Project Name:	Willowglen Systems Inc. (MTCLM) WIN	**Start Date:**	2026-01-01
Project Number:	2601	**Completion Date:**	2026-12-31

Project Details:

Scientific or Technological Objectives:

Measurement	Current Performance	Objective	Has results?
SIL rating (level)	2	4	Yes

This example is based on facts outlined in Willowglen Systems Inc. v. His Majesty the King, 2026 TCC 7 (judgment dated 14 January 2026).

Manual Train Control Logic Module (MTCLM) for Driverless Train

Technological Objective
Design and develop a centralized Manual Train Control Logic Module capable of enabling a driver to manually operate an otherwise autonomous train in emergency or maintenance situations, while meeting Safety Integrity Level 4 (SIL 4) functional safety requirements. The system had to consolidate previously distributed control and train-line functions into a single central box using redundant architectures, fail-safe diagnostics, and compliance with Bombardier's internal standards plus North American and international standards for safety, reliability, design for environment (DFE), and electromagnetic interference (EMI). [45]–[49]

Measurable / Specific Goals

- Achieve SIL 4 (highest level) rather than typical SIL 2.
- Eliminate single points of failure through multi-gate-array redundancy and diagnostic monitoring.
- Detect zero speed reliably under all operating conditions.
- Maintain required electrical isolation when combining logic and high-voltage functions on the same backplane.
- Produce a manufacturable design (moving away from hand-wired "crow's nest" prototypes). [47]–[54]

Field of Science/Technology:

Mechanical engineering (2.03.01)

Project Details:

Intended Results:	Improve existing processes
Work locations:	Commercial Facility
Key Employees:	Wayne Karpoff (Computer Science - MSc. (2000) / CEO), Douglas Kruger (Electrical - MEng. (2002) / Electrical Engineer)
Evidence types:	Test protocols, test data, analysis of test results, conclusions; Records of resources allocated to the project, time sheets; Samples, prototypes, scrap or other artefacts; Design, system architecture and source code; Design of experiments; Records of trial runs

Scientific or Technological Advancement:

Uncertainty #1: Technological uncertainty

It was not known, and could not be determined by routine engineering or standard procedures, whether a centralized control architecture could simultaneously satisfy SIL 4 reliability, redundancy, zero-speed detection, EMI rejection, and isolation requirements while remaining manufacturable. [48]–[54]

Key Uncertainties / Variables

1. Whether gate-array + relay designs could provide sufficient redundancy and fail-safe behaviour to meet SIL 4 (single-point failure was unacceptable). [48]

2. How to achieve reliable zero-speed detection in a SIL 4 environment. [54] (Minister conceded this portion was SR&ED.)

3. How to redesign the emergency brake safety relay assembly (and ultimately seven or eight boards) to increase diagnostic lines and monitoring without violating other standards. [50]–[51]

4. Whether the required point-to-multiple-point wiring and increased diagnostics could meet isolation spacing rules when logic and high-voltage functions shared a backplane. [52]–[53]

5. Compatibility of lead-free (DFE-compliant) components with the higher reliability demanded by MIL and SIL 4 standards. [49]

The most significant underlying key variables are:

gate-array + relay, safety relay assembly, components, spacing

Technology or Knowledge Base Level:

Activity #1-1: 2026 development (Fiscal Year 2026)

Methods of experimentation:

i. Systematic Investigation / Method

- Formulation of hypotheses around alternative redundancy architectures, diagnostic monitoring schemes, and board-level redesigns.

- Iterative prototyping: subsystem-level board testing followed by full prototype control-box integration.

- Multiple simultaneous engineering streams whose interactions only became visible at the full-system prototype stage.

- Testing and modification of firmware to add diagnostic functions; redesign of wiring topology; mechanical and cabling solutions. [50]–[53]

ii. Work Performed

- Initial design attempt using gate arrays and relays per Bombardier direction; determined it could not meet SIL 4.

- Proposed and implemented redesign of emergency brake safety relay (increased diagnostics); Bombardier RAMS team accepted the need for redesign.

- Redesigned seven or eight boards plus mechanical design and cabling.

