ONTARIO POWER GENERATION

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OPG-FORM-0076-R005*

Type 3 Business Case Summary

To be used for investments/projects meeting Type 3 criteria in OPG-STD-0076.

Executive Summary and Recommendations

Project Information			
Project #:	16-38948	**Document #:**	D-BCS-72100-10003
Project Title:	DN Zebra Mussel Mitigation Improvements		
Class:	☐ OM&A ☒ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	**Investment Type:**	Sustaining
Phase:	Execution	**Release:**	Full
Facility:	Darlington	**Target In-Service or Completion Date:**	2016-07-25

Project Overview

We recommend the release of $8,855 k, including [redacted] of contingency.
The estimated total project cost is $21,481 k, including [redacted] of contingency.

The quality of the estimate for this release is Class 2, and for the total project is Class 2.

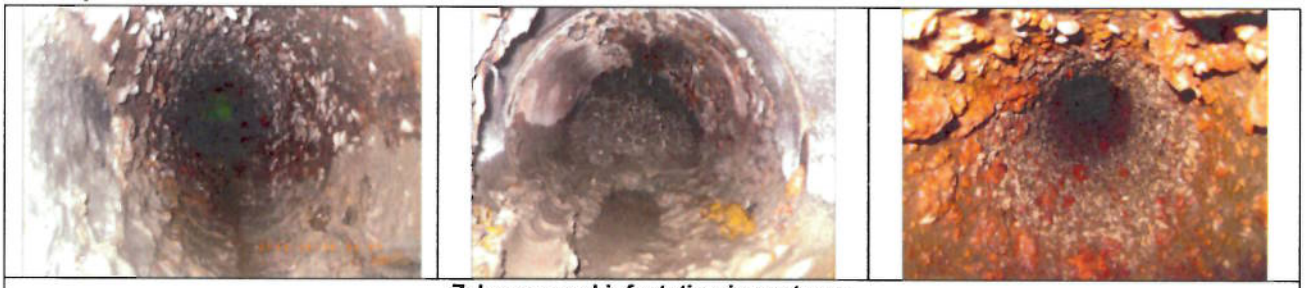
To date, detailed design for permanent de-chlorination and piping upgrades for chlorination system have been completed. In addition a bridging strategy for temporary de-chlorination along with partial Available for Service (AFS) for 4-unit continuous chlorination has been completed and placed into service.

This release will fund the following scope of work:

- Complete installation, commissioning, final AFS and project close-out of the 4-unit (continuous) chlorination & (permanent) de-chlorination modification.

Problem Statement/Business Need:

Zebra mussel fouling is the impairment of reliability of plant systems that use lake water, due to the undesired presence of zebra mussels (an invasive freshwater mussel not native to North America) in related system equipments. Zebra mussel fouling has been an issue in service water systems affecting equipment reliability. It is important to ensure a reliable supply of sufficient service water because the service water provides cooling to a number of safety and safety related loads such as shutdown cooling heat exchangers, shutdown cooling pump motor coolers, moderator heat exchangers, liquid zone control, and critical air conditioning units. See below for some sample pictures of zebra mussel infestation at the Darlington Service Water systems.



Zebra mussel infestation in systems:
(Left) Low Pressure Service Water (LPSW) booster pump 4-72100-P5, (Middle) Powerhouse Upper Level Service Water (PULSW) 1-72300-NV317, and (Right) PULSW 1-72300-V195

Zebra mussel fouling has caused unavailability of service water system equipment in the past. There has also been zebra mussel fouling causing unavailability of other critical station systems. As a result, there has been a significant increase of Station Condition Records (SCRs) trending over the past years relating to zebra mussel fouling. In addition, a recent World Association of Nuclear Operators (WANO) evaluation of Darlington pointed out that one of the areas for improvement (AFI) was zebra mussel fouling in low-flow and stagnant areas.

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Project #: 16-38948
Document #: D-BCS-72100-10003
Project Title: DN Zebra Mussel Mitigation Improvements, Full Execution Release

Project Overview

Summary of Preferred Alternative:

To mitigate zebra mussel fouling:

- Implement 4-unit (continuous) chlorination & (permanent) de-chlorination modification.

History of BCS releases and project cost estimates:

Scope of work for Partial Definition release (total project cost was [redacted] of contingency):

1) Value Engineering Sessions for the full project scope
2) Scope Definition phase (modification Design Requirements (MDRs), Master ECs, Design Scoping Check lists & associated forms for 4-unit Chlorination & Permanent De-Chlorination.
3) Request for Purchase (RFP) packages completed & Proposals obtained via competitive bids.

Scope of work for Partial Definition & Execution release (total project cost was [redacted] of contingency):

1) Bridging strategy with temporary de-chlorination to support 4- unit continuous chlorination has been completed and placed into service.
2) Detailed design for permanent de-chlorination and piping upgrades for chlorination system improvement has been completed.

The total project cost is now estimated at $21,481 k, including [redacted] of contingency. The decrease in the total project cost is due to the removal of the following scope:

- Complete feasibility studies for implementing closed loop supply for Primary Heat Transport (PHT) & Shutdown Cooling (SDC) pump motor cooling and replacement of Low Pressure Service Water (LPSW) Strainers in these systems.
- Complete scope definition phase (Modification Design Requirements/MDR, Modification Outline/MO and associated forms) for installing strainers on Powerhouse Upper Level Service Water (PULSW) & LPSW supply to safety and safety related loads in critical systems.

Estimate for the project were obtained from a third party estimator during initiation phase of the project, before the completion of value engineering sessions and scope definition. New estimates provided in this BCS are based on vendor estimates for an Engineer-Procure-Construct (EPC) Contract. Meetings were held with the EPC vendor to challenge the estimates as well as to provide alternate options to execute the project. This effort did not show a significant costs reduction due to the large scale of the scope still being required.

Total project cost changes are attributed to scope change via four Project Charter Revisions since the start of the project. The scope change is related to 1) the completion of feasibility studies for implementing closed loop supply for Primary Heat Transport (PHT) & Shutdown Cooling (SDC) pump motor cooling and replacement of Low Pressure Service Water (LPSW) Strainers in these systems and 2) completion of the scope definition phase for installing strainers on Powerhouse Upper Level Service Water (PULSW) & LPSW supply to safety and safety related loads in critical systems.

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Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Full Execution Release
Document #: D-BCS-72100-10003

Project Cash Flows, NPV, and OAR Approval Amount

k$	LTD	2015	2016	2017	2018	2019	2020	Future	Total
Currently Released	2,814	9,806	6	0	0	0	0	0	12,626
Requested Now	-	2,837	5,636	382	0	0	0	0	8,855
Future Required	-	0	0	0	0	0	0	0	0
Total Project Cost	2,814	12,643	5,642	382					21,481
Inventory	-	0	204	0	0	0	0	0	204
Ongoing Costs			750	750	750	750	750	750	
Grand Total	2,814	12,643	5,846	382					21,685

Estimate Class:	Class 2	Estimate at Completion:	[redacted]
NPV:	$N/A k	OAR Approval Amount:	$21,481 k

Additional Information on Project Cash Flows (optional):
Spare parts inventory for new installed chlorination & de-chlorination systems is estimated at $204k.
Ongoing chemical (sodium hypochlorite (NaOCl) & Sodium Bi-sulphite (SBS)) cost is estimated at $750k per year.

Approvals

	Signature	Comments	Date
The recommended alternative, including the identified ongoing costs, if any, represents the best option to meet the validated business need.			
Recommended by (Project Sponsor): Glenn Jager Chief Nuclear Officer			24SEP2015
I concur with the business decision as documented in this BCS.			
Finance Approval: Beth Summers SVP & Chief Financial Officer			30SEPT2015
I confirm that this project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.			
Approved by: Jeff Lyash President & CEO per OAR 1.1			7OCT 2015

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Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Full Execution Release

Document #: D-BCS-72100-10003

Business Case Summary

Part A: Business Need

Zebra mussel fouling has been an issue in service water systems effecting equipment reliability. Service water provides cooling to a number of safety and safety related loads such as shutdown cooling heat exchangers, shutdown cooling pump motor coolers, moderator heat exchangers, liquid zone control, and critical air conditioning units. Zebra mussel fouling can and has in the past resulted in unavailability of this equipment.

Zebra mussel fouling has resulted in unavailability of the shutdown cooling pumps on numerous occasions. Zebra mussel fouling has also resulted in debris blocking cooling lines, significant vault vapour recovery heat exchanger fouling and flow blockage. Other systems that were also affected by zebra mussels fouling were liquid zone control heat exchangers, vault coolers, confinement dryer heat exchangers and primary heat transport pump motor coolers. Flow blockages are typically a result of zebra mussel debris being introduced into these systems as a result of valving in of stagnant lines such as use of the LPSW inter-unit tie and PULSW recirculation at Darlington.

Zebra mussels are an invasive species not native to North America. Accordingly, the original design of the Darlington service water systems did not consider the need for zebra mussel mitigation and hence zebra mussel infestation became a problem after the service water systems were put in service. Presence of adult zebra mussels in station piping indicated that they are entering as veligers and growing as adulthood inside the piping over a period of time.

There is a significant increase of Station Condition Records (SCRs) trending over the past 8 years relating to low flow and pressure due to zebra mussel fouling such as LPSW Supply line to Instrument Air Compressors Cooling, PULSW Supply lines to Shutdown Cooling, and zebra mussels found in pump housing/piping.

Zebra mussel fouling in low flow and stagnant areas was the basis for an Area for Improvement (AFI) in Darlington's previous World Association of Nuclear Operators (WANO) evaluation.

A chlorination system was completed years ago to control zebra mussels but the frequencies of chlorination dosing (semi-continuous) were not adequate over time for effective zebra mussel control due to zebra mussels adapting to the dosing frequencies. Therefore implementation of continuous chlorination across all units is required to ensure effective zebra mussel control while maintaining Ministry of Environment (MOE) limits/requirements for outfall into lake.

There is also an operability reliability risk with the current service water chlorination system which presently have two types of sodium hypochlorite piping:

- Chlorinated Polyvinyl Chloride (CPVC), which has shown numerous leaks with the majority on threaded or glued joints; and,
- Polyvinylidene Fluoride (PVDF) piping, that has reached its end of design life.

Pickering station has implemented a De-Chlorination Systems to support continuous chlorination to eliminate zebra mussels fouling in service water systems. Operating Experience (OPEX) from the Pickering project scope is used for implementation into Darlington.

A Service Water Reliability Program – Strategy Manual completed in 2012 identified a program for minimizing/eliminating challenges to equipment reliability and plant operation due to zebra mussel fouling (as one of the factors) that may occur in open service water systems. Condition Assessments & Self-Assessments were completed in the past to identify areas for improvements with regards to Service Water Reliability Program and zebra mussel fouling. A short & long term strategy/program has been put in place to address service water reliability issues which include this project scope.

The business objective of this sustaining project is to:

1) Upgrading existing service water chlorination systems. These presently have two types of sodium hypochlorite piping; CPVC Piping which has shown numerous leaks & PVDF Piping which has reached its end of life.
2) Prevent zebra mussel attachment to service water equipment (Emergency Service Water (ESW), LPSW, PULSW) of chlorination points.
3) Implement continuous chlorination across all units. The present dosing schedule provides semi-continuous 90 mins ON, 270 mins OFF (in unit pump houses) and continuous in ESW pump house during the zebra mussel season (May to December).
4) Meeting ministry of Environment (MOE) limits for outfall.

Eliminate introduction of zebra mussel debris in critical station systems to prevent potential PULSW & LPSW outages which could result in unit outage extensions.

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Part B: Preferred Alternative: Implementation of the Recommended Modifications

Description of Preferred Alternative

During the initiation phase of the project a vendor was consulted to evaluate the issues & mitigation improvements of Zebra Mussel fouling in Service water systems. A conceptual design report was issued which addresses various areas in the Darlington service water systems. Value engineering sessions were also held to refine and prioritize the scope of the project considering their impact on the station and associated risks.

The recommended modifications are to be implemented as part of the long term strategy/program for eliminating & preventing zebra mussel fouling in station service water systems. The project will be driven to a closure after the successful installation of the permanent chlorination & dechlorination systems if proved to be adequate. This strategy will ensure funding streams for project phase deliverables are per governance. The scope of this project is restricted to complete:

A - Liquid Chlorination System Improvement

1) CPVC Chlorination piping to be replaced with new PVDF piping.
2) Replacement of existing PVDF chlorination piping with new PVDF Piping since its reaching its end of life.

Implementation of 4-unit (continuous) chlorination including an automatic interface with de-chlorination system.

B - De-chlorination System Installation

1) Installation of a new (permanent) de-chlorination system to permit 4-unit (continuous) chlorination.

Deliverables:	Associated Milestones (if any):	Target Date:
Start of Installation (Tie-ins) for Permanent De-Chlorination & 4- Unit Chlorination Modification	4 Unit De-Chlorination/Chlorination Tie-ins – Start of Installation (SOI)	01April2016
Complete 4-Unit Chlorination and Permanent De-Chlorination Modifications AFS	Chlorination/De-Chlorination – Final AFS (AFS)	25July2016
Project Closeout	OPG Project Closeout	30June2017

Part C: Other Alternatives

Summarize all viable alternatives considered, including pros and cons, and associated risks. Other alternatives may include different means to meet the same business need, and a reduced or increased scope of work, etc.

Alternative 2: Base Case – No Project

Failure to complete this modification would result for the continued need for outage extensions due to the need for LPSW outages: 4 days outage extensions per planned outage for LPSW for 2/3 of Darlington Nuclear (DN) Outages to effect zebra mussel abatement. These outages would have to take place at the end of each outage when heat loads are lowest. This option would reduce the reliability of the Service Water Systems and zebra mussel fouling could increase due to no continuous chlorination. In addition, it would also increase maintenance to attempt to continue manage the leaks through vigorous maintenance procedures.

Alternative 3: Delay Work

Station has OPEX and a history of adverse conditions relating to zebra mussels and zebra mussel debris fouling the service water systems cooling lines. Zebra mussel fouling has been an issue in service water systems effecting equipment reliability and resulting in unavailability of safety and safety related systems. Delaying this project increases the risk of re-occurring events which could potentially de-rate units.

Alternative 4: Implement portion of the scope.

Implement the 4-unit (continuous) chlorination modification only and continue to use the temporary de-chlorination system currently in service i.e. do not implement the (permanent) de-chlorination system. However, this alternative is not a long term viable option for the station due to the following:

- Current temporary de-chlorination system was designed to support two-unit continuous chlorination only.
- There will be lack of (automatic) communication interface between the chlorination system and the de-chlorination

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Alternative 4: Implement portion of the scope.

system. Lack of automatic systems creates the risk scenario if the de-chlorination system becomes impaired; the continuous chlorination would not stop and could result in exceeding ministry of environment limits. Current de-chlorination injection rates are based on manual inspections and operator rounds necessitating significant human intervention. There is a potential risk of human error.

