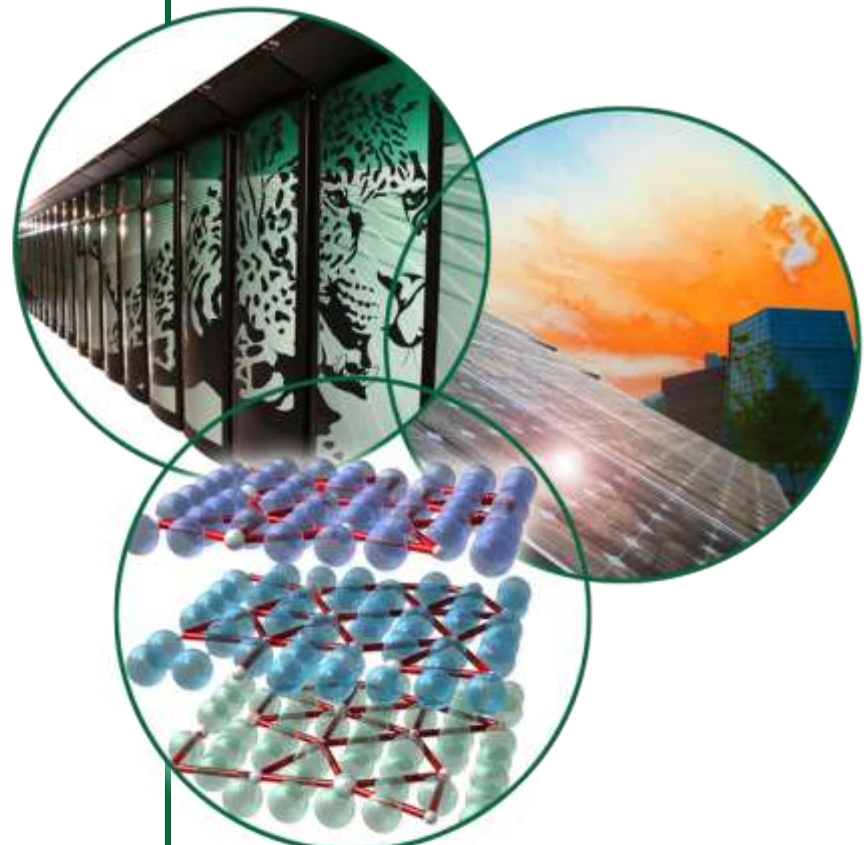
Remote Handling Operations at SNS



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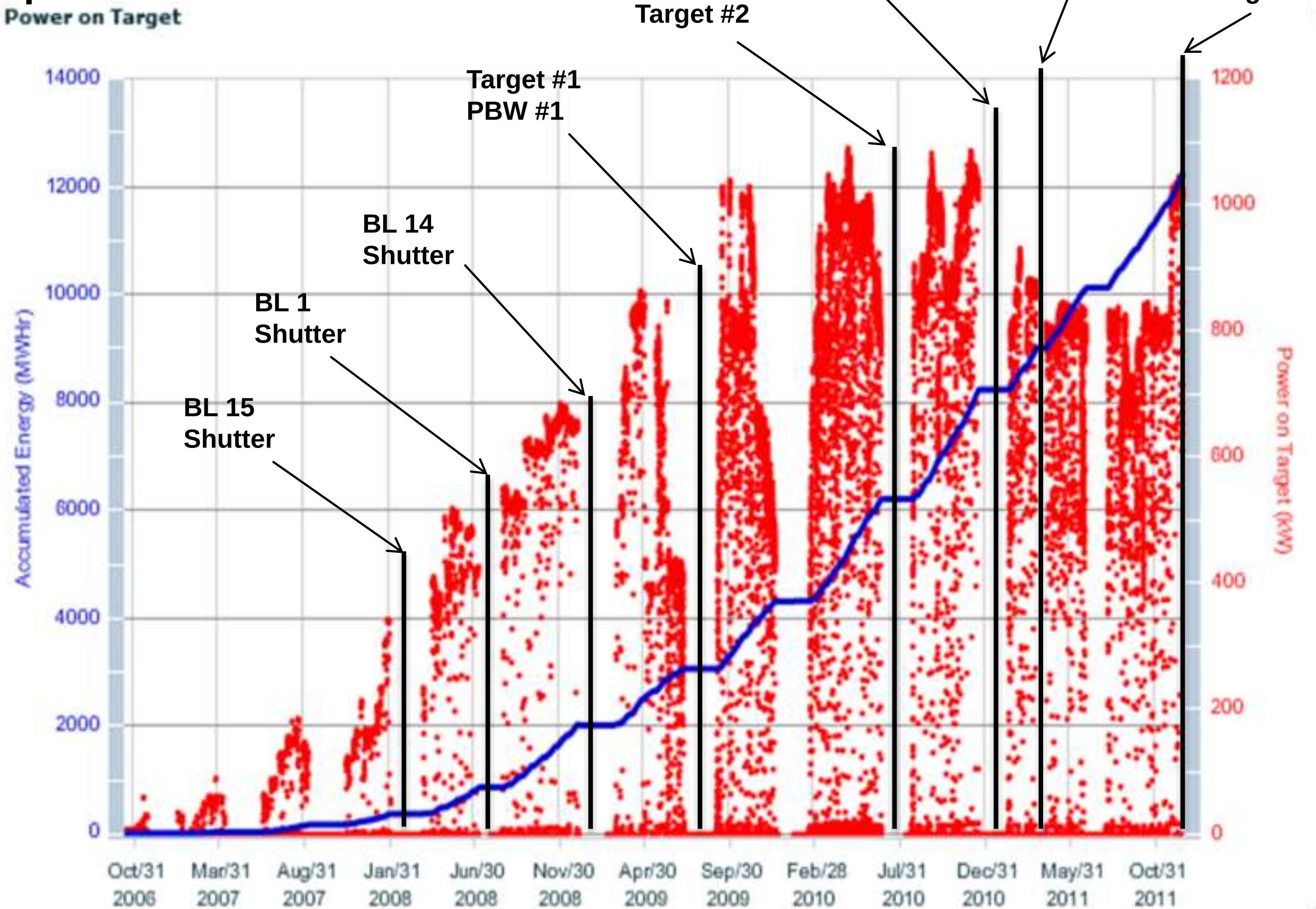
Remote Handling Engineer

