Fatigue crack initiation experiments will be conducted in air on both ex-service material and unirradiated material, as well as in a reactor water environment on unirradiated material to support regulatory commitments to use the current 'interim approach' and make subsequent changes to the evaluation procedures. A task group is currently evaluating the benefit of testing ex-service irradiated material in a reactor water environment. Pickering B will be able to demonstrate acceptability of more flaws, remove cycle limitations imposed by fatigue crack initiation, and minimize inspection requirements. Third Party external experts have confirmed acceptability of proposed program for evaluation of fatigue for irradiated material in reactor environment.

Probabilistic Core Assessments and Leak-Before-Break
The Probabilistic Core Assessment tool will be updated to reflect the current understanding of fuel channel degradation, as determined by other parts of this project, to offer a more realistic assessment of reactor core integrity. In addition, the tool will be qualified to the requirements of CSA N286.7, as an Industry Standard Tool (IST).

Improvement of the current Leak-Before-Break methodology to include a probabilistic approach of selected parameters is also being explored.

The project work will also include ensuring that condition monitoring prescribed in the OPG Fuel Channel Aging and Life Cycle Management Strategy and Plan is executed. The resultant data is essential to determine when fitness-for-service limits will be reached. In addition, it is essential that experimental results be analyzed and technical basis documents developed to support improved methodologies meeting technical and regulatory requirements.

5/ QUALITATIVE FACTORS

This work is part of an industry-wide initiative to gain greater certainty on the fitness-for-service limits for fuel channels. As this is being executed as a COG Joint project, it gives all industry partners important information concerning the timing of possible refurbishment activities. This will help the industry to optimize refurbishment plans, and may reduce the strain on resources to conduct refurbishment of many units in parallel. It would also help to manage a significant impact on the availability of base load nuclear generation in the Province.

Even if it is determined that the current base case is accurate, and Darlington refurbishment activities must be brought forward in time from 2016, this project provides valuable knowledge to enable an orderly approach to Darlington unit refurbishments and to the management of remaining service life of Pickering B units.

This work is part of a comprehensive Fuel Channel Life Management Plan which has been developed to drive to higher levels of confidence in longer pressure tube lives for the OPG nuclear units. Achieving higher levels of confidence has many benefits which are not easy to quantify including providing enhanced flexibility to OPG to:

(i) Manage the lead time constraints, and other preparatory issues (e.g. resource constraints, long lead time material, project mobilization) and manage the overall refurbishment schedule for the nuclear units, particularly the uncertainty around the refurbishment schedule for the Darlington units given current uncertainties in unit service life;
(ii) Manage the uncertainties created by any potential delays to new nuclear in-service dates; and
(iii) Manage the potential significant capital and resource requirements and financial sustainability of OPG associated with multiple simultaneous refurbishments and new build nuclear campaigns;
(iv) Enhance OPG credibility with CNSC
(v) Manage the Provincial power supply

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6/ RISKS ANALYSIS (See Attachment D for details)

Risk Associated with the Fuel Channel Life Management Portion (OM&A)

Low 1 to 3	Medium 4 to 9	High 10 to 25

Probability \ Impact	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Risk Description	Mitigating Activities	Mitigation	Probability X Impact: Finance	Schedule	Quality	Corporate Reputation	Regulatory	Health & Safety	Environmental	Nuclear Safety	Risk Rating (1 to 25)
Specialized resources may be unavailable to do the work in the required timeframe.	Close collaboration with the COG fuel channel work program to ensure optimum utilization of existing resources. OPG Senior Management involvement to ensure vendor commitments is met.	Before		16							16
		After		12							12
Schedule delay due to incomplete planning of the following areas: a) Discovery issue resolution process b) Commissioning of new process and facility c) CNSC review of submission documents	a) COG Project Manager to issue instructions and communicate on need to report promptly issues/ unusual results for resolution b) Prepare equipment commissioning plan. Involve more technical experts. Obtain external consultant services from internationally established experts. c) Agree on closure criteria ahead of review process to establish clear acceptance requirements.	Before	15	20							20
		After	10	10							10
Results indicate degraded properties which impact on continued operations (including other stations). Specific examples are as the following: a) Results from inspections show increased D-uptake rate in RJ b) Irradiated spacer properties indicate that properties are continuing to degrade	Pre-establish performance criteria and evaluate impact Monitor results progressively with hold points to ensure that expected performance attained and potential impact. Establish more comprehensive fitness-for-service assessments. a) Use this work as basis, if possible, for increasing EOL limits b) More comprehensive assessments will be conducted to demonstrate fitness-for-service	Before	10			10	10				10
		After	4			4	4				4

