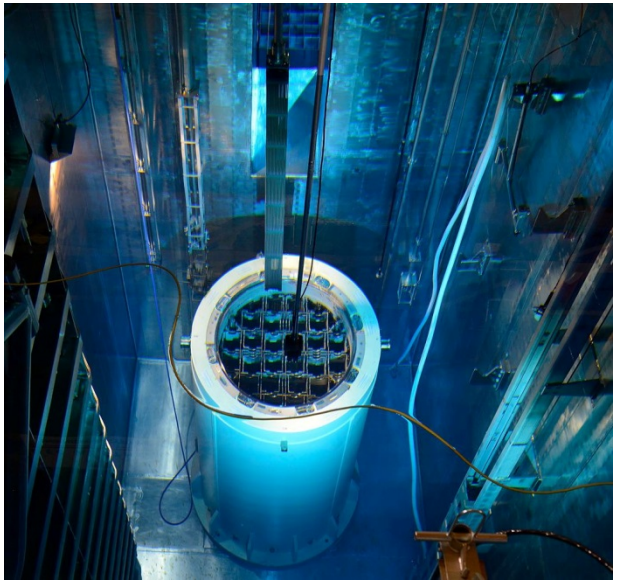
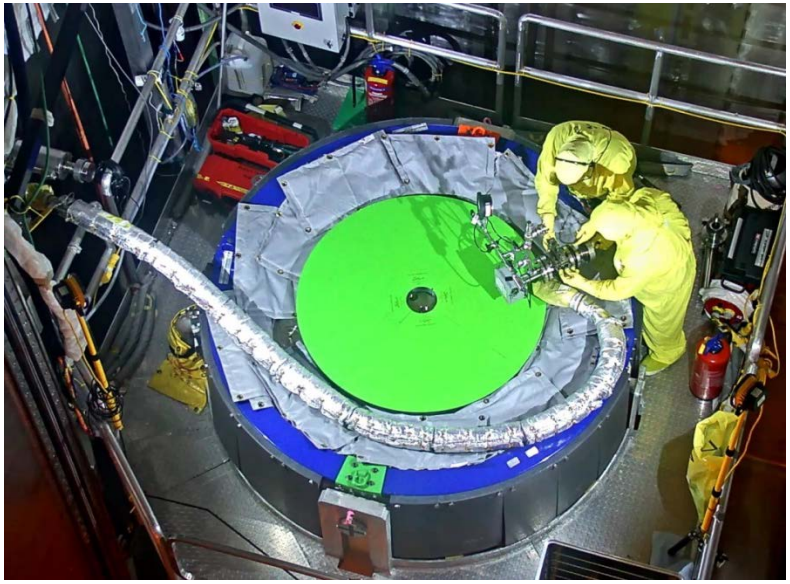




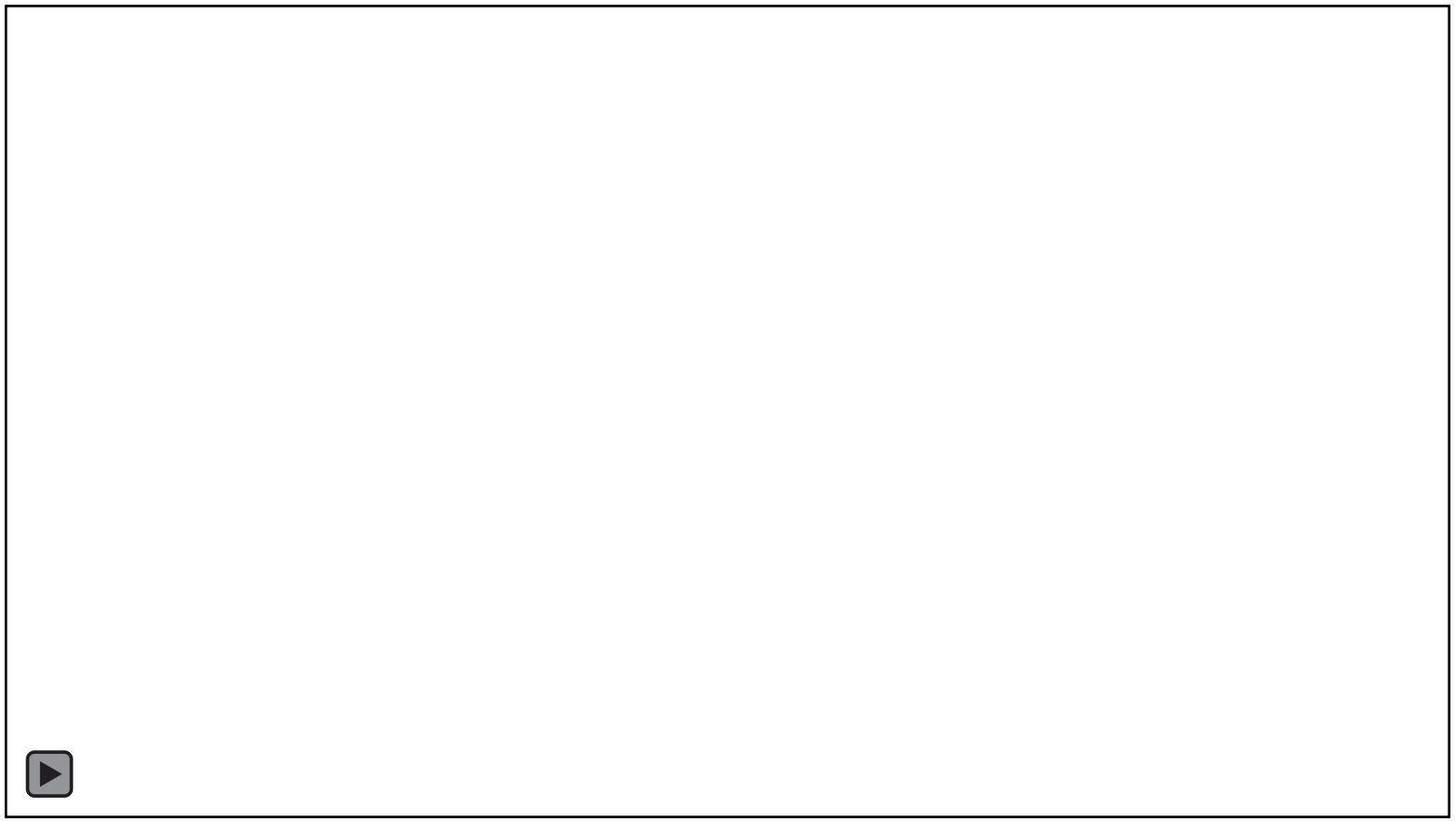
Operational Experience of the first Dry Fuel Storage Campaign at Sizewell B

