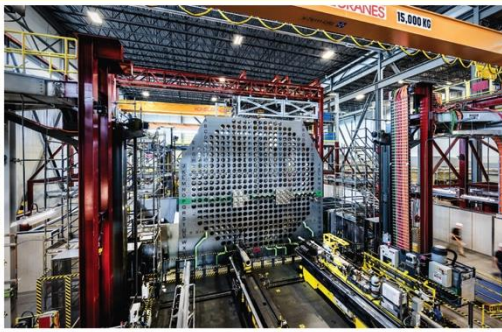
ONE
TEAM
ONE
GOAL

Planning for a Mega-Program: Lessons from the Front Line

Darlington Refurbishment Program

Gary Rose, VP Nuclear PMO, OPG

November 21, 2017



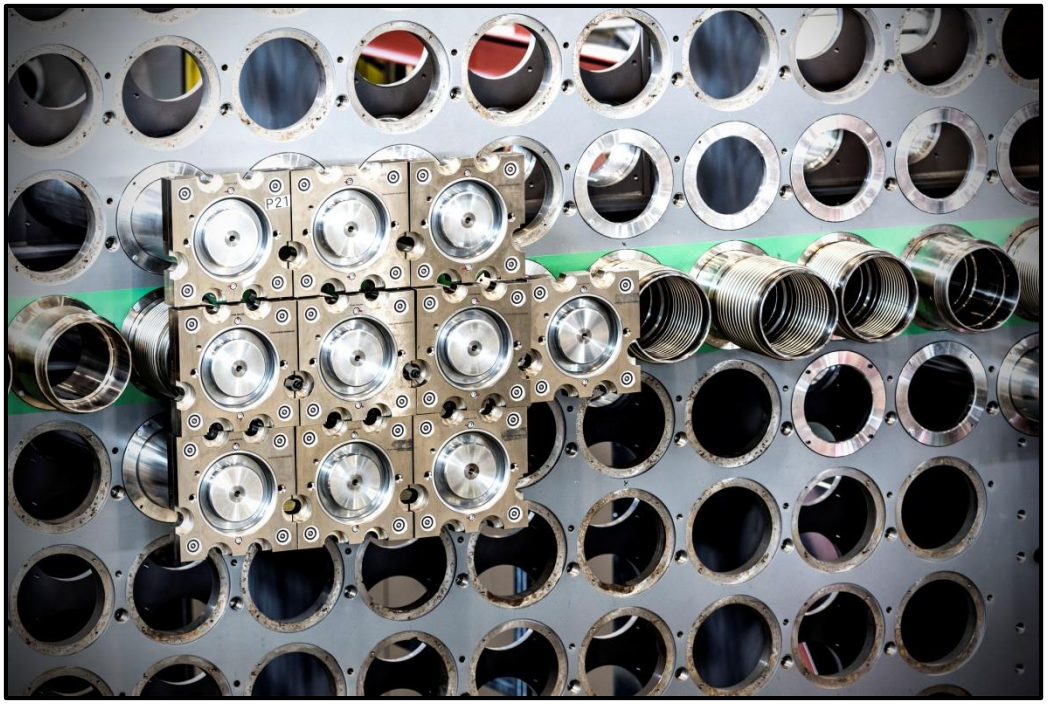
Safety
Quality
Schedule
Cost

Black & McDonald
BWXT Canada Ltd.
FOX CONSTRUCTORS
SNC·LAVALIN Nuclear
AECON Joint Venture

ONTARIO POWER GENERATION

Agenda

- Ontario Power Generation – Overview
- The Project: Darlington Refurbishment Program **(the "DRP")**
- How we approached Planning of this Mega-Program
- Monitoring and Control
- Key Lessons Learned
- Questions



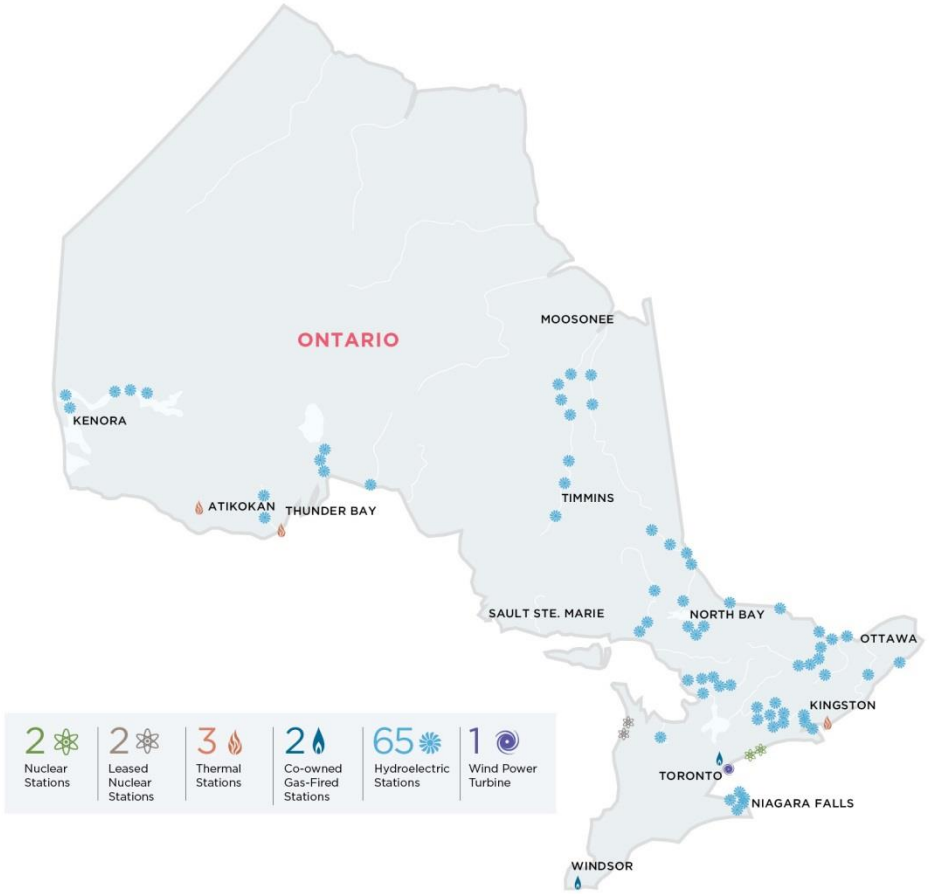
ONTARIO POWER GENERATION

ONTARIO POWER GENERATION OVERVIEW

ONTARIO POWER GENERATION

OPG Overview

- Produces about 50% of Ontario's electricity (at 40% less cost)
- 65 hydro, 2 nuclear, 2 biomass station
  - 2 leased nuclear stations
  - 2 co-owned gas plants
- Closed last coal plant in 2014
- 99 percent GHG emission-free
- 9,200 employees (20% reduction since 2011 levels)
- Ontario's low-cost electricity producer



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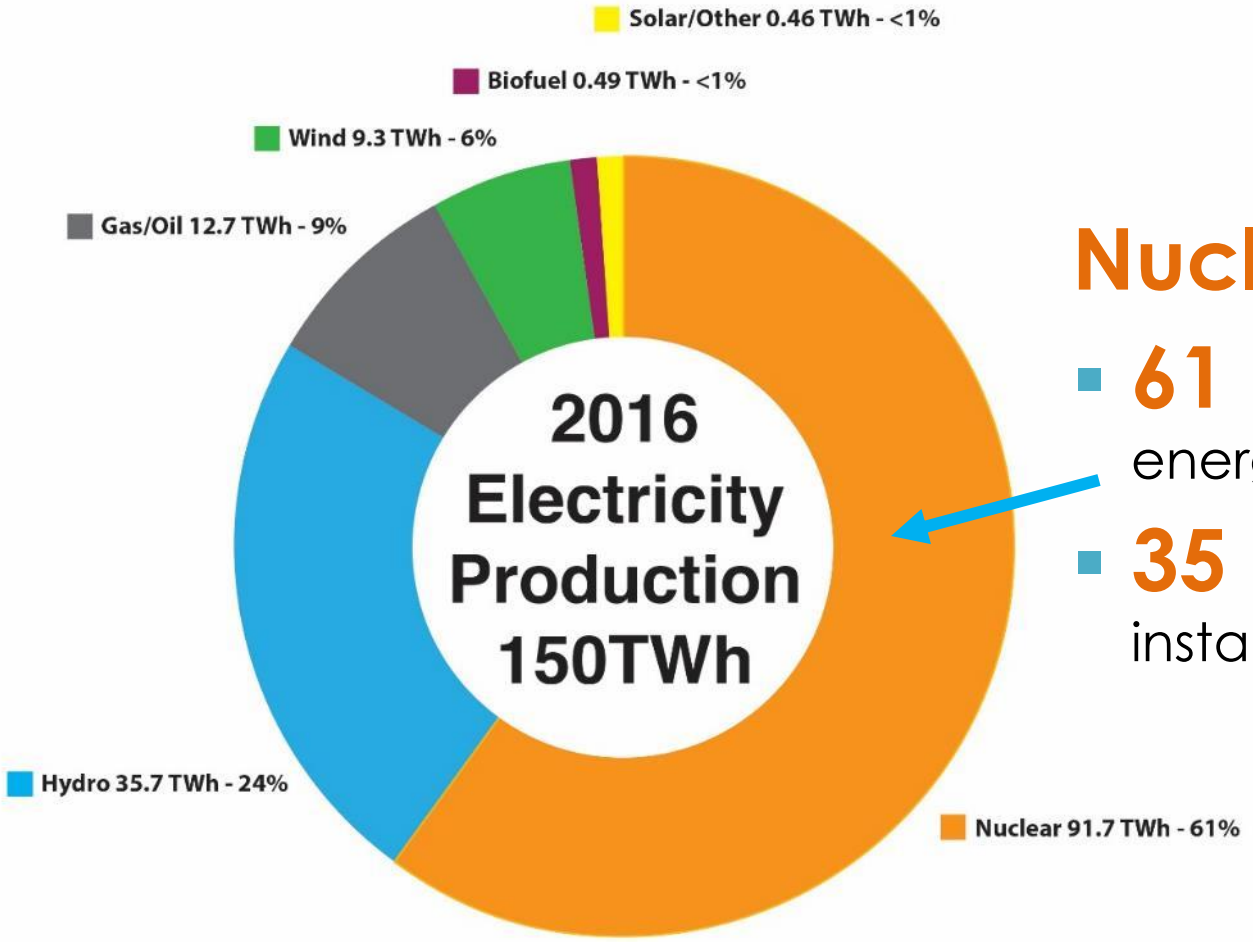
Ontario Generation by Source

