Research Statement

My research focuses on embedded systems, cyber-physical systems (CPS), fault tolerance, machine learning, and cost-effective strategies for dependability in safety-critical domains such as automotive systems and industrial IoT. I aim to bridge the gap between academic innovation and real-world deployment by efficiently reducing the computational overhead of safety-critical applications in the cost-effective Commercial-Off-The-Shelf (COTS) devices, instead of designing new computing devices or exploiting redundant ones.

Past Work:

My doctoral dissertation, *System-Level Approaches to Manage Physical Overheads in CPS*, introduced architectures that leverage Digital Twins (DTs) and computational redundancy to enhance reliability without incurring hardware duplication. I developed *virtual sensors*—computational substitutes for physical devices—that reduce hardware needs while maintaining reliability. These approaches were validated on Commercial-Off-The-Shelf (COTS) microcontrollers and published in leading venues such as the *IEEE Internet of Things Journal* and *IEEE Transactions on Intelligent Vehicles*.

Beyond academia, I founded and led a startup specializing in performance-critical embedded applications, delivering GPU-accelerated systems and real-time embedded platforms for industrial partners. This experience highlights the importance of cost, availability, and reliability in the design of dependable CPS.

Current Work:

At IPM, my postdoctoral research expands toward *Assured Digital Twins (ADTs)*. DTs hold transformative potential across sectors, yet challenges remain around cost-effectiveness, security, and safety in distributed, latency-sensitive environments. My research addresses three parameters:

1. **Cost-effectiveness** – ensuring cost-effective DTs can be implemented efficiently to meet the safety-critical requirements.
2. **Security** – identifying vulnerabilities in DT data pipelines and implementing lightweight anomaly detection mechanisms to detect vulnerabilities.
3. **Safety Assurance** – integrating cost-effectiveness and security guarantees into safety applications, enabling practical adoption in domains such as automotive and robotics.

ADT can be effectively employed as a virtual redundant device to reduce the physical overhead of CPSs.

Future Directions:

I aim to expand these directions in collaboration with colleagues in **Cyber Security, Artificial Intelligence, and CPS**. My long-term goals are to:

- Develop scalable ADT frameworks that combine AI with domain-specific assurance for Industry 5.0 applications.
- Pursue interdisciplinary funding opportunities across CPS, networking, and trustworthy computing.
- Build partnerships with industrial and societal stakeholders to ensure research outcomes have a real-world impact.

I look forward to advancing fundamental research while pursuing challenge-led, interdisciplinary collaborations.