Richard Parlone, Radiation Protection Adviser, richard.parlone@edf-energy.com



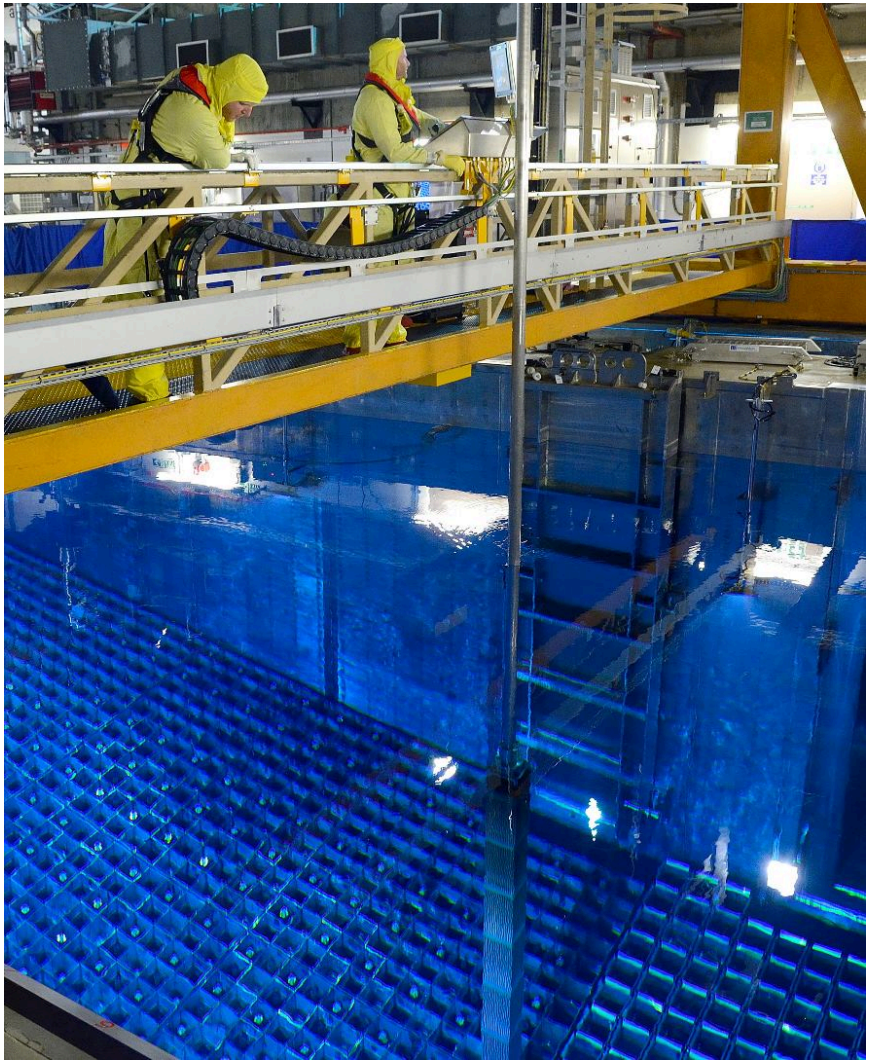

Sizewell B Power Station in the UK

- 1200 MW(e) 4 loop Westinghouse SNUPPS PWR, with UK modifications
- First criticality 14-FEB-1995



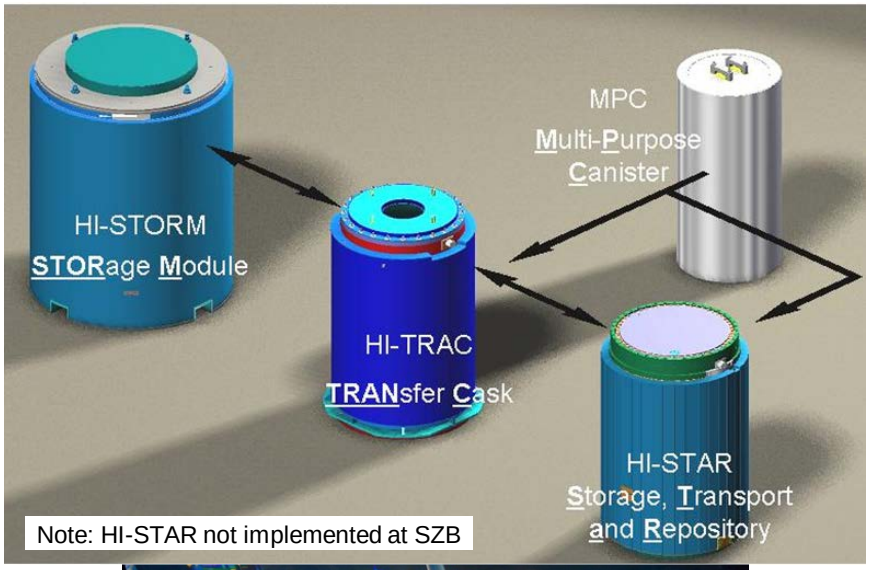
Sizewell B - why Dry Fuel Storage?

- Original design was ~40 years of Fuel Storage Pond storage (100% rack usage) then shipment offsite for reprocessing
- Safety case limited rack storage, with storage limit reached in 2017… & no reprocessing route
- Optioneering identified dry fuel storage in casks as ALARA & BAT
- Holtec selected as vendor

