Phalanx Block 1B Sensor Upgrade

EMEA 5036: Systems Engineering and Program Management Final Project

Phalanx Block 1B Sensor Upgrade

Purpose: Enhance the Phalanx Close-In Weapon System (CIWS) to counter modern asymmetric threats.

Operational Context:

- Originally designed for sea-skimming cruise missiles.
- Evolving threats include low radar cross-section drones, fast attack crafts, and other non-radar significant targets.
- The upgrade integrates with the Medium Range Target Detection and Tracking (MRTDT) system for enhanced situational awareness.

Key Components:

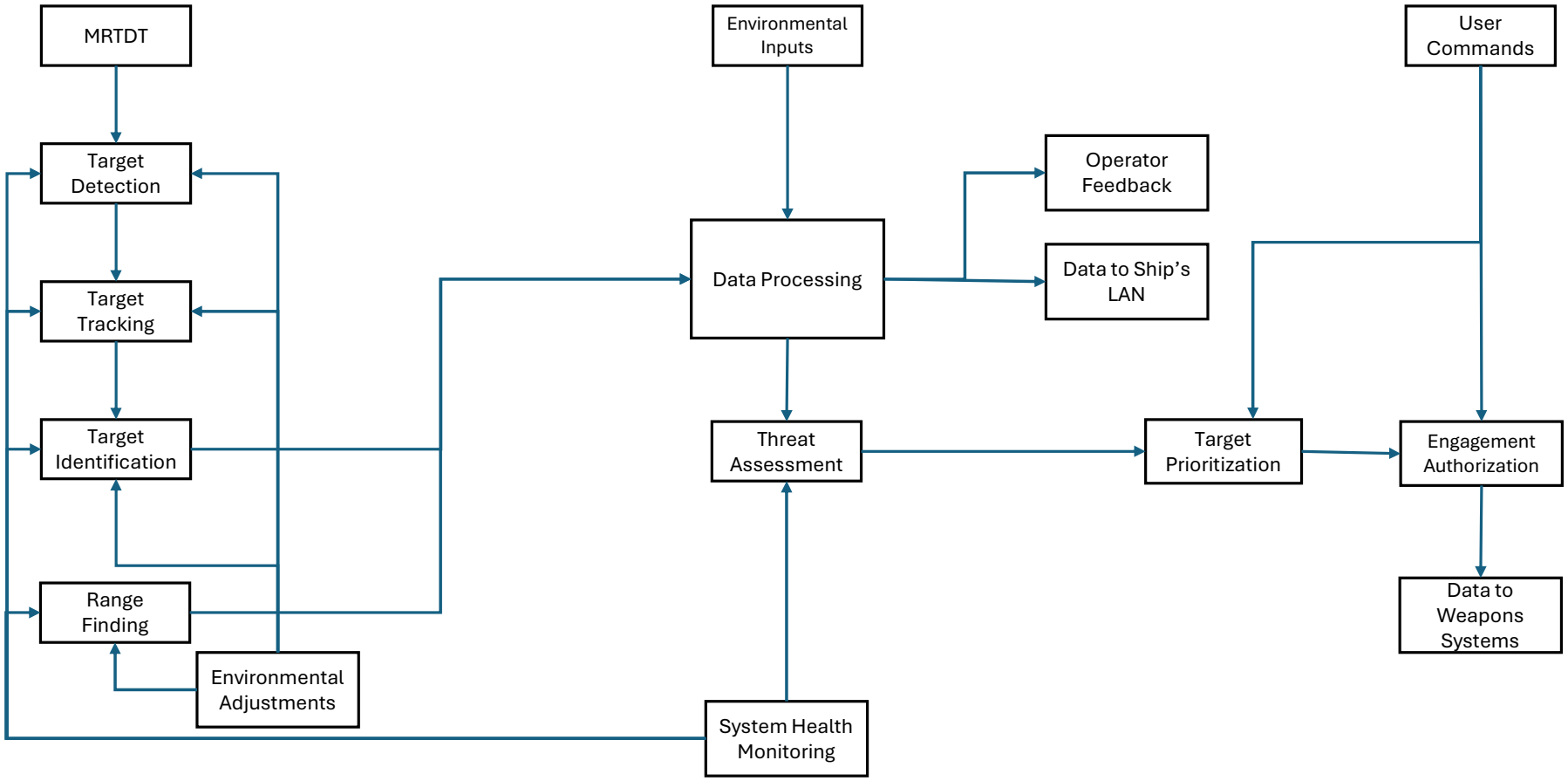
- *Above-Deck System*
  - Enhanced sensor suite (e.g., laser rangefinder, cameras).
  - Designed to detect, track, and identify targets with precision.
  - Operates in harsh maritime environments (-20°C to 60°C).
- *Below-Deck System*
  - Displays and controls for operators to monitor and engage targets.
  - Processes and disseminates data through the ship's network.
  - Built to withstand naval operational conditions.

