Environmental Stress Testing Report - Cold Operations

Polar Dynamics Robotics, Inc.

Report Date: January 11, 2024

Document Reference: EST-2024-C01

1. Executive Summary

This Environmental Stress Testing Report documents the comprehensive cold operations testing protocol and results for Polar Dynamics Robotics' autonomous mobile robot (AMR) systems, specifically focusing on the IceNav(TM) Series 3000 platform. Testing was conducted between October 15, 2023, and December 31, 2023, at our Delaware Testing Facility (DTF-1) and the Advanced Cold Operations Laboratory (ACOL) in Minneapolis, MN.

2. Testing Scope and Objectives

1. Primary Testing Parameters

- Operating temperature range: +5 C to -40 C
- Humidity variation: 20% to 95% RH
- Duration: 1,000 cumulative hours per unit
- Test units: 5 production-grade IceNav(TM) Series 3000 AMRs
- Navigation accuracy validation
- Battery performance metrics
- Actuator responsiveness
- Thermal management system efficiency

2. Compliance Standards

- ISO 13849-1:2015 Safety of machinery
- IEC 60068-2-1 Environmental testing - Cold
- ANSI/RIA R15.08-1-2020 Industrial Mobile Robot Safety
- FDA 21 CFR Part 11 (for pharmaceutical applications)

3. Testing Methodology

1. Environmental Chamber Specifications

- Thermal Testing Chamber: Thermotron SE-2000-15-15
- Chamber dimensions: 20' x 15' x 12'
- Temperature control accuracy: ± 0.5 °C
- Humidity control accuracy: ± 2% RH

2. Testing Protocols

- Progressive temperature reduction: 5 °C/hour
- 24-hour stabilization periods at target temperatures
- Automated navigation courses with variable obstacles
- Load-bearing tests (0-500kg payloads)
- Emergency stop validation at temperature extremes
- Sensor calibration verification

4. Test Results

1. Mechanical Systems Performance

- Actuator response time maintained within 50ms at -40 °C
- Zero mechanical failures across all test units
- Proprietary cold-resistant bearings showed <2% efficiency loss
- Thermal expansion compensation systems performed within specifications

2. Navigation and Sensor Performance

- LiDAR accuracy: 98.7% maintained across temperature range
- Camera systems: 99.1% object recognition reliability
- IceNav(TM) pathfinding success rate: 99.8%
- Position accuracy: ± 5mm at all tested temperatures

3. Power Systems

- Battery capacity retention: 92% at -40 °C
- Charging efficiency: 94% across temperature range
- Power consumption variation: +15% at lowest temperatures
- Thermal management system power draw: Within design parameters

5. Compliance Verification

1. Safety Systems

- Emergency stop function: 100% reliable across all temperatures
- Obstacle detection: Exceeds ANSI/RIA R15.08 requirements
- Safety light curtain operation: Validated across temperature range
- Wireless emergency stop latency: <100ms

2. Regulatory Requirements

- FDA 21 CFR Part 11 compliance verified
- CE marking requirements satisfied
- UL certification standards met
- IP65 rating maintained throughout testing

6. Risk Assessment

1. Identified Risks

- Minor condensation on external sensors below -35 C
- Slight increase in power consumption at extreme temperatures
- Battery charging time extended by 12% at lowest temperatures

2. Mitigation Measures

- Implementation of automated sensor heating systems
- Enhanced battery insulation system
- Updated power management firmware
- Additional thermal protection for critical components

7. Conclusions and Recommendations

1. Performance Validation

The IceNav(TM) Series 3000 platform has demonstrated robust performance across all tested parameters, meeting or exceeding design specifications for cold environment operations.

2. Recommendations

- Implement quarterly calibration protocol for thermal management systems
- Update operational guidelines for -35 C to -40 C range
- Enhanced operator training for extreme temperature scenarios

- Regular monitoring of battery performance metrics

8. Certification

This Environmental Stress Testing Report has been reviewed and certified by:

Dr. James Barrett

Chief Robotics Officer

Polar Dynamics Robotics, Inc.

Date: January 11, 2024

Katherine Wells

Chief Financial Officer

Polar Dynamics Robotics, Inc.

Date: January 11, 2024

9. Legal Disclaimer