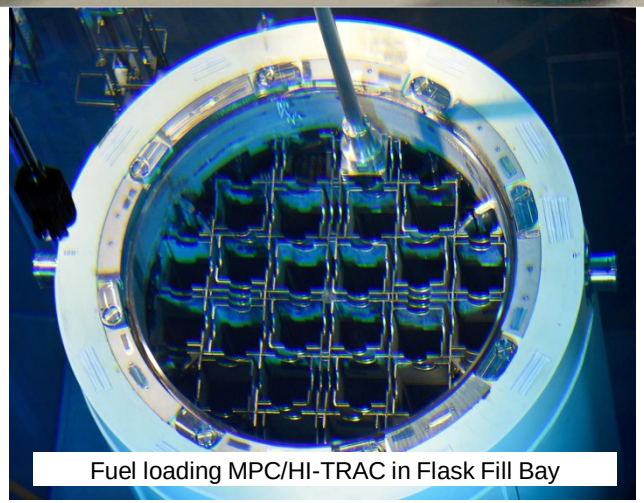


Holtec Dry Fuel Storage system at Sizewell B

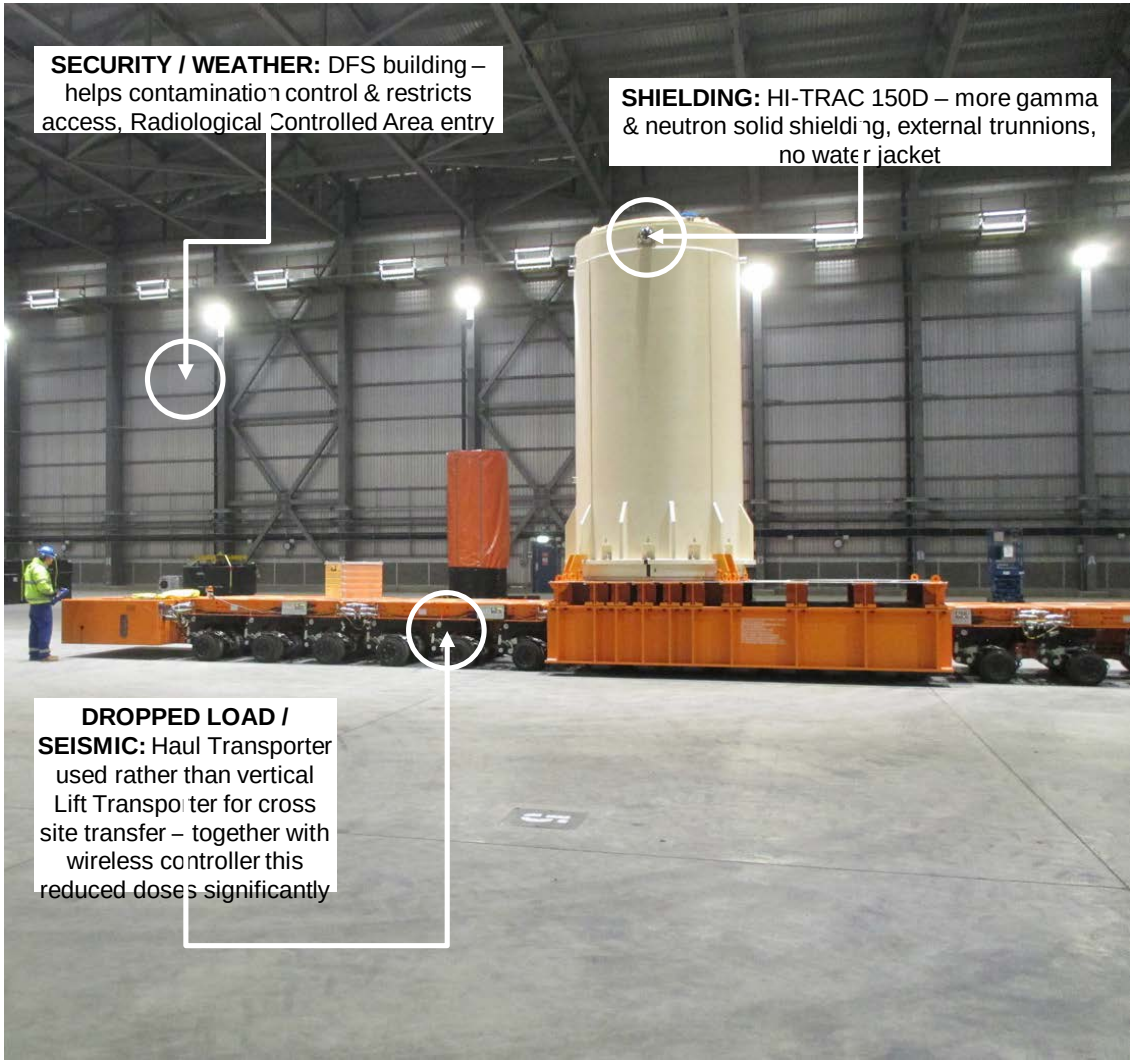
- Canister MPC 24DW:
  - Stainless steel dual walled
  - 24 PWR fuel assemblies
  - No ‘failed fuel’ (water sampling for Cs-137, gas sampling for Kr-85)
  - Dry helium pressurised to ~4 bar
  - Design life 100 years
  - Inspectable & retrievable
- HI-TRAC 150D transfer cask:
  - Neutron & gamma shielding
  - Not sealed, bolted top & bottom lids
- HI-STORM ‘MIC’ storage cask:
  - ‘Mega Impact Capable’
  - 210 tonne concrete, steel, Holtite, lead
  - Passive cooling via vents
  - Temperature monitoring system