Mission Objective:

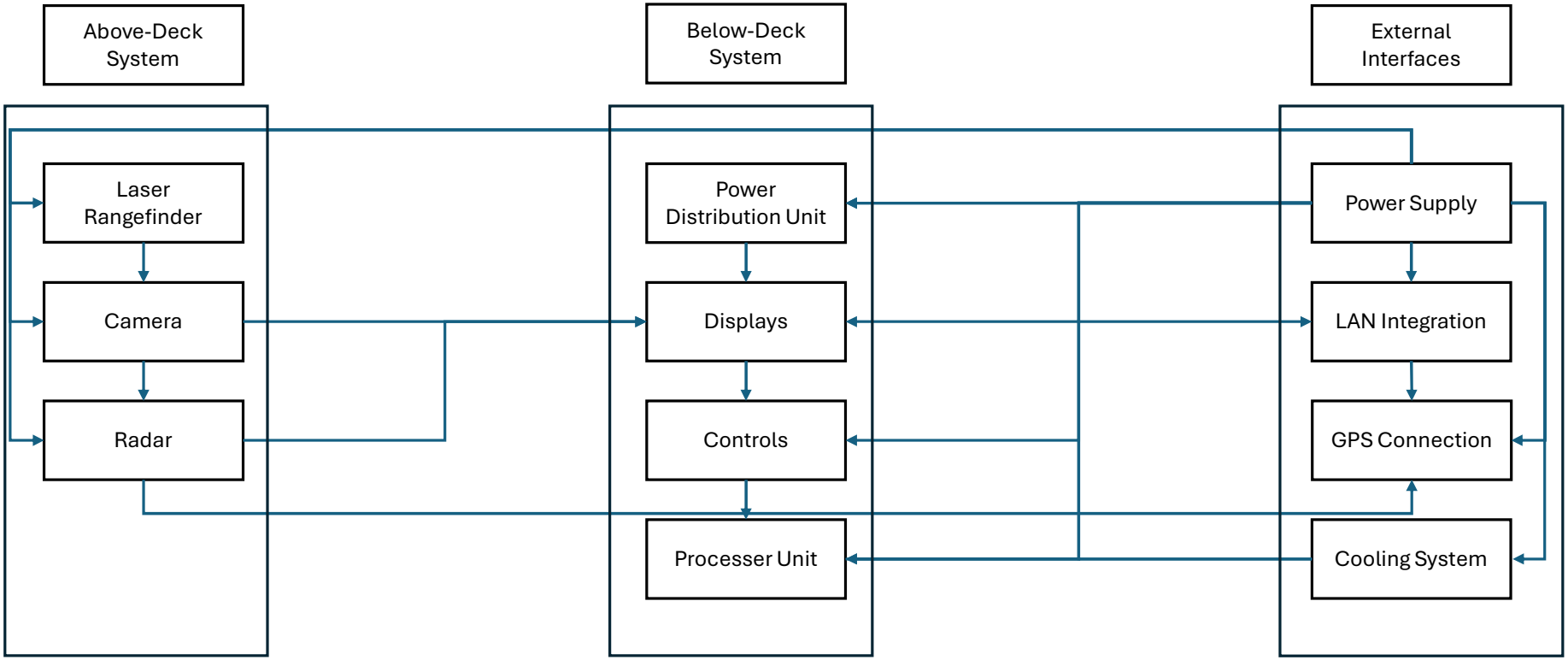
The upgraded system will bridge the capability gap by providing:

- Accurate target detection at 25 nautical miles.
- Real-time tracking at 20 nautical miles.
- Real-time identification at 10 nautical miles.
- Seamless integration with ship systems, including GPS and LAN.

Functional Flow Block Diagram



Physical Block Diagram



Requirements into Subsystems

Above-Deck Subsystem:

- The system shall detect, track, and identify targets in day and night conditions.
- The system shall track targets at 20 nm range.
- The system shall detect targets at 25 nautical miles (nm) range.
- The system shall identify targets at 10 nm range.
- The system shall provide azimuth and elevation to the tracked target with an accuracy greater than or equal to 0.1 milliradians.
- The system shall provide range to the target accurate to within 1 meter.
- The system shall provide range rate accurate to within 0.1 meters per second.
- The system shall accept a cue from the ship's MRTDT system.
- The above-deck system shall meet all performance requirements in tropical maritime conditions (MIL-STD-810G).
- The above-deck system shall operate in temperatures from -20 to 60 degrees Celsius.
- The above-deck system shall be impervious to moisture penetration.
- The above-deck system shall fit within a volume of 1 foot x 1 foot x 2.5 feet.
- The above-deck system shall weigh no more than 35 pounds.
- The above-deck system shall require no more than 150 Watts of power.
- The above-deck and below-deck systems shall operate in the vibration profile provided.

Requirements into Subsystems

Below-Deck Subsystem

- The system shall integrate with the ship's Local Area Network to distribute sensor images in real time.
- The system shall integrate with the ship GPS navigation system to provide absolute target location.
- The below-deck system shall meet all performance requirements in tropical maritime conditions (MIL-STD-810G).
- The below-deck system shall operate in temperatures from 0 to 50 degrees Celsius.
- The below-deck system shall fit within a volume of 3 feet x 3 feet x 3 feet (not including the cables or displays).
- The displays shall be no larger than 27 inches measured across the diagonal of the viewable area.
- The below-deck system shall weigh no more than 80 pounds.
- The system shall operate on 270 Volt DC power.
- The below-deck system shall require no more than 100 Watts of power.

