Operations Experience/ Remote Handling

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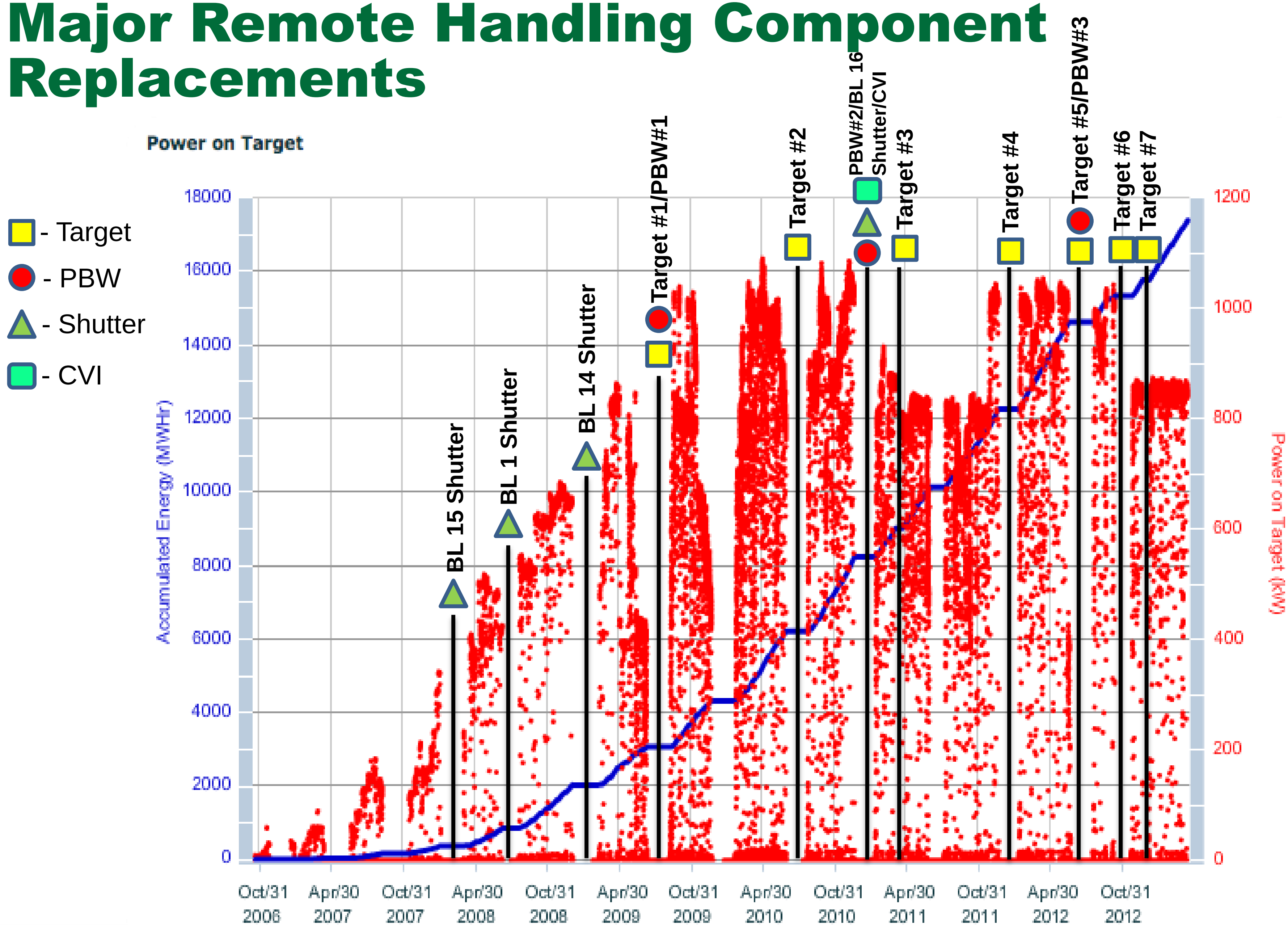
Remote Handling Engineer

Remote Handling Critical to SNS

- Since SNS operation began in 2006, a significant amount of remote handling operations have occurred
- Remote handling at SNS encompasses:
  - Major component replacement/operational planning for
    - Targets
    - Proton Beam Windows (PBW)
    - Shutter and Core Vessel Inserts (CVIs)
    - Ring Injection Dump
    - Inner Reflector Plug
  - Target Module PIE operations
  - Major component waste shipment operations
    - TN-RAM Cask shipments for target and PBW modules
    - Shutter Plug segment shipments

Major Remote Handling Component Replacements



Operational Planning is Critical

- 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

Numerous CY12 Target Replacements

- **Prior to CY2012, we had replaced three target modules in the history of SNS operation**
- ***Four targets were replaced* during calendar year 2012:**

Target #	Serial #	Date	Total MW-hrs	Total dpa
T4	MTX-006	Jan	3250	7
T5	MTM-001	Jul	2360	4.85
T6	MTX-004	Sep	617	1.4
T7	MTX-003	Oct	98	0.2

Target Replacement Operation is Continually Optimized

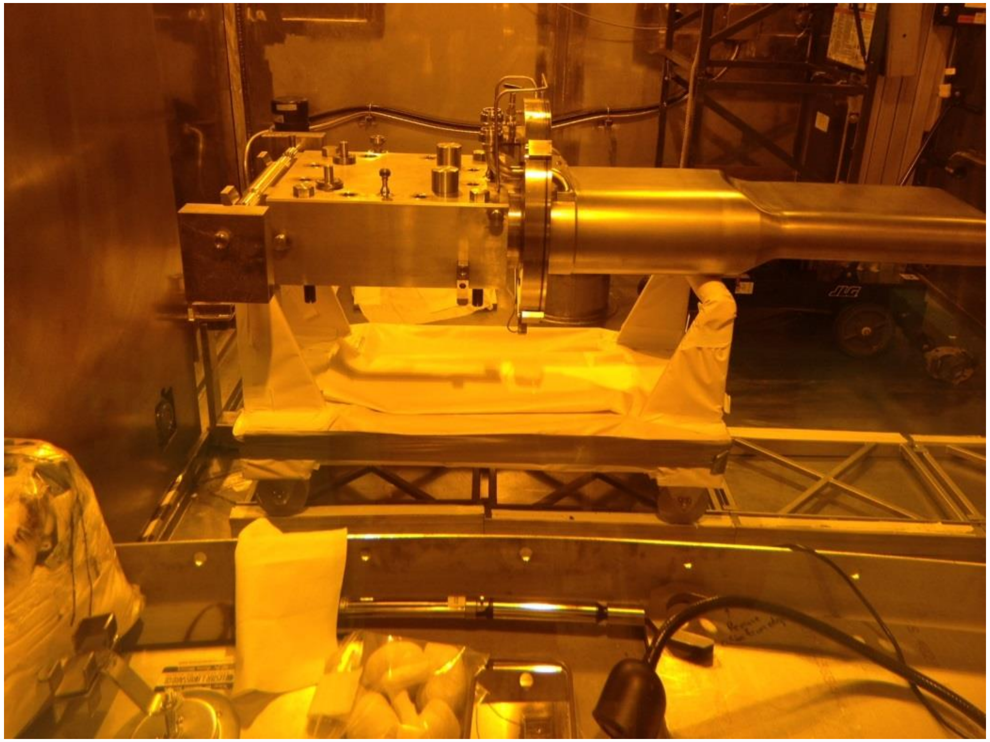
- Target installation and removal is performed in accordance with Internal Operating Procedure (IOP) TS-IOP-14
  - A continuous improvement process is utilized which has resulted in evolutionary changes to both the process and the tooling
  - Trending data for each of the ~95 major steps of the process is captured to enable:
    - Understanding of operational variances/observations
    - System variances (testing results, dose rates, etc)
    - Human factors planning to aid in future planning

Target Replacement Operation is Continually Optimized

- The replacement process is rigorously controlled
  - A "second party verification" process is utilized which requires both Operations and Engineering personnel verify each step of the replacement
    - The working copy of the IOP is archived in ProjectWise
    - A "Replacement Log" is also maintained which documents the following:
      - Timelines of the replacement steps
      - Dose rates at various points in process
      - Torque values for all fitting/fasteners which require torquing
      - Test results for all post-installation testing
      - Observations of operational variances/occurrences