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Ability to construct a validated predictive model based on limited data	Complete planned test identified in COG joint projects. Use data from COG R&D programs. Develop best model available and recommend confirmatory inspection program to support model developed.	**Before**			12						**12**
		After			10						**10**
Delay in OPG supporting activities: a) Planned inspection work not completed during outages to obtain necessary data b) Delay in supporting activities such as the Gap and Spacer retrieval tooling development, and Outage inspections to provide required data may impact on viability or quality of the Fuel Channel Life Management Project deliverables.	Develop and understand scenarios where not all work is completed and devise alternate paths a) Ensure stations are aware of the impact of not conducting inspection work in outages. b) Develop OPG Stakeholder communication and decision making process at senior management level.	**Before**		10		12					**12**
		After		5		8					**8**
Regulator may require changes of the project work scope or disallow use of the results in determination of fitness for service limits.	Obtain buy-in from regulator on project plan and approach to be undertaken Keep the regulator informed of results as project progresses. Participate in the 'Success Path' process proposed by the Regulator	**Before**				6	12				**12**
		After				2	3				**3**

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Risk Associated with the Annulus Spacer Retrieval Tooling Project (Capital)

Low 1 to 3	Medium 4 to 9	High 10 to 25

Probability \ Impact	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Risk Description	Mitigating Activities	Mitigation	Finance	Schedule	Quality	Corporate Reputation	Regulatory	Health & Safety	Environmental	Nuclear Safety	Risk Rating (1 to 25)
			Probability X Impact								
High force may be required to push all 4 springs the length of the channel, which could impact the integrity of the annulus spacers and compromise the in-reactor condition.	This task evolution will have to be examined and tested on a mock-up.	Before	6	4	3						6
		After	3	2	2						3
Without any modifications to the Roadrunner flask design or to transportation procedures, there is a risk that spacers will continue to be damaged in transit.	Tool design requirements document specifies the need for modifications to the flask.	Before	6	8	12						12
		After	2	3	3						3
The sequence of how a Single Fuel Channel Replacement (SFCR) is normally performed will have to be reconfigured and could cause an increase in outage time greater than 24 hours.	The new procedure will have to be examined and tested on a mock-up. Obtain a letter of understanding from Darlington Outage Management in regard to the potential/ expected increase to the SFCR outage schedule associated with Annulus Spacer Retrieval.	Before	8	10							10
		After	4	2							4
Pressure Tube Push could be more difficult as the springs lessen the friction experienced during the push.	New springs may have to be installed to assist with the push.	Before	4	2							4
		After	4	2							2
Long lead items might affect schedule adherence.	Determine design requirements to tooling, with input from all stakeholders, early in the project and submit requests for proposals from vendors. Identify materials early in the project	Before	10	20							20
		After	2	2							2
After spacers are removed, there is a risk that the calandria tube could be damaged during pressure tube removal.	Detailed design requirements established early on. Develop devices (e.g. "dummy" spacers) to insert onto the pressure tube in place of the removed annulus spacers to minimize risk of damage to the calandria tube. Commission ASRT tooling on mock-up prior to first use. Consider having Calandria Tube Replacement (CTR) capability available before the Annulus Spacer Retrieval Tooling is deployed.	Before	20	20	20						20
		After	4	4	4						4