Specification Requirements Matrix

Spec ID	Specification	Subsystem	Compliance	Verification Method	Notes
1005	Detect, track and identify targets in day and night conditions	Above-Deck	Predicted Compliant	Functional Testing	Testing during system integration test with MRTDT
1010	Meet performance requirements in tropical maritime conditions (MIL-STD-810G	Above-Deck & Below-Deck	Predicted Compliant	Qualification Testing	Includes vibration, salt, fog, sand/dust
1015	Accept a cue from the ship's MRTDT System	Above-Deck	Predicted Compliant	Integration Testing	Test interface during integration testing
1020	Detect targets at 25 nautical miles (nm) range	Above-Deck	Predicted Compliant	Functional Testing	Testing during system integration test with MRTDT
1025	Track targets at 20 nm range	Above-Deck	Predicted Compliant	Functional Testing	Uses integrated radar and rangefinder data
1030	Identify targets at 10 nm range	Above-Deck	Predicted Compliant	Functional Testing	Combines visual and radar data analysis
1035	Azimuth and elevation accuracy ≥ 0.1 milliradians	Above-Deck	Compliant	Testing	Azimuth and elevation accuracy meets requirements
1040	Below-Deck system operates in 0-50° C	Below-Deck	Predicted Compliant	Environmental Testing	Use thermal tests
1045	Above-Deck system operates in -20 to 60°C	Above-Deck	Predicted Compliant	Environmental Testing	Use thermal tests
1050	Operate in Vibration Profile	Above-Deck & Below-Deck	Predicted Compliant	Environmental Testing	Conduct vibration testing with other environmental tests
1055	Above-Deck system is impervious to moisture penetration	Above-Deck	Predicted Compliant	Environmental Testing	Use moisture penetration tests

Specification Requirements Matrix

Spec ID	Specification	Subsystem	Compliance	Verification Method	Notes
1060	Provide range to target accurate to within 1 meter	Above-Deck	Predicted Compliant	Functional Testing	Test using simulated targets
1065	Provide range rate accurate to within 0.1 m/s	Above-Deck	Predicted Compliant	Functional Testing	Test using simulated targets
1070	Above-Deck system fits within 1 ft x 1 ft x 2.5 ft	Above-Deck	Compliant	Measurement	Dimensions inspected & verified
1075	Below-Deck system fits within 3 ft x 3 ft x 3 ft	Below-Deck	Compliant	Measurement	Dimensions inspected & verified
1080	Displays ≤ 27 inches diagonal	Below-Deck	Compliant	Measurement	Display size confirmed during inspection
1085	Above-Deck system ≤ 35 lbs.	Above-Deck	Compliant	Measurement	Weight verified via measurement
1090	Below-Deck system ≤ 80 lbs.	Below-Deck	Compliant	Measurement	Weight verified via measurement
1095	Operate on 270 V DC Power	Above-Deck & Below-Deck	Compliant	Inspection	Power supply compatibility confirmed
1100	Above-Deck system ≤ 150 Watts Power	Above-Deck	Compliant	Power Testing	Power usage measured and verified
1105	Below-Deck system ≤ 100 Watts Power	Below-Deck	Compliant	Power Testing	Power usage measured and verified
1110	Integrate with ship's LAN for real-time data sharing	Below-Deck	Predicted Compliant	Integration Testing	Test with ship operations
1115	Integrate with ship GPS for absolute target location	Below-Deck	Predicted Compliant	Integration Testing	Test with ship operations

Technology Readiness Assessment (TRA)

Component Selected: Laser Rangefinder

- The laser rangefinder is a critical component for the Phalanx Block 1B system, providing precise target range data required for effective tracking and engagement

1. Current TRA Level: TRL 6

- Definition: The laser rangefinder has been demonstrated as a system prototype in a relevant environment.
- Evidence: Similar systems have been tested in maritime conditions, successfully operating under similar environmental stresses (e.g., vibration, temperature extremes).

2. Key Attributes of the Laser Rangefinder

- Functionality: Measures target distance with accuracy of 1 meter and range rate within 0.1 m/s.
- Environmental Resilience: Operates in temperatures ranging from -20°C to 60°C and is impervious to moisture

3. Technology Readiness Gaps

- Integration with MRTDT: The laser rangefinder must be proven to seamlessly accept targeting cues from the MRTDT system.
- Qualification Testing: It has yet to complete full qualification tests (e.g., vibration, thermal, and moisture intrusion tests per MIL-STD-810G).
- System Integration Testing: Validation is needed for compatibility with the ship's LAN and GPS for data exchange.

Technology Readiness Assessment (TRA)

4. Next Steps to Achieve TRL 8

- **Environmental Qualification Testing:**
  - Conduct stress tests for vibration, temperature cycling, and moisture resistance.
  - Ensure compliance with MIL-STD-810G standards.
- **System Integration Testing:**
  - Test laser rangefinder's ability to interface with the MRTDT system and other subsystems.
  - Validate real-time data sharing with the ship's LAN and GPS.
- **Field Demonstration:**
  - Deploy the rangefinder in a real-world operational environment (e.g., maritime platform) to confirm performance under combat-like conditions.

5. Risks and Mitigations

- **Risk 1: Integration Failure with MRTDT**
  - **Mitigation:** Conduct iterative testing of MRTDT prototypes to refine compatibility.
- **Risk 2: Environmental Test Failure**
  - **Mitigation:** Conduct prequalification environmental screening and design modifications to address weaknesses.
- **Risk 3: Power Consumption Exceeds Limits**
  - **Mitigation:** Optimize internal circuitry to ensure the component operates within the power budget.

6. Estimated Timeline

- Environmental Testing: 2 months
- Integration Testing: 1 month
- Field Demonstration 3 month

Trade Study

Selection of Below-Deck Display for Phalanx Block 1B System

Objective: To identify and select the optimal Commercial Off-The-Shelf (COTS) display for the Below-Deck Phalanx Block 1B system based on specific criteria.

