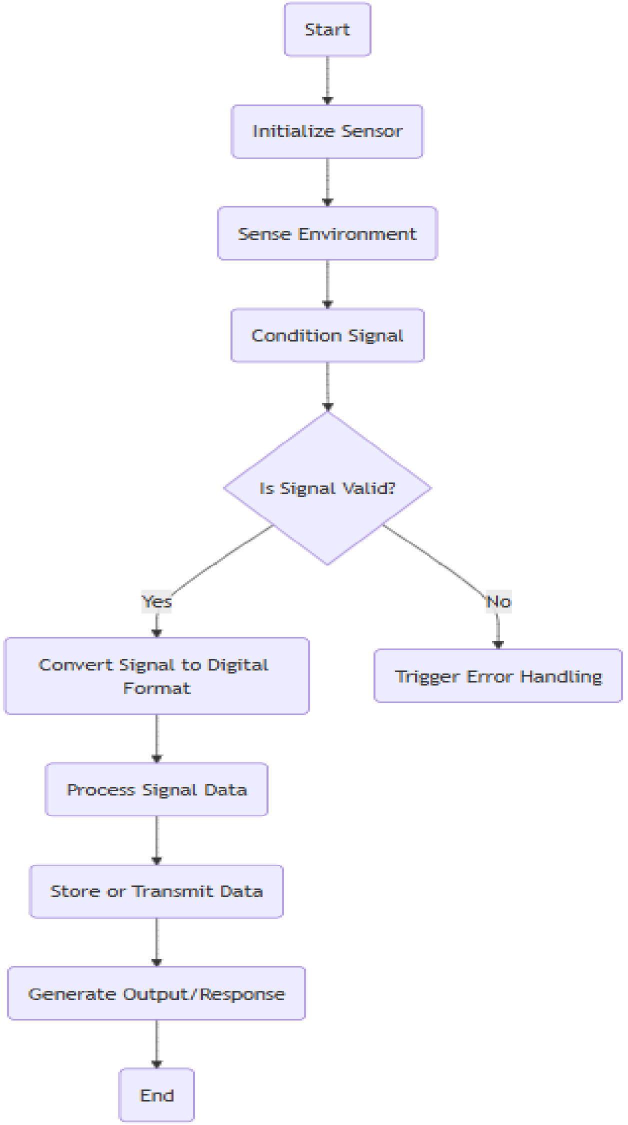
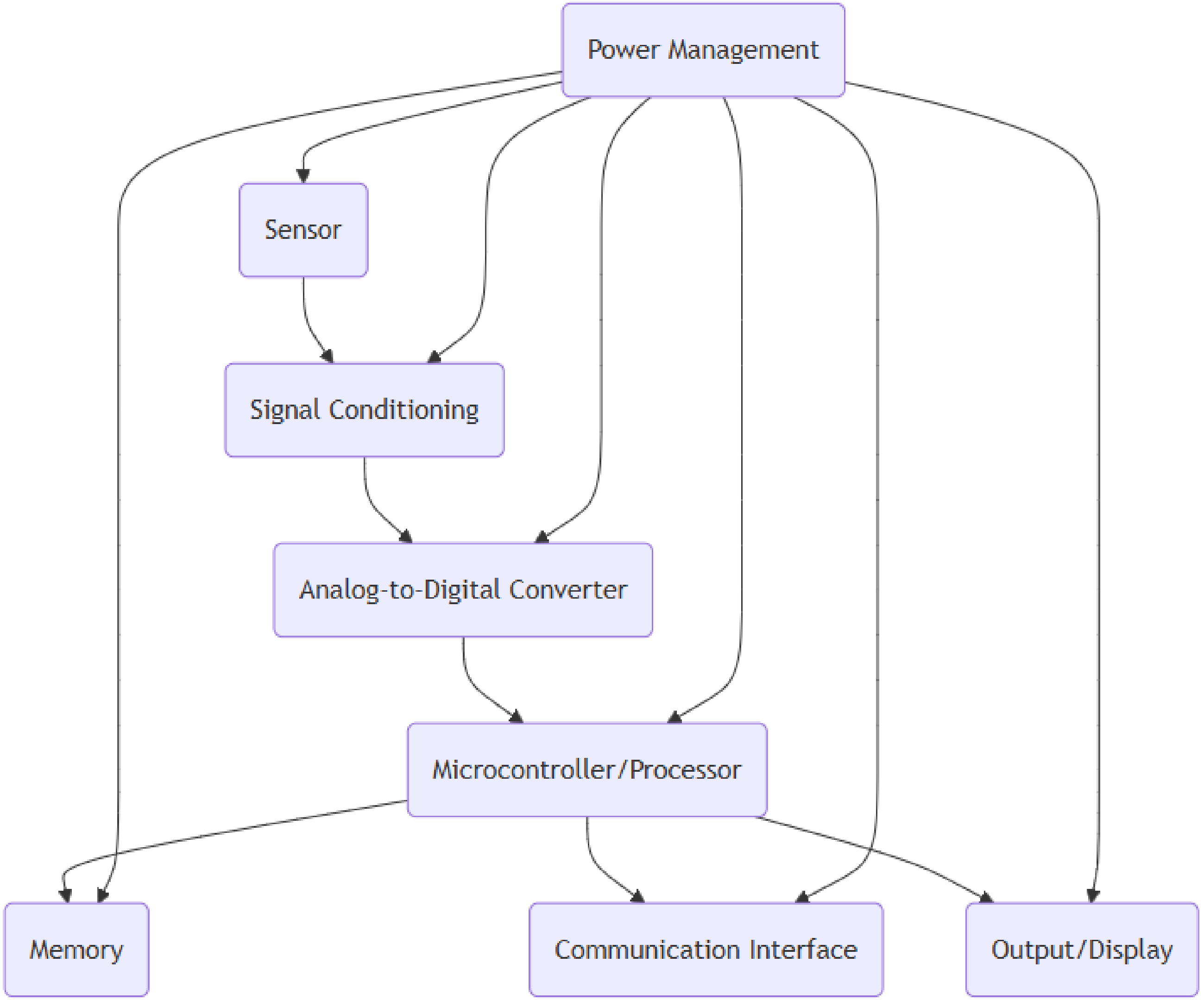
Sensor Upgrade for the fielded Phalanx Block 1A Close-In Weapon System (CIWS) Preliminary Design Review

