The Journey of Continuous Improvement in the Reliability and Availability of the OPAL Reactor

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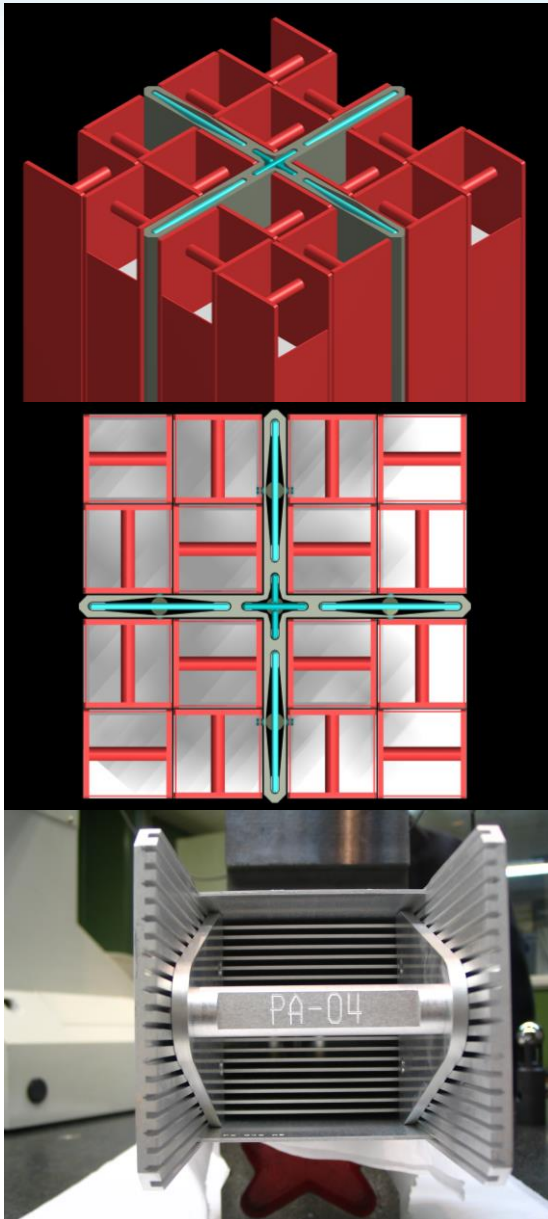
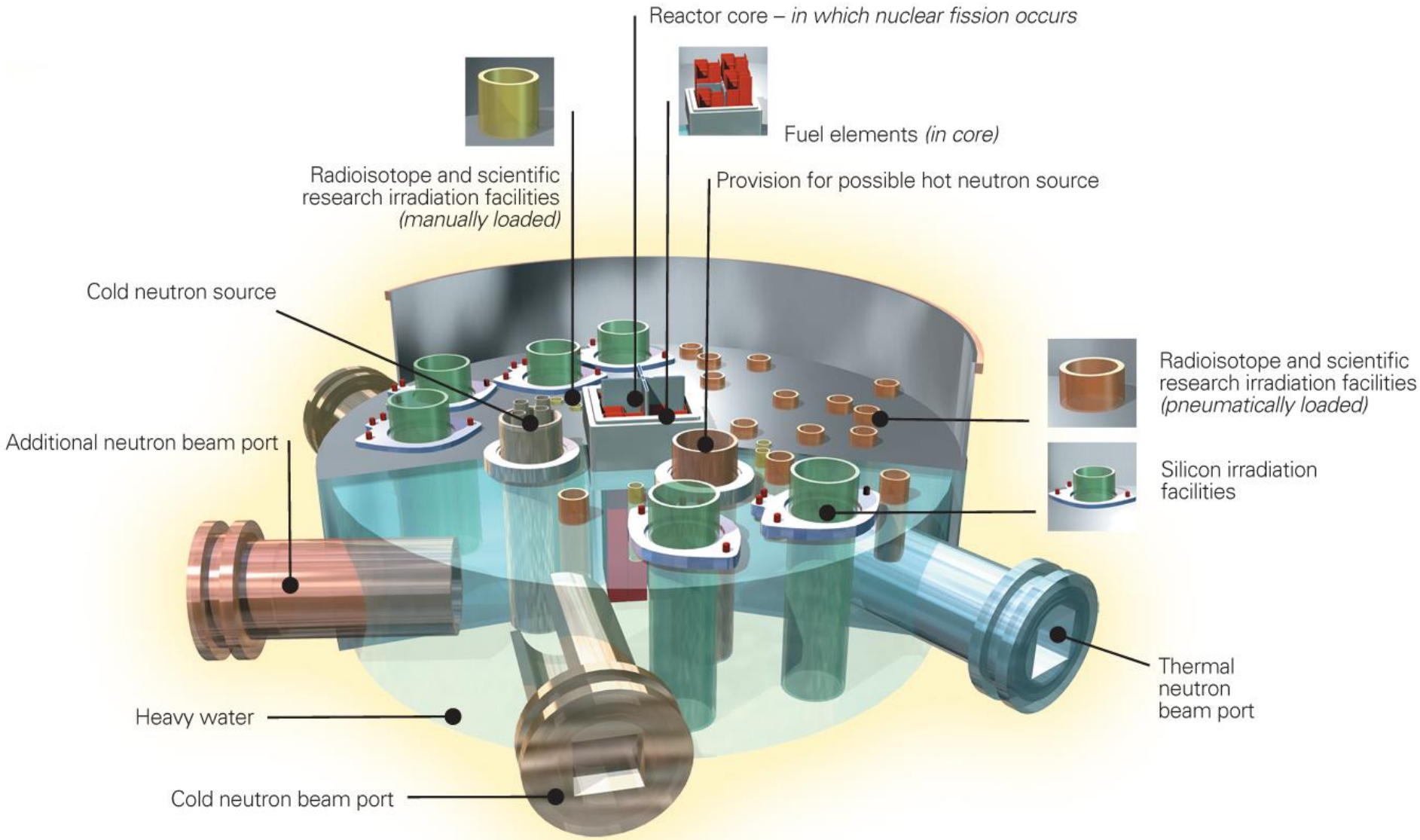
IGORR 18 – Sydney, Australia

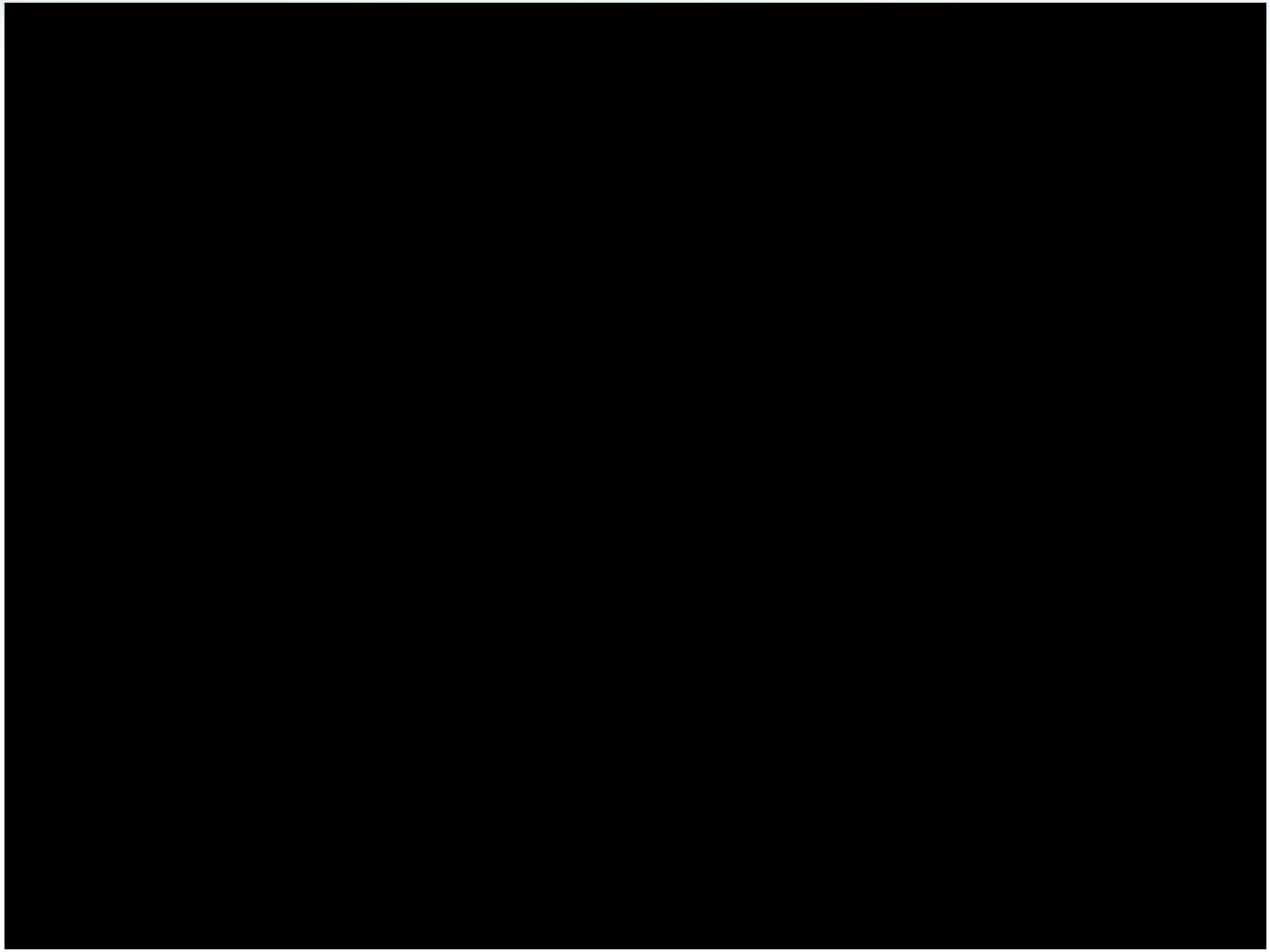
OPAL Reactor

- 20MW Thermal Multi-Purpose Reactor Facility
- 16 LEU FAs
- Compact Core (~300kW/L)
- D_2O Reflector
- Light Water Cooled and Moderated
- 2 x Independent and Diverse Protection and Shutdown Systems
- Inherent Passive Safety Systems
- >5000 I/O Control and Monitoring System

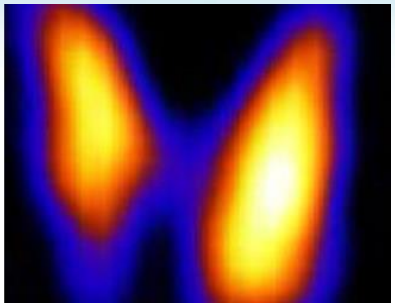


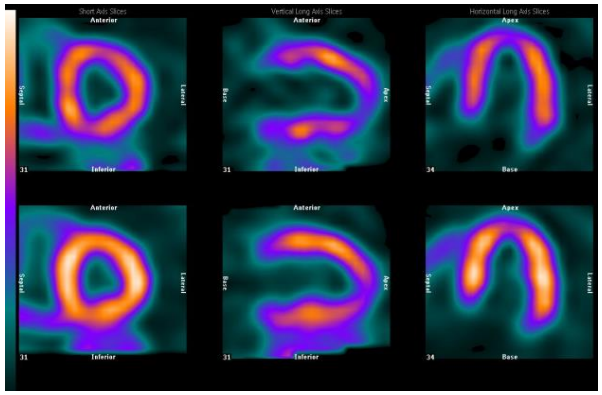

Reactor core – *in which nuclear fission occurs*
Fuel elements *(in core)*
Radioisotope and scientific research irradiation facilities *(manually loaded)*
Provision for possible hot neutron source
Cold neutron source
Radioisotope and scientific research irradiation facilities *(pneumatically loaded)*
Additional neutron beam port
Silicon irradiation facilities
Thermal neutron beam port
Heavy water
Cold neutron beam port

