

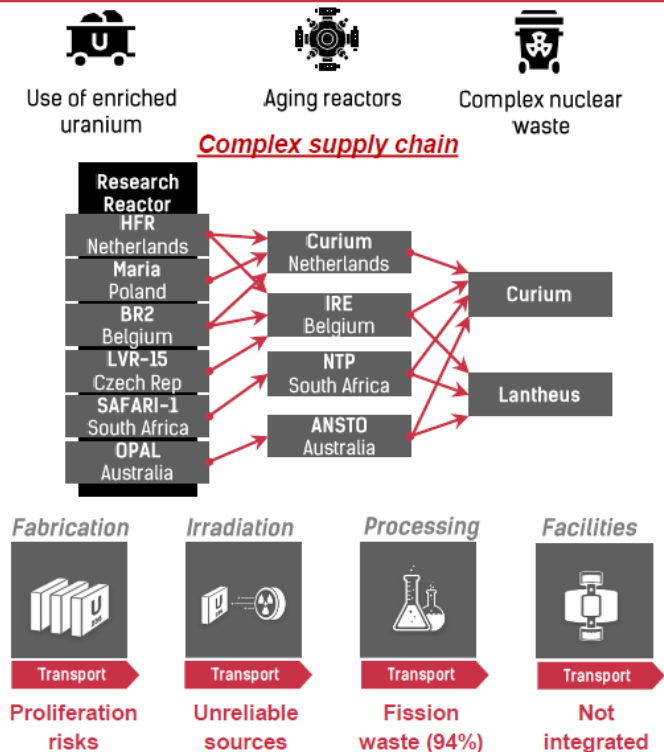


Mo99 Production: Neutron Capture-Based Production via Power Reactor and Potential Market Penetration

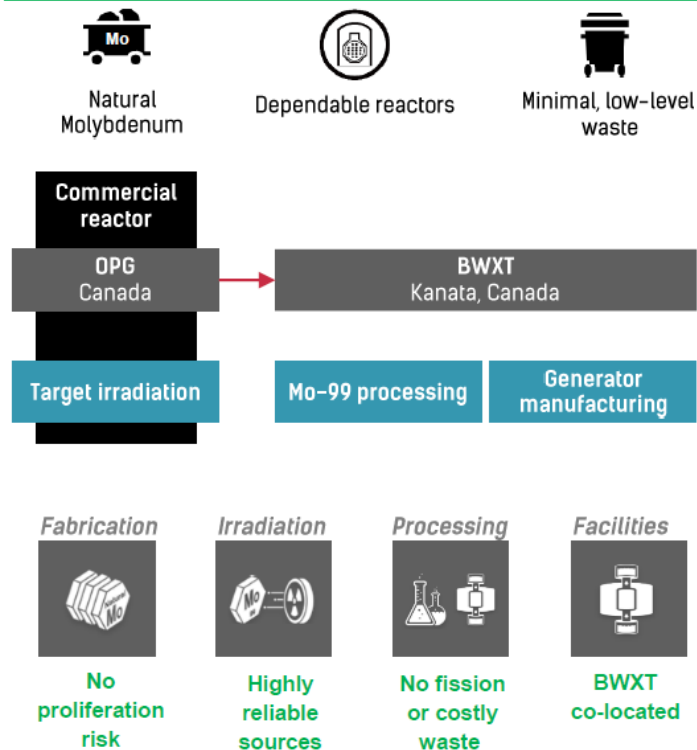
OCT 2022

Mo-99 Neutron Capture Production: An Innovative Solution

Current supply dynamics



BWXT supply dynamics



Lower Cost



More Reliable



Drop-in Replacement

Solution A New Canadian Frontier: Integrating Isotope Production with Commercial Power

- Up to when production ceased in 2016, National Research Universal (NRU) provided up to 40% of global Mo-99 demand
- Canada has a long history of providing global isotope supply (Co60, H3), with Laurentis recently becoming a key exporter of He3 gas
- Strengthen OPG's commitment to its Strategic Imperative of Social Licence through community support and positive impact on society's quality of life
- Target Delivery System at Darlington Nuclear to be the **FIRST** global commercial power generation station to produce the life-saving isotope
 - Potential for other isotopes to be irradiated using this new technology