Additional Rigor is now Employed during Initial Target Installation

- Initial installation and alignment of T6 resulted in unacceptable target manifold seal performance
  - This anomaly resulted in an unprecedented entry into the Transfer Bay to replace the soft iron manifold gasket



T6 moved into Transfer Bay for Dimensional Inspection and Gasket Replacement
- General area dose rates ~700 mR/hr

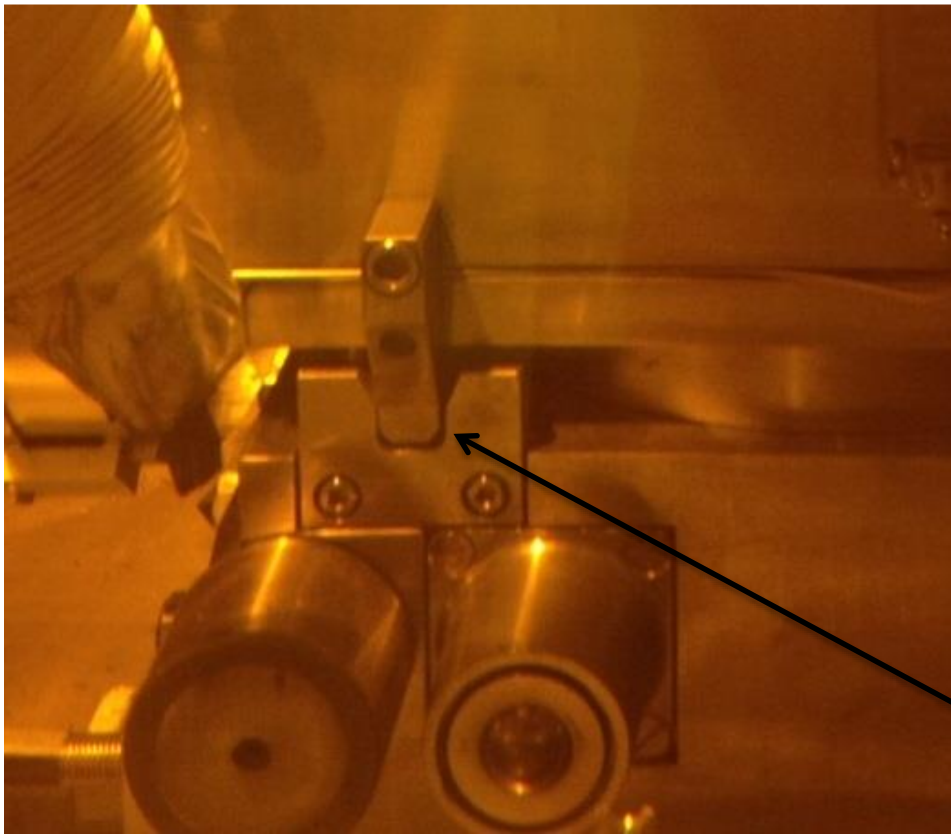
Initial Installation Process Now Receives Additional Scrutiny

- All phases of this portion of the installation process were reviewed to understand why the problem occurred
- Two major factors were found to be critical:
  - Gasket positioning during installation (feeler gages now employed to ensure centering)
  - Initial coarse alignment of the target module onto the Carriage
    - "Before and After" pictures are now taken during each target installation to assess and document initial and final alignment

Installation Photos are Taken to Document Alignment

- Coarse Alignment Guides at Target-to-Carriage Interface

← West



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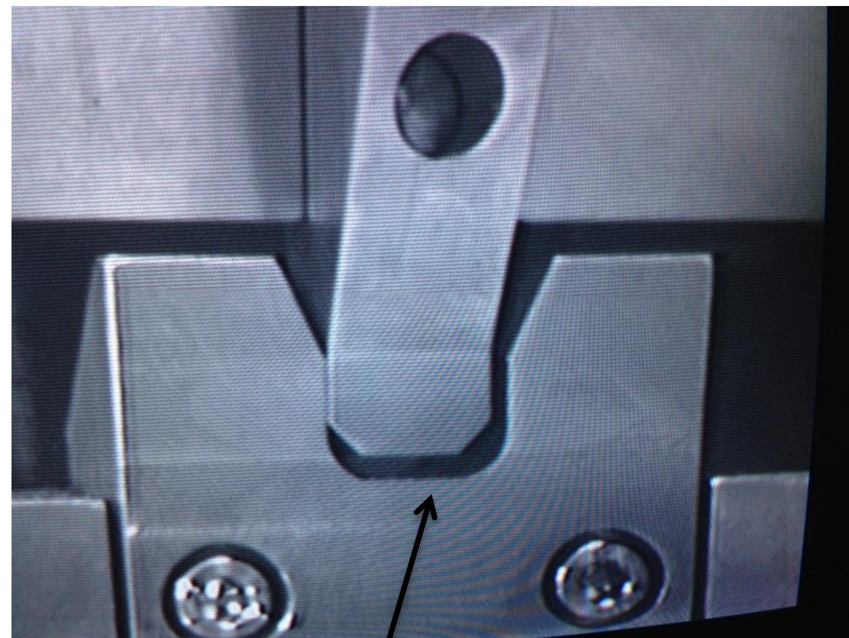

Note offsets indicating a clockwise twist

Installation Photos are Taken to Document Alignment

- Coarse Alignment Guides at Target-to-Carriage Interface

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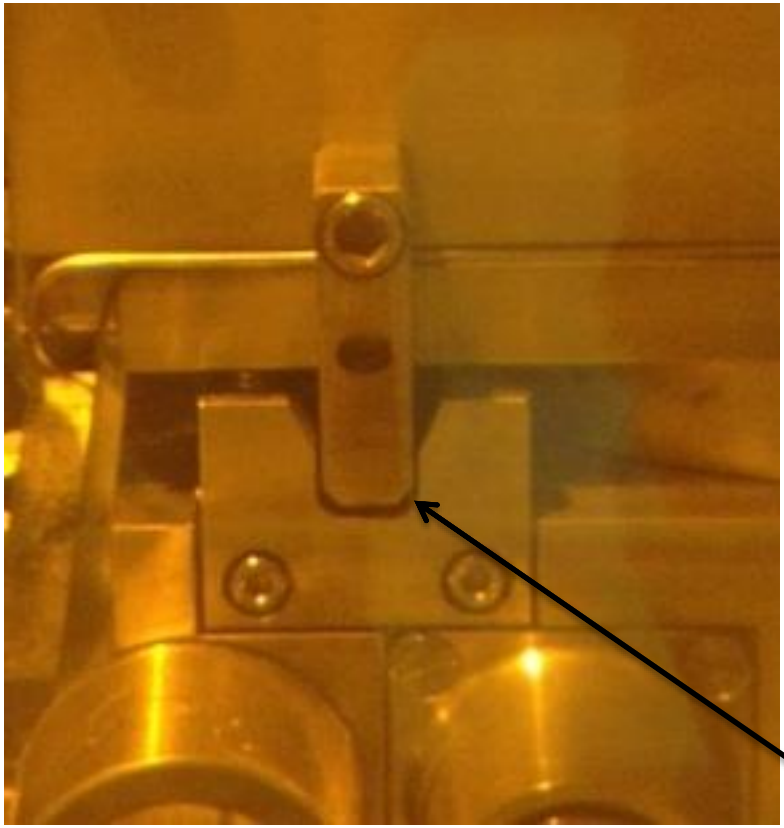