2016 Energy Production



Nuclear:

- **61** per cent of annual energy supply
- **35** per cent of total installed capacity

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THE PROJECT: DARLINGTON REFURBISHMENT

ONTARIO POWER GENERATION

Darlington: Top Performing Station

- Darlington's Ontario Electricity contribution: 20%
- Canada's Largest Clean Energy Project

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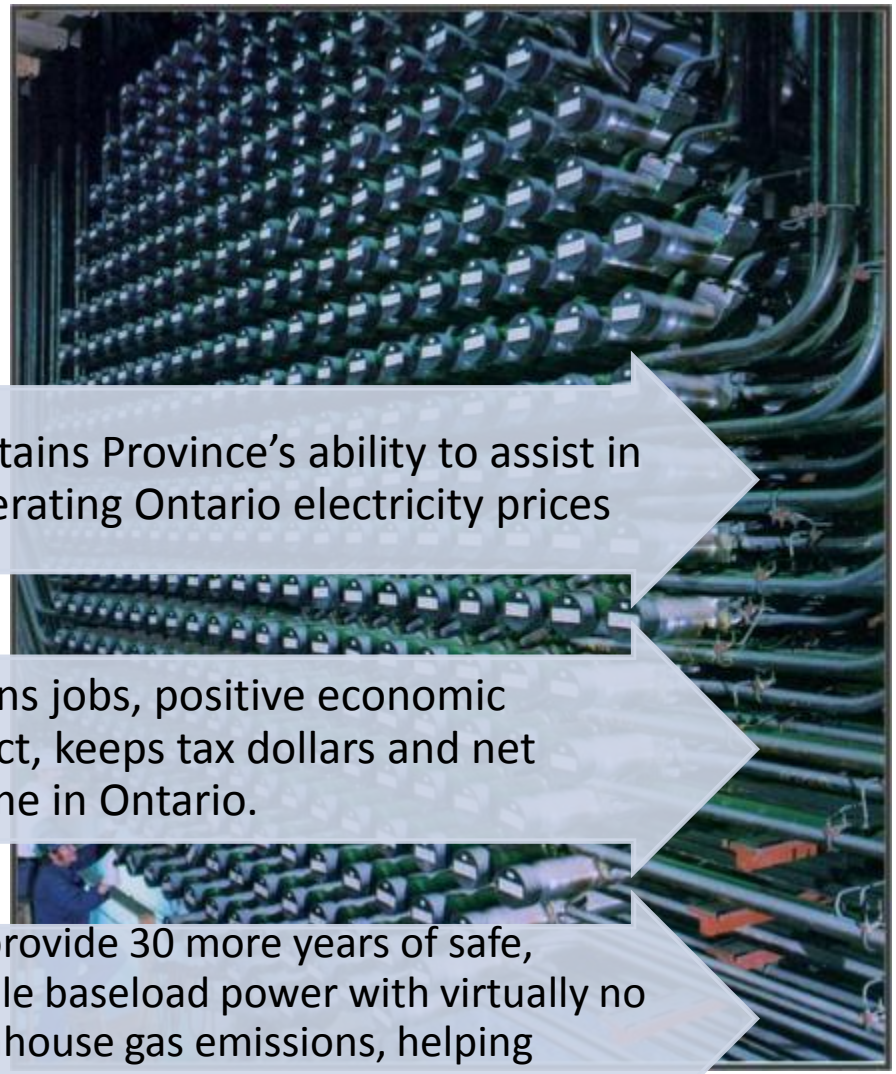
Why Refurbish Darlington Nuclear?

- Mid-life refurbishment required for CANDU
  - World class high performing and well maintained asset
  - For Darlington that time is now



Significant Rate Payer Price Benefits

- Maintains Province's ability to assist in moderating Ontario electricity prices

Significant Economic Benefits for the Province

- Retains jobs, positive economic impact, keeps tax dollars and net income in Ontario.

Maintains a Diverse Generation Portfolio with a Low Carbon Footprint

- Will provide 30 more years of safe, reliable baseload power with virtually no greenhouse gas emissions, helping Canada meet its climate change targets

ONTARIO POWER GENERATION

DRP Economic Footprint

20%
of Ontario's power is supplied by Darlington

$89.9 BILLION
boost to Ontario's GDP

704,112
person-years of increased employment

8¢/kWh
30 years of power below average costs

CONTINUED OPERATIONS OF DARLINGTON
(2017 - 2055)

Average number of jobs per year
14,200

Government revenues
$9.3 billion

Corporate profits before tax
$7 billion

INCREASE IN:

Household consumption
$53.4 billion

Personal income
$61.4 billion

Exports
$11 billion

EVERY $1 INVESTED INTO THIS STATION IS A $1.40 INCREASE TO THE GDP

ONTARIO POWER GENERATION

Resources

- OPG is the Owner/General Contractor for this Project
- In addition to OPG resources, OPG, through our vendor partners, rely heavily on construction/building trades…

Over 3,000 additional trades, currently on site, supporting Refurbishment

BWXT
BWX Technologies, Inc.

SNC·LAVALIN Nuclear

AECON
Joint Venture

FOX CONSTRUCTORS

amec foster wheeler

WorleyParsons
resources & energy

Black & McDonald

TEAMSTERS LOCAL UNION 230

POWER WORKERS' UNION

Canadian Piping Trades Local 401

LABOURERS LOCAL 183 TORONTO

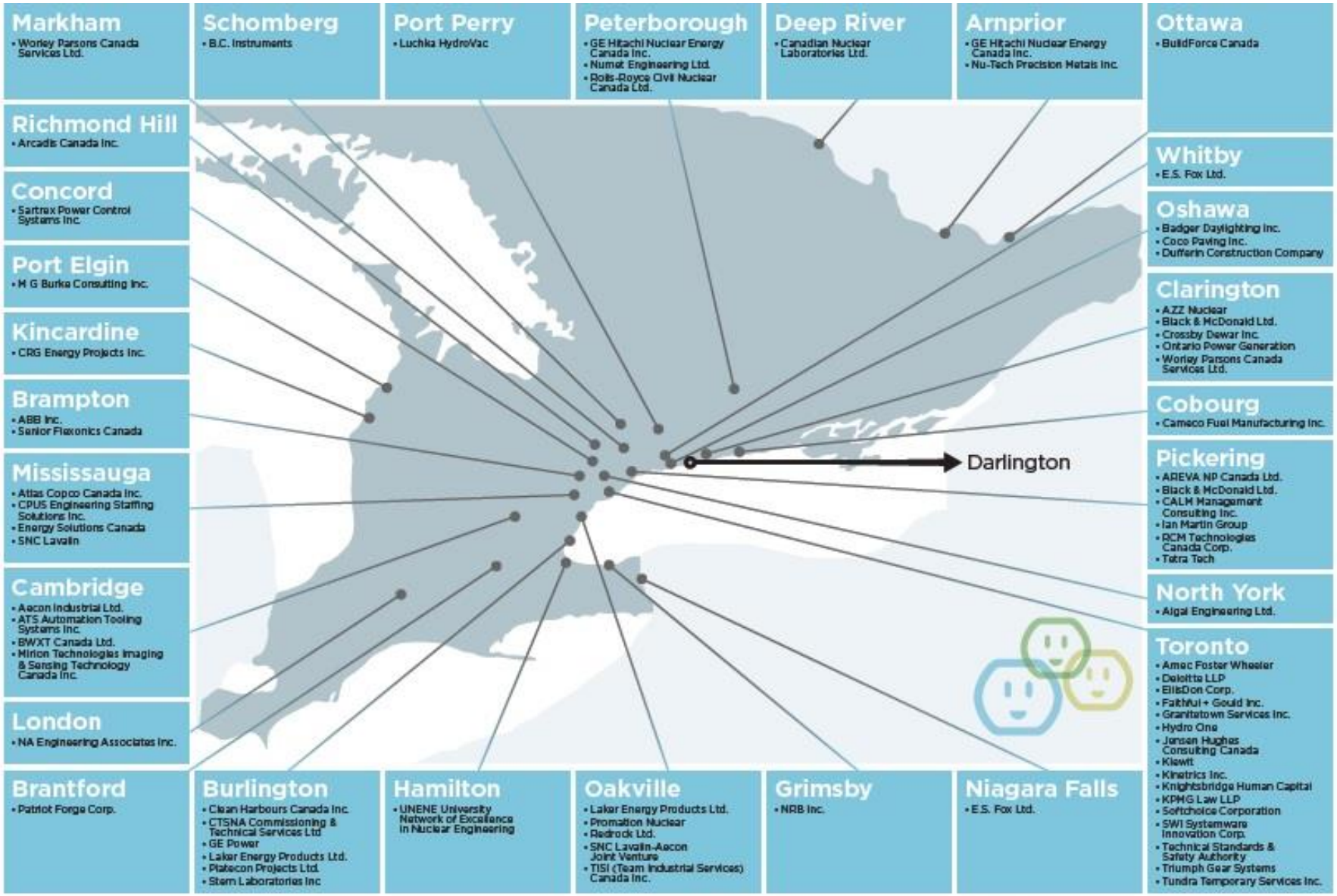
CUSW THE CANADIAN UNION OF SKILLED WORKERS

