ONTARIOPOWER GENERATION

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Business Case Summary

Project #	83039	**Controlled Doc #**	N-BCS-30540-0764598
Project Title	Rapid Delivery Machine (RDM)		
Facility	Darlington	**Investment Classification**	Sustaining
Project Level (Scalability)	A	**Financial Classification**	☐ OM&A ☒ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others: [if applicable]
Release: Gate and Project Phase	☐ Choose an item. G0☐: Initiation ☐ Choose an item. G1☐: Choose an item.		☒ Superseding G2☐: Definition ☐ Choose an item. G3☐: Execution
Estimate Class (overall project)	Class 4	**Target Project Completion Date**	DEC-2025

Recommendation

We recommend an additional release of $15.7 M. This will bring the total released-to-date to $108.0 M including [redacted] of contingency.

The estimated total project cost is $160.4 M, including [redacted] of contingency.

The purpose of this Superseding Business Case is to document the removal of the Pickering RDM scope from the project, and to establish a new cost and schedule baseline for the Rapid Delivery Machine project at Darlington only. The removal of the Pickering RDM scope was approved by the Board of Directors on November 13, 2019, along with the delegation of subsequent approvals within the Board approved envelop of $162.2M. The Pickering RDM was eliminated due to an unachievable development schedule.

The Pickering RDM scope was classified as a value enhancing investment. With its removal, the Darlington scope is classified as sustaining, and is targeted to be available for the first required inspections post refurbishment in 2025. This release will continue detailed engineering for the Darlington RDM.

The project is continuing within the Board approved envelope of $162.2M, with subsequent approvals delegated to the President, Nuclear as per the Organizational Authority Register, Element 1.1.

Investment Cash Flows

$K	LTD	2019	2020	2021	2022	2023	2024	Future	Total
Previous + Current release	33,895	12,659	30,603	19,327	9,206	1,658	293	360	108,001
Total released to date	**33,895**	**12,659**	**30,603**	**19,327**	**9,206**	**1,658**	**293**	**360**	108,001
Future required	-	-	1,522	24,092	13,605	4,630	2,435	6,122	52,407
Total Project Cost	**33,895**	**12,659**	**32,124**	**43,420**	**22,811**	**6,288**	**2,728**	**6,483**	**160,408**
Ongoing Costs	-								
					Gate:	**G3**	**OAR Approval:**		**$162,200 K**

Approvals	Signatures	Date
The recommendation, including the identified ongoing costs, if any, represents the best option to meet the validated business need.		
Recommended by: Project Sponsor Subo Sinnathamby VP, Inspection & Reactor Innovation		Dec 10, 2019
I concur with the business decision as documented in this BCS.		
Finance Approval: Vice President Controllership	Barbara Kerr	10 December 2019
I confirm that this investment/project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.		
Line Approval per OAR 1.1: Dominique Miniere President Nuclear		11th December 2019

*Associated with OPG-STD-0076, Developing And Documenting Business Cases

EXECUTIVE SUMMARY – Project Overview

The Rapid Delivery Machine project is a required to maintain the capability to perform the required fuel channel inspections for the years of operation at Darlington post-refurbishment.

At Darlington, Fuel Channel (FC) inspections are currently performed using aging Channel Inspection and Gauging Apparatus (CIGAR). CIGAR use requires a Fuel Handling (F/H) Trolley for the duration of the inspection. Scrape samples collected from pressure tubes require the use of manual tool sets and installation of ice plugs. The RDM will provide a delivery platform designed with the latest available industry standard automated tooling to allow for safe and reliable fuel channel inspections to meet code and licensing requirements for the next 30 years. Additionally, the delivery machine technology will accommodate new tooling technology for performing machined delivered scrape to yield enhanced radiological protection by removing requirements for ice plugging used in manual scrape campaigns, reducing personnel radiation exposure, and addressing equipment obsolescence.

This project is required to meet DNGS post refurbishments targets for outage durations of >92% Unit Capacity Factor (UCF), which is required in order to achieve top quartile generation cost per MWh.