- Requires increase of chemicals and storage required. No space available to store more chemicals using rental equipment.

Potential costs increases in the long term due to rental of equipment, associated mobilization and demobilization costs incurred each season and increase of oversight to support the de-chlorination system vendor with day to day operation of the system.

Part D: Project Cash Flows, NPV, and OAR Approval Amount

K$.	LTD	2015	2016	2017	2018	2019	2020	Future	Total
Currently Released	2,814	9,806	6	0	0	0	0	0	12,626
Requested Now	-	2,837	5,636	382	0	0	0	0	8,855
Future Required	-	0	0	0	0	0	0	0	0
Total Project Cost	2,814	12,643	5,642	382					21,481
Inventory	-	0	204	0	0	0	0	0	204
Ongoing Costs			750	750	750	750	750	750	
Grand Total	2,814	12,643	5,846	382					21,685

Estimate Class:	Class 2	**Estimate at Completion:**	[redacted]
NPV:	$N/A k	**OAR Approval Amount:**	$21,481 k

Additional Information on Project Cash Flows (optional):
Spare parts inventory for new installed chlorination & de-chlorination systems is estimated at $204k.
Ongoing chemical (sodium hypochlorite (NaOCl) & Sodium Bi-sulphite (SBS)) cost is estimated at $750k per year.

Part E: Financial Evaluation

k$	Preferred Alternative	Base Case	Delay Work	Continue to use existing de-chlorination system	Stagger Scope and no fast-tracking
Project Cost	21,481	N/A	N/A	N/A	N/A
NPV	N/A	N/A	N/A	N/A	N/A
Other (e.g., IRR)	N/A	N/A	N/A	N/A	N/A

Summary of Financial Model Key Assumptions or Key Findings:
Sustaining Investment, NPV not required.

Part F: Qualitative Factors

WANO evaluation of Darlington Station for Areas of Improvement
Reliability of Darlington Station Systems/Equipment.

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Part G: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	There is a risk of the EPC vendor underestimating the modifications and the level of effort required to install and commission the modification.	Estimates are based on design work completed and that contingency has been set aside for unforeseen conditions and/or delays.	Low	Medium
Scope	There is a risk of scope change to address the relocation of a sampling station.	The EPC vendor will provide an action plan to ensure minimal impact on project cost & schedule.	Medium	Medium
Scope	There is a risk that certain equipment or structures outside the modification will need to be modified or undergo changes to allow the modification to be installed and operated.	The scope has been defined and reviewed with OPG stakeholders to ensure no interference issues exist.	Low	Medium
Schedule	There is a risk of not having all the materials delivered on time, leading to installation and commissioning delays.	Additional time has been included into the schedule to account for material delay.	Low	Medium
Resources	There is a risk of not receiving stakeholders support when required. Lack of support from key stakeholders may delay project execution, leading to cost and schedule overruns.	A level 1 schedule has been created and distributed to the team to notify them in advance for when their contribution/support will be required so they can plan ahead.	Medium	Low
Quality/ Performance	There is a risk that environmental regulations will be changed with respect to the allowable level of chlorine in discharge water (via lagoons).	Amendment to existing ECA will capture environmental regulation changes.	Low	High
Technical	There is a risk of not completing the open design items as per the assigned TCDs (Design has been completed but is premised upon exceptions/deviations specifically for equipment vendor packages. This strategy (as agreed by Design Authority) is to facilitate progress of rough-ins construction prior to final tie-ins to station systems).	As part of install planning for tie-ins, progress on disposition of such exceptions/deviations is being closely tracked/monitored on a regular basis with enhanced management oversight to ensure rigour/adequacy and mitigate any impact to the final in service timeline.	Medium	Medium

Additional Risk Analysis:

N/A

Part H: Post Implementation Review (PIR) Plan

Type of PIR Report	Target In-Service or Completion Date	Target PIR Completion Date
Comprehensive PIR Report	2016-07-25	2017-05-15

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Number of Leaks on Chlorination Piping	Approximately 35 leaks on CPVC Chlorination during 3 years of operation	Leaks will be significantly reduced by 90%	Comparisons of Corrective Maintenance WOs before and after mod. implementation	Performance Engineering, Chlorination SRE
Residual Chlorine in LPSW outfall	Residual chlorine is being discharged in the LPSW outfall	Reduce residual chlorine level to current acceptable level for allowing 4 unit chlorination	Residual levels: Below limit set in the Certificate of Authorization	Chemistry and Environment

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Project Title: DN Zebra Mussel Mitigation Improvements, Full Execution Release

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Adult Zebra Mussels found in the LPSW System	Live adult zebra mussels found in the LPSW Bioboxes	Zero live adult zebra mussels found in the LPSW Bioboxes and during the D1711 PULSW Outage	Observation of Bioboxes and field observations from the D1711 PULSW Outage	Chlorination Program Co-ordinator Or Chlorination SRE

Part I: Definitions and Acronyms

PHT: Primary Heat Transport
PVDF: Polyvinylidene Fluoride
CPVC: Chlorinated Polyvinyl Chloride
SDC: Shutdown Cooling
PULSW: Powerhouse Upper Level Service Water
LPSW: Low Pressure Service Water
ESW: Emergency Service Water
AFS: Available for Service
RCW: Re-circulated Cooling water
MOE: Ministry of Environment
EPC: Engineering, Procurement, Construction
WANO: World Association of Nuclear Operators
AFI: Area for Improvements
EC: Engineering Change
OPEX: Operating Experience
MDR: Modification Design Requirements

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For Internal Project Cost Control

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Appendix A: Summary of Estimate										
Project Number:	16-38948									
Project Title:	DN Zebra Mussel Mitigation Improvements									
K$	LTD	2015	2016	2017	2018	2019	2020	Future	Total	%
OPG Project Management	357	746	639	75	0	0	0	0	1,817	7
OPG Engineering (Including Design)	327	723	414	36	0	0	0	0	1,500	6
OPG Procured Materials	0	0	0	0	0	0	0	0	0	0
OPG Other	0	0	0	0	0	0	0	0	0	0
Design Contract(s)	[redacted]									
Construction Contract(s)										
EPC Contract(s)										
Consultants										
Other Contracts/Costs (Removal Costs)										
Interest										
Subtotal										
Contingency										
Total	2,814	12,643	6,642	382	0	0	0	0	21,481	100

Notes			
Project Start Date	2013-01-03	Total Definition cost (excludes unspent contingency for Nuclear)	[redacted]
Target In-Service (or AFS) Date	2016-07-25	Contingency included in this BCS (Nuclear only)	
Target Completion Date	2017-06-30	Total contingency released plus contingency in this BCS (Nuclear only)	
Escalation Rate	2.5%	Total released plus this BCS without contingency (Nuclear only)	
Interest Rate	5.0%	Total released plus this BCS with contingency (Nuclear only)	$21,481 k
Removal Costs	$60 k	Estimate at Completion (Includes only spent contingency for Nuclear)	[redacted]

Prepared by:	Approved by:
Bassam Alawi 09-09-2015	
Bassam Alawi Modification Team Leader, Design Projects, Projects & Modifications Date YYYY-MM-DD	Rajbir Singh Section Manager, Design Projects Projects & Modifications Date YYYY-MM-DD 2015-09-15

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Appendix B: Comparison of Total Project Estimates and Project Variance Analysis

Comparison of Total Project Estimates

Phase	Release	Approval Date	Total Project Estimate in k$ (by year including contingency)						Future	Total Project Estimate
			2013	2014	2015	2016	2017	2018		
Definition	Partial	2012-11-30	631	4,396	5,537	2,562	2,268	2,231	1,254	18,879
Definition & Execution	Partial	2014-02-14	323	10,587	7,423	5,448	1,169	2,095	11,259	38,303
Execution	Full	2015-08-30	323	2,491	12,643	5,642	382	0	0	21,481

Project Variance Analysis

k$	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OPG Project Management	357	2,957	1,817	(1,140)	Project management cost has been reduced due to the removal of additional scope.
OPG Engineering (including Design)	327	2,743	1,500	(1,243)	OPG Engineering cost has been reduced due to the removal of additional scope.
OPG Procured Materials	0	0	0	0	
OPG Other	0	0	0	0	
Design Contract(s)	[redacted]				
Construction Contract(s)					
EPC Contract(s)					
Consultants					
Other Contracts/Costs					
Interest					
Subtotal					
Contingency					
Total	2,814	38,303	21,481	(16,822)	

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Appendix C: Financial Evaluation Assumptions
Key assumptions used in the financial model of the Project are (complete relevant assumptions only):
N/A

Appendix D: References
1) Charter: D-PCH-72100-10003 R003 2) Conceptual Design Report: NK38-DRT-72100-10009 3) Value Engineering Study: NK38-REP-72100-0478327 4) ESW & LPSW Chlorination Upgrade MDR: NK38-MDR-74950-10004. 5) Installation of Permanent De-Chlorination System MDR: NK38-74950-10003 6) Zebra Mussel Mitigation Improvements – Phase I (4-Unit Continuous Chlorination and De-Chlorination) Scope of Work NK38-SOW-74950-10002.

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Records File Information
See Guidance Section

OPG-FORM-0076-R003*

Type 3 Business Case Summary

Final Security Classification of the BCS: **OPG Confidential**

To be used for investments/projects meeting Type 3 criteria in OPG-STD-0076.

Executive Summary and Recommendations					
Project #:	16-73706	**Title:**	Holt Road Interchange Upgrade		
Phase:	Execution		**Release:**	Full	
Facility:	DN		**Records File:**		
Class:	Capital		**Investment Type:**	Value Enhancing	

Project Overview

We recommend the release of $31,022 k [redacted] base costs plus [redacted] contingency).

This release will fund a portion of the upgrade of the Highway 401 – Holt Road interchange to be executed by the Ontario Ministry of Transportation (MTO) in 2014 and 2015.

Refurbishment of the Darlington units requires a significant increase in personnel and material deliveries to the station and the area immediately to the west of the station. The current road infrastructure cannot handle the anticipated increase in vehicular traffic, which would result in delays and increased cost. Additionally, backups onto Highway 401 and the South Service Road would impact commuters going to and from the Greater Toronto Area from Bowmanville and points east as well as impacting other businesses adjacent to the Darlington site. Improvements to the Highway 401/Holt Road interchange are required to minimize traffic delays that could impact on the cost and schedule of the Refurbishment project and minimize the impact of the project on the surrounding community and the environment.

Road access was identified as a key risk to the Darlington New Nuclear Project (DNNP) due to the volume of traffic from the simultaneous execution of new station construction and refurbishment of the existing Darlington units. In 2008, the DNNP agreed to fund preliminary design work for the upgrade of the Holt Road interchange, which was supported by the DNNP Environmental Assessment. However, with the delay in the New Nuclear Project, design work was stopped in the Summer of 2011.

The Environmental Assessment for Darlington Refurbishment and Continued Operations confirmed the need for the upgrade. A follow-up assessment was completed in January 2012 to determine the impact of DN Refurbishment only. This assessment recommended improvements, albeit at a lesser scope. In November 2011, the Darlington Refurbishment project opened discussions to resume design work based on refurbishment staffing and material delivery volumes only. This design work resumed in February 2012 with a Memorandum of Understanding (MOU) between OPG and the MTO regarding funding signed in August 2012

The Highway 401 – Holt Road interchange is to be upgraded as follows to improve access to and from Highway 401 as well as improving the traffic flow along the South Service Road – Holt Road intersection:

(1) The off-ramp from Highway 401 East to Holt Road will be reconfigured so that the South Service Road does not cross the off-ramp. This will eliminate the potential choke point at the current crossing as well as the collision risk.

(2) A new eastbound on-ramp from Holt Road to Highway 401 will be constructed. This eliminates the need to travel to Waverley Road along the South Service Road to access the eastbound Highway 401. This would also minimize the disruption of the increased traffic to the local businesses located on the South Service Road. It also addresses local concerns regarding potential traffic using Baseline Road from Holt Road to access the eastbound on-ramp at Waverley Road.

(3) A new westbound off-ramp from Highway 401 to Holt Road will be constructed. This eliminates the need to exit at Waverley Road and travel westbound on the South Service Road or Baseline Road to Holt Road. It also eliminates the left turn to travel south on Holt Road to access the station that can be a significant congestion and collision risk.

(4) A new bridge over Highway 401 at Holt Road will be constructed. This bridge will increase the number of lanes traversing the highway to accommodate the increased traffic. Additionally, the new bridge will facilitate widening of Highway 401 in the future.

(5) Construct three roundabouts to facilitate smoother transitions to and from Holt Road and the South Service Road to Highway 401. Roundabouts have a number of benefits over stop-controlled intersections including reduced frequency and severity of collisions, improved traffic flows, fewer stops and delays, and

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less idling and pollution.

(6) Realignment and reconstruction of the South Service Road from Solina Road to east of Holt Road as well as the eastbound Highway 401 off-ramp to accommodate the Highway 401 – Highway 407 East Durham Link. OPG is funding the realignment east of Holt Road only.

Design work is 60% complete and is the basis for the release being requested. Cost risk to OPG is limited to the cost estimate developed at 90% design complete. The release amount includes sufficient contingency to address any cost increases determined between 60% and 90% complete.

The Net Present Value of this project is estimated to be $32.9 Million (2013 $) based on revenue timing impacts arising from later completion of the Refurbishment project due to reduced productivity arising from trades reporting at the gate rather than the work location. Additional labour costs ranging from $11 Million to over $100 Million (2013 $), depending on the loss of productivity, would further enhance the attractiveness of this investment.

Project Cash Flows

k$	LTD	2013	2014	2015	2016	2017	2018	Future	Total
Currently Released	-	-	-	-	-	-	-	-	-
Requested Now	-	3,195	15,241	8,347	1,015	1,064	1,113	1,047	31,022
Future Required	-	-	-	-	-	-	-	-	-
Total Project Cost	-	3,195	15,241	8,347	1,015	1,064	1,113	1,047	31,022
Ongoing Costs	-	-	-	-	-	-	-	-	-
Grand Total	-	3,195	15,241	8,347	1,015	1,064	1,113	1,047	31,022

Estimate Class:	Class 4	**Estimate at Completion:**	[redacted]
NPV:	$32,934 k	**OAR Approval Amount:**	31,022

Additional Information on Project Cash Flows (optional):

Cash flows represent OPG portion of total cost of Holt Road interchange estimated by the Ministry of Transportation. Contingency is [redacted] of OPG's contribution to the project.