The Goals to build sensor detection software to target non-radar to detect a threat from Iranian drone and protect the U.S. Navy ship

Functional Flow Block Diagram



System Block Diagram of Sensor Radar

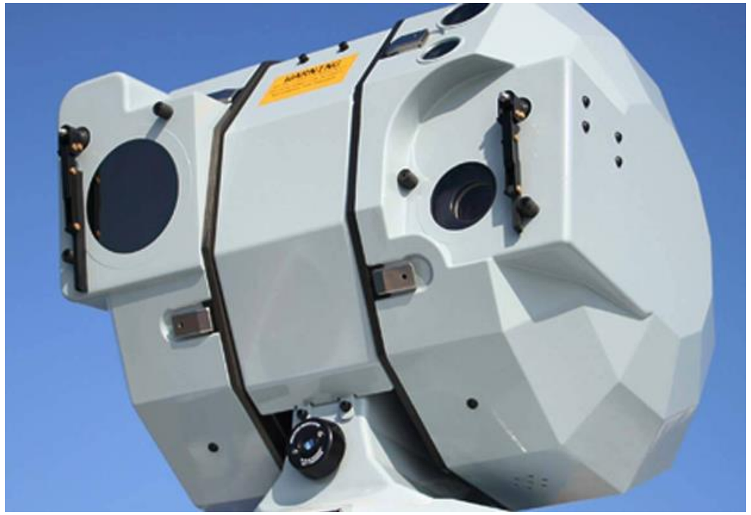


Allocate requirements to subsystems

- Sensor Unit Detect, track, and identify targets in day and night conditions. Detect targets at 25 nautical miles (nm) range.Track targets at 20 nm range. Identify targets described on slide 7 at 10 nm range.
- Signal Processing UnitProvide azimuth and elevation to the tracked target with an accuracy greater than or equal to 0.1 milliradians. Process cues from the ship's MRTDT system for enhanced detection and tracking.
- Environmental and Structural Design Ensure operation in tropical maritime conditions as defined in MIL-STD-810G.
- Enable below-deck system operation in temperatures from 0-50 degrees Celsius.
- Ensure below-deck and above-deck systems comply with the specified vibration profile.
- Communication and Control Interface Accept cues from the ship's MRTDT system. Facilitate seamless integration with shipboard systems.