The preferred alternative is the development of a Rapid Delivery Machine (RDM) for DNGS. The project will deliver a remotely operated fuel channel inspection tool delivery machine that installs on reactor during a planned outage. The project also includes the RDM delivered tooling for fuel channel inspection and scrape to the latest industry standard.

This release will continue detailed engineering for the Darlington RDM and include long lead procurement, including:

- Design of the Darlington Cable Penetration Module.
- Release the funding for the prototype/non-production RDM.
- Design of Darlington RDM Design
- Design of the Darlington Fuel Channel Tooling
- Design of the Site Modifications to interface with Darlington RDM.
- Procurement of long lead manufactured components and tooling.

A future release will include:

- Execution (Fabrication/Testing) of the Darlington RDM
- Execution of MDS and ANDE tool mods for Darlington
- Execution of the Darlington Site Mods
- Commissioning of the Darlington RDM

The primary risks to the project are cost and schedule. Rigorous upfront planning with the prime vendor through a 6 month plan development period sets out the basis for the cost and schedule of the RDM. Comprehensive project controls, oversight, and enhanced contractual liquidated damages are planned to address these risks.

Business Need

For Project Level A or B

The RDM Business Need is based on:

- **Inspection Machine Availability and Reliability –** Inspections of the Fuel channels are regulated by the codes and standards per CSA N285.4. They are required by OPG's operating license and will continue to be needed during the next 30 years of Darlington operations post refurbishment. CIGAR is currently used for volumetric and dimensional inspections. CIGAR was commissioned in the 1970s and is considered dated and has challenging obsolescence issues and is not expected to be able to meet the station's needs post refurbishment due to increasing obsolescence and maintenance demands.

  The RDM will be able to deliver current established technology for volumetric and dimensional inspections using the Advanced Non-Destructive Examination (ANDE) tooling to collect pressure tube samples to measure the deuterium content uptake over time using the latest in machine delivered scrape (MDS) technology. Machine Delivered Scrape technology has now been proven at other CANDU facilities. This tooling technology needs to be deployed on reactor under automatic control of a delivery machine, such as RDM, to avoid the use of workers on the reactor face using manual tooling. At Darlington, the RDM will provide a means of delivering this tooling technology for the collection of scrape samples throughout the life post refurbishment.

- **Worker Dose Uptake** –The current manual scrapes performed at DNGS are considered high-hazard work and result in high-dose exposure to nuclear energy workers. With the successful development of Machine Delivered Scrape (MDS) tools at other CANDU sites, it is no longer acceptable to expose workers to dose using the manual tools. The Rapid Delivery Machine will enable the capability of delivering the MDS tool at Darlington and significantly reduce the required

Business Need	For Project Level A or B

open face work and dose received by workers. During the first deployment of MDS at Pickering in 2018, cumulative worker dose was reduced from 11 to 2 REM. Comparable reductions can be expected at Darlington as well. There are additional dose savings associated with operations and the feeder ice plugging by moving to MDS technology.

- **Nuclear Safety –** By bringing MDS capability to Darlington, the need for feeder ice plugging and the associated risks to nuclear safety and work protection are eliminated. With the availability of proven MDS technology, maintaining the Nuclear safety risk associated with the use of ice plugging is no longer acceptable. In addition to nuclear safety concerns, ice plugging can also result in economic losses related to critical path delays when the forming of ice plugs is not successful.
- **Reduced Outage critical path –** In-vault inspections have traditionally defined the outage durations at Darlington. OPG's post refurbishment business objective is to lower generating cost per MWh to be top quartile. In order to achieve this planned outage durations need to be reduced such that a >92% UCF is achieved. The RDM enables the required critical path reductions in the following areas:
    a. ***Fuel Channel Scrape***: DNGS currently performs its regulatory fuel channel scrape inspections using manual scrape tools. This requires extensive pre-requisite activities that are time consuming and dose intensive. The deployment of the MDS tool using the RDM will result in critical path savings.
    b. ***Fuel Channel Volumetric Inspection***: DNGS Fuel Channel Inspections cannot be performed using OPG's most advanced tooling due to the absence of a suitable delivery machine for DNGS. Introducing the RDM will allow inspections to be performed using the Advanced Non-Destructive Examination (ANDE) Mk2 tool. For comparison, the average critical path time for volumetric inspection of fuel channels using ANDE Mk2 is 9 hours per channel, while CIGAR (current DNGS inspection tool) requires an average of 19 hours per channel.
- **Fuel Machine Availability and Reliability -** Currently at DNGS, OPG relies on Fuel Handling (F/H) equipment for the execution of fuel channel inspections and scrape campaigns. During CIGAR outages one FM (Fuelling Machine) and trolley is fully dedicated for the duration of the CIGAR campaign. For scrape campaigns, a FM and trolley is also required for the significant pre-requisite and post-requisite work.