Approvals

	Signature	Comments	Date
This BCS represents the best option to meet the validated business need in a cost effective manner.			
Recommended by: Dietmar Reiner SVP Nuclear Refurbishment Project Sponsor			Nov 6, 2013
I concur with the business decision as documented in this BCS.			
Finance Approval: Donn Hanbidge SVP & Chief Financial Officer			Nov 14/13
I confirm this project will address the business need, is of sufficient priority to proceed, and provides value for money.			
Approved by: Tom Mitchell President & Chief Executive Officer, per OAR 1.1	for Tom Mitchell		Nov 19/13

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Records File Information: See Guidance Section

OPG-FORM-0076-R003*

Type 3 Business Case Summary

Final Security Classification of the BCS: **OPG Confidential**

Business Case Summary

Part A: Business Need

Business Need:

Refurbishment of the Darlington units requires a significant increase in personnel and material deliveries to the station and the area immediately to the west of the station. The current road infrastructure cannot handle the anticipated increase in vehicular traffic, which would result in delays and increased cost. Additionally, backups onto Highway 401 and the South Service Road would impact commuters going to and from the Greater Toronto Area from Bowmanville and points east as well as impacting other businesses adjacent to the Darlington site. Improvements to the Highway 401/Holt Road interchange are required to minimize traffic delays that could impact on the cost and schedule of the Refurbishment project and minimize the impact of the project on the surrounding community and the environment.

History

Discussions with the Ministry of Transportation (MTO) began in 2006 when road access was identified as a key risk to the Darlington New Nuclear Project (DNNP). DNNP identified that the volume of traffic resulting from the simultaneous execution of new station construction and refurbishment of the existing Darlington units would overwhelm the existing infrastructure. In 2008, the DNNP agreed to fund preliminary design work for the upgrade of the Holt Road interchange [(1)]. In 2009, the need for improvements to the road infrastructure was supported by work in support of the DNNP Environmental Assessment [(2)].

However, with the delay in the New Nuclear Project, design work was stopped in the Summer of 2011.

As part of the Environmental Assessment for Darlington Refurbishment and Continued Operations, a traffic and transportation assessment was completed in December 2011 [(3)]. This assessment included DNNP site preparation work in its baseline scenario. At the request of the Municipality of Clarington, a follow-up assessment was completed in January 2012 to determine the impact of DN Refurbishment only [(4)]. This assessment also recommended improvements, albeit at a lesser scope than the recommendations of the DNNP assessment.

In November 2011, the Darlington Refurbishment project opened discussions to resume design work based on refurbishment staffing and material delivery volumes only. This design work resumed in February 2012 with a Memorandum of Understanding (MOU) between OPG and the MTO regarding funding signed in August.

The MTO conducted two public information sessions in May and September 2012 to inform the public of the proposed changes and to obtain feedback on the proposed changes. Preliminary design was completed in November 2012 with the issuance of the Transportation Environmental Study Report.

Detailed design work for the interchange upgrade started in January 2013 and is scheduled for completion in February 2014.

A draft MOU for the Construction Phase was issued to the MTO for comment in 2013.

Current Configuration

The current configuration of the Highway 401 – Holt Road interchange provides only limited on- and off-ramp access. There is no westbound off-ramp to Holt Road and no eastbound on-ramp from Holt Road as shown in Figure 1. Westbound traffic going to Darlington has to exit at Waverley Road and travel west along the South Service Road to either Holt or Park Road. Eastbound traffic from Darlington similarly has to travel east along the South Service Road from Holt or Park Road to Waverley Road.

Alternative routes to Highway 401 include travelling west on the South Service Road to the eastbound and westbound ramps at Courtice Road or travelling north on Holt Road to Baseline Road to travel to either Waverley Road or Courtice Road. The Municipality of Clarington has expressed concern about increased traffic on Baseline Road between Holt Road and Waverley Road, which is south of current residential lands.

Parking lots for Refurbishment personnel plus the access point to the Protected Area will be constructed near the foot of Park Road. Eastbound traffic can exit at Courtice Road and travel east from there to Park Road. Westbound traffic will have to exit at Waverley Road and travel west along the South Service Road, crossing both Holt Road and the Highway 401 – Holt Road off-ramp in the process. Since all of the intersections along the South Service Road are stop-controlled intersections, with the increased volume of traffic, there is increased likelihood of traffic back-ups and collisions.

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Records File Information
See Guidance Section

OPG-FORM-0076-R003*

Type 3 Business Case Summary

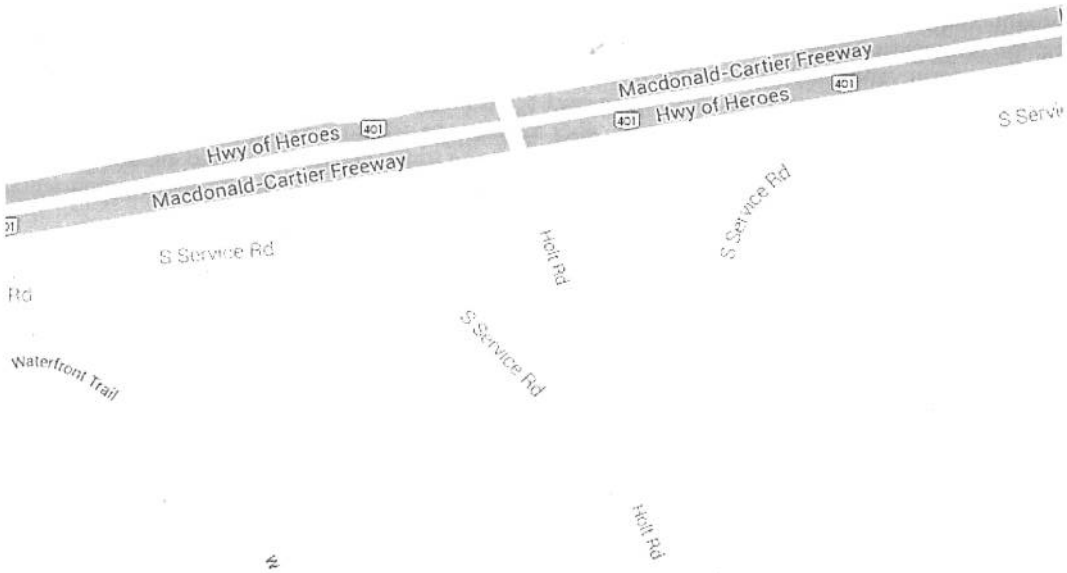

Figure 1: Current Holt Road Interchange

Part B: Preferred Alternative

Description of Preferred Alternative: Support the Upgrade of the Holt Road Interchange by the Ministry of Transportation

The preferred alternative is to support and provide funding for the MTO's upgrade of the Highway 401 – Holt Road interchange as described below and shown in Figure 3.

The Highway 401 – Holt Road interchange is to be upgraded as follows to improve access to and from Highway 401 as well as improving the traffic flow along the South Service Road – Holt Road intersection:

(1) The off-ramp from Highway 401 East to Holt Road will be reconfigured so that the South Service Road does not cross the off-ramp. This will eliminate the potential choke point at the current crossing as well as the collision risk.

(2) A new eastbound on-ramp from Holt Road to Highway 401 will be constructed. This eliminates the need to travel to Waverley Road along the South Service Road to access the eastbound Highway 401. This would also minimize the disruption of the increased traffic to the local businesses located on the South Service Road. It also addresses local concerns regarding potential traffic using Baseline Road from Holt Road to access the eastbound on-ramp at Waverley Road.

(3) A new westbound off-ramp from Highway 401 to Holt Road will be constructed. This eliminates the need to exit at Waverley Road and travel westbound on the South Service Road or Baseline Road to Holt Road. It also eliminates the left turn to travel south on Holt Road to access the station that can be a significant congestion and collision risk.

(4) A new bridge over Highway 401 at Holt Road will be constructed. This bridge will increase the number of lanes traversing the highway to accommodate the increased traffic. Additionally, the new bridge will facilitate widening of Highway 401 in the future.

(5) Construct three roundabouts to facilitate smoother transitions to and from Holt Road and the South Service Road to Highway 401. Roundabouts have a number of benefits over stop-controlled intersections including

ONTARIO POWER GENERATION

Records File Information:
See Guidance Section

OPG-FORM-0076-R003*

Type 3 Business Case Summary

reduced frequency and severity of collisions, improved traffic flows, fewer stops and delays, and less idling and pollution.

(6) Realignment and reconstruction of the South Service Road from Solina Road to east of Holt Road as well as the eastbound Highway 401 off-ramp to accommodate the Highway 401 – Highway 407 East Durham Link. OPG is funding the realignment east of Holt Road only.

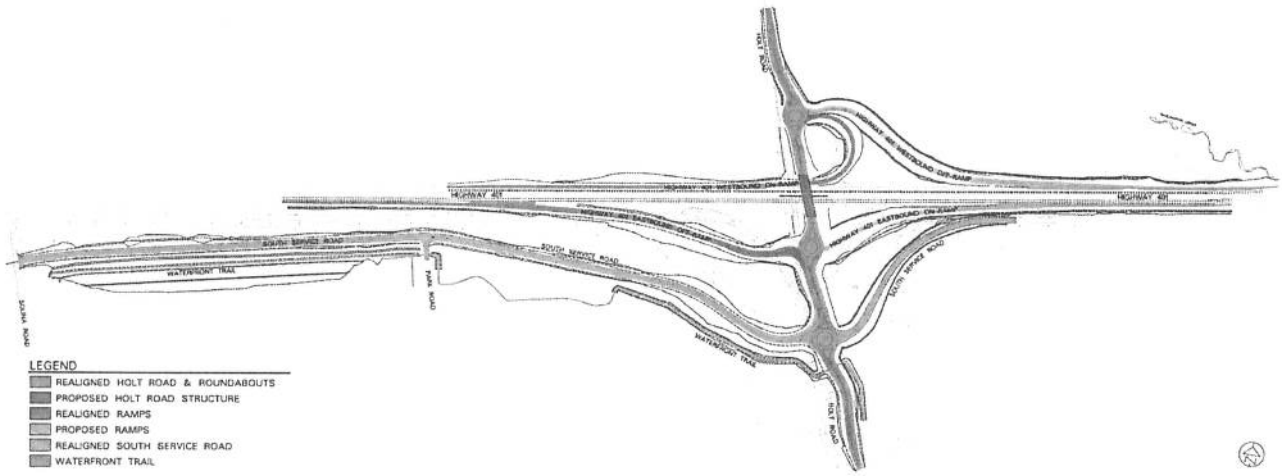

Figure 2: Proposed Improvements to Highway 401 – Holt Road Interchange

Deliverables:	Associated Milestones (if any):	Target Date:
Upgraded Highway 401 – Holt Road interchange.	Start clearing and grubbing of site	January 2014
Realigned South Service Road	Detailed Design	February 2014
	Construction start	May 2014
	Construction completion	December 2015

Part C: Other Alternatives

Base Case: Status Quo – No Project

If the Holt Road interchange is not upgraded in advance of the start of the Darlington Refurbishment, traffic studies done in support of the Refurbishment Environmental Assessment indicate that there will be significant delays in personnel accessing the site. This would increase the cost and duration of the project as detailed below.

Traffic Impact

The staffing profile for the Darlington Refurbishment, as shown in Figure 3, is approximately 2,650 over the Operations staffing at peak. This compares with a peak of approximately 800 incremental staff that participated in the most recent Vacuum Building Outage, which is the site workforce peak during routine operations.

In the traffic and transportation assessments conducted for the Refurbishment Environmental Assessment, it is assumed that there would be an average of 1.33 persons per vehicle, which translates to approximately 2,000 more vehicles accessing the site. The majority of trips in and out of the site are assumed to occur within 1 hour of the morning and afternoon start and finish times. The incremental number of workforce trips estimated to occur in these hours peaks at 870 vehicles in the morning and 795 in the afternoon with 80% of these trips via the Park Road access.

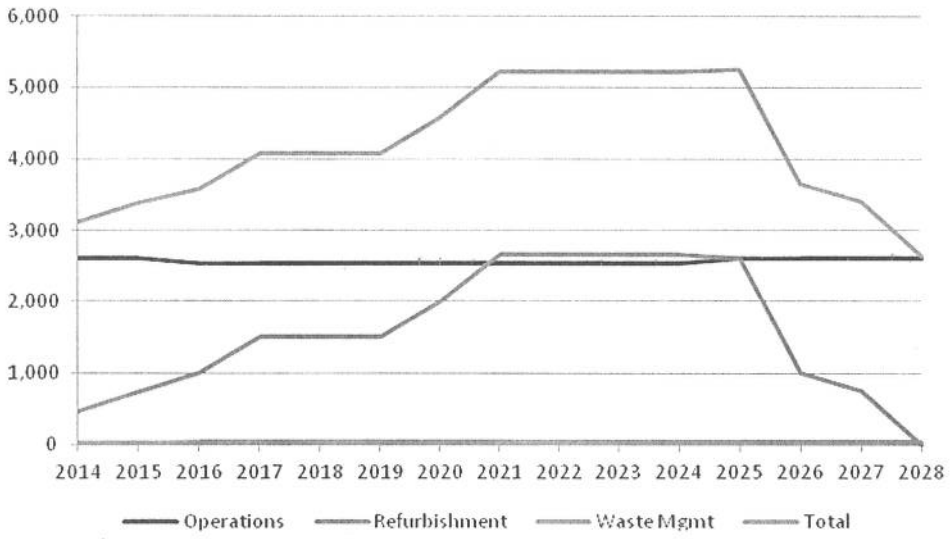

Figure 2: Darlington Refurbishment Workforce

Project Impact

To maximise the productivity at the refurbishment jobsites, one of the items in negotiations with the trades unions is to have the trades report for work at the jobsite, not at the entrance to the site. Agreement with the trades unions is contingent upon OPG minimising impediments that would hinder the movement of the trades onto and off the site. A separate portal to the protected area, separate change/shower facilities and separate parking facilities for the Refurbishment personnel are three of the initiatives to smooth the movement on and off-site. The upgrade of the Holt Road Interchange is also expected as an initiative to make it easier for the trades to report to work.

If the Holt Road Interchange upgrade does not proceed, it is expected that the agreement for the reporting location will not be approved. In this case, the existing agreements would apply. The trades would report for work at the gate and would be entitled to time to change into the appropriate clothing (browns, etc) in the change room and then walk to the jobsite. This would be in the order of 20 to 30 minutes at the start of the shift (depending on the unit being refurbished). Furthermore, they would also be entitled to time at the end of the shift to walk to the change room, shower and change before the nominal end of shift.

These reductions on working time at the jobsites will impact on productivity and, therefore, the cost and duration of the project. OPG, through the contractors, will be paying the trades for up to an hour of unproductive time per day that would otherwise be productive if the reporting location agreement is approved. Furthermore, the duration of the critical path will be extended compared to the current plan due to less time per shift actually being worked.

This has two financial impacts – the cost of the Refurbishment would go up compared to current estimates and the timing of the revenue from the unit upon return to service would be delayed.

(i) The current cost estimate makes the assumption that there is no lost time reporting to the work locations within the station. If the project does not proceed, there will be a loss of productivity that translates to higher costs, assuming that the person-hours necessary to complete all of the tasks in the Refurbishment are constant regardless of reporting location. The increase in the cost of labour, based on the current Class 5 estimate is $54 Million (in 2013$) for the most likely duration of time expended between reporting at the gate and arriving at the work location (range is $11 to over $100 Million depending on the amount of time lost per shift).

