Target Systems Performance and Plans

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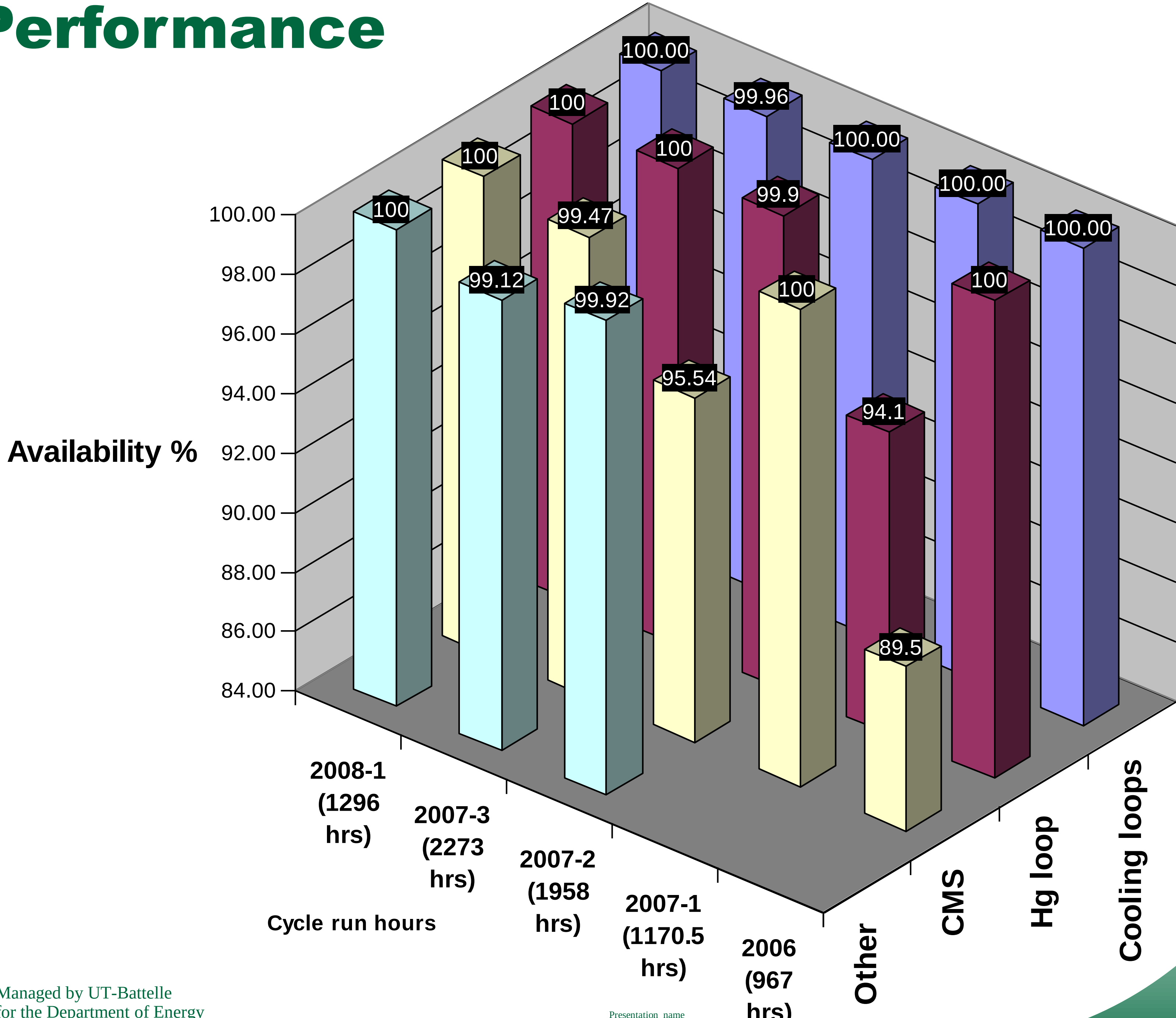
Outline

- **Performance history of Target Systems**
- **Beam Profile requirements in Operating Envelope**
- **Target System development to support power ramp up**
  - **System development**
  - **New profile diagnostic development**
  - **Post Irradiation Examination planning**
- **Rotating Solid Target development (LDRD)**

Performance



Cooling Loops

- **All 4 loops have had nearly 100 % availability**
- **System performance consistent with design**
- **No water leaks on any loop or within core vessel**
- **One loop 2 pump failed**
  - **Automatic switch over to second pump accomplished**
  - **Failed pump replaced**