Allocate requirements to subsystems

1. Subsystem: Above-Deck Unit Operate in temperatures from -20 to 60 degrees Celsius. Be impervious to moisture penetration. Provide range to target accurate to within 1 meter. Provide range rate accuracy to within 0.1 meters per second. Fit within a volume of 1 foot x 1 foot x 2.5 feet. Weigh no more than 35 pounds. Require no more than 150 Watts of power.
2. Subsystem: Below-Deck Unit Fit within a volume of 3 feet x 3 feet x 3 feet (excluding cables or displays). Weigh no more than 80 pounds. Require no more than 100 Watts of power.
3. Subsystem: Display and User Interface Displays shall be no larger than 27 inches diagonally.
4. Subsystem: Power Management Operate on 270 Volt DC power.
5. Subsystem: Communication and Networking Integrate with the ship’s Local Area Network to distribute sensor images in real time. Integrate with the ship's GPS navigation system to provide absolute target location.



Specification Compliance Matrix: Upgraded Sensors Hardware

Requirement ID	Requirement Description	Sensor Type	Compliance Status	Comments
RQ-01	Operate in -20°C to 60°C	Environmental Sensor	✅ Compliant	Tested and verified under standard operating conditions.
RQ-02	Detect vibration with sensitivity < 0.01g	Accelerometer	⚠ Partial Compliance	Sensitivity slightly above threshold in high-noise environments.
RQ-03	Noise filtering with SNR > 40 dB	Data Processing Unit	✅ Compliant	Meets standard signal-to-noise ratio requirements after preprocessing.
RQ-04	Compatible with 12V/24V DC power supply	Power Supply Interface	✅ Compliant	Fully compatible with legacy system power interfaces.
RQ-05	Transmit data securely over Wi-Fi	Communication Module	✅ Compliant	Supports AES-256 encryption and tested under various network conditions.
RQ-06	Response time < 2ms	Data Processing Unit	✅ Compliant	Verified during integration tests.
RQ-07	Detect objects within 1-meter range	Proximity Sensor	❌ Non-Compliant	Current sensor limited to a 0.8-meter detection range.
RQ-08	Log data for at least 30 days	User Interface/Storage	✅ Compliant	Sufficient onboard storage and optimized for data retention.
RQ-09	Operate in 90% relative humidity	Environmental Sensor	✅ Compliant	Tested in high-humidity test chamber.
RQ-10	Support remote firmware updates	Communication Module	⚠ Partial Compliance	Firmware updates require manual intervention under certain conditions.

Specification Compliance Matrix Upgraded Sensors Software

Requirement ID	Requirement Description	Sensor Type	Compliance Status	Comments
RQT-01	Operate in Window Xp	Soft Sensor	✅ Compliant	Tested and verified under standard operating conditions backward compatibility.
RQT-02	Upgrade via secure computing central servers	Secure	⚠ Partial Compliance	Sensitivity slightly above threshold in Monthly update window supports.
RQT-03	Data Encoding	SON, XML, or binary formats for easy integration.	✅ Compliant	Meets standard image compressor requirements after preprocessing.
RQT-04	Supported Communication Protocols	Wi-Fi (e.g., 802.11 protocols)	✅ Compliant	Ethernet or CAN bus for industrial applications.
RQT-05	Driver and Firmware Compatibility:	Windows Module	✅ Compliant	Firmware updates that integrate with fielded systems for ongoing support..
RQT-06	APIs for Integration	Cloud services (AWS IoT, Azure IoT, Google Cloud IoT).	✅ Compliant	Verified during integration tests.
RQT-07	Middleware Support	Data aggregation (e.g., Kafka, RabbitMQ).	❌ Non-Compliant	Current sensor limited to Real-time operating systems (RTOS) like FreeRTOS.