OPAL Reactor

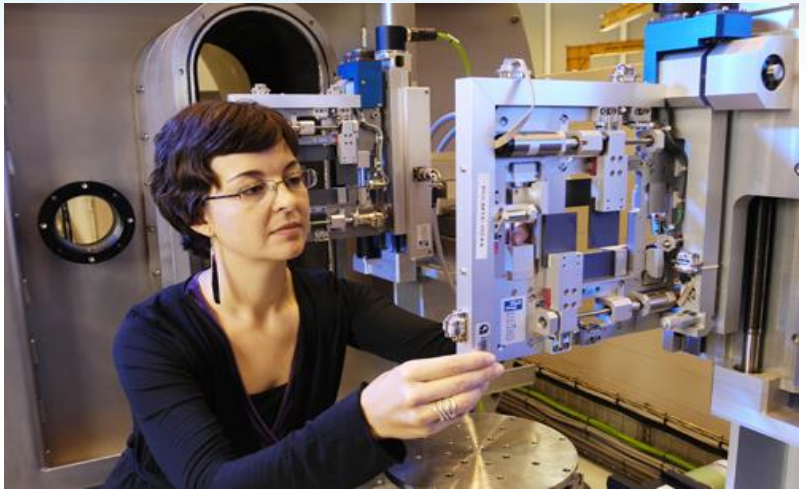


OPAL Utilisation

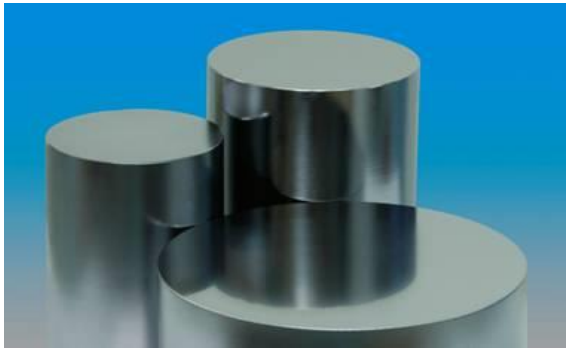




Neutrons for Health



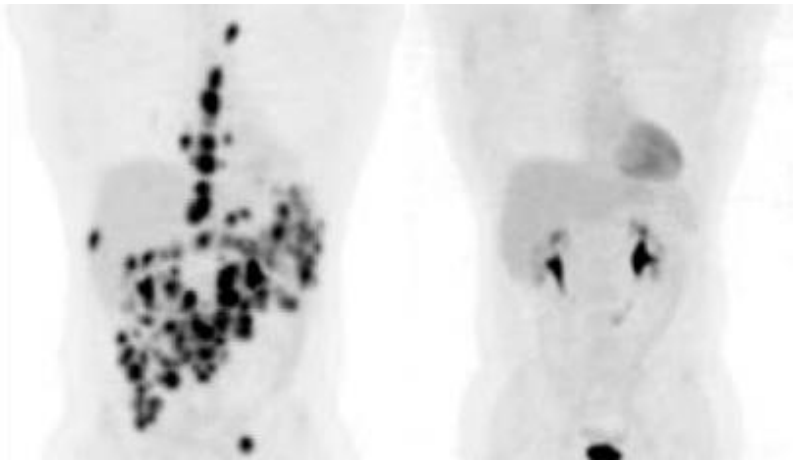
Neutrons for Science

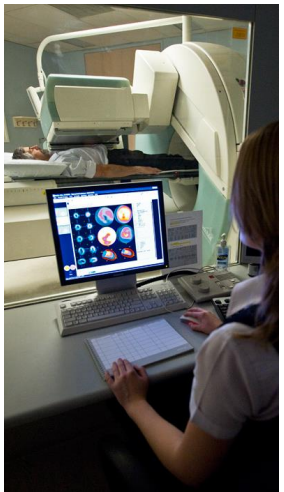


Neutrons for Industry

Reactor Based Health Products

Product	Indication
Mo-99	Bulk export
Gentech /Tc-99m	Organ imaging of the liver, lung, bone, kidney & heart
Sodium Iodide I-131	Hyperthyroidism & Thyroid cancer
Quadramet Sm-153	The relief of bone pain in patients with painful osteoblastic skeletal metastases
Chromium Cr-51	The determination of GFR rate
Lutetium-177	Diagnosis and treatment of Neuroendocrine. Tumors

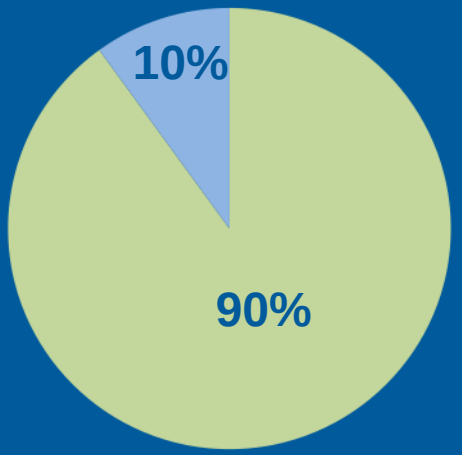




Neutrons – For Health

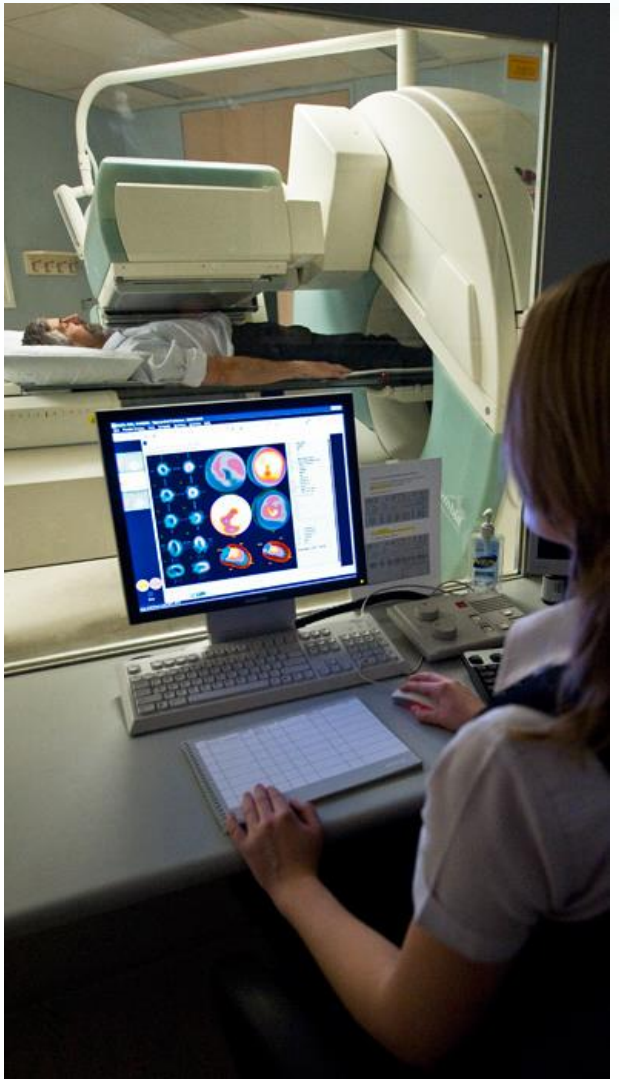
10,000 hospitals in the world use radioisotopes

40 million patients per year



Diagnostics (cardiology, oncology, neurology)

Therapy / palliative care



OPAL

Irradiated LEU Targets

ANM Mo-99 Facility

ANM ILLW Transfer

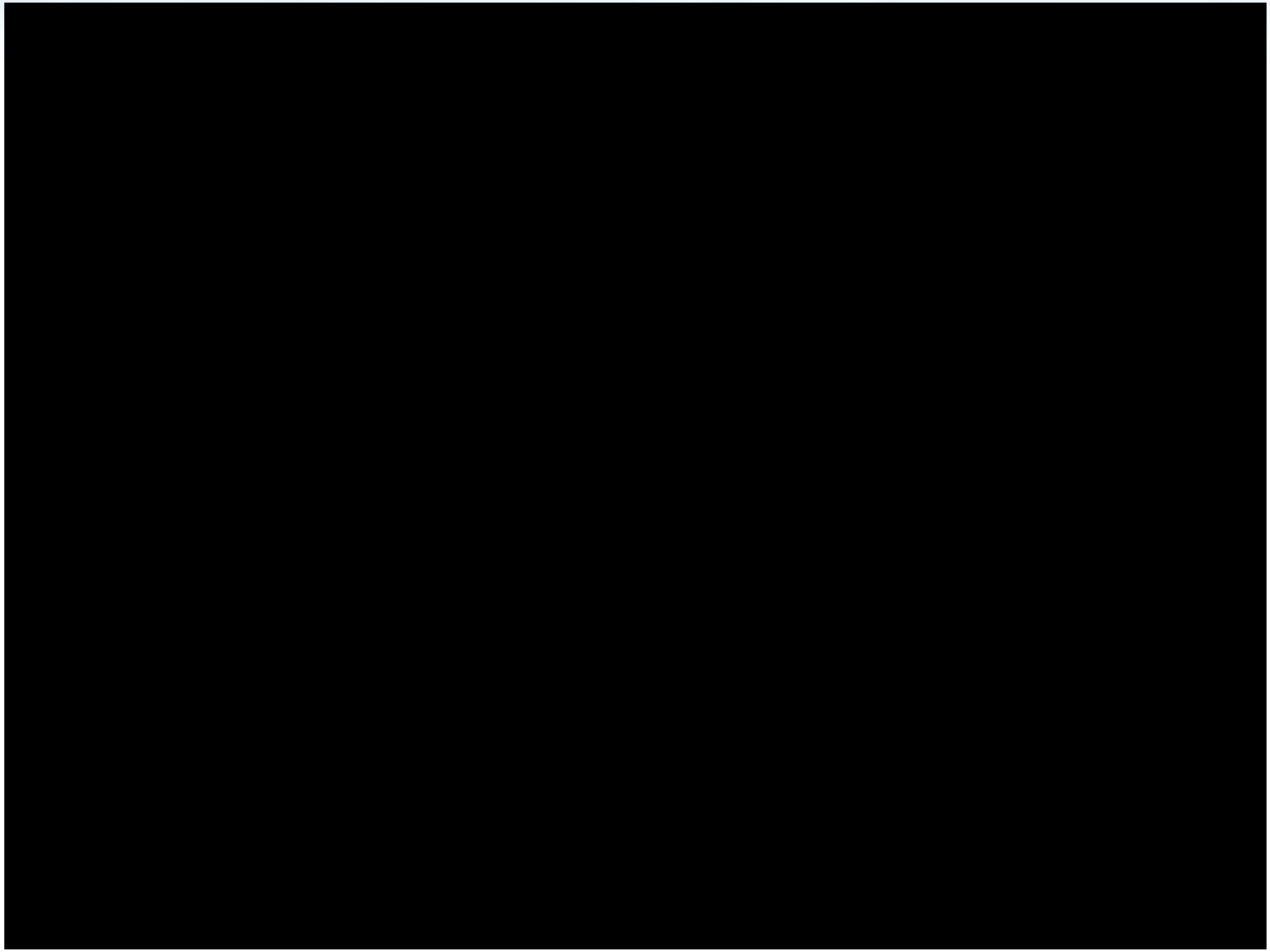
Synroc Waste Plant

Supply Chain

OPAL Reactor	Processing Plant (ANM)	Global distribution	Local distribution of finished goods	Hospital and Pharmacy	Clinical Imaging	Health Outcomes
LEU U^{235} targets irradiated in OPAL	Mo-99 separated and purified	Bulk Mo-99 Shipped to meet global demand	Tc-99m Generators dispensed and transported	Tc-99m eluted and combined with cold kits	Product administered to patients for imaging	Imaging helps diagnosis & leads to appropriate treatments
7-12 days	1 day	1 day	1 day	5 minutes	-	-