MARBLE, TILE & TERRAZZO

THE SOCIETY OF ENERGY PROFESSIONALS IPFPE LOCAL 160

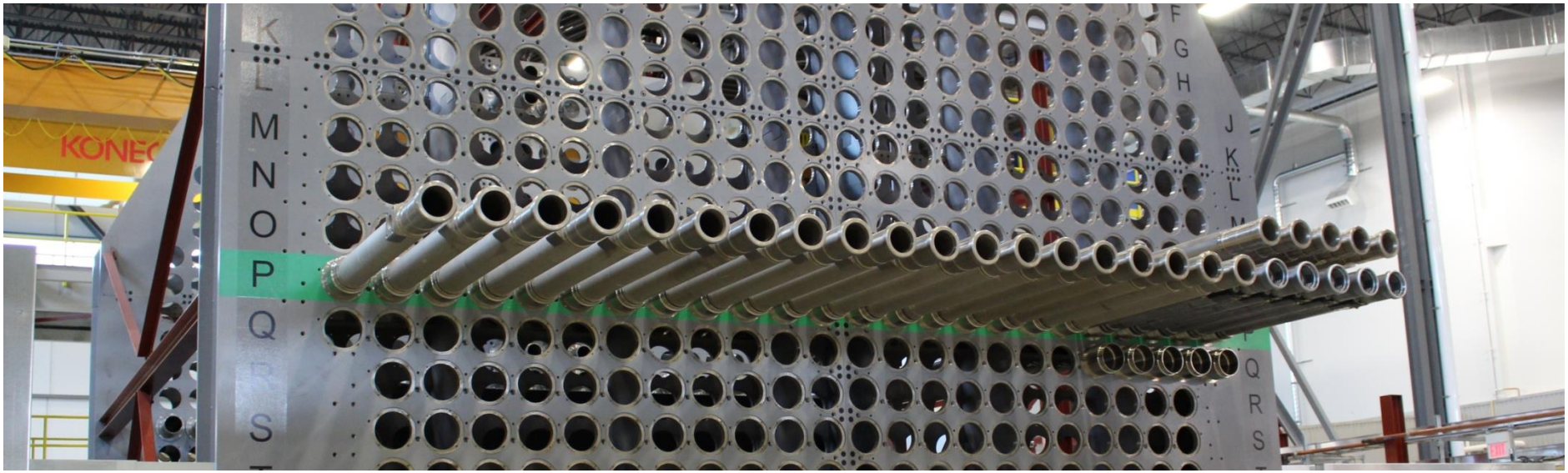
EPSCA
ELECTRICAL POWER SYSTEMS CONSTRUCTION ASSOCIATION

An Investment in Jobs



Darlington Refurbishment Program

- January 11, 2016 - Province announced Ontario will undertake refurbishment of the four-unit Darlington GS
- A multi-year, multi-phase mega-program to enable safe and reliable operation until ~2055
  - Significant employment and economic benefits to Ontario during program and beyond
  - Maintains a diverse generation portfolio with a low carbon footprint, helping Canada meet its climate change targets



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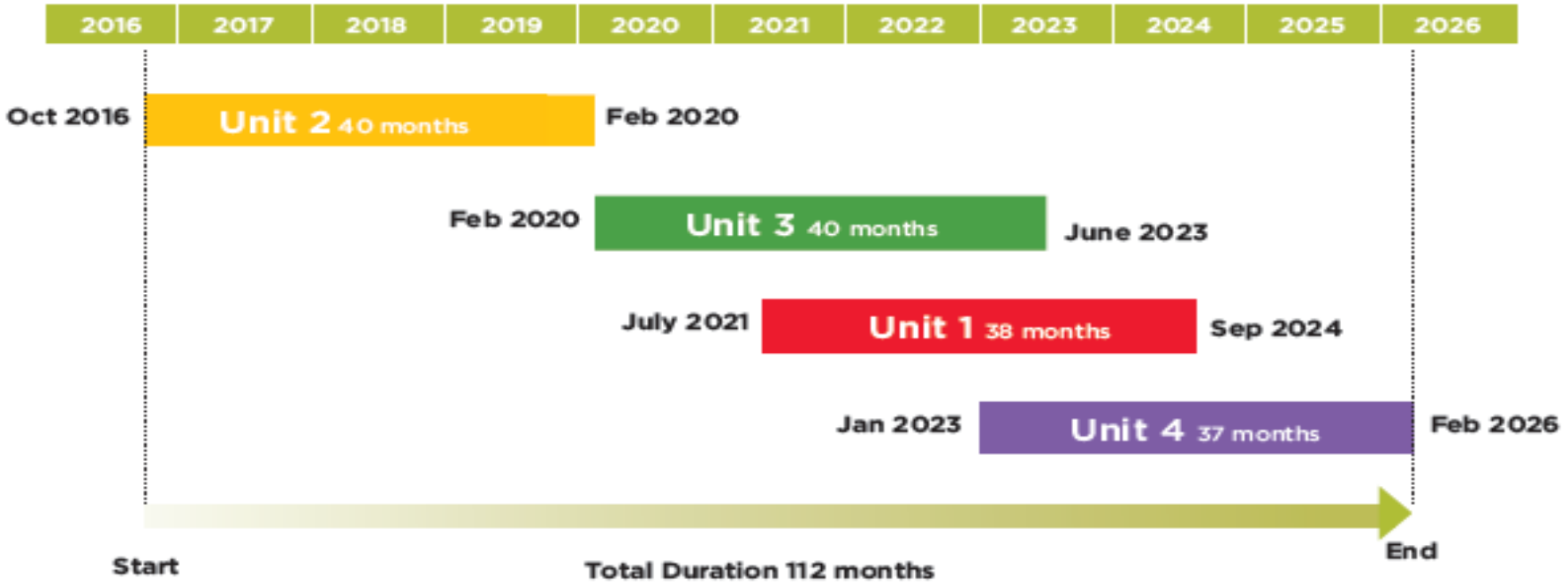
Schedule and Off Ramps

- The final schedule for the Project is 112 months (all four units)
- The phased release approach provides opportunities to change course – OPG must obtain approvals, and funding, for each successive unit.



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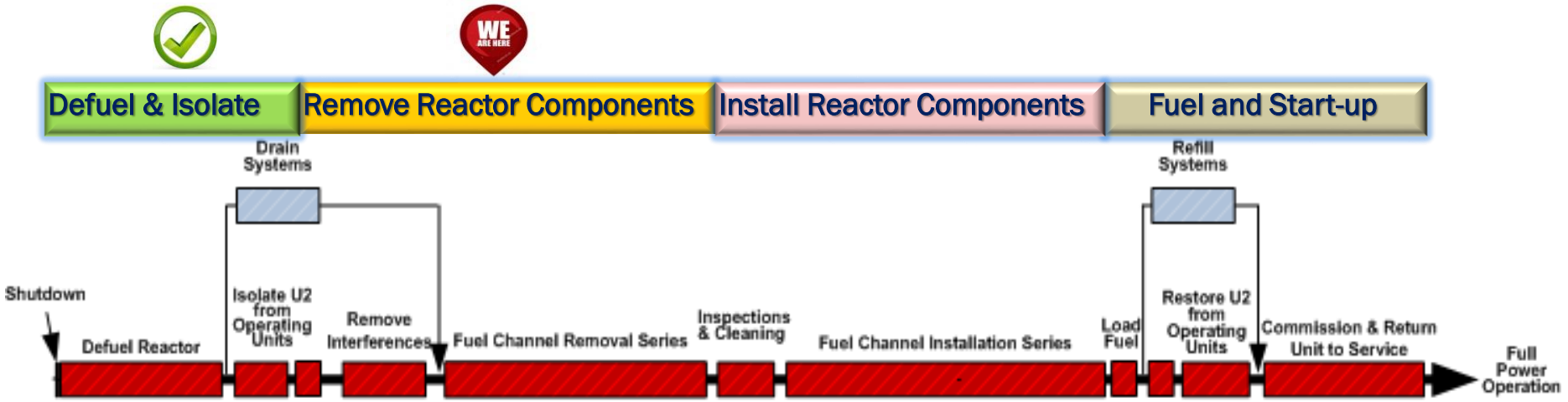
What is Involved: Critical Path



STEP 1	SHUTDOWN The Reactor	✓	STEP 6	REFURBISH major components	
STEP 2	REMOVE fuel and heavy water	✓	STEP 7	PLACE new fuel in the reactor	
STEP 3	ISLAND the unit	✓	STEP 8	RETURN heavy water to reactor	
STEP 4	REMOVE feeder pipes and tubes		STEP 9	RETURN reactor to service	
STEP 5	REPLACE feeder pipes and tubes		STEP 10	RETURN reactor to full power	

Overhaul other systems and equipment

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HOW WE APPROACHED PLANNING OF THIS MEGA-PROGRAM

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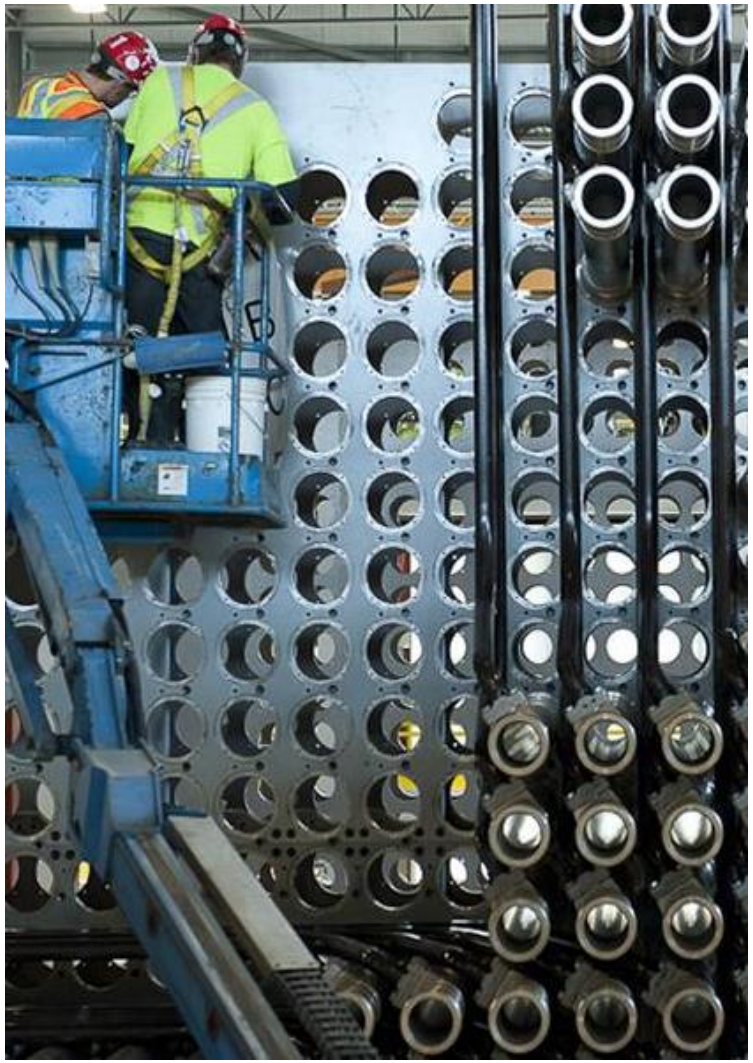
Extensive Preparations



