# PDR-NAV-207: LiDAR Integration Protocol for Sub-Zero Environments

**PROPRIETARY AND CONFIDENTIAL**

**Polar Dynamics Robotics, Inc.**

**Version 3.2 - Effective Date: January 15, 2024**

## 1. PURPOSE AND SCOPE

1. This Protocol ("PDR-NAV-207") establishes the mandatory technical and operational requirements for the integration, calibration, and deployment of LiDAR sensing systems within Polar Dynamics Robotics' IceNav-enabled autonomous mobile robots operating in sub-zero environments ("Cold Environment AMRs").

2. This Protocol applies to all Cold Environment AMRs manufactured by Polar Dynamics Robotics, Inc. ("Company") incorporating the TX-850 Series Thermal-Hardened LiDAR arrays and associated IceNav processing modules.

## 2. DEFINITIONS

1. "Cold Environment" means any operational environment with ambient temperatures below 0 C (32 F).

2. "Critical Operating Temperature" means -40 C (-40 F) to 0 C (32 F).

3. "IceNav System" means the Company's proprietary navigation and control system designed for Cold Environment operations.

4. "LiDAR Array" means the TX-850 Series thermal-hardened LiDAR sensor assembly and associated hardware.

5. "Thermal Management System" means the Company's proprietary temperature control and condensation prevention system.

## 3. TECHNICAL SPECIFICATIONS

1. LiDAR Array Configuration

a) Each Cold Environment AMR shall be equipped with minimum three (3) TX-850 LiDAR sensors

b) Primary sensor mounting points: forward-facing (1), lateral (2)

c) Minimum scan rate: 40Hz at Critical Operating Temperature

d) Operating voltage: 24V DC  5%

e) Power consumption:  45W per sensor array

2. Environmental Protection Requirements

a) IP67 rated enclosure for all external components

b) Heated optical surfaces with automatic defrost cycling

c) Condensation detection and mitigation systems

d) Thermal isolation from primary robot chassis

## 4. INTEGRATION PROCEDURES

1. Physical Installation

a) Mount LiDAR Arrays using Company-approved cold-rated mounting brackets

b) Install thermal interface material per Specification TIM-203

c) Route all cables through designated cold-protected conduits

d) Apply specified torque values for all fasteners (ref: Table A-1)

2. System Integration

a) Flash IceNav firmware version 5.2 or higher

b) Configure thermal management parameters per Section 5

c) Perform initial calibration sequence

d) Verify sensor fusion alignment with IMU data

## 5. THERMAL MANAGEMENT PROTOCOLS

1. The Thermal Management System shall maintain LiDAR Array operating temperature within specified ranges:

a) Startup temperature: minimum -45 C

b) Continuous operation: -40 C to +5 C

c) Maximum temperature differential: 15 C/hour

2. Heating Element Control

a) Primary heating cycle: 2-minute duration

b) Standby power: 5W maximum

c) Peak heating power: 30W per array

d) Temperature ramp rate: 5 C/minute maximum

## 6. CALIBRATION AND TESTING

1. Initial Calibration Requirements

a) Perform in controlled environment at -30 C  2 C

b) Minimum 4-hour temperature stabilization period

c) Execute full range motion tests

d) Verify point cloud accuracy  98%

2. Validation Testing

a) Complete full startup sequence at Critical Operating Temperature

b) Verify sensor fusion accuracy across operating range

c) Document all test results in Company-approved format

## 7. SAFETY AND COMPLIANCE

1. All installations must comply with:

a) ISO/TS 15066:2016 for collaborative robots

b) IEC 61496-1:2020 for electro-sensitive protective equipment

c) Company Safety Standard CSS-104 for Cold Environment Operations

2. Emergency Systems

a) Maintain redundant obstacle detection capabilities

b) Implement fail-safe protocols per Section 8

c) Enable automatic system shutdown if thermal parameters exceeded

## 8. MAINTENANCE AND INSPECTION

1. Scheduled Maintenance

a) Monthly inspection of optical surfaces

b) Quarterly calibration verification

c) Semi-annual thermal system evaluation

d) Annual complete system recertification

2. Documentation Requirements

a) Maintain calibration records for 3 years

b) Log all maintenance activities in Company database

c) Report any deviations from specified parameters

## 9. PROPRIETARY RIGHTS

1. This Protocol contains confidential and proprietary information of Polar Dynamics Robotics, Inc. and is protected under applicable intellectual property laws.

2. No part of this Protocol may be reproduced, distributed, or disclosed without prior written authorization from the Company's Legal Department.

## 10. REVISION HISTORY

Version 3.2 - January 15, 2024

Version 3.1 - October 1, 2023

Version 3.0 - June 15, 2023

APPROVED BY:

_

Dr. James Barrett

Chief Robotics Officer

Polar Dynamics Robotics, Inc.

_

Marcus Chen

Chief Technology Officer

Polar Dynamics Robotics, Inc.

Date: January 15, 2024