Hackfinity 3.0 Hardware Problem Statement

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
1. Embedded Systems & IoT				
HF3-HW-01	**Secure Over-the-Air Firmware Update and Automatic Rollback Protection System for IoT Devices**	Hardware	Embedded Systems & IoT	**Background:** IoT devices deployed in remote or inaccessible locations require regular firmware updates to improve functionality, fix software bugs, and address security vulnerabilities. However, performing firmware updates over unreliable wireless networks can lead to interrupted or corrupted installations, potentially rendering devices permanently inoperable (bricked). This creates significant maintenance challenges, increases operational costs, and reduces the reliability of large-scale IoT deployments. Therefore, a secure and fault-tolerant firmware update mechanism is essential to ensure uninterrupted device operation and long-term system reliability. **Description:** Develop a secure Over-the-Air (OTA) firmware update system for ESP32-based IoT devices that enables wireless firmware upgrades while ensuring update integrity and system reliability. The solution should verify the authenticity and integrity of the firmware using checksum or digital signature validation before installation. It should implement a dual-partition OTA mechanism with rollback protection, allowing the device to automatically restore the previous stable firmware if the updated version fails to boot correctly or does not pass a predefined self-test. The system should demonstrate seamless recovery by deploying an intentionally faulty firmware update and automatically reverting to the last working version without requiring manual intervention. **Expected Solution:** A secure, reliable, and user-friendly OTA firmware update platform that enables ESP32-based IoT devices to receive wireless firmware updates safely. The solution should provide firmware integrity verification, secure installation, automatic rollback to the previous working firmware in case of update failure, and real-time update status monitoring. The system should ensure uninterrupted operation of deployed IoT devices while minimizing maintenance efforts, improving security, and preventing device failures caused by unsuccessful firmware updates.
HF3-HW-02	**AI-Driven Pipeline Integrity Monitoring and Predictive Leak Detection System**	Hardware	Embedded Systems & IoT	**Background:** Oil, gas, and water pipelines are critical infrastructure that transport essential resources over vast geographical regions. These pipelines are exposed to varying pressure, environmental conditions, and operational stresses, making them vulnerable to leaks, corrosion, pressure

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				fluctuations, and structural failures. Traditional inspection methods rely on periodic manual surveys, which are time-consuming, expensive, and unable to provide continuous real-time monitoring. Delayed detection of pipeline faults can result in environmental damage, resource loss, safety hazards, and increased maintenance costs. Therefore, there is a growing need for an intelligent monitoring system capable of continuously assessing pipeline health and identifying potential failures before they become critical. **Description:** Develop an intelligent embedded pipeline monitoring system that continuously collects data from sensors measuring pressure, flow rate, vibration, temperature, humidity, and other environmental parameters. The system should analyze the collected data using AI and machine learning techniques to detect abnormal operating conditions, predict potential leaks or structural failures, estimate the location of faults, and generate real-time alerts for maintenance personnel. The platform should support remote monitoring through a web or mobile dashboard, enabling operators to visualize pipeline health, receive notifications, and take preventive actions before significant damage occurs. **Expected Solution:** A secure and intelligent IoT-based pipeline monitoring platform that continuously monitors pipeline operating conditions and accurately detects anomalies using AI-driven analytics. The solution should provide real-time visualization of sensor data, early leak and fault detection, fault location estimation, automated alert generation, and predictive maintenance recommendations. By enabling continuous monitoring and timely intervention, the system should improve pipeline safety, reduce operational costs, minimize environmental impact, and enhance the overall reliability of pipeline infrastructure.
HF3-HW-03	**Secure Embedded Firmware Update Framework**	Hardware	Embedded Systems & IoT	**Background:** Embedded systems in industrial automation, healthcare, automotive, and consumer electronics require regular firmware updates for security and functionality. Many still rely on insecure methods like USB drives or unencrypted channels, exposing devices to tampering, malware injection, and failed-update damage. A secure framework is needed to authenticate, encrypt, and safely update firmware with rollback protection. **Description:** Develop a secure embedded firmware update framework that authenticates firmware using cryptographic signatures, encrypts data during

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				transmission, and verifies integrity before installation. The system should support secure boot, fail-safe recovery through backup firmware storage, and rollback protection to block reinstallation of older, vulnerable versions. It should remain lightweight enough for resource-constrained microcontrollers while supporting updates over wired or wireless channels with status logging for audit purposes. **Expected Solution:** A secure, tamper-resistant firmware update platform that authenticates, encrypts, and verifies updates end-to-end while supporting automatic rollback and recovery from failed installations. The framework should prevent downgrade attacks, block unauthorized modifications, and maintain device availability without physical intervention, improving the security, reliability, and operational continuity of embedded devices across industrial, healthcare, automotive, and consumer applications..
HF3-HW-04	**AI-Driven Real-Time Distributed Traffic Signal Coordination System**	Hardware	Embedded Systems & IoT	**Background:** Urban traffic congestion has become a major challenge due to increasing vehicle density and rapidly growing transportation demands. Conventional traffic signal systems generally operate using fixed timing schedules and independent controllers, making them unable to adapt effectively to changing traffic conditions. Additionally, centralized traffic management systems rely heavily on continuous communication with cloud or control centers, making them vulnerable to network congestion and communication failures. Delayed traffic management can result in longer travel times, increased fuel consumption, higher emissions, and reduced transportation efficiency. **Description:** Develop an intelligent distributed traffic signal coordination system that enables neighboring intersections to exchange real-time traffic information and dynamically adjust signal timings based on current traffic conditions. The system should use embedded controllers and IoT communication to monitor vehicle density, traffic flow, queue length, and waiting times while applying AI and machine learning algorithms to optimize signal coordination. The solution should perform local decision-making without relying on continuous cloud connectivity and provide a centralized dashboard for monitoring traffic conditions, signal status, and system performance. **Expected Solution:** A secure and intelligent distributed traffic management platform that continuously monitors traffic conditions and