Technology Readiness Assessment: Sensor Upgrade

Subsystem	Current TRL	Description	Challenges	Recommended Actions
Cable Sensor Unit	TRL 6: Prototype	Tested for sensitivity and accuracy in relevant conditions.	Sensitivity to noise; durability in extreme conditions.	Perform field tests and refine noise reduction.
Data Processing Unit	TRL 7: Operational Prototype	Real-time filtering and preprocessing demonstrated.	High power consumption during processing loads.	Optimize firmware and adopt low-power algorithms.
Communication Module	TRL 5: Laboratory Validation	Secure data transmission validated over Wi-Fi and ZigBee.	Limited testing on long-range protocols; interference in urban areas.	Expand testing to remote areas and improve protocol interoperability.
Power Supply Interface	TRL 8: Fully Integrated	Tested with existing field power systems.	Insufficient support for alternative energy sources.	Incorporate solar/battery backup options.
Firmware Update System	TRL 5: Laboratory Validation	Secure OTA updates demonstrated in lab settings.	Compatibility issues with legacy systems.	Conduct field testing and simplify update mechanisms.
Environmental Sensor	TRL 6: Prototype	Validated in simulated environmental conditions.	Limited testing in high-humidity or corrosive environments.	Perform extended tests in extreme environments.
User Interface (UI)	TRL 6: Prototype	Provides real-time visualization and alerts.	Scalability for multiple sensors and diverse data streams.	Develop a cloud-based scalable architecture.

Technology Readiness Assessment: Sensor Upgrade

Subsystem	Current TRL	Description	Challenges	Recommended Actions
thermistors Sensor Unit	TRL 6: Prototype	Measure ambient or object temperature (e.g., thermistors, thermocouples, RTDs).	Temperature moisture levels in the air (e.g., capacitive or resistive humidity sensors).	Perform field tests and refine noise reduction.
Acoustic Sensors:	TRL 7: Operational Prototype	Detect sound waves, vibrations, or ultrasonic signals.	Acoustic sensors are highly sensitive to background noise, which can affect their accuracy in detecting specific signals.	Optimize firmware and adopt low-power algorithms.
Infrared Sensors Module	TRL 5: Laboratory Validation	Detect thermal radiation or measure distances (used in remote controls or heat imaging).	The effective range of IR sensors is limited compared to other sensing technologies like radar or LIDAR, particularly in open spaces.	Use protective enclosures or filters to mitigate interference from dust, smoke, or fog.
Vibration Sensors	TRL 8: Fully Integrated	Monitor machinery health by measuring vibrations (e.g., piezoelectric sensors).	Difficulty in integrating with advanced monitoring systems or legacy equipment due to protocol or compatibility issues.	Provide detailed guidelines and tools to simplify installation and ensure optimal sensor placement.
Hall Effect Sensors:	TRL 5: Laboratory Validation	Detect magnetic fields (used for position or speed sensing).	Improper alignment of the sensor with the magnetic source can lead to measurement errors or reduced sensitivity.	Incorporate high-sensitivity Hall Effect sensors for applications requiring the detection of weak or distant magnetic fields.
Electromagnetic Field Sensors:	TRL 6: Prototype	Monitor electromagnetic interference or wireless signals.	Sensor performance can vary with temperature changes, impacting accuracy and reliability.	Use directional EMF sensors or filtering algorithms to focus on specific sources of electromagnetic fields.
Conductivity Sensors	TRL 6: Prototype	Measure electrical conductivity of materials or solutions.	Difficulty in integrating conductivity sensors with existing monitoring systems due to communication protocol mismatches or lack of standardization.	Adopt industry-standard communication protocols compatibility with modern systems.

Trade Study Displays

- Aydin Displays 19" Rugged COTS Smart Display
- Designed for shipboard, airborne, and ground mobile environments.
- Optional 28 VDC power and fiber Ethernet.

Trade Study
AESA radar

- Altum RF has developed a family of PAs for AESA radar at X-band (8 to 12 GHz) and Ku-band (13.5 to 17.5 GHz) with saturated output power in the 0.5W to 2W range.
- Highly efficient and meet the thermal and ruggedness requirements for AESA radar applications.
- These PAs are fabricated using a high-performance, cost effective GaAs pHEMT process and housed in a 4X4 mm² QFN plastic package.
- A standard pinout and package outline drawing is illustrated below in Figure 2. A performance summary of these PAs is listed below in Table 1

effective GaAs pHEMT process and housed in a 4X4 mm² QFN plastic package. A standard pinout and package outline drawing is illustrated below in *Figure 2*. A performance summary of these PAs is listed below in *Table 1*.

