# ISO 13849-1 Safety Control System Documentation

**Polar Dynamics Robotics, Inc.**

Document Reference: PDR-ISO-13849-2024-001

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## 1. Purpose and Scope

1. This documentation establishes compliance with ISO 13849-1:2015 "Safety of machinery - Safety-related parts of control systems" for Polar Dynamics Robotics, Inc.'s ("PDR") IceNav-enabled autonomous mobile robots and their integrated safety control systems.

2. This documentation covers all safety-related parts of the control system (SRP/CS) implemented in PDR's Arctic Series AMR platforms, including:

- Emergency stop functions
- Safety-rated monitored stop
- Speed and separation monitoring
- Temperature-compensated safety sensing
- Protective stop functions
- Safety-rated soft axis and space limiting

## 2. System Architecture and Safety Functions

1. Performance Level (PL) Classification

- Overall system safety integrity: Performance Level d (PLd)
- Category 3 architecture with diagnostic coverage (DC)  90%
- Mean Time to Dangerous Failure (MTTFd): 30 years
- Common Cause Failure (CCF) score: 75

2. Safety Function Implementation

The following safety functions are implemented through redundant channels:

a) Primary Safety Controller

- Manufacturer: T V-certified Safety PLC
- Model: SafetyPRO 5000

- Software version: 4.2.1
- Safety certification: IEC 61508 SIL 3

b) Secondary Monitoring System

- Independent microcontroller-based system
- Hardware watchdog timer
- Cross-checking of critical parameters
- Fault detection and diagnostic systems

## 3. Risk Assessment and Mitigation

1. Identified Hazards

- Collision risks in cold storage environments
- Thermal stress on safety components
- Sensor degradation in extreme temperatures
- Emergency stop reliability in frost conditions
- Battery system safety in sub-zero operations

2. Risk Reduction Measures

- Redundant temperature-hardened sensors
- Fail-safe brake systems with thermal compensation
- Multiple emergency stop circuits
- Independent safety monitoring channels
- Regular validation of safety function performance

## 4. Validation and Testing Protocols

1. Safety Function Validation

All safety functions undergo the following validation:

- Factory Acceptance Testing (FAT)
- Site Acceptance Testing (SAT)
- Annual performance verification
- Post-maintenance validation
- Environmental stress testing (-40 C to +50 C)

2. Testing Documentation

- Test procedures according to ISO 13849-2
- Validation records maintained for 10 years
- Third-party certification documentation
- Environmental qualification reports
- Fault injection test results

## 5. Maintenance and Monitoring

1. Preventive Maintenance Schedule

- Monthly safety function verification
- Quarterly sensor calibration
- Semi-annual firmware validation
- Annual third-party safety audit
- Continuous monitoring of safety parameters

2. Documentation Requirements

- Maintenance logs
- Calibration certificates
- Software version control records
- Component replacement history
- Safety performance metrics

## 6. Training and Operation

1. Personnel Requirements

- Certified safety system operators
- Qualified maintenance technicians
- Safety system administrators
- Emergency response team members

2. Training Program

- Initial safety system training
- Annual refresher courses

- Emergency procedure training
- Documentation and record-keeping
- Incident response protocols

## 7. Certification and Compliance

1. The safety control system has been certified by:

- T V S D (Certificate No. TC-2023-985)
- DEKRA Testing and Certification
- UL Safety Certification

2. Applicable Standards

- ISO 13849-1:2015
- IEC 61508:2010
- ANSI/RIA R15.06-2012
- EN 62061:2005+A2:2015

## 8. Legal Disclaimer

This documentation is confidential and proprietary to Polar Dynamics Robotics, Inc. While every effort has been made to ensure accuracy and compliance, this documentation should be reviewed by qualified safety professionals before implementation. PDR assumes no liability for any damages arising from the use or misuse of this information.

## 9. Document Control

Version: 2.1

Approved By: Dr. James Barrett, Chief Robotics Officer

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[SIGNATURE PAGE FOLLOWS]