7/ POST IMPLEMENTATION REVIEW

Type of PIR:	Targeted Final AFS Date:	Targeted PIR Approval Date	PIR Responsibility (Sponsor Title)
Simplified		30-Jun-15	VP, Science and Technology Development Department

	Measurable Parameter	Current Baseline	Targeted Result	How will it be measured?	Who will measure Person / Group?
1.	Results received from experiments and analyses	2016 assuming COG funding remains at current level, and appropriate task funded.	August 2012	Date final results are received to support next parameter	Director, FCLMP
2.	Issue memo regarding confidence (high confidence is >70%) on Pickering B FC service life to 240k EFPH based on experiment results and analysis	High confidence to 210k EFPH Confidence level on FC service life to 240k EFPH is 50%	December 2012	Fuel Channel experts concur with high confidence	Director, FCLMP
3.	Issue memo regarding confidence (high confidence is >70%) on Darlington FC service life to 210k EFPH based on experiment results and analysis	High confidence to 185K EFPH Confidence level on FC service life to 210k EFPH is 50%	December 2012	Fuel Channel experts concur with high confidence	Director, FCLMP
4.	Complete submission of technical basis to modify FFS to regulator	2016 based on appropriate results (see Item 1)	December 2013	Date of acceptance/ rejection by regulator on submission	Project Sponsor
5.	Transfer of CNSC action (for new inspection requirements) to MCED.	CNSC will grant only short-term licenses (i.e. 6 months) if new program is not implemented.	June 2015	New inspection program is included in 2015 LCMP.	Project Sponsor

APPENDIX "A' GLOSSARY (acronyms, codes, technical terms)

ASRT	Annulus Spacer Retrieval Tool
BOT	Body of Tube
CNSC	Canadian Nuclear Safety Commission, Canadian regulator under the Nuclear Safety and Control Act
COG	CANDU Owners Group
CT	Calandria tube
D-ingress	With hot operation, deuterium enters pressure tube material
EOL	End-of-life, based on a target service life
FFS	Fitness-for-Service
H_{eq}	Equivalent hydrogen concentration if all deuterium [D] were replaced with protium [H] (H_{eq} = [H] + [D]/2)
Hydriding	The process of adding hydrogen (deuterium or protium) to pressure tube material to simulate later life conditions
PCA	Probabilistic Core Assessment, used to evaluate degradation of all fuel channels based on established methodologies and inspection results
PHTS	Primary Heat Transport System
PT	Pressure tube
RJ	Rolled joint between the pressure tube and end fitting
CSA N285.4	"Periodic inspection of CANDU nuclear power plant components" This Standard specifies the inspection requirements for nuclear power plant components. Clause 12 outlined the inspection and evaluation requirements of fuel channel. This Standard is the basis of the OPG periodic inspection plant which is submitted to the CNSC.
CSA N285.8	"Technical requirements for in-service evaluation of zirconium alloy pressure tubes in CANDU reactors" The specific fitness-for –service evaluation requirements are listed in this Standard.
CSA N286.7	"Quality Assurance of Analytical, Scientific and Design Computer Programs for Nuclear Power Plants" This Standard specifies the requirements for the quality assurance program applicable to the design, development, maintenance, modification, and use of analytical, scientific, and design computer programs that are used in nuclear power plant applications.

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APPENDIX "B"

Comparison of Total Project Estimates

$ 000's		This Appendix compares the Total Project Estimate for each BCS									
			Total Project Estimate (by Year incl Contingency)								
BCS Type	Class	Mth	Yr	2009	2010	2011	2012	2013	2014	2015	Later	Total Project Est
Partial	OM&A	Aug	2009	2,533	9,728	7,741	4,010	908				24,920
Partial	OM&A	Aug	2010	2,489	6,502	8,978	6,841	2,188				26,998
Partial	OM&A	Aug	2011	2,489	5,683	12,830	13,403	3,332	1,861	332		39,930
Partial	Capital	Aug	2010	0	0	867	2,217	82				3,166
Partial	Capital	Aug	2011	0	0	939	2,145	82				3,166
												0
LTD Spent	OM&A	Dec	2010	2,489	5,683							8,172
LTD Spent	Capital	Dec	2010	0	0							0
LTD Spent												0

Comments:

The overall increase in the total project estimate by $12.9 Million is due to the OM&A portion of the project only.