Challenging supply chain

Neutrons for Science



Neutron Beam Instruments at OPAL

Wombat
(Hi-Intensity Powder Diffractometer)

Kowari
(Residual Stress / Strain Scanner)

Platypus
(Neutron Reflectometer)

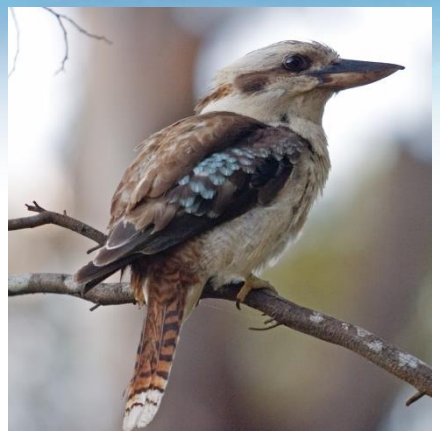
Quokka
(SANS)

Echidna
(Hi-Resolution Powder Diffractometer)

Koala
(Single Crystal Laue Diffractomter)

Taipan
(Thermal Triple Axis Spectrometer)

Neutron Beam Instruments at OPAL



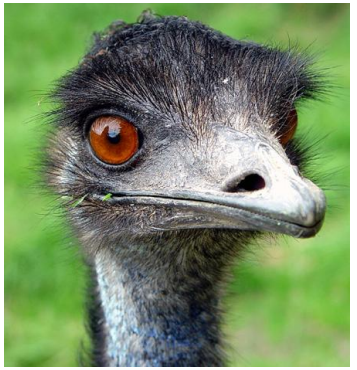
Kookaburra
(Ultra Small Angle Neutron Scattering)

Sika
(Cold Triple Axis Spectrometer)

Pelican
(Time of Flight Polarised Spectrometer)

Bilby
(SANS)

Dingo
(Neutron Radiography)



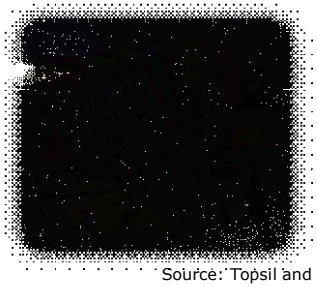
Emu
(Backscattering)

Neutrons – For Industry

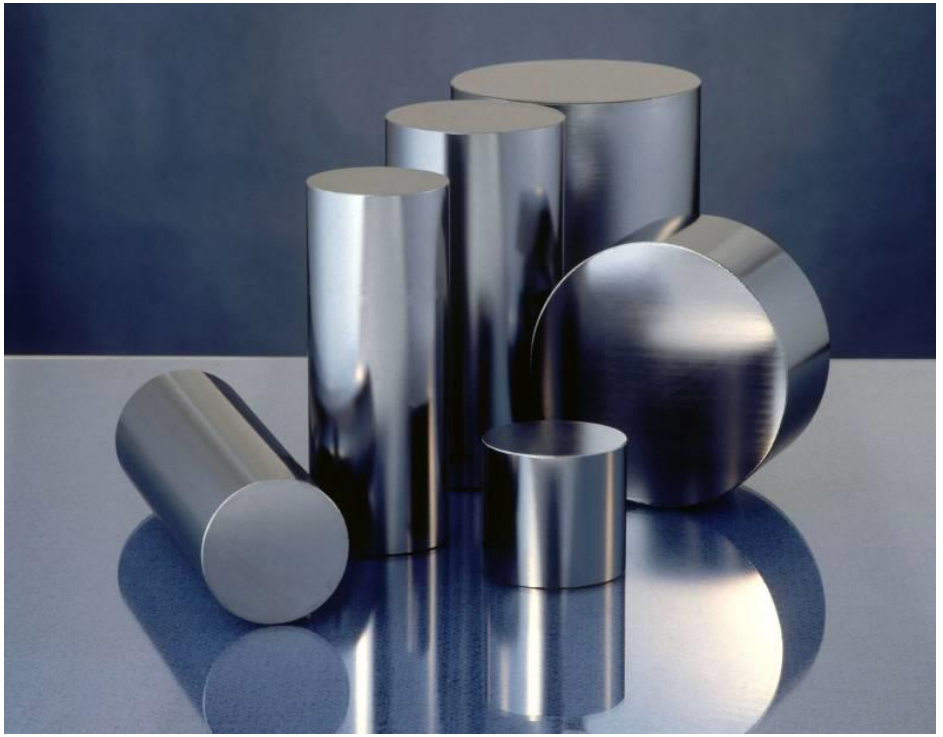
NTD - Silicon

- High and very high voltage markets
- Low volume specialty products

- High and medium voltage markets
- Medium volume specialty products



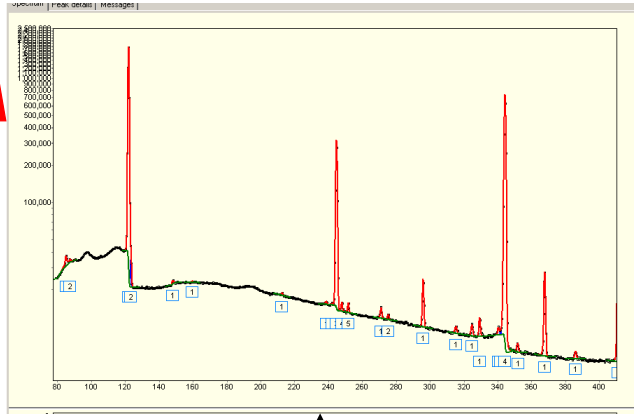
Source: Yole Development

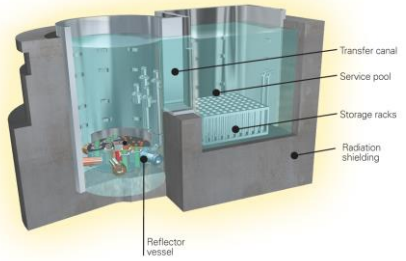


Neutrons for Industry
Neutron Activation Analysis

concentration

energy → element identification





ANSTO Corporate Plan

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ANSTO's vision

To deliver excellence in insight and innovation and create value through our people, partnerships, nuclear expertise and landmark infrastructure for the benefit of Australia and the world

Putting people first

Equipping and empowering our people to respond to the growing nuclear science and technology needs of Australia and the world

Organisational renewal

Support an engaged, flexible, agile inclusive and empowered workforce, with a focus on diversity and gender equity initiatives

Safety and security culture

Strengthen our commitment to provide a safe, secure and healthy workplace

Growth and development

Support the learning and development objectives of our people to allow them to reach their full potential

Agility

Equip and empower our people to work effectively in diverse environments and across boundaries – locally, regionally and internationally, and with industry, government, researchers and academia

World class science and technology outcomes

Create innovative solutions to complex problems and provide new insights into our world

Aligned research

Engage in impactful research that develops intellectual property and delivers commercial opportunities, with a focus on human health, the environment and the nuclear fuel cycle

Partnerships and collaboration

Establish strategic partnerships and collaborations to leverage effective research and innovation outcomes for Australia

Build human capital

Promote Science, Technology, Engineering and Mathematics (STEM) careers in Australia and develop the next generation of nuclear scientists and engineers

Strategic management of landmark and national infrastructure

Realise opportunities, serve users and create value

Meet user requirements for quality and reliability

Provide excellent service to our user base and engage them in future planning

Operational excellence

Provide best-practice resource utilisation, reliable data outputs and continual improvement

Asset management and expansion

Invest in the life cycle and renewal of landmark and national infrastructure platforms to serve the needs of users, collaborators and partners

Nuclear expertise and advice

Provide expert advice and services to support Australia's nuclear policy and strengthen Australia's nuclear knowledge base

Trusted advice

Support government in protecting the national interest through the provision of specialised nuclear advice and support

International engagement and leadership

Engage with key international nuclear organisations and contribute to global and regional nuclear discussions to implement Australian Government policy and ensure Australia remains a nuclear science and technology leader

Nuclear education

Provide resources that meet the needs of the secondary and tertiary educators and demonstrate the benefits of nuclear science and technology

Engage and inform

Provide timely, relevant and accessible information for multiple stakeholders and audiences to enhance public knowledge of ANSTO's work

Nuclear business and innovation

Provide services and products to our customers that benefit the broader community

Responsive service

Operate our businesses to effectively serve our clients and the community

Translate research

Leverage and translate research outcomes into new products and services

Realise new opportunities

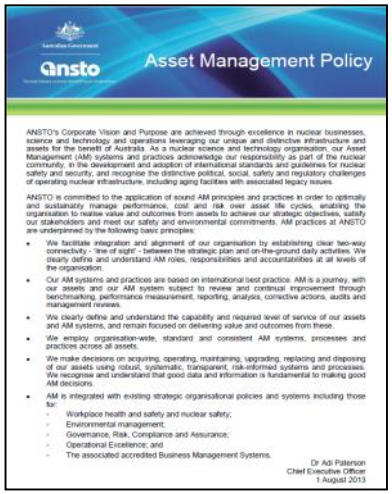
Serve new markets, create opportunities and introduce new products and services for the benefit of Australian people and industry