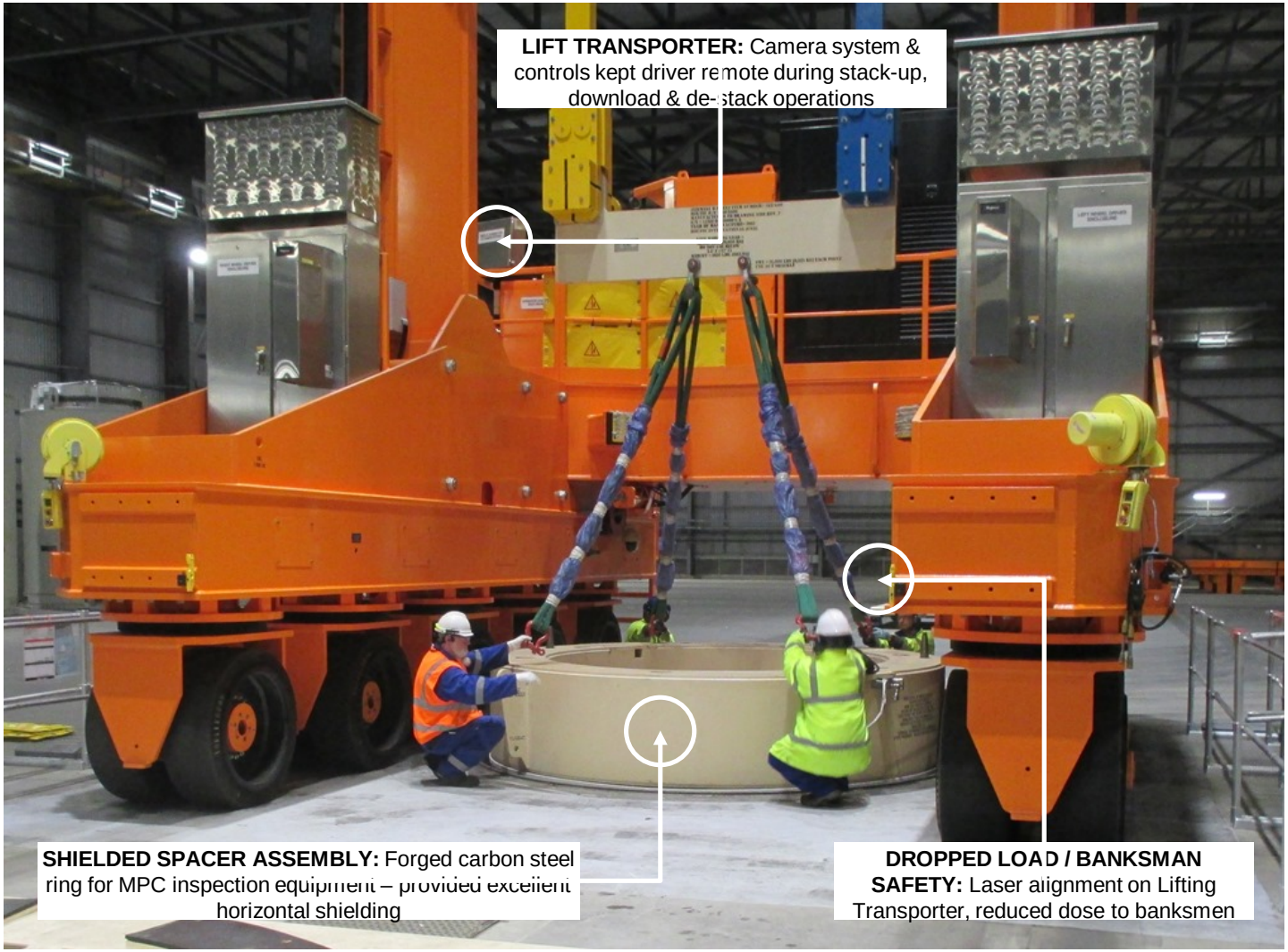
Note: HI-STAR not implemented at SZB


Fuel loading MPC/HI-TRAC in Flask Fill Bay

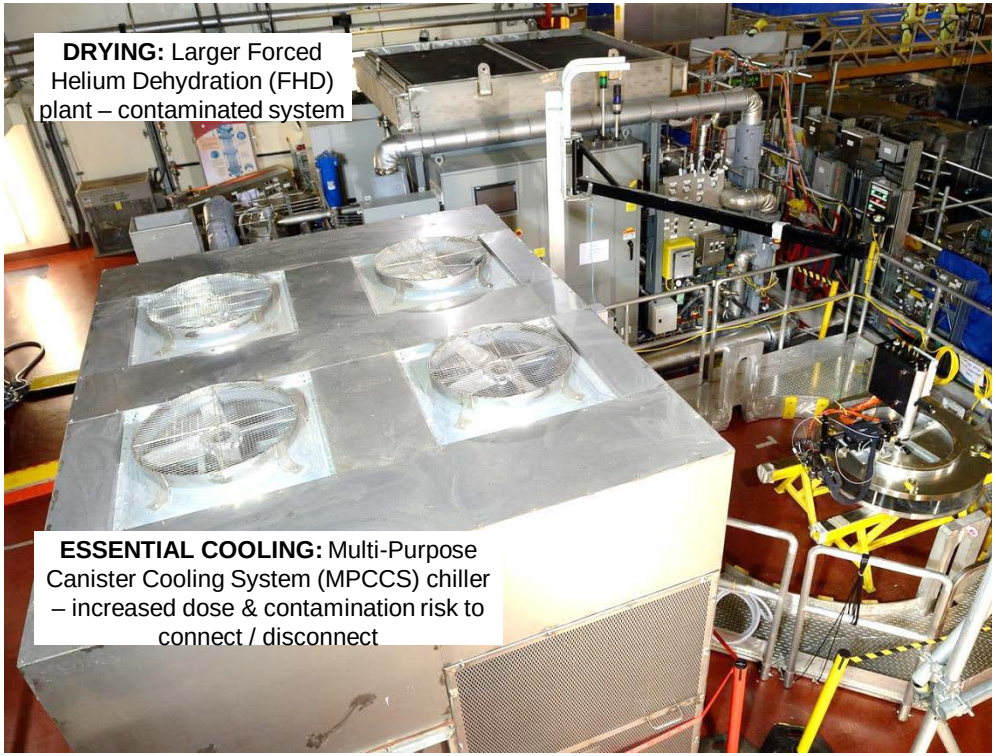
DFS Safety Case & Design – less dose & RP risk



DFS Safety Case & Design – less dose & RP risk

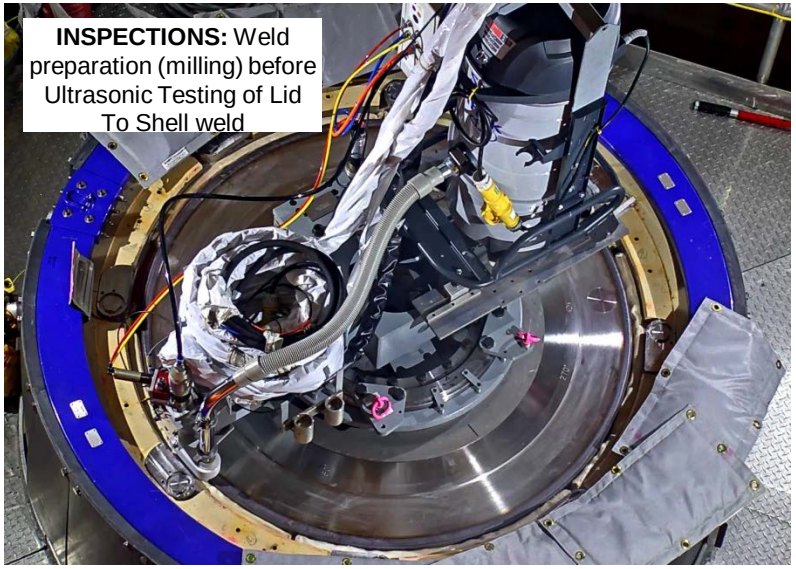


DFS Safety Case & Design – more dose & RP risk



DRYING: Larger Forced Helium Dehydration (FHD) plant – contaminated system

ESSENTIAL COOLING: Multi-Purpose Canister Cooling System (MPCCS) chiller – increased dose & contamination risk to connect / disconnect



INSPECTIONS: Weld preparation (milling) before Ultrasonic Testing of Lid To Shell weld

