PROGRAM SCOPE

1.0 OVERVIEW

OPG has engaged in an extensive planning process for the Darlington Refurbishment Program ("DRP"), the foundation of which has been OPG's thorough, methodical and disciplined process for identifying and defining the scope of the work that is to be undertaken as part of the DRP. This section describes (1) the steps taken by OPG during the Definition Phase to identify and define the scope of the DRP, including in particular the work to be performed for Unit 2, (2) completion of the detailed design and engineering work, and (3) the resulting scope of work identified for each of the major work bundles.

2.0 SIGNIFICANCE OF SCOPING TO PROGRAM SUCCESS

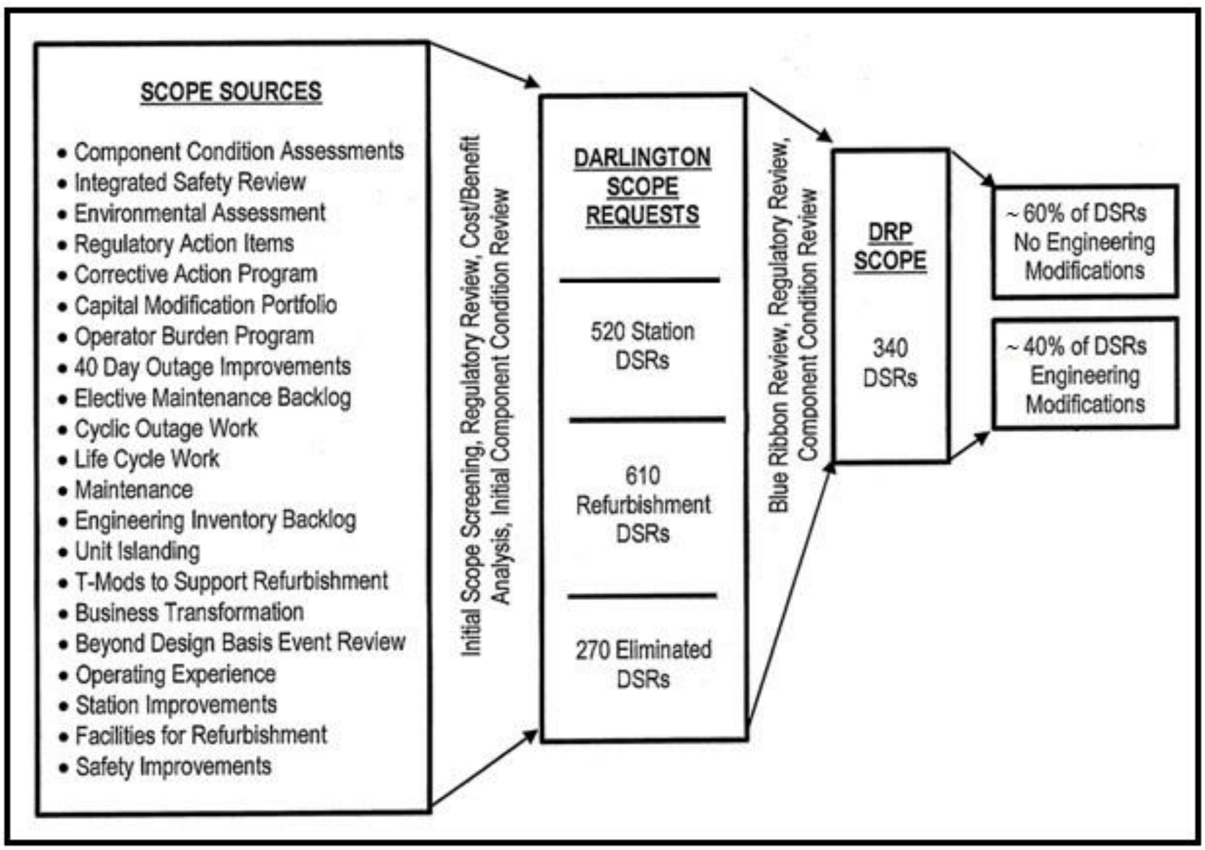
A failure to adequately define scope, in advance of setting the budget and schedule for a project, will substantially increase the likelihood of project failure. For the DRP, OPG has established a clear, well-defined program scope, which provides the proper basis for establishing high confidence estimates of the budget and schedule. OPG has also implemented a change control process to control scope growth. This process addresses operating experience from each of the Pickering 'A' Return to Service project, the Pt. Lepreau refurbishment and various Bruce Power restart projects, where cost and schedule overruns were significantly driven by scope growth.