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				coordinates signal operations using AI-driven edge analytics and embedded communication. The solution should enable real-time adaptive signal control, improve vehicle flow across connected intersections, reduce travel time, fuel consumption, and traffic congestion, while maintaining reliable operation during communication outages. The platform should provide real-time traffic visualization, performance analytics, and automated alerts, enhancing the efficiency, sustainability, and reliability of urban transportation systems
HF3-HW-05	**Closed-Loop Greenhouse Climate Control and Multi-Variable Optimization System**	Hardware	Embedded Systems & IoT	**Background:** Greenhouses provide controlled environments for crop cultivation, where maintaining optimal temperature, humidity, carbon dioxide (CO_2), and light levels is essential for maximizing plant growth and productivity. Conventional greenhouse control systems typically manage these environmental parameters independently using fixed threshold values. However, these variables are highly interdependent; for example, opening ventilation to reduce temperature can also decrease humidity and CO_2 levels, negatively affecting plant health. Such isolated control strategies often lead to inefficient resource utilization, conflicting actuator operations, and suboptimal growing conditions. Therefore, there is a need for an intelligent climate control system that simultaneously considers multiple environmental factors and optimizes control decisions in real time. **Description:** Develop an intelligent IoT-based greenhouse climate control system that continuously monitors temperature, humidity, CO_2 concentration, light intensity, and other environmental parameters using multiple sensors. The system should employ AI and multi-variable optimization techniques to evaluate the combined effect of these parameters and determine the most effective control action among available actuators such as ventilation, heaters, humidifiers, cooling fans, and artificial lighting. Instead of relying on independent threshold-based rules, the system should use weighted decision-making to balance trade-offs between environmental variables and maintain optimal growing conditions. The solution should also provide remote monitoring, visualization, and control through a web or mobile dashboard. **Expected Solution:** A secure and intelligent greenhouse climate management platform that continuously monitors environmental conditions and optimizes actuator operations using AI-driven multi-variable decision-making. The solution should

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				provide real-time sensor visualization, adaptive climate control, automated actuator management, predictive environmental adjustments, and remote monitoring through an intuitive dashboard. By intelligently balancing temperature, humidity, CO_2, and light conditions, the system should improve crop yield, reduce energy and water consumption, optimize resource utilization, and enhance the efficiency and sustainability of greenhouse farming.
HF3-HW-06	**Hardware-Based Lightweight Real-Time Operating System (RTOS) Development and Energy-Aware Task Scheduling Platform**	Hardware	Embedded Systems & IoT	**Background:** Modern embedded systems used in automotive electronics, industrial automation, robotics, medical devices, aerospace, and IoT applications require predictable and efficient real-time task execution. Conventional operating systems often introduce scheduling delays and unnecessary resource overhead, making them unsuitable for resource-constrained embedded hardware. Additionally, battery-powered and energy-sensitive devices require intelligent task scheduling to maximize operational efficiency while ensuring that critical tasks always meet their deadlines. There is a growing need for a lightweight hardware-oriented Real-Time Operating System (RTOS) capable of providing deterministic task scheduling, efficient resource management, interrupt handling, and energy-aware operation on embedded microcontrollers. **Description:** Develop a lightweight custom Real-Time Operating System (RTOS) for embedded hardware using C/C++ and deploy it on a microcontroller platform such as STM32, ESP32, ARM Cortex-M, or similar embedded development boards. The RTOS should implement a preemptive scheduler, task management, interrupt handling, mutexes, semaphores, timers, and inter-task communication mechanisms. The embedded system should support mixed-criticality task execution by prioritizing safety-critical tasks while dynamically adjusting task scheduling based on available power and energy conditions. Hardware peripherals such as LEDs, LCD/OLED displays, buttons, sensors, timers, and communication interfaces (UART, SPI, I2C, CAN, etc.) should be integrated to demonstrate real-time task execution, interrupt servicing, context switching, and energy-aware scheduling. The platform should also provide real-time visualization of task execution, processor utilization, interrupt latency, and power consumption through an onboard display or external monitoring interface. **Expected Solution:** A fully functional hardware prototype consisting of an embedded microcontroller running a custom lightweight RTOS capable of

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				deterministic real-time task scheduling and efficient resource management. The system should demonstrate reliable preemptive multitasking, interrupt handling, mutex and semaphore synchronization, energy-aware scheduling, mixed-criticality task execution, and peripheral control under varying workloads. The prototype should provide real-time visualization of task execution timelines, processor utilization, scheduling decisions, interrupt response, and energy consumption. The solution should improve the reliability, efficiency, and predictability of embedded systems while serving as a scalable hardware platform for robotics, industrial automation, automotive, healthcare, and IoT applications requiring real-time operation.
HF3-HW-07	**Self-Healing Embedded Communication System for Reliable IoT Networks**	Hardware	Embedded Systems & IoT	**Background:** Embedded and IoT devices deployed in industrial automation, smart agriculture, healthcare, environmental monitoring, and smart city applications rely on reliable communication to exchange critical data. However, wireless and serial communication channels are often affected by noise, interference, signal attenuation, and packet loss, leading to unreliable data transmission and reduced system performance. Existing communication protocols may fail to provide timely recovery during adverse network conditions, resulting in delayed responses and system failures. Therefore, there is a growing need for a hardware-based self-healing communication system capable of maintaining reliable data exchange, detecting transmission errors, and automatically recovering from communication failures while ensuring low latency and continuous operation. **Description:** Develop a hardware-based embedded communication system using microcontrollers such as ESP32, STM32, Arduino, or similar platforms integrated with communication modules including Wi-Fi, LoRa, Zigbee, Bluetooth, or serial interfaces. The system should implement a reliable communication protocol featuring packet sequencing, CRC-based error detection, automatic retransmission with exponential backoff, acknowledgment mechanisms, and timing control. The embedded devices should continuously monitor communication quality, detect packet loss or transmission errors, automatically recover from communication failures, and maintain reliable data transfer under noisy environments. The prototype should demonstrate real-time communication between multiple embedded nodes while operating