100 YEAR ASSURANCE: 'Spot facing' of vent & drain ports prior to helium leak test

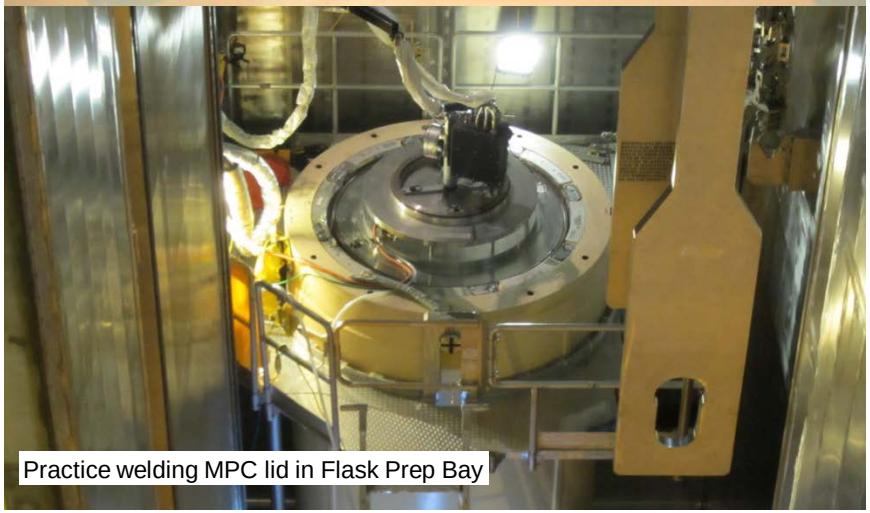
- UK modifications / extra safety case requirements:
  - Additional cooling system (MPCCS)
  - Lid To Shell weld - milling before ultrasonic testing
  - Milling of vent & drain ports to ensure zero port leakage
  - Work in Flask Preparation Bay (contamination area)
  - Strict sulphate limits on cask water to support 100 year storage

Operational RP preparatory work

- Benchmarking visit to Diablo Canyon NPP in August 2013
  - Lots of valuable operational experience, including potential dose rates, high risk evolutions, major contamination hazards
  - DCPP very kindly provided their Used Fuel Storage ALARA plan, RP surveys & RP instructions – these were excellent & greatly aided the SZB first campaign
- Q&A via networks (ISOE, PWR ALARA, Holtec User Group)
  - Excellent support, especially on shielding
- Review of IAEA & other documents:
  - SSG-15 (storage of fuel), TECDOC-1081 (decontamination)
- Inactive commissioning:
  - Practice steps e.g. MPC trunnion removal
  - Full set of lessons learned

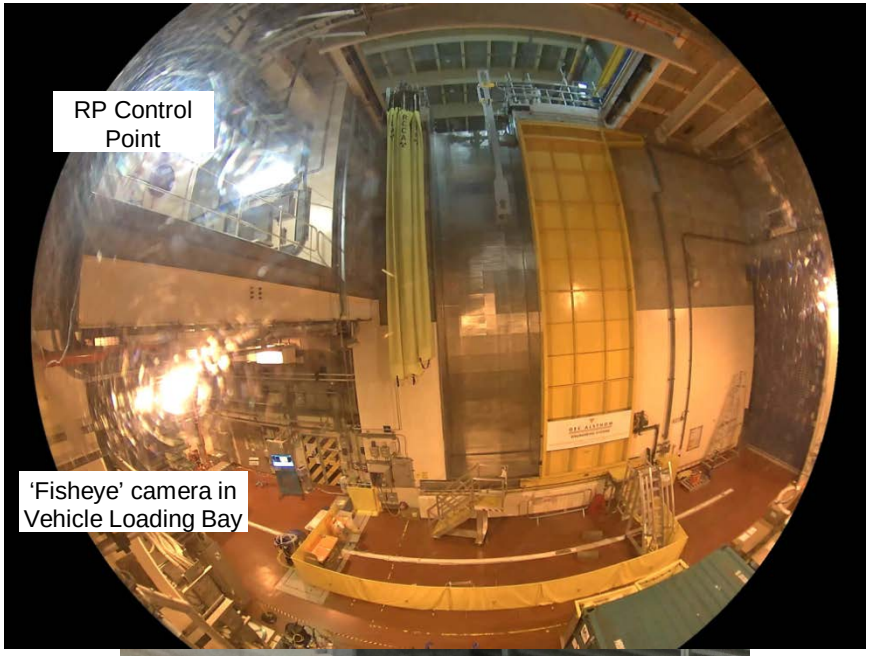
→ Pre-campaign ALARA report


Practice MPC trunnion fitting onto MPC lid


Practice welding MPC lid in Flask Prep Bay

Key pre-campaign ALARA report recommendations

- Design & purchase shielding for work platform & MPC lid:
  - Ideally pre-assemble in low dose rate area
  - Use feedback from USA
  - Must meet safety case requirements on heat, seismic, chemistry
- Use remote monitoring package (CCTV, teledosimetry, Telex comms):
  - Utilise refuelling outage experience
  - Purchase additional cameras
- Reduce decontamination doses:
  - Improve surface finish of HI-TRAC
  - Use simple method (hot water brush wash)
- Control significant beams during MPC stack-up, download & de-stack:
  - Shielding on pool lid, mobile racks
  - Shielding 'walkway' onto MPC lid
- Assess neutron spectra & doses



SZB DFS Campaign 1 targets

- Collective Radiation Exposure (CRE):
  - Original design target 2.5 man.mSv/cask, did not include all processes
  - ALARA report target 10 man.mSv (Cask 1) decreasing to 3.5 man.mSv (Cask 7)
- Maximum individual dose 2 mSv
- Personal Contamination Events target:
  - Target of zero regulator reportable PCE (>4 Bq/cm^2 at a RCA boundary, EPRI Level 2)
  - Target <10 non-reportable PCE (EPRI Level 1)
- Neutron monitoring:
  - Spectra fully assessed
  - Neutron dosimetry evaluated for performance & doses integrated into campaign reporting
- Shielding performance evaluated & placement optimised
- Cask programme 12 days per cask