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APPENDIX "C" FINANCIAL MODEL – ASSUMPTIONS

Financial Assumptions:

Discount Rate:	7%	Cost Escalation (Yr)	2%	SR&D Opportunity	Choose
Progress Payments	Choose	Foreign Currency	Choose	Retainer Fee	Choose
Depreciation Rate (Capital)	Choose	PST	Choose	Interest Rate (Capital)	Choose
Revenue Rate	Choose	Leasing	Choose	Indexed Priced Contract	Choose

Comments:

Please refer to the Major Assumptions table provided in section 3 of the BCS.

Project Cost Estimate:

Design Complete:	Choose	Fixed Price Contract	Choose	3rd Party Estimate	Choose
Quality of Estimate	Release +15% to -10%	OPEX used	Choose	Lessons Learned	Choose
Similar Projects	Yes	Budgetary Quote	Choose	First Unit Actual Used	N/A
Firm Vendor Proposal	No	Cost Sharing	Yes	Competitive Bid	Choose
Reviewed by Sponsor	Yes	Fee for Service	Choose	Contracts in place	Yes

Comments:

Please note that Variance to Business Plans includes contingency. (See Attachment A and B) (i.e. Variance to Budget is calculated by subtracting Project Funding and Contingency Funding from 2011-2015 Business Plan.)

Rationale for Capital Cost Classification:

Generation Plan Assumptions:

Station	Unit	EOL or Refurb	MW	Planned Outages for Project Work						
Pickering A	1	Jun-20	515							
	4	Jun-20	515							
Pickering B	5	Nov-18	516							
	6	Nov-18	516							
	7	Jun-20	516							
	8	Jun-20	516							
Darlington	1	Feb-18	878							
	2	Oct-16	878							
	3	Sep-19	878							
	4	Jan-21	878							

Comments:

APPENDIX "D"

FINANCIAL MODEL – ASSUMPTIONS
Impact on Operations

Please see Section 3 (Alternatives & Economic Analysis)

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ATTACHMENT "A" PROJECT COST SUMMARY

Fuel Channel Life Management Project – OM&A Portion

	$ 000's OM&A	LTD Dec 2010	2011	2012	2013	2014	2015	2016	Later	Total
Accounting Basis	Project Mgmnt & Support	[redacted]								
	Engineering									
	Procurement									
	Construction									-
	Other									-
										-
										-
										-
	Interest (Capital Project)									-
	Project Costs									
	General Contingency									
	Specific Contingency									-
	Project Costs	8,172	12,890	13,343	3,332	1,861	333	-	-	39,930

12,830 13,403

	$ 000's OM&A		LTD Dec 2010	2011	2012	2013	2014	2015	2016	Later	Total
Funding Basis	**Current Release**	Project Costs									
		Contingency									
		Total									
	Adj to Current Release	Project Costs									
		Contingency									
		Total									
	This Release	Project Costs									
		Contingency									
		Total									
	TTD Released	Project Costs									
		Contingency									
		Total									
	Future Releases	Project Costs									
		Contingency									
		Total									
	Project Funding										
	Contingency Funding										
	Total Funding		8,172	12,830	13,403	3,332	1,861	332	-	(0)	39,930

Budget	2011 - 2015 Business Plan	8,991	7,807	8,012	2,188	0	0				26,998
	Variance to Budget	(819)	5,023	5,391	1,144	1,861	332	0	(0)		12,932
Other	Removal Costs (above)										-
	Inventory W / O										-
	Spare Parts in Invent										-

Reviewed by: (Date)

Nicholas van den Brekel 21 July 2011
Tom Lau N. C. VAN DEN BREKEL
Project Manager, FCLMP FOR T. LAU

Approved by: (Date)