  Overall, Fuel Channel Inspection Campaign reliance on F/H reduces the number of hours available for F/H maintenance. Introducing the RDM at DNGS would significantly reduce reliance on the fuel handling equipment during outages. This would increase F/H system reliability by reducing Fuelling Machine (F/M) wear and tear as well as allow more time for planned maintenance of the F/H systems.

Preferred Alternative:	**Development of a Rapid Delivery Machine (RDM) for DNGS**	For Project Level A, B or C

Description of Preferred Alternative

The preferred alternative is to design a new Rapid Delivery Machine (RDM) system to perform Fuel Channel inspections at DNGS. Pursuing this alternative supports the objectives of replacing ageing equipment with the latest in the industry standard in order to maintain OPG's licence to operate for 30 years post refurbishment. In addition to maintaining the capability to perform the required fuel channel inspections, this technology reduces worker dose by removing workers from performing manual tasks on the reactor face and improves nuclear safety by removing the reliance on feeder freezing during scrape campaigns. The technology chosen also results in significant critical path reductions due to increased automation and the use of modernized tooling. The benefits are summarized in the table further below.

The RDM machine would be capable of deploying the following Fuel Channel Inspection and Maintenance (FCIM) services:

- Fuel Channel NDE Inspections using ANDE Mk2 & ANDE Replica
- Machine Delivered Scrape (MDS) (Axial and Rolled Joint (RJ) Scrape)

RDM will also possess the ability to:

- Remotely access target fuel channel(s) and deploy FCIM tooling independently of a fuel handling machine and trolley.

<u>Machine Concept</u>

Modification Design Requirements have been prepared and approved for a machine that provides rapid deployment, similar to the current CIGAR system, and with the capability of the Pickering Universal Delivery Machine (PUDM). The RDM would be capable of locking onto fuel channels and removing closure and shield plugs as well as delivering the entire suite of available inspection tools.