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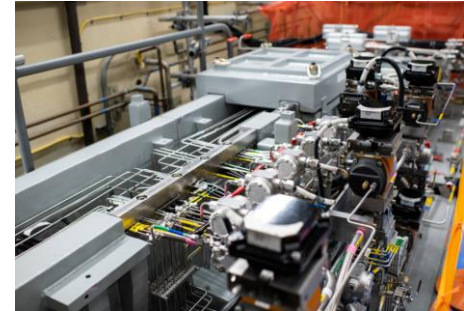
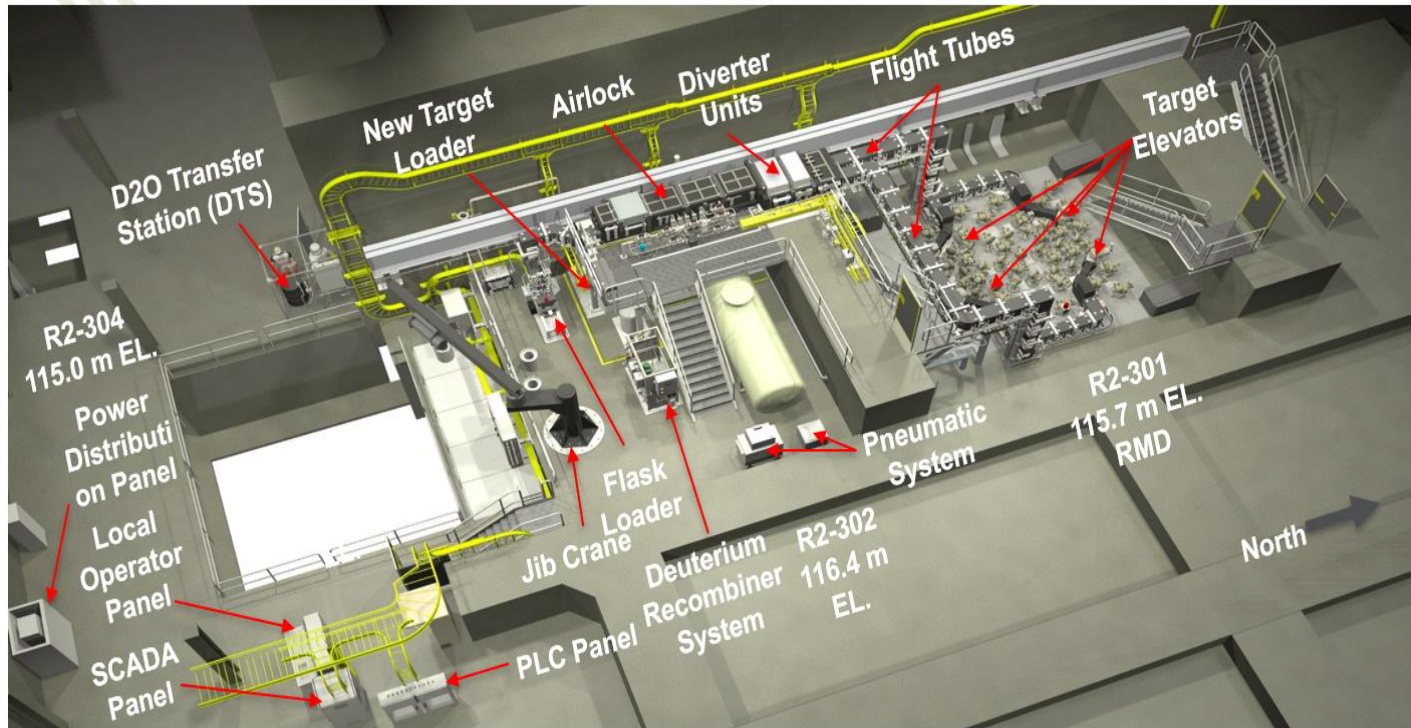