- Years of extensive project planning
- Lessons learned from other major projects have been incorporated
- Recommended practices from PMI, AACE, CII, and others are the basis for our planning approach
- Collaborative Front-End Planning Implemented
  - Scope, schedule and cost are developed to a level of detail not seen on prior projects
- Full Scale Reactor Mock-up Built for tool testing, estimate development, and worker training

Investment in Planning

Initiation Phase 2007-2009

PHASE 1

SCOPE OF WORK

- Initial determination of refurbishment scope through completion of:
  - Technical assessments of all major components
  - Condition assessments of balance of plant components
  - Initiation of regulatory processes; Integrated Safety Review and Environmental Assessment
- Develop reference plans for cost and schedule
- Complete economic feasibility assessment
- Establish project management approach and governance
- Establish overall contracting strategy
- OPG Board and Shareholder agree with recommendation to proceed with preliminary planning within the Definition Phase of the project

Definition Phase 2010-2015

PHASE 2

SCOPE OF WORK

- Obtain regulatory approvals:
  - Environmental Assessment
  - Integrated Safety Review
  - Integrated Implementation Plan
- Implement project management and oversight
- Complete infrastructure upgrades, i.e. Darlington Energy Complex
- Implement safety improvements
- Award major contracts
- Finalize project scope and complete engineering work
- Procure long lead materials
- Complete unit prerequisite work
- Construct reactor mock-up and fabricate and test tooling
- Develop release quality cost and schedule estimate
- Obtain all permits and licences
- Mobilize and train Trades staff

Execution Phase 2016-2026

PHASE 3

SCOPE OF WORK

- Unit shutdown and defueling
- Island unit and lay up systems
- Execute all refurbishment scope:
  - Reactor components
  - Fuel handling systems
  - Turbine / generator
  - Steam generators
  - Balance of plant
- Meet all regulatory commitments
- Plant maintenance and inspection activities
- Manage plant configuration
- Load fuel
- Commissioning
- Unit start-up
- Apply lessons learned to subsequent unit refurbishments
- Project close-out

PLANNING

RQE

ONTARIO POWER GENERATION

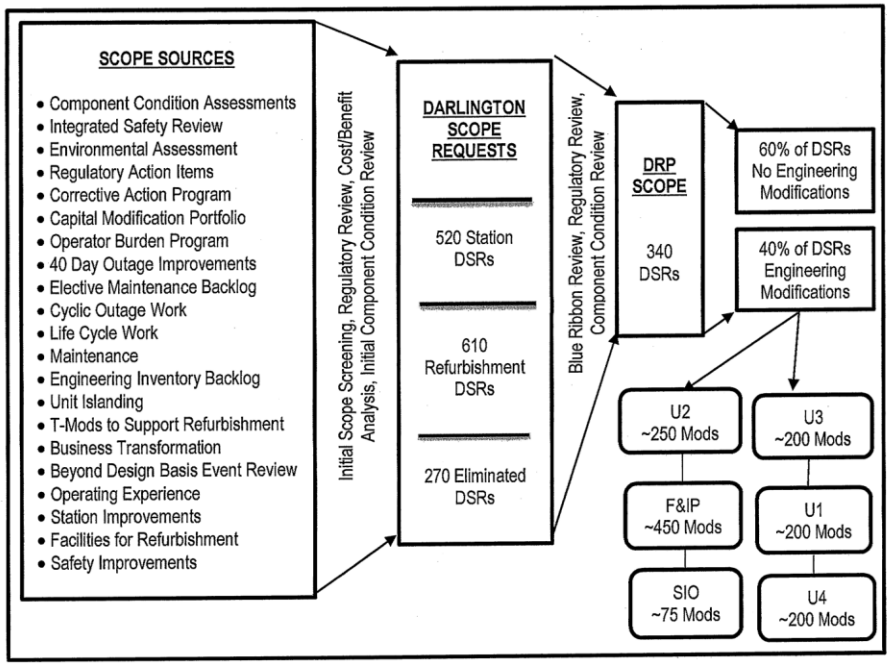
Major Planning Steps

Gated Process

- **Scope**
  - OPG commenced refurbishment planning in 2008 to fully assess the condition of the plant and complete regulatory studies to determine total scope and timing. A detailed scoping process was put in place to balance “must do” / “nice to do” scope.
- **Contracting**
  - Once scoping was completed, OPG selected the vendor partners’ to deliver the scope, EPC based contracts were implemented for all scopes of work.
- **Cost Estimating**
  - Gating process used to progressively develop project cost and schedules.
  - Documented the basis of estimate and assumptions for major cost elements in accordance with Class 3 estimate quality requirements as defined by AACE
- **Schedule**
  - Developed an integrated Level 2 schedule for the Program and an integrated and resource loaded Level 3 schedule for Unit 2
- **Risk and Contingency**
  - Performed a comprehensive review to identify and assess all known and foreseeable risks, to develop mitigation plans and quantify residual risk
- **Release Quality Estimate**
  - Over six years of effort culminated in the development of the release quality estimate
  - Independent reviews were performed to validate results
  - RQE approved by OPG’s Board in November 2015 and the Province in January 2016

Scope Definition

- Proper scope definition is necessary for cost estimation and also mitigates project risk
- OPG developed a Program Scope Review Board ("PSRB") and initially identified 1400 Scope Requests
- The PSRB assessed the scope to determine what work had to be done in the Refurbishment and categorized the scope into "Core", "Regulatory", "Core Support", "Value Enhancing"
- Core was the basis of Critical Path; all other scope assessed for do-ability against Critical Path
- The final DRP scope is 340 Scope Requests
- All other scope managed through ongoing station life-cycle management plans



Key:
PSRB must authorize any changes to scope, including removals.

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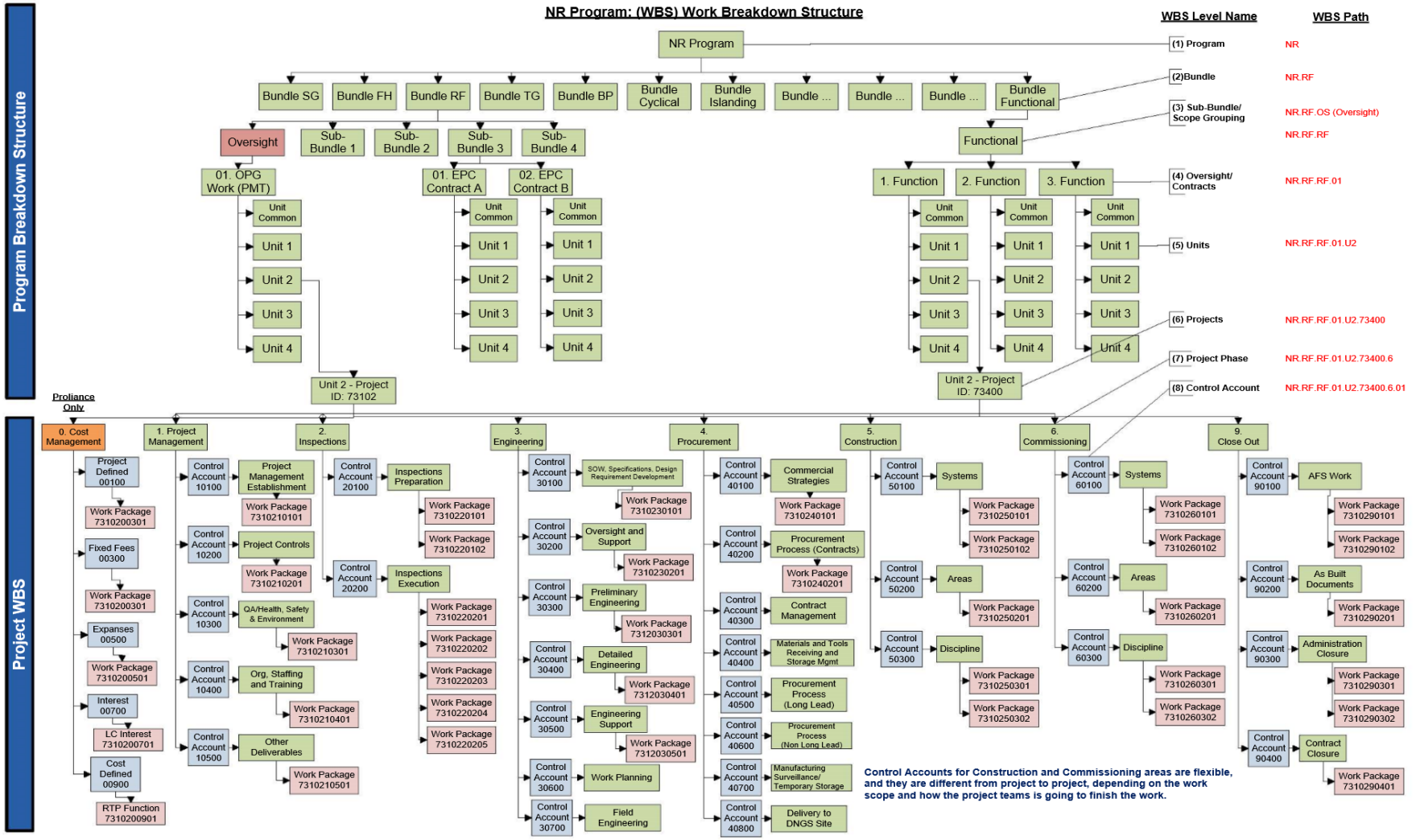
Program Work Breakdown

- The DRP scope was organized using a work breakdown structure and assigned to project bundles, Units, etc. **[CRITICAL step]**