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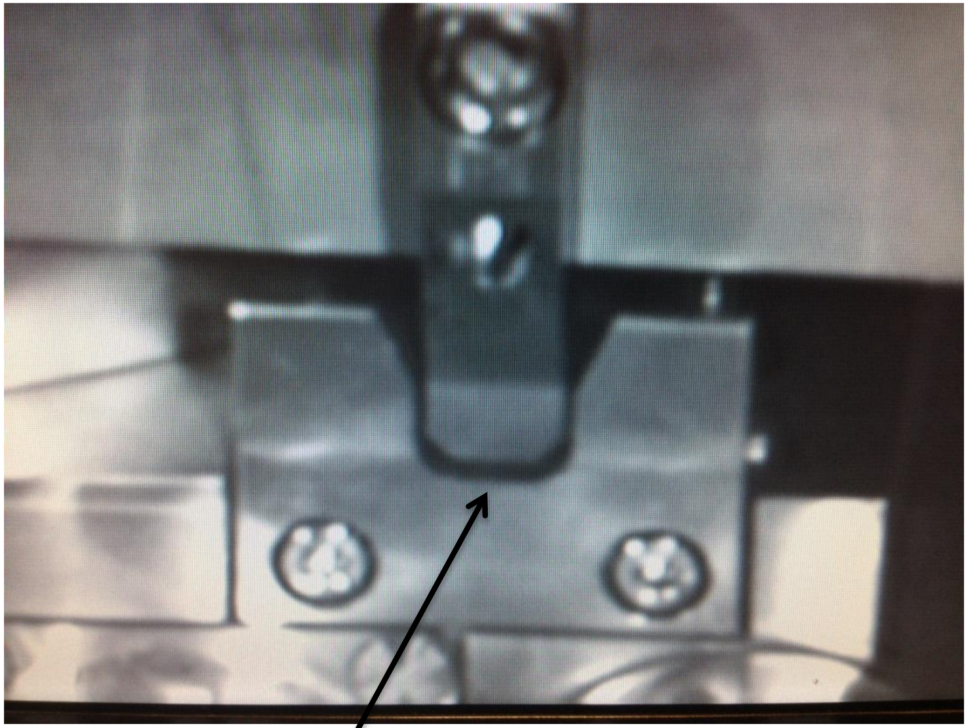


Positioning now shows proper alignment

Target Replacement Testing Shows Consistent Results

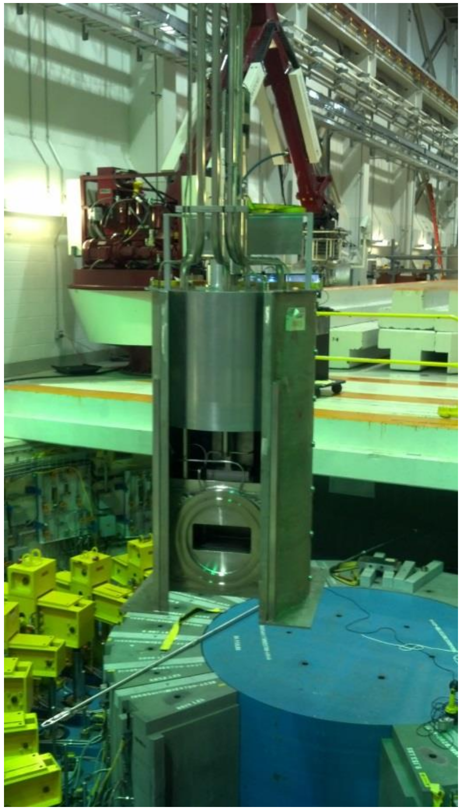
- **Trending of several key target replacement testing parameters indicates consistent, acceptable results:**
  - **Initial/operational position manifold seal testing**
  - **Core vessel rate of rise testing (inflatable seal performance)**
  - **Mercury loop rate of rise testing (mercury loop integrity)**

Parameter	Target T2	Target T3	Target T4	Target T5	Target T6	Target T7	Target T8
Manifold Seal Leak Rate (psi/hr)	NA	0.073	0.048	0.16	0.18	0*	0*
Core Vessel Minimum Pressure (mTorr)	NA	128	94	108	130	131	114
Core Vessel Rate of Rise (mTorr/hr)	NA	9	13	11	9	20	15
Mercury Loop Minimum Pressure (Torr)	NA	12	10.5	7	7	6	5.6
Mercury Loop Rate of Rise (Torr/hr)	NA	14	12	14	14	14.9	14

* No detectable leak rate observed

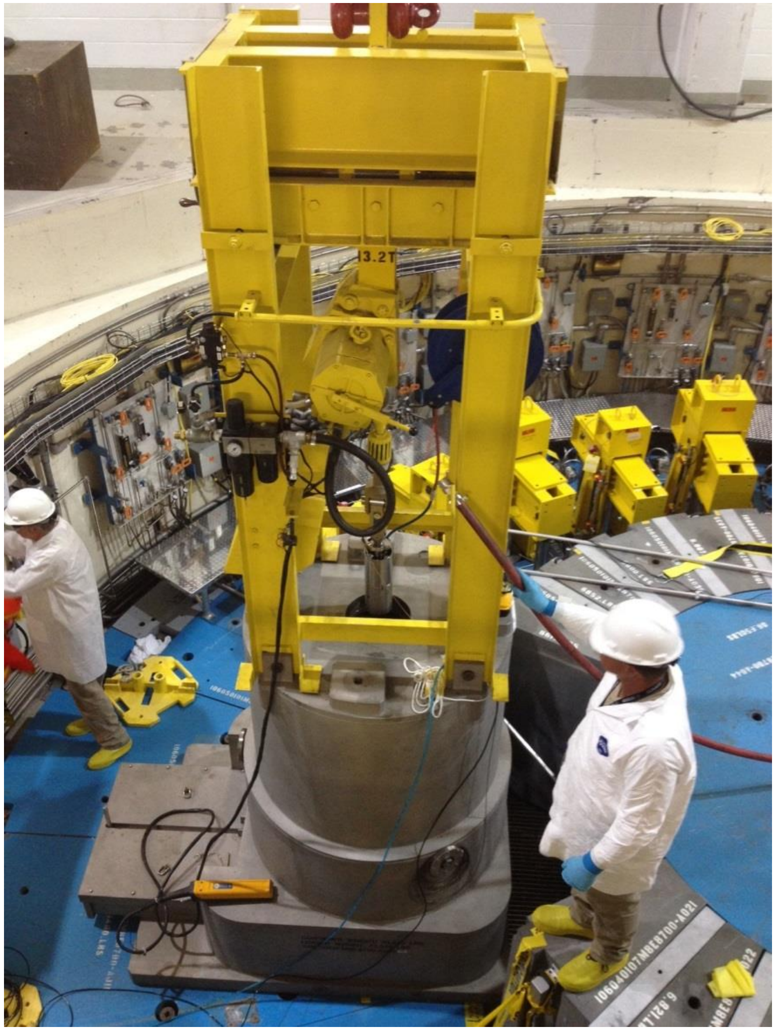
Successful Proton Beam Window Replacements Continue

- **Three Proton Beam Window modules have been replaced during 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 PBW replaced in 2013 received 6380 MW-hrs of energy with a resulting dpa level of 9.5 dpa
  - 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 all installations, Core Vessel and RTBT flight tube vacuum leak testing has indicated excellent PBW inflatable seal function