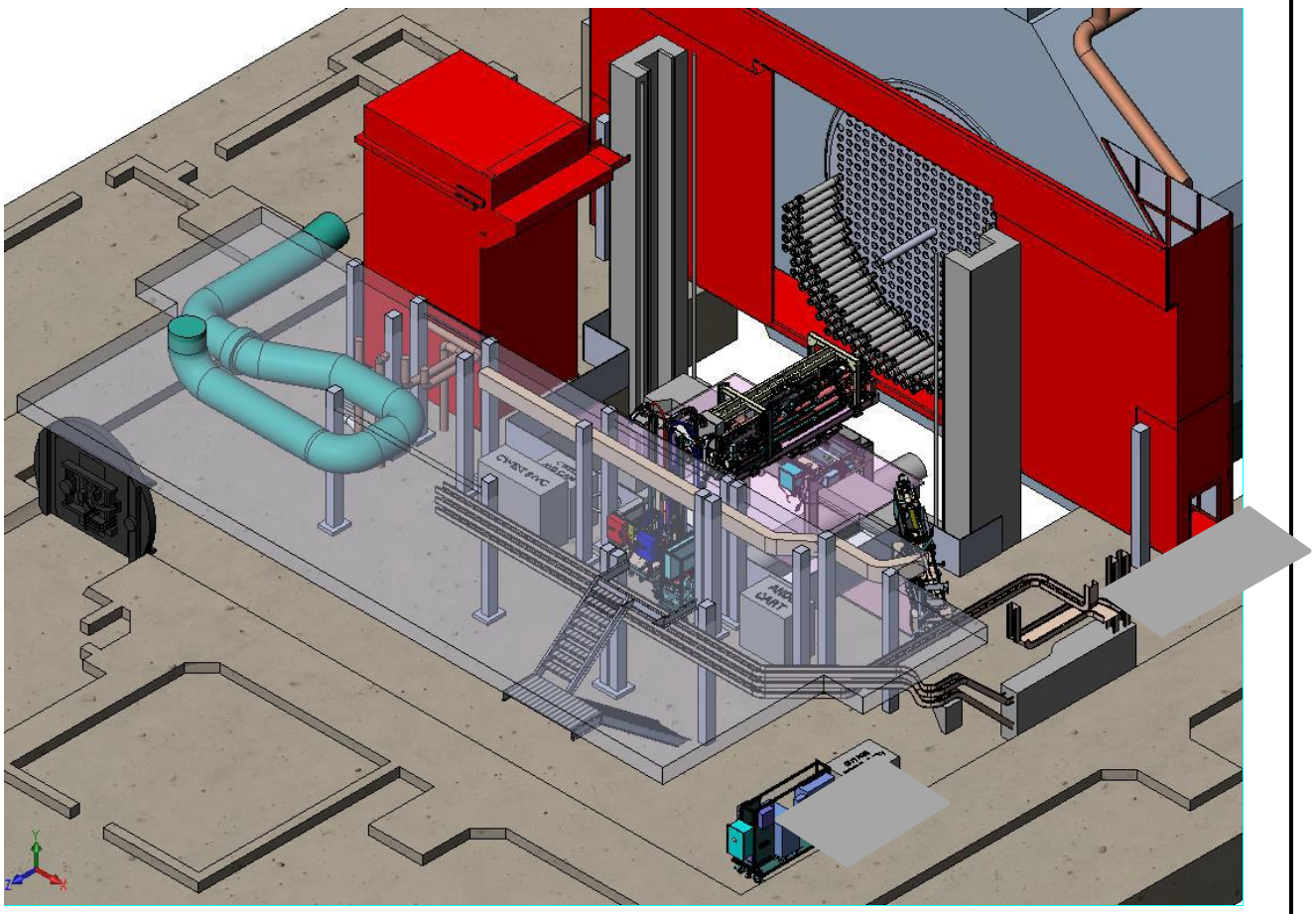
The concept for the RDM features a machine Head that includes a Snout and Magazine Assembly mounted on a Suspension system. The Snout provides the ability to sense the position of the end-fitting of the target fuel channel which drives the suspension in X, Y, Z, Pitch and Yaw to facilitate homing and locking onto the target channel. The two-stage

Preferred Alternative:	Development of a Rapid Delivery Machine (RDM) for DNGS	For Project Level A, B or C

Description of Preferred Alternative

horizontal magazine supports and aligns (2) Tool Mechanisms, (1) Closure Plug Mechanism and (1) Shield Plug Mechanism to the Snout within a compact footprint.

The Tool Mechanisms are based on UDM designs and provide the capability for delivering ANDE, Replica, and MDS FCIM tools.



As a part of the In-Vault Support Equipment, there are various components which facilitate FCIM tool change, function checks and calibration activities. These are generically referred to as the RDM Calibration Facility and Tooling Stations (CFTS). Machine transporters are to be integrated into the design to transport and position the RDM components in the vault and around the station. The ANDE/MDS CFTS will not need to be re-positioned each time the RDM interfaces with it. This is expected to provide significant time savings and allow the RDM system to yaw and engage with the CFTS remotely.

Vault floor based cable handling equipment is to be used in place of the UDM WINSKY design to improve system installation and removal performance. These units are responsible for management of the FCIM tool umbilical cables and also provide support for the RDM D2O lines and control cables. The in-vault control equipment includes Power Distribution Cart, and D2O pump cart.