(ii) The drop in productivity would also impact the duration of the Refurbishment. Using the same assumption of constant work duration described in (i) and assuming that the primary impact on the overall duration is on the Retube & Feeder Replacement critical path, the duration of the outages would increase an average of 35 days (delay would range between 7 to 78 days depending on the amount of time lost in each shift). This would shift the revenues from the units out, with a loss of near-term revenue and an increase in revenue at the end of commercial operations. The present value of this movement in revenue is ($53.4) Million (revenue shifting ranges between ($9.9) Million and ($112.2) Million depending on the time lost per shift).

Type 3 Business Case Summary

Alternative 2: Delay Work

The overall strategy for the interchange upgrade included the impact of changes being made to accommodate the Highway 401 – Highway 407 East Durham Link. The schedule for this link has the construction of the necessary interchange beginning in 2017. If the start of the Holt Road Interchange upgrade is deferred past 2015, there that work would be in parallel with the more extensive work occurring to the west. This would result in additional traffic congestion.

To mitigate the impact of both projects on the progress of the Darlington Refurbishment, upgrade of the Holt Road Interchange and the realignment of the South Service Road must be completed by the end of 2016. No financial evaluation was conducted for this alternative

Alternative 3: Bus Workers From Off-Site Parking Facility

Operational experience from using buses to move workers indicates this is not a viable concept. It would require a fleet of buses and the establishment of a large parking facility remote from the Darlington site. This fleet of buses would have to operate frequently during the peak periods as well as some time after the nominal start time to account for those arriving late or in the event of traffic difficulties in the vicinity. It also reduces the flexibility to use overtime to recover schedule losses unless the bus fleet was running continuously, which would drive up the cost.

In 2011, it was estimated that the cost of providing bus transportation from an off-site parking facility would be $98.2 Million.

Alternative 4:N/A

Part D: Project Cash Flows

k$	LTD	2013	2014	2015	2016	2017	2018	Future	Total
Currently Released	-	-	*	-	-	-	-	-	-
Requested Now	-	3,195	15,241	8,347	1,015	1,064	1,113	1,047	31,022
Future Required	-	-	-	-	-	-	-	-	-
Total Project Cost	-	3,195	15,241	8,347	1,015	1,064	1,113	1,047	31,022
Ongoing Costs	-	-	-	-	-	-	-	-	-
Grand Total	-	3,195	15,241	8,347	1,015	1,064	1,113	1,047	31,022

Estimate Class:	Class 4	**Estimate at Completion:**	[redacted]	**OAR Approval Amount:**	31,022

Additional Information on Project Cash Flows (optional):

Cash flows represent OPG portion of total cost of Holt Road interchange estimated by the Ministry of Transportation. Contingency is [redacted] of OPG's contribution to the project.

Part E: Financial Evaluation

k$	Preferred Alternative	Base Case	Delay Work	Bus from Offsite Parking	
Project Cost	31,022	N/A	N/A	57,784	
NPV (after tax)	32,934	N/A	N/A	29,282	

Summary of Financial Model Key Assumptions (see Guidance on this Type 3 BCS Form):

NPV considers only revenue timing impact.

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Type 3 Business Case Summary

Part F: Qualitative Factors

- Delays arising from increased traffic at Holt Road would also impact the Operations staff. OPG's Chief Physician has indicated that these delays in entering and leaving the site will result in increased stress that ultimately could result in higher benefit costs due to stress leave, medical costs, and prescription costs. There is also evidence to show that stress surrounding the commute for regular staff could impact on human performance and safety.
- A significant increase in the number of vehicles travelling on the South Service Road east of Holt Road would impact on the businesses on that thoroughfare. Relocation of the westbound exit to Holt Road will reduce traffic, making it easier for employees and customers to access these businesses. This demonstrates good citizenship on the part of OPG in ensuring that our operations have minimal effect on the surrounding area.
- Improving the flow of traffic will minimize environmental impacts of large numbers of idling vehicles. With the current arrangement, there are a couple of choke points for vehicles, especially those coming from the east. There would be long lines of vehicles waiting to make turns during the peak periods, resulting in higher vehicle emissions. By minimizing these backups, the impact on the environment is lessened.

Part G: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	Cost is based on Class 4 Estimate with 60% of design complete. Additional costs may be identified during the completion of the design work. Discovery work during construction may result in higher costs to complete.	A [redacted] general contingency has been included to account for any unexpected increases over the Class 4 estimate. Agreement with the Ministry caps the cost reimbursed by OPG at the estimate prepared at 90% design complete	Low	Low
Scope	Scope is well-defined	None	Low	Low
Schedule	Weather conditions may delay the completion of the construction.	Accept risk; planned completion of the interchange is 9 months before the planned start of the Refurbishment outage. This provides adequate float to make up weather delays in 2016.	Low	Low
Resources	Availability of sufficient trades may delay completion	Risk is accountability of Ministry to mitigate - cost impact of resource unavailability capped	Low	Low
Quality/ Performance	N/A			
Technical	N/A			
Other				

Additional Risk Analysis:

Part H: Post Implementation Review (PIR) Plan

Type of PIR	Target Project In Service Date	Target PIR Completion Date
Simplified	2015-12-31	2016-12-31

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)

Accessibility to Holt Road from Highway 401	No westbound Highway 401 to Holt Road exit No eastbound Holt Road to Highway 401 exit	Exits to and from Holt Road and Highway 401	Completion of interchange construction and opening to traffic	Manager, Refurbishment Construction
Reporting Location Agreement	Workers report at gate	Workers report at work location	Refurbishment agreement approved by EPSCA trades unions	Manager, Refurbishment Construction

Part I: Definitions and Acronyms

DNNP – Darlington New Nuclear Project
MOU – Memorandum of Understanding
MTO – Ministry of Transportation

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Type 3 Business Case Summary

For Internal Project Cost Control

Type 3 Business Case Summary

Appendix A: Summary of Estimate										
Project Number:	16-73706		**Facility:**	Darlington						
Project Title:	Holt Road Interchange Upgrade									
Estimated Cost in k$										
	LTD	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Future**	**Total**	**%**
OPG Project Management	-	-	-	-	-	-	-	-	-	-
OPG Engineering	-	-	-	-	-	-	-	-	-	-
Permanent Materials	[redacted]									
Design and Construction										
Consultants										
Other Contracts/Costs										
Interest										
Subtotal										
Contingency										
Total	-	3,195	15,241	8,347	1,015	1,064	1,113	1,047	31,022	100
Removal Costs Included										

Notes			
Project Start Date	2013-10-31	**Project Completion or In-Service Date**	2019-12-25
Interest Rate	5.0%	**Escalation Rate**	2.0%
Definition Cost Included	$0 k	**Estimate at Completion**	[redacted]

Prepared by:	Approved by:
Robin Granger Manager Construction 2013 NOV 05 Date	Mark Arnone VP Refurbishment Execution 7 Nov 2013 Date

Type 3 Business Case Summary

Appendix B: Comparison of Total Project Estimates										
Phase	Release	Date (YYYY-MM-DD)	Total Project Estimate in k$ (by year including contingency)						Later	Total Project Estimate
			2013	2014	2015	2016	2017	2018		
Execution	Full	2013-10-31	3,195	15,241	8,347	1,015	1,064	1,113	1,047	31,022

Project Variance Analysis					
Estimated Cost in k$					
k$	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OPG Project Management	-	-	-		Not applicable – first release
OPG Engineering	-	-	-		
Permanent Materials	-	-	-		
Design and Construction	-	-	-		
Consultants	-	-	-		
Other Contracts/Costs	-	-	-		
Interest	-	-	-		
Subtotal	-	-	-		
Contingency	-	-	-		
Total	-	-	-		
Removal Costs Included					

Type 3 Business Case Summary

Appendix C: Financial Evaluation Assumptions

Key assumptions used in the financial model of the Project are (complete relevant assumptions only):

Project Cost:

Project costs provided by Ministry of Transportation. OPG's cost excludes the following from overall estimate

(1) Waterfront Trail relocation ($3,362k)

(2) South Service Road relocation west of Holt Road ($2,548k)

(3) Water main relocation ($1,300k)

(4) 75% of other utility relocations ($1,125k)

(5) 25% of construction administration costs ($405k)

(6) 25% of traffic control costs

Financial:

(1) Delay due to reporting at gate rather than work location assumed to be 0.5 hour per shift.

(2) Near term revenue loss based on productivity losses in Retubing and Feeder Replacement portion of outage only.

(3) Bounds for labour cost and duration increases based on 0.1 and 1.0 hour delay each shift.

(4)

Project Life:

Interchange will last the life of Darlington station

Energy Production:

None

Operating Cost:

None

Other:

None

Attach further detail as appropriate from the Financial Evaluation spreadsheet.

Appendix D: References

1. NK054-CORR-01210-0247020 Sellers to Hammer
2. NK054-RPE-07730-00017 Traffic And Transportation Environment Assessment Of Environmental Effects Technical Support Document New Nuclear Darlington Environmental Assessment
3. NK38-REP-07730-10007 Traffic And Transportation Technical Support Document Darlington Nuclear Generating Station Refurbishment And Continued Operation Environmental Assessment
4. NK38-REP-07730-0375413 Additional Traffic Assessment Report No New Nuclear -Darlington Scenario DNGS Refurbishment And Continued Operation Project

Type 2 Business Case Summary

To be used for investments/projects meeting Type 2 criteria in OPG-STD-0076.

Project Information			
Project #:	16-80022	**Document #:**	D-BCS-60800-10004 R000
Project Title:	OH180 Aging Management Hardware Installation		
Class:	☐ OM&A ☒ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	**Investment Type:**	Sustaining
Phase:	Definition	**Release:**	Full
Facility:	Darlington	**Target In-Service or Completion Date:**	Q4, 2022

Project Overview

We recommend the release of $1,398k, including [redacted] of contingency.

The estimated total project cost is $47,203k, including [redacted] of contingency.

The quality of the estimate for this release is Class 4, and for the total project is Class 5.

This release will fund the following scope of work:

- Perform a cost/benefit analysis to determine the replacement strategy for the OH180 Input and Output (I/O) boards
- Preparation of Non-Identical Component Replacement (NICRs) for OH180 and Communication Module Power Supplies
- Prepare Scope of Work, Issue Request for Proposal (RFP) and Evaluate Bids for Engineering/Construction (EC) Contract
- Preparation and approval of Execution Partial Business Case Summary including Front-End Planning activities

Part A: Business Need

The OH180 Programmable Logic Controller (PLC) is an essential piece of plant equipment at Darlington. It was designed by Ontario Hydro (OPG's predecessor) and built by a third party manufacturer to replace the electro-mechanical relays used for control logic implementation in the previous CANDU stations. The OH180 is used to control the majority of process systems (including special safety and safety related systems), electrical distribution system breakers and the Class 3 Transfer System. Each OH180 PLC consists of several printed circuit boards (Central Processing Unit (CPU), Erasable Programmable Read Only Memory (EPROM) and, depending on the application, up to two power supplies, up to eight input and output boards and, in some cases, communications modules).

There are 1,336 OH180 programmable controllers installed at Darlington Nuclear Generating Station, consisting of 12,566 printed circuit boards. Although the OH180s still operate quite reliably, the circuit boards are over 25 years old and are not expected to last until the extended end of station life. It is anticipated that the failure rate of the legacy OH180 boards will increase in the near future due to aging electronic components. The existing hardware needs to be reverse engineered so that replacement boards can be manufactured. Investment in reliable replacement hardware will ensure operation and maintenance resources are not spent on troubleshooting OH180 failures.

The option to replace the OH180 with a commercial PLC has been investigated and no direct replacement of the OH180 was found. Adapting an existing PLC would require extensive station re-wiring, qualification of hardware and software, as well as converting all existing logic to a new format. The cost of implementing such a project would be substantially greater than the preferred alternative.

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

Part B: Preferred Alternative: Install Re-engineered Power Supplies and Input/Output Boards

Description of Preferred Alternative

The preferred alternative is to:

- Install re-engineered OH180 Power Supplies (1,922)
- Install re-engineered Communication Module Power Supplies (431)
- Install re-engineered Input Boards (2,477)
- Install re-engineered Output Boards (3,771)
- Upgrade EPROMs from version 112 of the OH180 executive program to version 117 as required (note: a number of OH180s have already been upgraded to version 117).
- Verify the existing OH180 database so that it may be used as an approved tool to facilitate the preparation of commissioning plans for ladder logic changes.

A cost/benefit analysis will be performed during the Definition phase to determine the most appropriate strategy for the input and output boards (i.e. either replace all input and output boards with new re-engineered boards or refurbish the existing boards by replacing obsolete components that have a high potential for failure). For the purposes of this Business Case, the option to replace all input and output boards with new re-engineered boards has been selected as the preferred alternative.

Pros:

- OH180 functional reliability will be extended.
- Improved OH180 power supply design.
- Reduced Operations and Maintenance burden.

Deliverables:	Associated Milestones (if any):	Target Date:
Current Release		
NICRs for OH180 and CM (Communication Module Power Supplies)	Detailed Design Complete (NICRs Complete for OH180 & CM Power Supplies)	18-Dec-15
Execution Partial Business Case Summary	Execution Partial Business Case Summary (BCS) Approved	31-Mar-16
Future Releases		
Issue EC Contract for Phase I	Phase I of EC Contract Awarded	14-Apr-16
Issue Purchase Order for Production of Materials	Materials Purchase Order Awarded	Q2, 2016
Turnover of Phase I Installation	Available for Service/Ops Turnover – Phase I	Q4, 2017
Execution Full Business Case Summary	Execution Full Business Case Summary (BCS) Approved	Q1, 2018
Issue EC Contract for Phase II	Phase II of EC Contract Awarded	Q2, 2018
Turnover of Phase II Installation	Available for Service/Ops Turnover – Phase II	Q4, 2022
Engineering and Project Closeout	Plan Complete	Q4, 2023

Part C: Other Alternatives

Summarize all viable alternatives considered, including pros and cons, and associated risks. Other alternatives may include different means to meet the same business need, and a reduced or increased scope of work, etc.

Alternative 2: Base Case – No Project

Pros:

- There are no pros associated with this alternative.

Cons:

- As the OH180s continue to age, the failure rate will continue to increase exponentially as the population of OH180s enter the wear-out region of electronics reliability curve [R-1]. The burden on maintenance would become too large to keep up with the repairs as maintenance only has so many refreshed boards ready for replacement at a time.
- Waiting for a field failure to occur brings down the OH180 and the associated controlled system in an unplanned manner, thus creating a large burden on Operations and Maintenance.
- This alternative would result in unreliable operation of the OH180s which has the potential to impact safety and production as the OH180s control the majority of process systems including special safety and safety related systems. If multiple OH180 failures were to occur during a shift, Operations and Maintenance may not have the resources available to make the repairs and might be forced to shut down the Unit.
- System health will decline as components will not be replaced until they fail. There are not likely to be enough spares on hand to support the expected failure rate.