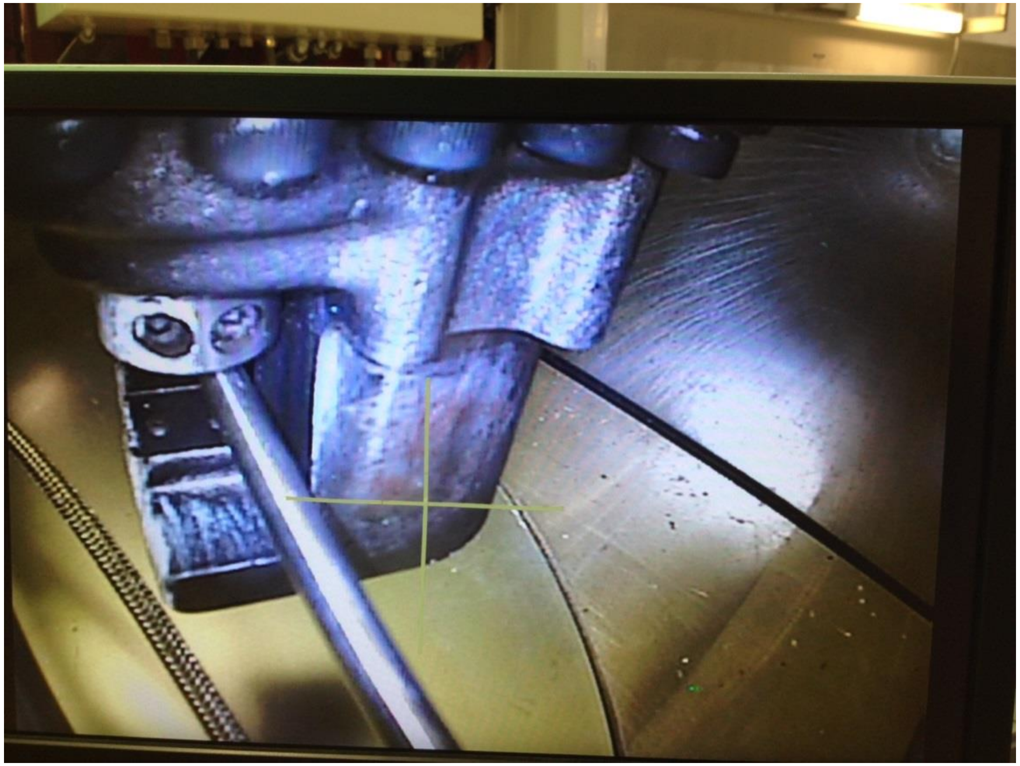


PBW#4 Installation

PBW Replacement Operation



PBW Lead-shielded Cask in Position
For Spent PBW Removal



Remote Camera View of Inflatable
Seal Helium Line Cutting

PBW Replacement Environment Steadily Becoming more Hazardous

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

Activity	Dose Rates
Block 6 removal	No dose, 14,000 dpm/large area smear Be-7
Block 5 removal	No dose, no smearable
Block 4 removal	2 mR/hr, 1,000,000 dpm Be-7
Block 3 Removal	320 mR/hr contact, 120 mR/hr @ 1 ft, 1 R at top of cavity
PBW Tubing Removal	400 mR/hr contact, 800k dpm smearable
PBW Removal	300 R/hr maximum dose seen
	8 R/hr on the bottom of the cask
	1.5 R/hr at the plane of the cavity, 700 mR/hr at 1 m
	220 mR/hr out of the top of the cask opening

BL 9 Shutter and Core Vessel Insert Replacement Planning is in Work

- Removal of the BL 9 (Corelli) concrete shutter plugs and CVI Plug along with installation of the operational shutter and CVI is planned for the upcoming outage
  - Replacement of the multi channel BL 16 Shutter/CVI was completed in January 2011 validating the process and tooling operation
  - AIP-31 developed the specific remote handling tooling required to replace the single channel BL 9 items
- Replacement of a Core Vessel Insert is considered the most difficult remote handling operation at SNS

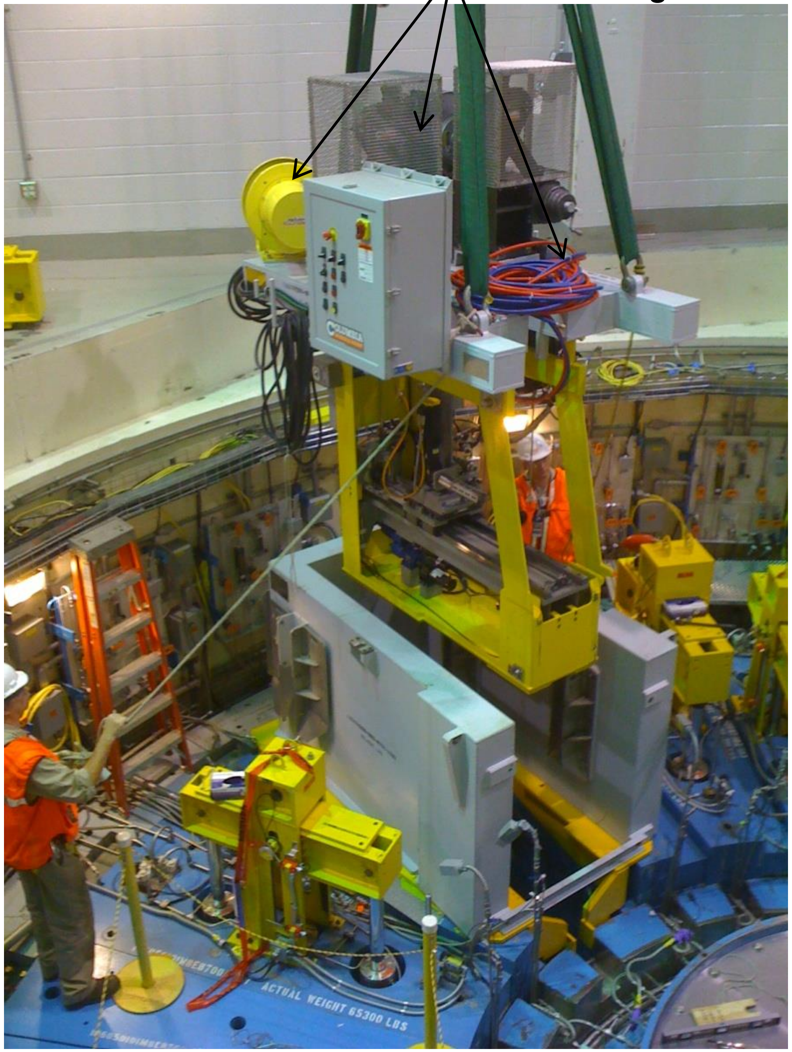
CVI Comprises the Innermost Portion of the Instrument

- 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
- Each CVI is water cooled and purged with helium

CVI Replacement Requires Complex Tooling/Process

- Concrete shutter plugs are removed from Shutter cavity (34000 lbs)
- The Robot is lowered into the shutter cavity using the Hoist Plate
- The CVI Robot is used to extract CVI Plug and place into shielded Cask
- The Robot then installs the new CVI into the Monolith
- The new functional Shutter (58,000 lbs) is then installed

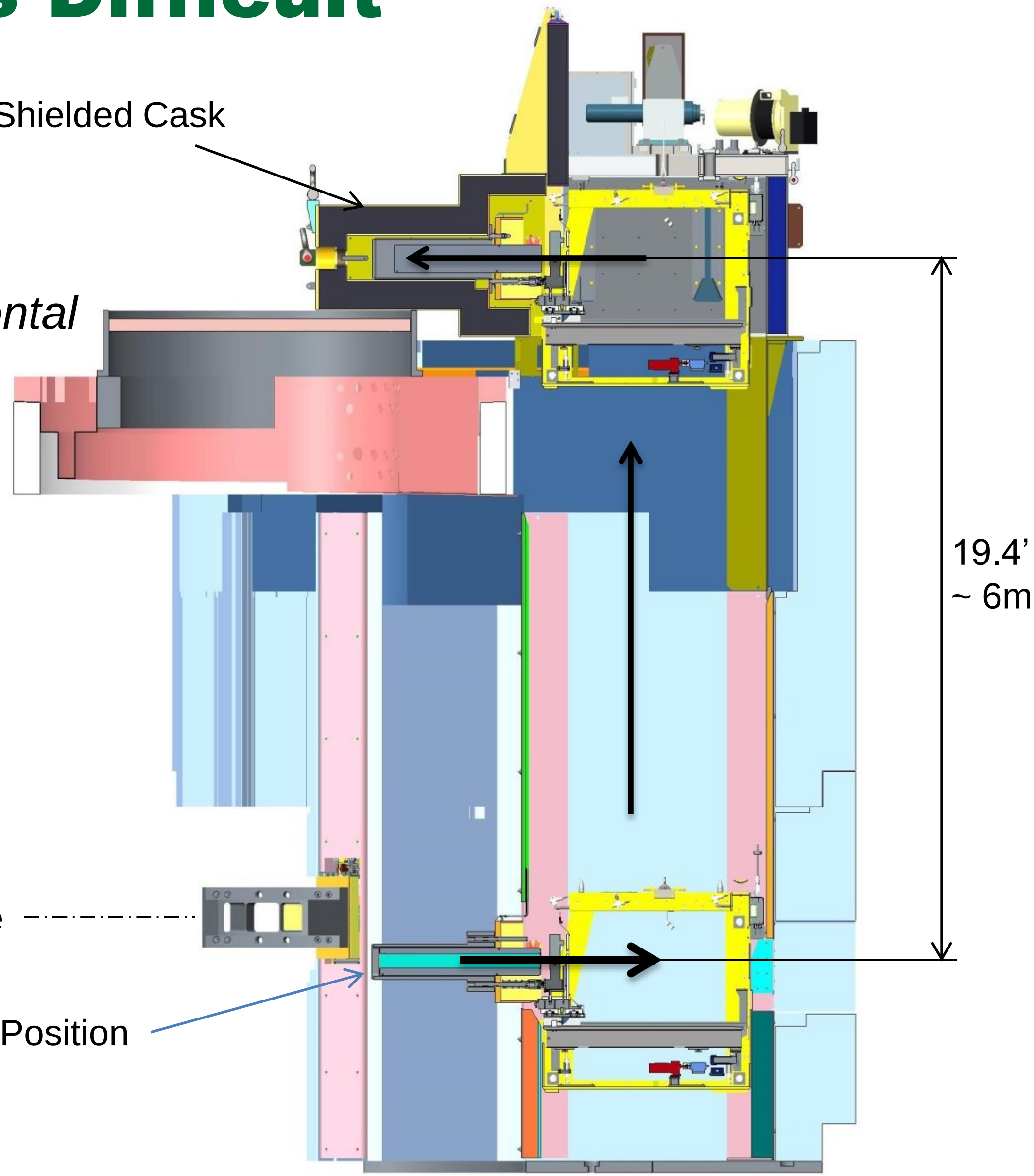
Synchronized hoists, pneumatic supply lines and robot power and data cabling