Target Utilities – Performance

- **Equipment problems**
  - PR2 magnetic drive cooling loop pump thrust bearing failure (likely due to pressure imbalance during startup)
  - Inflatable seal vacuum pump failure (actual operating pressure higher than recommended and pump overheated)
  - H2/O2 analyzers (original isolation amplifiers on H2 not working properly; grounding problems at Ring Injection Dump; restricted flow to analyzer, calibration issues)
  - Core vessel vacuum pump (controller electrical design problems)

Target and Mercury System

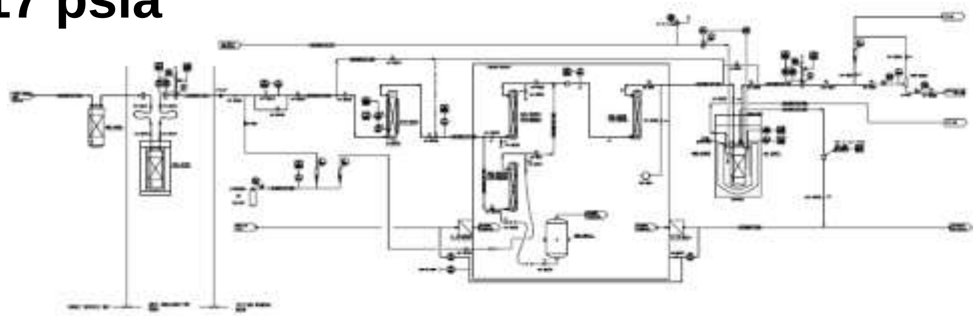
- **Shaft gas seal failure and grease leaks caused down time**
- **Repairs were performed in 2007 which have allowed stable operation**
  - **Sealed "tripod" zone with helium overpressure**
  - **Graphite packing added to grease seal**
  - **Pump speed reduced from 400 rpm to 150 rpm (will allow up to 350 kW operation at this speed)**
  - **Higher pump speed and beam power are expected to be acceptable after graphite packing has been operated**
- **Target Protection System failures occurred because of lightning strikes**
  - **Surge protection added to system**

Cryogenic Moderator System (CMS)

- **Helium Refrigeration System loss of capacity with time caused loss of availability**
- **Installing the helium heat exchanger in a vertical cold box has fixed the problem**
- **The 3 hydrogen loops have performed well**

Mercury Offgas Treatment System (MOTS)

- **Design flow 1.5 scfh helium (from Mercury Loop)**
- **Design pressure 16-17 psia**



- **Design Changes:**
  - **Design flow and pressure required modification after mercury pump seal failed**
    - **pressure is now 13.6 psia, flow is still 1.5 scfh nominal but can be 6 scfh**
  - **Considered a gold sorbent regeneration system, but do not believe that it is cost effective**
  - **Designing a brine-chilled condenser system which should relieve the Hg load significantly thus greatly extending gold sorbent lifetime**
  - **Parallel back-up carbon adsorber being designed**
    - **To be refrigerated instead of LN2 cooled**

MOTS Problems Encountered (since April 2006)

- Dose rate issues with noble gas hold-up in the system
  - Xenon conditioning of gold bed
  - Relocation/shielding of gold bed and CuO bed
  - CuO bed shielding not yet installed
  - Additional shielding to be considered when the need arises
- Excess moisture issues
  - Changed mol sieve bed design
    - regenerable beds instead of throw-away
  - Dried out system
    - Tritium was detected in the removed water
  - This issue is now resolved
- Carbon Adsorber Reliability Issues
  - Parallel back-up adsorber being designed

Isotopes of Interest Detected in MOTS

Ar-41		
Kr-77	Br-77	
Kr-79		
Kr-85m		
Kr-87		
Kr-88	Rb-88	
Xe-120		
	I-121	Te-121
Xe-122	I-122	
Xe-123	I-123	
Xe-125		
Xe-127		

- **All isotopes detected have >2 hr half lives**
- **There are other shorter lived isotopes that do not appear because their half lives are shorter and therefore decay in the Hg tank head space**
  - **2 hr holdup time**
- **Xenon-127 (36 d) causes stack emissions when mercury loop is drained/filled**
  - **Because gas flow is not through MOTS during system transients**
  - **Modification of piping and procedures may be required**

Other Systems- He, N2 and vacuum systems

- **Good overall availability**
  - Minor problems with core vessel helium system valve – corrected
  - Some instrumentation problems with hydrogen and oxygen monitoring systems for the gas liquid separator tanks
- **Core vessel has routinely maintained >99.95% helium**
  - Good seal performance and no significant leaks

Beam Profile Requirements

- **Limits on the peak target beam intensity (protons/ mm^2/pulse) have been incorporated in the Operating Envelope**
- **The intent of the limits is to extend the target life while ramping up in power, particularly before a production capacity has been established for multiple targets per year**

Target Lifetime Scaling

- The approach is based upon using an assumed life at 1 MW and 60 Hz with the nominal beam profile and scaling from that assumed life as shown below.