[R-1] *Evaluating the Effects of Aging on Electronic Instrument and Control Circuit Boards and Components in Nuclear Power Plants*. EPRI, Palo Alto, CA: May 2005. 1011709.

Alternative 3: Delay Work until a Future Outage after Darlington Refurbishment Outage

Delay the installation of OH180 re-engineered hardware until a future outage after the Darlington Refurbishment outage.

Pros:

- Delaying the installation would defer costs.

Cons:

- Same as those listed above for Alternative 2.

Alternative 4: Install Re-engineered Power Supplies and Refurbish Input/Output Boards

Install re-engineered OH180 Power Supplies and Communication Module Power Supplies. Refurbish Input and Output Boards by replacing components that are susceptible to aging with new components. In addition, upgrade EPROMs by replacing version 112 of the OH180 executive program with version 117 as required (note: a number of OH180s have already been upgraded to version 117). The existing OH180 database will also be verified so that it may be used as an approved tool to facilitate the preparation of commissioning plans for ladder logic changes.

Refurbishing the input and output boards (i.e. replacing only certain components) is not the preferred alternative as it is expected that refurbished boards will have a lower reliability than new re-engineered boards due to the age of the components that would not be replaced. However, a cost/benefit analysis will be performed during the Definition phase to determine the most appropriate strategy (i.e. replace all input and output boards with new re-engineered boards or refurbish the existing boards by replacing obsolete components that have a high potential for failure).

Pros:

- OH180 functional reliability will be extended.
- Improved OH180 power supply design.

Alternative 4: Install Re-engineered Power Supplies and Refurbish Input/Output Boards

Cons:

- Components that are not replaced as part of refurbishing the input and output boards could start to fail necessitating replacement of those components or ultimately requiring the whole board to be replaced. If additional components start to fail at a rate greater than anticipated requiring entire boards to be replaced, the 10% spare re-engineered boards being procured by project 34011 may not last until station extended end of life.

Part D: Project Cash Flows, NPV, and OAR Approval Amount

k$	LTD	2014	2015	2016	2017	2018	2019	Future	Total
Currently Released	-	-	-	-	-	-	-	-	-
Requested Now	-	9	1,348	41	-	-	-	-	1,398
Future Required	-	-	-	2,520	7,302	7,454	7,179	21,350	45,805
Total Project Cost	-	9	1,348	2,561	7,302	7,454	7,179	21,350	47,203
Ongoing Costs	-	-	-	-	-	-	-	-	-
Grand Total	-	9	1,348	2,561	7,302	7,454	7,179	21,350	47,203

Estimate Class:	Class 5	**Estimate at Completion:**	[redacted]
NPV:	Not Required (Sustaining Investment)	**OAR Approval Amount:**	$1,398k

Additional Information on Project Cash Flows (optional):

[redacted] contingency is included in this release. [redacted] contingency is included in future releases.

Part E: Financial Evaluation

k$	Preferred Alternative	Base Case	Delay Work	Alternative 4	
Project Cost					
NPV					
Other (e.g., IRR)					

Summary of Financial Model Key Assumptions or Key Findings:

Financial evaluation not required as this is a Sustaining investment.

Part F: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	There is a risk that the cost of installation/commissioning will increase due to the fact that detailed scoping is not complete. It has yet to be determined which boards can be replaced online and which require an outage.	Detailed scoping will be completed during the Definition phase. Impact of taking each OH180 out of service to install new boards will be determined and a detailed installation schedule will be developed.	Medium	Medium
Scope	There is a risk that NICRs or ECs may be required to install the new re-engineered input and output boards. Currently it is assumed that the input and output boards will be an item equivalency and will follow the IEE process, but this has to be confirmed by project 34011 once all design documentation has been completed.	Discussions have taken place with the Computers and Control Design section who believes the re-engineered boards will qualify as equivalent to the existing.	Low	Medium

Part F: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
Schedule	There is a risk that preparation of the NICRs for the OH180 and Communication Module Power Supplies could take longer than expected to complete.	Hold regular status meetings with Design to closely track progress. Ensure issues are promptly identified and raised to an appropriate level for quick resolution.	High	High
Resources	There is a risk that resources could be diverted from this project to support higher priority projects/station issues. System Engineers/Operations are required to provide input to the project scoping/installation planning activity. Unavailability of resources when required would result in schedule slippage.	Obtain resource commitments from Performance Engineering and Operations.	High	High
Cost	There is a risk that the cost of the new re-engineered power supplies and input/output boards will change once the production/delivery strategy has been determined based on the installation schedule. Current estimate is based on preliminary vendor quotes.	Detailed project scoping will be completed in the Definition phase. Revised estimates will be obtained from the vendor prior to approval of the next BCS.	Medium	Medium
Operational	There is a risk that the replacement hardware will fail in the field and result in an unexpected system response.	Replacement hardware is based on the original design. The hardware undergoes extensive qualification testing. Failure modes are examined and defined. The installation strategy will incorporate risk management.	Low	High

Part G: Post Implementation Review (PIR) Plan

☒ It is determined appropriate that only a Project Closure Report (PCR) is needed as the PIR for this project, due to its straight forward deliverables, which do not require any measures other than confirmation of completion or delivery.

Type of PIR Report	Target In-Service or Completion Date	Target PIR Completion Date
Project Closure Report (PCR)	Q3, 2022	Q4, 2023

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)

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Type 2 Business Case Summary

Project #: 16-80022
Project Title: OH180 Aging Management Hardware Installation, <Full> <Definition> Release

Document #: D-BCS-60800-10004 R000

Approvals			
	Signature	**Comments**	**Date**
The recommended alternative, including the identified ongoing costs, if any, represents the best option to meet the validated business need.			
Recommended by (Project Sponsor): Rick Hohendorf Director, Components Engineering			Nov 26, 2014
I concur with the business decision as documented in this BCS.			
Finance Approval: Ann Brooks Finance Controller per OPG-STD-0076	A Brooks	Project reclassified to CAPITAL. Interest not estimated. Will need to manage within release & include in next project release BCS.	Dec 8/14
I confirm that this project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.			
for **Approved by:** C. Spence Steve Gregoris Director, Darlington Operations and Maintenance per OAR 1.1	G Spence		Dec 9/14

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OPG-FORM-0075-R004

Type 2 Business Case Summary

Project #: 16-80022
Document #: D-BCS-60800-10004 R000
Project Title: OH180 Aging Management Hardware Installation, <Full> <Definition> Release

Appendix A: Summary of Estimate										
Project Number:	16-80022									
Project Title:	OH180 Aging Management Hardware Installation									
k$	LTD	2014	2015	2016	2017	2018	2019	Future	Total	%
OPG Project Management	-	5	200	231	284	258	263	1,054	2,295	5
OPG Engineering (including Design)	-	4	253	295	765	864	867	2,650	5,698	12
OPG Procured Materials	[redacted]									
OPG Other										
Design Contract(s)										
Construction Contract(s)										
EPC Contract(s)										
Consultants										
Other Contracts/Costs										
Interest	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-
Subtotal	[redacted]									
Contingency										
Total		9	1,348	2,562	7,301	7,454	7,179	21,350	47,203	100

← Will attract Interest Capitalized

Notes			
Project Start Date	2014-12-15	**Total Definition cost** (excludes unspent contingency for Nuclear)	[redacted]
Target In-Service (or AFS) Date	2022-10-14	**Contingency included in this BCS** (Nuclear only)	
Target Completion Date	2023-11-09	**Total contingency released plus contingency in this BCS** (Nuclear only)	
Escalation Rate	2.0%	**Total released plus this BCS without contingency** (Nuclear only)	
Interest Rate	N/A – OM&A	**Total released plus this BCS with contingency** (Nuclear only)	$1,398k
Removal Costs		**Estimate at Completion** (includes only spent contingency for Nuclear)	[redacted]

Prepared by:		Approved by:	
Shelley Jones Senior Technical Officer Projects & Modifications	2014-11-26 Date YYYY-MM-DD	Scott Ritzie Section Manager Projects & Modifications	2014-11-26 Date YYYY-MM-DD

Type 2 Business Case Summary

Project #: 16-80022
Document #: D-BCS-60800-10004 R000
Project Title: OH180 Aging Management Hardware Installation, <Full> <Definition> Release

Appendix B: Comparison of Total Project Estimates and Project Variance Analysis

Comparison of Total Project Estimates

Phase	Release	Approval Date	Total Project Estimate in k$ (by year including contingency)						Future	Total Project Estimate
			2014	2015	2016	2017	2018	2019		
Definition	Full	Nov 2014	9	1,348	2,562	7,301	7,454	7,179	21,350	47,203

Project Variance Analysis

Choose an item.	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OPG Project Management					Project variance not applicable as this is the first release.
OPG Engineering (including Design)					
OPG Procured Materials					
OPG Other					
Design Contract(s)					
Construction Contract(s)					
EPC Contract(s)					
Consultants					
Other Contracts/Costs					
Interest					
Subtotal					
Contingency					
Total					

Type 2 Business Case Summary

To be used for investments/projects meeting Type 2 criteria in OPG-STD-0076.

Project Information			
Project #:	16-80078	**Document #:**	D-BCS-69000-10008
Project Title:	Darlington Digital Control, Common Process and Sequence of Events Monitoring Computer Aging Management		
Class:	☐ OM&A ☒ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	**Investment Type:**	Regulatory
Phase:	Definition	**Release:**	Partial
Facility:	Darlington	**Target In-Service or Completion Date:**	JUN-2025

Project Overview

We recommend the release of $1,661 k, including [redacted] of contingency.
The estimated total project cost is $47,253 k, including [redacted] of contingency. An additional amount of $9,068 k, including [redacted] of contingency is required for the lifetime spares of the obsolete computer components.

The quality of the estimate for this release is Class 4, and for the total project is Class 5.

This release will fund the following scope of work:
Preliminary engineering and complete planning of project definition phase, as follows:

- Start and complete the vendor design revision of the Count Down Register (CDR) circuit board and Disk/Tape emulator.
- Start and complete the procurement of lifetime spares for the CDR circuit board and Disk/Tape emulator.
- Start and complete the preliminary engineering and the procurement of the design services for the following components: Input/Output (I/O) subsystems (over 20 circuit board types) and Watchdog circuit board.
- Start and complete the preliminary engineering for the following components: computer keyboards, UNIBUS repeater, Delua and Datalink circuit boards.
- Start and complete the planning and provide a refined cost and schedule estimate for the detailed design phase (i.e. reverse engineering of obsolete components).

History of BCS releases and project cost estimates:
This is the first BCS release and project cost estimate.

History of scope and schedule changes:
There is no history of scope and schedule changes.

Part A: Business Need

The Component Condition Assessments (CCAs) performed for the Digital Control Computers (DCCs), Common Process (CP) Computer and the Sequence of Events Monitoring (SEM) Computers identify the computer components that require assessment, replacement and additional spares for Darlington extended life. The pertinent CCAs were selected, and through appropriate screening, were approved as Darlington Scope Requests (DSRs) for inclusion into the Life Extension program.

The assessment of the computer Input/Output (I/O) cabling and connectors has identified that these components are in good condition for extended life and, as a result, will not be replaced. Subsequently the computer components that require replacement shall meet the following objectives, which are reflected in Part B – Preferred Alternative:

- Preserve the current system configuration and functionality, in order to minimize the installation, commissioning and maintenance costs.
- Maintain the capability of interfacing with the existing computer equipment already replaced for the station lifetime as part of the Projects 16-33509 and 16-33977, and also with the existing I/O cabling.

This project addresses the following DSRs and associated CCAs, which include approximately 30 types of obsolete computer

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

Type 2 Business Case Summary

Project #: 16-80078 Document #: D-BCS-69000-10008

Project Title: Darlington Digital Control, Common Process and Sequence of Events Monitoring Computer Aging Management, <Partial> <Definition> Release

Part A: Business Need

boards and devices that require reverse engineering, replacement and purchasing of lifetime spares to ensure the continuing operation of the DCC/CP/SEM computers until the extended plant end of life:

DSRs: TS0360-1, TS0360-3, TS0360-4, TS0360-5, TS0360-6, TS0360-9.

CCAs: 709, 710, 729, 732, 3459, 3461, 3462, 3463, 3464, 3465, 3466, 3467, 3468, 3469.

Assessments completed to date for each computer component criticality, failure rate and current spare parts availability, have determined that the DCC/CP/SEM computer obsolescence can be addressed in stages via individual projects. Much of the computer hardware has been replaced under capital projects 16-33509 and 16-33977, including the core computer. The modification to replace selected computer hardware was identified to the CNSC in the Integrated Implementation Plan (IIP), NK38-REP-03680-10185 R000, as Regulatory Action for CCAs 710 (Core Computer spares, Watchdog and Count Down Register (CDR) Printed Circuit Boards (PCB) replacement) and 729 (Transfer of Control and Input/Output system).

The summary of outstanding computer equipment (most are common between DCC, CP and SEM computers) that must be addressed for Darlington life extension as part of this project is:

- Over 20 types of I/O subsystem circuit boards reverse engineering with spares (IIP – regulatory)
- Watchdog and CDR circuit boards reverse engineering with spares (IIP – regulatory)
- Power supplies and power filters replacements with spares
- UNIBUS segment isolator/repeater reverse engineering with spares
- Disk and Tape emulator reverse engineering and spares
- Class II Automatic Transfer Relays replacement
- Computer keyboards and associated electronics reverse engineering with spares
- LA120 computer terminal reverse engineering with spares
- Communication circuit boards (e.g. Datalink, Delua) reverse engineering with spares
- DCC cabinet blower replacements with spares and DR11-M circuit board reverse engineering with spares (not currently listed in CCAs but an emerging DCC system health issue)

The replacement of the majority of these computer component types is a regulatory commitment.

Part B: Preferred Alternative: Reverse Engineering, Replacement and Purchasing of Lifetime Spares for Obsolete Computer Components

Description of Preferred Alternative

Most of the obsolete computer components were custom designed for Darlington, using 1980's technology, which can no longer be implemented. The preferred alternative is to reverse engineer the obsolete components using current technology, replace them in the plant and purchase sufficient spares to maintain the DCC/CP/SEM computers until the extended plant end of life.

The OPG engineering expertise will be used to prepare the engineering specifications for the obsolete computer components, and subsequently provide support to Supply Chain's external bidding process, to identify the qualified vendors able to perform the required reverse engineering. Once the vendors are selected and the costs of reverse engineering are known, a more accurate cost and schedule estimate for the detailed design can be done as part of the second stage of the project definition phase, which will be the subject of the next release request.