I Malek 21 July 2011
Imtiaz Malek
Director, FCLMP

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ATTACHMENT "A" PROJECT COST SUMMARY

Annulus Spacer Retrieval Project – Capital Portion

	$ 000's Capital	LTD Dec 2010	2011	2012	2013	2014	2015	2016	Later	Total
Accounting Basis	Project Mgmnt & Support		100	28						128
	Engineering		50							50
	Procurement		625	100						725
	Construction		[redacted]							
	Other									
	SAVH									
										-
										-
	Interest (Capital Project)		[redacted]							
	Project Costs	-								
	General Contingency									
	Specific Contingency									
	Project Costs	-	939	2,145	82	-	-	-	-	3,166

	$ 000's Capital		LTD Dec 2010	2011	2012	2013	2014	2015	2016	Later	Total
Funding Basis	Current Release	Project Costs		[redacted]							
		Contingency									
		Total									
	Adj to Current Release	Project Costs									
		Contingency									
		Total									
	This Release	Project Costs									
		Contingency									
		Total									
	TTD Released	Project Costs									
		Contingency									
		Total									
	Future Releases	Project Costs									
		Contingency									
		Total									
	Project Funding										
	Contingency Funding										
	Total Funding		-	939	2,145	82	-	-	-	-	3,166

Budget	2011 - 2015 Business Plan	0	867	2,217	82					3,166
	Variance to Budget	0	72	(72)	0	0	0	0	0	0

Other	**Removal Costs (above)**									-
	Inventory W / O									-
	Spare Parts in Invent									-

Reviewed by: (Date)

Rob Harness — July 21, 2011

Perry Bowles
Project Manager

Approved by: (Date)

21 July 2011

John Stopar
Manager, IMS

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ATTACHMENT "B" PROJECT VARIANCE ANALYSIS

Fuel Channel Life Management Project – OM&A Portion

	$ 000's OM&A	LTD Dec 2010	Total Project: Last BCS Aug 2010	Total Project: This BCS Aug 2011	Variance	Comments
Scores Basis	Project Mgmnt & Support	[redacted]				See Note 1
	Engineering					See Note 2
	Procurement				-	
	Construction				-	
	Other				-	
					-	
	Interest (Capital Project Only)				-	
	Project Costs (Scores Basis)					
	General Contingency					
	Specific Contingency					
	Project Costs (Scores Basis)	**8,172**	**26,998**	**39,930**	**12,932**	

Other	**Removal Costs included above**				-	
	Inventory to be written off				-	
	Spare Parts in Inventory				-	

Comments:

- Note 1:
  Additional Project Management funding required:
  - $3.4 Million for added new scope to oversee supporting projects (e.g. Gap and Spacer Retrieval Tooling), supporting activities, and to confirm integration of R&D work into surveillance programs.

- Note 2:
  Additional Engineering funding required:
  - [redacted] Million for new funding to allow OPG to enter into negotiations with Bruce Power to obtain critical spacer degradation data for Darlington FFS demonstration through the Bruce Power SFCR project in 2012.
  - $4.5 Million for the added R&D to obtain CNSC concurrence based on 18 technical submissions per agreed CNSC Protocol.

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Annulus Spacer Retrieval Project – Capital Portion

	$ 000's OM&A	LTD Dec 2010	Total Project Last BCS Aug 2010	Total Project This BCS Aug 2011	Variance	Comments
Scores Basis	Project Mgmnt & Support		278	128	(150)	
	Engineering		400	50	(350)	
	Procurement		300	725	425	
	Construction		[redacted]			
	Other					Assigned for project close-out
	SAVH					
	Interest (Capital Project Only)					
	Project Costs (Scores Basis)					
	General Contingency					
	Specific Contingency					
	Project Costs (Scores Basis)	-	3,166	3,166	-	

Other	**Removal Costs included above**				-	
	Inventory to be written off				-	
	Spare Parts in Inventory				-	

Comments:

The total project estimate has not changed since the last partial release. However, the funding allocation has been adjusted to allow for the procurement of the tool from an external vendor.