Figure 2: ARF1108Q4 Pinout, 24-Pin 4X4 mm² QFN Package, and Evaluation Board

Power Amplifier	Min. Frequency (GHz)	Max. Frequency (GHz)	Gain (dB)	P1dB (dBm)	PSAT (dBm)	PAE (%)	Package
ARF1108Q4	8.5	12	23	26.5	27.5	30	4 × 4 QFN
ARF1109Q4	8	12	25	29	30	40	4 × 4 QFN
ARF1110Q4	8.5	12	25	31	32	35	4 × 4 QFN
ARF1111Q4	13	17.5	22	27	28	40	4 × 4 QFN
ARF1112Q4	13.5	17	24	29	30	25	4 × 4 QFN
ARF1113Q4	14	17.5	18	31	32.5	25	4 × 4 QFN

Table 1: Summary of X- and Ku-band PAs for AESA Radar Applications

Trade Study / Ground Based Radar Systems

- Monopoles Automatic Tracking Surveillance Maritime / Ground Based Radar Systems
- Auto detection and tracking sea-surface or air targets
- Auto switch to multisensory tracking under electronic jamming
- Precisely 3D tracking data
- Mounted on any sea or ground platform for medium and short range air-defense

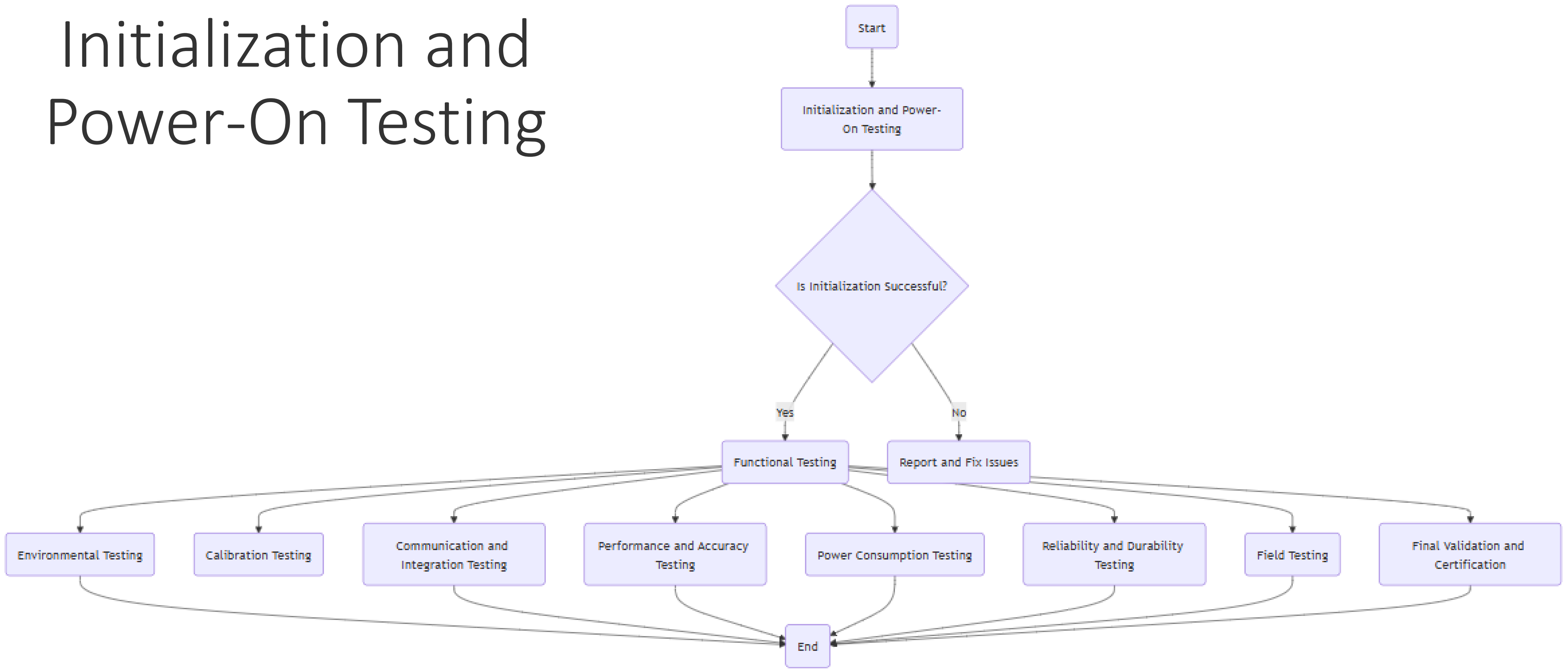
Trade Study Systems Airborne Infrared

- JHS640-240P4 Eo Ir Systems Airborne Infrared Optical Multi - Sensor High Stability
- Detection, Recognition and Recognition of Designated Targets Day and Night
- Multiple Tracking Algorithms, Real-time Acquisition and Reporting of Target Location
- High Precision Gyro Stabilization
- Optional built-in IMU provides carrier-to-frame attitude
- Wireless transmission

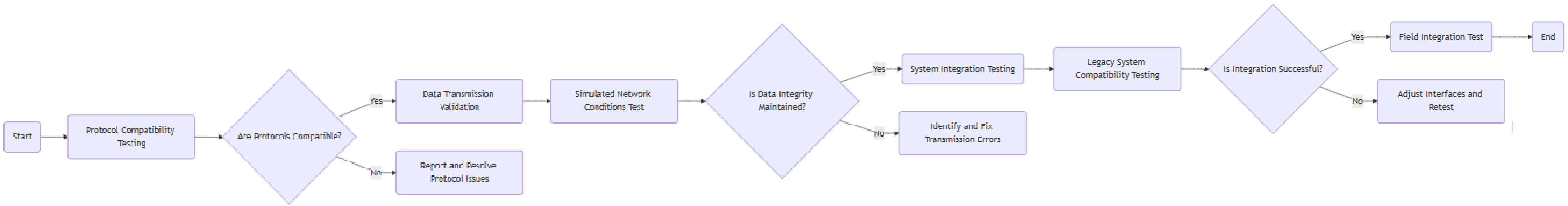
Technical Performance Measures (TPM)

TPM	Definition	Measurement Method	Use to Track Maturity	Status
