

SR&ED Project Description: Adaptive Vision System for Frost-Covered Frozen Produce Picking

October 2026

Scientific and Technological Uncertainties in Frost-Adapted Produce Recognition

Northern Lattice Robotics Inc. encountered significant technological uncertainties when attempting to automate the picking of frozen produce on high-speed conveyor lines. Standard machine vision systems rely on distinct color gradients and edge contrasts to identify objects. In industrial freezing environments, rapid frost accumulation creates a homogeneous white layer that obscures these visual features, rendering conventional RGB-based segmentation algorithms ineffective. The core uncertainty was whether non-invasive optical sensing could reliably differentiate between the geometric structure of the underlying produce and the random, crystalline topology of surface frost without physical contact or thermal disruption of the product.

Further uncertainty existed regarding the spectral reflectance properties of frost-covered organic matter in the near-infrared (NIR) spectrum. While literature suggests NIR can penetrate certain semi-translucent materials, the variable thickness of frost layers - ranging from micro-crystals to thick rime - introduced unpredictable scattering effects. It was not known if a consistent correlation could be established between backscattered NIR intensity and the underlying produce geometry under dynamic conveyor conditions. Existing public knowledge and standard industry practices did not provide a validated model for real-time frost compensation, necessitating experimental investigation to determine if multi-spectral fusion could resolve the ambiguity between frost noise and produce signal.

Limitation of Standard Practices. Standard off-the-shelf vision sensors failed during initial baseline testing, confirming that existing publicly available knowledge was insufficient to resolve the frost-obscuration problem without systematic experimental development.

Systematic Experimental Work to Resolve Optical and Thermal Ambiguity

Northern Lattice Robotics Inc. conducted a series of systematic investigations between March 2025 and September 2026 to resolve the inability of standard machine vision systems to distinguish between frost accumulation and the underlying geometry of frozen produce. The core hypothesis posited that multi-spectral imaging combined with active thermal pulsing could reveal sub-surface structural features obscured by surface ice crystals. Initial baseline tests using standard RGB cameras at -18°C demonstrated a 92% failure rate in edge detection due to light scattering from frost layers exceeding 2mm thickness.

Methodological Approach. All experiments were conducted in a controlled environmental chamber simulating industrial freezer conditions. Iterations followed a strict design-of-experiments protocol to isolate variables such as frost density, conveyor speed, and ambient humidity.

The first experimental iteration focused on near-infrared (NIR) spectrum analysis. Engineers hypothesized that NIR wavelengths would penetrate superficial frost better than visible light. Tests revealed that while penetration improved, the reflectance signature of wet frost (formed during brief defrost cycles) remained indistinguishable from the produce skin. This failure necessitated a pivot to active thermal modulation. A secondary hypothesis suggested that brief, localized heating (0.5 seconds) would cause differential sublimation rates between ice and organic tissue, creating a transient thermal contrast map.

Experiment ID	Variable Tested	Hypothesis	Outcome	Iteration Decision
EXP-01	RGB Lighting Intensity	Higher lumens reduce scatter	Failed: Increased glare on ice crystals	Abandoned
EXP-02	NIR Spectrum (850nm)	Penetrates 2mm frost layer	Partial: Failed on wet frost	Modified
EXP-03	Active Thermal Pulse	Differential sublimation reveals edges	Success: 85% accuracy achieved	Optimized

Subsequent iterations refined the thermal pulse duration and intensity to prevent damage to the produce. Experiments EXP-04 through EXP-09 tested pulse durations ranging from 100ms to 800ms. Data indicated that a 350ms pulse at 40°C provided optimal contrast without raising the core temperature of the produce above safety thresholds. The final configuration integrated this thermal trigger with a synchronized high-speed NIR capture window. This sensor-fusion approach required the development of a custom timing controller to manage the millisecond-level synchronization between the heating element and the camera shutter, representing a significant technological advancement over off-the-shelf solutions.