Having a detailed understanding of scope enables the development of a schedule that is inclusive of all work. Moreover, because of the interrelated nature of the work being executed, changes to scope made during execution could potentially result in cascading impacts and cost and schedule consequences. By investing in scope definition prior to execution, OPG is minimizing the risk of such costs and schedule consequences. In addition, having a detailed definition of scope enables OPG and its contractors to take the necessary steps to ensure completion of all corresponding engineering in advance of unit execution, and to secure necessary materials, parts, tools, labour and craft resources to support the schedule.

3.0 APPROACH TO WORK SCOPE DEFINITION

The work scope definition process for DRP commenced in 2008 with a number of scope assessments for the major components within the nuclear plant, including the reactor components, steam generators, and turbine generator sets and other nuclear and conventional components. In 2011, OPG performed nearly 3,000 component condition assessments and reviewed numerous other sources in order to determine the potential scope to be executed on the DRP, as depicted in Figure 1.

Figure 1 - Scope Definition Process Overview



Based on consideration of these sources, OPG identified and documented, in the form of Darlington Scope Requests (“Scope Requests”), specific proposals for work that might be included as part of the DRP. Each Scope Request included a description of the particular work being proposed, the units to which the work would apply, whether and how the work responds to regulatory requirements, as well as various means of classifying the work based on its objectives and relationship to other work. This process generated a total of 1,400 Scope Requests.

OPG established a Project Scope Review Board ("PSRB") to review and approve (or reject) proposed Program scope. The PSRB is a senior, cross-functional board with representation from the Darlington site and supporting business units, and is chaired by the Refurbishment Planning and Project Controls Function. The PSRB decided on whether proposed scope should be included or not, and how it should be categorized. In making these decisions, the PSRB was primarily concerned with whether the proposed scope needed to be included in the DRP or could be performed through normal station work processes (or was required at all). Based on this initial screening process, the PSRB in 2013 determined that 610 of the 1400 Scope Requests were within the scope of the DRP. The remainder were found to be either capable of being performed as part of normal station work or were not required.

Following this initial scope rationalization process, three further steps were taken. First, OPG undertook a detailed review of the component condition assessments which were found to have prompted many of the Scope Requests. Second, OPG worked with CNSC staff to finalize the regulatory requirements for extending the life of Darlington (see section 4 of Ex. D2-2-1 for discussion of regulatory requirements). Third, OPG formed a Darlington Nuclear Refurbishment Scope Review Panel (also referred to as the "Blue Ribbon Task Force")[1] in late 2013 to perform a detailed review of all Scope Requests that the PSRB intended (based on its initial screening) to include in the DRP. The primary considerations for the Blue Ribbon Task Force, in determining which scope should be included in the DRP, were:

- whether the work to be executed required defueled and dewatered conditions;
- whether the work to be executed required a unit outage that would be significantly longer than a standard unit outage; and/or

[1] The Blue Ribbon Task Force was comprised of senior representatives from Darlington and the refurbishment organization, including the Senior Manager of Plant Design, Director of Fleet Operations, the Senior Vice President, and the Director of Nuclear Safety. Its objective was to ensure that only Scope Requests required to support the refurbishment of Darlington units are included in the approved DRP scope.

- whether the work could be completed in a manner that is substantially safer, results in a lower radiation dose and/or is easier to complete if accomplished during the refurbishment outage rather than during operation or a normal maintenance outage.

Based on the Blue Ribbon Task Force's review and recommendations, the DRP scope was reduced to 340 Scope Requests. The scope of the DRP, which was fixed as of June 1, 2015, is based upon these 340 Scope Requests. Any proposed changes are subject to OPG's scope change process, which includes the need for PSRB approval. OPG's scope change process is described in section 3 of Ex. D2-2-9.

3.1 Engineering Modifications

Scope Requests specify whether engineering modifications or changes are needed. These are changes to final design documents that affect a system, structure, component, software or engineered tool. They also include modifications that affect or alter the design, function or method of performing a particular function, such as the removal, abandonment or retirement of equipment that is currently installed. Changes may be required temporarily for purposes of refurbishing a unit or on a permanent basis. Of the 340 Scope Requests within DRP scope, approximately 40% include engineering modifications, with Unit 2 requiring approximately 340 engineering changes that are permanent plant modifications for the extended life of the station. The completion of engineering for the DRP is further discussed in section 2.1.2 of Ex. D2-2-4.