Investment in Asset
ANSTO Asset Management System

ANSTO Corporate Plan

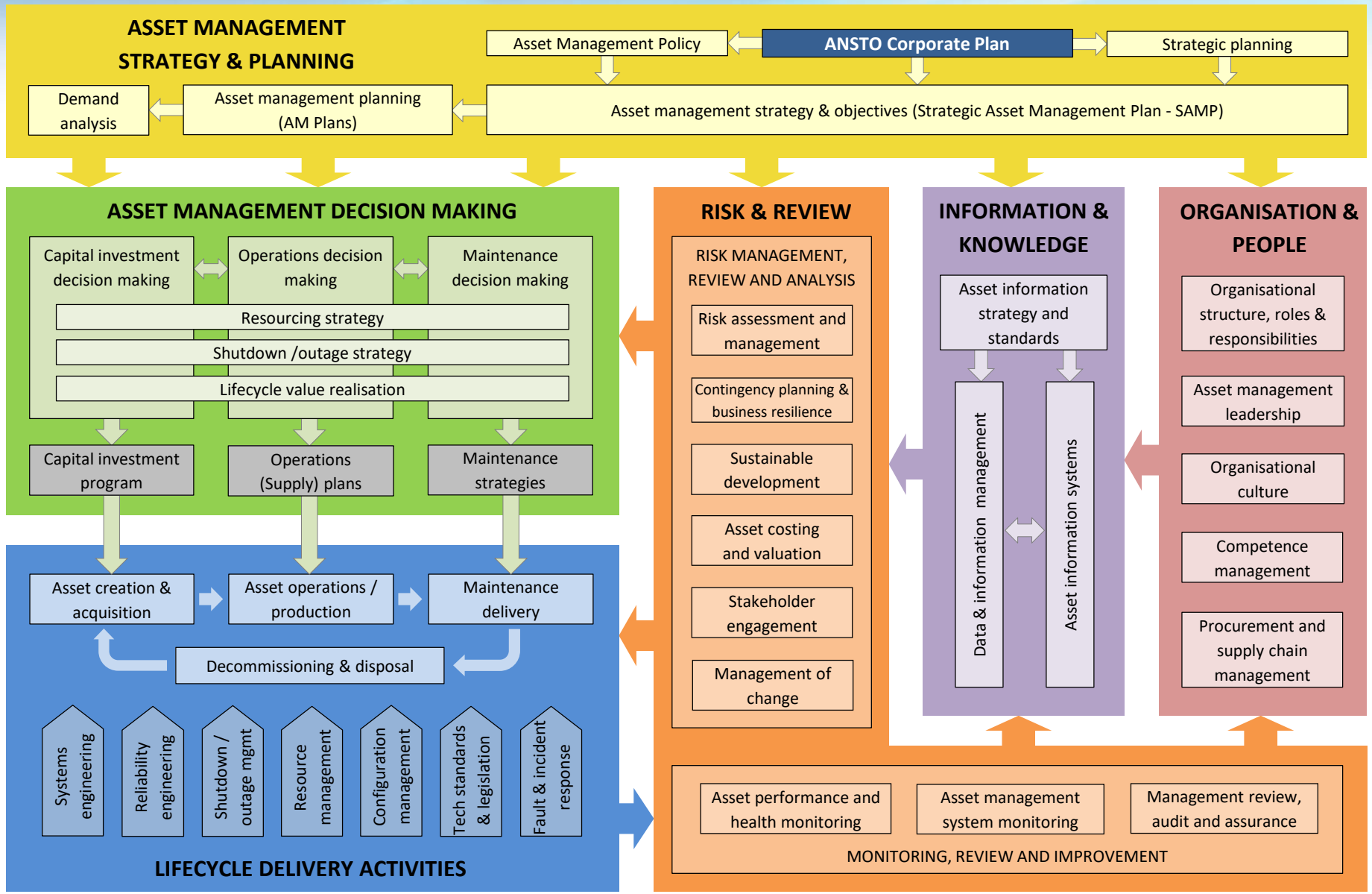
“Enabling ANSTO to realise best value and outcomes from assets to achieve strategic objectives”

Asset Management Policy

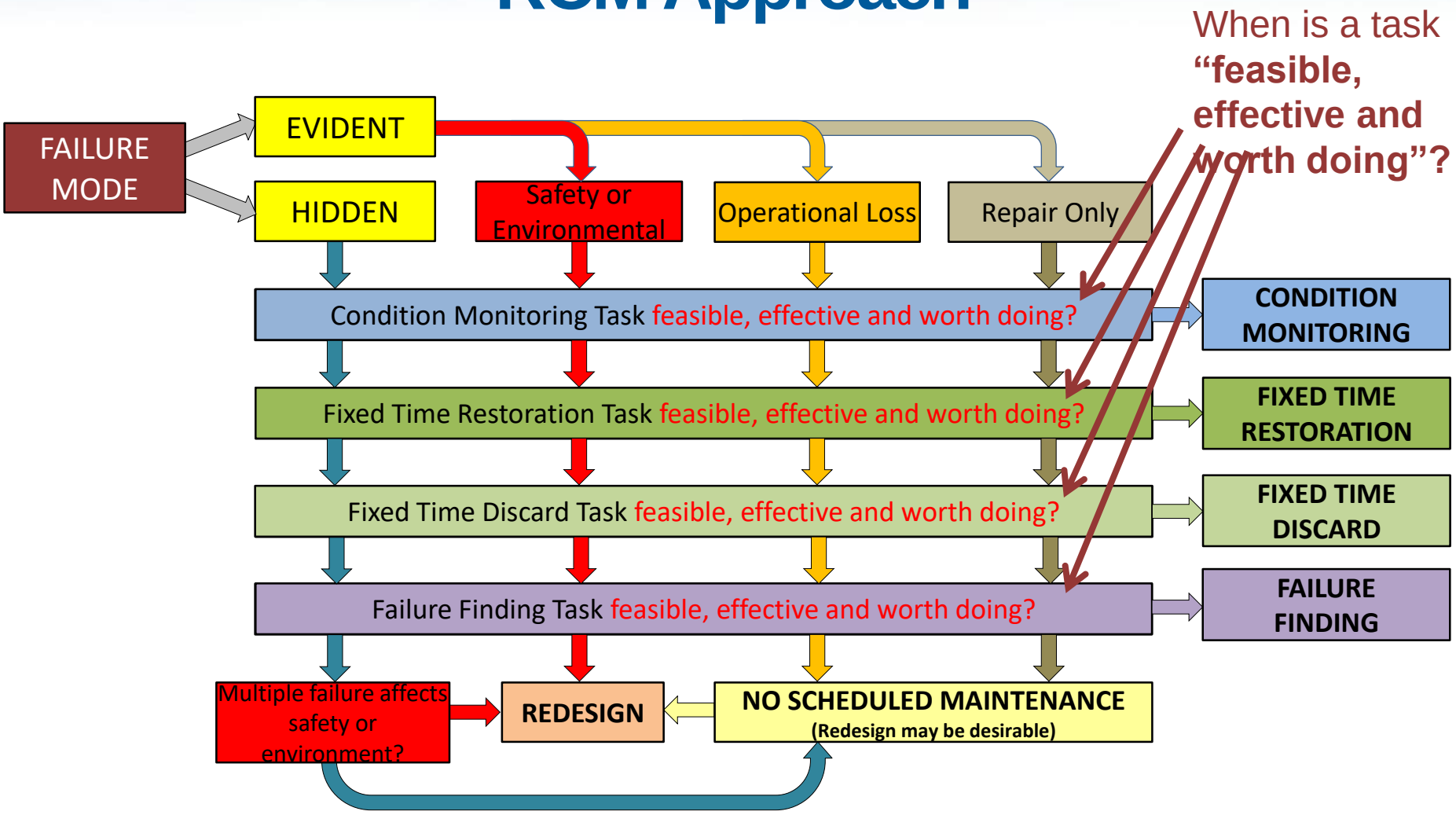


Strategic Asset Management Plan

ASSET MANAGEMENT FRAMEWORK



Reliability Engineering
RCM Approach



Maintenance Strategy

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OMM 1000-001
Primary Cooling System - Maintenance Strategy

System No	1010/1050/1090	System Name	Primary Cooling System

1. PROACTIVE MAINTENANCE TASKS (PM)

Planned proactive maintenance performed periodically to manage failure modes through either:

Condition Monitoring (CM) tasks that collect and analyse data on plant condition in order to detect a potential failure (P) condition with a P-F interval that allows the potential failure to be repaired prior to functional failure (failure modes in Quadrant 2 or 3 as per OP 11 that have a defined and useable P condition and P-F interval).

Fixed Time (FT) overhaul, restoration or replacement tasks that are performed periodically to address failure modes that exhibit a wear out failure pattern (failure modes in Quadrant 1 or 2 as per OP 11). Note that while termed 'fixed time', the interval for FT tasks may be specified in units other than time (e.g. run hours, no. of operations)

Failure Finding (FF) tasks that are performed periodically to detect hidden failures (failure modes in Quadrant 4H as per OP 11).

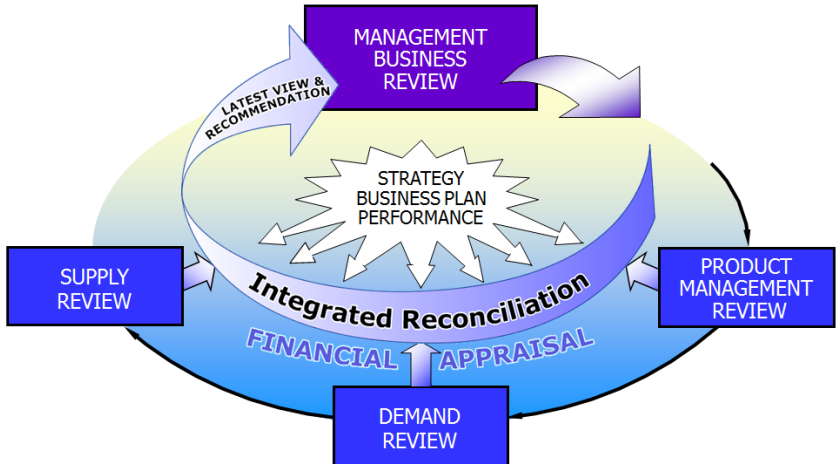
Relevant repair tasks associated with the above strategies should be referenced from Section 2 Corrective Maintenance Tasks (CrM). For CM, this includes repair of detected potential failures or unexpected functional failures. For FT this includes repair of unexpected early failures. For FF this includes repair of detected hidden failures.