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				efficiently under varying packet loss and interference conditions. **Expected Solution:** A fully functional hardware prototype consisting of multiple embedded communication nodes capable of reliable and self-healing data transmission in noisy communication environments. The system should accurately detect transmission errors, recover lost packets through automatic retransmission, maintain bounded communication latency, and ensure reliable data delivery using embedded communication protocols. The prototype should demonstrate robust wireless or serial communication, efficient error recovery, low-power operation, and stable performance under high interference and packet loss conditions. The solution should improve the reliability, resilience, and efficiency of IoT and embedded communication systems used in industrial, healthcare, environmental, and smart infrastructure applications.
2. Edge AI & Hardware Acceleration				
HF3-HW-08	**AI-Driven Edge-Based Utility Infrastructure Monitoring System**	Hardware	Edge AI & Hardware Acceleration	**Background:** Critical utility infrastructure such as transformers, water pumping stations, electrical substations, and communication facilities play a vital role in delivering essential public services. These assets operate in diverse and often remote environments, making continuous monitoring crucial for ensuring reliability and preventing unexpected failures. Traditional monitoring systems primarily depend on centralized cloud processing, which introduces communication delays and limits system functionality during network outages. Delayed fault detection can lead to service interruptions, increased maintenance costs, equipment damage, and reduced operational efficiency. **Description:** Develop an intelligent edge-based monitoring system that continuously collects operational data from utility infrastructure using sensors to measure parameters such as voltage, current, temperature, vibration, pressure, humidity, and equipment status. The system should perform local AI-based anomaly detection on an embedded edge device, store critical operational data, and generate immediate alerts without relying on cloud connectivity. The solution should support remote monitoring through a web or mobile dashboard while enabling the management of multiple utility assets deployed across different locations. **Expected Solution:** A secure and intelligent edge-based utility monitoring platform that continuously monitors critical infrastructure using embedded IoT

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				devices and AI-driven analytics. The platform should perform real-time local anomaly detection, generate instant alerts during abnormal operating conditions, maintain local data storage during communication failures, and synchronize information with a central dashboard when connectivity is available. The solution should improve infrastructure reliability, reduce maintenance costs, minimize service interruptions, and ensure uninterrupted monitoring of utility assets, even in remote or low-connectivity environments.
HF3-HW-09	**TinyML-Based Predictive Machine Failure Detection System**	Hardware	Edge AI & Hardware Acceleration	**Background:** Manufacturing industries rely on the continuous operation of industrial machines to maintain productivity and efficiency. Unexpected equipment failures can cause production downtime, increased maintenance costs, reduced operational efficiency, and significant financial losses. Traditional predictive maintenance systems depend on cloud computing and high-performance servers to analyze sensor data such as vibration, acoustic signals, and temperature. These systems introduce communication delays, require continuous internet connectivity, and are less suitable for remote factories and safety-critical industrial environments. Recent advancements in TinyML enable lightweight machine learning models to run directly on embedded microcontrollers, allowing fast and reliable fault detection at the edge while minimizing latency and power consumption. **Description:** Develop an intelligent TinyML-based embedded system that continuously monitors industrial machines by collecting data from vibration, acoustic, temperature, and other relevant sensors. The system should use lightweight machine learning models deployed on microcontrollers to analyze sensor data locally, identify early signs of equipment degradation, distinguish between normal and abnormal operating conditions, and generate real-time alerts for maintenance personnel. The solution should perform low-latency inference without relying on cloud connectivity while operating efficiently within the memory, processing, and power constraints of embedded hardware. A web or mobile dashboard should also provide remote monitoring, equipment status visualization, and maintenance insights. **Expected Solution:** A secure and intelligent Edge AI-based predictive maintenance platform that continuously monitors industrial equipment using TinyML-powered embedded devices. The solution should accurately detect abnormal machine behavior, perform real-time local inference with

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				minimal latency, reduce false alarms, and generate timely maintenance alerts. The platform should provide real-time visualization of machine health, historical sensor data, predictive maintenance recommendations, and system performance through an intuitive dashboard. By enabling early fault detection and local AI processing, the solution should improve equipment reliability, reduce downtime and maintenance costs, enhance operational efficiency, and support sustainable smart manufacturing environments
HF3-HW-10	**AI-Driven Intelligent PPE Compliance Monitoring System**	Hardware	Edge AI & Hardware Acceleration	**Background:** Industrial workplaces, construction sites, manufacturing plants, and laboratories require workers to wear Personal Protective Equipment (PPE) such as helmets, gloves, reflective jackets, safety goggles, and protective footwear to ensure workplace safety and reduce the risk of accidents. Manual monitoring of PPE compliance is time-consuming, labor-intensive, and prone to human error, making it difficult to ensure continuous safety enforcement. Cloud-based video analytics solutions often introduce communication delays, increase bandwidth requirements, and raise privacy concerns due to continuous transmission of surveillance footage. Therefore, there is a growing need for an intelligent edge-based monitoring system capable of performing real-time PPE detection locally while maintaining worker privacy and ensuring reliable safety compliance. **Description:** Develop an intelligent Edge AI-based PPE compliance monitoring system that uses onboard cameras and embedded image processing to continuously detect whether workers are wearing the required personal protective equipment. The system should utilize AI and computer vision algorithms to identify safety helmets, gloves, reflective jackets, safety goggles, and other mandatory PPE under varying lighting and environmental conditions. The solution should perform all inference locally on embedded hardware without transmitting video to external servers, generate immediate alerts upon detecting non-compliance, and provide a web or mobile dashboard for monitoring compliance statistics, incident reports, and system status. **Expected Solution:** A secure and intelligent Edge AI-based PPE monitoring platform that performs real-time detection of personal protective equipment using embedded computer vision. The solution should accurately identify missing safety equipment, generate instant alerts for safety violations, maintain worker privacy by processing data locally, and operate efficiently on resource-constrained