Remote Handling

- Since SNS operation began in 2006, a significant amount of remote handling operations have occurred
- Remote handling at SNS encompasses:
  - Major component replacement (target, PBW, CVI, etc)
  - PIE operations
    - Target Post-Irradiation Examination relies heavily on remote handling
  - Waste shipment operations
    - Cask loading and waste handling require significant remote handling
- The following provides an overview of these remote handling operations along with plans for future operations

Remote Handling

- **Major Remote Handling Component Replacements**



Remote Handling Planning

- Planning for remote handling operations utilizes the following variables:
  – End of life tracking for major components
    - A spreadsheet is maintained to track end of life for targets, PBWs, Inner Reflector Plug, Ring Injection Dump window and beam stop, etc
    - End of life for each item is estimated based on projected beam power, run schedules, availability, etc., and then updated monthly with actuals
  – Beam Line Instrument requirements
    - Shutter replacements and CVI installation requirements are tracked based on instrument operational need dates
- These variables are then managed to ensure tooling and resource availability and to provide near and long term maintenance planning

Target Module Replacement

SNS Target Module

- Target Replacement
  - Target Maintenance Environment
    - Target Service Bay
    - Maintenance Equipment
    - Radiation and Contamination
  - Target Replacement Operations
  - Target Replacement Lessons Learned
- Replacement of the target modules is accomplished using only remote handling tooling and procedures (hands-on operations are not possible)
- While the tooling and procedures utilized enable successful replacement of the targets, continuous process improvement is employed to ensure successful replacements

Target Module Replacement

- Four window workstations each containing a pair of master-slave manipulators are built-into the target Service Bay. Only one is workstation is dedicated to target change-out
- A servo-manipulator is required to perform most operations including bolt torquing, tool transport, inspections and precision operations

Manipulator Gallery

Remote Handling Control Room

Target Module Replacement

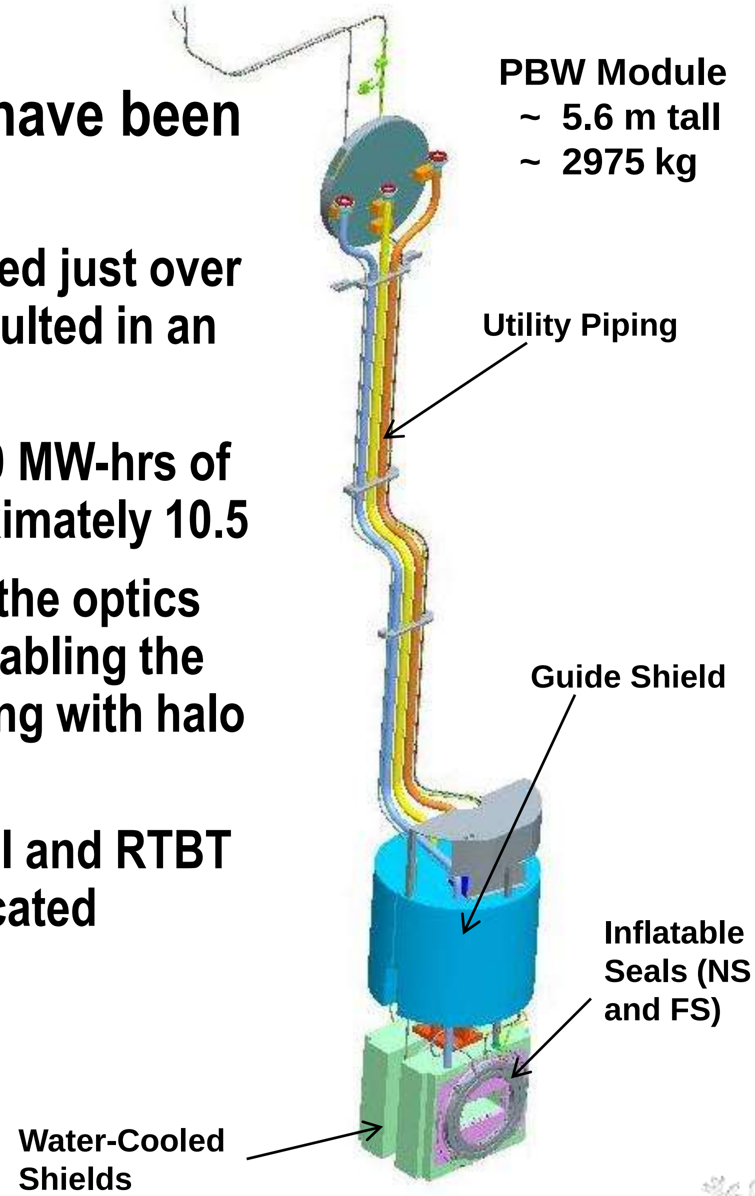
- Radiation and Contamination Environment:
  - Experience has shown that the isotopic particulate contamination is long-lived and wide-spread inside the Service Bay
    - A systematic program of obtaining smears from within the Service Bay has been initiated to characterize the contamination environment
      - Current contaminations levels range from 10,000 dpm to 3-5,000,000 dpm
  - Radiation levels at various locations in the process bay are tracked during target replacements
    - The maximum dose rates observed during Target #3 replacement:
      - Mercury Pump: 21.45 R/hr (.215 Gy/hr)
      - Coolant Water Return Line from Carriage: 2475 R/hr (24.75 Gy/hr)
      - Mercury Return Line from Carriage: 2717 R/hr (27.17 Gy/hr)