WHAT							WHEN	WHY		WHO	HOW		
No.	Task/Activity Description	Relevant FL(s)	CM	FT	FF	Relevant CrM Tasks	Interval[1]	Purpose/Justification/Functional Failure Describe why the task/activity is worth doing, making reference to the relevant failure mode(s) being addressed	CR[2]	Work Centre[3]	SAP Maint Plan ID	Integrated Support Docs[4]	Outage Req'd[5]
1.	PCS water chemistry control: Pool water conductivity (OLC SR 3.4.5.1)	1010/1050/1090	X			CrM: Replace purification resins or filters (Refer RWPS Maint Strategy: System 20)	7D	RCM failure modes: 1/A/MP-PVF, MP-PIF, MP-PIW, FV-MCF, FV-SFF, DT-TIF, HX-CDC, DT-CDC, PV-CDC, PV-VFC, PV-CVP 2/A/FV-MCF, FV-FLK 4/A/DT-TIF 5/A/PV-VFI, PV-CVI 6/A/PV-VFF, PV-CVF 7/A/FF-EBF 8/A/MP-PFC, MP-PCF, HX-PFC, DT-MWF, PV-NPF, PV-EPF 9/A/PV-IVS, PV-DVS, PV-DVB 9/B/FF-RDB, DT-RDB 10/A/PV-BVS 11/A/MP-LSR, HX-LSR, DT-LSR, FF-LSR, PV-LSR, IN-LSR 15/A/FV-SEF, FV-SMF 18/A/IN-ANB	Y	ROPS	OSR-004	OOI 7230-016 OCM 0000-001	-
2.	PCS water chemistry control: Pool water pH and chloride concentration (OLC SR 3.4.5.2)	1010/1050/1090	X				35D		Y	CHEM	OSR-018	OOI 7230-017 OCM 0000-001	-
3.	PCS water chemistry control: Pool water ion concentration (OLC SR 3.4.5.3)	1010/1050/1090	X				12M		Y	CHEM	OSR-042	OOI 7230-018 OCM 0000-001	-
4.	PCS water chemistry control: Pool water full chemistry analysis as per OCM 0000-001	1010/1050/1090	X				1M		N	CHEM	OCS-010	OCM 0000-001	-
5.	RPS/PAM instrument channel checks (OLC SR): - PAM PCS flap valve position - FRPS PCS flow - FRPS PCS core DP - SRPS PCS core DP - FRPS PCS core inlet T - FRPS PCS core DT - SRPS PCS core outlet T	1090-Z-034/035/036/037 1090-F-031 1090-PD-040 1090-PD-042 1090-T-033 1090-TD-038 1090-T-052			X	CrM: Remove / repair / replace flap valve FF: FRPS/SRPS instrument channel calibrations CrM: Repair / replace instrument	1D	RCM failure modes: 15/A/FV-MLM, FV-SEF, FV-SMF, FV-SLA 16/A/IN-ELF, IN-CDR 17/A/IN-ELF, IN-RCD	Y	ROPS	OSR-001	OOI 7230-001	-
6.	Operator surveillance of MCR indications and alarms for motor, flywheel and pump bearing vibration and temperature.	1010-AB-001A/B/C	X			CM: Vibration & thermography analysis CrM: Repair / replace instrument	1D	RCM failure modes: 1/A/MP-BGW	N	ROPS	OPO-097 to 105	OOF 065 OOM 7250-002 Vol 1	-

Operational Excellence

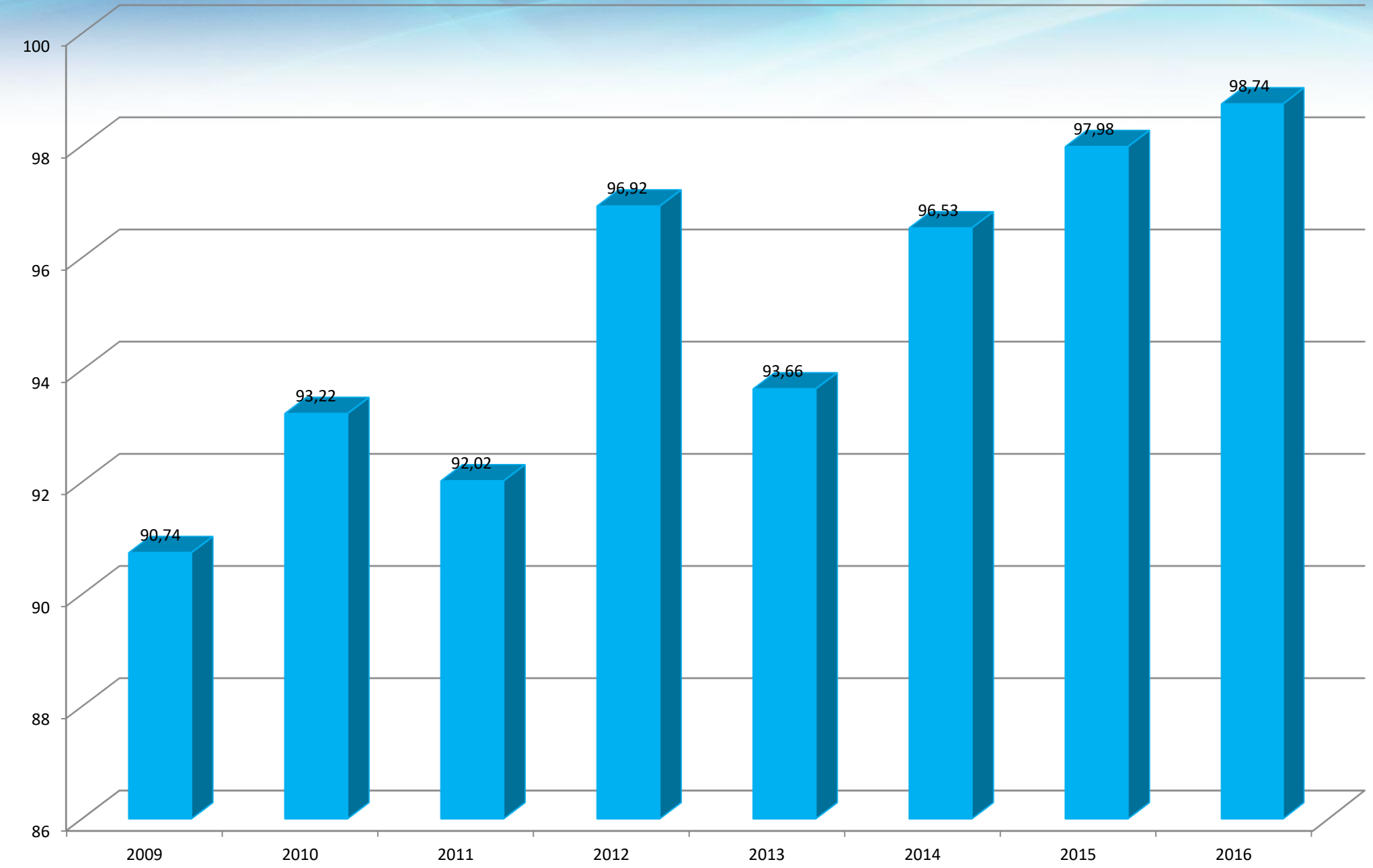
- Managing the Strategic Planning Process
- Managing and Leading People
- Driving Business Improvement
- Integrated Business Planning
- Managing Demand
- Managing Internal and External Supply Chain
- Decision Making in Line with Business Objective
- Best For Business Decision Making

The Strategy/Integrated Planning team will deliver an Integrated Business Planning (S&OP) process