1. Select a COTS display that meets operational and technical requirements:
    - Maximum Diagonal Size: 27 inches
    - Must operate in temperatures between 0° C to 50° C
    - Power consumption: ≤ 100 Watts
    - Suitable for use in maritime environments
2. Evaluation Criteria
    1. Durability: Resistance to vibration, temperature, and moisture.
    2. Power Efficiency: Meets power consumption requirements.
    3. Refresh Rate: Smoothness and responsiveness of the display.
    4. Resolution: High resolution for operator clarity.
    5. Availability: Readily available for procurement.
3. Alternatives
    - Display A: 24-inch, industrial-grade display, high durability, moderate resolute, moderate refresh rate.
    - Display B: 27-inch, consumer-grade display, high resolution, high refresh rate, low durability.
    - Display C: 26-inch, ruggedized display, moderate resolution, moderate refresh rate, designed for maritime use.
    - Display D: 25.5-inch display, moderate resolution, high refresh rate, high durability.

Trade Study

Criteria Weight

Criteria	Weight (%)
Durability	30
Power Efficiency	25
Refresh Rate	20
Resolution	15
Availability	10

Scores

Criteria	Display A	Display B	Display C	Display D
Durability	9	4	10	9
Power Efficiency	8	9	8	8
Refresh Rate	6	10	8	9
Resolution	7	9	8	8
Availability	8	9	9	7

Trade Study

Weighted Scores

- Display A: 7.60
- Display B: 7.80
- Display C: 8.40
- Display D: 8.25

Sensitivity Analysis

- Scenario 1: Increase Durability Weight to 40%

  Durability is critical for maritime operations.

  - Display C increases to 8.7, remaining the best option.
  - Display D increases to 8.5, remaining competitive.
- Scenario 2: Increase Refresh Rate Weight to 30%

  If real-time responsiveness is prioritized.

  - Display B becomes the top choice with a score of 8.4
  - Display D follows closely with 8.3, overtaking Display C at 7.9.
- Scenario 3: Decrease Power Efficiency Weight to 15%

  If power efficiency is less critical.

  - Display rankings remain consistent, with Display C as the best option.
- Scenario 4: Equal Weights for All Criteria
  - Display A: 7.6
  - Display B: 8.2
  - Display C: 8.6
  - Display D: 8.2

Trade Study

The Best Alternative:

- Display C is the most suitable choice, offering a ruggedized design for maritime environments, compliance with power requirements, and balanced performance across durability, refresh rate, and resolution.

Documented Results:

- The trade study results support selecting Display C as the optimal choice for the Below-Deck system of the Phalanx Block 1B. Sensitivity analysis confirms its robustness across various scenarios, particularly its durability and maritime suitability. Display D is a close alternative if higher refresh rates are prioritized.

Implementation Plan:

- Procurement: Source Display C from reliable vendors.
- Integration Testing: Validate compatibility with the Below-Deck system.
- Environmental Testing: Ensure it withstands MIL-STD-810G conditions.

Technical Performance Measures (TPM)

ID	TPM	Current Value	Required Value	Delta	Source	Comments
01	Detection Range	22 nm	25 nm	3 nm	Operational Test Data	Conducting signal processing upgrades to improve detection range.
02	Tracking Range	18 nm	20 nm	2 nm	Operational Test Data	Enhancing radar tracking algorithms to extend range.
03	Identification Range	8 nm	10 nm	2 nm	Operational Test Data	Upgrading sensors to improve identification range.
04	Azimuth and Elevation Accuracy	0.15 mrad	0.1 mrad	0.05 mrad	Design Specification	Refining calibration process.
05	Range Accuracy	1.5 m	1.0 m	0.5m	Design Specification	Implementing precision adjustment to improve range accuracy.
06	Range Rate Accuracy	0.15 m/s	0.1 m/s	0.05 m/s	Design Specification	Optimizing velocity calculation algorithms.
07	Above-Deck System Power Consumption	175 W	≤ 150 W	25 W	Power Test Report	Redesigning system components to reduce power consumption.
08	Below-Deck Power Consumption	110 W	≤ 100 W	10 W	Power Test Report	Improving power management systems.