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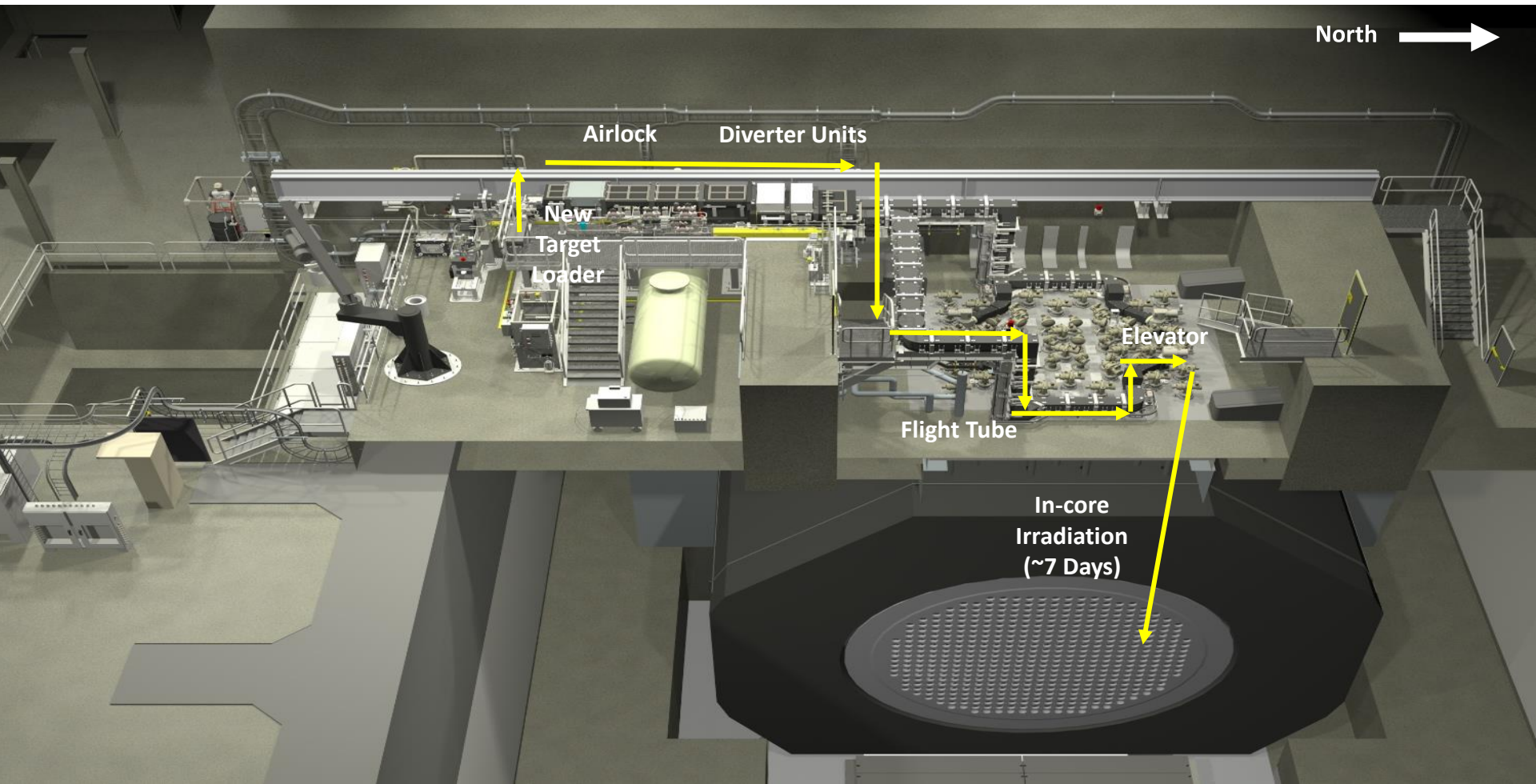
CANDU: Canadian Deuterium-Uranium Reactors at Darlington