- $L/L_{1MW}=[1/E*I_0/I]^4*(60/f)/C_f$

  Where

  L= target lifetime (beam-hours)

  E= energy in Gev

  I= Protons/mm^2/pulse (I_0= 1.3x10^9)

  f= frequency (Hz)

  C_f= ratio of damage per pulse at f versus at 60 Hz

OE Intensity Limits below 400 kW

For $L/L_{1MW}=F$

$I=3.62\times10^{10}/E/[F*C_f*f]^{1/4}$

For F=13 (6 months if 1 MW life is 2 weeks)

f=30 hz, E=.88 Gev and $C_f = 4$

$I= 6.5\times10^{9}$ Protons/mm^2

f=60 hz, E=.88 Gev and $C_f =1$

$I= 7.78\times10^{9}$ Protons/mm^2

OE Intensity Limits below 400 kW con't

5.1.1.1.1.1 To have estimated target lifetimes of at least 6 months, the peak beam pulse intensity on Target is limited as given in the table below when operating at or below 400 kW.

- The peak Intensities may be exceeded by up to 10 % for 30 minutes.
- Peak Intensities > 25% of the limit require rapid beam shut down.

Nominal rep rate (Hz)	**Peak Protons/m^2/pulse 880 MeV**	**Peak Protons/m^2/pulse 1.0 GeV**	**Power at limit with nominal profile (kW)**
5	**8.1×10^{15}**	**7.2×10^{15}**	**46**
15	**6.2×10^{15}**	**5.4×10^{15}**	**105**
30	**6.5×10^{15}**	**5.8×10^{15}**	**221**
60	**7.8×10^{15}**	**6.8×10^{15}**	**526**

The normalized peaking factor allowed at 60 Hz and 400 kW is therefore 1.3 (526kW/400kW)

Ramp-up from 400 kW to 1 MW

Power (kW)	Normalized Peaking Factor	Peak Protons/m^2/pulse @ 1 GeV, 60 Hz
400	1.3	**6.85×10^{15}**
600	1.2	**9.49×10^{15}**
800	1.1	**1.16×10^{16}**
1000	1.0	**1.30×10^{16}**

This assumes we can improve the peaking factors as we go up in power to match the ICD limit at 1 MW

Actual Beam Peaking history

Creation Date	Beam Energy (MeV)	Proton Per Pulse	Rep Rate (Hz)	Power	Peak Proton Density Target	Normalized Peaking Factor Target	RMS Wdth Target (mm)	RMS Height Target (mm)
26-Dec-07	845	3.77E+13	30	1.53E+05	6.24E+09	1.32	37.4	15.0
18-Dec-07	845	3.94E+13	30	1.60E+05	5.86E+09	1.19	40.0	14.9
13-Dec-07	845	2.45E+13	60	1.99E+05	5.33E+09	1.74	32.3	13.8
4-Dec-07	845	4.16E+13	30	1.69E+05	6.51E+09	1.25	38.0	16.4
28-Nov-07	845	3.34E+13	30	1.36E+05	5.57E+09	1.33	35.1	15.2
15-Nov-07	845	2.58E+13	30	1.05E+05	4.38E+09	1.36	37.8	16.1
15-Nov-07	845	2.58E+13	30	1.05E+05	4.37E+09	1.36	37.8	16.1
30-Aug-07	885	3.25E+13	30	1.38E+05	6.08E+09	1.50	41.5	14.6
29-Aug-07	885	3.45E+13	30	1.47E+05	5.07E+09	1.18	41.5	14.7
23-Aug-07	885	2.81E+13	30	1.19E+05	4.36E+09	1.24	43.8	15.5
21-Aug-07	885	4.27E+13	30	1.82E+05	6.46E+09	1.21	46.7	15.9
16-Aug-07	885	3.65E+13	30	1.55E+05	4.63E+09	1.02	45.7	16.0
19-Jul-07	885	2.43E+13	30	1.03E+05	3.13E+09	1.03	48.0	15.5
21-Jun-07	885	1.50E+13	30	6.36E+04	2.13E+09	1.14	47.2	14.3
5-Apr-07	887	2.90E+13	15	6.18E+04	3.60E+09	0.99	52.0	16.0
28-Mar-07	887	2.70E+13	15	5.76E+04	3.90E+09	1.16	43.3	15.5
28-Mar-07	887	2.70E+13	15	5.76E+04	6.90E+09	2.04	40.2	13.9
28-Mar-07	887	4.20E+13	15	8.95E+04	5.56E+09	1.06	40.1	15.7
15-Mar-07	887	2.90E+13	15	6.18E+04	4.29E+09	1.18	44.2	15.7
6-Mar-07	887	2.41E+13	15	5.14E+04	4.21E+09	1.40	41.9	14.8