Hackfinity 3.0 Hardware Problem Statement

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				hardware. The platform should provide real-time compliance monitoring, historical incident records, performance analytics, and centralized dashboard visualization, improving workplace safety, reducing accidents, minimizing compliance monitoring efforts, and enhancing overall industrial safety management.
HF3-HW-11	**Hardware-Accelerated Real-Time Sign Language Recognition and Translation System**	Hardware	Edge AI & Hardware Acceleration	**Background:** Communication between hearing-impaired individuals and the general public remains a significant challenge in healthcare, education, banking, transportation, and public service environments. The limited availability of professional sign language interpreters often creates communication barriers, while cloud-based sign language recognition systems suffer from network latency, internet dependency, and privacy concerns. Additionally, many conventional embedded platforms lack the computational capability required for real-time gesture recognition. There is a growing need for a dedicated hardware-based solution that can perform fast, accurate, and privacy-preserving sign language recognition locally without relying on external cloud services. **Description:** Develop a hardware-accelerated embedded sign language recognition system capable of detecting and translating hand gestures in real time using onboard cameras and embedded AI hardware. The system should integrate high-speed image sensors, embedded processors (such as FPGA, NVIDIA Jetson, Raspberry Pi AI Kit, ESP32-S3 with AI acceleration, or similar platforms), and computer vision modules to recognize sign language gestures locally. The embedded hardware should perform real-time image acquisition, gesture recognition, and translation into text or speech without transmitting video data to external servers. The system should operate efficiently under varying lighting conditions, support continuous gesture recognition with low latency, and provide immediate visual and audio feedback through an integrated display and speaker. **Expected Solution:** A dedicated hardware prototype that combines embedded AI processors, cameras, displays, speakers, and edge computing technology to perform real-time sign language recognition and translation. The system should accurately recognize sign language gestures, convert them into text and speech with minimal latency, operate independently without internet connectivity, and preserve user privacy through local processing. The prototype should demonstrate reliable performance in real-world environments while providing an affordable,

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				portable, and energy-efficient communication aid for hearing-impaired individuals.
HF3-HW-12	**Vision Vehicle Speed and Traffic Violation Detection System**	Hardware	Edge AI & Hardware Acceleration	**Background:** Road traffic accidents caused by speeding, red-light violations, lane indiscipline, illegal parking, and wrong-way driving continue to pose significant challenges to public safety. Traditional traffic enforcement methods rely on manual monitoring and standalone speed cameras, which provide limited coverage and are often unable to monitor multiple violations simultaneously. Environmental conditions such as poor lighting, adverse weather, and heavy traffic further reduce the effectiveness of conventional systems. There is a growing need for an intelligent hardware-based traffic monitoring solution capable of continuously detecting vehicle speed, identifying multiple traffic violations, and supporting automated enforcement while operating reliably in real-world conditions. **Description:** Develop a hardware-based vision traffic monitoring system using embedded Edge AI hardware capable of continuously monitoring road traffic through high-resolution cameras and onboard processing units. The system should integrate cameras, radar or LiDAR speed sensors (optional), embedded AI processors (such as NVIDIA Jetson, Raspberry Pi AI Kit, Google Coral, or FPGA), GPS, and wireless communication modules to estimate vehicle speed, detect red-light violations, lane discipline violations, illegal parking, and wrong-way driving in real time. The embedded hardware should perform local image processing, Automatic Number Plate Recognition (ANPR), and violation detection without relying on continuous cloud connectivity. The system should operate efficiently under varying weather and lighting conditions while storing evidence locally and transmitting violation records to a central monitoring station. **Expected Solution:** A fully functional hardware prototype that combines embedded AI processors, vision sensors, speed detection modules, and wireless communication hardware to perform real-time traffic monitoring and automated violation detection. The system should accurately estimate vehicle speed, recognize vehicle license plates, detect multiple traffic violations simultaneously, and generate immediate alerts and enforcement records. The prototype should demonstrate reliable operation under diverse environmental conditions, low-latency edge processing, local data storage, and efficient power consumption. The solution should improve road safety, reduce manual traffic enforcement efforts, enhance monitoring accuracy, and support

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				intelligent transportation infrastructure through autonomous hardware-based operation.
HF3-HW-13	**Federated Edge Learning System with Privacy-Preserving Continual Adaptation**	Hardware	Edge AI & Hardware Acceleration	**Background:** Modern IoT and edge devices deployed in smart factories, healthcare systems, autonomous vehicles, smart agriculture, and environmental monitoring continuously generate large volumes of sensor data. Transferring this data to centralized cloud servers raises privacy concerns, increases communication overhead, and introduces latency. Additionally, edge devices often operate in dynamic environments where data patterns change over time, causing traditional machine learning models to become less accurate. Limited computational resources, intermittent network connectivity, and heterogeneous hardware platforms further complicate collaborative learning across distributed devices. Therefore, there is a growing need for an intelligent hardware-based federated learning system that enables edge devices to collaboratively improve AI models while preserving data privacy and adapting to changing operating conditions. **Description:** Develop a hardware-based federated learning platform using multiple embedded edge devices such as ESP32, Raspberry Pi, NVIDIA Jetson, STM32, or similar microcontroller and edge AI boards. Each device should integrate sensors such as temperature, vibration, humidity, motion, gas, or vision sensors to continuously collect real-world data and locally train lightweight AI models. The embedded system should support decentralized model updates without sharing raw sensor data, using encrypted communication and privacy-preserving aggregation techniques. The hardware platform should adapt to continuously changing sensor data, perform local model updates to prevent catastrophic forgetting, handle intermittent wireless connectivity, and synchronize model parameters whenever communication becomes available. The system should demonstrate secure communication between heterogeneous edge devices while operating within the memory, processing, and power limitations of embedded hardware. **Expected Solution:** A fully functional hardware prototype consisting of multiple interconnected embedded edge devices capable of collaborative federated learning without transmitting raw sensor data. The system should demonstrate local AI model training, secure wireless communication, encrypted model aggregation, continual learning under changing environmental conditions, and reliable operation despite intermittent connectivity. The