- Built first full prototype control box by hand (weeks of effort); identified isolation and manufacturability problems.

- Iterative cycles of testing, diagnosis, and modification of hardware, firmware, and wiring. [50]–[53]

Results:

- SIL rating: 4 level (100% of goal)

The original gate-array and single-relay approach was confirmed not to meet SIL 4 due to unacceptable single points of failure. [48], [50]
Redesign of the emergency brake safety relay assembly (with increased diagnostic lines and monitoring) was accepted by Bombardier's RAMS team as necessary to achieve SIL 4 compliance. [50]

Seven boards required redesign, together with mechanical design and cabling solutions, after subsystem and full-prototype testing revealed interactions that were not visible at the component level. [51]–[52]

First full prototype control box (hand-built over several weeks) demonstrated that point-to-multiple-point wiring and added diagnostics created isolation spacing problems when logic and high-voltage functions shared a backplane; the design was not yet manufacturable. [52]–[53]

Iterative modifications to firmware (addition of diagnostic functions) and wiring topology produced progressive improvements in diagnostic coverage and fail-safe behaviour. [52]
Zero-speed detection capability was developed and was later conceded by the Minister to constitute SR&ED. [4], [54]

Conclusion:

Demonstrated that a centralized architecture incorporating multi-gate-array redundancy, enhanced diagnostic monitoring, and redesigned boards could satisfy SIL 4 requirements that could not be met by the original distributed or single-relay design. [48]–[52]

Established new design rules and practical implementation methods for simultaneously achieving SIL 4 fail-safe behaviour, electrical isolation, EMI compliance, and manufacturability in a rail control system. [49]–[53]

Generated new knowledge regarding the interaction between diagnostic coverage, wiring topology (point-to-multiple-point), and isolation spacing when logic and high-voltage functions share a common backplane. [52]–[53]

Confirmed that reliable zero-speed detection could be integrated into a SIL 4 centralized control module. [4], [54]

Produced a technical foundation for a manufacturable SIL 4 Manual Train Control Logic Module that met Bombardier’s safety and reliability specifications. [Judgment (a)–(b)]

Significant variables addressed: components, gate-array + relay, safety relay assembly, spacing

Documentation:

- Offline Documents: docs

2601 - Willowglen Systems Inc. (MTCLM) WIN	
BENCHMARKS	**ACTIVITIES BY YEAR**
Internet searches: 7 Articles	2026
Similar prior in-house technologies: 3 products / processes	1-1
Queries to experts: 1 responses	2026 development
OBJECTIVES	**RESULTS**
SIL rating: 4 level	4
UNCERTAINTIES & KEY VARIABLES	**CONCLUSIONS**
1 - Technological uncertainty	
components	Y
gate-array + relay	Y
safety relay assembly	Y
spacing	Y
	METHODS
Analysis	11
Trials	8
Prototypes	1
Lines of code	
	COSTS
Hours	2700.00
Materials $	25000.00
Subcontractor $	

Project Name:	Flexible Silicone Rubber WIN	**Start Date:**	2026-01-01
Project Number:	2602	**Completion Date:**	2026-12-31

Project Details:

Scientific or Technological Objectives:

This project is example is based on the facts in the tax court judgment of Les Éléments Chauffants Tempora Inc. v. His Majesty the King, 2025 TCC 173.

Technological Objective

Develop a flexible heating element system using silicone rubber and Kapton materials capable of reliable operation in adverse outdoor environments (including train tracks and stations), with the goal of replacing traditional salt-based de-icing methods and improving the lifespan of cold-weather infrastructure.

ii. Measurable / Specific Goals

- Achieve consistent heating performance in outdoor conditions where existing flexible heaters were not designed or validated for adverse environments.

- Integrate the heater with infrastructure materials (including concrete) so that the system could reach and maintain target temperatures within approximately 20 minutes.

- Extend the functional lifespan of the heated infrastructure under repeated freeze-thaw and outdoor exposure cycles.