Detection Range	Maximum distance for accurate detection	Lab and field tests	Prototype, mid-phase validation, final tests	In Progress
Accuracy	Match between measurements and reference values	Controlled test objects	Benchmark, refinement, operational validation	In Progress
Response Time	Time for detection and processing	Time-stamped events	Circuit validation, optimization, live testing	Achieved
Environmental Resilience	Functionality in harsh conditions	MIL-STD tests	Simulations, lab tests, field testing	Testing
Power Efficiency	Power usage during operation	Mode-based power measurement	Comparison, optimization, deployment validation	In Progress
False Positives/Negatives	Error rates in detection	Controlled scenarios	Algorithm validation, system integration	Testing
Integration Compatibility	Ease of integration with existing systems	Interface and protocol tests	Design, system integration, final validation	Planned
Reliability (MTBF)	Operational time between failures	Accelerated life testing	Component analysis, operational validation	Planned
SWaP	Size, weight, and power constraints	Physical measurement and analysis	Design, prototyping, operational testing	Achieved
Cost	Total development and operational cost	Budget tracking	Trade studies, prototyping, production validation	In Progress

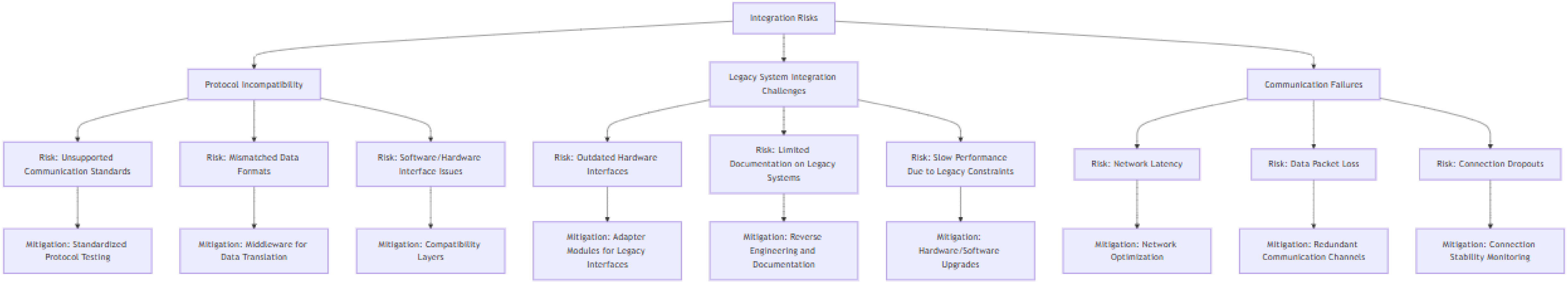
Test Flow Initialization and Power-On Testing



