Mesum Ali Irfani

Aerospace and Robotics Engineer | Islamabad, Pakistan

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Aerospace and robotics engineer working on motion planning and control for autonomous vehicles, with five years of industry experience in UAV design and propulsion. My MS research built a complete planning and control stack for unmanned surface vehicles: a bidirectional global planner, a kinodynamic trajectory optimizer, a COLREGs-supervised nonlinear MPC with control-barrier-function safety, and the estimation layer underneath, validated over 14,400 statistically tested runs. At work I lead a propulsion team taking piston, turbine and solid-rocket systems from analysis and design through instrumented bench and flight testing.
Research interests: motion planning and trajectory optimization; model predictive and safety-critical control; estimation and intent inference for multi-agent interaction; system identification and digital twins of physical systems; autonomy for aerial and marine vehicles.

Education

National University of Sciences and Technology (NUST), SMME — Islamabad, Pakistan
MS in Robotics and Intelligent Machine Engineering, CGPA 3.95/4.0 — *Sep 2023 – Sep 2026*

- Completed part-time alongside full-time industry work. Coursework (all A): Robot Mechanics and Control, Mobile Robotics, Artificial Intelligence, Computer Vision, Advanced Engineering Mathematics, Advanced Programming in Python; SLAM.
- Supervisor: Dr. Khawaja Fahad Iqbal. Committee: Dr. Yasar Ayaz, Dr. Saqib Nazir.

MS Thesis: Obstacle Avoidance for Marine Robots (Grade A) — *May 2025 – Sep 2026*

- **Global planning:** designed MCS-Connect, a bidirectional sampling-based planner with adaptive inter-tree attraction and an obstacle-proximity penalty, implemented in C++. First feasible solution one to two orders of magnitude faster than RRT-Connect, Informed RRT* and BIT*, with 40 to 500 times fewer nodes explored, and 100% success on all 24 benchmark scenarios where baselines reached 0 to 44% (manuscript under review, *Ocean Engineering*).
- **Trajectory optimization:** B-spline kinodynamic optimizer enforcing turning-radius, surge-speed and acceleration limits, with a self-validating guard that certifies the delivered trajectory against a minimum-clearance requirement.
- **Predictive control:** constrained nonlinear MPC (direct multiple shooting, ERK4, SQP, acados) on the experimentally identified 3-DOF CyberShip II model, solving one exact-Hessian SQP step per sample under a real-time iteration scheme with partial condensing and warm starting; actuator saturation and rate limits as constraints, keep-out regions as high-order control barrier functions.
- **Rule compliance:** COLREGs supervision of the controller so that overtaking, head-on and crossing encounters are resolved by the manoeuvre the rules require of each party.
- **Estimation:** Interacting Multiple Model cubature Kalman tracker whose mode posterior gives a probabilistic estimate of each vessel's intent, and a disturbance observer recovering wave, current and wind loads from navigation data.
- **Validation:** designed and ran a 14,400-run Monte-Carlo planner benchmark (6 environments, 4 scenarios, 6 algorithms) with Welch tests and Cohen's d, plus 28 closed-loop scenarios covering confined water, dense multi-vessel traffic and full sea state, completed with zero collisions.

Institute of Space Technology (IST) — Islamabad, Pakistan
BS in Aerospace Engineering, CGPA 3.58/4.0, cum laude — *Sep 2017 – Jul 2021*

- Coursework included spacecraft dynamics and control, flight dynamics, aerodynamics, propulsion and aircraft design.
- Final year project: design, multidisciplinary analysis and optimization of a battery-electric aircraft (see Projects).

Professional Experience

NaqCoDE Technologies, NUST — Islamabad, Pakistan
Team Lead, Propulsion Systems — *Jul 2024 – present*

- **Technical leadership:** lead a six-engineer multidisciplinary team delivering propulsion subsystems (piston-prop engines, micro turbines, solid rocket motors) for unmanned aerial platforms, coordinating with aerodynamics, structures, avionics and flight-dynamics groups and with external university partners.
- **Modelling and system identification:** build grey-box models of propulsion systems identified from limited instrumented test data, predictive across the operating envelope and validated against measurement, so that design decisions are made against the model rather than against further testing.
- **Simulation and optimization frameworks:** developed an automated workflow linking geometry, meshing and analysis tools under genetic-algorithm and Bayesian-optimization drivers for constrained design-space explo-

ration; lead coupled fluid-thermal-structural analysis of solid rocket motors.
- **Bench and field testing:** design and commission fully instrumented test benches (thrust, torque, flow, temperature); plan and run engine, turbine and static-firing campaigns and reduce the sensor data into validated models; support flight-test campaigns.
- **Control-system specification:** authored engine-control-unit parameter specifications and a software requirements specification for an engine control interface covering RS232 telemetry, state estimation and fail-safe behaviour under telemetry loss.
- **Training:** develop and deliver internal technical courses on solid rocket motor design and development.

NaqCoDE Technologies, NUST Islamabad, Pakistan
Design Engineer, Aerodynamics and Design Group *Oct 2022 – Jul 2024*

- **Flight-control system design:** designed the complete manual mechanical flight-control system for a six-seat passenger aircraft (Veloce 600) covering flaps, ailerons, elevator and rudder: derived the forward and inverse kinematics of the linkage chain from pilot stick and pedal input through to control-surface deflection, sized the mechanism against travel and load requirements, and carried it through component CAD to assembly-level integration.
- **Propulsion integration:** inlet, nacelle and duct aerodynamics; propeller selection and matching; vehicle performance estimation (range, endurance, climb) from propulsion data.
- **Numerical analysis:** CFD and finite-element analyses on complex geometries, including two-way fluid-structure interaction and aeroelastic studies; shape optimization studies.
- **Vehicle development:** took multiple unmanned aerial vehicles from concept through detailed design to manufacture, supplying aerodynamic and stability derivatives to flight-dynamics, structures and avionics teams across design iterations.