3.2 Regulatory Scope

OPG has determined that approximately 80% of the DRP scope is driven directly by regulatory requirements, with the remainder being related to non-nuclear systems and/or scope that is required to be in place to support the refurbishment (e.g., refurbishment project office). OPG's Global Assessment Report and Integrated Implementation Plan ("IIP") were accepted by the CNSC in December 2015, thereby confirming the regulatory scope for DRP.

3.3 Work Bundles

For each Scope Request that was approved as part of the DRP scope, the corresponding work was then assigned to one of the five major work bundles that are described in Ex. D2-2-3 or to the functional support groups described in section 3.2 of Ex. D2-2-2.

After the Scope Requests were assigned to specific work bundles, the corresponding project teams, through studies or preliminary engineering, further defined the particular scopes of work to be performed in connection with each Scope Request. Not all scopes need to be completed for each unit.

When applied to the four units, the result is approximately 560 specific projects to be completed over the life of the DRP. Of these, a large portion, more than for any other unit, will need to be completed directly for Unit 2. In addition, there are projects that involve work that is common to two or more of the units, projects completed during the Definition Phase that are not part of any outage, as well as Safety Improvement Opportunities ("SIO") and Facility and Infrastructure Projects ("F&IP"). Some examples of projects completed during the Unit 2 outage that are not completed for other units include:

- the Irradiated Fuel Bay Heat Exchanger Plate Replacement project is a common system scope that is executed as a pre-requisite to the Unit 2 outage (see section 4.3.4, and section 2.2.2 of Ex. D2-2-10 for more information);
- engineering and procurement for Defueling (Defueling execution work is the same for all units, but there will be no additional engineering scope for the remainder of the units);
- the Work Control Area project is required for all four units, but will be executed during Unit 2 outage;
- the Service Air Capacity Enhancement project will be executed during the Unit 2 outage, which consists of an engineering modification that will enhance the capacity of service air;
- as part of the Retube and Feeder Replacement ("RFR") work package, calandria tube sheet boring polishing validation is required for Unit 2 but will not be performed for any other unit; and

- as part of the Steam Generators work package, a bleed cooler inspection/repair is only required for Unit 2.

Because the scope is not the same for each unit, the cost will not be the same for each unit. Unit 2 is expected to be the most costly unit to refurbish because it includes more scope than the subsequent units and, due to station configuration and various requirements that are common across the station, many engineering changes and other supporting scope is only required for Unit 2 (as they would already be in place for the remaining units). Costs are discussed in Ex. D2-2-8.

4.0 SCOPE FOR MAJOR WORK BUNDLES

For each major work bundle, OPG has appropriately and to a high level of specificity defined the relevant work, as well as effectively planned and integrated the work into the Program and Unit 2 schedules. The scope of work associated with each of the major work bundles for Unit 2 refurbishment is as follows.