Installation of Hoist Plate and CVI Robot onto U-Block

Access to CVI is Difficult

Removal the CVI requires horizontal extraction from the Monolith, vertical movement through up through the Shutter cavity and then horizontal insertion into the Shielded Cask



Cross-Section of BL 9 Shutter Cavity

BL 9 Shutter and Core Vessel Insert Replacement Planning is in Work

- **The Mock Up Test Stand (MUTS) has been reconfigured to replicate a single channel shutter cavity:**

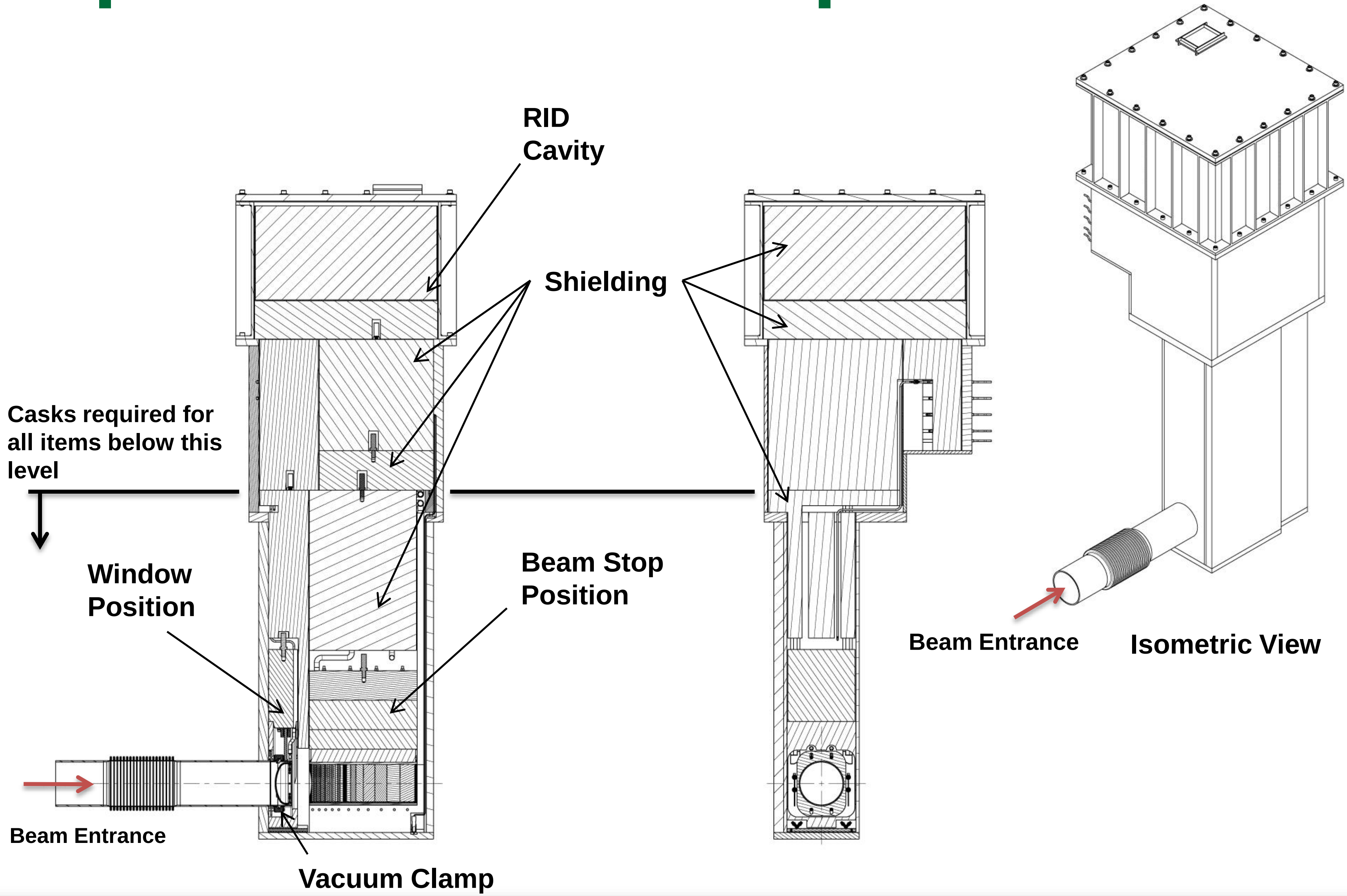
New Single Channel Robot has been Delivered and is in Testing

CVI Robot Mounted in Maintenance Frame and Integrated to New Hoist Plate Undergoing Operational Testing

Ring Injection Dump Remote Tooling is in Fabrication

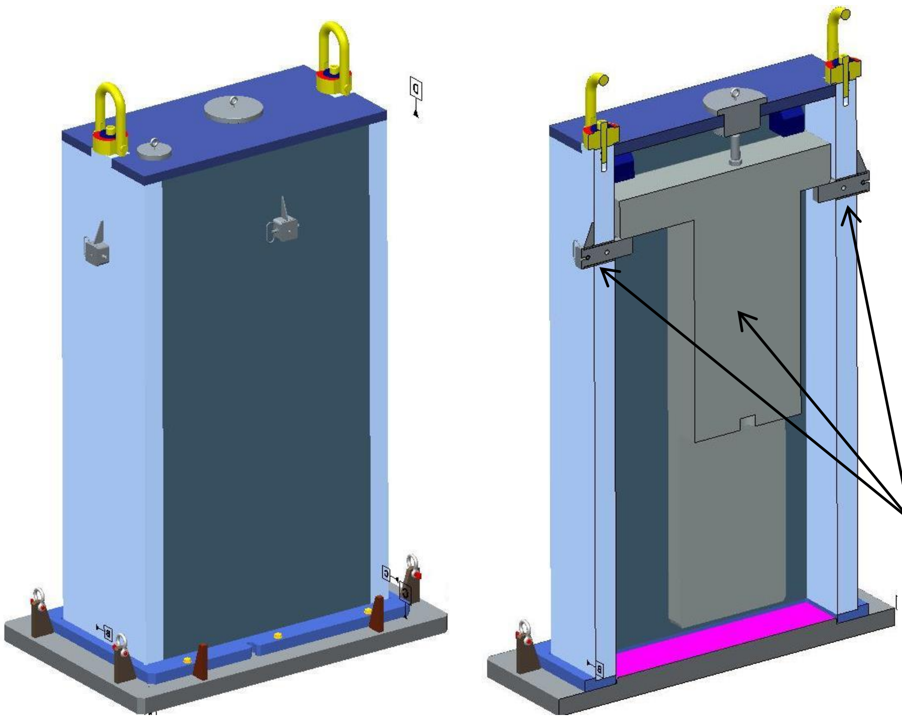
- Replacement of the Ring Injection Dump (RID) Window and Beam Stop is tentatively planned for the winter outage of 2017
  - A spare vacuum Window is on hand
  - A spare Beam Stop was procured and was received last year
- Remote tooling for replacement of these components has been designed and is currently in fabrication
  - Delivery of the tooling is expected this FY

