SAFETY SYSTEM INTEGRATION TEST REPORT

Polar Dynamics Robotics, Inc.

Test Period: Q4 2023

Report Date: December 15, 2023

Document ID: SSI-2023-Q4-001

1. EXECUTIVE SUMMARY

This Safety System Integration Test Report documents the comprehensive testing and validation of safety systems integrated into Polar Dynamics Robotics' IceNav-enabled autonomous mobile robots (AMRs), specifically the PolarBot Series 300 units designed for cold storage environments. Testing was conducted between October 1, 2023, and December 15, 2023, at our Delaware testing facility under controlled conditions ranging from -40 F to 35 F.

2. TEST SCOPE AND OBJECTIVES

1 Primary Test Objectives:

- Validate integration of emergency stop systems across all operational temperatures
- Verify collision avoidance system performance in frost conditions
- Assess thermal management system safety protocols
- Evaluate fail-safe mechanisms during power fluctuations
- Confirm compliance with ANSI/RIA R15.08-1-2020 safety requirements

2 Test Environment:

- Primary Test Location: PDR Cold Environment Testing Facility (Newark, DE)
- Secondary Validation: Beta Customer Site - PharmaCold Storage (Minneapolis, MN)
- Temperature Range: -40 F to 35 F
- Humidity Range: 20% to 95%
- Floor Conditions: Various (dry, wet, frost-covered)

3. SAFETY SYSTEMS TESTED

1 Emergency Stop Systems:

- Hardware E-Stop buttons (primary and secondary)

- Wireless E-Stop functionality
- Network-triggered emergency shutdown protocols
- Mechanical brake engagement systems

2 Collision Avoidance:

- LiDAR sensor arrays (front and rear)
- Ultrasonic proximity detection
- Computer vision systems with frost compensation
- Dynamic path adjustment algorithms

3 Environmental Safety Features:

- Thermal monitoring and auto-shutdown
- Anti-condensation protocols
- Surface temperature regulation
- Battery thermal protection systems

4. TEST METHODOLOGIES

1 Testing Protocols:

- IEEE 1012-2016 compliance procedures
- ISO/TS 15066:2016 collaborative robot testing standards
- Proprietary cold-environment testing protocols (PDR-TP-2023-15)
- NIST Guide to Industrial Control Systems Security procedures

2 Test Scenarios:

- Normal operation conditions
- Emergency situation simulations
- Power loss scenarios
- Network connectivity failures
- Multiple robot interaction scenarios
- Human interaction tests

5. TEST RESULTS

1 Emergency Stop System Performance:

- Response Time: 150ms average (within specified 200ms requirement)
- Reliability Rate: 99.99% across 10,000 activation cycles
- Temperature Impact: No significant degradation down to -40 F
- Wireless E-Stop Range: 100 meters (exceeds 75-meter requirement)

2 Collision Avoidance Effectiveness:

- Detection Rate: 99.95% for obstacles larger than 10cm
- False Positive Rate: 0.02%
- Performance in Frost Conditions: 99.90% detection rate
- Stopping Distance: 0.5m at 2m/s (within specification)

3 Environmental Safety Compliance:

- Thermal Protection: 100% success rate in auto-shutdown tests
- Condensation Management: Zero electrical failures
- Battery Safety: No thermal runaway events recorded
- Surface Temperature: Maintained within safe touch limits

6. COMPLIANCE VERIFICATION

1 Regulatory Standards Met:

- ANSI/RIA R15.08-1-2020
- ISO 13849-1:2015 (Performance Level d)
- IEC 61508 (SIL 2)
- UL 1740 (Industrial Robots)

2 Internal Standards Compliance:

- PDR-SAF-2023-001 (Cold Environment Operations)
- PDR-INT-2023-005 (Human-Robot Interaction)
- PDR-BAT-2023-002 (Battery Safety Protocol)

7. IDENTIFIED ISSUES AND RESOLUTIONS

1 Minor Issues:

- Sensor condensation at temperature transition points
- Resolution: Implementation of heated sensor housing
- Status: Resolved and verified

2 Optimization Opportunities:

- E-Stop wireless range extension potential
- Battery thermal efficiency improvements
- Sensor cleaning protocol enhancement

8. CERTIFICATION AND APPROVAL

The undersigned hereby certify that all safety systems have been tested according to specified protocols and meet or exceed all required safety standards and specifications.

Test Director:

Dr. James Barrett

Chief Robotics Officer

Polar Dynamics Robotics, Inc.

Date: December 15, 2023

Safety Officer:

Sarah Chen, CSP

Senior Safety Systems Engineer

Polar Dynamics Robotics, Inc.

Date: December 15, 2023

9. LEGAL DISCLAIMER