Two computer components, the CDR circuit board and Disk/Tape emulator, would not require reverse engineering, but only a design revision, if executed before most of their parts become obsolete and the original designer retires. Project cost savings of approximately $800k can be accomplished if the full design and procurement cycle for these computer components is included in the partial release for the project definition phase.

This BCS addresses the following scope of work:

- The vendor design revision and procurement of lifetime spares for the CDR circuit board and Disk/Tape emulator.

Part B: Preferred Alternative: Reverse Engineering, Replacement and Purchasing of Lifetime Spares for Obsolete Computer Components

Description of Preferred Alternative

- The preliminary engineering for the remaining obsolete computer components (i.e. engineering specifications and procurement of vendor design services).

Two additional BCSs will be submitted for approval in the future, as follows:

- Definition Phase – Full Release in Q4 of 2017 for the detailed design (internal and reverse engineering contracts)
- Execution Phase – Full Release in 2020 for cost of materials, installation and commissioning, and procurement of lifetime spares, after the detailed design is complete

The preferred alternative identifies a proactive approach to DCC/CP/SEM computer life extension, which would be more beneficial than performing the work reactively (i.e. replacing computer boards as they fail). The timing for the reverse engineering and installation of various computer components was determined after a thorough analysis of the current spare parts availability via CCAs, and subsequently the replacement need dates. Based on the past experience of replacing the DCC/CP/SEM computers with hardware emulators, it is anticipated that after the life extension work for this project is complete, the failure rate would decrease significantly.

Pros:

Although the purchase of computer components lifetime spares for 25-30 years is not a common approach, as opposed to 10-15 years, it was selected for the following reasons:

- It eliminates the need for another project start not later than 2030 with similar scope and cost as this one, which will have to address the obsolescence issues at that time and provide sufficient spares for the continuing DCC/CP/SEM computer operation until the extended plant end of life.
- Most of the computer components currently installed in the plant and the related spares lasted for over 25 years, and some of them are still expected to function for another 5-10 years.
- Enhanced packaging requirements for long term storage can be applied to the lifetime spares, by taking the same approach used for the DCC/CP/SEM computer replacements with hardware emulators (Project 16-33977).

The final decision on the lifetime spares approach (except for the CDR circuit board and Disk/Tape emulator) could be postponed until the Full Release for the Execution Phase in 2020, when a more accurate cost of materials and required quantities will be available.

Cons:

The lifetime spare approach will result in

- Higher inventory levels
- Risk of not specifying enough spares to last to the end of commercial operations
- Risk of specifying too many spares resulting in higher write-offs at the end of commercial operations
- Reduced return on asset once these lifetime spares are fully depreciated

Part E, Financial Evaluation, provides the estimate of cost difference between the preferred alternative and other alternatives.

Deliverables:	Associated Milestones (if any):	Target Date:
BCS – Definition, Partial Release for preliminary engineering and procurement of engineering services	**OAR Approval of BCS**	**DEC-2015**
CDR board and Disk/Tape emulator design documentation and prototypes	CDR and Disk/Tape emulator design revision accepted by OPG	DEC-2016
CDR board and Disk/Tape emulator lifetime spares procurement documentation	PO issued for CDR and Disk/Tape emulator lifetime spares	MAR-2017
BCS – Definition, Full Release for detailed design (internal and reverse engineering contracts)	**OAR Approval of BCS**	**OCT-2017**

Type 2 Business Case Summary

Project #: 16-80078 Document #: D-BCS-69000-10008
Project Title: Darlington Digital Control, Common Process and Sequence of Events Monitoring Computer Aging Management, <Partial> <Definition> Release

Deliverables:	**Associated Milestones (if any):**	**Target Date:**
Engineering specification, bid evaluation and vendor selection documentation for I/O subsystems reverse engineering	PO issued for I/O subsystems design services	DEC-2017
Engineering specification, bid evaluation and vendor selection documentation for Watchdog circuit board reverse engineering	PO issued for Watchdog circuit board design services	DEC-2017
Engineering specification, bid evaluation and vendor selection documentation for computer keyboards reverse engineering	PO issued for computer keyboards design services	AUG-2018
Engineering specification, bid evaluation and vendor selection documentation for Delua circuit board reverse engineering	PO issued for Delua circuit board design services	JUN-2019
Watchdog circuit board design documentation and prototype	Watchdog board design accepted by OPG	NOV-2019
Watchdog circuit board – materials procurement documentation	PO issued for Watchdog circuit board	JAN-2020
Engineering specification, bid evaluation and vendor selection documentation for Datalink circuit board reverse engineering	PO issued for Datalink circuit board design services	JUL-2020
Engineering specification, bid evaluation and vendor selection documentation for UNIBUS repeater reverse engineering	PO issued for UNIBUS repeater design services	SEP-2020
BCS – Execution, Full Release for materials cost, installation and commissioning and procurement of lifetime spares	**OAR Approval of BCS**	**DEC-2020**
Computer keyboards – materials procurement documentation	PO issued for computer keyboards	FEB-2021
Computer keyboards design documentation and prototypes	Computer keyboards design accepted by OPG	MAR-2021
I/O subsystems design documentation and prototypes	I/O subsystems design accepted by OPG	APR-2021
I/O subsystems – materials procurement documentation	PO issued for I/O subsystem circuit boards	JUN-2021
SEM computer keyboards replacement	Operations turnover	JUN-2021
LA120 computer terminal design documentation and prototype	LA120 computer terminal design complete	SEP-2021
Watchdog circuit board replacement	Operations turnover	NOV-2021
Delua circuit board design documentation and prototype	Delua board design accepted by OPG	DEC-2021
SEM I/O subsystem replacement	Operations turnover	DEC-2021
LA120 computer terminal – materials procurement documentation	PO issued for LA120 computer terminal	JAN-2022
CP computer keyboards replacement	Operations turnover	FEB-2022
Delua circuit board – materials procurement documentation	PO issued for Delua circuit board	APR-2022
CP I/O subsystem replacement	Operations turnover	SEP-2022
Datalink circuit board design documentation and prototype	Datalink board design accepted by OPG	DEC-2022
UNIBUS repeater design documentation and prototype	UNIBUS repeater design accepted by OPG	FEB-2023
Datalink circuit board – materials procurement documentation	PO issued for Datalink circuit board	APR-2023
UNIBUS repeater – materials procurement documentation	PO issued for UNIBUS repeater	MAY-2023
DCC computer keyboards replacement	Operations turnover	SEP-2023
LA120 computer terminal replacement	Operations turnover	NOV-2023
Delua circuit board replacement	Operations turnover	MAY-2024
DCC I/O subsystem replacement	Operations turnover	JUN-2024
Datalink circuit board replacement	Operations turnover	MAR-2025
UNIBUS repeater replacement	Operations turnover	JUN-2025

Part C: Other Alternatives

Summarize all viable alternatives considered, including pros and cons, and associated risks. Other alternatives may include different means to meet the same business need, and a reduced or increased scope of work, etc.

Alternative 2: Base Case – No Project

Current performance of the DCC/CP/SEM computers is monitored through the System Health Reporting. Most of the critical electronic components addressed in this project are approximately 30 years of age. There is currently an increasing trend of the failure rate for the aged components. However, as electronic components age, it is inevitable that there will be a point reached where the failure rate begins to increase more significantly. This, combined with very limited numbers of available spares, some exhausted, will put the continuing performance and operation of the DCC/CP/SEM computers at risk after 2020.

The obsolete computer components are no longer manufactured, as the old technology is out of date. Therefore no spare parts can be purchased to replace the defective components.

In summary, the "No Project" alternative is not recommended for the following reasons:

- Failure to meet the regulatory commitment of replacing the critical obsolete computer components by 2024
- Dual Unit DCC failure as a result of inability to perform repairs due to the lack of spare parts would force the Unit shutdown.

Alternative 3: Delay Work – Reverse Engineering, Replacement and Purchasing of Lifetime Spares for Obsolete Computer Components

A project start delay past 2016 is not recommended for the following reasons:

- The project duration is mainly dictated by the most diverse computer components, the I/O subsystems, which contain over 20 types of circuit boards and power supplies. In order to meet the regulatory commitment of replacing the I/O subsystems by 2024, the preliminary engineering must start in 2016, followed by the detailed design, reverse engineering and procurement by 2021, then define and execute a program to install and commission approximately 4,500 circuit boards in the DCC/CP/SEM computers over a 3-4 year period.
- One criterion for the timing of the reverse engineering and replacement of various computer components was based on the current spare parts availability. Project delays would increase the risk of DCC failures due to the lack of spare parts, which would subsequently lead to the Unit shutdown. This would result in significant production loss, which is difficult to quantify, but it could be several million dollars.
- The original designer of the CDR circuit board and Disk/Tape emulator would be able to revise their design prior to his retirement in 2016 for a substantially smaller cost (by approximately $800 k) than contracting out to various vendors for reverse engineering later on.
- OPG engineering expertise in Darlington control and monitoring computers built over a 30 year period, which is critical for the success of this project, will diminish due to retirements in the next few years. Project delays will translate into additional costs of up to $1,000 k for expertise substitution.

Part E, Financial Evaluation, provides the estimate of cost difference between "Delay Work" and other alternatives.

Alternative 4: Reverse Engineering, Replacement and Purchasing of Spares for 15 Years of Operations

This alternative is the same as the preferred one in terms project strategy, cash flows and total cost for the reverse engineering and replacement of the obsolete computer components. The only difference is the inventory cost as a result of a different approach for spares, 15 years instead of lifetime (25-30 years).

Pros:

Purchasing of spares for 15 years of operations will result in

- Lower inventory levels
- More accuracy in identifying the required number of spares for a shorter period of time (15 instead of 30 years)
- Higher return on asset, as the spares will not reach full depreciation until after 15 years

Cons:

Type 2 Business Case Summary

Project #: 16-80078
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Alternative 4: Reverse Engineering, Replacement and Purchasing of Spares for 15 Years of Operations

- The need for another project start not later than 2030 with similar scope and cost as this one, which will have to address the obsolescence issues at that time and provide sufficient spares for the continuing DCC/CP/SEM computer operation until the extended plant end of life.
- The cost of an additional project is much higher than the cost resulting from purchasing of spares beyond 15 years of operations, as indicated in the preferred alternative.
- High risk that the required engineering expertise, both internal and external, to execute a similar project will not be available after 2030.

Part E, Financial Evaluation, provides the estimate of cost difference between alternative 4 and other alternatives.

Part D: Project Cash Flows, NPV, and OAR Approval Amount

k$	LTD	2016	2017	2018	2019	2020	2021	Future	Total
Currently Released	-								
Requested Now	-	807	854						1,661
Future Required	-			3,060	6,485	13,010	10,824	12,213	45,592
Total Project Cost		807	854	3,060	6,485	13,010	10,824	12,213	47,253
Ongoing Costs	-								
Inventory	-		450	150	75	2,663	2,910	2,820	9,068
Grand Total		807	1,304	3,210	6,560	15,673	13,734	15,033	56,321

Estimate Class:	Class 4	**Estimate at Completion:**	[redacted]
NPV:	N/A	**OAR Approval Amount:**	$2,111 k

Additional Information on Project Cash Flows (optional):

Inventory costs have been added to reflect the amounts required for the purchase of lifetime spares.

[redacted] contingency is included in the amounts requested now.

[redacted] contingency is included in the future required amounts and inventory.

Part E: Financial Evaluation

k$	Preferred Alternative	Base Case	Delay Work	Alternative 4	
Project Cost	56,321	N/A	58,121	103,574	
NPV	N/A		N/A	N/A	
Other (e.g., IRR)					

Summary of Financial Model Key Assumptions or Key Findings:

1. [redacted] contingency applied to all alternatives

The estimate for the vendor reverse engineering is based on the assessment of each computer component complexity and information from recent contract values related to the DCC replacement project 16-33977. However, relatively small cost deviations on the reverse engineering of individual computer components may result in significant variance for the overall cost of a large number (over 30) of computer board and device types that require replacement.

The costs of materials are mostly estimated based on individual computer component complexity. Given the large number of computer boards and devices that require replacement (approximately 4,500), the resulting total cost of materials is not sufficiently accurate.

Therefore [redacted] contingency was currently applied to the future costs of both reverse engineering and materials (including

Summary of Financial Model Key Assumptions or Key Findings:

inventory). The outcome of this partial release for the definition phase will be a more accurate cost estimate, based on vendor proposals, which will be reflected in the future release requests.

2. Inventory costs incorporated in all alternatives

Inventory costs are the only difference between alternative 4 and the preferred one. Therefore they were incorporated in all alternatives for proper evaluation.

3. Project cost estimate for Preferred Alternative

See Part D, Grand Total of $56,321k.

4. Project cost estimate for Delay Work

Preferred alternative cost of $56,321k plus the following additional costs: $800k for delayed reverse engineering of CDR circuit board and Disk/Tape emulator, and $1,000k for expertise substitution.

5. Project cost estimate for Alternative 4

Two similar projects, one starting in 2016, the other in 2030, each costing $47,253k for a total of $94,506k.
Inventory costs: two $4,534k amounts for 15 year period spares after each project, for a total of $9,068k.

NOTES

- The cost estimate for Preferred Alternative will be slightly higher, due to additional inventory cost for lifetime spares and reduced return on asset, which are difficult to quantify at this stage. However, these additional costs would be absorbed by the applied [redacted] contingency.
- Present dollar value was used for the cost estimate of the second project and related inventory.
- The second project identified in Alternative 4 could potentially have a higher cost, as required engineering expertise may not be available in 2030.
- The cost of Delay Work listed at $58,121k is likely to be higher by several million dollars. Potential production loss as a result of DCC failures due to the lack of spare parts, resulting in Unit shutdown, is hard to quantify, and therefore not included in this financial evaluation.

Part F: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	There is a risk that the costs of vendor reverse engineering and materials (computer components replacements) will be higher than estimated.	Estimate was performed based on past experience for similar computer component replacements. [redacted] contingency was added for both reverse engineering and materials costs.	Medium	Low
Scope	There is a risk that approval will not be obtained for lifetime spares.	Justification will be submitted to Materials Review Board, stating that other alternatives for spare parts would increase the overall costs by $47,253 k.	High	Medium
Schedule	There is a risk that the reverse engineering of a large number of computer component types (over 30 circuit boards and devices) in parallel by	Contract out the reverse engineering for groups of functionally related computer components, in order to eliminate or minimize the need for coordination	High	Medium

Part F: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
	various vendors will delay the schedule.	between vendors. Apply [redacted] contingency to the vendor committed schedules. Provide continuous vendor oversight during detailed design phase.		
Resources	There is a risk that internal engineering expertise will be lost due to retirements, as this is a long project to be executed over a 9 year period.	Knowledge retention program in place to preserve the required core of expertise for internal design, product validation testing, installation and commissioning, qualified vendor oversight and technical support.	High	Low
Quality/ Performance	There is a risk that vendor design deliverables and/or manufactured computer components will not meet the design and QA requirements, which will result in prolonged OPG review/acceptance time.	Select vendors with appropriate QA program that previously performed high quality work for OPG. Provide continuous vendor oversight during detailed design phase. Computer component replacements to undergo Factory and Site Acceptance Test.	Medium	Medium
Technical	There is a risk that technical challenges will occur for at least some of the large number of computer component types during the design and validation testing.	Apply recent lessons learned and provide continuous vendor oversight during detailed design phase. Maintain sufficient in-house engineering expertise to be able to provide troubleshooting and technical support to the vendors.	Medium	Medium

Part G: Post Implementation Review (PIR) Plan

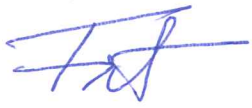
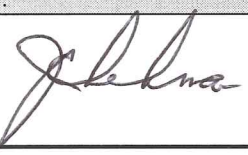
☐ It is determined appropriate that only a Project Closure Report (PCR) is needed as the PIR for this project, due to its straight forward deliverables, which do not require any measures other than confirmation of completion or delivery.