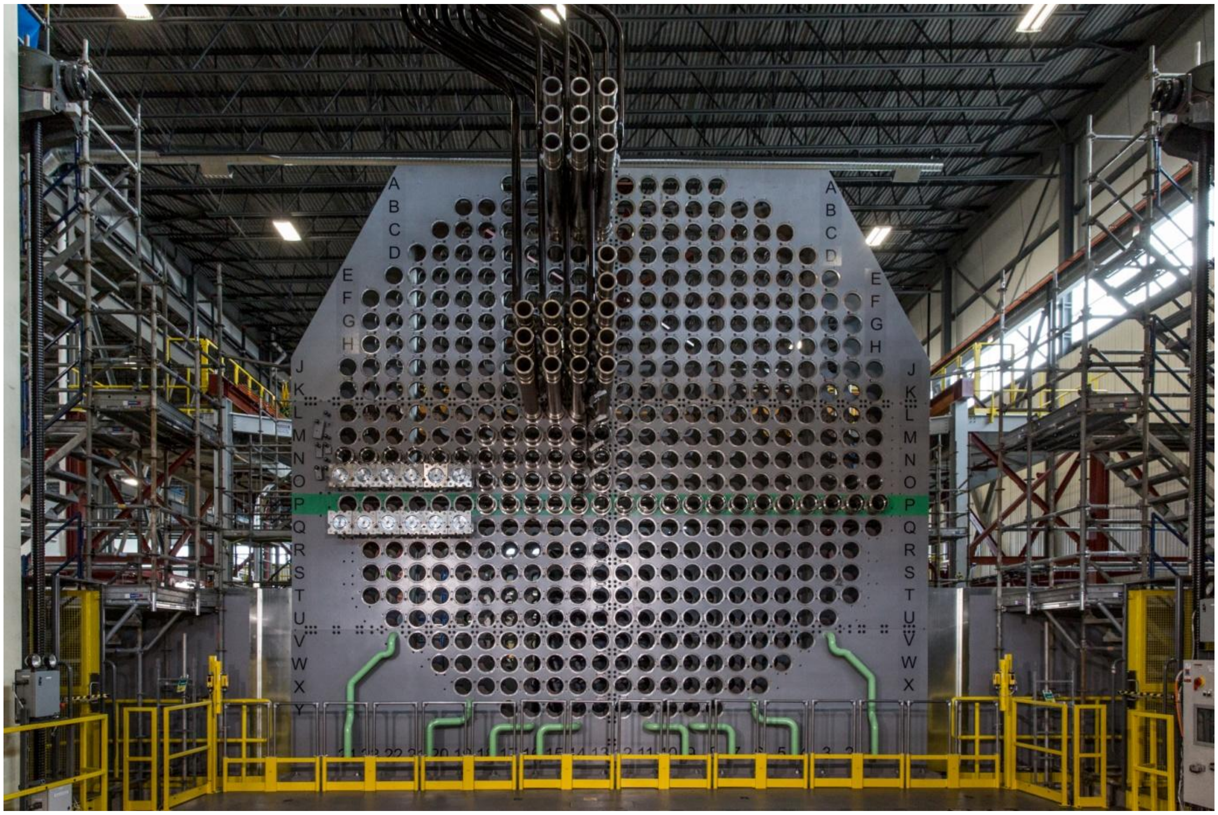
4.1 Retube and Feeder Replacement

The RFR major work bundle is comprised of three broad areas of scope, consisting of (1) RFR Definition Phase work, (2) Retube Waste Processing Building, and (3) RFR Execution Phase work.

4.1.1 <u>RFR Definition Phase Work</u>

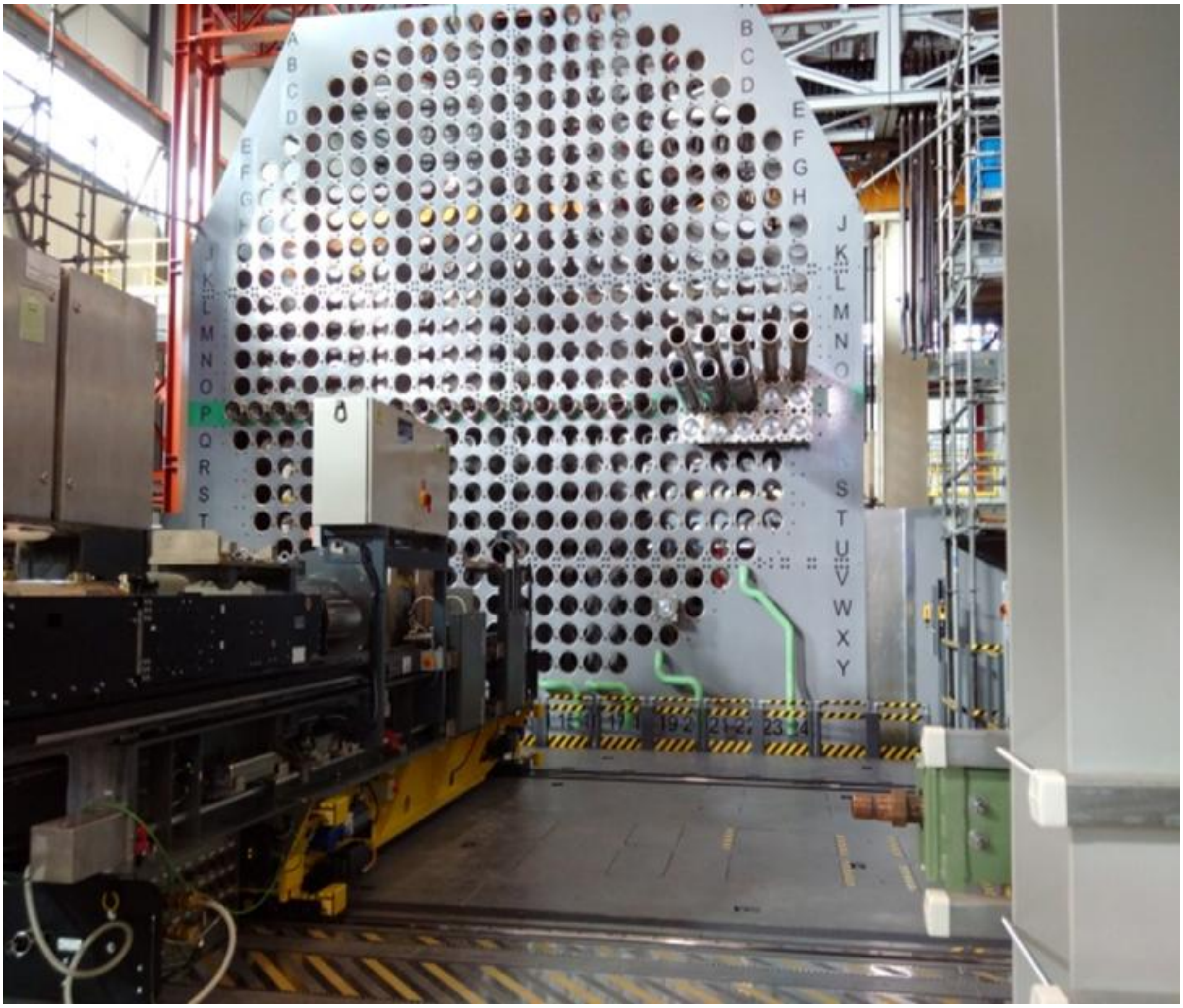
(a) *Mock-up.* The full-scale reactor mock-up was completed and went into service at the Darlington Energy Complex on budget and ahead of schedule on March 31, 2014. The successful installation of the mock-up facility included the design, manufacture and installation of the reactor face and all components, fueling machine bridge and two retube tooling platforms. The mock-up has been, and will continue to be used to train workers, providing predictable Execution Phase performance and minimizing the need for workers to overcome any learning curves while performing work during the refurbishment outage.