Replacement of RID Components

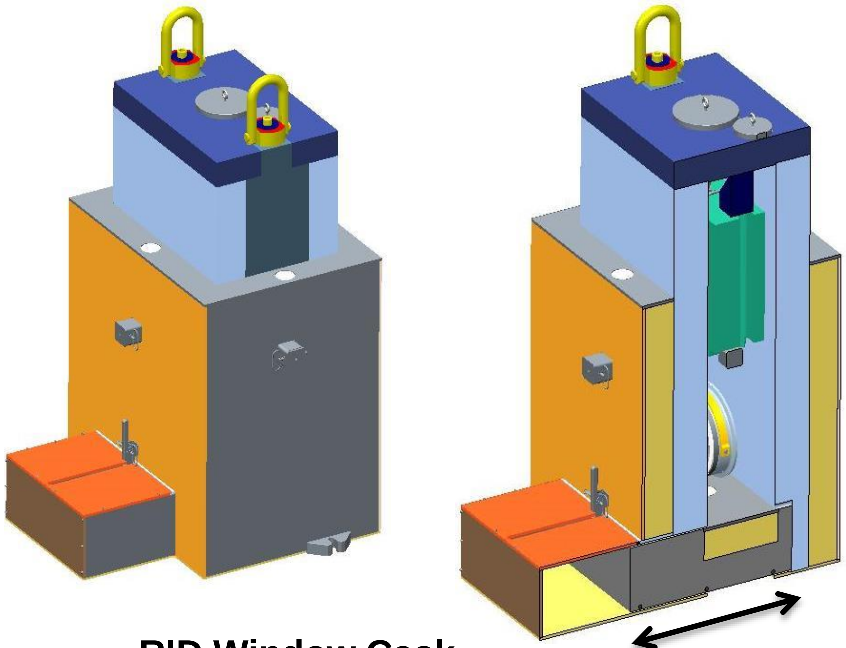


RID Tooling Utilizes Existing Remote Handling Concepts

RID Window Shield Block Cask



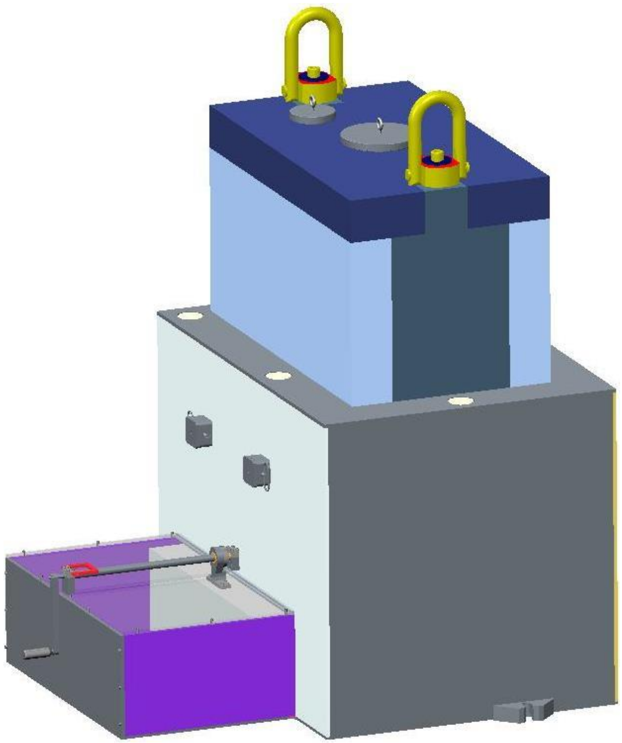
Shield Block is retained inside Cask with Pins to enable re-installation into the cavity



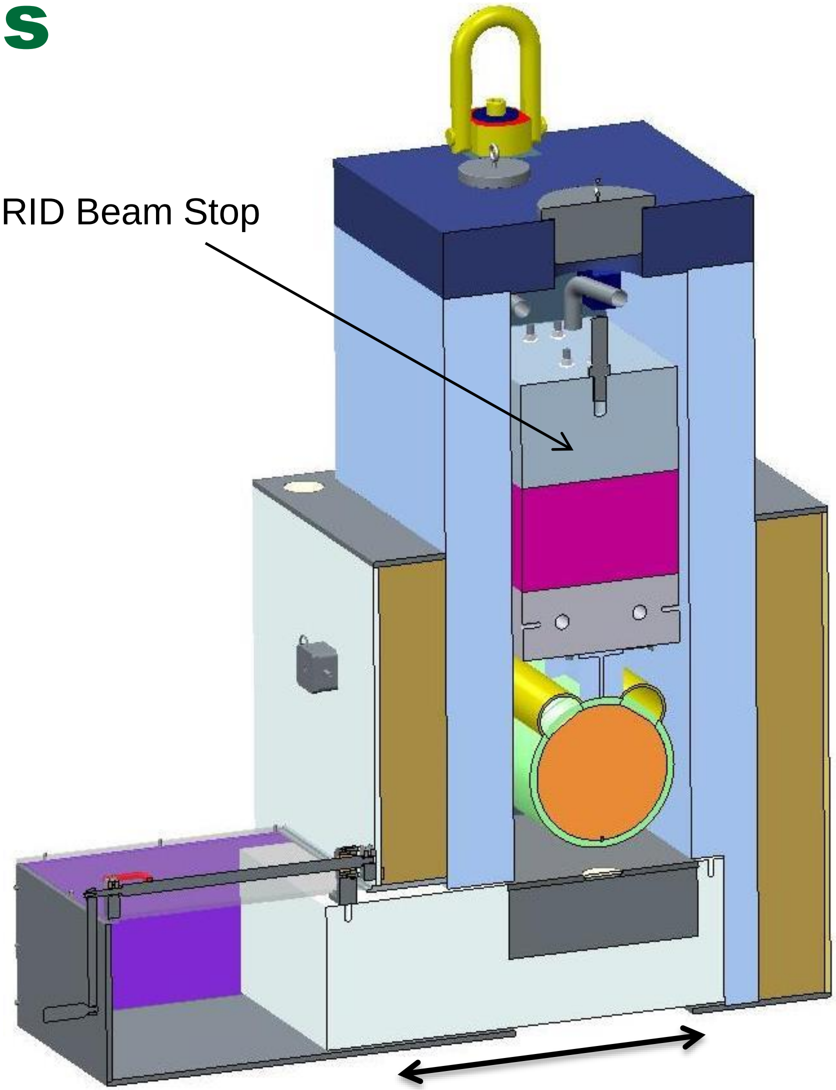
RID Window Cask

Shielded Door Slides to Enable Window Module to be Pulled up and into Cask

RID Tooling Utilizes Existing Remote Handling Concepts

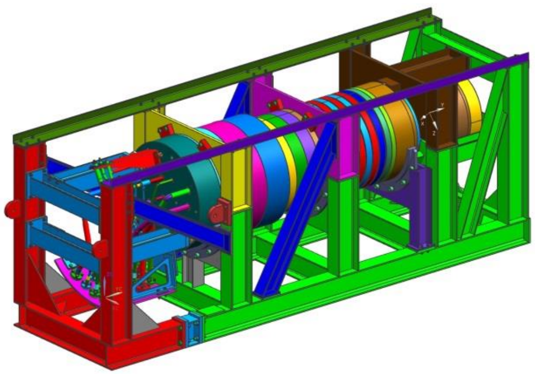


RID Beam Stop Cask



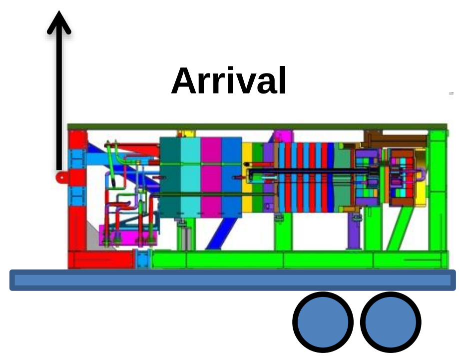
Planning for Delivery of Spare IRP is in Work