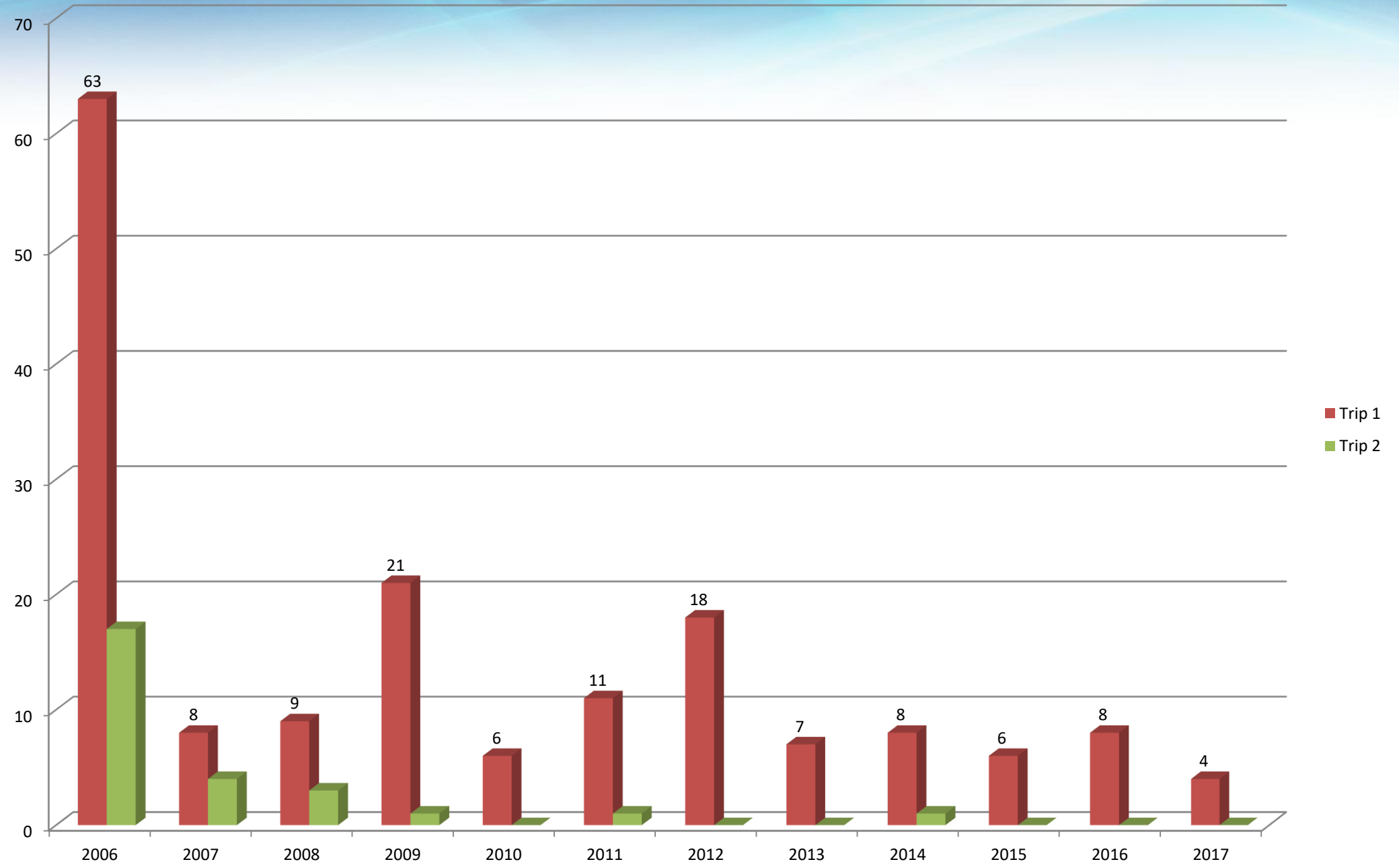


OPAL Safe Days at Power - Calendar Year

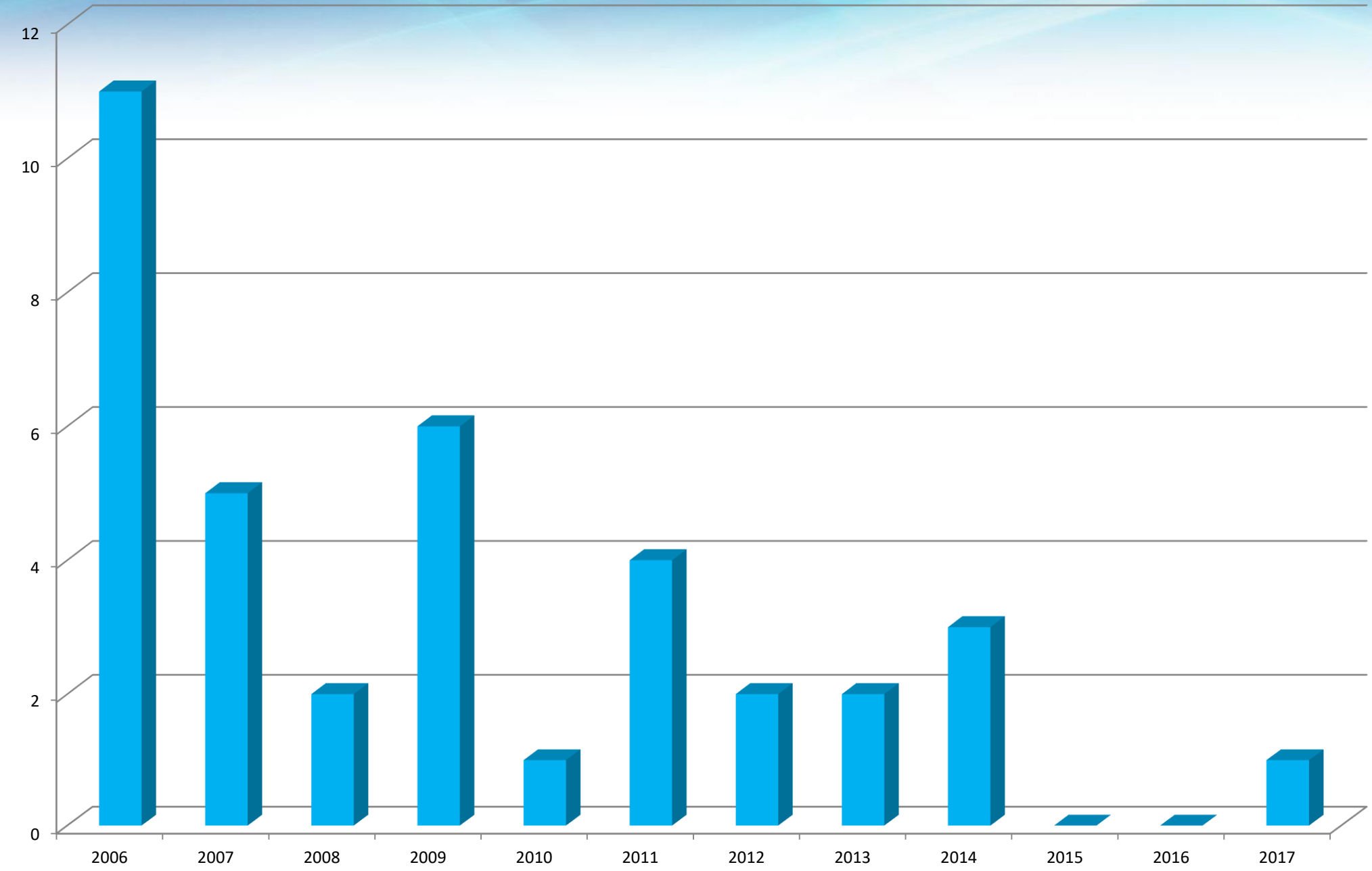
OPAL Reliability - Calendar Year



Reactor Trip per Year



Reactor Trip From Human or Procedural Error



OPAL Reactor Performance Indicators

No.	Target Description and Definition	Coordinator	Target	Metric - Monthly	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Perform. Summary	
Safety Performance Indicators																		
SPI-1	SPI-1 Number of Safety Significant Events (INES Level 1 or above)	Licensing Officer	0 1-2 >2	events/ month	0	0	0	0	0	0	0	0	0				0	rolling 12 month
SPI-2	SPI-2 Number of INES Rated Events with Human Related Causes	Licensing Officer	1 2-4 >4	events/ month	0	0	0	0	0	0	0	0	0				0	rolling 12 month
SPI-3	SPI-3 Percentage of Safety Category 1 Maintenance Plans in Compliance	Licensing Officer	>90 80-90 <80	%	92	88	89	88	90	N/A	85	93	80					Monthly value (%)
SPI-4	SPI-4 Percentage of Safety Category 2 Maintenance Plans in Compliance	Licensing Officer	>80 70-80 <70	%	82	80	80	80	82	N/A	67	70	74					Monthly value (%)
SPI-5	SPI-5 Unplanned Automatic Trips per 7000 hrs Critical excluding LOOP Trips	Licensing Officer	<4 4-8 >8	trips/ month	0	2	0	0	0	1	0	0	0				3.96	rolling/ 7000 h
SPI-6	SPI-6 Unplanned Automatic Trips per 7000 hrs Critical caused by LOOP Events	Licensing Officer	TBD	TBD	0	1	0	0	0	0	0	0	0				2.02	rolling/ 7000 h
SPI-7	SPI-7 Number of Unplanned Automatic Engineered Safety Feature Actuations	Licensing Officer	12 13-20 >20	actuations/ month	0	0	0	0	0	1	0	0	2				4	rolling 12 month
SPI-8	SPI-8 Number of Unplanned FRPS/SRPS Train or Channel Trips	Licensing Officer	6 7-12 >12	trips/ month	0	1	0	1	3	3	0	0	2				19	rolling 12 month
SPI-9	SPI-9 Number of Unplanned Limiting Condition Entries	Licensing Officer	12 13-24 >24	entries/ month	3	1	3	2	0	1	1	0	1				18	rolling 12 month
SPI-10	SPI-10 Number of Surveillance Requirement 3.0.3 Discoveries	Licensing Officer	0 1 >1	events/ month	0	0	0	0	0	0	0	0	0				0	rolling 12 month
SPI-11	SPI-11 Maximum Individual Effective Dose	Licensing Officer	<2 2-5 >5	dose/ month	1.68	1.85	2.00	1.97	1.95	1.82	1.85	1.93	2.07				2.07	mSv/rolling 12 month
SPI-12	SPI-12 Average Individual Effective Dose	Licensing Officer	<1 1-2 >2	dose/ month	0.73	0.75	0.72	0.69	0.71	0.68	0.70	0.72	0.71				0.71	mSv/rolling 12 month
SPI-13	SPI-13 Number of Personal Contamination Events with "Minor" Severity	Licensing Officer	<15 15-30 >30	events/ month	1	3	0	4	0	1	1	0	5				19	mSv/rolling 12 month
SPI-14	SPI-14 Number of Personal Contamination Events with "Moderate" or Above Severity	Licensing Officer	0 1-5 >5	events/ month	0	0	0	0	0	0	0	0	0				0	mSv/rolling 12 month
SPI-15	SPI-15 Number of Safety Observations Performed	Licensing Officer	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD					Monthly value
SPI-16	SPI-16 Housekeeping Inspection Scores	Licensing Officer	>90 80-90 <80	%	90	N/A	100	N/A	97	86	N/A	92	86				92.4	rolling 12 month

OPAL Reactor Performance Indicators

No.	Definition	Coordinator	Target	Metric - Cycle	OP 84	OP 85	OP 86	OP 87	OP 88	OP 89	OP 90	OP 91	OP 92	OP 93	OP 94	OP 95	Perform. Summary	Metric - Yearly
Operations Performance Indicators																		
O1	**Days at Power** Sum of durations of reactor operation ≥10 MW; cumulative from 1 January.	NAS/ Ops Manager	NA	days	31.4	28.9	32.4	31.1	30.3	23.1	24.9	29.3					231.4	Total Days
O2	**Overall availability** $\frac{\text{Days at Power ≥10 MW in report period}}{\text{Total time in report period}} \times 100$	NAS/ Ops Manager	>78 71-78 <71	%	91	84	75	89	86	83	71	86					83	Average (%)
O3	**Planned availability** $\frac{\text{Days at Power ≥10 MW in report period}}{\text{Scheduled days at power in report period}} \times 100$ The power cycle is specified in the published reactor schedule. A day begins/ends at midnight. Can be >100% if operation continues past the planned shutdown time.	NAS/ Ops Manager	TBD	%	105	96	98	100	101	100	83	101					98	Average (%)
O4	**No. days of unplanned shutdown** Sum of duration of <10 MW unplanned according to reactor schedule.	NAS/ Ops Manager	NA	days	0.0	1.4	0.6	0.0	0.0	0.0	5.1	0.0					7	Total Days
O5	**No. of unplanned shutdowns** According to the reactor schedule. A shutdown can include if the reactor power falls from nominal to less than 10 MW and after the power rises above 10 MW on ascension to power. Rolling previous 12 months.	NAS/ Ops Manager	TBD	No.	0	3	1	0	0	1	0	0					5	Total No.
O6	**Average power** The average thermal operating power of the reactor (calculated sum of the thermal power generated in the core and the reflector vessel). $\frac{\sum \text{Thermal power (measured per minute)}}{\text{Actual operating time of OPAL (minutes)}}$	NAS/ Ops Manager	>19 18-19 <18	MW	20	19	19	20	19	19	19	19					19	Average (MW)
O7	**Reliability** $\frac{\text{Actual operating time of OPAL}}{\text{(Actual operating time of OPAL + time of unplanned shutdowns)}} \times 100$	NAS/ Ops Manager	>98 95-98 <95	%	100	95	98	100	100	100	83	100					97	Average (%)
O8	**CNS reliability** $\frac{\text{Actual operating time of CNS}}{\text{(Actual operating time of OPAL + time of unplanned shutdowns)}} \times 100$	NAS/ Ops Manager	>95 90-95 <90	%	100	95	98	100	100	100	83	100					97	Average (%)
O9	**Cold Neutron Supply reliability** $\frac{\text{CNS NO mode on scheduled OPAL days at powerx shutter operability}}{\text{CNS scheduled days}} \times 100$	NAS/ Ops Manager	>95 90-95 <90	%	100	100	100	98	100	100							100	Average (%)
O10	**Work Order backlog** The number of work orders not closed, where the current date is past the planned date for completion of the work (or the %). SAP transaction IW38 using the work order end date.	Maintenance Manager	<300 300-600 >600	No.	0													
O11	**No. of breakdown maintenance occurrences** The number of demands for the rectification of a failed SSC, the failure of which caused either a reactor shutdown or a significant loss of production capability, pending the repair of that SSC. Captures failures in essential systems where there is not an installed spare available for operation.	Maintenance Manager	TBD	No.	Note: This KPI is being developed.												#DIV/0!	Average
O12	**Shutdown program task completion to schedule** $\frac{\text{Tasks in schedule completed}}{\text{Total tasks in schedule}} \times 100$	Operations Manager	>90 85-90 <85	%	95	100	100	94									97	Average
O13	**Shutdown program schedule deviation** $\frac{\text{Actual shutdown duration} - \text{Scheduled shutdown duration}}{\text{Scheduled shutdown duration}} \times 100$	Operations Manager	>0 0-10 <10	%	-37.9	-17.0	6.0	1.0									-12.0	Average