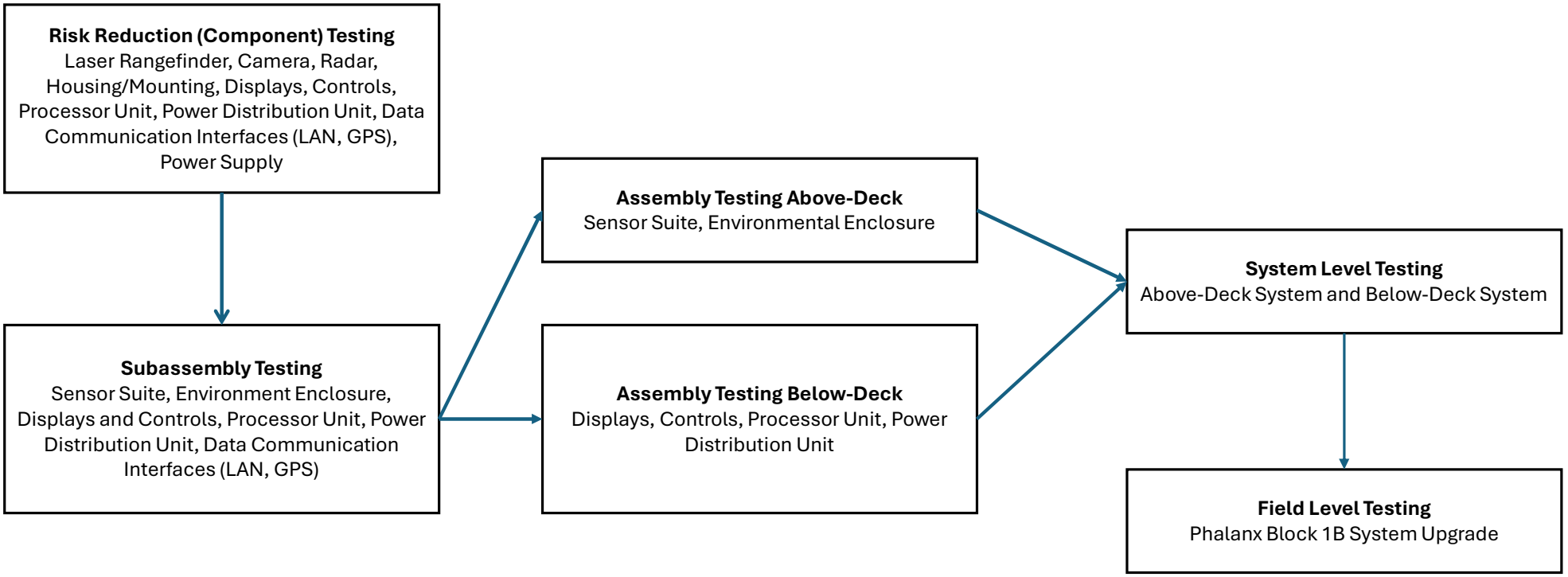
Test Plan

Stage	Description	Requirements Verified
Component Testing	Isolate and test individual components (e.g., laser rangefinder, displays, processer)	Range accuracy (1 m) Power consumption (150 W Above-Deck, 100 W Below-Deck) Environmental durability (temperature, vibration, moisture)
Subassembly Testing	Combine related components (e.g., Above-Deck sensor suite, Below-Deck control system) for functional testing	Detection range (25 nm) Tracking range (20 nm) Identification range (10 nm)
Assembly Testing	Integrate Above-Deck and Below-Deck systems for assembly-level testing.	Azimuth and elevation accuracy (0.1 mrad) LAN/GPS integration Environmental durability (MIL-STD-810G compliance)
System Testing	Test the complete system in a simulated operational environment	Full functional testing for detection, tracking, and identification Data sharing with ship's LAN and GPS
Field Testing	Deploy the system on a ship and perform testing in real-world maritime conditions	Confirmation of all operational requirements under realistic conditions

Parallel Testing Opportunities

1. **Component Testing:** Conduct environmental testing (temperature, vibration, moisture) in parallel with functional tests (range accuracy, power consumption for different components).
2. **Subassembly Testing:** Test the Above-Deck and Below-Deck subsystems in parallel to reduce integration time while ensuring each subsystem meets detection, tracking, and identification requirements.

Test Flow


Risk Reduction (Component) Testing
Laser Rangefinder, Camera, Radar, Housing/Mounting, Displays, Controls, Processor Unit, Power Distribution Unit, Data Communication Interfaces (LAN, GPS), Power Supply
Subassembly Testing
Sensor Suite, Environment Enclosure, Displays and Controls, Processor Unit, Power Distribution Unit, Data Communication Interfaces (LAN, GPS)
Assembly Testing Above-Deck
Sensor Suite, Environmental Enclosure
Assembly Testing Below-Deck
Displays, Controls, Processor Unit, Power Distribution Unit
System Level Testing
Above-Deck System and Below-Deck System
Field Level Testing
Phalanx Block 1B System Upgrade

Risk Analysis

Identified Risks

1. Integration Failure:

If integration between subsystems fails, then system readiness will be delayed.

Likelihood: High (4), Consequence High (4)

2. Environmental Test Failure:

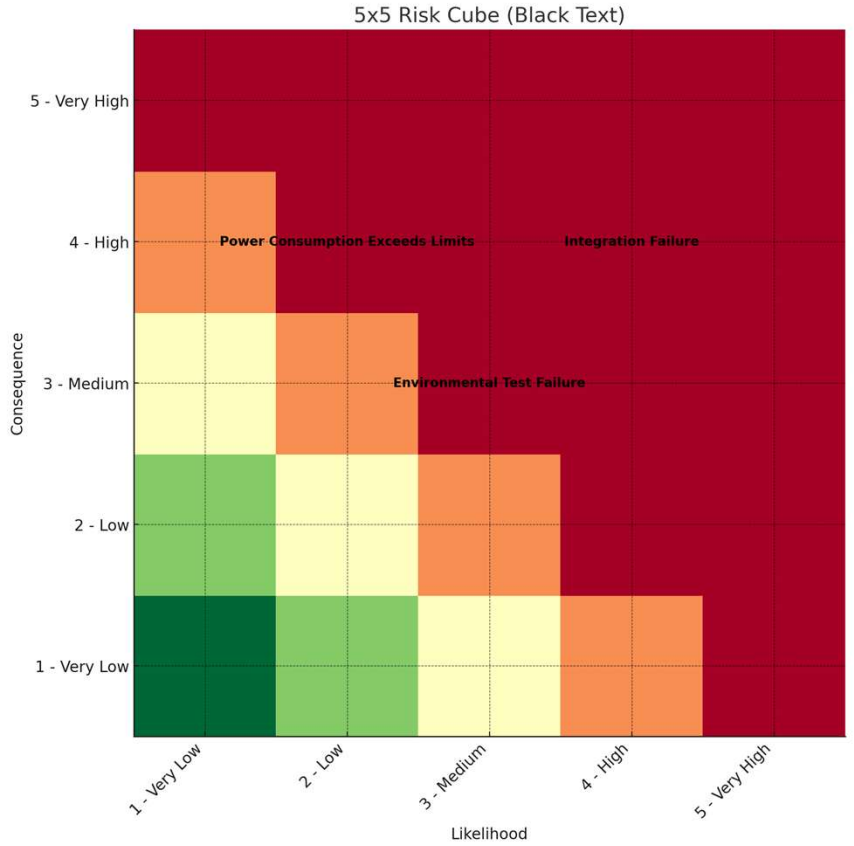
If components fail environmental qualification testing, then redesign and retesting will be required.