Field of Science/Technology:

Composites (including laminates, reinforced plastics, cermets, combined natural and synthetic fibre fabrics) (2.05.04)

Project Details:

Intended Results:	Develop new processes
Work locations:	Commercial Facility
Key Employees:	Shady Elhami (machine design - Self taught (2000) / President)
Evidence types:	Test protocols, test data, analysis of test results, conclusions; Records of resources allocated to the project, time sheets; Samples, prototypes, scrap or other artefacts; Design of experiments; Records of trial runs

Scientific or Technological Advancement:

Uncertainty #1: Technological uncertainty

It was not known, and could not be resolved by routine engineering, whether a silicone rubber / Kapton flexible heater could be designed and integrated to function reliably in adverse outdoor environments (moisture, freeze-thaw, mechanical stress, and variable ambient conditions) while meeting the required heating performance and durability targets.

Key Uncertainties / Variables

- Compatibility and thermal performance of silicone rubber and Kapton constructions under outdoor exposure.

- Interaction between the heating element and the surrounding infrastructure materials (particularly concrete composition and thermal properties).

- Ability to achieve rapid, uniform temperature rise and stable control in real outdoor conditions rather than laboratory settings.

- Long-term durability and resistance to environmental degradation.

The most significant underlying key variables are:

compatibility, component interactions, environment

Technology or Knowledge Base Level:

Activity #1-1: 2026 development (Fiscal Year 2026)

Methods of experimentation:

i. Systematic Investigation / Method

Formulation of hypotheses regarding material selection, heater construction, and integration with infrastructure.

Prototyping and iterative testing of flexible heater designs.

Collaboration with a university professor on the chemistry and composition of the concrete used in the target infrastructure, to better understand and optimize heat transfer and material compatibility. [215]

Outdoor and simulated environmental testing, including integration of sensors for temperature monitoring and control.

Systematic variation of design parameters and recording of results in Excel parameter roadmaps. [53]–[56], [65]

ii. Work Performed

Design and fabrication of flexible silicone rubber and Kapton heating element prototypes.

Joint technical work with a professor focused on concrete chemistry and composition. [215]

Sensor integration and control system development for temperature management.

Iterative testing under conditions representative of train tracks and stations, with analysis of heating rate, uniformity, and stability.

Documentation of test parameters, results, and modifications in contemporaneous Excel files. [53]–[56], [65]

Results:

Prototypes demonstrated the ability to reach and maintain the desired temperature in outdoor / adverse-environment conditions within approximately 20 minutes.

Collaboration with the professor provided specific insights into concrete composition that improved understanding of thermal behaviour and material interactions at the heater–infrastructure interface. [215]

Sensor-based monitoring confirmed controllable and repeatable heating performance under the tested conditions.

The system showed potential to reduce reliance on salt-based de-icing and to extend infrastructure lifespan in cold-weather applications.

Conclusion:

New design knowledge for adverse environments: Demonstrated that a silicone rubber and Kapton flexible heating element could be engineered to deliver reliable, controlled heating in outdoor conditions (moisture, freeze-thaw cycles, and mechanical exposure) for which standard flexible heaters had not previously been validated. This established practical performance boundaries and design rules beyond those available through routine engineering.

Material–infrastructure interaction knowledge: Through targeted collaboration with a university professor on concrete chemistry and composition, new understanding was generated of the thermal interface between the flexible heater and infrastructure materials. This enabled improved heat-transfer efficiency and durability at the heater–concrete boundary. [215]

Significant variables addressed: compatibility, component interactions, environment

Documentation:

Offline Documents: docs

2602 - Flexible Silicone Rubber WIN	
BENCHMARKS	**ACTIVITIES BY YEAR**
Internet searches: 5 Articles Queries to experts: 1 responses	2026
	1-1
	2026 development
OBJECTIVES	**RESULTS**
Time to target temperature: : 20 min	22
Temperature uniformity: 5 Deg C	6
UNCERTAINTIES & KEY VARIABLES	**CONCLUSIONS**
1 - Technological uncertainty	
compatibility	Y
component interactions	Y
environment	Y
	METHODS
Analysis	
Trials	
Prototypes	
Lines of code	
	COSTS
Hours	
Materials $	
Subcontractor $	