

# **Robot Safety Risk Assessment Report**

## **Cold Storage Division**

**Polar Dynamics Robotics, Inc.**

**Report Date: January 11, 2024**

**Document Reference: RSA-2024-CS-001**

## **1. Executive Summary**

This safety risk assessment evaluates operational hazards and mitigation measures for Polar Dynamics Robotics' autonomous mobile robots (AMRs) deployed in cold storage environments. The assessment focuses on the IceNav-enabled AMR fleet operating in temperatures ranging from -30 C to +5 C.

## **2. Scope of Assessment**

### **1. Systems Evaluated**

- IceNav(TM) Navigation Platform v4.2
- PDR-CS300 Cold Storage AMR Units
- Thermal Management System v2.1
- Emergency Stop Systems
- Human-Robot Interface Components

### **2. Operating Environment Parameters**

- Temperature Range: -30 C to +5 C
- Humidity: Up to 95% RH
- Floor Conditions: Varied (concrete, epoxy-coated, metal gratings)
- Operating Areas: Cold storage warehouses, freezer zones, temperature-controlled staging areas

## **3. Risk Assessment Methodology**

### **1. Assessment Framework**

- ISO 10218-2:2011 Robots and robotic devices
- ISO 13849-1:2015 Safety of machinery
- ANSI/RIA R15.06-2012 Industrial Robots and Robot Systems

- Proprietary PDR Cold Environment Risk Matrix

## 2. Risk Categories

- Mechanical Hazards
- Electrical Safety
- Software/Control System Failures
- Human Interaction Risks
- Environmental Impact Risks

## 4. Identified Hazards and Risk Levels

### 1. High-Priority Risks

- Condensation-related electrical system failures (Risk Level: B2)
- Ice formation on sensor arrays (Risk Level: B1)
- Battery performance degradation in extreme cold (Risk Level: C2)
- Emergency stop system reliability below -25 C (Risk Level: B1)

### 2. Medium-Priority Risks

- Reduced traction on frost-covered surfaces (Risk Level: C3)
- Human operator response time in cold conditions (Risk Level: C3)
- Communication system latency in metal-walled environments (Risk Level: D2)
- Thermal stress on mechanical components (Risk Level: C3)

## 5. Mitigation Measures

### 1. Engineering Controls

- Proprietary thermal management system for critical components
- Redundant sensor arrays with heating elements
- Enhanced grip patterns on drive wheels
- Sealed IP65-rated enclosures for electrical systems

### 2. Administrative Controls

- Mandatory operator cold-weather safety training
- Regular maintenance schedules adjusted for cold conditions

- Emergency response protocols specific to cold environments
- Zone-specific operating procedures

### 3. Technical Safeguards

- Real-time performance monitoring system
- Automated thermal management alerts
- Progressive speed reduction based on environmental conditions
- Enhanced detection of ice-related hazards

## 6. Testing and Validation

### 1. Test Protocols

- Cold chamber validation (-35 C to +10 C)
- Accelerated lifecycle testing under varying conditions
- Emergency stop testing at temperature extremes
- Human-robot interaction scenarios in cold environments

### 2. Validation Results

- All critical systems maintained functionality through 1000-hour cold exposure
- Emergency stop systems operational to -32 C
- Battery performance maintained above 85% capacity at -30 C
- Sensor arrays demonstrated 99.97% reliability with anti-icing measures

## 7. Compliance and Certification

### 1. Regulatory Compliance

- UL 1740 Safety Standard for Robots and Robotic Equipment
- CE Marking requirements for low-temperature operation
- FDA 21 CFR Part 11 compliance for pharmaceutical environments
- OSHA workplace safety requirements

### 2. Third-Party Certifications

- T V S D certification for cold environment operation
- SGS safety certification for human-robot collaboration

- IP65 rating verification by Intertek

## **8. Recommendations**

### **1. Immediate Actions**

- Implementation of enhanced operator training program
- Installation of additional emergency stop stations in high-traffic areas
- Upgrade of thermal management system firmware to version 2.1.4
- Development of cold-specific maintenance protocols

### **2. Long-term Improvements**

- Development of advanced ice detection algorithms
- Integration of predictive maintenance based on cold exposure
- Enhancement of battery thermal management systems
- Implementation of zone-specific speed controls

## **9. Conclusion**

Based on comprehensive testing and analysis, the PDR-CS300 AMR system demonstrates acceptable safety performance in cold storage environments when operated within specified parameters and with implemented control measures. Residual risks have been reduced to acceptable levels through engineering controls and administrative measures.

## **10. Authentication**

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Date: January 11, 2024

### **Legal Disclaimer**

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