Aviation Research, Indigenization and Development (AvRID) Kamra, Pakistan
Design Officer, Damage Tolerance Analysis Lab *Jan 2022 – Jun 2022*

- CFD load analysis and finite-element fatigue assessment to identify fatigue-critical locations on an airframe.

Technical Skills

Motion planning: graph-search and sampling-based optimal planners (RRT-Connect, Informed RRT*, BIT*, F-RRT*, Q-RRT*), bidirectional search, kinodynamic trajectory optimization and B-spline parameterization, receding-horizon replanning, rule-compliant decision logic

Control: nonlinear model predictive control (direct multiple shooting, SQP, real-time iteration, acados), constrained optimal control, control barrier functions and forward-invariant safe sets, Lyapunov and stability analysis, disturbance rejection, flight and spacecraft dynamics

Estimation and perception: Kalman and cubature Kalman filtering, Interacting Multiple Model estimation, sensor fusion, SLAM and localization, occupancy-grid mapping, OpenCV

Modelling, simulation and optimization: grey-box system identification from instrumented test data, physics-based vehicle dynamics, Monte-Carlo campaigns with significance testing, Bayesian optimization, genetic algorithms, automated CAD-mesh-solve workflows

Propulsion and aerodynamics: piston-prop engines, micro turbines, solid rocket motors; internal ballistics; propeller selection and matching; inlet, nacelle and duct aerodynamics; performance estimation (range, endurance, climb); instrumented thrust-stand testing

Software and tools: C++, Python (NumPy, SciPy, scikit-learn), MATLAB/Simulink, ROS 2, Gazebo, Linux, Git, LaTeX, embedded C (ESP32, Arduino)

CAE: ANSYS Fluent and Mechanical (CFD, FEA, two-way FSI, System Coupling), ICEM CFD, SolidWorks, CATIA V5, VSPAero, QBlade

Languages: English (C1, IELTS 7.5), Urdu (native)

Research and Engineering Projects

- **Bayesian optimization for planner tuning:** Gaussian-process Bayesian optimization (expected improvement) over the planner cost-function parameters, followed by one-dimensional sensitivity sweeps around the optimum; three analysis modes with publication-quality figure output.
- **Sampling-based planner implementations:** F-RRT* and Q-RRT* on image-based maps with real-time visualization and metric tracking; kinodynamic planner benchmarking on Dynobench unicycle environments.
- **Robot navigation and SLAM (ROS 2 Humble, TurtleBot3):** graph-based occupancy-grid mapping with slam_toolbox, localization against the saved map, Nav2 path planning to goal poses, and localization studies under injected Gaussian sensor noise; a separate autonomous maze-solving stack with laser-scan feedback, wall following and goal-directed execution.
- **Manipulator control for liquid pouring (ROT3U arm):** inverse kinematics and joint-space trajectory generation

under end-effector orientation constraints, executed on Arduino-driven servos for a pick, pour and return task.
- **NAO humanoid receptionist and guide:** customized a NAO robot as an interactive receptionist for the NUST-Coventry Human-Robot Interaction Lab.
- **Phonocardiogram pathology classification:** normal/abnormal heart-sound classification on the PhysioNet/CinC 2016 dataset using librosa features (zero-crossing rate, MFCCs, spectral statistics) and a gradient-boosting classifier, deployed as a Flask web app.
- **Design, analysis and optimization of an electric aircraft (BS final year project):** weight, battery and component sizing of a baseline, sizing-matrix-plot optimization constrained by range, rate of climb and take-off distance, CATIA model, and CFD, aerodynamic, propulsion, battery and performance analyses in ANSYS, MATLAB, VSPAero and QBlade.
- **Custom EFI and ECU for a DLE 60 engine (personal, ongoing):** conversion of a carbureted two-stroke UAV engine to electronic fuel injection with a self-built ESP32 ECU for closed-loop fuel and ignition control.

Publications

- M. A. Irfani, K. F. Iqbal, Y. Ayaz, M. S. Nazir and K. Faraz, "Magnetically Coupled Sunlight-Connect: Accelerating Bidirectional Path Planning Through Adaptive Inter-Tree Attraction for Unmanned Surface Vehicles in Complex Marine Environments," *Ocean Engineering* (Elsevier), under review, 2026.
- M. A. Irfani, "Obstacle Avoidance for Marine Robots," MS Thesis, SMME, NUST, 2026.

Certifications

- Robotics: Computational Motion Planning, University of Pennsylvania (Coursera), May 2025
- Robotics: Human-Robot Interaction, Udemy, Nov 2024
- Supervised Machine Learning: Regression and Classification, DeepLearning.AI and Stanford Online (Coursera), Oct 2023
- Robotics: Aerial Robotics, University of Pennsylvania (Coursera), Sep 2022
- Mastering ANSYS CFD (Level 1), Udemy, Dec 2021

Honors and Additional

Honors: MS thesis graded A; cum laude, BS Aerospace Engineering. **Tests:** IELTS Academic 7.5 (Oct 2026); GRE Quantitative 160. **References:** available on request.