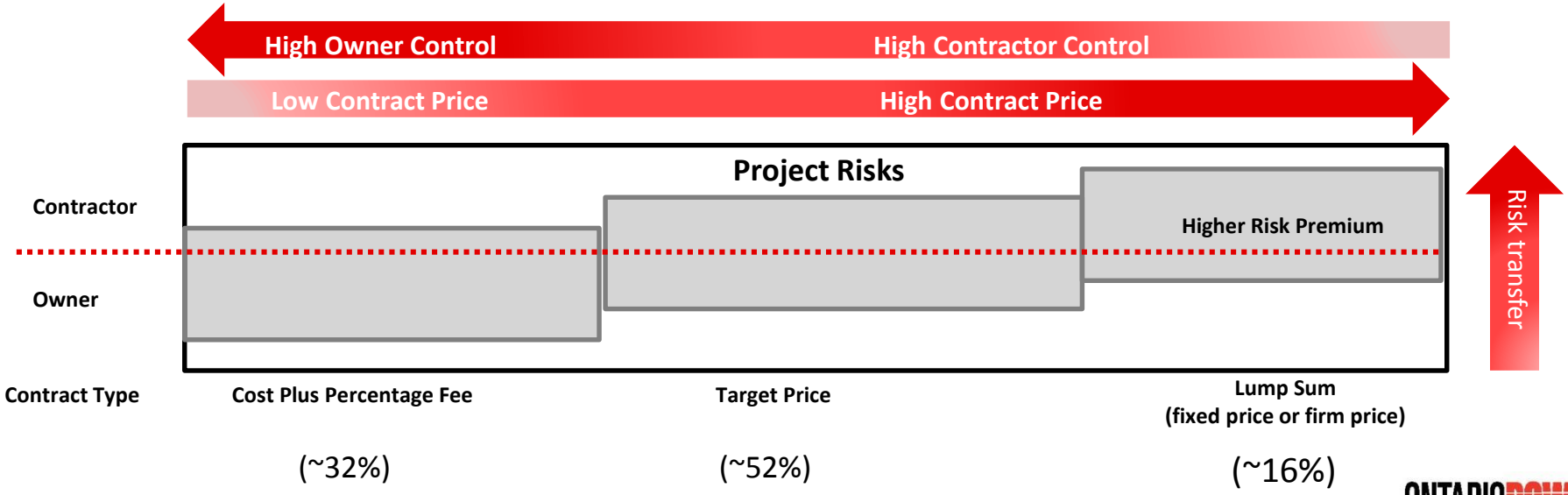


Commercial and Contracting Model

- OPG made a strategic decision to retain control over the DRP and chose a multi-prime EPC (engineering, procurement and construction) contracting model
- Different procurement methods, contracting strategies and pricing models apply to the major work packages to address varying degrees of complexity, uncertainty and need for collaboration
- Rather than award a single project management contract to one contractor, multiple prime contractors are working on the Program– each with distinct expertise and contracts
- OPG is the integrator between the various prime contractors and sets the standards for how the Program is planned and managed
- Incentives and disincentives align all parties to a common goal
- EPC model ensures that handoffs between engineering, procurement and construction are effective

Pricing Models

- In contracting the various work packages, OPG implemented different pricing models to optimize risk transfer and value-for-money
  - Fixed pricing is used for highly definable tasks where control over the work is in the hands of a contractor
  - Cost plus % Fee is used where work is complex and not highly definable, and where the owner is required to have control over the work
  - Target Price provides strong commercial incentives, similar to fixed pricing, but still allows the owner to have control over certain aspects of the work



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Target Price Model

- The negotiated Target Price is a jointly developed estimate of the cost of work for a defined scope plus a negotiated Fixed Fee for overheads, profit and risks

- Vendors are paid actual costs plus the Fixed Fee based on the locked scope of work with rigid controls for change orders
- Fixed Fee is capped
- Parties share savings below targets and overruns above targets
- The cost incentives/disincentives mechanism is structured to achieve alignment of contractor interest and limit cost increases and schedule delays
- A target schedule (total days) is also set to perform the work, and is also subject to incentives/disincentives

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Refurbishment Scope and Vendors

Defuel, Fuel Handling, Special

BWXT
BWX Technologies, Inc.

Retube and Feeder Replacement

SNC·LAVALIN Nuclear
AECON Joint Venture

Turbine / Generator

GE
SNC·LAVALIN Nuclear
AECON Joint Venture

Steam Generators

BWXT
BWX Technologies, Inc.

Balance of Plant

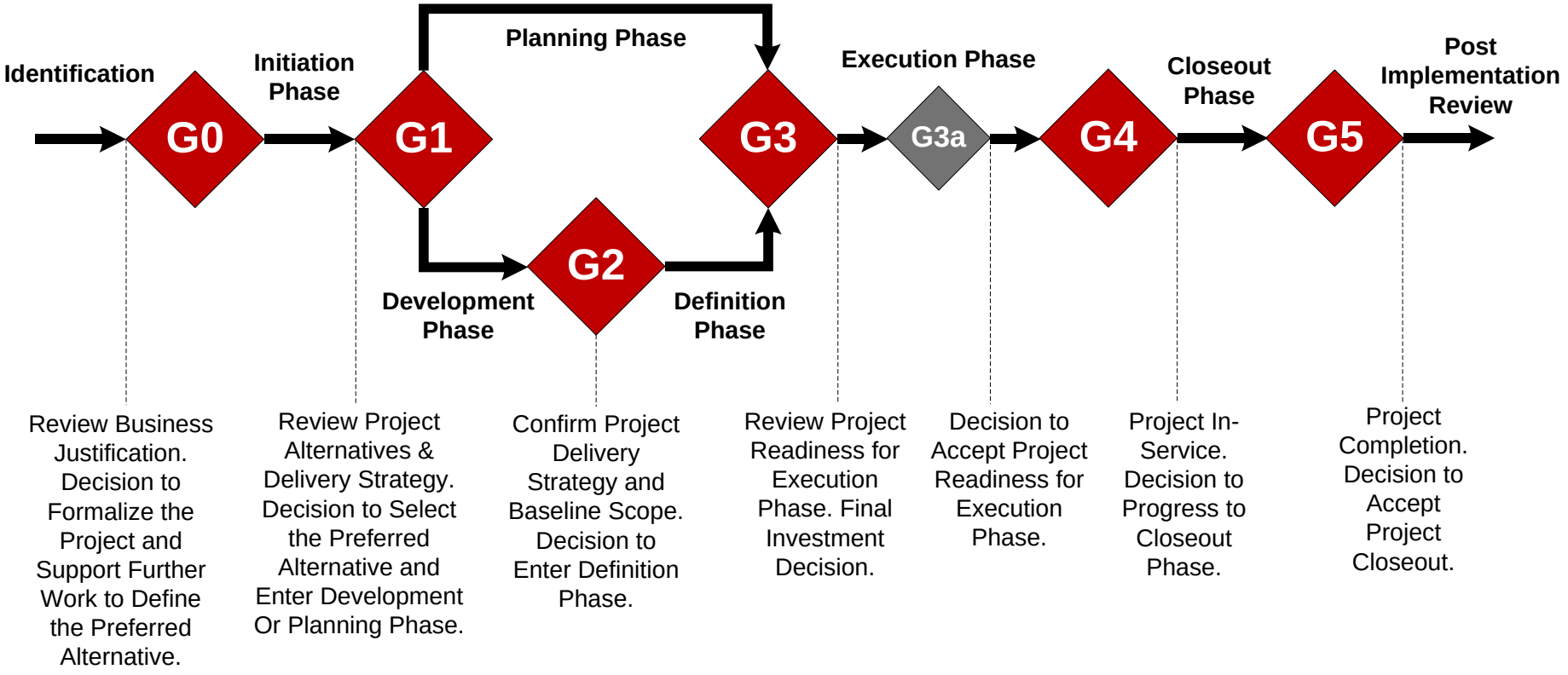
FOX E.S. LTD. CONSTRUCTORS

Cyclic Outage

Black & McDonald

Gated Process

- All of OPG's Projects, **including DRP projects**, progress through a Gated Process providing management an opportunity to assess readiness for the project to proceed to the next phase…



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Gated Expectations

Gate	Project Level	Planning	Financial	Design / Engineering	Scope Definition	Schedule (Project, Next Phase)	Cost Estimate (Project, Next Phase)	Risk Mgmt Plan	Contract Mgmt Plan
0	All	Charter / ToR	Business Plan	N/A	N/A	N/A	N/A	N/A	N/A
1	A	Charter	Type 3 BCS	Conceptual	Preliminary	L1, L3	Class 5, Class 3	L2	N/A
	B		Type 2 BCS			L1, L2	Class 5, Class 4	L1	N/A
	C		Type 1 BCS			L1, L2	Class 5, Class 4	L1	N/A
	D		Type 1 BCS			L1, L1	Class 5, Class 5	L1	N/A
2	A	L2 PMP/PEP	Type 3 BCS	Preliminary	Detailed, PDRI (Large)	L2, L3	Class 4, Class 3	L2	L2
	B	L2 PMP/PEP	Type 2 BCS		Detailed, PDRI (Small)	L2, L3	Class 4, Class 3	L2	L2
	C	L1 PMP/PEP	Type 1 BCS		Detailed	L2, L2	Class 5, Class 4	L1	L1
	D	L1 PMP/PEP	Type 1 BCS		Detailed	L1 [2], L1 [2]	Class 5, Class 5 [4]	L1	L1
3	A	L2 PMP/PEP	Type 3 BCS	Preliminary/ Detailed *	Detailed, PDRI (Large)	L3, L3	Class 3, Class 3	L2	L2
	B	L2 PMP/PEP	Type 2 BCS		Detailed, PDRI (Small)	L3, L3	Class 3, Class 3	L2	L2
	C	L1 PMP/PEP	Type 1 BCS		Detailed, PDRI (Small)	L2 [3], L2 [3]	Class 4 [3], Class 4 [3]	L1	L1
	D	L1 PMP/PEP	Type 1 BCS		Detailed	L1 [3], L2 [3]	Class 4 [3], Class 4 [3]	L1	L1
4	All	Closeout Plan	REIS, AFS	Detailed *	N/A	N/A	N/A	N/A	N/A
5	All	Closeout	PCR	N/A	N/A	N/A	N/A	N/A	N/A
PIR	A	N/A	Comprehensive	N/A	N/A	N/A	N/A	N/A	N/A
	B		Simplified	N/A	N/A	N/A	N/A	N/A	N/A
	C		Simplified	N/A	N/A	N/A	N/A	N/A	N/A
	D		PCR	N/A	N/A	N/A	N/A	N/A	N/A