OPAL Reactor Performance Indicators

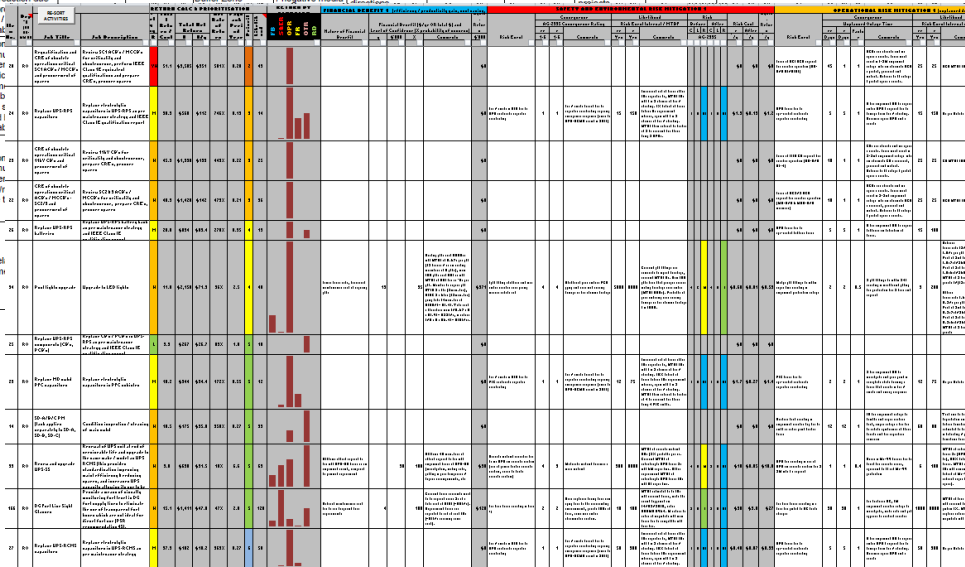
No.	Definition	Coordinator	Target	Metric - Qtrly	1st Qtr 2017	2nd Qtr 2017	3rd Qtr 2017	4th Qtr 2017	Performance Summary	Metric - Yearly
Environmental Performance Indicators										
E1	**Tritium release via Building 80 stack** Notification levels are detailed in the F0157 Operating Licence.	LEC	<38.75 38.75-77.5 >77.5	GBq					#DIV/0!	GBq/ quarter
E2	**Volume of LLSW generated** Count of the uncompacted LLSW forms/containers sent to Waste Operations, converted to litres.	LEC	TBD	Litres	7474	6808			7141.00	Litres
E3	**Electricity consumption** Monthyl electricity consumption	LEC	TBD	MWh	4238.3	4058.2			4148.24	MWh
E4	**Water consumption** Monthly daily cooling tower makeup water	LEC	TBD	kL	0				0.00	ML
Radiation Protection Performance Indicators										
R1	**Extremity dose** Maximum extremity dose received	RPS Manager	<50 50-100 >100	mSv	1.2	1.5	2.8		1.8	Average (mSv)
R2	**Scheduled survey completion rate** $\frac{Number\ of\ completed\ tasks}{Number\ of\ scheduled\ tasks} \times 100$	RPS Manager	>90 70-90 <70	%	94	94	89		92	Average (%)
Training Performance Indicators										
T1	**OPAL Reactor specific and safety training compliance** Safety training overdue or due in the next 100 days.	Training Coordinator	>90 70-90 <70	%	new KPI	68			68	Average (%)
Quality Performance Indicators										
Q1	**Actioned proposals for BMS documents** Proposals actioned and closed in the previous 3 months	QA & Config Manager	≥80 70-79 <70	%	106.1	134.7	91.1		111	Average (%)
Q2	**BMS Documents** Total BMS documents revisions open for over 3 months	QA & Config Manager	≤20 20-29 >30	%	19.4	21.1	20.9		20	Average (%)
Q3	**Offline Controlled Documentation Management** Number of system faults detected	QA & Config Manager	≤5 6-10 >10	No.	tba	tba	tba		#DIV/0!	Average No.
Q4	**Non-conformances** EMS/Quality/Non-conformances (events overdue)	QA & Config Manager	≤5 6-10 >10	No.	3	2	3		2.7	Average No.
Q5	**Audit Observations** GRC/Quality/Audit Observations (audit issues overdue)	QA & Config Manager	≤5 6-15 >15	No.	27	13	12		17.3	Average No.
Q6	**Improvement Opportunities** EMS/Quality/Imp.Opportunities (events overdue)	QA & Config Manager	≤5 6-15 >15	No.	1	1	0		0.7	Average No.
Q7	**Customer Feedback** EMS/Quality/Customer Feedback (events overdue)	QA & Config Manager	0 1-5 ≥6	No.	0	0	0		0	Average No.
Q8	**Ageing Documents** Number of BMS documents reviewed in the last 5 years	QA & Config Manager	≥95 90-95 <90	%	96.5	94.9	93.9			
Q9	**Ageing Document Proposals** Ageing proposals returned to CMG within 6 months	QA & Config Manager	≥95 90-95 <90	%	98.5	98.9	98.4		99	Average No.
Q10	**Action Plans** EMS/Quality/Action Plans (overdue)	QA & Config Manager	≤5 6-15 >15	No.	1	2	4		2.3	Average No.

OPAL Prioritisation Process

Risk Analysis Matrix

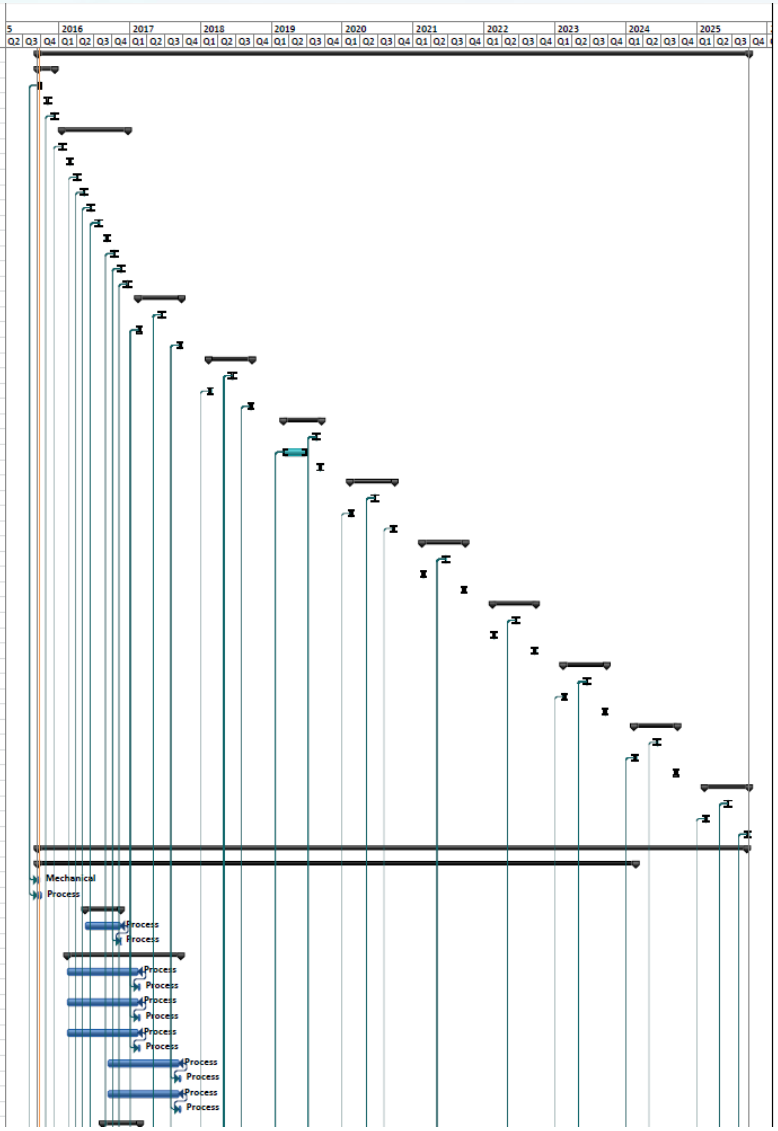
Medium	High	High	Very High	Very High	Very High	Very High	6	Catastrophic
Low	Medium	Medium	High	High	Very High	Very High	5	Severe
Low	Low	Medium	Mediu			Very		
Very Low	Very Low	Low	Low					
Very Low	Very Low	Very Low	Very Lo					
Very Low	Very Low	Very Low	Very Lo					
A	B	C	D					

Impact Level	Impact Description	Financial (Business-specific impact)	Financial (ANSTO impact)	Project Schedule	Project Cost Overrun	Project Quality	Operations / Plant and Equipment	Injury or Disease	Patient Safety	Radiation (whole body - worker dose)	Radiation (whole body - public offsite dose)	Environment (Refer to ISO-9342 Environmental sub-category risk consequence description for detailed guidance)	Security	Legal / Compliance	Information Technology Services	Reputation	Government Relations	Human Resources
6	Catastrophic	>50% impact on net profit	>$30M	>18 months	>20% of the total approved budget or >$250k	Total failure of the delivered system thus preventing it from meeting its primary purpose	Total loss of production / operations untenable in near to mid term	Multiple fatalities or serious permanent injuries	Death of a patient / Comcare notifiable	>1000mSv or severe dose to multiple people	>50mSv or severe dose to multiple people	Very long-term damage (>10 yrs.) or a nationally significant impact or release	Cessation of all operations / multiple fatalities / major criminal or terrorist event	Cancellation, permanent suspension of site license / repeal of ANSTO Act / Board and/or CEO removal / senior officers barred from office / imprisonment	Complete loss of all services for greater than 5 days	Prolonged international and national condemnation	Loss of government support for agency operations as a whole	Agency-wide strike action
5	Severe	30 - 50% impact on net profit	$20M – $30M	12 - 18 months	From >15 to 20 % of the total approved budget or between $200- 250k	Inability to achieve one or more critical requirements	Critical operations seriously affected > 6 months	Death, permanent disability or permanent ill health	General customer health problem that could attract public interest / Comcare notifiable	100 mSv - 1000mSv	10 - 50 mSv	Long-term damage (3-10 yrs.) or a regionally significant impact or release	Impact on all operations (>24 hours) / shutdown / single fatality / crime or terrorism attempt	Prolonged regulatory suspension of operating license/s / major restriction of core activities / major compensation payable / prosecution (civil/criminal) or other serious administrative action for legislative breaches / large fines	Complete loss of all services for less than 5 days	International and national criticism	Extraordinary government enquiries called or examination into agency operations as a whole	Strikes at several facilities
4	Major	20 - 30% impact on net profit	$10 - $20M	8 - 12 months	From >10% to 15% of the total approved budget or between $100-200k	Significant shortfall in the required performance or functionality of the delivered product /service /system	Critical operations seriously affected 1-6 months	Long term illness or serious injury, but recovery probable	Customer/ community health problem causing significant backlog of patients or non-treatment / Possible adverse drug reaction due to a pr... issue / notifiab...	20 - 100 mSv / >500 mSv (skin extremity dose)	1 - 10 mSv	Medium-term damage (1-3 yrs.) or an impact or release confined to Buffer Zone	Impact on some operations (>24 hours) / regulatory impact / injuries / negative media	Medium compensation / work suspension orders / regulatory	Loss of critical service(s) for more than 1 day	Very negative national criticism	Loss of government support for specific agency operations or	Strike at one facility
3	Moderate	10 - 20% impact on net profit	$5M - $10M	4 - 8 months	From >5% to 10% of the total approved budget or between $50-100k	Moderate shortfall in the required performance or functionality of the delivered product /service /system	Limited damage to equipment and/or facility / loss of production <1 month / Report to Regulator	Medical attention / several lost time days	Custom... commu... proble... signific... treatm... Possib... recall s... Could i... notifiat...									
2	Minor	5 - 10% impact on net profit	$3M - $5M	2 - 4 months	From 2% to 5% of the total approved budget or between $25-50k	Minor shortfall in the required performance or functionality of the delivered product /service /system	Insignificant damage to equipment / short interruption to some operations (hours)	First aid	Custom... commu... proble... delay/r... some t...									
1	Negligible	<5% impact on net profit	<$3M	<1 month	<2% of the total approved budget or between $10-25k	Insignificant impact on the required performance or functionality of the delivered product /service/ system	Superficial damage to equipment / no loss of production	Minimal effects / very small injury not requiring treatment	No del... treatm...									