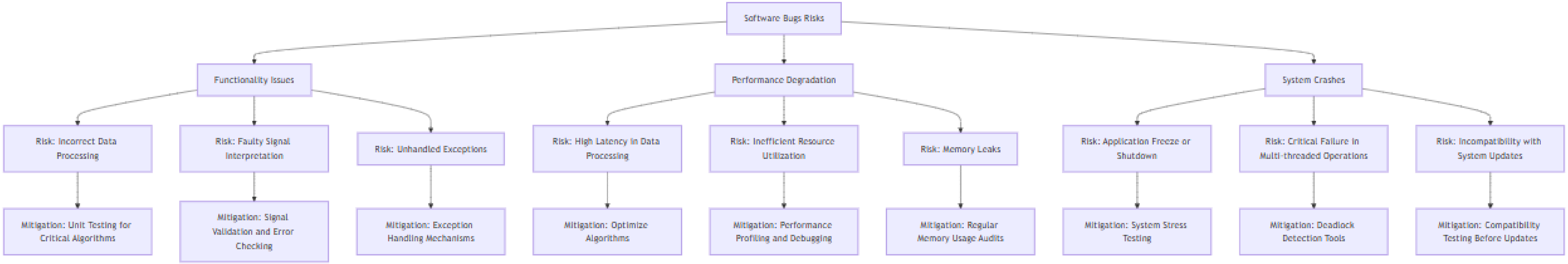
Test Flow Communication and Integration



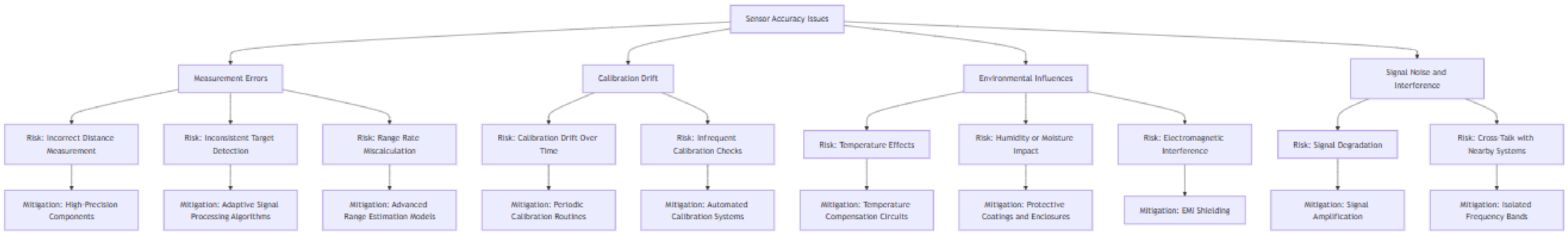
Risk Analysis in Integration Risks Sensor upgrade Integration