The strategy for this alternative is to commission the RDM during the first post-refurb Fuel Channel Inspection outages (D2521). This on channel commissioning at Darlington is targeted during the turbine outage of D2521 when the commissioning activities are expected to be completed off critical path.

Preferred Alternative:	**Development of a Rapid Delivery Machine (RDM) for DNGS**	For Project Level A, B or C

Description of Preferred Alternative

Benefits of RDM

Benefits:	**Details**
Inspection Machine Availability and Reliability	With the refurbishment of Darlington, asset management of the new fuel channels requires a periodic inspection program for the life of the units. • Eliminate reliance on CIGAR technology that was first commissioned in the 1970s and the associated ageing obsolescence. • Replace manual Scrape tools with more reliable and efficient Machine Delivered Scrape technology.
Dose Savings	Dose uptake during Scrape campaigns at DNGS can be reduced from 20 Rem to <6 Rem for standard 6 rolled joint and 10 body of tube scope by replacing current manual Scrape tooling with the automated Machine Delivered Scrape.
Decreased Nuclear Safety Risks	By providing the capability to deploy Machine Delivered Scrape we eliminate the requirement for feeder ice-plugging associated with manual Scrape work.
Reduce Critical Path Duration	Enabler for achieving critical path fuel channel inspection duration required to support a 38 day outage critical path leading to a >92% UCF. • Streamlined mobilization and demobilization • Improved equipment reliability during the critical path activities. • Replacement of Manual Scrape with Machine Delivered Scrape • Replacement of CIGAR volumetric inspections with ANDE MK2
Fuel Machine Availability and Reliability	The RDM System acts completely independently of the FM (Fuelling Machine) and trolley. This provides the following benefits: • Eliminates inspection induced wear and tear during outages • Allows more time for scheduled FM Maintenance which is expected to improve performance • Allows the FM to service other units during the outage • Eliminate need for reconfiguring the F/M Trolley to receive the Trolley Mounted Magazine (TMM) required for supporting multiple channel isolation.

To elaborate on the potential fuel handling benefits, the RDM would create fuel handling maintenance hours by not requiring a dedicated Fuel Handling (F/H) Trolley during fuel channel inspection campaigns. Specifically the RDM would eliminate the following uses:

- Currently during CIGAR campaigns at DNGS, one F/H Trolley is required to move the CIGAR package from channel to channel. The RDM will be able to deliver FCIM tooling to channels independently from F/H equipment similar to PUDM which will free up the Trolley during the outage. The only requirement on the F/H Trolley will be to assist with de-fueling the target channels. This is consistent with current operation.
- Currently during CIGAR campaigns, one F/H Trolley is dedicated for the duration of CIGAR campaign due to the required recall time to remove the CIGAR package in the event of an emergency. As stated above, the RDM would be capable of independently removing FCIM tooling, thus freeing the F/H Trolley up for maintenance during fuel channel inspections.
- Currently during scrape campaigns, F/H equipment is utilized to install vented closure plugs (VCP) and channel isolation plugs (CIP). The Machine Delivered Scrape (MDS) tooling operates in a flooded channel thereby eliminating the need for channel isolation and draining.

Deliverables:	Associated Milestones (if any):	Target Date:
Current release:		
SBCS Gate 2 Approval		January 2020
OPG DA WARR1 Authorization (Head & Suspension)		July 2020
RDM Fabrication Start (Head & Suspension)		Sept 2020
ANDE Design Work Complete		April 2021
MDS Design Work Complete		March 2021
Plant Modification Design Complete		July 2021
Future release:		
RDM Fabrication Complete		March 2021
RDM Assembly Complete		November 2021
RDM Power On		December 2021
RDM Delivered to OPG		October 2022
RDM Site Acceptance Testing Complete		December 2022
RDM In-vault commissioning complete		June 2025

Alternative 2:	Base Case – No Project	For Project Level A, B or Value-Enhancing

The "No Project" alternative is not selected as new fuel channel inspection tooling is required to support the continued operation at Darlington going forward post refurbishment. Current tooling is ageing and the technology currently used is no longer industry standard.