Target Module Replacement

- Following each target replacement, a "lessons learned" activity is conducted to ensure continuous improvement of the replacement procedures and tooling
  - Enhancements to the process and tooling improvements enable replacement of a target in approximately 100 hours
- Each target replacement yields new challenges and issues
  - Target #1: Leaking Hiltap fitting in the mercury process loop required extensive real-time testing to identify and correct
  - Target #2: Inadequate target bolt torquing resulted in degraded mercury seal testing results requiring additional effort to identify and correct the issue prior to target insertion
  - Target #3: Leaking Hiltap fitting in the water coolant loop required real-time testing to identify and correct resulting in a two day delay in completion of target replacement

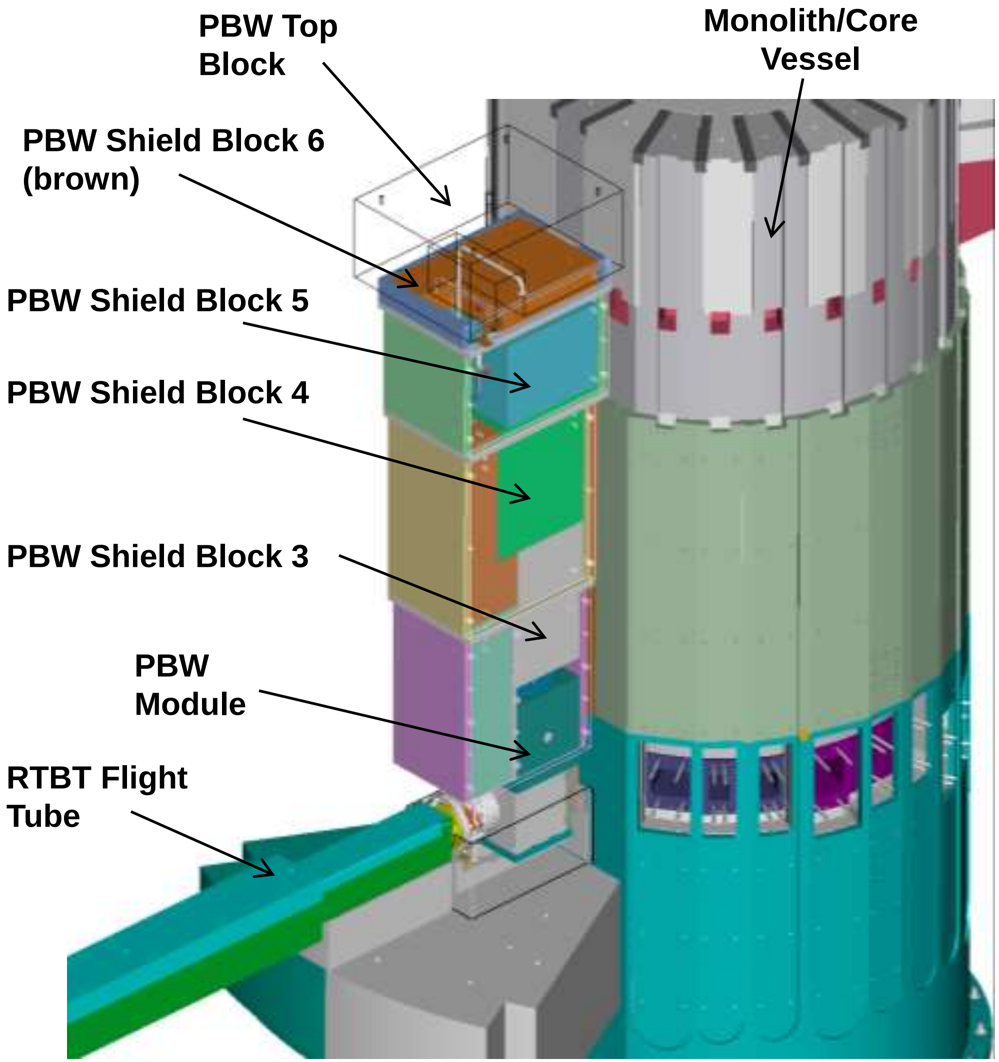
Proton Beam Window Replacement

- Two Proton Beam Window modules have been replaced at SNS:
  - The initially-installed window had received just over 3000 MW-hrs of accumulated energy resulted in an approximate dpa level of 6.5
  - The second window had received ~ 5200 MW-hrs of energy resulting in a dpa level of approximately 10.5
  - The Proton Beam Windows incorporate the optics portion of the Target Imaging System enabling the viewing of the coated Target Module along with halo thermocouples to aid in beam centering
  - Following both installations, Core Vessel and RTBT flight tube vacuum leak testing has indicated excellent PBW inflatable seal function