- Darlington Nuclear Generating Station is Canada's second-largest nuclear facility by total output
 - 3,500MW – 4 x CANDU units (480 Fuel Channels)
 - Units are currently undergoing mid-life refurbishment in a phased approach to ensure clean, reliable electricity for the future
 - Thermal Neutron Reactor - cooled and moderated using heavy water
-
- Use natural uranium fuel supply – online refueling to minimize maintenance outage frequency
 - Optimized containment design permits access to reactivity mechanism devices above the reactor, thereby a pathway to irradiate isotopes
 - Units have been in operation since the early 1990s, highlighting a history of reliable and safe operation and strong community relationship

Target Delivery System Overview



Target Travel Path: Seed, Harvest





Mo-99 Program

- Staff from Laurentis and OPG will be assigned to support the Mo-99 production program
- BWXT processing facility in Kanata will manage all distribution
- Patent-pending process to extract Mo-99 into Tc-99m generators

Molybdenum Target Process Map Overview

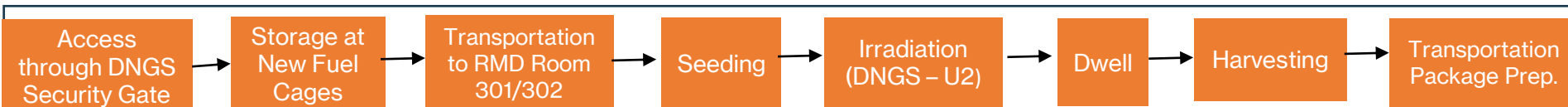
OPG Source
Surveillance

**BWXT NEC
(Peterborough, ON)**
Target Designer,
Manufacturer and
Supplier



**BWXT ITG
(Kanata, ON)**

- Mo-99 Chemical Processing
- Tc-99m Generators Supplier to medical customers



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ONTARIO **POWER**
GENERATION



Operational and Safety Considerations: Irradiation

- Priority remains the safe operation of the reactor for power production
- Training simulators developed for both field control panel and main control room panel
- Nuclear and operational safety analyses conducted to assess impact on potential accidents
- Extensive testing to demonstrate reactor containment and pressure boundary is always maintained
- Interface between the Target Delivery System and ongoing fueling activities impacting reactor control – upgrades to fueling software to improve planning capabilities and operation within approved safety limits; reactivity impacts are limited (see table)

Reactivity	Reactivity Worth
Adjusters Banks	~ 1 – 2 mk
Four Bundle Shift	~ 0.1 mk
Eight Bundle Shift	~ 0.2 mk
TDS String	0.062 mk

Processing Considerations: Tc-99m Generators

Molybdenum target manufacturing



Molybdenum target irradiation



**Ontario Power Generation's
Darlington Commercial
Power Reactor**

Radiochemistry (Drug Substance Manufacturing)



- Target Receipt/Processing
- Chemistry process
- Filtration & drying
- Sizing & transfer to drug substance container

Radiopharmacy (Drug Product Manufacturing)



- Drug substance dosing
- Elution/conditioning
- Sterilization
- Generator assembly
- Labeling

Packaging



- Generator packaging/boxing
- Shipping labels
- Palletizing

Opportunities for Expansion



- TDS offers flexibility, replicability and continuity for Mo-99 production with potential expansion to other product lines
- CANDU Units are deployed world-wide at various ages, with many holding 25+ years of operation
- Operating experience gained from the TDS will form the basis for expansion into other countries
- New generation of nuclear technology offers the potential to integrate isotope production
- Risk reduction by having regional supply of Mo-99 integrated into existing infrastructure

Global Market Opportunities

Country	Type of Reactor	Units	Net Capacity (MWe)
Argentina	CANDU	1	600
Canada	CANDU	19	13,513
China	CANDU	2	1,280
India	CANDU + CANDU-derived	2 + 16	277 + 3,480
Pakistan	CANDU	1	125
Romania	CANDU	2	1,305
South Korea	CANDU	4	2,579





Questions?

Andrew Lukomski | LEP Projects Manager | lukomski.andrew@laurentisenergy.com
Michael Flagg, BWXT Medical | mflagg@bwxt.com
Jamie Leebody, LEP Design Manager | leebody.jamie@laurentisenergy.com