Photo 1 - Reactor Face Mock-up



(b) *Tooling Fabrication and Testing.* The manufacturing of all prototype tools is complete and all tooling has been tested. Test times were used to develop a reliable critical path schedule and comprehensive risk register. Tool testing in the reactor mock-up has enabled OPG to avoid costs that otherwise would have been incurred if issues experienced in the mock-up occurred during actual field execution. Manufacturing of the production tools is in progress with all tool sets scheduled for delivery by mid-2016.

Photo 2 - End Fitting Removal Tool Performance Testing



(c) *Modification Engineering, Procurement and Execution Planning.* Detailed engineering for station modifications required to execute the RFR major work bundle is complete. All long lead materials including pressure tubes, calandria tubes, fuel channel end fitting assemblies, feeders and retube waste containers are ordered for Unit 2.

4.1.2 Retube Waste Processing Building

This project includes the design, construction and commissioning of a Retube Waste Processing Building ("RWPB"). The RWPB will house a waste volume reduction tooling system, process intermediate-level refurbishment waste, and accommodate all low level waste container shipments for the DRP pursuant to OPG's radioactive waste management plans. Used reactor components will also be delivered from the outage unit to the RWPB in appropriately shielded flasks. The RWPB will enable OPG to optimize waste processing and packaging operations during the DRP. The RWPB is planned to be available for use in June 2017 and commissioning of the RWPB, including the waste tooling system, will be completed by July 2017.

4.1.3 RFR Execution Phase Work

The RFR Execution Phase work is scope that supports the primary reason for executing a refurbishment outage at Darlington. This scope includes the removal and replacement of each reactor's 480 fuel channel assemblies consisting of two end fittings, pressure tubes and calandria tubes, and the removal and replacement of the 960 feeder pipes in each reactor. Major activities also include the installation of new pressure tubes, new calandria tubes, new end fittings and the fabrication and installation of new feeders.

4.2 Turbine Generators

The Turbine Generators work bundle for Unit 2 is a maintenance outage (including turbine blade inspections). Unit 2 Turbine does not include any modifications in the field. It includes installation of a maintenance simulator to support training and testing, and is comprised of three broad areas of scope: (1) Turbine and Auxiliaries Work, (2) Moisture Separator Reheater Work, and (3) Generator and Auxiliaries.

Photo 3 - Turbine Generator

Unit 2 scope excludes upgrades to turbine and excitation controls, which are within the scope for subsequent units. The exclusion of the turbine and excitation control scope from Unit 2 was recommended by the Blue Ribbon Task Force and accepted by the PSRB as there is still useful life left in the existing control system on Unit 2 and it is more cost effective to defer the upgrades. Moreover, deferral provides a risk mitigation measure for Unit 2. Based on lessons learned from previous projects, there have been challenges encountered with turbine generator control system upgrades that impacted schedule. DRP is undertaking simulator testing on the new design outside of the Unit 2 refurbishment to reduce the risk of impact on critical path.