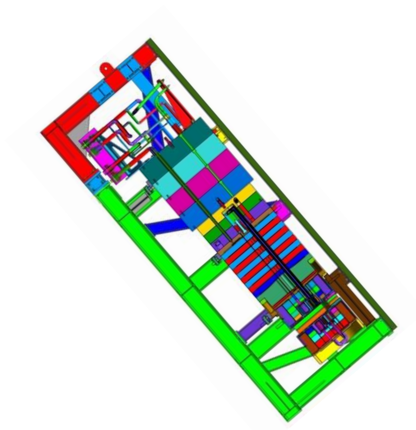
- **Working with IRP vendor to develop hoisting and rigging plans to transfer the Spare IRP into the Mock Up Test Stand**
  - **Horizontal shipping orientation to a vertical testing position:**

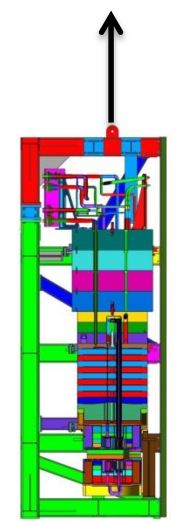


IRP in Shipping Frame
- 21 feet in length
- 86,000 lbs

Arrival







Rotation to Vertical Orientation for Installation into MUTS

Target Failure Experiences have resulted in Enhanced PIE Capabilities

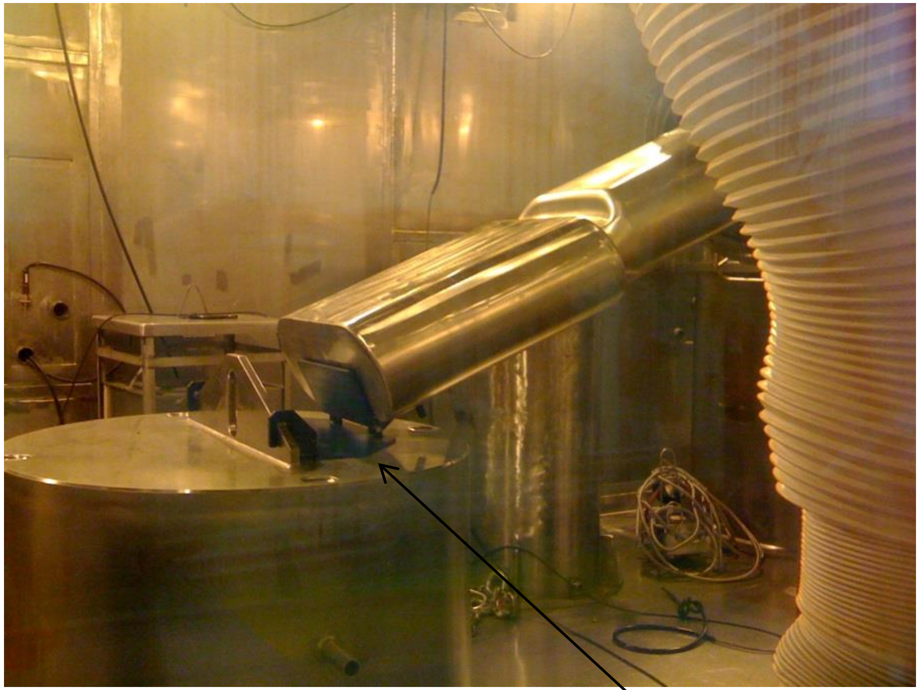
- **Post Irradiation Examination of spent targets has been ongoing since the removal target T1**
  - PIE consisted primarily of remotely cutting nose samples to enable subsequent inspection/materials testing
- **The successive target failures during CY2012 resulted in the development of additional PIE capabilities**
  - Enhanced video scope inspection capabilities
  - Pressure testing and pressure decay testing of both the water shroud and interstitial regions
  - Leak detector testing of installed/removed targets
  - Transfer Bay photography of specimens

Horizontal Rotation of Spent Targets Enables Pre-Cutting Video Scoping

- Spent targets are stored in a vertical, nose-down orientation following removal from service
  - Pooling of residual mercury in the nose region prevented video scope inspection of the nose region prior to cutting the nose samples
- A process and tooling was developed to rotate spent targets into a horizontal orientation in the Service Bay for video scope inspections

Horizontal Rotation in the Service Bay

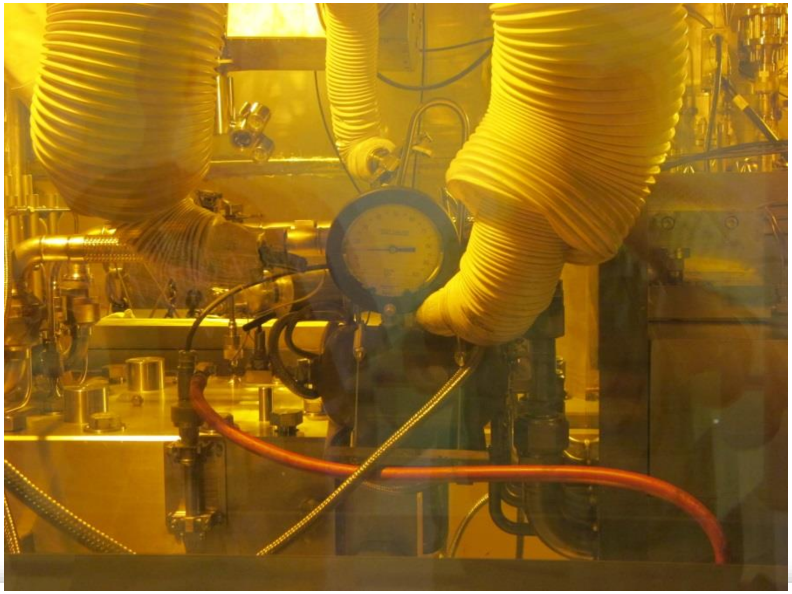
Rotation utilizes existing structures within the Service Bay in addition to a simple Rotation Fixture



Rotation Fixture

Additional Pressure Testing Capabilities have been Developed

- The ability to perform a variety of pressure tests has been developed
  - Pressurization of the interstitial region with the target mounted to the Carriage
  - Pressurization of the Water Shroud on a spent target
  - Pressurization of the Interstitial Region on a spent target



Performing Interstitial Region Leak Testing on Target T7 in the installed Position

Waste Disposal of Removed Shutter System Components is Critical

- Seven instrument beam lines were outfitted with concrete shutter plugs in lieu of functional shutters
  - To date, remote handling operations have replaced four of these sets of shutter plugs with functional shutters
- Additionally, Core Vessel Insert (CVI) Plugs were installed in four of these locations
  - The BL 16 CVI plug has been removed and is currently in storage in a shielded Cask
- Upcoming remote handling operations require use of these storage casks, so efforts are underway for waste disposal of these items

Waste Disposal of over 100 Tons of Shutter Plugs Completed

- Each beam line Shutter Plug assembly consists of four segments:
  - Three high-density concrete
  - One carbon steel
- Due to the activation levels of these items, they were able to be processed as Low Level, LSA waste
- A total of 209,250 lbs of shutter plugs were shipped for disposal
  - A total of 16 segments were shipped