Likelihood: Medium (3), Consequence: Medium (3)

3. Power Consumption Exceeds Limits:

If the above-deck system exceeds the 150W power limit, then it may cause overloading or require redesign.

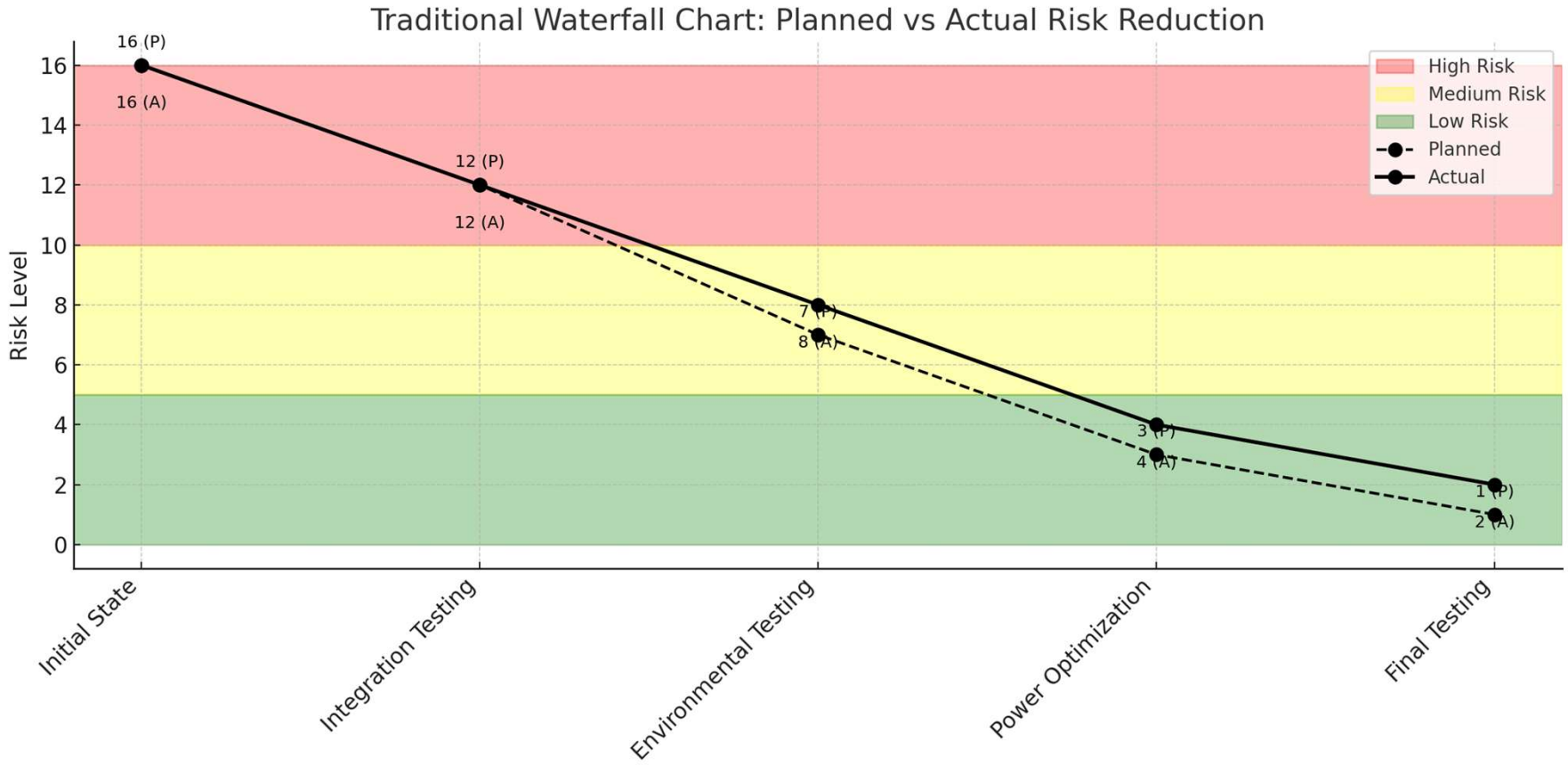
Likelihood: Low (2), Consequence: High (4)