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				prototype should showcase efficient embedded processing, low-power operation, privacy-preserving data handling, adaptive AI model updates, and real-time monitoring through a gateway or local dashboard. The solution should improve data privacy, reduce communication bandwidth, enhance distributed intelligence, and provide a scalable hardware platform for next-generation Edge AI and Industrial IoT applications.
HF3-HW-14	**Robust edge-based anomaly detection with adversarial robustness and explainability**	Hardware	Edge AI & Hardware Acceleration	**Background:** Critical edge systems used in industrial automation, smart grids, healthcare devices, transportation, and infrastructure monitoring continuously process sensor data to ensure safe and reliable operation. These systems are vulnerable to abnormal operating conditions, sensor failures, cyber-attacks, and adversarial inputs that can manipulate AI models and reduce detection accuracy. Conventional cloud-based anomaly detection solutions introduce communication delays, privacy concerns, and dependency on network connectivity, making them unsuitable for mission-critical applications. Additionally, many existing AI models function as "black boxes," providing little insight into the reasons behind anomaly detection, making it difficult for operators to take informed corrective actions. Therefore, there is a growing need for an intelligent hardware-based Edge AI system capable of performing robust anomaly detection, resisting adversarial attacks, and providing explainable decision support while operating efficiently on embedded hardware. **Description:** Develop a hardware-based Edge AI anomaly detection system using embedded processors such as NVIDIA Jetson, Raspberry Pi AI Kit, ESP32-S3, FPGA, STM32, or similar platforms integrated with multiple sensors including temperature, vibration, current, voltage, pressure, gas, humidity, and motion sensors. The embedded system should continuously analyze streaming sensor data locally to identify abnormal operating conditions while remaining resilient against adversarial data manipulation and sensor spoofing attacks. The system should generate interpretable explanations for detected anomalies through an onboard display or monitoring interface, enabling operators to understand the reason for each alert. The hardware should support real-time processing, local data storage, secure communication, wireless connectivity, and low-power operation without relying on continuous cloud connectivity. **Expected Solution:** A fully functional hardware prototype consisting of embedded Edge AI hardware

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				integrated with multiple sensors, wireless communication modules, and local monitoring interfaces capable of performing real-time anomaly detection under adversarial conditions. The system should accurately identify abnormal events, resist adversarial perturbations and sensor manipulation, provide interpretable explanations for generated alerts, and maintain reliable performance within the memory, processing, and power constraints of embedded devices. The prototype should demonstrate efficient sensor integration, low-latency edge processing, secure operation, real-time alert generation, and explainable AI capabilities. The solution should enhance the security, reliability, transparency, and operational safety of industrial IoT, smart infrastructure, and other mission-critical embedded systems.
HF3-HW-15	**Hardware-Based TinyML Model Optimization and Edge Deployment System**	Hardware	Edge AI & Hardware Acceleration	**Background:** TinyML enables machine learning models to run directly on resource-constrained microcontrollers, making intelligent edge devices suitable for applications such as industrial monitoring, healthcare, agriculture, and smart infrastructure. However, deploying deep learning models on embedded hardware is challenging due to limited memory, processing power, storage, and energy availability. Large neural networks often exceed the capabilities of microcontrollers, resulting in slow inference and high power consumption. There is a growing need for a hardware-based TinyML optimization system capable of reducing model size and computational complexity while maintaining acceptable prediction accuracy for real-time embedded applications. **Description:** Develop a hardware-based TinyML optimization platform using embedded processors such as STM32, ESP32, Arduino Nano 33 BLE Sense, Raspberry Pi Pico, or similar microcontroller boards. The system should optimize neural network models using mixed-precision quantization and structured pruning before deploying them on embedded hardware. The optimized model should perform real-time inference using onboard sensors such as temperature, vibration, motion, humidity, or sound sensors while operating within the memory, processing, and power constraints of the microcontroller. The platform should also monitor inference latency, memory usage, energy consumption, and model accuracy, displaying performance metrics through an onboard display or monitoring interface. **Expected Solution:** A fully functional hardware prototype capable of deploying optimized TinyML

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				models on resource-constrained embedded devices. The system should demonstrate efficient model quantization and pruning, real-time inference using onboard sensor data, low-latency execution, reduced memory usage, and energy-efficient operation while maintaining the required prediction accuracy. The prototype should provide a comparative analysis of model size, inference speed, power consumption, and accuracy before and after optimization, demonstrating the feasibility of deploying AI applications on low-power embedded hardware for industrial, healthcare, agricultural, and IoT environments.
3. Robotics & Sensor Systems				
HF3-HW-16	**AI-Driven Intelligent Fire Detection and Emergency Response Robot**	Hardware	Robotics & Sensor Systems	**Background:** Fire incidents in industrial plants, warehouses, laboratories, commercial buildings, and other critical facilities pose significant risks to human life, infrastructure, and business operations. Rapid detection and response are essential to minimize damage and improve emergency management. However, sending firefighters into hazardous environments with extreme heat, toxic smoke, and unstable structures exposes them to serious danger. Existing firefighting robots often perform limited tasks and lack the intelligence required for autonomous navigation, environmental awareness, and real-time decision-making. Therefore, there is a growing need for an intelligent robotic system capable of detecting fire hazards, navigating dangerous environments, and assisting emergency responders while reducing human exposure to life-threatening situations. **Description:** Develop an intelligent autonomous emergency response robot capable of detecting fire sources using flame, temperature, smoke, gas, and environmental sensors while navigating hazardous environments through AI-based obstacle detection and path planning. The robot should continuously monitor environmental conditions, identify safe operating routes, detect obstacles, and provide real-time situational awareness using onboard cameras and embedded Edge AI processing. The system should generate immediate alerts, transmit critical information to emergency personnel through a web or mobile dashboard, and support first responders by enabling remote monitoring and safe navigation in smoke-filled and high-temperature environments. **Expected Solution:** A secure and intelligent AI-powered emergency response robot that autonomously detects fire hazards, monitors