Nominal Beam Profile has target peak (p/mm2) = 1.3e-4*# protons/pulse

Target System Development- Cooling loops

- Use of D_2O in Reflector Plug loop (HWS/PR4) projected to improve neutron flux by ~15% for neutron energies ~ 1eV.
- HWS/PR4 Cooling Loop:
  – 2228 gallons circulating; 4823 gal total
    - ~5 MT (~1315 gallons) in 28 drums from Savannah River
      – "High purity" D2O: > 99.67 mol % D2O
      – Low levels of tritium (≤1.5 mCi/L)
      – Weighed upon receipt and sampled for analysis
      – Does not meet SNS pH/pD, conductivity and impurity level requirements
      – Must be processed through temporary cleanup loop at SNS to remove impurities (tritium can not be removed)
    - ~15 MT (~3508 gallons) in ~67 drums from other source

  – PR4 Drying test planned for February-March 2008
- Controls Issues:
  – Inventory control
  – Flow meter re-calibration

Target System Development- Hg

- **Target Module procurements started**
- **Spare Mercury Pump in fabrication/testing**

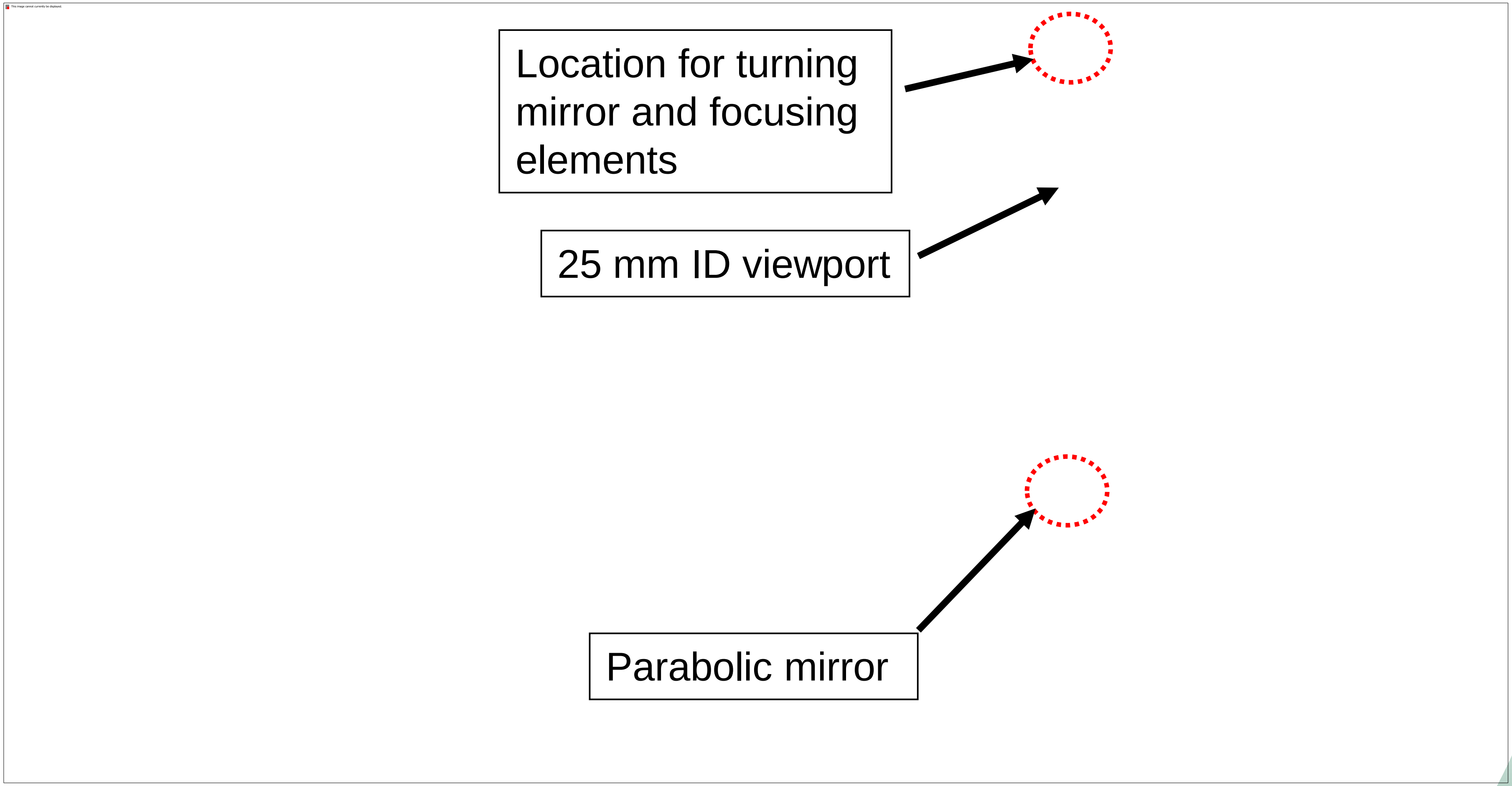
Target System Development- Spares

- Spare Inner Reflector Plug in design
  - Incorporates improvements to reduce fabrication complexity while maintaining performance
  - Procurement package is being prepared now
- Spare Proton Beam Window (PBW) on site
  - Follow on procurement to start this year
- Remote handling systems for PBW in fabrication

New Profile Diagnostic Development

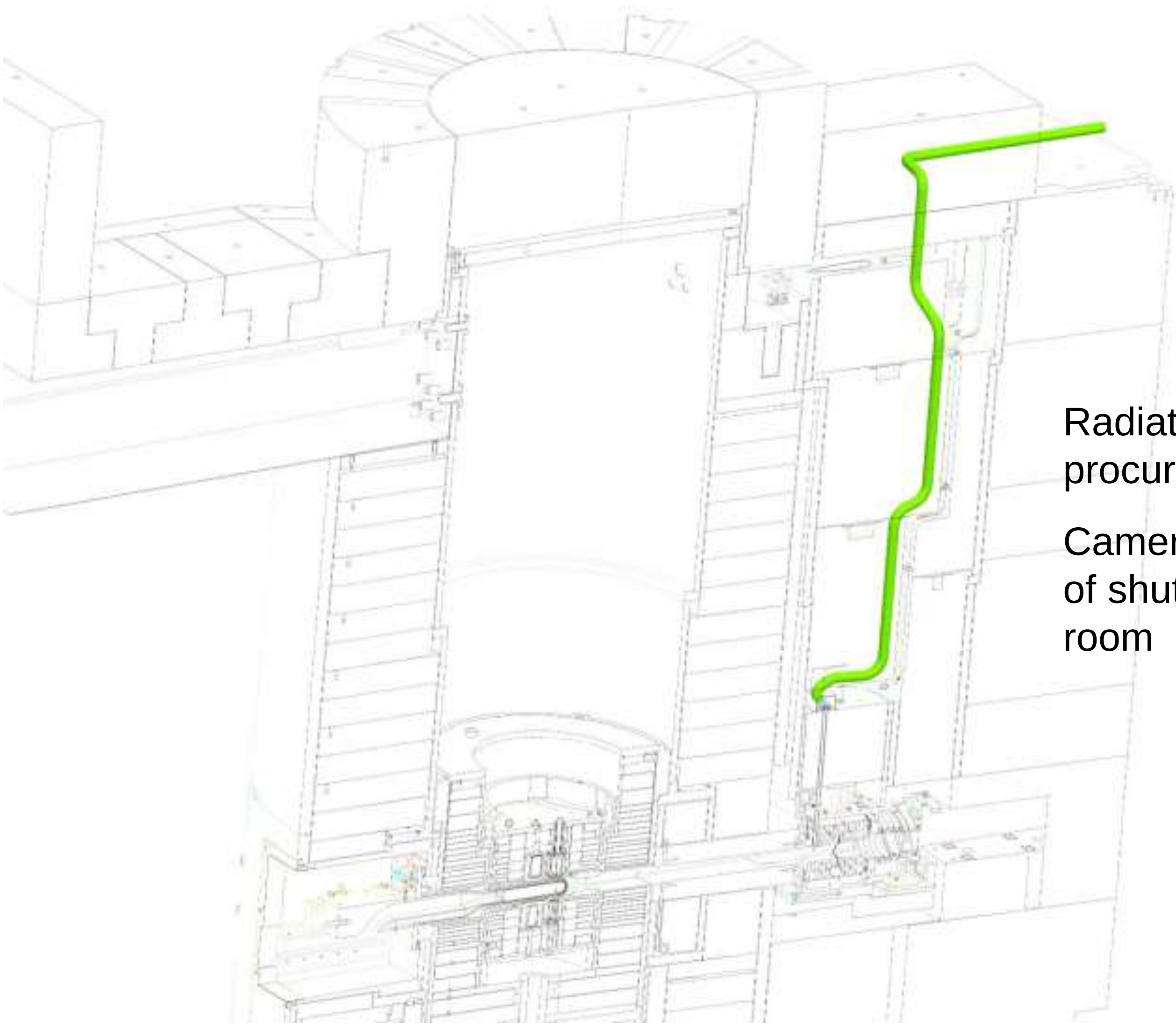
- **Because of the importance of peak intensity on target life and the know uncertainties in current methods of estimating the peak, a new diagnostic is in development which will allow viewing the target nose region**
- **The design will allow viewing a temporary viewscreen to qualify new beam optics at reduced power by the beginning of next FY**
- **Future full power options will be studied next year including:**
  - **Viewing of a tungsten mesh**
  - **Viewing light from the helium**