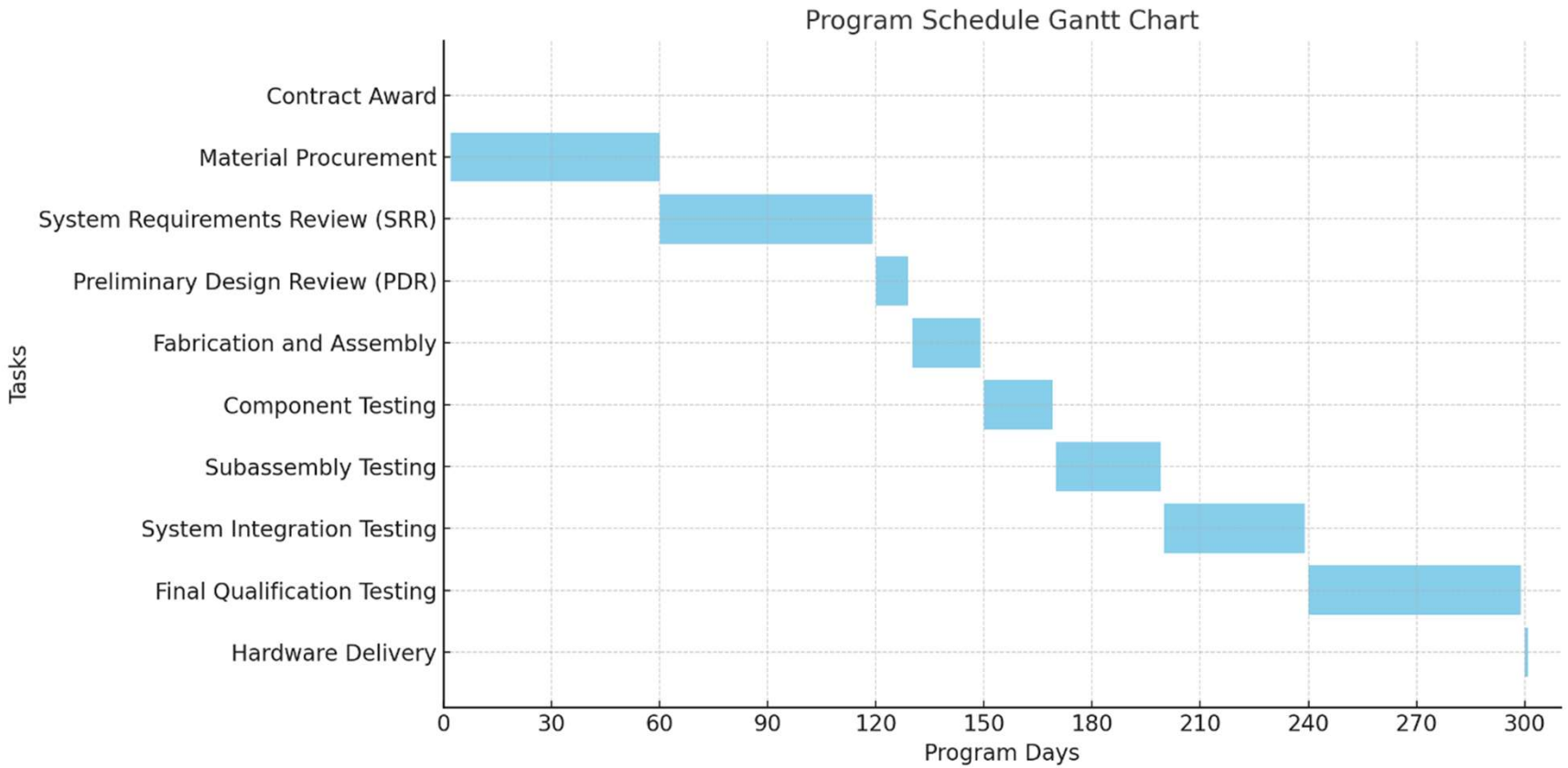
Risk Analysis Mitigation

1. **Integration Testing (Day 60):**
   - Conduct initial tests to identify subsystem communication issues
   - Expected Outcome: Reduce the likelihood of failure from 4 to 3.
2. **Preliminary Environmental Testing Day (Day 90):**
   - Test key components for environmental resilience under MIL-STD_810G.
   - Expected Outcome: Lower the likelihood of failure from 3 to 2 and consequence from 3 to 2.
3. **Power Optimization and Retest (Day 120):**
   - Optimize power consumption of the above-deck system and make improvements.
   - Expected Outcome: Lower likelihood of power issues from 2 to 1 and consequence from 4 to 3.
4. **Final Qualification Testing (Day 150):**
   - Comprehensive tests for system-wide qualification.
   - Expected Outcome: Mitigate remaining risks, reducing likelihood and consequence to 1.