Additionally, selecting this alternative forgoes the ability to reduce the outage critical path times in the fuel channel inspection activities to meet the required >92% UCF, impacting OPGs generation targets post refurbishment. Additionally, this alternative does not reduce IRI's' reliance on Fuel Handling (F/H) trolleys nor does it provide additional (F/H) maintenance hours. Obsolescence of existing tooling would drive an immediate need to implement alternative projects in order to maintain the capability to perform fuel channel inspections in order to meet code and licensing requirements.

Consequently, this alternative is not recommended.

Alternative 3:	Delay/Pause project expenditures using up schedule float ahead of commissioning to 2025	For Project Level A or B or Value-Enhancing

The alternative to delay/pause work and commissioning until 2025 is not recommended. The current baseline project schedule shows a float from when the Site Acceptance Testing (SAT) is complete and the start of on-channel commissioning.

Pros and Cons:

The Pros for pausing progress of the RDM project (due to change in commissioning outage schedule) are limited to capital cost flow deferral only. This would make more near term capital available.

The Cons for pausing progress of the RDM project (due to change in commissioning outage schedule) are:

- Costs would increase for the project due to additional demobilization and re-mobilization costs for OPG and for at least three (3) vendors (RDM vendor, DNGS Site Mods vendor, and MDS Vendor). Based on the contractual terms and conditions, this would be substantial;
- The project would be exposed to additional schedule risk as the current plan to be ready for commissioning the RDM in 2023 provides float in case of schedule delays. Also, the new equipment and the associated benefits would not be available to support any emergent or planned demands that may come up during the course of this project.
- There would be additional costs and strains on resources as the CIGAR machine, and Manual Scrape equipment would need to be poised and available;

Key Risk Assessment				For Project Level A, B or C
Risk Class	**Description of Risk**	**Response Type/ Actions/Final TCD**	**For Additional Review**	**Residual Ranking**
Schedule	There is a risk that modifications for tooling (MDS, and ANDE) may be delayed thereby impacting the dates of the RDM Delivery Machine FAT, and SAT.	Mitigate through aggressive monitoring of the schedule, regular project and technical meetings, and weekly progress and performance reporting, including earned value management from vendors	No	Medium
Quality	There is a risk that there are interface issues between the existing station equipment and the new RDM and tooling resulting in installation or performance issues. This includes adequate space to fit the RDM inside and through the equipment airlocks.	Mitigate. • OPEX reviews will take place along with the development of detailed SAT and commissioning plans. Space frame walk downs will be completed in all units.	No	Medium
Cost & Schedule	There is a risk of discoveries during the detailed design that may have an impact of cost and schedule.	Mitigate: • Schedule and cost contingency have been accounted for to mitigate moderate discovery during the design phase. Risk reduction prototype testing is planned as input to the final design. • Representative Factory Acceptance Testing has been planned as part of the scope to identify and resolve any issues at the prime vendor. • A detailed scope alignment at the preliminary design stage has occurred through a plan development period with the prime RDM vendor.	Yes	Medium
Cost	There is a risk that the RDM on-channel commissioning may not be completed within the prime vendors warranty period. Latest OPG Generation Plan identifies no planned outages before 2025 after the RDM is on-site.	Mitigate: • Identify windows during refurbishment for early in-vault commissioning. • Negotiate an extended warranty period with the prime vendor if required.	No	Medium
Cost & Schedule	There is a risk that OPG Design deliverable acceptance is delayed or prolonged, impacting cost and schedule with the vendor.	Mitigate: • The prime vendor has the accountability to maintain a detailed level 3 schedule with all deliverable submissions updated weekly. • OPG Project has implemented an engineering work management process to plan and monitor progress with internal escalation protocols.	No	Medium

Financial Evaluation			For Project Level A, B (with multiple feasible alternatives) or Value-Enhancing		
$M	Preferred Alternative	Base Case (No Project)	Delay work		
Project Cost	160.4	N/A	N/A		
NPV	N/A	N/A	N/A		
Other: (e.g., IRR)					

Analysis of Financial Evaluation – Key Assumptions and Key Results:

A financial evaluation is not required for sustaining projects as per section 3.2 of the BCS Standard.