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				environmental conditions, navigates hazardous areas, and provides real-time situational awareness using embedded sensors and Edge AI. The solution should accurately detect fire sources, identify safe navigation paths, generate instant emergency alerts, and deliver live operational data through an intuitive monitoring dashboard. By enabling autonomous fire detection, intelligent navigation, and remote emergency support, the system should improve firefighter safety, reduce response time, minimize property damage, and enhance the overall efficiency and reliability of emergency response operations
HF3-HW-17	**Autonomous Drone-Based Inventory Inspection and Warehouse Monitoring System**	Hardware	Robotics & Sensor Systems	**Background:** Modern warehouses manage thousands of products stored across multiple racks and shelves, making inventory inspection a complex and time-consuming task. Manual inventory counting is labor-intensive, prone to human error, and challenging in high-bay warehouses where access is difficult and potentially hazardous. Inventory inaccuracies can result in shipment delays, financial losses, and reduced supply chain efficiency. While fully automated warehouse solutions exist, they are often expensive and unsuitable for small and medium-sized enterprises. Therefore, there is a growing need for an affordable hardware-based autonomous inspection system that can perform inventory monitoring with minimal human intervention. **Description:** Develop an autonomous drone-based inventory inspection system capable of navigating warehouse aisles using onboard sensors and embedded controllers. The drone should integrate cameras, barcode/QR code scanners or RFID readers, ultrasonic/LiDAR sensors, IMU, and obstacle detection modules to safely fly through warehouse environments while identifying and verifying inventory items. The embedded system should process scanned data locally, detect missing or misplaced products, estimate inventory discrepancies, and communicate the collected information wirelessly to a monitoring station. The drone should support autonomous navigation, real-time obstacle avoidance, accurate shelf inspection, and automatic return-to-base for battery charging or mission completion. **Expected Solution:** A fully functional hardware prototype of an autonomous inventory inspection drone built using embedded controllers, onboard sensors, cameras, RFID/barcode scanning modules, and wireless communication technology. The system should autonomously navigate warehouse aisles, inspect inventory, identify missing or misplaced

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				items, and transmit inspection results in real time while operating safely around warehouse infrastructure. The prototype should demonstrate reliable autonomous flight, accurate inventory verification, obstacle avoidance, efficient battery management, and improved warehouse inventory accuracy, reducing manual effort, operational costs, and inspection time.
HF3-HW-18	**Autonomous Infrastructure Inspection Rover for Structural Health Monitoring**	Hardware	Robotics & Sensor Systems	**Background:** Critical infrastructure such as bridges, railway tracks, tunnels, dams, industrial pipelines, and power plants requires regular inspection to ensure structural integrity and public safety. Conventional inspection methods rely on manual surveys, specialized equipment, and temporary service interruptions, making the process expensive, time-consuming, and potentially hazardous for inspection personnel. Furthermore, early signs of structural deterioration such as cracks, corrosion, surface deformation, and material fatigue may remain unnoticed until they develop into major failures. There is a growing need for an intelligent hardware-based inspection system capable of autonomously monitoring infrastructure, reducing human exposure to hazardous environments, and enabling early detection of structural defects. **Description:** Develop an autonomous infrastructure inspection rover capable of navigating complex terrains and confined environments using embedded controllers, electric motors, and advanced sensor modules. The rover should integrate high-resolution cameras, ultrasonic sensors, LiDAR, IMU, GPS, thermal imaging sensors, vibration sensors, and environmental sensors to continuously inspect critical infrastructure. Using onboard Edge AI hardware, the rover should perform real-time detection of cracks, corrosion, surface damage, structural deformation, and other anomalies without relying on cloud processing. The system should support autonomous navigation, obstacle avoidance, route planning, wireless communication, and local data storage while transmitting critical inspection results to a remote monitoring station. The rover should operate reliably in harsh outdoor and industrial environments with minimal human intervention. **Expected Solution:** A fully functional hardware prototype of an autonomous infrastructure inspection rover built using embedded controllers, Edge AI processors, cameras, multiple inspection sensors, and autonomous navigation hardware. The rover should independently traverse inspection routes, detect structural defects in real time, capture visual

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				and sensor data, and generate immediate alerts for potential safety hazards. The prototype should demonstrate reliable autonomous navigation, obstacle avoidance, AI-based defect detection, wireless monitoring, and efficient operation in challenging environments. The solution should reduce inspection time, minimize risks to engineers, lower maintenance costs, and improve the safety, reliability, and longevity of critical infrastructure.
HF3-HW-19	**Intelligent Neuro-Symbolic Assistive Exoskeleton Control System**	Hardware	Robotics & Sensor Systems	**Background:** Assistive exoskeletons play a vital role in improving mobility for individuals with neurological disorders, spinal cord injuries, stroke rehabilitation needs, and age-related mobility impairments. However, most existing exoskeleton control systems rely on fixed rule-based controllers or purely AI-driven models, which often struggle to accurately interpret a user's movement intentions in dynamic environments. These limitations can result in delayed responses, unnatural movement assistance, increased user fatigue, and reduced rehabilitation effectiveness. There is a growing need for an intelligent hardware-based exoskeleton control system that combines advanced sensing, embedded processing, and adaptive decision-making to deliver safe, responsive, and personalized mobility assistance. **Description:** Develop an intelligent assistive exoskeleton system using embedded hardware capable of continuously monitoring user movement through multiple sensors such as EMG (Electromyography), IMU, force, pressure, joint angle, and motion sensors. The system should integrate embedded AI processors and real-time motor controllers to interpret user movement intentions using a neuro-symbolic control framework that combines neural learning with symbolic decision-making. Based on sensor inputs, the controller should provide smooth and adaptive assistance by driving servo or BLDC motors while ensuring safe human-robot interaction. The system should include onboard safety mechanisms such as overload protection, emergency stop functionality, balance monitoring, and battery management. Wireless communication and an embedded display may be incorporated for real-time monitoring, system diagnostics, and rehabilitation progress tracking. **Expected Solution:** A fully functional hardware prototype of an intelligent assistive exoskeleton built using embedded controllers, AI-enabled edge processors, wearable sensors, motor drivers, actuators, and safety modules. The system should