Risk Analysis Sensor Upgrade for Software Bugs



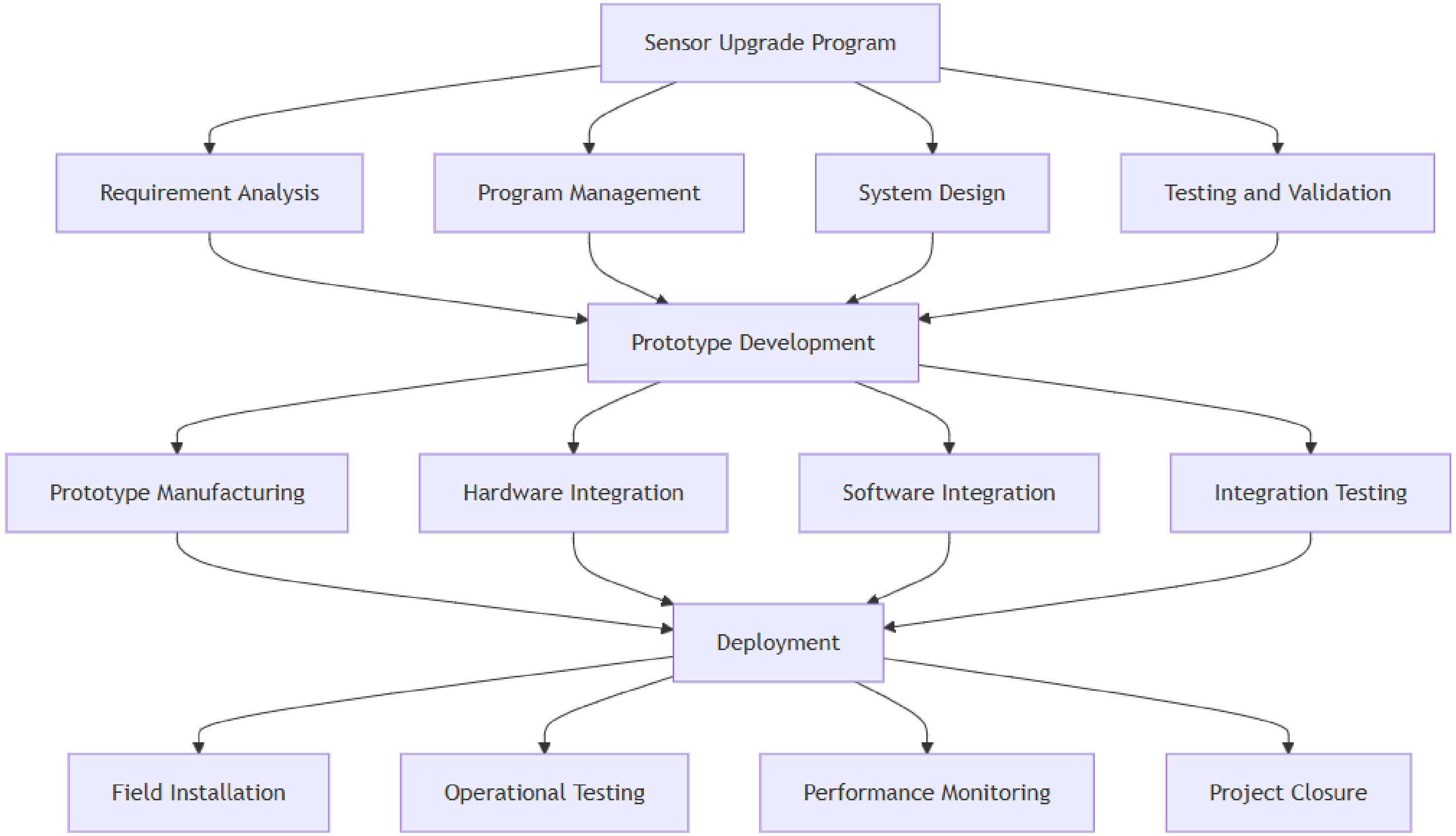
Risk Analysis Sensor Upgrade for Sensor Accuracy Issues



Program Schedule

Task ID	Task Name	Start Date	End Date	Duration (Days)	Milestone
1	Project Initiation	1/1/2025	1/14/2025	14	Project Start
2	Requirement Analysis	1/15/2025	1/31/2025	16	Requirements Finalized
3	System Design	2/1/2025	2/28/2025	28	System Design Complete
4	Sensor Prototype Development	3/1/2025	3/31/2025	31	Prototype Complete
5	Initial Testing and Debugging	4/1/2025	4/30/2025	30	Initial Testing Complete
6	Integration with Legacy Systems	5/1/2025	5/31/2025	31	Integration Ready
7	Environmental and Stress Testing	6/1/2025	6/30/2025	30	Stress Testing Complete
8	Final System Validation	7/1/2025	7/31/2025	31	System Validated
9	Field Deployment	8/1/2025	8/31/2025	30	Deployed
10	Project Closure	9/1/2025	9/15/2025	15	Project Complete

Work Breakdown Structure (WBS) for the Sensor Upgrade Software Program



Work Breakdown Structure (WBS) for the Sensor Upgrade Hardware Program