Bonner Sphere neutron spec for Cask 1 in Flask Prep Bay

Shield Bell being lifted onto HI-TRAC

SZB DFS Campaign 1 RP performance

SIZEWELL B DRY FUEL STORAGE CAMPAIGN 1 - ALARA/ALARP PERFORMANCE

COMPLETE

Task	All Casks		Cask 1		Cask 2		Cask 3		Cask 4		Cask 5		Cask 6		Cask 7	
	SZB Best Ever		MPC 003		MPC 004		MPC 005		MPC 006		MPC 007		MPC 002		MPC 001	
			18 kW		18 kW		18 kW		18 kW		18 kW		18 kW		18 kW	
	mSv	mrem	mSv	mrem	mSv	mrem	mSv	mrem	mSv	mrem	mSv	mrem	mSv	mrem	mSv	mrem
Cask Target	**3.5**	**350**	**10.0**	**1000**	**8.0**	**800**	**6.5**	**650**	**5.5**	**550**	**4.5**	**450**	**4.0**	**400**	**3.5**	**350**
161 Fuel Cask Preparation & Loading	0.030	3	0.114	11	0.138	14	0.156	16	0.057	6	0.043	4	0.052	5	0.030	3
162 Fuel Cask Loaded Operations	0.364	36	1.172	117	0.998	100	0.505	51	0.811	81	0.529	53	0.364	36	0.394	39
163 Fuel Cask Welding/ISI/Drying	0.850	85	2.192	219	1.265	127	1.407	141	0.910	91	0.986	99	1.062	106	0.850	85
164 Fuel Cask Cross Site Transfer	0.007	1	0.058	6	0.020	2	0.018	2	0.014	1	0.013	1	0.007	1	0.014	1
167 Fuel Cask RP & Decon	0.295	30	1.188	119	0.715	72	0.606	61	0.640	64	0.479	48	0.435	44	0.295	30
168 Fuel Cask MPC Download Ops	0.106	11	0.216	22	0.204	20	0.243	24	0.169	17	0.143	14	0.106	11	0.166	17
169 Dry Fuel Store General	0.000	0	0.000	0	0.007	1	0.001	0	0.004	0	0.007	1	0.000	0	0.001	0
7000 Neutron Dose Cask Water Filled	0.002	0	0.118	12	0.009	1	0.011	1	0.028	3	0.027	3	0.021	2	0.002	0
7001 Neutron Dose Cask Water Drained	0.588	59	1.464	146	0.779	78	0.783	78	0.715	72	0.653	65	0.685	69	0.588	59
TOTAL DOSE	**2.242**	**224**	**6.522**	**652**	**4.135**	**414**	**3.730**	**373**	**3.348**	**335**	**2.880**	**288**	**2.732**	**273**	**2.340**	**234**

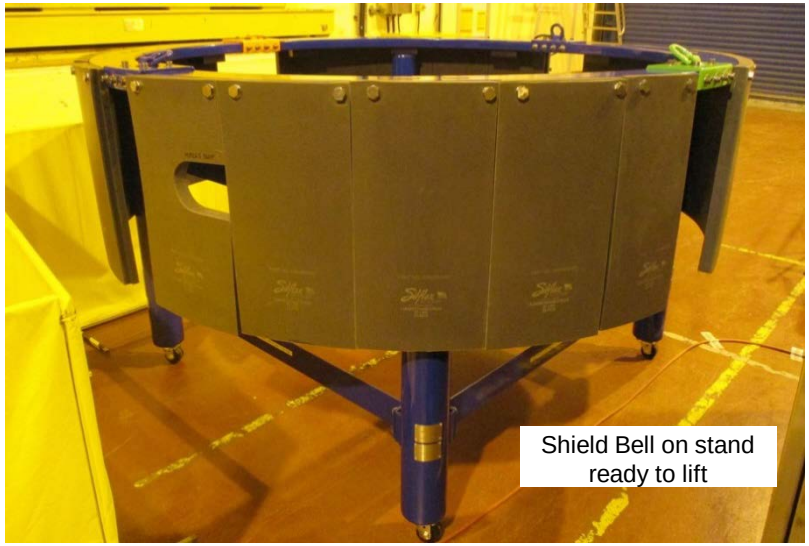
PCE	
11	EPRI Level 1
2	EPRI Level 2

Maximum Individual Doses (mSv, x100 to get mrem) (gamma & neutron)

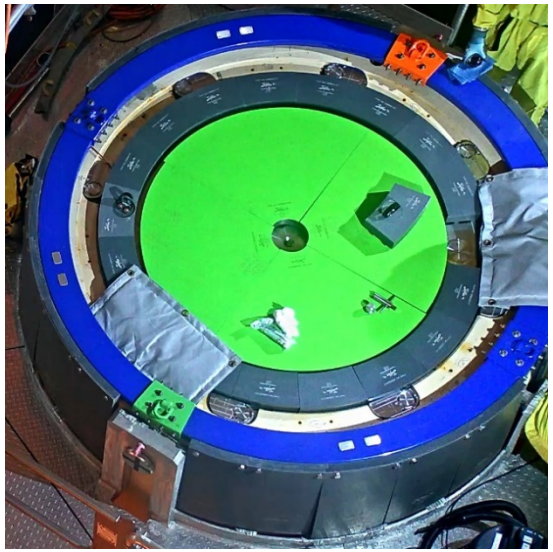
	PCI Welding & PT			Holtec Cask Team			Machining & UT ISI			Rigging & Banksmen			RP & Decon		
		mSv	mrem		mSv	mrem		mSv	mrem		mSv	mrem		mSv	mrem
1	Welder	1.941	194	Cask Tech	1.017	102	UT ISI	0.588	59	Rigger	0.426	43	Decon	0.669	67
2	Welder	1.817	182	Cask Tech	0.964	96	Machinist	0.515	52	Rigger	0.360	36	Decon	0.541	54
3	PT ISI	0.96	96	Cask Tech	0.961	96							RP Tech	0.505	51
4	PT ISI	0.739	74	Cask Tech	0.935	94									
5				Cask Tech	0.714	71									

Operational RP experience – shielding (1)

- ‘Shield Bell’ work platform shielding:
  - Tungsten/neutron Silflex™ blankets
  - Assembled in low dose area (1 hour)
  - Lifted onto HI-TRAC (10 minutes)
  - Minimal impact when MPC is water filled
  - 10-30% reduction in neutron dose rates & >50% reduction in gamma dose rates when MPC is helium filled
- MPC lid & annulus shielding:
  - Neutron centre sections, tungsten neutron outer sections, plus lead blankets
  - Annulus ‘snake’ shielding (Braidwood design) used as well from Cask 4 onwards
  - Significant gamma & neutron dose rate reduction e.g. annulus 10 mSv/h max in contact unshielded to ~1 mSv/h fully shielded
  - Detailed choreography required – this was recorded in ‘checklists’ with photographs taken of each stage