Proton Beam Window Replacement

- **Replacement of a PBW module involves the following basic operations:**
  - Removal of five shield blocks (45 tons of shielding)
  - Drying (water removal) of PBW module
  - Cutting and removal of activated utility piping
  - Withdrawal of PBW module from cavity
  - Installation of new PBW module
  - Connection of utility piping
  - Leak testing of inflatable seals and piping connections
  - Re-installation of shielding



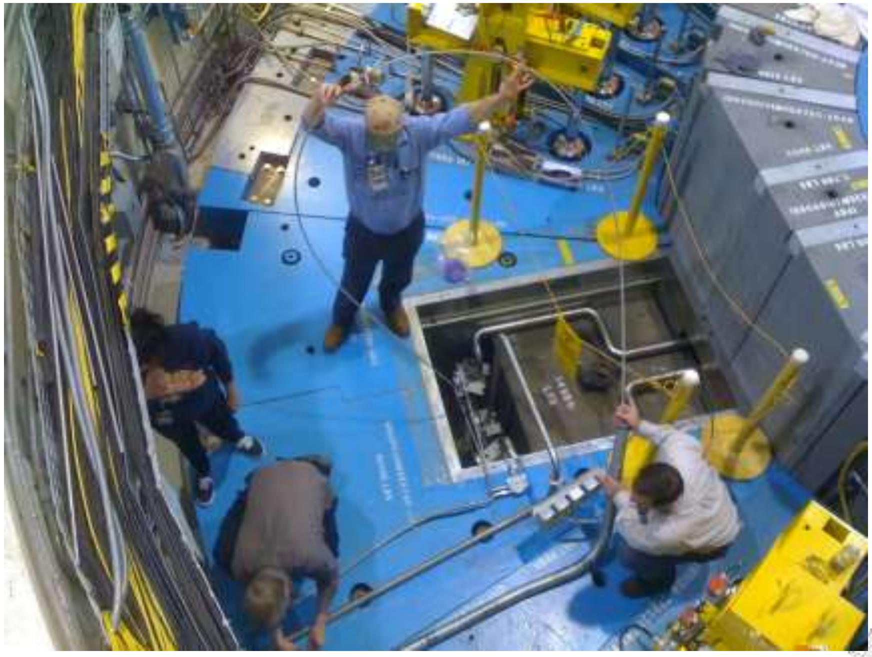
PBW replacement requires approximately 9 days

Proton Beam Window Replacement

New PBW Installation

Jumper Installation

TIS Fiber Optic Cable Installation



Proton Beam Window Replacement

- **Radiological surveys are done during every aspect of PBW replacement operations. The following are some of the findings from the most recent operation:**

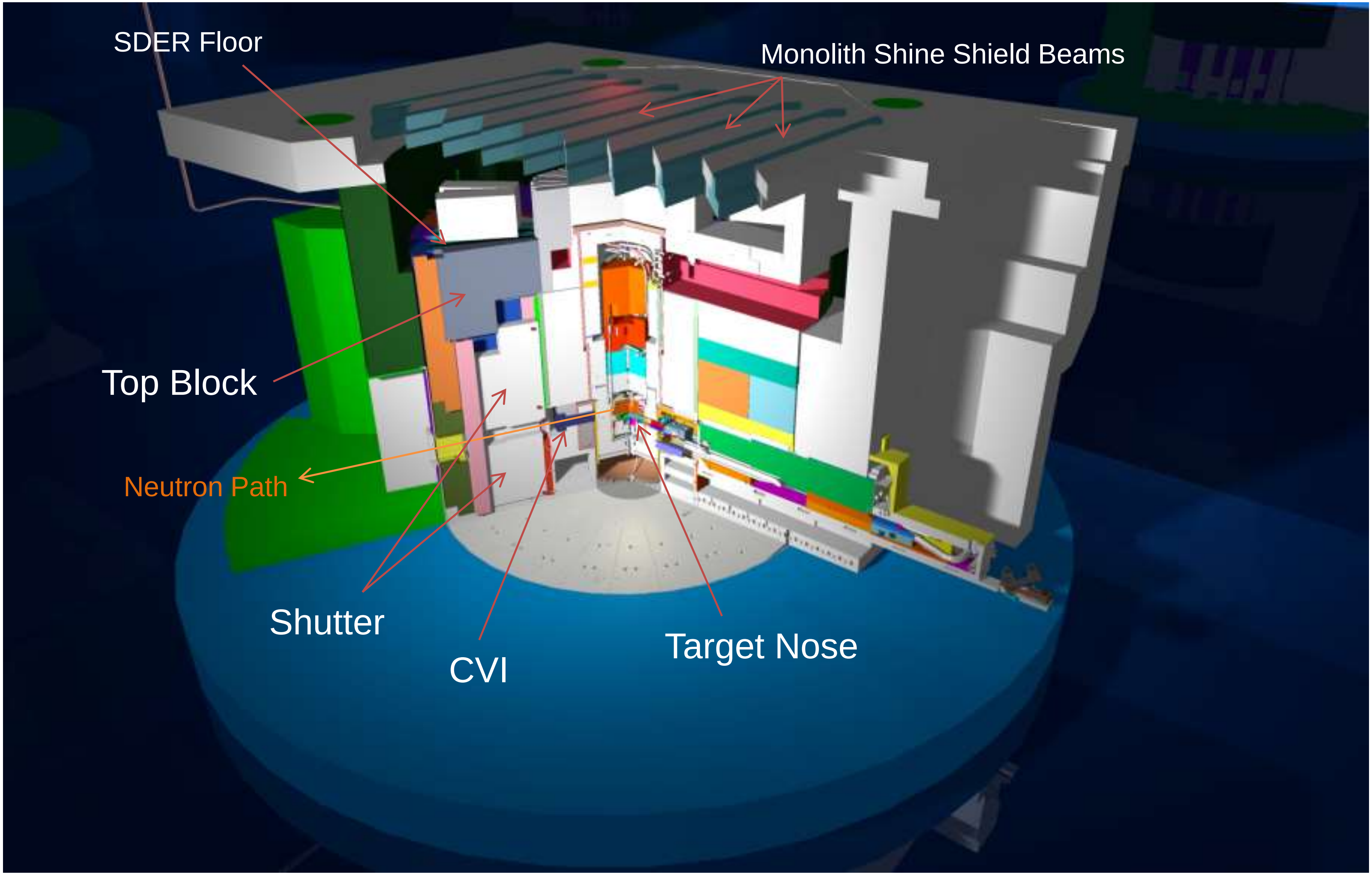
Item	Dose Rates (1)	Contamination	
PBW Top Block	Neglible	None	
Shield Block 6	Neglible	Minor Be-7 on lower surface	
Shield Block 5	.1 - .2 mR/hr	Minor Be-7 contamination	
Shield Block 4	1.5 mR/hr	Minor Be-7 contamination	
Shield Block 3	680 mR/hr	150,000 dpm	
Utility Piping	~ 120 mR/hr	None (4)	
PBW Module	600 R/hr (2)	(3)	
Notes:			
1. Contact dose rates unless otherwise specified.			
2. Dose rate at approximately 1 m - unshielded.			
3. No measurement taken.			
4. No external contamination.			