** – Dependent on the Project Delivery & Contracting Strategy.*
[#] – Nuclear Minimum.

Cost Estimating

- Cost estimate development followed AACE Recommended Practices including the following steps:
  - Identifying the scope of work, constraints and assumptions
  - Completing engineering and determining resource and material requirements
  - Quantifying the resources required, including labour and non-labour resources
  - Applying costs to the resources
  - Adjusting or factoring pricing based on project environment
  - Documenting the Basis of Estimate
- OPG obtained specialized personnel with experience conducting the work, including independent estimating professionals
- Use of the reactor mock-up added rigor to the estimates through use of actual durations from the tool testing

AACE Estimate Classifications

ESTIMATE CLASS	PROJECT PHASE	PROJECT DEFINITION	END USAGE	ACCURACY RANGE
Class 5	Identification	0% to 2%	Initial Evaluation/ Feasibility of Project	-50% to +100%
Class 4	Initiation	1% to 15%	Study or Feasibility	-30% to +50%
Class 3	Planning	10% to 40%	Budget Authorization or Control	-20% to +30%
Class 2	Execution	30% to 75%	Control or Bid/Tender	-15% to +20%
Class 1	Execution	65% to 100%	Check Estimate or Bid/Tender	-10% to +15%

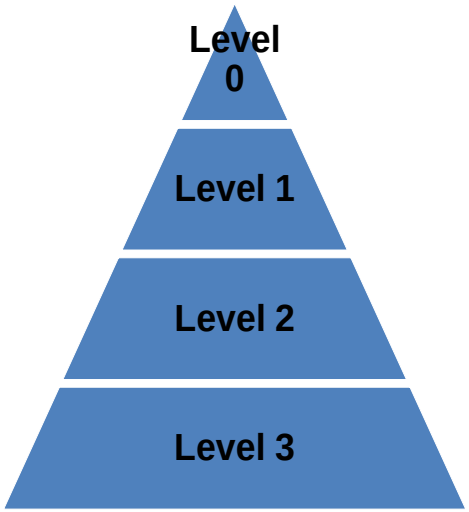
- OPG Requires an estimate to be at Class 3 or better by the time it reaches Gate 3 (which is also the basis for the DRP RQE)

Schedule Development

- Developed a fully integrated program schedule that integrates project schedules of the major work bundles
- Schedule includes:
  - Scope of work
  - Key activities' start and finish dates, duration, and resources
  - Sequence and logical interrelationship of activities and milestones
  - Identification and optimization of the critical path
  - Incorporates risks and includes duration contingencies
  - Methods for determining Earned Value to measure progress of work
- Will allow regular monitoring and updating to track performance, initiate corrective actions and to plan and manage priorities, opportunities and threats

Multi-level Scheduling

- Multi-level scheduling approach allows control at the appropriate level of the organization
  - The lower the level, the greater the level of detail
  - OPG as owner performs project management and control utilizing Levels 0 to 2
  - Level 3 typically controlled by contractors and/or OPG groups performing the work
  - Contractors may have level 4 and 5 schedules for day-to-day work control and field supervision



Level 0: Nuclear Program Milestone Schedule (PMSS), controlled by OPG Senior Management.

Level 1: Nuclear Program Integrated Master Schedule (PIMS), controlled by OPG Senior Management. Program Level 1 contains all Control Accounts from all Projects as well as for Program Management work.

Level 2: Nuclear Program Coordination & Control Scheduled (C&C), controlled by OPG Nuclear Program/Project teams. Program Level 2 contains all Work Packages in the Program and they are interrelated.

Level 3: Nuclear Project Detailed Production Schedules (PDPS), controlled at the project level, by contractors or OPG (for OPG executed projects).

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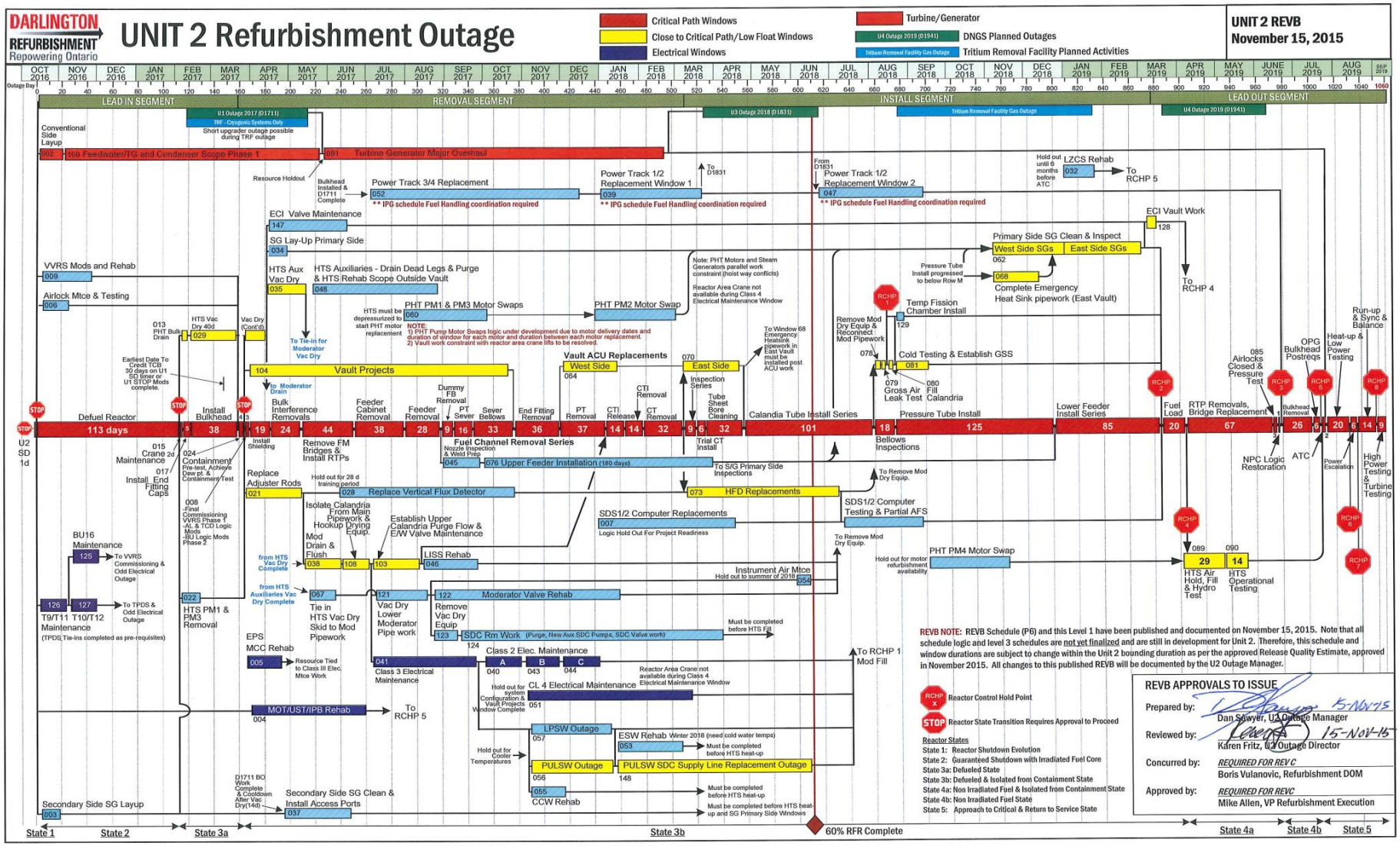
Level 1 Early Finish Schedule



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Risk Identification and Assessment

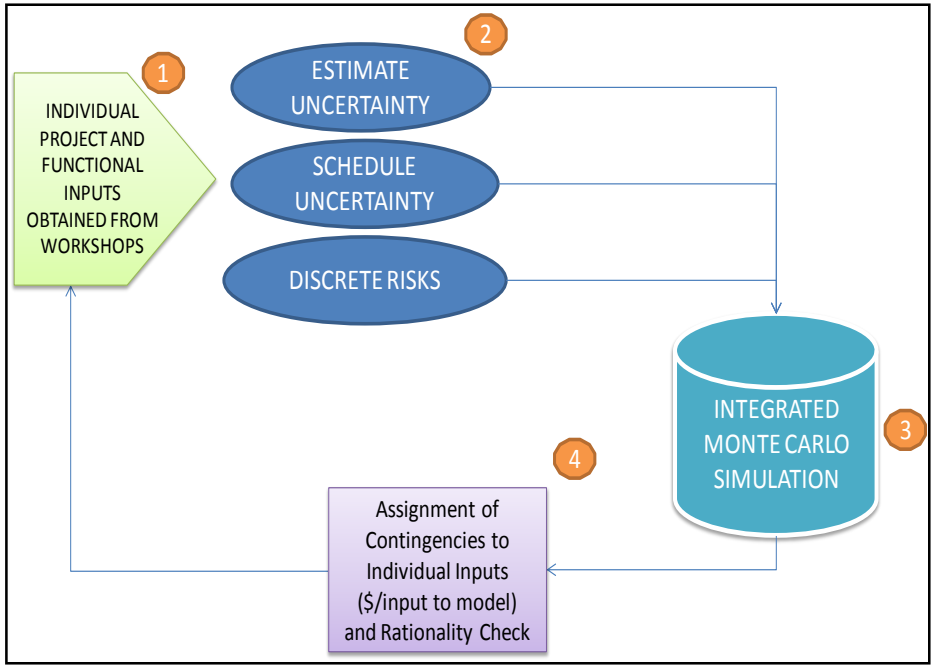
- Risks were identified and assessed for the projects within the major work bundles; program risks were also identified and assessed.
  - Mitigation plans were developed as appropriate
- Risks were classified under three categories:
  - **Cost estimating uncertainty** is the possibility that the costs of the projects are more or less than the applicable estimates
  - **Schedule estimating uncertainty** is the possibility that the actual schedule durations for the projects are more or less than the estimated durations
  - **Discrete risks** are the incremental cost and schedule impacts if specific risk events were to occur
- OPG's risk management process requires active risk mitigation. Oversight is in place to ensure that this is occurring, including a bi-monthly Risk Oversight Committee (R-ROC)

Contingency Development

- Contingency is an amount added to an estimate to allow for items, conditions or events, for which the state, occurrence or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs
  - Contingency is generally included in most estimates, and is expected to be expended
- OPG's contingency development process followed AACE International's Recommended Practices
  - Owners establish contingency levels based on an acceptable risk level, degree of uncertainty, and the desired confidence levels for meeting baseline requirements
  - When used to absorb the impacts of uncertainty, contingency is a form of risk mitigation
- The determination of the amount of contingency is integral to the estimating, scheduling and risk management process of a project or program
  - Active and transparent monitoring of contingency allocations provides OPG with visible oversight on how risks are impacting the Program

Contingency Development Process

- OPG's detailed contingency development process is shown in the following schematic:
  - Detailed inputs were collected from project bundles and functions
  - A detailed evaluation of the three categories of risks was undertaken
  - Performance of an integrated cost and schedule Monte Carlo simulation (1)
  - Management reviews the results to validate the overall adequacy of the contingency estimate, and to establish the required confidence level for inclusion into the RQE (P90)



Note 1.