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				accurately interpret user movement intentions, provide adaptive and real-time motion assistance, maintain safe operation during rehabilitation and daily activities, and continuously monitor user performance. The prototype should demonstrate reliable sensor integration, intelligent motor control, low-latency embedded processing, energy-efficient operation, and robust safety features. The solution should improve mobility, reduce user fatigue, enhance rehabilitation outcomes, and provide a personalized and reliable assistive platform for individuals with mobility impairments.
HF3-HW-20	**Intelligent Distributed Sensor Network Calibration and Fault Diagnosis System**	Hardware	Robotics & Sensor Systems	**Background:** Large-scale distributed sensor networks are widely used in environmental monitoring, structural health monitoring, industrial automation, smart agriculture, and critical infrastructure management. These networks consist of heterogeneous sensors deployed over wide geographical areas to continuously monitor physical parameters. However, over time, sensors may experience calibration drift, hardware degradation, communication failures, or malicious data injection, resulting in inaccurate measurements and unreliable system performance. Traditional calibration methods require manual maintenance and centralized processing, making them costly, time-consuming, and unsuitable for large-scale deployments. There is a growing need for an intelligent hardware-based sensor network capable of automatically detecting faulty or compromised sensors, performing self-calibration, and maintaining accurate measurements while operating reliably in distributed environments with limited connectivity. **Description:** Develop an intelligent distributed sensor network using embedded hardware capable of continuously monitoring environmental or structural parameters through heterogeneous sensors such as temperature, humidity, pressure, vibration, gas, strain, and displacement sensors. Each sensor node should integrate a microcontroller, wireless communication module (LoRa, Zigbee, Wi-Fi, or BLE), local storage, and power management circuitry to perform onboard calibration and fault diagnosis. The embedded system should compare measurements from neighboring nodes, identify faulty, drifting, or malicious sensors using redundancy and physics-based constraints, automatically compensate for calibration errors, and continue operating under sparse connectivity and asynchronous data reporting. The network should support decentralized decision-making, local

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				anomaly detection, wireless communication, and real-time monitoring through a central gateway. **Expected Solution:** A fully functional hardware prototype consisting of multiple embedded wireless sensor nodes capable of self-calibration, fault detection, and distributed sensing without relying on continuous centralized control. The system should accurately identify faulty or compromised sensors, correct systematic measurement errors, estimate reliable environmental parameters, and maintain continuous monitoring even under communication failures or limited network connectivity. The prototype should demonstrate reliable sensor integration, embedded processing, wireless communication, low-power operation, decentralized fault diagnosis, and real-time monitoring. The solution should improve the accuracy, reliability, scalability, and resilience of large-scale sensor networks used in industrial, environmental, and infrastructure monitoring applications.
HF3-HW-21	**Intelligent Multi-Sensor SLAM System for Real-Time Autonomous Navigation**	Hardware	Robotics & Sensor Systems	**Background:** Autonomous robots deployed in warehouses, industrial facilities, disaster response, agriculture, and smart cities rely on Simultaneous Localization and Mapping (SLAM) to navigate safely and accurately. However, real-world environments often contain repetitive structures, moving objects, temporary obstacles, and changing surroundings that create challenges such as perceptual aliasing, loop closure ambiguity, and localization errors. Conventional SLAM systems may struggle to maintain accurate maps and reliable localization under these conditions, leading to navigation failures and reduced operational efficiency. There is a growing need for an intelligent hardware-based SLAM system capable of performing robust real-time localization and mapping using multiple sensors while operating reliably in dynamic and complex environments. **Description:** Develop an intelligent embedded SLAM system using hardware components capable of performing real-time localization and mapping through the integration of multiple sensing technologies such as RGB/RGB-D cameras, LiDAR, radar, IMU, ultrasonic sensors, GPS (where applicable), and wheel encoders. The system should utilize an embedded AI processor (such as NVIDIA Jetson, FPGA, Raspberry Pi AI Kit, or similar) to process sensor data locally, detect and filter moving objects, identify perceptual aliasing, resolve loop closure ambiguities, and maintain accurate maps during navigation. The robot should support autonomous navigation, obstacle avoidance,

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				probabilistic consistency checking, sensor fusion, and recovery from temporary localization failures while operating with low latency in dynamic environments. Wireless communication should enable remote monitoring, diagnostics, and map visualization. **Expected Solution:** A fully functional hardware prototype consisting of an autonomous mobile robot equipped with embedded AI hardware, LiDAR, vision sensors, radar, IMU, and other navigation sensors capable of performing robust real-time SLAM in dynamic environments. The system should accurately generate and update maps, maintain reliable localization despite moving obstacles and repetitive environments, recover from localization failures, and navigate autonomously with minimal latency. The prototype should demonstrate reliable multi-sensor fusion, embedded edge processing, autonomous obstacle avoidance, real-time mapping, and efficient power management. The solution should improve navigation accuracy, operational safety, and reliability for autonomous robots deployed in industrial, commercial, and outdoor environments.
HF3-HW-22	**Intelligent Multi-Modal Active Perception Robot for Autonomous Object Search**	Hardware	Robotics & Sensor Systems	**Background:** Autonomous robots operating in warehouses, hospitals, homes, industrial facilities, and search-and-rescue environments often need to locate and identify objects placed in cluttered or partially obstructed areas. Conventional object detection systems rely on fixed camera viewpoints and single-sensor perception, making them less effective when objects are occluded, poorly illuminated, or surrounded by obstacles. Sensor failures and dynamic environmental changes further reduce detection accuracy. There is a growing need for an intelligent hardware-based robotic perception system capable of actively selecting the best sensing strategy, combining data from multiple sensors, and autonomously searching for objects while minimizing search time and energy consumption. **Description:** Develop an intelligent autonomous robot equipped with multiple sensing devices, including RGB/RGB-D cameras, LiDAR, ultrasonic sensors, tactile sensors, IMU, and optional sonar modules, integrated with embedded AI hardware such as NVIDIA Jetson, Raspberry Pi AI Kit, FPGA, or similar processors. The robot should autonomously navigate indoor environments, actively adjust camera viewpoints or sensing positions, and select the most informative sensing action to maximize object detection accuracy while considering movement time and power consumption.