Shutter and CVI Replacement

- At the completion of SNS construction, seven instrument beam lines contained concrete shutter plugs in lieu of fully-functional shutters
  - To date, four of these beam lines have been updated to remove the shutter plug assemblies and install operational shutters
- Additionally, four beam lines contained Core Vessel Insert plugs in lieu of functional inserts
  - The BL 16 CVI was replaced during the winter 2011 outage
- The following slides give an overview of the BL 16 CVI and shutter replacement operation

Shutter and CVI Replacement

Target Monolith

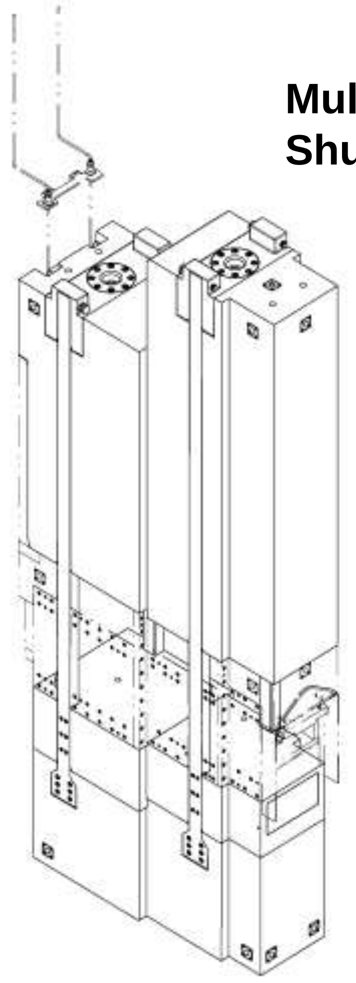


Shutter and CVI Replacement

- Each beam line has its own user-operated primary shutter
  - 12 single channel shutters
    - 30 tons each (27,215 kg)
  - 6 multi channel shutters
    - 50 tons each (45,350 kg)
  - Each shutter incorporates a beam stop and a helium-purged optical insert

Multi Channel Shutter Assembly

195” x 78” x 31”
(4.9m x .8m x 2m)



Shutter and CVI Replacement

BL 16 CVI
- ~ 1900 lbs (860 kg)
- 22 feet tall (6.7 m)

- The CVI interfaces directly with the Core Vessel and becomes part of the Vessel vacuum boundary
  - Aligns to the Core Vessel via two alignment pins
  - Secured using four 1.25” (31.75mm) diameter studs
  - Utilizes a double o-ring (metal) seal
    - These seals require 40,000 lbs (~18,100 kg) of tensile force in each stud
    - Tensioning methods are used to stretch the studs in lieu of torquing
      - Metal seals require high compressive forces
      - Tensioning provides more repeatable, consistent seal compression
- Comprises the innermost portion of the instrument beam line
- Each CVI is water cooled and purged with helium

Shutter and CVI Replacement

- **Installation of the new BL 16 CVI proceeded following loading of the CVI into the Robot and installation of the O-ring seal:**

Loading of BL 16 CVI into Robot

Shutter and CVI Replacement

- **Stud tensioning was completed followed by leak testing of the CVI O-ring seal**
  - **Leak testing involves evacuation of the interstitial region between the two o-rings followed by isolation and then a rate-of-rise test**

Seal Leak Testing

<u>Testing:</u>
Test criteria: Evacuate to < 100mTorr
Isolate and measure rate-of-rise over 3-hour period
Permissible pressure rise: 50 mTorr/3 hr

Test results: 83 mTorr/3 hr

Originally installed (hands-on) CVI plug was only able to achieve a 95 mTorr/3 hr rate, so new CVI performed better than the initially-installed plug

Subsequent Core Vessel testing indicated an excellent leak rate of .017 Torr-L/sec