- Monte Carlo simulation is a probabilistic, computational technique that simulates execution of the project thousands of times, accounting for potential realization of risk events and uncertainties, taking into account probabilities and impacts
- The simulation results are integrated to estimate amount of contingency required at specific confidence levels

ONTARIO POWER GENERATION

EXECUTION: MONITORING AND CONTROL

ONTARIO POWER GENERATION

OPG's Role as the OWNER

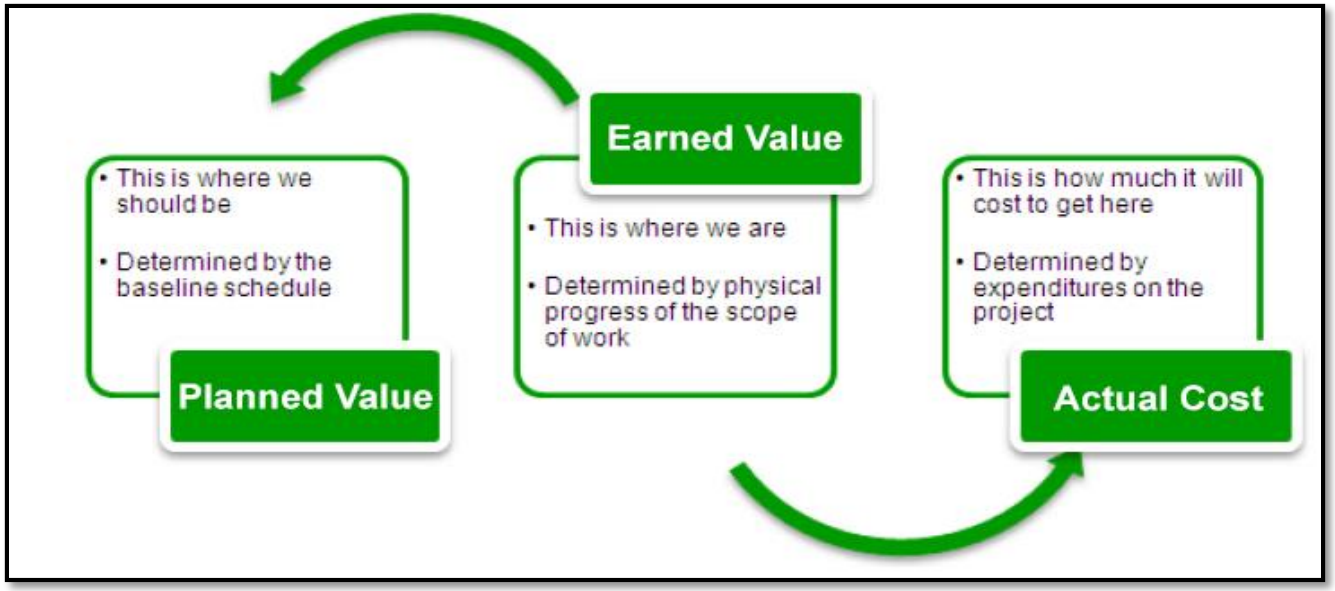
- OPG retains overall responsibility for the Program, controls the integrated schedule and deliverables and is the license holder and design authority for the plant. Its functions include:
- **Project Management Teams** - these teams are responsible for management, oversight and delivery of specific major work bundles
- **Program Support Functions** - support the major work bundles and the DRP as a whole in areas such as engineering, procurement and oversight
  - Provide the required support, coordination, integration, and oversight of the work that will be performed by the Project Management Teams and external contractors
- **Execution Support Functions** - support the execution of the fieldwork
  - Fieldwork is conducted by contractors- Project Execution Support provides support for construction execution, quality management, and purchase and delivery of parts
  - Work Control / Project Office integrates and controls the individual unit outage and execution schedules and ensures all deliverables are known, communicated and completed in accordance with expectations
  - Operations and Maintenance Function is the "custodian" of the operating units in the plant, ensuring that refurbishment work does not adversely impact the operating units

Project Controls Integration

- Project Controls Integration
  - P6 (Schedule) / Ecosys (Cost) / Integrated Data Base (IDB).
  - Paper-less change management via Ecosys.
  - Microsoft BI (MSBI) - standardized & automated reporting.
- RMO, Risk Management / Oversight Tool
  - Risks / Opportunities, Assumptions, Actions, Issues, Decisions.
- SharePoint / Team sites

Earned Value Reporting

- OPG uses an Earned Value Management methodology including **pre-defined rules of credit** and/or **commodity tracking**
- Allows for continuous analysis of progress achieved against plan
- Allows OPG to implement strategies should the project track "off-plan", including managing allocation of contingencies



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Earning Rules - Engineering

Set the Planned Value (PV) in Primavera/Proliance

WBS Structure/Other

Step 1
- Create WBS/Control Account for each MEC.
- Create WBS/Work Package for Prelim. Engineering and Detailed Engineering
- EC related activities should be under each Work Package

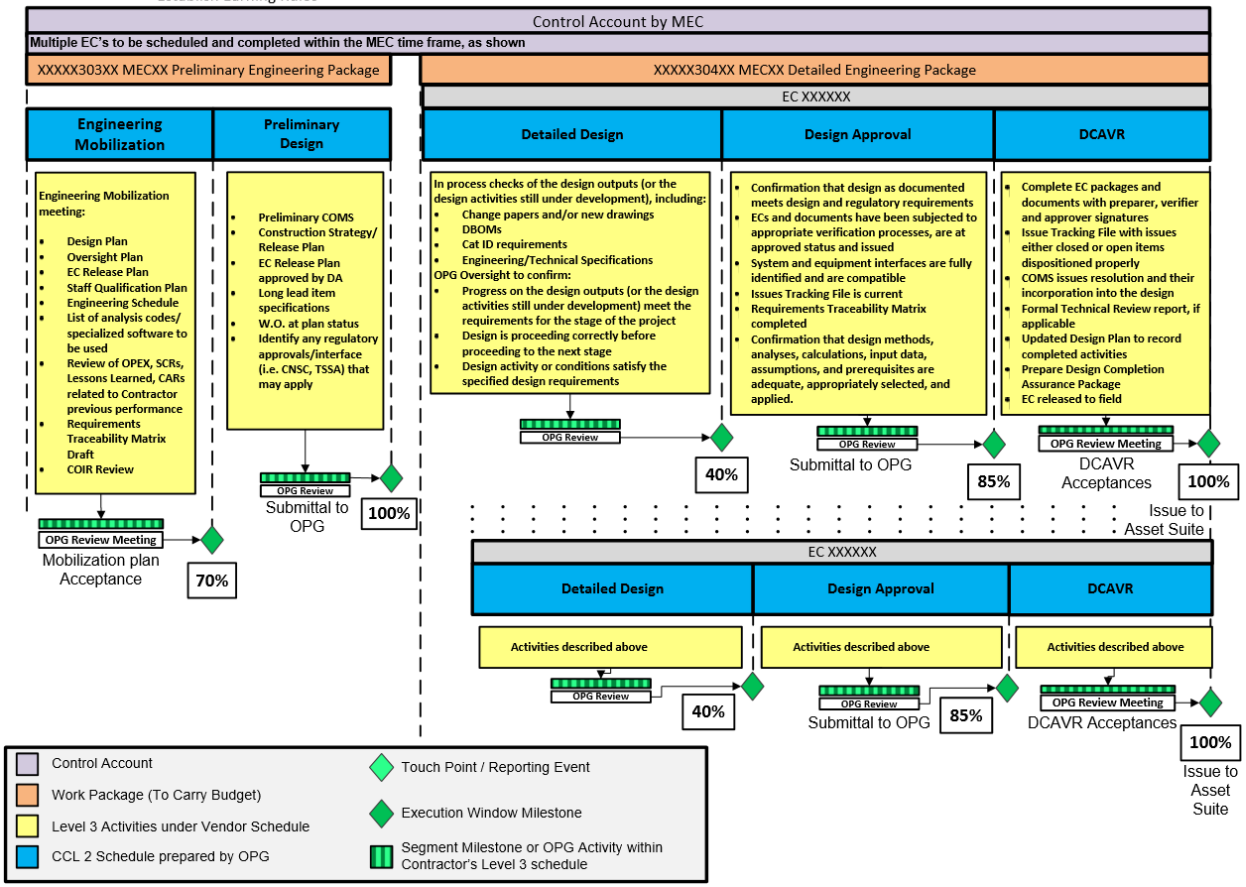
Step 2
- Estimate total Hours/Dollars by Work Package
- Establish Earning Rules

Primavera

Step 3
- Load WBS Summary with Total Budget hours (VUL)
- Contractor prepares Detailed L3 Schedule including OPG interfaces.
- Project CSAs to prepare rollup to C&C schedule.

Proliance

Step 4
- Establish BCWS dollars.
- Establish Earning Rules (use generic template). Need adaption for each PO.