The three main areas comprising the scope of the Turbine Generators major work bundle for Unit 2 are further described below:

4.2.1 Turbine and Auxiliaries Work

This scope involves: (1) disassembly, inspection, and reassembly of the low pressure and high pressure turbines and auxiliaries; (2) procuring long lead and maintenance spares for the disassembly and assembly of the steam turbines and auxiliaries; (3) the installation of erosion protection rings on blade carriers of the low pressure -turbines to address erosion-corrosion; and (4) inspecting and repairing condenser struts, as required.

Photo 4 - Inspection of Turbine Generator Blades

4.2.2 Moisture Separator Reheater Work

This scope involves inspections, overhauls, repairs and replacements of specific equipment and components associated with the Moisture Separator Reheater.

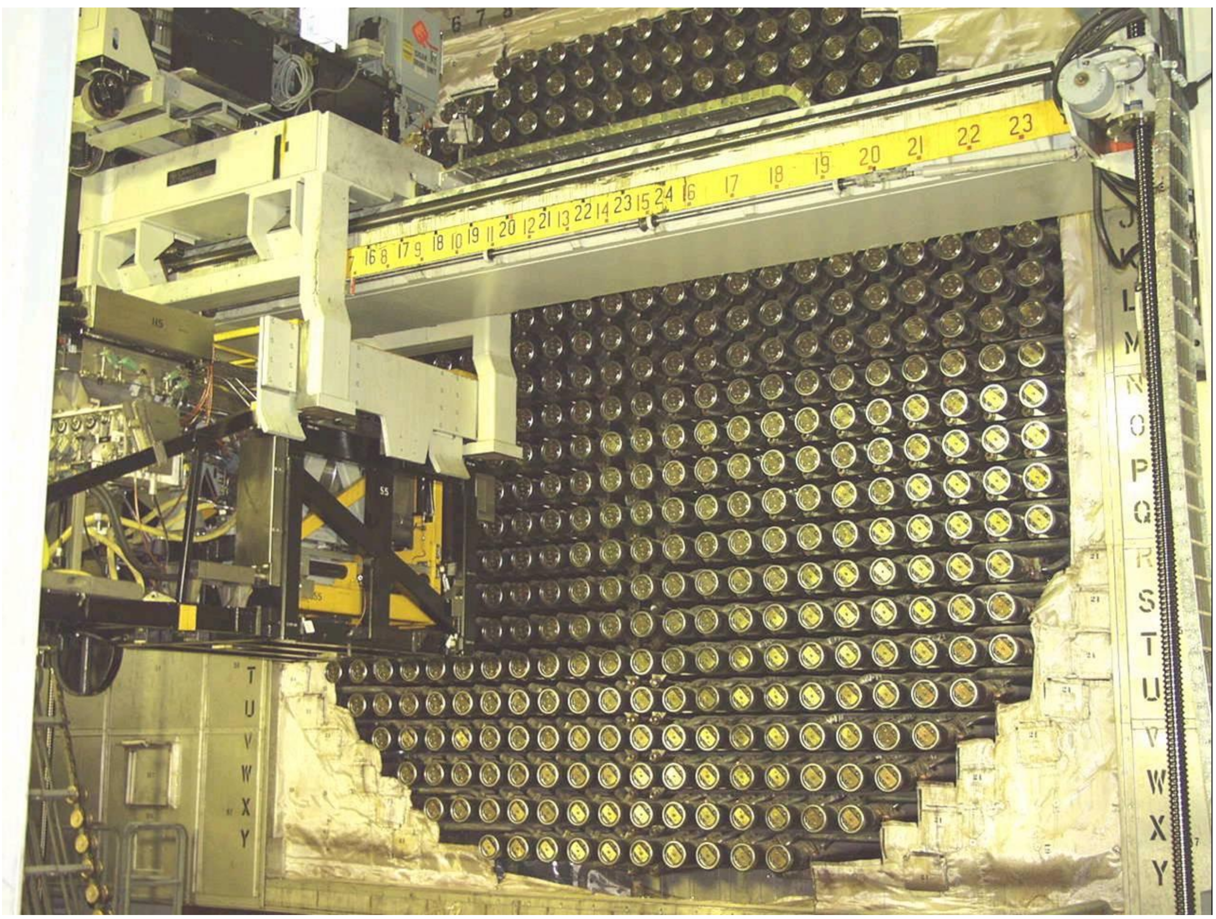
4.2.3 <u>Generator and Auxiliaries Work</u>

This scope involves inspections, overhauls, repairs, and replacements of specific equipment and components associated with the Generators and Auxiliaries.