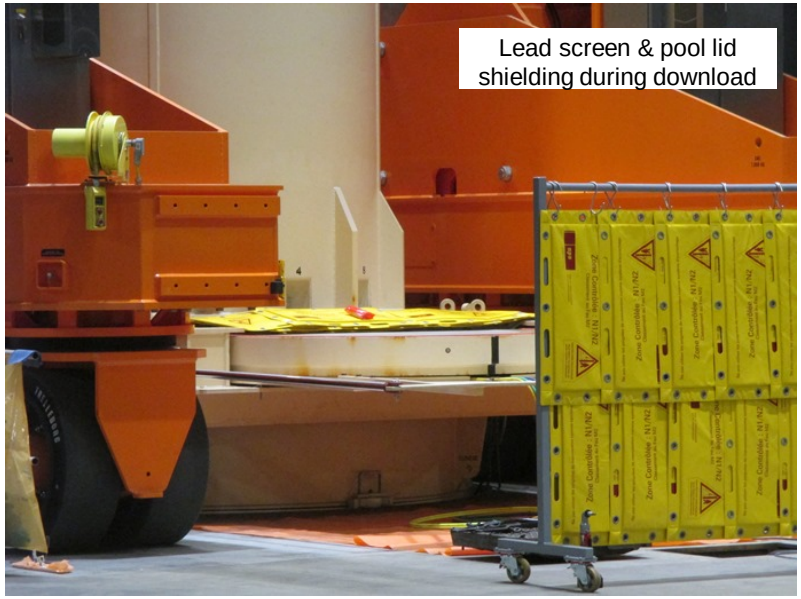
Shield Bell on stand ready to lift



Shield Bell on HI-TRAC, MPC lid shielding in place, annulus shielding ‘snakes’ underneath

Operational RP experience – shielding (2)

- Highly collimated gamma beam mitigated during MPC download:
  - Estimated 100 mSv/h (10 R/h) beam through mating device drawer
  - Double layer lead blankets added to pool lid
  - Double layer lead blankets on screen, reducing dose rate to 0.01 mSv/h
  - Measured using EPDs in teleadapters
- MPC trunnion block removal:
  - Man-entry onto 80°C lid
  - 60 to 180 mSv/h annulus in contact
  - 0.5 mSv/h at 0.5m above shielding 'walkway'
  - Even lower doses when operator kneeled or crouched on blankets
  - Blankets removed by ropes
- Shielding also put on Lift Transporter handrails to reduce doses to driver

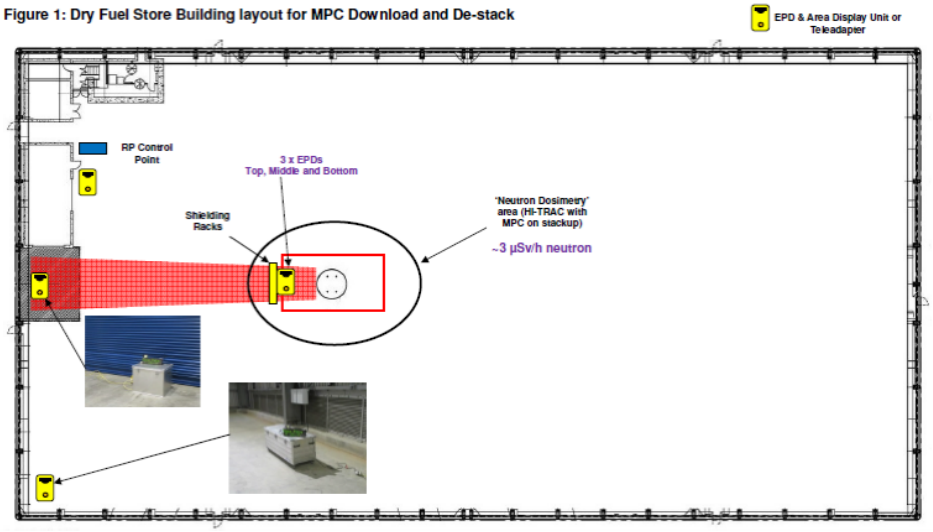


Operational RP experience – procedures

- Plant Operating Instructions (POI) for cask loading & processing were evolved during the campaign with RP notes & hold points
- RP checklists also updated with more feedback, dose rates, photos, OE – often by the RP technicians

NOT PROTECTIVELY MARKED	SIZEWELL B POWER STATION HEALTH PHYSICS CHECKLIST	No: DF05 Rev: 003 Page: 14 of 16

Figure 1: Dry Fuel Store Building layout for MPC Download and De-stack

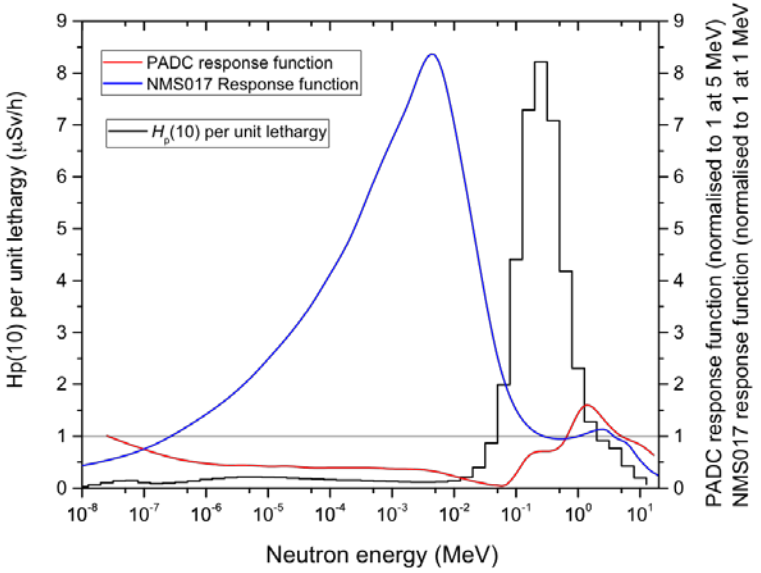


NOT PROTECTIVELY MARKED	SIZEWELL B POWER STATION HEALTH PHYSICS CHECKLIST	No: DF05 Rev: 004 Page: 8 of 16

Step	Task	Initial when complete	Notes
	update the Controlled Area log (BLR 8012). 		Autolog Cask 2 MPC download
3.3	**WARNING!** MPC download is a very high dose rate task and takes approximately 25 minutes. Liaise with the cask supervisor to restrict non-essential personnel in the work area. Ideally personnel should remain in the entrance lobby during download. Critical manning is: • LT driver (in teledosimetry and generally in a neutron and gamma field of <0.01 mSv/h) • Remote Ops camera support (control desk to the east of the LT in ~0.25 mSv/h n+g, but operative can retreat to a low dose rate area) • Cask supervisor (remains at RP control point) • Teledosimetry operator (on cask team comms) • RP technician available either in DFSB foyer or at RP Control Point. • RP supervisor either in DFSB foyer or at RP control point. • Other personnel as justified by the cask supervisor and OCC health physicist.		OPEX Cask 2: EPD on east side of lead screen ~0.2 mSv/h, but no greater than 1 µSv/h observed at West Roller Shutter door, or 3 µSv/h at the building internal periphery OPEX Cask 4: Dose at roller shutter door is 0.005mSv/hr. Further monitoring required during Cask 5. RP Technician ideally on cask team comms, performing site surveys and placing additional shielding on lead wall where required.
3.4	During the download, perform a perimeter survey and use the teledosimetry and area gamma EPDs to verify dose rates are acceptable. Record results on SZB/TH/F570. **CAUTION:** if dose rates are likely to exceed a Radiation Controlled Area R2 (>3 µSv/h) on the roadway outside the DFSB, then add more lead blankets to the screen.		OPEX Cask 1: RP Control Point area reached ~6 µSv/h, but West roller shutter door was ~3 µSv/h.
3.5	Once the MPC is safely downloaded into the HI-STORM, radiation dose rates will drop to low levels around the		