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				The embedded system should fuse information from multiple sensors, detect and recognize target objects, compensate for sensor failures, avoid obstacles, and continuously update its search strategy based on real-time environmental conditions. The robot should support onboard processing, wireless communication, and remote monitoring while operating independently without continuous cloud connectivity. **Expected Solution:** A fully functional hardware prototype of an autonomous multi-modal perception robot capable of intelligently searching for and recognizing objects in cluttered indoor environments. The system should integrate embedded controllers, AI-enabled edge processors, multiple sensing modules, autonomous navigation hardware, and wireless communication to perform real-time object detection and sensor fusion. The prototype should demonstrate adaptive viewpoint selection, reliable object recognition, obstacle avoidance, sensor fault tolerance, and efficient onboard processing. The solution should improve search accuracy, reduce search time, minimize energy consumption, and provide a robust hardware platform for autonomous inspection, warehouse automation, healthcare assistance, and search-and-rescue applications.
HF3-HW-23	**Online Sensor Fault Detection & Virtual Sensor Replacement**	Hardware	Robotics & Sensor Systems	**Background:** Critical edge systems used in industrial automation, smart grids, healthcare, transportation, and infrastructure monitoring require continuous monitoring to ensure safe and reliable operation. These systems are vulnerable to equipment failures, sensor faults, cyber-attacks, and adversarial inputs that can compromise detection accuracy. Conventional cloud-based anomaly detection systems introduce communication delays, privacy concerns, and dependency on network connectivity, making them unsuitable for mission-critical applications. There is a growing need for a hardware-based Edge AI solution capable of performing secure, real-time anomaly detection while providing interpretable alerts on resource-constrained embedded devices. **Description:** Develop a hardware-based Edge AI anomaly detection system using embedded processors integrated with multiple sensors such as temperature, vibration, current, voltage, pressure, gas, humidity, and motion sensors. The system should continuously monitor and analyze sensor data locally to detect abnormal operating conditions, resist adversarial attacks and sensor spoofing, and provide explainable alerts through an onboard

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				display or monitoring interface. The solution should support real-time processing, local data storage, secure wireless communication, and low-power operation without relying on continuous cloud connectivity. **Expected Solution:** A hardware prototype capable of performing real-time anomaly detection using embedded Edge AI hardware and multiple sensors. The system should accurately identify abnormal events, withstand adversarial inputs, generate explainable alerts, and operate reliably within the processing, memory, and power constraints of embedded devices. The solution should improve the security, reliability, and operational safety of industrial IoT and other mission-critical embedded systems.
HF3-HW-24	**Hardware-Based Subsurface Soil Moisture Mapping System Using Ground-Penetrating Radar and Edge AI**	Hardware	Robotics & Sensor Systems	**Background:** Efficient irrigation management depends on accurate measurement of soil moisture at different depths beneath the surface. Conventional soil moisture sensors, such as capacitive or resistive probes, only measure moisture at a single point and limited depth, making them inadequate for understanding the complete subsurface moisture distribution. This often results in over-irrigation, water wastage, and reduced crop productivity. Ground-Penetrating Radar (GPR) offers a non-invasive method for sensing subsurface conditions, but extracting accurate soil moisture information from radar reflections is computationally challenging and expensive using traditional physics-based approaches. Therefore, there is a growing need for a low-cost hardware-based system capable of mapping subsurface soil moisture using embedded radar sensing and intelligent edge processing. **Description:** Develop a hardware-based subsurface soil moisture mapping system using a low-cost Ground-Penetrating Radar (GPR) or Ultra-Wideband (UWB) radar module integrated with an embedded processor such as NVIDIA Jetson, Raspberry Pi, STM32, FPGA, or similar hardware. The system should collect radar reflection data while scanning agricultural fields and process the signals locally to estimate soil moisture at multiple depths using embedded AI and signal processing techniques. The prototype should integrate GPS for location tracking, motorized scanning mechanisms, onboard data storage, wireless communication, and a display for real-time visualization. The hardware should continuously acquire radar data, reconstruct two-dimensional or three-dimensional subsurface

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				moisture maps, and operate efficiently under field conditions with low power consumption. **Expected Solution:** A fully functional hardware prototype capable of generating real-time subsurface soil moisture maps using embedded radar sensing and Edge AI. The system should accurately capture radar reflections, estimate moisture distribution at multiple soil depths, and provide visual moisture maps to assist irrigation planning. The prototype should demonstrate reliable radar signal acquisition, embedded processing, wireless communication, GPS-based field mapping, and energy-efficient operation. The solution should improve irrigation efficiency, reduce water consumption, enhance crop productivity, and provide an affordable precision agriculture platform for farmers and agricultural researchers.
HF3-HW-25	**Hardware-Based Bioacoustic Soil Health Monitoring System Using Embedded Acoustic Sensing and Edge AI**	Hardware	Robotics & Sensor Systems	**Background:** Soil health plays a vital role in determining crop productivity, water retention, and sustainable agricultural practices. Conventional methods for assessing soil health require collecting soil samples and sending them to laboratories for analysis of parameters such as organic matter, microbial biomass, and biological activity. These methods are expensive, time-consuming, and unsuitable for continuous field monitoring. Recent research suggests that biological activities within the soil, including earthworm movement, microbial respiration, root growth, and gas release, generate subtle acoustic signals that can provide valuable information about soil health. Therefore, there is a growing need for a hardware-based embedded sensing system capable of continuously monitoring underground bioacoustic activity and estimating soil health without disturbing the soil. **Description:** Develop a hardware-based bioacoustic soil health monitoring system using embedded acoustic sensors buried beneath the soil surface. The system should integrate highly sensitive microphones or geophones, vibration sensors, environmental sensors (soil moisture, temperature, humidity, pH), and an embedded processor such as ESP32, STM32, Raspberry Pi, NVIDIA Jetson, or similar hardware. The embedded system should continuously capture underground acoustic signals, filter environmental noise and vibrations, identify biological sound patterns associated with earthworm movement, microbial activity, and root growth, and estimate soil health using onboard Edge AI and signal processing techniques. The system should support local data storage, wireless communication,

Hackfinity 3.0 Hardware Problem Statement

Problem Statement ID	Title of the Problem	Category	Theme	Problem Description
				GPS-based field mapping, and real-time monitoring through an onboard display or gateway. **Expected Solution:** A fully functional hardware prototype capable of continuously monitoring underground bioacoustic activity using embedded acoustic sensing and Edge AI. The system should accurately capture and process soil acoustic signals, reduce environmental noise, estimate soil health indicators, and provide real-time monitoring without destructive soil sampling. The prototype should demonstrate reliable sensor integration, embedded signal processing, low-power operation, wireless communication, and continuous field monitoring. The solution should enable affordable, non-invasive soil health assessment, improve precision agriculture practices, reduce dependence on laboratory testing, and support sustainable farming through continuous embedded monitoring.