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ATTACHMENT "C" SCHEDULE

Key Milestones

Completion Date	Description
31-Aug-12	Full Release BCS submitted
31-Aug-12	COG Fuel Channel Joint Projects 4363 and 4299 (Experimental Work)Complete
31-Dec-12	High Confidence Statement based on improved technical basis reported
31-Dec-12	CNSC Protocol requirements are met
31-Jun-13	Support for Pickering license renewal process completed
31-Dec-13	Confirmation of IMS ASRT project completion
31-Dec-14	Support for Darlington license renewal process completed
31-Dec-14	Regulatory submission for application of new methodologies at Pickering and Darlington submitted to CNSC
30-Jun-15	Confirmation that LCMPs have been updated according to COG R&D results
30-Jun-15	Project Complete

A Project Execution Plan (PEP) will be approved by 31-Oct-11

In Service Declarations: (Capital only)

Date	Description	$000's (Total = Project Cost incl contg)	% In Service (= 100%)
15-Oct-12	Spacer Retrieval Tool Report of Equipment in Service Issued	3,166	100

Comments:

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Risk Probabilities Chart

Likelihood	Improbable	Unlikely	Possible	Likely	Probable
Probability	<= 1 in 100	About 1 in 100	About 1 in 10	About 1 in 5	>= 3 in 4
Rank	1	2	3	4	5

Risk Impact Chart

Impact Rating	Financial	Project Schedule 12 month	Quality	Corporate Reputation	Regulatory / Legal	Health & Safety	Environment	Nuclear Safety
5	>80% of Total Project $	> 90 day delay	Significant, unacceptable non-conformance requiring extensive rework	National and international adverse coverage or impacts	Non-compliance with potential for significant implications for personnel, potentially large damages or Criminal Charges OR Potential loss of operating licenses	Potential for fatality(s)	Spill or release causing immediate and extended impact with off-site impacts, e.g.:Clean-up costs > $15MCat. A spill (>55 pts)	Loss or serious degradation of a safety system
4	30% - 80% of Total Project $	30 - 90 day delay	Unacceptable non-conformance requiring some rework, but not major	Long-term local or national impact	Legislative non-compliance with potential for fines, charges, and damages ORMajor degradation of reputation with regulatory bodies	Potential for life-threatening critical injury or permanent total disability, including occupational disease	Exceedances resulting in charges or Director's OrderCat. A spill (45 - 55 pts)Public complaints with OPG implications Explosion and/or major fire	Reduced effectiveness of a safety system
3	15% - 30% of Total Project $	10 - 30 day delay	Non-conformance bordering design tolerances, potential to require rework	Major local impact or minor national impact.Minor local damage	Systematic non-compliance with potential for finesORPotential to cause strained relationship with regulator, increased surveillance and/or regulations	Potential for less serious critical injuries (e.g. fractures), permanent partial disabilities and temporary total disabilities of a significant nature	Cat. B spills Emission in exceedance of regulatory or legal limits Field orders or Amp's Public complaints with OPG implications Danger to health, life, or property	Reduced effectiveness of redundant safety system components
2	5% - 15% of Total Project $	3 - 10 day delay	Acceptable non-conformance, within design tolerances, no rework required	Complaints from local officials / politicians	Systematic non-compliance with impacts to project scheduleORPossibility of regulatory / legal implications	Potential for less serious temporary disabilities and injuries requiring off-site medical attention other than first-aid. Complete recovery by worker.	Cat. C spills - reportableAdministrative infractionsPublic Complaints with plant level implications	Impact on a safety support or safety related system
1	<5% of Total Project $	< 3 day delay	Minimal impact on qualityRoutine non-conformance, can be easily dispositioned	Complaints from local public	Isolated non-complianceORRoutine approval / notification	No medical attention beyond first aid, no impairment to worker or complete recovery of worker	Administrative, non-reportable eventsCat. C spills non-reportable and spills resulting from Acts of God	