Type of PIR Report	Target In-Service or Completion Date	Target PIR Completion Date
Comprehensive PIR	JUN-2025	JUN-2026

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Equipment Reliability	YELLOW indicator in System Health Report for average number of functional failures (RED for Unit 4 DCC)	Improve the average number of failures indicator to WHITE in System Health Report	Health Reports and SCRs	Computers and Control Design
Equipment Maintainability	YELLOW indicator in System Health Report for spare parts	Improve the spare parts indicator to WHITE in System Health Report	Verify spares available in inventory	Computers and Control Design

Type 2 Business Case Summary

Project #: 16-80078
Document #: D-BCS-69000-10008
Project Title: Darlington Digital Control, Common Process and Sequence of Events Monitoring Computer Aging Management, <Partial> <Definition> Release

Approvals			
	Signature	**Comments**	**Date**
The recommended alternative, including the identified ongoing costs, if any, represents the best option to meet the validated business need.			
Recommended by (Project Sponsor): Bobby Fichman Senior Manager, Computers and Control Design		FINANCIAL IMPACT OF THE PREFERRED ALTERNATIVE TO BE VALIDATED PRIOR TO NEXT RELEASE OF BCS	2015-NOV-20
I concur with the business decision as documented in this BCS.			
Finance Approval: ~~John Sawler~~ GEORGE TURNER Director, Controllership per OPG-STD-0076			2015. NOV. 24
I confirm that this project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.			
Approved by: Jeff Lehman Director, Station Engineering per OAR 1.1		Approved as PAC	Nov 24/15

Type 2 Business Case Summary

Project #: 16-80078
Document #: D-BCS-69000-10008
Project Title: Darlington Digital Control, Common Process and Sequence of Events Monitoring Computer Aging Management, <Partial> <Definition> Release

Appendix A: Summary of Estimate										
Project Number:	16-80078									
Project Title:	Darlington Digital Control, Common Process and Sequence of Events Monitoring Computer Aging Management									
Choose an item.	**LTD**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Future**	**Total**	**%**
OPG Project Management	-	60	90	192	192	204	204	408	1,350	2.8
OPG Engineering (including Design)	-	360	480	576	576	600	600	1200	4,392	9.3
OPG Procured Materials	-				100	3,725	4,060	3,920	11,805	25.0
OPG Other	[redacted]									
Design Contract(s)										
Interest										
Subtotal										
Contingency										
Total	-	**807**	**854**	**3,060**	**6,485**	**13,010**	**10,824**	**12,213**	**47,253**	**100**
Inventory	-		450	150	75	2,663	2,910	2,820	9,068	

Notes			
Project Start Date	JAN-2016	**Total Definition cost** (excludes unspent contingency for Nuclear)	[redacted]
Target In-Service (or AFS) Date	JUN-2025	**Contingency included in this BCS** (Nuclear only)	
Target Completion Date	DEC-2025	**Total contingency released plus contingency in this BCS** (Nuclear only)	
Escalation Rate	2.0%	**Total released plus this BCS without contingency** (Nuclear only)	
Interest Rate	5.26%	**Total released plus this BCS with contingency** (Nuclear only)	$1,661 k
Removal Costs	$150 k	**Estimate at Completion** (includes only spent contingency for Nuclear)	[redacted]

Prepared by:		**Approved by:**	
Octavian Dumitru Project Leader Computers and Control Design	Date 2015-11-04	Bobby Fichman Senior Manager Computers and Control Design	Date 2015-11-20

Type 2 Business Case Summary

Project #: 16-80078
Document #: D-BCS-69000-10008
Project Title: Darlington Digital Control, Common Process and Sequence of Events Monitoring Computer Aging Management, <Partial> <Definition> Release

Appendix B: Comparison of Total Project Estimates and Project Variance Analysis

Comparison of Total Project Estimates

Phase	Release	Approval Date	Total Project Estimate in k$ (by year including contingency)						Future	Total Project Estimate
			2016	2017	2018	2019	2020	2021		
Definition	Partial		807	854	3,060	6,485	13,010	10,824	12,213	47,253

Project Variance Analysis

Choose an item.	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OPG Project Management			1,350		First BCS, no variance
OPG Engineering (including Design)			4,392		
OPG Procured Materials			11,805		
OPG Other			[redacted]		
Design Contract(s)					
Interest					
Subtotal			[redacted]		
Contingency			[redacted]		
Total			**47,253**		

Type 3 Business Case Summary

To be used for investments/projects meeting Type 3 criteria in OPG-STD-0076.

Executive Summary and Recommendations

Project Information			
Project #:	80111	Document #:	D-BCS-42100-10001
Project Title:	DN Generator Stator Core Capital Spare		
Class:	☐ OM&A ☐ Capital ☒ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	Investment Type:	Sustaining
Phase:	Execution	Release:	Full
Facility:	Darlington	Target In-Service or Completion Date:	2019

Project Overview

We recommend the release of $35M, including [redacted] of contingency.
The estimated total project cost is $35M, including [redacted] of contingency.

The quality of the estimate for this release is Class 1, and for the total project is Class 1.

This release will fund the following scope of work:

- Purchase of a Darlington spare generator stator core mid section complete with improved stator windings.
- Provide long term storage and maintenance cost to keep the spare stator ready at all times.

Problem Statement/Business Need:

OPG does not currently have a spare generator core on hand, and in the event of a catastrophic failure would be in a forced outage for up to two (2) years (the lead time for an urgent stator core is approximately eighteen (18) months, plus six (6) months installation). Based on OEM and industry experience, expected lifetime of a generator core is forty (40) years and Darlington stators are showing signs of degradation. Degredation mechanisms are age related and it is not expected that Darlington Stators will reach end of second life without major failures or significant maintenance/refurbishment. A conservative approach is to acquire a spare stator which will allow replacement(s)/rewind(s) to allow reliable station operaton to 2050.

Summary of Preferred Alternative:

A stator mid section (stator core complete with improved design of stator windings) is procured from the generator OEM vendor. Materials request is initiated now with an approximate delivery in 3 years. Since it is a long lead item, the spare stator will be delivered in July 2019 and is available to support planned refurbishment activities for Unit 3 Refurbishment starting in 2020. Two stator winding rewinds are accomplished utilizing the spare. Improved stator winding design is installed in two units during their refurbishment outage. Improved stator reliability on these units post swap and an improved spare is available post refurbishment outages for spare coverage on 4 units on the remaining second life of Darlington to approximately 2050.

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Type 3 Business Case Summary

Project #: 80111
Project Title: DN Generator Stator Core Capital Spare, <Full> <Execution> Release

Document #: D-BCS-42100-10001

Project Overview

Project Cash Flows, NPV, and OAR Approval Amount

M$	LTD	2015	2016	2017	2018	2019	2020	Future	Total
Currently Released									
Requested Now						35			35
Future Required									
Total Project Cost						35			35
Ongoing Costs								1	1
Grand Total						35		1	36

Estimate Class:	Class 1	**Estimate at Completion:**	[redacted]
NPV:	$4M	**OAR Approval Amount:**	$36M

Additional Information on Project Cash Flows (optional):

This BCS provides OAR approval for the materials request to acquire a Darlington Spare Generator Stator Core mid section complete with stator windings. For this material request there will be progress payments. These payments will be collected in a pre-paid account until receipt of the stator is accomplished. The economic benefit identified as NPV above has the following assumptions on progress payments: 2015 – 26%, 2016 – 12%, 2017 – 12%, 2018 – 30% 2019- 20%.To keep the spare stator ready at all times, incremental storage and maintenance cost ($1M OM&A) are required for long term spare storage from post refurbishment outages to 2050.

Approvals

	Signature	Comments	Date
The recommended alternative, including the identified ongoing costs, if any, represents the best option to meet the validated business need.			
Recommended by (Project Sponsor): Brian Duncan SVP Darlington		This BCS covers purchase of a new stator only. Rewind of 2 existing stators will need a separate BCS.	Sept 10/2015
I concur with the business decision as documented in this BCS.			
Finance Approval: Carla Carmichael VP, Nuclear Finance per OPG-STD-0076		Finance to follow up forensic OAR compliance.	Sept 15/15
I confirm that this project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.			
Approved by: Glenn Jager Chief Nuclear Officer, per OAR element 1.5			30 SEPT 2015

ONTARIO POWER GENERATION

Records File Information:
Records SCI/USI Retention
- See Guidance Section

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Type 3 Business Case Summary

Document #: D-BCS-42100-10001

Project #: 80111
Project Title: DN Generator Stator Core Capital Spare, <Full> <Execution> Release

Business Case Summary

Part A: Business Need

The currently installed generator stators at Darlington are the original Brown Boveri Canada BBC models (HTG691508) which were installed in the early 1990s, and are four poles type generator that operate at 1800 RPM. Based on industry standards and OEM recommendations, the expected lifetime of generator stator is approximately forty (40) years. The Stator is composed of the stator core and stator windings.

The stator core provides a low reluctance path for the magnetic flux required for induction of the output voltage in the stator windings. Eddy current loses and the resultant heat is minimized within the core by the use of many very thin laminations electrically insulated from each other. The laminations are clamped together to minimize lamination vibrations and insulation breakdown, and eventual core destruction by flux heating and core melt. Critical parameters affecting core life are:

- Maintaining core temperatures within the limits of core insulation
- Maintaining the core clamping pressure above a level at which lamination vibration would lead to lamination cracking and breaking from the core
- Prevent overfluxing the core that would breakdown insulation between the laminations resulting in high eddy current and stator core melting.

An example of a generator stator core melt catastrophic failure is provided in Appendix E.

The stator windings are composed of bars mechanically secured in core slots and in end winding support structures. Critical parameters affecting winding life are:

- Maintaining operating temperatures within thermal limits of winding insulation
- Preventing insulation abrasion from relative motions at winding supports.

Darlington has started to exhibit signs of stator core and stator winding degradation as detailed below:

- Some of the end wedges have been found partially loose by visual inspection and also by Diagnostic Inspection with Rotor in Situ (DIRIS) tapping. This is an increasing trend.
- Partial discharge indications at some phase separations.
- Greasing (or signs of movement / rub) at core press fingers.
- The end winding supports were found loosening; and tightened to specifications was required.

A generator vendor (GE) indicates that its fleet of generators experiences increasing failure rates as generators age. Illustrative failure rates and their "bathtube" curves are in included in Appendix E.

The active failure mechanism associated with these findings is the abrasion between the stator bars and core near the slot exits. Grease is the product of wear between the stator bars and core teeth in the presence of seal oil. Stator bars vibrate continuously during operation and end windings also move during grid disturbances or sudden change in load. Based on recent inspections, the units which carry the most risk are Units 3 and 4 as the number of loose end wedges and slot exits are increasing.

OEM's OPEX has shown that loosening of stator core compression appears within several years at a level where laminated core re-tightening is no longer effective. The end sections in particular, must be inspected during overhauls. Note that a low flux measurement cannot find loose laminations as long as the sheets are not short-circuited and provides only limited information about the electrical conditions of the end sections.

EPRI report 1007960 "Main *Generator & Exciter Life Cycle Management Plans at STARS Nuclear Plants*" provides a good summary of generator issues with the US nuclear fleet. Of the four multi-unit sites covered in the report, two have recommended a Long Term Stator Core Spare for life extension to 60 years. A single spare would cover three operating units at Palo Verde. The two unit site at Diablo Canyon was assessed as having shorter that nominal 60 year life on both the stator core and stator winding. A spare stator was recommended in the 60 year Life Cycle Management (LCM) Plan for both sites.

The site specific report for South Texas project, 1009159 " *Life Cycle Management Plan for Main Generator at South Texas Project,* identified that the largest uncertainties in its probabilistic analysis of Net Present Value of the Life Cycle Plan included the stator failure rate and resultant lost production. Two specific items are referenced from these reports:

- *"Core failures are very infrequent. However if and when they do occur, they can put a unit out of service for a period*

Type 3 Business Case Summary

Project #: 80111
Project Title: DN Generator Stator Core Capital Spare, <Full> <Execution> Release

Part A: Business Need

of up to two years, or more given that no spare or replacement stator is available." (1009159)

- *We conclude for generators, the benefit that drives the choice of optimum LCM is completely dominated by the estimated saved cost of lost generation."* (1007960)

OPG does not currently have a spare generator core on hand, and in the event of a catastrophic failure would be in a forced outage for up to two (2) years (the lead time for an urgent stator core is approximately eighteen (18) months, plus six (6) months installation). Therefore, it is necessary to procure a spare stator core and have it available by 2019 to limit the consequences of a catastrophic failure. In the case of a failure, the spare stator core would be utilized to limit the duration of a forced outage.

The purchase of a spare stator core is aligned with the long-term equipment strategy for the generators and is integrated with Refurbishment Project plans. The purchase will allow for some flexibility in-terms of Refurbishment scope. Based on the current unit generator component condition assessments (CCA), the spare is planned to be installed in Unit 3 during its refurbishment outage. The original stator core from Unit 3 will be rewound and installed in Unit 4 during its refurbishment. At present it is expected that Unit 1 and Unit 2 stators may last until the end of life. The stator removed from Unit 4 will be rewound and provided spare coverage for all four units after completion of the refurbishment outages. Rewound stators will last until station's end of life in 2050 with low risk of significant failure. Per expert opinion, the risk of significant failure for Units 1 and 2 can be mitigated by; performing expanded online/offline monitoring, executing a minimum set of refurbishment scope and securing a spare stator.

The windings of the new stator core spare will be of a different (improved) design. During refurbishment outages and prior to a stator rewind it is vital that the entire laminated core and the press plate be inspected visually and electrically. If the laminated core or the press plate shows any deteriation, then (as a long term solution) a so called stator midsection replacement is recommended, requiring a stator mid section spare as a contingency to refurbishment generator condition assessments perfomed during refurbishment outages.