Earning Rules for Design Phase

(Percentages to be agreed upon submittal of L3 Schedule)

ONE MEC	Preliminary Engineering Package	30%	Engineering Mobilization	70%
			Preliminary Design	100%
	Detailed Engineering Package	100%	Detailed Design	40%
			Design Approval	85%
			DCAVR	100%

Project - Control Account ID

Project ID	LOCAL		
XXXXX	X	XX	XX
	Phase	Unique Identifier	Work Package

Monitor the Progress – Calculate SPI/CPI

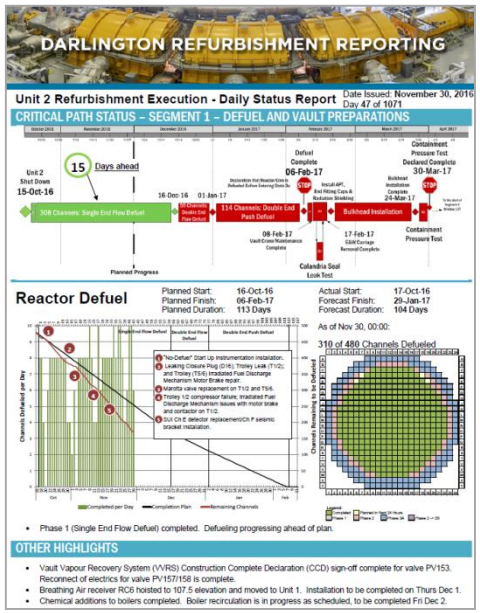
Oncore/TEMPUS
- Setup TEMPUS & Oncore with Work Package #
- Collect Actual spent by Work Package

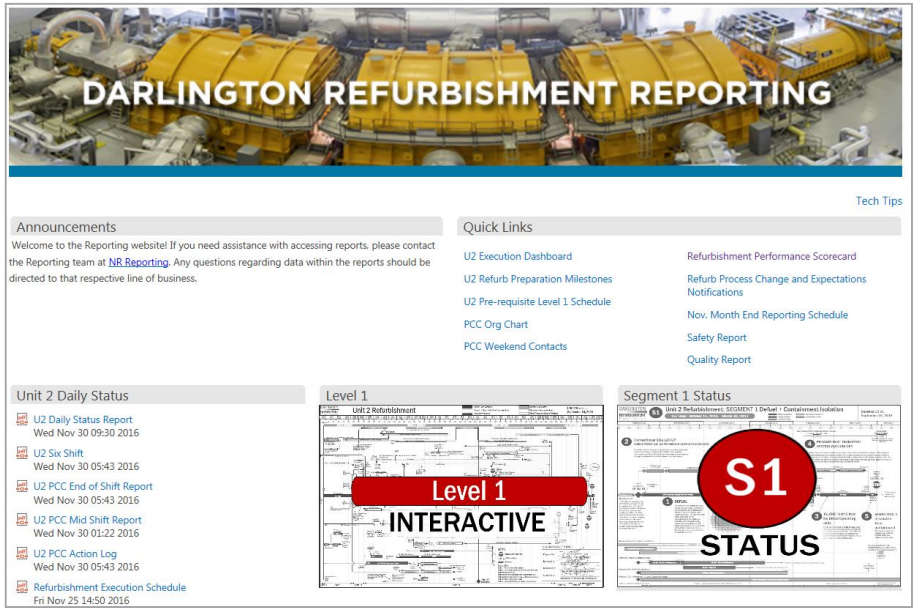
Primavera
- Update the schedule with status and calculate % complete based on earning rules
- Project CSAs to prepare status and % complete by Work Package to Proliance

BI Reporting
- SPI/CPI will be calculated for every Work Package

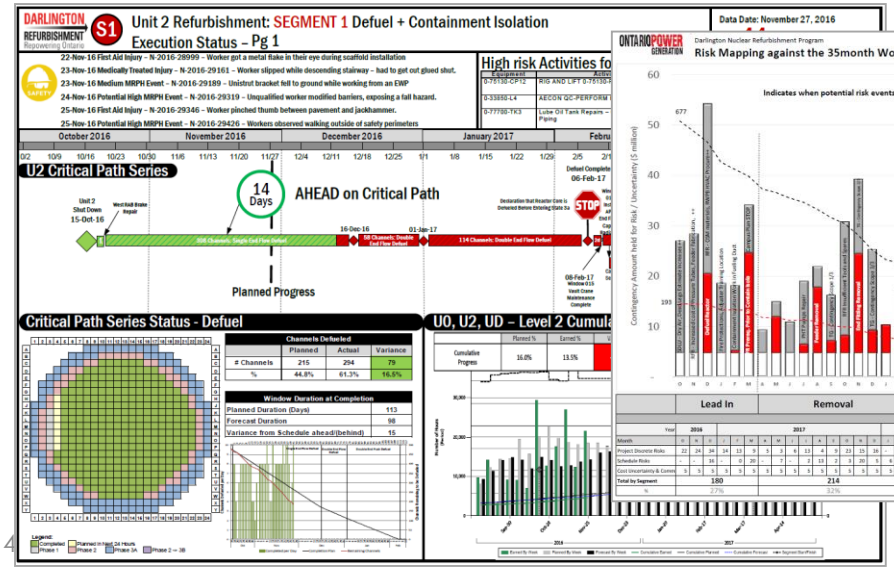
ONTARIO POWER GENERATION

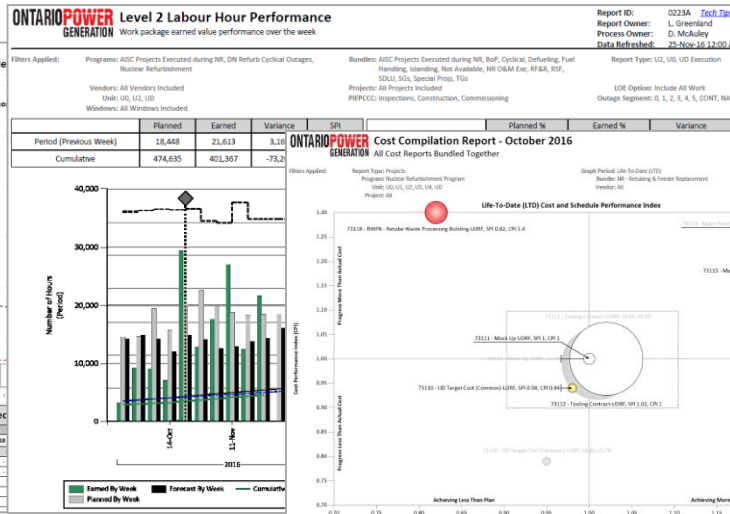
Reporting





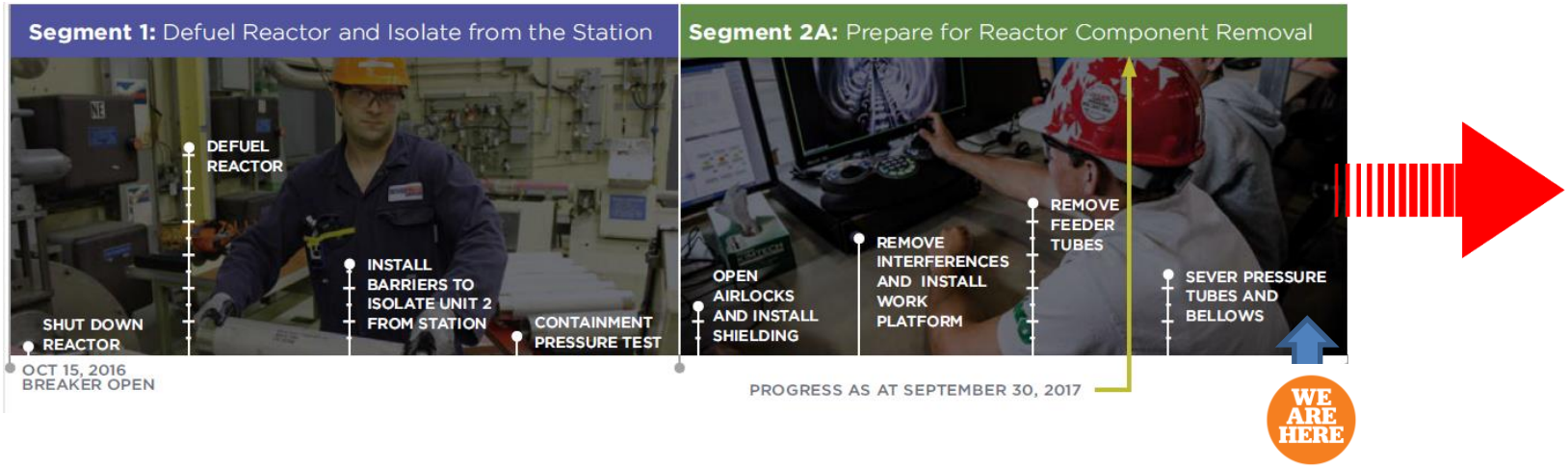
- Daily information
- Up-to-date reporting website available to all staff
- Critical Path and Non-Critical path performance measurements





Unit 2 Project Progress

- Just past the one-year mark – 40 per cent complete
- Entering third phase (Phase 2B) – Reactor Component Removal
- Project is ahead of schedule and on budget



ONTARIO POWER GENERATION

KEY LESSONS LEARNED

ONTARIO POWER GENERATION

Key Lessons Learned

- Plan, Plan, Plan, or Plan to Fail!!!
  - Planning is no guarantee of success, but failure to plan is a guarantee of failure.
  - Ensure that basis of estimates, and schedules, is fully documented.
  - Invest time into understanding all potential risks and developing mitigation strategies to resolve those risks, should they occur.
- If you fast track a project – ensure you have sufficient contingency for the additional risks you are taking on.
- Scoping is Fundamental - Clearly define it & minimize changes
  - Conduct an in-depth plant condition assessment to understand the full scope of the Program and avoid surprises
  - Obtain the required regulatory approvals early and establish scope to address identified gaps
  - Complete Scoping, Engineering, cost and schedule estimating before commencing execution phase.
- Employ contractors to execute the fieldwork while the owner retains overall Program management and schedule integration
  - Select the right contract partners and align to a common goal
  - Build an integrated team capable of managing the Program

Key Lessons Learned

- The complexity of mega-projects is often due to the fact that the project team is so big to perfectly integrate all activities
  - develop a division of responsibilities for all work so that everyone clearly understands their role.
- Commit to attracting skilled and knowledgeable people; and to their training and development, i.e. reactor mock-up
- Structure the schedule to allow completion of entire evolutions on one unit before starting that evolutions on the next, allowing lessons learned to be applied in real time
- Ensure sufficient schedule and cost contingency to accommodate both project and program level risks
- Effectively integrate cost and schedule and establish rules of credit to measure progress.
  - Focus on a few key metrics that the entire team can align around (earned value (hours ahead/behind), schedule variance, cost variance and variance at completion)
  - If the metrics don't point out areas for management to take action, they are not helping you.
- Set up independent oversight or third party experts to ensure that you don't have any blind spots.

Questions?



To learn more about Canada's Largest Clean Energy Project visit: www.opg.com and subscribe to the Darlington Refurbishment Newsletter

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