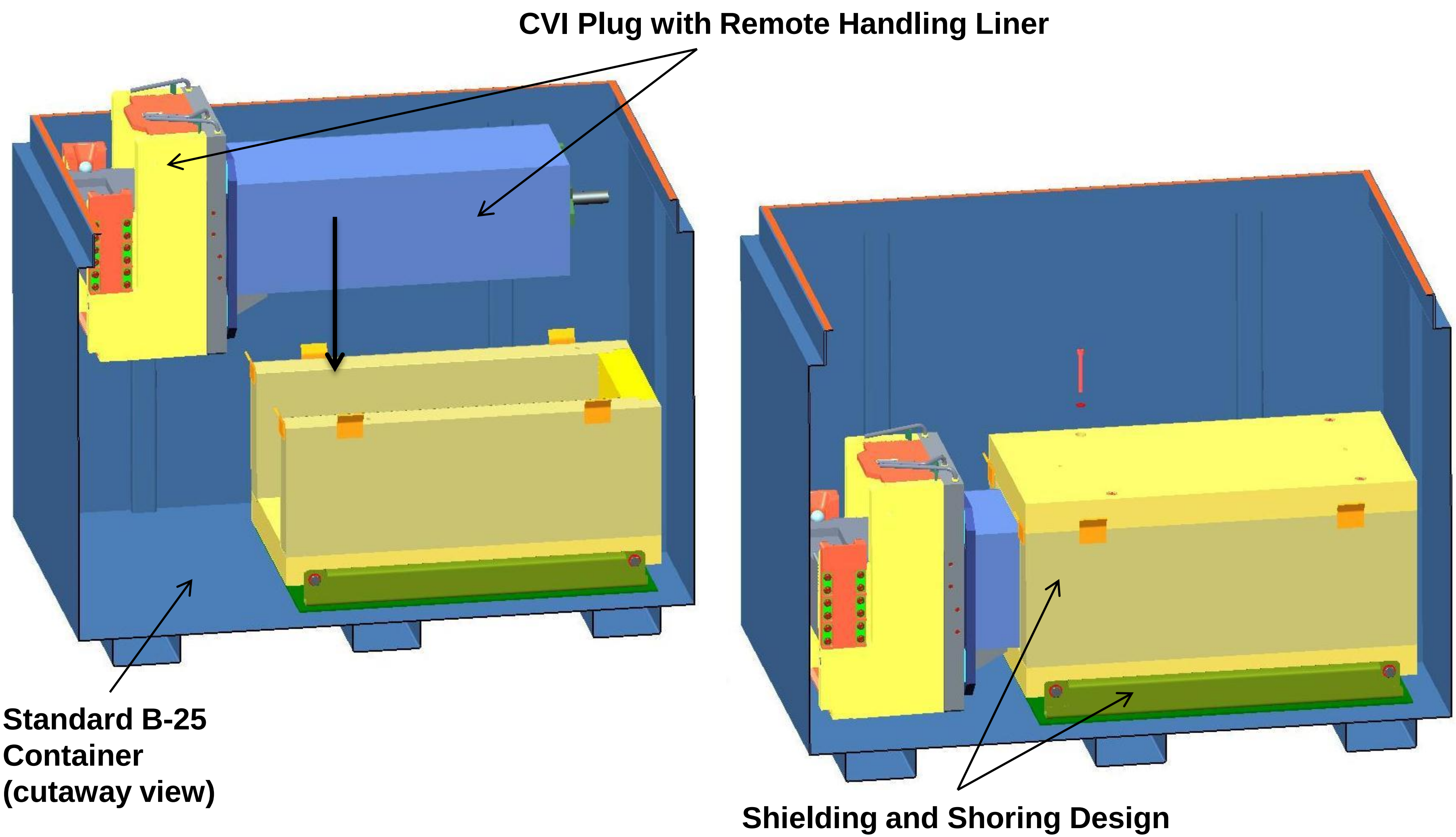
Waste Shipment Required Significant Coordination

Waste Shipment Activities

Waste Disposal of CVI Plug Method Simplified

- Neutronics analyses along with scrutiny of DOT requirements revealed that the CVI Plug can be shipped for waste disposal in a standard B-25 Container
  - Shipment of the CVI Plug in this manner requires additional shielding within the B-25
    - Neutronics analyses indicate that an additional 4" of steel shielding is required to meet DOT requirements
- Shipment via B-25 Container drastically reduces the costs associated with a typical TN-RAM cask shipment
- A design concept has been completed to develop the shielding and internal shoring to package the CVI Plug in the B-25

Simplified B-25 Packaging Details



TN-RAM Cask Scheduling Issues

- The SNS facility is designed to utilize the TN-RAM Cask
  - The TN-RAM is the largest waste cask certified for over-the-road use
  - There is only one TN-RAM in existence and must accommodate many customers
  - Four shipments were made in FY2012
- SNS shipments must be coordinated with all other customers

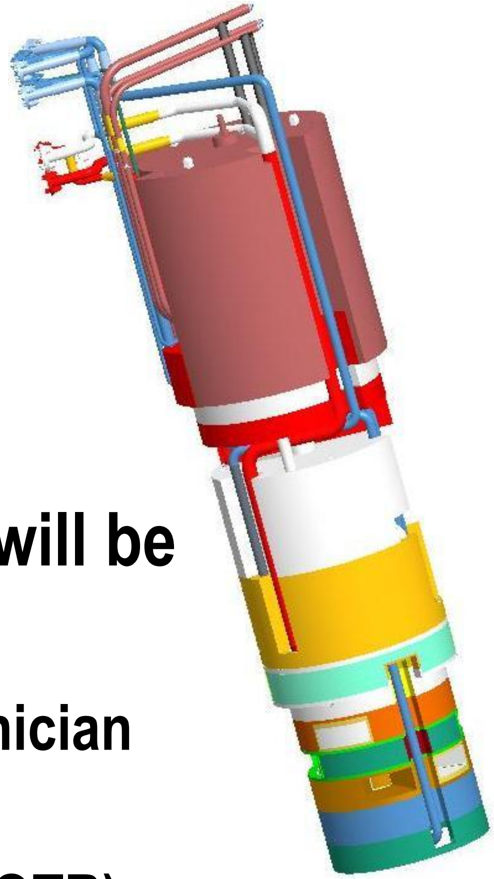
TN-RAM being moved through the Target Building

TN-RAM Shipment Delay

- A recently planned TN-RAM shipment was delayed due to excessive external contamination
  - Cask is currently undergoing decontamination efforts to attempt shipment of Target T7 prior to the upcoming outage

IRP Disposal Planning in Work

- The current (and spare) IRPs – following removal – will consist of the following:
  - Upper Segment
  - Middle Segment
  - Lower Segment
  - Piping cut during removal process
- During the removal process, each segment will be placed into a shielded storage cask
  - These storage casks provide shielding for technician protection during remote handling operations
  - These casks are not suitable for over-the-road (OTR) transportation
    - On-site (SNS) transport will be permitted



68200 lbs
186” tall

IRP Upper Segment Disposal Plan is Clear

- Upper Segment Disposal
  - Recent neutronics and waste disposal analyses indicate that the activation and radionuclide inventory of the Upper Segments meets Class A/Type A disposal requirements
  - This indicates that the disposal of this segment can be accomplished as an LSA II (Low Specific Activity II) shipment requiring only a "strong tight container"
  - Additional work will be required to enable transfer of the Upper Segment from the remote handling storage cask to the strong tight container needed for shipment
    - Additional tooling and procedures will be required to enable this operation

Middle Segment Disposal Plan is also Understood

- Middle Segment Disposal
  - Neutronics analyses are required to determine the Class/Type requirements for disposal of this segment
    - Assuming a similar Class A/Type A determination, a strong tight container may be the easiest solution for disposal
    - If a Type B disposal cask is required, it is possible that an existing 8-120B or 10-160B cask can be utilized
      - Each of these casks meet the dimensional and payload capacity requirements for disposal of a Middle Segment
      - Cask availability and neutronics suitability would need to be evaluated
  - In either case, additional work will be required to enable transfer of the Middle Segment from the remote handling storage cask to the strong tight container/cask needed for shipment

Lower Segment Disposal is More Complex

- Lower Segment Disposal
  - The design of the lower IRP segment is not compatible with the TN-RAM cask
  - While larger casks exist, the amount of shielding, etc., requires rail transport
    - SNS/ORNL has no rail access
    - The remote handling storage casks cannot be utilized for over-the-road shipment to a rail spur
  - Further investigation is required to understand the availability of these larger rail casks and the transportation logistics needed for utilization
    - This effort is underway

Summary

- **At this point in SNS operation, remote handling and waste disposal operations comprise critical efforts with significant operational implications**
- **A philosophy of diligent planning prior to operations and subsequent continuous improvement have enabled a significant number of successful operations**