4.3 Fuel Handling and Defueling

The Fuel Handing and Defueling work bundle is comprised of four broad areas of scope: (1) defueling work, (2) power track work, (3) reactor area bridge and carriage refurbishment, and (4) irradiated fuel bay heat exchanger replacement, as follows:

Photo 5 - Fuel Handling and Defueling Machine Operating at Darlington



4.3.1 Defueling Work

The first major step once the refurbishment outage commences is to remove irradiated fuel from the reactor core (i.e. 480 channels each containing 13 fuel bundles for a total of 6240 irradiated fuel bundles in each unit) in order to allow the downstream activities, including RFR, to be executed. Defueling, therefore, is the first segment on the critical path once the refurbishment breaker is opened.

The two major engineering changes related to this scope are the implementation of universal carriers and the equipment required to defuel an entire reactor. The universal carriers will be permanently installed on the station fuel handling systems and will allow a Darlington fueling machine to fuel and defuel without having to change out the carriers, which was not the original design. The equipment required to defuel the reactor includes the dummy fuel bundles, the flow restricting outlet bundle, and the fuel push tool.

Figure 2 – Universal Carriers and Equipment Required for Defueling

4.3.2 <u>Power Track Work</u>

The fuel handling system at Darlington performs routine online fuelling operations using fuelling machines mounted on trolleys. The power track provides a flexible avenue for power, control and signal cables to be connected to the trolleys from the central service area. One of the major activities of the DRP is refurbishing the three existing power tracks to ensure the continued reliable operation of the fuel handling system to the end of station life. This is to be done with the support of an external contractor, who will be responsible for the procurement and construction of the components for the power track. This is a "like-for-like" replacement, with no engineering modifications required.

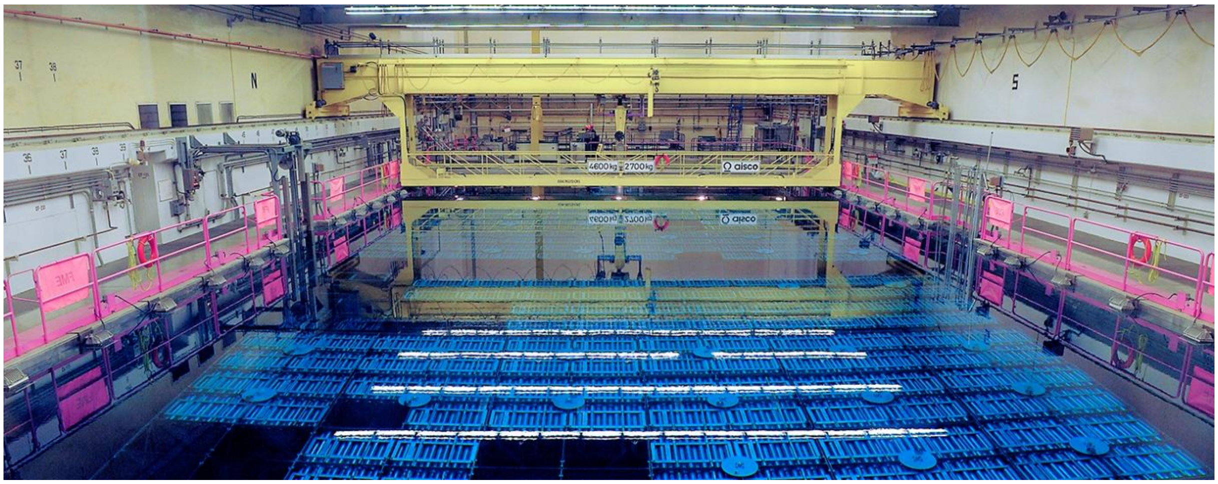
4.3.3 Reactor Area Bridge and Carriage Refurbishment

The reactor area bridge assembly supports a fueling machine carriage, which accepts the fueling machine head and suspension from the transport trolley in the duct and supports them while in the reactor vault. This scope involves replacing a number of major components on the bridge and carriage. This scope is a critical path activity.

4.3.4 Irradiated Fuel Bay Heat Exchanger Plate Replacement

The fuel bay system is comprised of eight heat exchangers and corresponding piping equipment. Along the sides of the station are fuel storage and reception bays for a total of 4 bays and eight heat exchangers. The existing heat exchangers are reaching their end of life. They are not able to accommodate the extra cooling load when a complete reactor load of irradiated fuel is deposited, over a short duration, as part of refurbishment reactor defueling activities. This scope involves a "like-for-like" replacement of "plate packs" for all eight heat exchangers in order to restore cooling capacity. This scope is a prerequisite to Unit 2 refurbishment and was completed in June 2015. Because the irradiated fuel bay heat exchangers serve all Darlington units, the project is used and useful to the station upon going into service in 2015 at a cost of $6.2M, and with $234K for projected close out costs in 2016 (see Ex. D2-2-10).