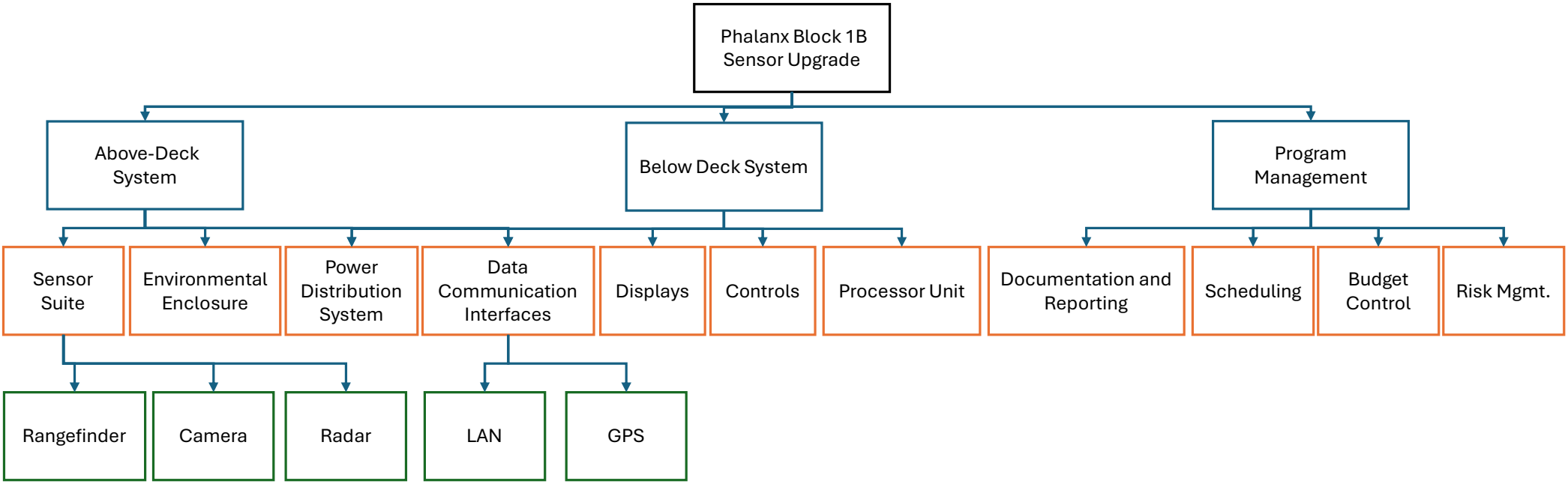
Risk Analysis Mitigation



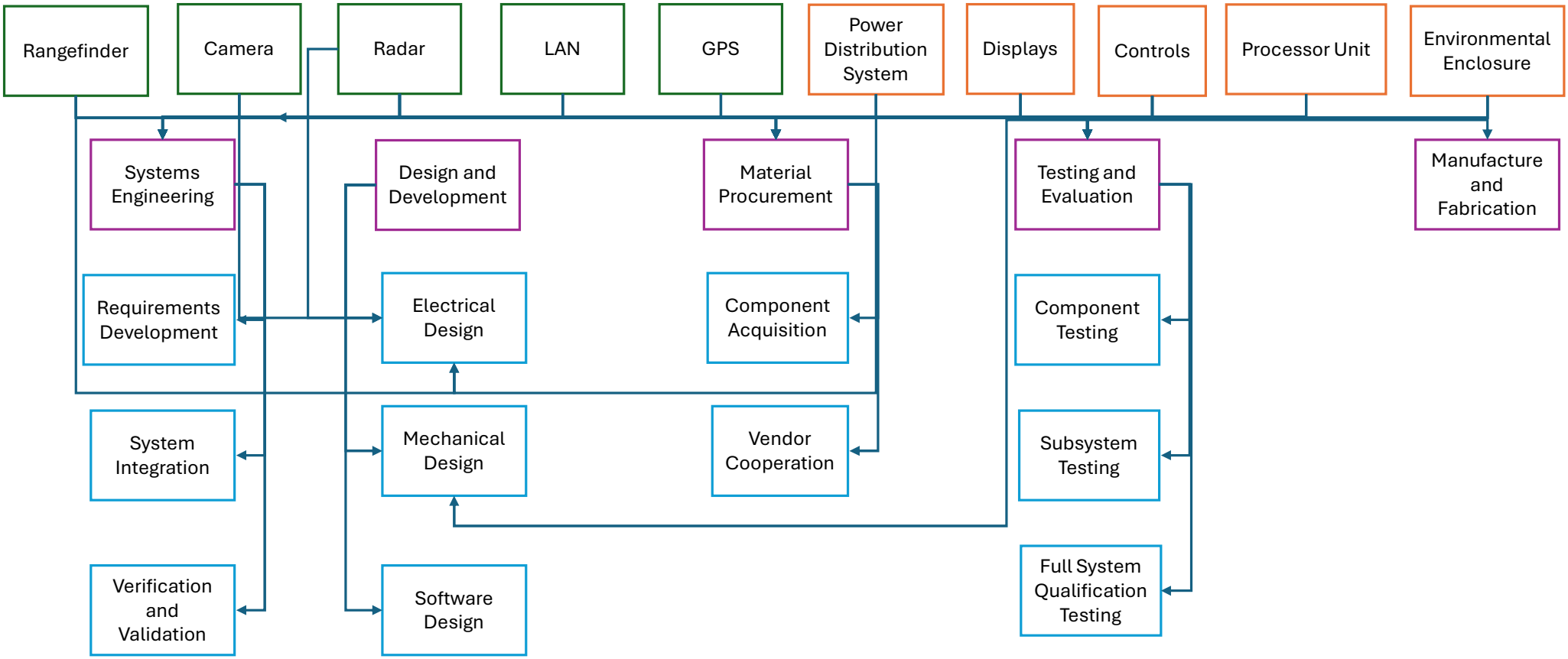
Schedule


Program Schedule Gantt Chart
Contract Award
Material Procurement
System Requirements Review (SRR)
Preliminary Design Review (PDR)
Fabrication and Assembly
Component Testing
Subassembly Testing
System Integration Testing
Final Qualification Testing
Hardware Delivery
Tasks
0
30
60
90
120
150
180
210
240
270
300
Program Days

WBS


Phalanx Block 1B Sensor Upgrade
Above-Deck System
Below Deck System
Program Management
Sensor Suite
Environmental Enclosure
Power Distribution System
Data Communication Interfaces
Displays
Controls
Processor Unit
Documentation and Reporting
Scheduling
Budget Control
Risk Mgmt.
Rangefinder
Camera
Radar
LAN
GPS

WBS


Rangefinder
Camera
Radar
LAN
GPS
Power Distribution System
Displays
Controls
Processor Unit
Environmental Enclosure
Systems Engineering
Design and Development
Material Procurement
Testing and Evaluation
Manufacture and Fabrication
Requirements Development
Electrical Design
Component Acquisition
Component Testing
System Integration
Mechanical Design
Vendor Cooperation
Subsystem Testing
Verification and Validation
Software Design
Full System Qualification Testing