Viewscreen reflective optical path



Detail design of the optics is in progress

Viewscreen – Fiber routing

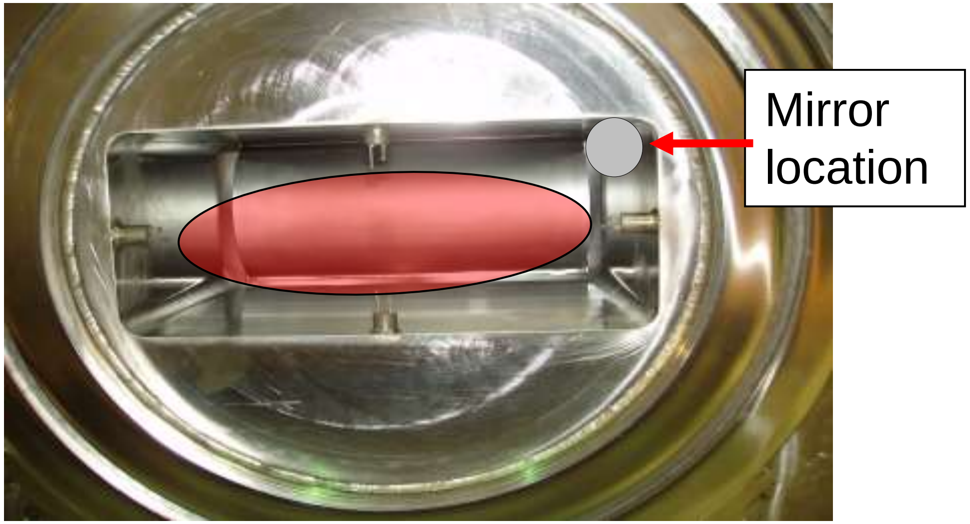


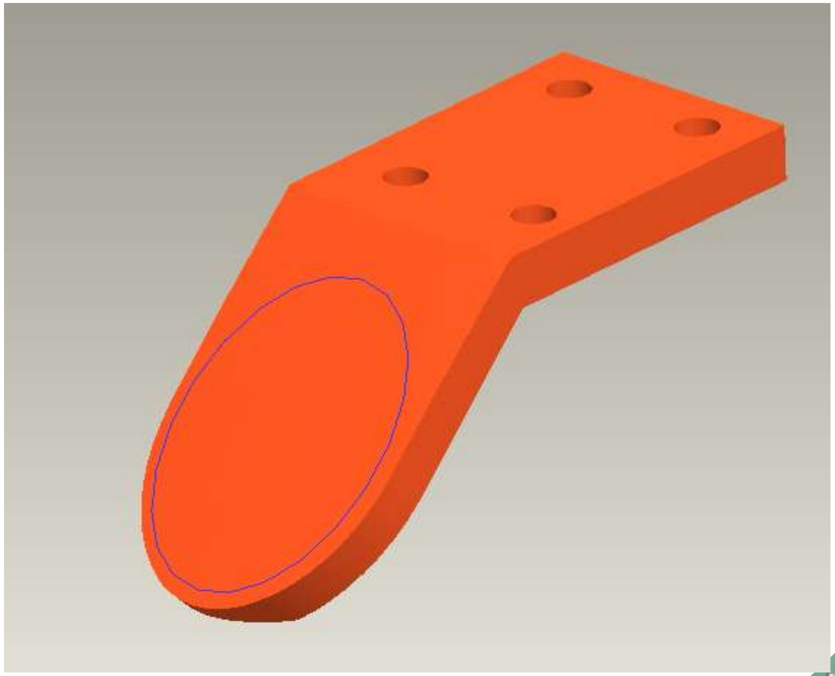
Radiation Hard Fiber procurement started