Qualitative Factors For Project Level A or B

As described above, the benefits of the RDM include:

- Dose Reduction
- CIGAR Reliability and Obsolescence
- Fuel Machine Availability and Reliability
- Nuclear Safety

Post Implementation Review (PIR) Plan (refer to OPG-PROC-0056)

Type of PIR Report	Comprehensive PIR	**PIR Completion Date**	Dec-2026

☐ Detailed PIR KPIs will be provided in future BCS(s) when Execution Phase BCS release is requested.

PIR KPIs	Current Baseline	Target Result	How to measure?	Who will measure?
FH Trolley availability during outage campaign	0 hours/outage	200 hours/outage	Campaign Actuals post first deployment	DAMS, SME
Dose Reduction (Scrape Campaign)	20 REM/outage	<6 REM/outage	Campaign Dosimetry At first deployment	DAMS, SME
Average Volumetric Inspection Time per Channel	19 hours/channel	9 hours/channel	Inspection logs from ANDE deployment at DNGS	Fuel Channels, SME
Feeder Ice-Plugging for Fuel Channel Inspections	Feeder Ice Plugging Occurs	No Feeder Ice Plugging	Campaign Report At first deployment	DAMS, SME

Definitions and Acronyms

AFS - Available for Service
ANDE - Advanced Non Destructive Examination
BCS - Business Case Summary
BOT – Body of Tube
CIP - Channel Isolation Plug
DAMS - Delivery and Reactor Maintenance Systems
DNGS – Darlington Nuclear Generation Station
FCIM – Fuel Channel Inspection and Maintenance
F/H - Fuel Handling
F/M - Fuelling Machine
IRI - Inspection and Reactor Innovation
MDS - Machine Delivered Scrape
MWh - Mega Watt-hour
NPV - Net Present Value
OPEX - Operating Experience
OPG - Ontario Power Generation
PIR - Project Implementation Report
PNGS – Pickering Nuclear Generation Station
PUDM – Pickering Universal Delivery Machine

Definitions and Acronyms
RJ – Rolled Joint
SME – Subject Matter Expert
UCF – Unit Capacity Factor
UDM - Universal Delivery Machine
VCP - Vented Closure Plug

APPENDICES

Appendix A1: Summary of Estimate - Total Project Cost										
Project Number:	**83039**									
Project Title:	**Rapid Delivery Machine**									
$K	**LTD**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**Future**	**Total**	**%**
Project Mgmt	1,678	2,023	928	693	723	327	172	110	6,652	4%
Inspection	[redacted]									
Engineering										
Procurement										
Construction										
Commissioning										
Closeout										
Subtotal										
Outside WBS										
Contingency										
Subtotal w/ Contingency										
Interest										
Other										
Total	**33,358**	**12,659**	**32,124**	**43,420**	**22,811**	**6,288**	**2,728**	**6,483**	**159,871**	**100%**
OM&A (Project# 80077)	537	-	-	-	-	-	-	-	**537**	0%

Appendix A2: Summary of Estimate – Notes			
Escalation Rate	2.90%	**Interest Rate (going-forward)**	4.41%

Appendix A3: Summary of Estimate – In-Service Estimates				
$M	Only applicable to capital projects. In-Service amount shall include interest but exclude removal costs.			
Project #	**Date (YYYY-DD-MM)**	**Description**	**Amount**	**%**
83039	2020-30-08	Non-Production RDM	[redacted]	
83039	2022-15-12	Partial AFS - Out of vault commissioning		
83039	2025-30-06	Final AFS - In-vault commissioning		
83039	2025-15-12	Close out		
Total				

Prepared by:		Reviewed and Endorsed by:	
Brent Achtymichuk Project Leader IRI Fuel Channel Innovation	November 29, 2019 Date	Bradley Greenland Manager Projects IRI Fuel Channel Innovation	November 29, 2019 Date