2025 NCAA Division II Cross Country National Championships
Two-time USTFCCCA Academic All-American (2024, 2025)

References

References available upon request.