Documented Scientific and Technological Advancements Achieved

The systematic experimental work conducted between March 2025 and September 2026 resulted in specific technological advancements that resolve the previously identified uncertainties regarding optical ambiguity in frost-covered environments. These advancements represent a departure from standard industry practices, which typically rely on manual intervention or non-adaptive static thresholds that fail under variable frost accumulation.

A primary advancement is the development of a real-time frost-compensation algorithm capable of dynamically adjusting spectral sensitivity based on localized thermal gradients. This algorithm successfully decouples the visual signature of the underlying produce from the superimposed frost layer, achieving a recognition accuracy of 94% in controlled trials where previous methods failed below 60%. This capability allows for autonomous picking decisions without human oversight in sub-zero conveyor environments.

The project yielded a novel multi-sensor calibration model that synchronizes LiDAR depth data with hyperspectral imaging in high-humidity, low-temperature conditions. This model corrects for refraction errors caused by ice crystallization on sensor lenses, enabling precise spatial mapping of irregularly shaped frozen items. The resulting system reduces false-positive pick attempts by 35% compared to baseline

commercial solutions, demonstrating a measurable improvement in operational efficiency and energy conservation.

Technological Significance. These advancements constitute a significant improvement in the state of technology for automated food processing, specifically addressing the lack of reliable, non-contact inspection methods for frost-obscured objects in industrial settings.

Eligible SR&ED Expenditures Summary (CAD, Fiscal Year 2026)

The following table summarizes the eligible expenditures incurred between January 1, 2026, and December 31, 2026, for the development of the adaptive vision system. These costs reflect direct efforts to resolve technological uncertainties in machine vision under extreme thermal conditions. All amounts are in Canadian Dollars (CAD). Note that these figures are indicative estimates based on records available as of October 14, 2026. Confirm current supplier prices and final payroll adjustments before submission.

Expenditure Category	Description	Amount (CAD)
Salaries and Wages	Direct labor for R&D personnel (Engineers, Technologists) working on sensor fusion algorithms and frost-compensation logic.	\$185,000.00
Materials	Consumables used in experimentation, including frozen produce samples, specialized lighting rigs, and thermal camera components.	\$22,500.00
Subcontractor Fees	Specialized calibration services for multi-spectral imaging sensors not available in-house.	\$15,000.00
Total Eligible Expenditures		\$222,500.00



Figure 1. Amount (CAD)

Verification Note. Ensure all timesheets linked to these expenditures explicitly reference the project code for the frost-adapted vision system. General overheads and capital equipment purchases are excluded from this summary as per CRA guidelines.

Supporting Evidence Inventory and Custodial Verification

The following table details the primary evidence supporting the technological uncertainties, experimental work, and advancements claimed in this T661 filing. These documents were created contemporaneously with the research activities conducted between March 2025 and September 2026. They demonstrate the systematic approach taken to resolve the inability of standard machine vision systems to distinguish between frost artifacts and produce geometry on conveyor lines.

Evidence ID	Document Type	Creation Date	Custodian	Description
EV-2025-001	Lab Notebook	March 12, 2025	Lead Vision Engineer	Initial hypothesis log detailing failure rates of standard RGB cameras under -18°C frost conditions.
EV-2025-004	Test Report	May 20, 2025	R&D Manager	Comparative analysis of Near-Infrared (NIR) vs. Thermal imaging sensors for frost penetration.
EV-2025-009	Code Repository Log	July 15, 2025	Senior Software Developer	Version control history for the iterative development of the frost-compensation algorithm v1.0 through v3.2.
EV-2026-002	Validation Data	February 10, 2026	QA Lead	Statistical results from pilot line testing showing 94% pick accuracy after algorithmic refinement.
EV-2026-005	Meeting Minutes	September 30, 2026	Project Manager	Final review minutes confirming the resolution of technological uncertainties and project closure.

Record Retention Notice. All electronic records are stored on secure, access-controlled servers at the Waterloo facility. Physical lab notebooks are kept in locked fire-resistant cabinets. Confirm current supplier prices before submission.