Shutter and CVI Replacement

- **The replacement process concluded with the installation of the new BL 16 shutter components:**

Lower Segment Installation (31,000 lbs/14,000kg)

Middle Segment Installation (20,000 lbs/9100kg)

Upper Segment Installation (50,000 lbs/22,600kg)

Shutter and CVI Replacement

- This operation was the first fully-remote replacement of a CVI at SNS
- The replacement was completed over a period of 15 working days
  - Total cumulative dose for all workers involved in the replacement was 7 mR (.07 mSv)
  - Maximum dose for any individual was < 2 mR (.02 mSv)
- While several challenges were encountered, the design of the tooling, extensive testing and innovative real-time solutions enabled a successful replacement of this critical component

PIE Operations

- Post-Irradiation Examination (PIE) has been conducted on each of spent target modules following replacement
- PIE operations have utilized the following tools:
  - Pressure decay testing to verify the integrity of portions of the target vessel (interstitial volume and water shroud)
  - Nose Sampling to remove samples of each target nose for subsequent testing
  - Video scope inspection to enable visual inspection of areas of interest within the mercury vessel
- Non-destructive methods (decay testing and video scope) are employed prior to nose sampling

PIE Operations

- **Target Video Scope Image:**

Video scope image of the interior of the Target Mercury Vessel at the Nose location showing significant cavitation damage

Video scope being inserted into target nose following sample cutting

PIE Operations

- **Target Nose Sampling Operations:**

Spent Target suspended vertically in remote-operated Nose Sampling Cutter Assembly

View of Target nose following the fourth cutting operation

Waste Shipment Operations

- SNS is design to utilize an over-the-road waste shipment cask known as the TN-RAM for disposal operations
  - To date, three waste shipments have been completed:
    - Target #1 shipped in May 2010
    - PBW #1 shipped in December 2010
    - Target #2 shipped in May 2011
  - Cask loading occurs via the Service Bay and involves significant remote handling
    - Handling of activated components
    - Loading of the cask liner
    - Cask liner bolt torquing

Waste Shipment Operations

PBW Waste Preparation

PBW Cask Liner is Loaded into the Service Bay

PBW Cask is positioned over Top Loading Port

PBW is lowered into Service Bay for loading Into Liner

Waste Shipment Operations

Cask Lifting from Truck

Translating Cask over for Lowering into Cask Cart

Waste Shipment Operations

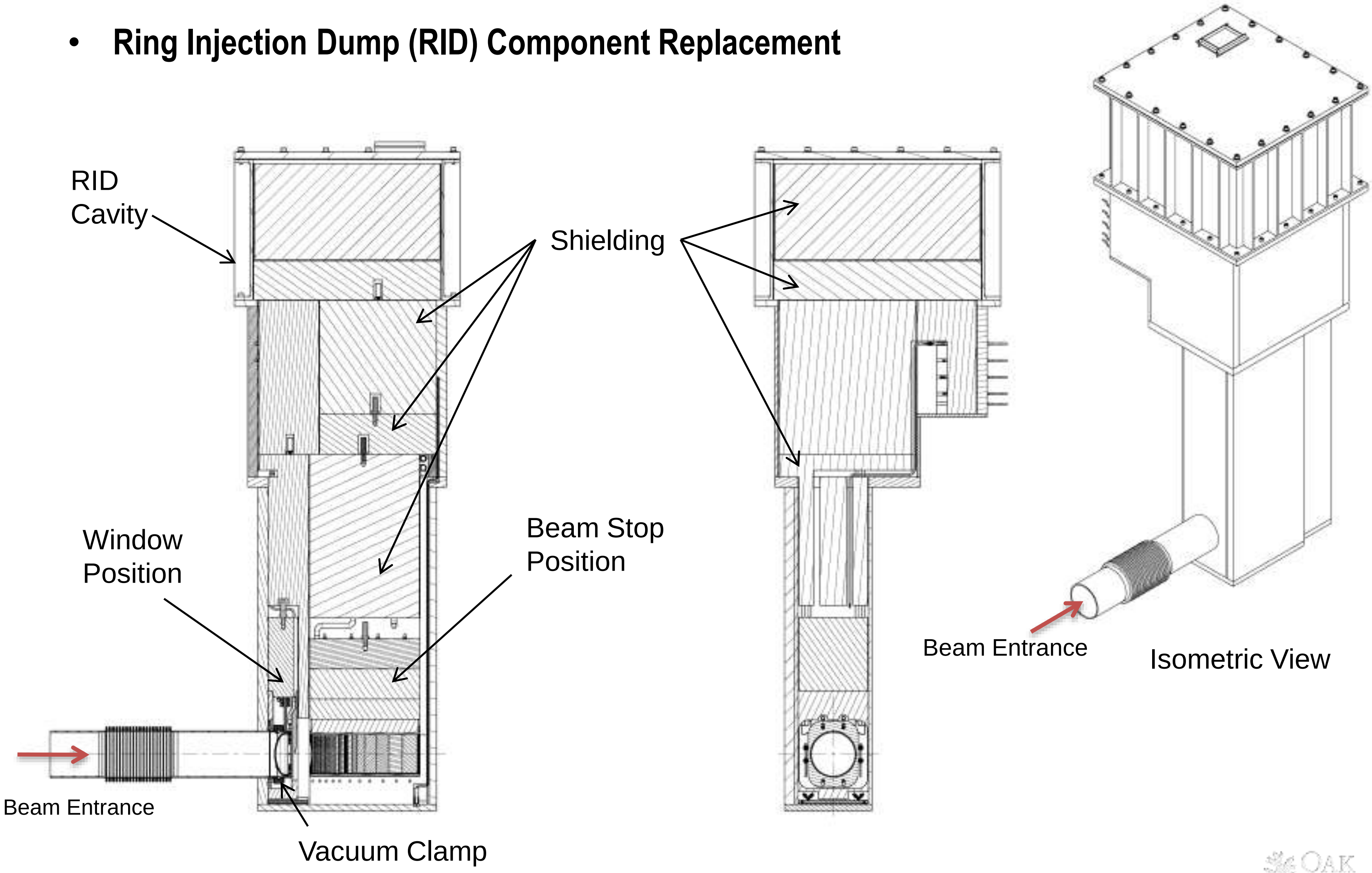
- **Following loading of the Cask, leak testing and radiological surveys are performed to ensure DOT compliance**