Camera to be located outside of shutter drive equipment room

Parabolic Al 6061 Mirror

- **Diamond Turned aluminum mirror in fabrication**
- **Threaded holes for mounting in PBW**
- **Provides ~ 200 mm diameter field of view at target nose**
- **Delivery in January**
- **Final optical design of turning mirror and focusing elements to fiber optical cable in progress**
- **Bench top testing of optical design planned**



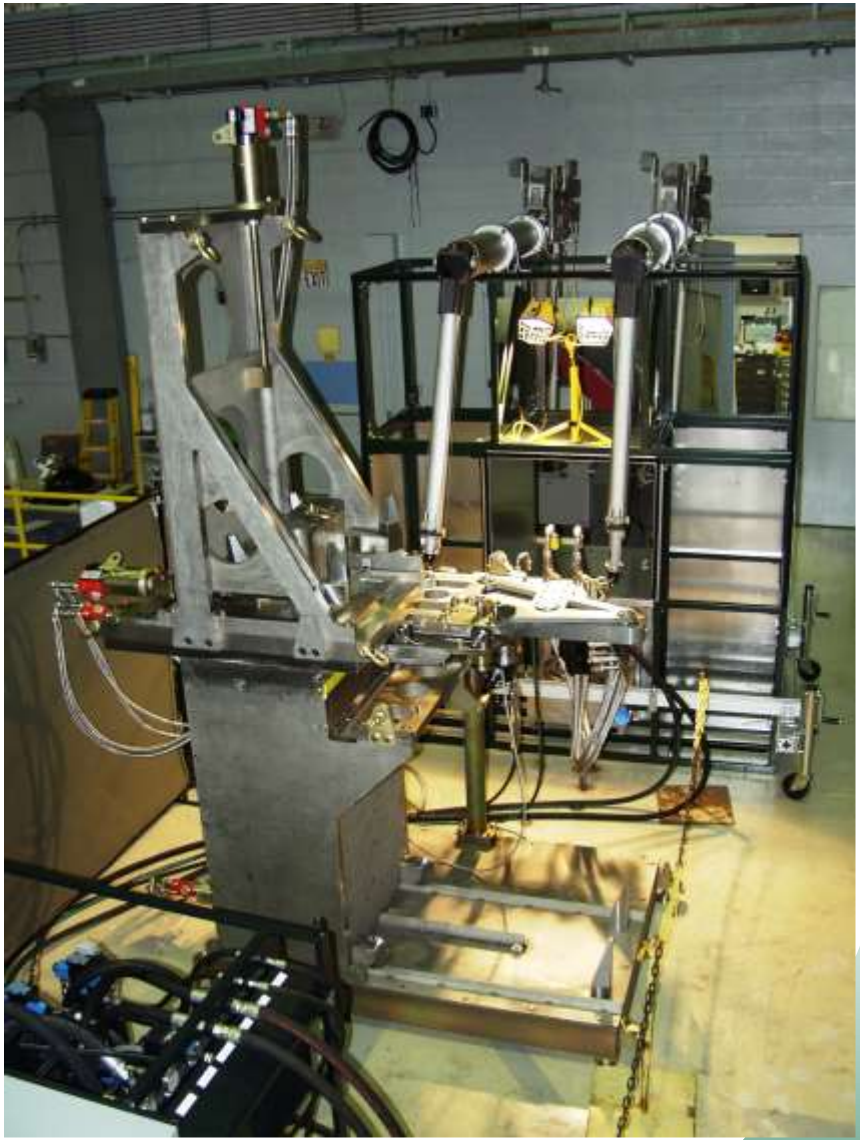


Post Irradiation Examination of Targets

Final Saw Factory Acceptance Testing completed (March 07)