Expert opinion also has concerns about stator rewinds done insitu, with the quality of rewind not expected to match the standards of a OEM or vendor factory setting. This is expected to contribute to higher risk of failure or shorter lifespan for cores rewound in situ. Therefore the acquistion of a spare stator is recommended where manufacture is in a factory setting vs an emergent rewind insitu following a generator stator failure. To have the stator available for the Unit 3 refurbishment window the manufacture must begin now.

Part B: Preferred Alternative: Purchase of Spare Generator Stator Core Complete With Upgraded Stator Windings

Description of Preferred Alternative

A stator mid section (stator core complete with improved design stator windings) is procured from the generator OEM vendor. Materials request is initiated now with an approximate delivery in 3 years. The spare is available to support planned refurbishment activities for Unit 3 Refurbishment. Two stator rewinds are accomplished utilizing the spare. Improved stator winding design is installed in two units during their refurbishment outage. Improved stator reliability on these units post swap and an improved spare is available post refurbishment outages for spares coverage on 4 units on the remaining second life of Darlington to approximately 2050.

Economic analysis shows positive NPV for this alternative based on a conservative low probability of a stator core failure, and long duration forced outages (> 2 years) as the base case, and shorter duration outages (~95 days) when a spare is available.

Positive NPVs are also estimated if only higher probability random stator winding failures are assumed (at published EPRI failure rates) for Unit 1 and 2 for the remainder of second life at Darlington.

Deliverables:	Associated Milestones (if any):	Target Date:
Stator Core Mid Section Design Complete	Stator ordered	July 2017
Manufacturing Complete	Successful Factory Acceptance Test	Oct 2018
Spare Available	Receipt of Stator at Darlington	July 2019

Type 3 Business Case Summary

Project #: 80111
Project Title: DN Generator Stator Core Capital Spare, <Full> <Execution> Release

Part C: Other Alternatives

Summarize all viable alternatives considered, including pros and cons, and associated risks. Other alternatives may include different means to meet the same business need, and a reduced or increased scope of work, etc.

Alternative 2: Base Case – No Capital Spare

This alternative is not recommended. There is significant risk for Units 3 and 4, which have exhibited degradation. Without a spare stator a random failure or age related failure associated with this degradation causes extended forced outages of 2 years or greater while a replacement stator is acquired and installed. Expidited procurement would increase the cost of stator core midsection from 35 M$ to 45 M$.

Alternative 3: N/A

Alternative 4: N/A

Alternative 5: N/A

Part D: Project Cash Flows, NPV, and OAR Approval Amount

M$	LTD	2015	2016	2017	2018	2019	2020	Future	Total
Currently Released	0								
Requested Now	-					35			35
Future Required	-								
Total Project Cost						35			35
Ongoing Costs	-							1	1
Grand Total						35		1	36

Estimate Class:	Class 1	**Estimate at Completion:**	[redacted]
NPV:	$4M	**OAR Approval Amount:**	$36M

Additional Information on Project Cash Flows (optional):

This BCS provides OAR approval for the materials request to acquire a Darlington Spare Generator Stator Core mid section complete with stator windings. For this materials request there will be progress payments. These payments will be collected in a pre-paid account until receipt of the stator is accomplished. The economic benefit identified as NPV above has the following assumptions on progress payments: 2015 – 26%, 2016 – 12%, 2017 – 12%, 2018 – 30% 2019- 20%.

To keep the spare stator ready at all times, incremental storage and maintenance cost ($1M OM&A) are required for long term spare storage from post refurbishment outages to 2050.

Part E: Financial Evaluation

Choose an item.	Preferred Alternative	Base Case	Delay Work	Alternative 4	Alternative 5
Project Cost	[redacted]	$0			
NPV	4-10 M$				
Other (e.g., IRR)					

Summary of Financial Model Key Assumptions or Key Findings:

The financial assessment utilized two different approaches to estimate the economic benefit of having a stator capital spare and initiating stator core rewinds on Darlington Unit 3 and 4 during their refurbishment outages. They are:

- Assume a stator winding failure rate based on the US nuclear experience captured in EPRI report 1009159 "Life Cycle Management Plan for Main Generator and Exciter at South Texas Project" [0.016 failures/year based on 115 failure states on 65 generators over 12 years on 104 US nuclear plants]. In this methodology only the failure rate forecast changed, and a stator in-situ rewind was assumed at 95 days.

Type 3 Business Case Summary

Project #: 80111
Project Title: DN Generator Stator Core Capital Spare, <Full> <Execution> Release

Summary of Financial Model Key Assumptions or Key Findings:

- Assume a much lower probability of complete stator catastrophic failure (1/20 of failure probability assumed above = 0.0008 failures/year). Without a spare stator the forced outage duration was assumed at 2 years for procurement and installation. If a spare was on hand this duration was reduced to 95 days.

Both of these cases were evaluated at a constant failure rate, and an increasing (bath tub curve) failure rate to assess the impact of aging degradation and increasing risks as the stator core and windings suffer age related degradation mechanisms. In the second scenario the failure rate assumed at 30 years was double at 35-40 and tripled by 45 years in service. This matches the GE large generator fleet experience. The assessment results are shown in the following table.

Economic Assessment NPV (M$)	Constant Uniform Failure Rate	Increasing Failure Probability
Stator Winding Failure – greater risk to D3/D4 until core and winding replaced – (0.016 failures/year)	10	106
Catastrophic Stator Core Failure (0.0008 failures/year). 2 year FO if spare stator not available. 95 day FO is spare available	4	36

Part F: Qualitative Factors

Part G: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	There is a risk that spare acquisition cost is greater than forecast.	Inclusion of contingency.	Low	Low
Scope			Choose an item.	Choose an item.
Schedule	There is a risk that the stator mid section is not available for the Unit 3 refurbishment window	Start procurement activities now and monitor schedule.	Low	Low
Resources			Choose an item.	Choose an item.
Quality/ Performance	There is a risk that improved stator winding design is ineffective.	It is planned to have the OEM vendor provide the updated design and manufacture. Reverse engineering of existing design is not required.	Low	Low
Technical	There is a risk around the non-like for like replacement stator	Proprietary OEM drawing and design will ensure the same form/fit/function	Low	Low

Additional Risk Analysis:

Part H: Post Implementation Review (PIR) Plan

Type of PIR Report	Target In-Service or Completion Date	Target PIR Completion Date
Simplified PIR	2019-07-16	2023-02-28

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Stator Mid Section Spare Available	No spare available	Spare utilized to initiate stator rewinds, first unit - Unit 3	Successful RTS on Unit 3	Performance Engineering

Part I: Definitions and Acronyms

Type 3 Business Case Summary

Project #: 80111
Project Title: DN Generator Stator Core Capital Spare, <Full> <Execution> Release

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Project #: 80111

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Project Title: DN Generator Stator Core Capital Spare, <Full> <Execution> Release

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Type 3 Business Case Summary

Project #: 80111
Project Title: Spare Generator Stator Core, <Full> <Execution> Release

Document #: D-BCS-42100-10001

Appendix A: Summary of Estimate										
Project Number:	80111									
Project Title:	Spare Generator Stator Core									
M$	LTD	2015	2016	2017	2018	2019	2020	Future	Total	%
OPG Project Management										
OPG Engineering (including Design)										
OPG Procured Materials	[redacted]									
OPG Other										
Design Contract(s)										
Construction Contract(s)										
EPC Contract(s)										
Consultants										
Other Contracts/Costs										
Interest										
Subtotal										
Contingency										
Total						35			35	

Notes			
Project Start Date	DEC 2014	Total Definition cost (excludes unspent contingency for Nuclear)	[redacted]
Target In-Service (or AFS) Date	N/A	Contingency included in this BCS (Nuclear only)	
Target Completion Date	JULY 2019	Total contingency released plus contingency in this BCS (Nuclear only)	
Escalation Rate	0%	Total released plus this BCS without contingency (Nuclear only)	
Interest Rate	N/A%	Total released plus this BCS with contingency (Nuclear only)	$35M
Removal Costs	NA	Estimate at Completion (includes only spent contingency for Nuclear)	[redacted]

Prepared by:	Approved by:
Ken Lee Section Manager (Acting), Darlington Performance Engineering Date: SEP - 8 2015	Dave Burger Manager, Darlington Performance Engineering Date: Sept. 9, 2015

Type 3 Business Case Summary

Project #: 80111
Project Title: Spare Generator Stator Core, <Full> <Execution> Release

Appendix B: Comparison of Total Project Estimates and Project Variance Analysis

Comparison of Total Project Estimates

Phase	Release	Approval Date	Total Project Estimate in M$ (by year including contingency)						Future	Total Project Estimate
			2015	2016	2017	2018	2019	2020		
Execution	Full	Sept 2015					35			35

Project Variance Analysis

M$	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OPG Project Management					
OPG Engineering (including Design)					
OPG Procured Materials					
OPG Other					
Design Contract(s)					
Construction Contract(s)					
EPC Contract(s)					
Consultants					
Other Contracts/Costs					
Interest					
Subtotal					
Contingency					
Total					

First Release – Project Variance Analysis not required.

Type 3 Business Case Summary

Project #: 80111
Project Title: Spare Generator Stator Core, <Full> <Execution> Release

Appendix C: Financial Evaluation Assumptions

Key assumptions used in the financial model of the Project are (complete relevant assumptions only):

Appendix D: References

EPRI Report 1007423 "Life Cycle Management Planning Source Book, Volume 5: Main Generator", Jul 2003
EPRI Report 1007960 "Main Generator and Exciter Life Cycle Management Plans at STARS Nuclear Plants", Sep 2003
EPRI Report 1009159 "Life Cycle Management Plan for Main Generator and Exciter at South Texas Project", Sep 2003
EPRI Report 1014783 " Plant Support Engineering: Main Generator End-of-Life and Planning Considerations, Jun 2007
GE Energy, "GE Generator Fleet Experience and Available Refurbishment Options, [GER-4223], (01/04)
NK38-REP-09701-0322754 " Darlington Turbine And Generator Condition Assessment", 29 Jan 2010

Appendix E: Additional Information

Table 1 below is a summary of failure rate forecasts for 6 US nuclear facilities extracted from EPRI Report 1007960 "Main Generator and Exciter Life Cycle Management Plans at STARS Nuclear Plants"

Table 1 - Summary of EPRI Report 1007960: "Main Generator and Exciter Life Cycle Management Plans at STARS Nuclear Plants:

Long Term Stator Core Spare for 60 Year Operation	Long Term Stator Rewind 60 Year Operation	Re-wedge Stator	Site Name	Number of Units	Stator Core Lifetime Estimate (years)	Stator Winding Lifetime Estimate (years)	Range of Stator Failure Rate Forecasts (Failures/year) for 40 year operation [Historical]	Site Stator Experience [SW – Stator Winding] [SC – Stator Core]
No	Yes	Yes	**Wolf Creek**	1	60	30	0.016-0.100 [0.120]	SW – loose windings & greasing, oil ingress SC – No significant findings
No	No	No	**Calloway**	1	60	40	0.016-0.060 [0.110]	SW – loose windings & greasing SC – No significant findings
Yes	No	No	**Palo Verde**	3	60	40-60	0.015-0.030 [0.022]	SW – Winding water leak in early life, oil ingress SC – No significant findings
No	No	No	**South Texas Project**	2	60	60	0.038 [0.038]	SW – Winding water leak, re-wedge due to looseness, oil ingress SC – Retightening performed & will be redone
Yes	No	No	**Diablo Canyon**	2	40-60 (60 if enact aggressive condition monitoring and corrective maintenance)	30-40	0.015-0.060 [0.120]	SW – Water leak, oil ingress, winding failure SC – Core bolt elongation corrected by retightening
No	No	No	**Comanche Peak**	2	60	60	0.010 [0.00]	SW - Oil ingress SC – No significant findings

Example of a Catastrophic Stator Core Failure

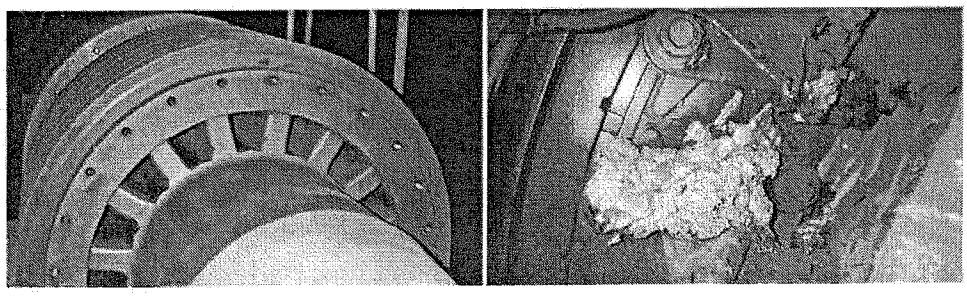
Type 3 Business Case Summary

Project #: 80111
Project Title: Spare Generator Stator Core, <Full> <Execution> Release

Appendix E: Additional Information

On November 24, 2000, PacificCorp experienced a massive generator failure at its Hunter Power Plant in Castle Dale, Utah. Post-event inspection of the generator revealed a serious failure of the stator core—a stacked laminated cylindrical structure nearly 19 feet long and more than 8 feet across—which had begun to partially melt. At the time, the generator was operating at 415 megawatts, below its maximum capacity. Sparks and heavy arcing were observed before the unit tripped automatically, shutting the system down within 5.5 minutes.

The cause was investigated. It was determined that three narrow wormhole-like tunnels had melted along the lengthwise axis of the stator of the generator, resulting in some 200 pounds of molten metal flowing out over the end of the stator core. We also determined that a small, inter-laminar short grew into a major melt zone that triggered two other melt areas caused by intense over-fluxing of the magnetic circuit in the stator core. The resulting induction heating was high enough to melt the steel laminations.



Bath Tube Failure Curve Experience of GE Generator Fleet

The GE fleet is over 6000 installed medium and large generators.

(From GER 4223 GE Generator Fleet Experience and Available Refurbishment Options (01/04)

Fig 2a Turbine Generator Reliability Trend

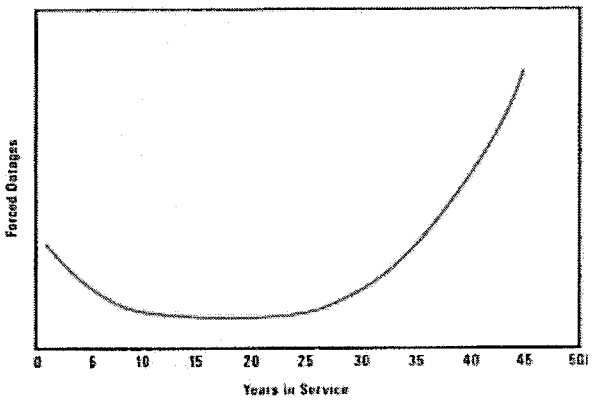


Fig 2b Turbine Generator Reliability Improvement Trend