Future Remote Handling Operations

- Ring Injection Dump (RID) Component Replacement
  - The RID contains two items that must be replaced via remote handling operations:
    - A window to isolate the high vacuum of the accelerator from the nominal atmospheric pressure of the RID cavity
    - A beam dump fabricated from copper plates to absorb the energy from the proton beam
  - Current life expectancy planning for these items indicate that replacement will be required no sooner than the summer outage of 2016
  - Procurement of the tooling required to replace these items is underway (AIP-29)
  - Procurement of a spare Beam Stop Assembly is also in work (AIP-29)

Future Remote Handling Operations

- **Ring Injection Dump (RID) Component Replacement**



Future Remote Handling Operations

- Inner Reflector Plug (IRP) Replacement
  – The SNS IRP has a nominal life expectancy of 30,000 MW-hrs
    - Based on current planning, the first IRP replacement will occur no sooner than the winter outage of 2015
  – The remote handling tooling has been fabricated and delivered
  – Mockup testing and detailed procedure development remains to be completed

Future Remote Handling Operations

- Replacement of the IRP is complex for many reasons
  - Target module retraction is required due to the fact that the target nose extends into the Lower Inner Plug
    - Target retraction itself requires 2-3 days of remote operations in the Service Bay
  - The IRP is vertically integrated into the Core Vessel through the Shutter Drive Equipment Room(SDER) requiring the unstacking of a significant amount of shielding
    - 46 shield blocks + Monolith Shine Shield Beams must be removed to access the IRP
  - The size and weigh of the IRP requires removal in segments
  - The large amount of utility piping complicates removal
    - This piping must be accessed, cut and removed during the operation