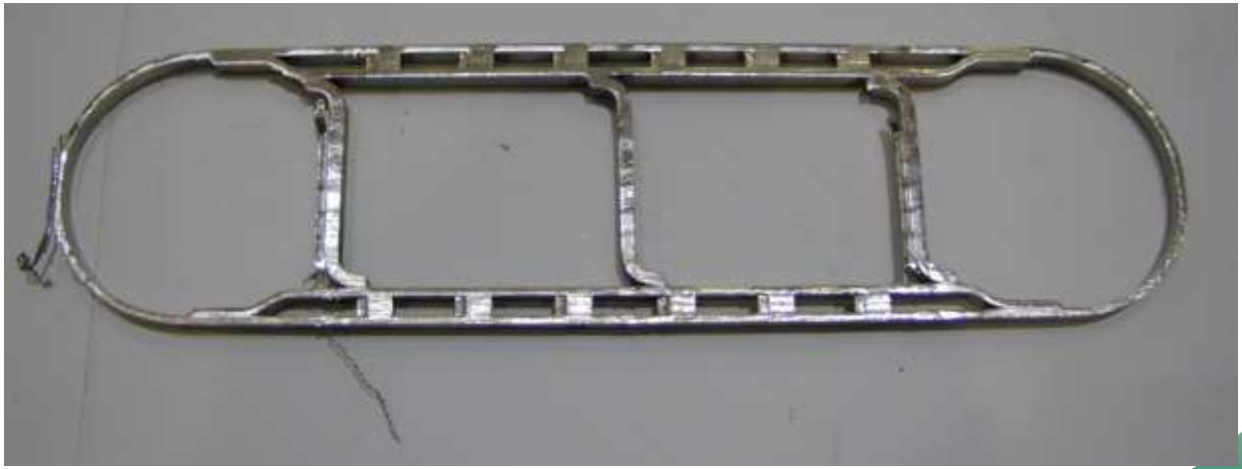
Post Irradiation Examination (PIE)

- **The PIE Tooling is functionally ready – final mods for in-cell use are being completed.**
- **The vertical saw has been fully tested and is now being operated to optimize cutting speeds.**
- **The PIE Tooling will be installed after the first target change-out. This keeps the target service bay clear and allows the target activation to decay.**
- **Once installed, the PIE tooling will be left in cell until needed or replaced.**



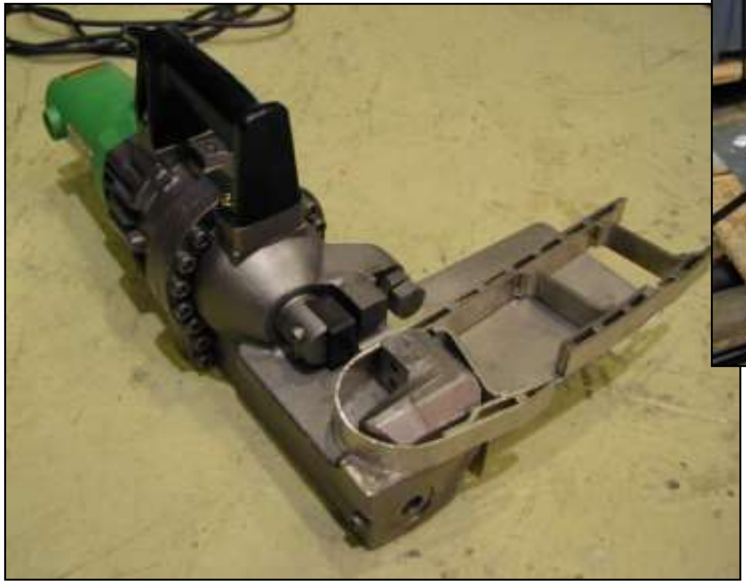
PIE Samples

- **Target disassembly inside the cell will permit immediate visual observation of damaged areas.**
- **Tooling will reduce sections of interest to samples suitable for processing in Metallurgical Cells at ORNL.**



PIE Secondary Tooling

- **Numerous tools and containers have been built to support PIE operations:**
  - **Scrap Storage Container**
  - **Small Shear**
  - **Hole Drill**
  - **Hole Punch**



Rotating Solid Target Concept Development

- Conceptual design for a solid rotating target for potential use in the second SNS target station has started as an LDRD project
- Design concepts are being developed for up to 3 MW operation with long pulses
- Neutronic evaluations are being done for such a target with two large coupled moderators above and below the target
- The LDRD is for 2 years and in the second year a mockup of the rotating seal and bearing system is to be tested

Preliminary Results

- Evaluations are being done at 3 MW and 20 hz for a tungsten/tantalum clad target 1 - 1.2 m in diameter and 70 - 80 mm thick
- Steady-state cooling does not appear to be a problem
- Moderator Neutronic performance is equal or better than for a mercury target
- Target lifetime for 10 dpa > 5 years
- Decay heat of ~35 kW probably requires a separate cooling loop in the hub region
- Bearings and seals can be located above the target and maintained separately
  - Much of the experience with the cantilever mercury pump is applicable to this design

Summary

- **Target Systems are maturing and achieving excellent availability**
- **Planning is in progress for the next phase of operations as targets and other components reach the end of service life**
  - **Major component spares are being procured and are expected to be available prior to anticipated need dates**
  - **Handling systems for activated components are being procured ahead anticipated need dates**