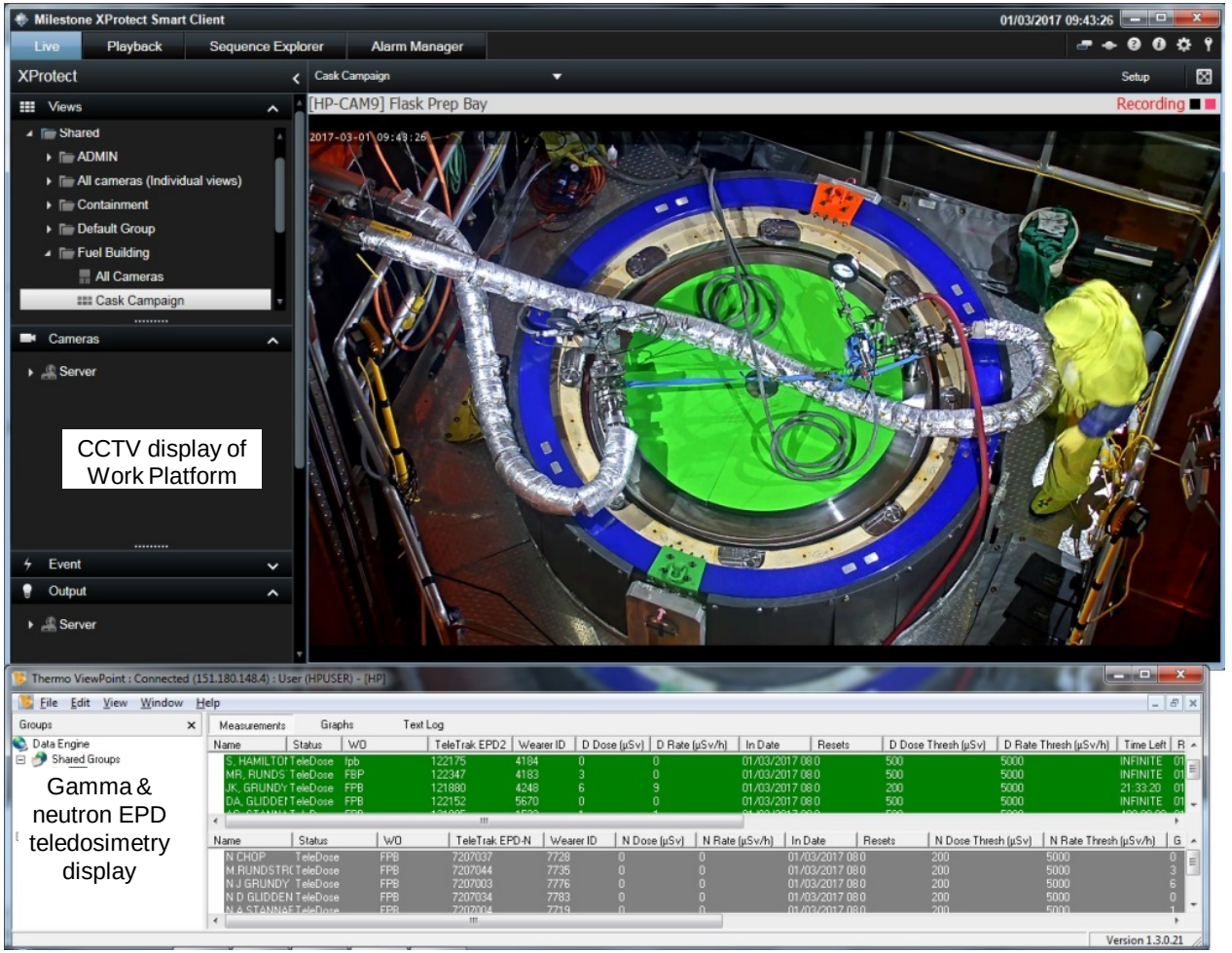
Operational RP experience – neutron monitoring

- Neutron spectrometry for Cask 1:
  - Spectra was quite hard (0.1 to 1 MeV)
  - Poly-allyl diglycol carbonate (PADC / CR39) passive badge was effective with a correction factor of 2 (worn for 3 months, minimum dose 0.2 mSv or 20 mR)
  - Validated selection of 'John Caunt' NMS017 neutron monitor & EPD-N2 dosimeter
- EPD-N2 worked very well:
  - Instant neutron dose readout for every visit into neutron posted areas plus neutron alarms
  - Worn along with gamma EPD as teledosimeters
  - Good agreement between gamma EPD+PADC & EPD-N2 when worn in 'uniform' field
  - Neutron doses were 20% of total dose
- Campaign CRE reported to management, workers & regulator used the EPD-N2:
  - 25.7 man.mSv vs 21.4 man.mSv 'legal' dose
  - Desire to move to 'one dosimeter', EPD-N2



Other operational RP experience

- Pre-rinsing HI-TRAC significantly aided decon, hot water wash worked well
- Large TV display in low dose area showed camera feed & doses
- RP techs helped update ‘checklists’ (detailed instructions, photos & survey results)
- Area display units linked to teledosimetry used during download
- Dose tables, ownership & competition – very positive (e.g. Cask Techs, PT team)



Post-campaign ALARA report summary

- ✓ Dose performance improved across the campaign, with positive ownership & challenge across different work groups:
  - ✓ Whole campaign delivered for 60% of CRE estimate
  - ✓ All casks delivered below ALARA report dose estimates
  - ✓ Casks 4 to 7 delivered below stretch goal of 3.5 man.Sv
  - ✓ Cask 7 delivered below original design target of 2.5 man.mSv
- ✓ Providing a clear dose summary to teams encouraged competitive 'buy in'
- ✓ Standard 'refuelling outage' RP tools & structure worked well
- ✓ Shielding, teledosimetry, neutron EPDs, cameras etc all effective

- ☒ PCE performance could be improved; mostly human performance errors
- ☒ Some enhancements were not implemented for the first campaign & these would have saved further dose & reduced contamination risk:
  - ☒ High quality 'glossy' paint finish for HI-TRAC
  - ☒ 'Cable bridge' in the Fuel Building for better cable management