Future Remote Handling Operations

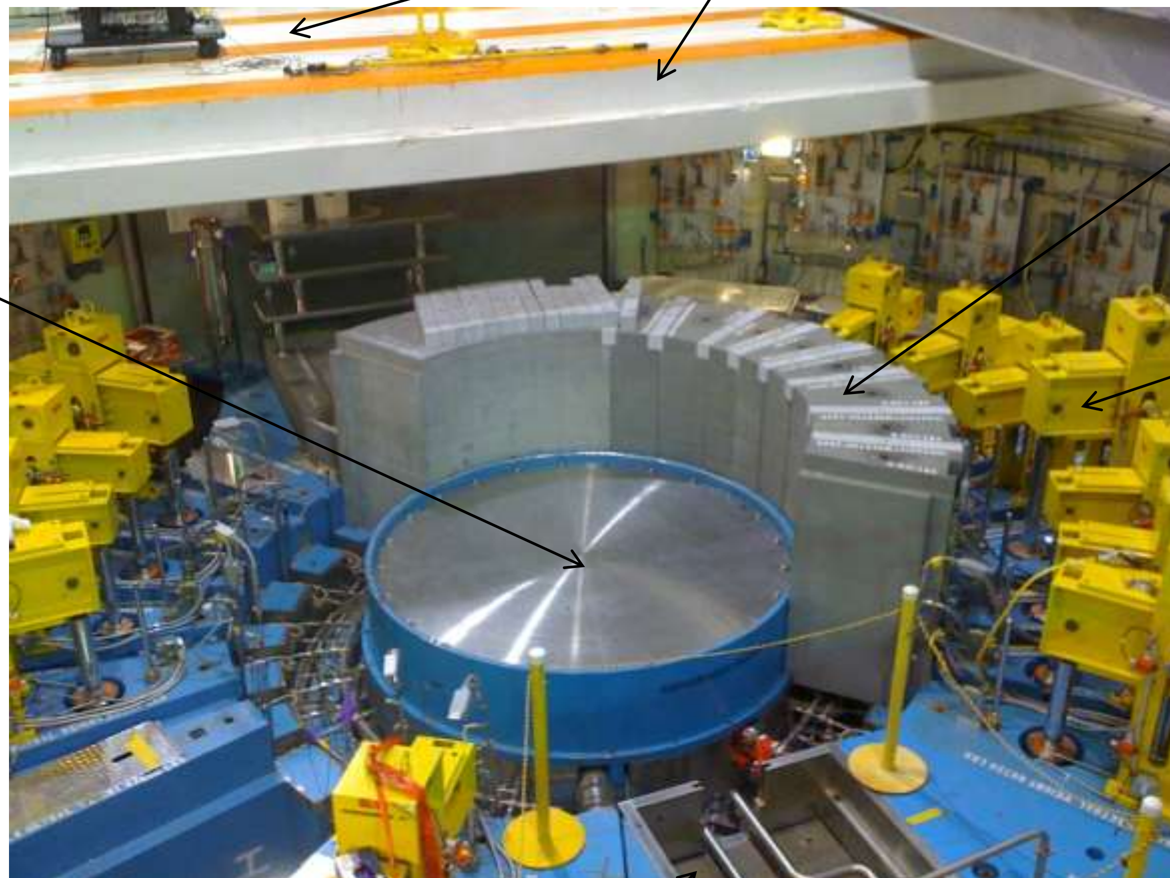
SDER Showing Access to IRP

Monolith Shine Shield Beams

Shield Plate Directly Above IRP

Pan Shield Blocks

Hydraulic Shutter Drives



PBW Cavity

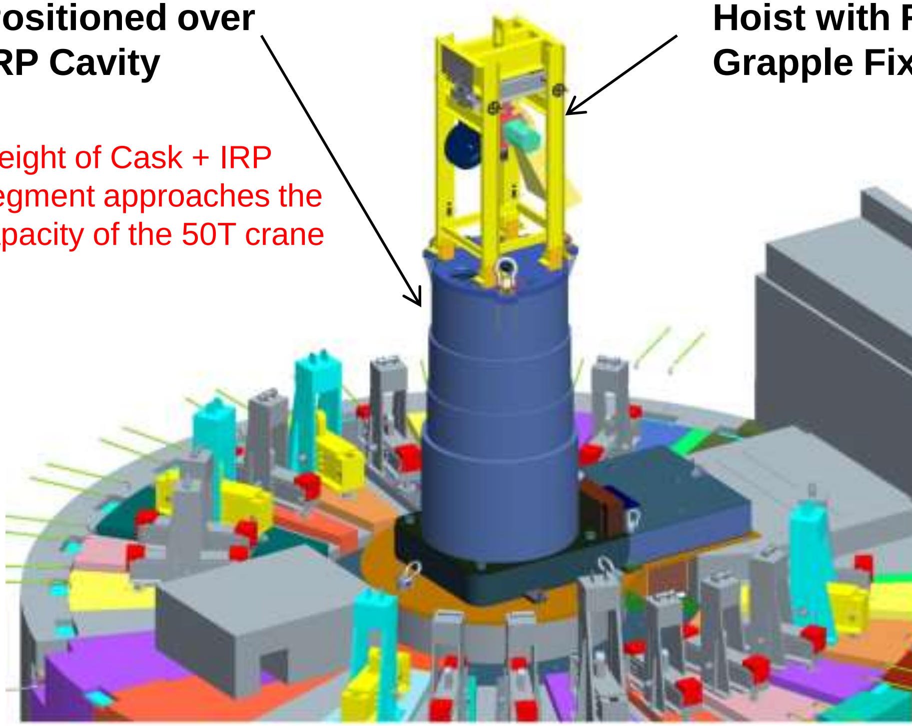
Future Remote Handling Operations

Removal of the Lower Inner Plug

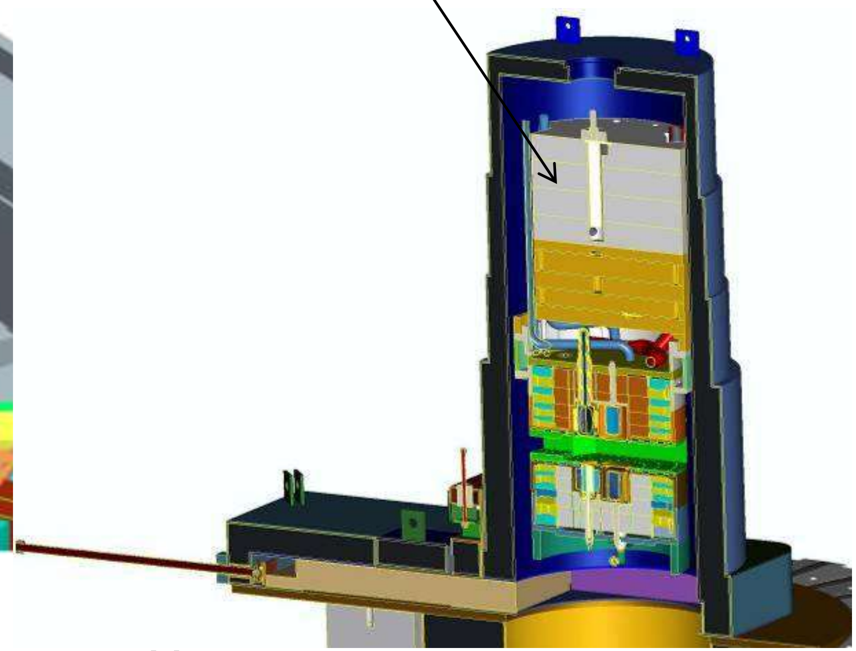
Lead-Shielded Cask Positioned over IRP Cavity

Air-operated Chain Hoist with Remote Grapple Fixture

Weight of Cask + IRP Segment approaches the capacity of the 50T crane



Lower Inner Plug Is withdrawn into Cask



Lead shield door provides technician protection during removal of Cask

Future Remote Handling Operations

- Near term:
  - Target #4 replacement: January 2012
  - PBW #3 replacement: July 2012
  - Target #5 and BL 9 Shutter/CVI: January 2013
- Inner Reflector Plug Replacement
  - Anticipated to occur no sooner than January 2015
  - All tooling has been designed and delivered
  - Testing and procedure development remain
- Ring Injection Dump Window and Beam Stop
  - Anticipated to occur no sooner than January 2016
  - Tooling procurement in work