Photo 6 - Irradiated Fuel Bay



4.4 Steam Generators

Each reactor unit at Darlington has four steam generators, measuring 22 metres in height and containing 4,663 U-shaped tubes which carry hot heavy water under high pressure pumped from the reactor. OPG's station condition assessments and component inspections have shown that the steam generators can operate reliably for another 30 years and do not need to be replaced.

Figure 3 - Steam Generator Schematic

The specific work activities for the Steam Generators work bundle are:

(1) Primary Side Cleaning – Involves a mechanical cleaning of magnetite from the inner diameter of the steam generator tubes;

(2) Secondary Side Cleaning (Waterlancing) – Involves cleaning the outer diameter of the tubes and tubesheet with a combination of high pressure lancing and low pressure/annulus flushing at the tubesheet area, including visual inspections;

(3) Access Port Installation – Allows additional visual inspection locations of steam generator internals during and post refurbishment, and is needed to provide future

ability to clean the upper support plates and preheater region through waterlancing or future chemical cleaning, access for foreign material retrieval, and remote inspection of U bend region and upper supports;

(4) Inspection and Repair – Required pursuant to the Steam Generator Life Cycle Management Plan, and includes tube plugging work if required based on inspection results;

(5) Divider Plate Inspections, Boiler Open/Close, and Inspection Support – Primary side divider plate leakage measurements using an acoustic leakage inspection system will be undertaken during the refurbishment outages to assess for coolant bypass and can be used to compare with previous and future outage inspections to trend the divider plate performance; and

(6) Bleed Cooler Inspection and Bundle Replacement – In accordance with the Component Condition Assessment, wall thickness measurements will be taken. Based on the results, tube plugging may be required. Bleed cooler bundle replacement is contingent on the results of the initial inspection.

All engineering for the installation of the access ports and detailed design for the tooling is complete. Full steam generator tube mock-up testing on the primary side cleaning optimization has also been conducted. The remaining work has been scheduled.

4.5 Balance of Plant

The Balance of Plant major work bundle is comprised of five broad areas of scope: (1) Balance of Plant Work, (2) Unit Islanding, (3) Refurbishment Support Facilities, (4) Shutdown, Layup and Services, and (5) Specialized Projects. Each of these areas is relatively distinct and is considered separately in Chart 1.

Chart 1 - Balance of Plant – Areas of Scope

Area of Scope	Description
Balance of Plant Work	The Balance of Plant Work scope includes work on two distinct systems, namely nuclear and conventional systems. This work involves engineering modifications, as well as a high number of like-for-like replacement work.
Unit Islanding	The Unit Islanding scope includes work needed to create a safe, precise work area that is separated from the operating plant through a system of physical barriers and controls. Once separated, the goal will be to maximize the ability for OPG and contract staff to perform work safely and efficiently on the unit that is being refurbished while minimizing the impact on the operating units.
Refurbishment Support Facilities	This scope includes work that is needed to support the refurbishment scope and staff in and around the station. It includes common areas such as shops and storage, washrooms and offices for refurbishment workers.
Shutdown, Layup and Services	This scope includes work that is needed to establish specific conditions for the shutdown of each unit and layup of the unit's systems to maintain a protected environment until the systems are returned to service following completion of refurbishment activities. This includes upgrades and modifications to breathing air and service air systems to support vault work and other execution activities, as well as modifications to support power and cooling water needs.
Specialized Projects	This scope involves two main areas of specialized work, relating to (1) the shutdown system computer network, and (2) the vault coolers, as follows: (a) Shutdown System Computers The shutdown system computers are made up of a network of 14 computers for each reactor unit, which are connected to a shutdown system monitor computer that is common to all four reactor units. This work will involve replacing obsolete computers to improve system reliability and plant safety, producing computer hardware and software in accordance with CNSC licensing requirements, assessing and resolving operational issues, providing sufficient spare parts and major components and procuring hardware simultaneously for all four units to ensure consistency. (b) Vault Coolers This work involves like-for-like replacement in each unit of vault cooler coils, as well as fan motors, as there is no economically viable alternative that would provide a noticeable improvement in vault temperatures.