20 Year Schedule

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names	Due Date	Functional Location	Shutdown Type	Total Shutdown Days	Lead Time
1		**REACTOR SCHEDULE**	**3668 days**	**Mon 14/09/15 12:00 AM**	**Mon 29/09/25 12:00 AM**							
2		**2015**	**89 days**	**Mon 14/09/15 12:00 AM**	**Sat 12/12/15 12:00 AM**							
3		SEPTEMBER	21 days	Mon 14/09/15 12:00 AM	Mon 5/10/15 12:00 AM	56SS,5						
4		NOVEMBER	5 days	Mon 2/11/15 12:00 AM	Sat 7/11/15 12:00 AM							
5		DECEMBER	5 days	Mon 7/12/15 12:00 AM	Sat 12/12/15 12:00 AM	129SS,						
6		**2016**	**341 days**	**Sun 17/01/16 12:00 AM**	**Fri 23/12/16 12:00 AM**							
7		JANUARY	5 days	Sun 17/01/16 12:00 AM	Fri 22/01/16 12:00 AM	213SS						
8		FEBRUARY	12 days	Mon 22/02/16 12:00 AM	Sat 5/03/16 12:00 AM							
9		APRIL	5 days	Mon 4/04/16 12:00 AM	Sat 9/04/16 12:00 AM	211SS						
10		MAY	5 days	Mon 9/05/16 12:00 AM	Sat 14/05/16 12:00 AM	132SS,						
11		JUNE	5 days	Mon 13/06/16 12:00 AM	Sat 18/06/16 12:00 AM	133SS,						
12		JULY	5 days	Mon 25/07/16 12:00 AM	Sat 30/07/16 12:00 AM	136SS,						
13		AUGUST	12 days	Mon 29/08/16 12:00 AM	Sat 10/09/16 12:00 AM							
14		OCTOBER	5 days	Mon 10/10/16 12:00 AM	Sat 15/10/16 12:00 AM	137SS,						
15		NOVEMBER	5 days	Mon 14/11/16 12:00 AM	Sat 19/11/16 12:00 AM	59SS,8						
16		DECEMBER	5 days	Sun 18/12/16 12:00 AM	Fri 23/12/16 12:00 AM	156SS,						
17		**2017**	**224 days**	**Mon 13/02/17 12:00 AM**	**Mon 25/09/17 12:00 AM**							
18		STANDARD	5 days	Mon 12/06/17 12:00 AM	Sat 17/06/17 12:00 AM	86SS,8						
19		FEBRUARY	14 days	Mon 13/02/17 12:00 AM	Mon 27/02/17 12:00 AM	62SS,6						
20		SEPTEMBER	14 days	Mon 11/09/17 12:00 AM	Mon 25/09/17 12:00 AM	68SS,7						
21		**2018**	**224 days**	**Mon 12/02/18 12:00 AM**	**Mon 24/09/18 12:00 AM**							
22		STANDARD	5 days	Mon 11/06/18 12:00 AM	Sat 16/06/18 12:00 AM	93SS,9						
23		FEBRUARY	14 days	Mon 12/02/18 12:00 AM	Mon 26/02/18 12:00 AM	91SS						
24		SEPTEMBER	14 days	Mon 10/09/18 12:00 AM	Mon 24/09/18 12:00 AM	125SS,						
25		**2019**	**196 days**	**Mon 4/03/19 12:00 AM**	**Mon 16/09/19 12:00 AM**							
26		STANDARD	5 days	Mon 19/08/19 12:00 AM	Sat 24/08/19 12:00 AM	79SS,8						
27		MARCH	120 days	Mon 4/03/19 12:00 AM	Tue 2/07/19 12:00 AM	76SS,1						
28		SEPTEMBER	14 days	Mon 2/09/19 12:00 AM	Mon 16/09/19 12:00 AM							
29		**2020**	**231 days**	**Mon 10/02/20 12:00 AM**	**Mon 28/09/20 12:00 AM**							
30		STANDARD	5 days	Mon 15/06/20 12:00 AM	Sat 20/06/20 12:00 AM	115SS,						
31		FEBRUARY	14 days	Mon 10/02/20 12:00 AM	Mon 24/02/20 12:00 AM	264SS						
32		SEPTEMBER	14 days	Mon 14/09/20 12:00 AM	Mon 28/09/20 12:00 AM	321SS						
33		**2021**	**224 days**	**Mon 15/02/21 12:00 AM**	**Mon 27/09/21 12:00 AM**							
34		STANDARD	5 days	Mon 14/06/21 12:00 AM	Sat 19/06/21 12:00 AM	120SS,						
35		FEBRUARY	14 days	Mon 15/02/21 12:00 AM	Mon 1/03/21 12:00 AM							
36		SEPTEMBER	14 days	Mon 13/09/21 12:00 AM	Mon 27/09/21 12:00 AM							
37		**2022**	**224 days**	**Mon 14/02/22 12:00 AM**	**Mon 26/09/22 12:00 AM**							
38		STANDARD	5 days	Mon 13/06/22 12:00 AM	Sat 18/06/22 12:00 AM	177SS,						
39		FEBRUARY	14 days	Mon 14/02/22 12:00 AM	Mon 28/02/22 12:00 AM							
40		SEPTEMBER	14 days	Mon 12/09/22 12:00 AM	Mon 26/09/22 12:00 AM							
41		**2023**	**224 days**	**Mon 13/02/23 12:00 AM**	**Mon 25/09/23 12:00 AM**							
42		STANDARD	5 days	Mon 12/06/23 12:00 AM	Sat 17/06/23 12:00 AM	185SS,						
43		FEBRUARY	14 days	Mon 13/02/23 12:00 AM	Mon 27/02/23 12:00 AM	199SS						
44		SEPTEMBER	14 days	Mon 11/09/23 12:00 AM	Mon 25/09/23 12:00 AM							
45		**2024**	**224 days**	**Mon 12/02/24 12:00 AM**	**Mon 23/09/24 12:00 AM**							
46		STANDARD	5 days	Mon 10/06/24 12:00 AM	Sat 15/06/24 12:00 AM	223SS						
47		FEBRUARY	14 days	Mon 12/02/24 12:00 AM	Mon 26/02/24 12:00 AM	121SS,						
48		SEPTEMBER	14 days	Mon 9/09/24 12:00 AM	Mon 23/09/24 12:00 AM							
49		**2025**	**231 days**	**Mon 10/02/25 12:00 AM**	**Mon 29/09/25 12:00 AM**							
50		STANDARD	5 days	Mon 9/06/25 12:00 AM	Sat 14/06/25 12:00 AM	193SS,						
51		FEBRUARY	14 days	Mon 10/02/25 12:00 AM	Mon 24/02/25 12:00 AM	198SS						
52		SEPTEMBER	14 days	Mon 15/09/25 12:00 AM	Mon 29/09/25 12:00 AM	253SS,						
53		JOBS	3656 days?	Mon 14/09/15 12:00 AM	Wed 17/09/25 12:00 AM							
54		MECHANICAL & PROCESS	3083 days?	Mon 14/09/15 12:00 AM	Thu 22/02/24 12:00 AM							
55		EXTERNAL INSPECTION & NDT OF CRD ROOM PENETRATION	10 days	Mon 14/09/15 12:00 AM	Thu 24/09/15 12:00 AM	3SS	Mechanical	2015	0310 & 1110	S2		
56		RWPS POLISHING FILTER	20 days	Mon 14/09/15 12:00 AM	Sun 4/10/15 12:00 AM	3SS	Process	2016	2010	S2	20	12
57		**PCS DECAY TANK LOWER SHELL INSPECTION & UT TESTING**	**184 days**	**Mon 16/05/16 12:00 AM**	**Wed 16/11/16 12:00 AM**			**2016**	**1050-BR-001**	**S1**	**2**	**6**
58		PLANNING PCS DECAY TANK INSPECTION & UT TESTING	182 days	Mon 16/05/16 12:00 AM	Mon 14/11/16 12:00 AM	59SF	Process					
59		EXECUTION	2 days	Mon 14/11/16 12:00 AM	Wed 16/11/16 12:00 AM	15SS 58SF	Process					
60		**VARIOUS PLATE HX RE-GASKETING**	**585 days**	**Sun 14/02/16 12:00 AM**	**Thu 21/09/17 12:00 AM**		**Process**	**2016**	**1010-BI-001A/B/C 1110-BI-0(**	**S2**		**12**
61		PLANNING 1010-BI-001-A	365 days	Sun 14/02/16 12:00 AM	Mon 13/02/17 12:00 AM	62SF	Process					
62		1010-BI-001-A	10 days	Mon 13/02/17 12:00 AM	Thu 23/02/17 12:00 AM	19SS 61SF	Process	**2016**	1010-BI-001-A	S2	10	12
63		PLANNING 1010-BI-001-B	365 days	Sun 14/02/16 12:00 AM	Mon 13/02/17 12:00 AM	64SF	Process					
64		1010-BI-001-B	10 days	Mon 13/02/17 12:00 AM	Thu 23/02/17 12:00 AM	19SS 63SF	Process	**2016**	1010-BI-001-B	S2	10	12
65		PLANNING 1010-BI-001-C	365 days	Sun 14/02/16 12:00 AM	Mon 13/02/17 12:00 AM	66SF	Process					
66		1010-BI-001-C	10 days	Mon 13/02/17 12:00 AM	Thu 23/02/17 12:00 AM	19SS 65SF	Process	**2016**	1010-BI-001-C	S2	10	12
67		PLANNING 1110-BI-002	365 days	Sun 11/09/16 12:00 AM	Mon 11/09/17 12:00 AM	68SF	Process					
68		1110-BI-002	10 days	Mon 11/09/17 12:00 AM	Thu 21/09/17 12:00 AM	20SS 67SF	Process	**2016**	1110-BI-002	S2	10	12
69		PLANNING 1310-BI-001	365 days	Sun 11/09/16 12:00 AM	Mon 11/09/17 12:00 AM	70SF	Process					
70		1310-BI-001	10 days	Mon 11/09/17 12:00 AM	Thu 21/09/17 12:00 AM	20SS 69SF	Process	**2016**	1310-BI-001	S2	10	12
71		**SCS EXPANSION BELLOWS REPLACEMENT**	**192 days**	**Mon 15/08/16 12:00 AM**	**Thu 23/02/17 12:00 AM**		**Process**	**2018**	**2110**	**S2**	**10**	**6**



Investment in People

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Tim Rownes
OPAL Shift Manager
ANSTO
22 November 2017

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Engineering and Operations at the

OPAL Reactor

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Open Pool Australian Light water (OPAL) Reactor

- 20 MW,
- Open pool design
- Light water cooled and moderated
- Compact core (350 × 350 × 615 mm) of 16 fuel assemblies
- Low enriched fuel (U_3Si_2-Al dispersion)
- First criticality in August 2006
- 300 days of operation in 2015
- Replaced the 10 MW, High Flux Australian Reactor (HIFAR) (1958-2007)

Watch a 4-minute animation about the OPAL Reactor at www.ansto.gov.au/AboutANSTO/OPAL

OPAL's key uses are...

1 Radioisotope production – including Molybdenum-99 and Iodine-131

2 Neutron-based research – using cold and thermal neutron guides

3 Neutron Transmutation Doping (NTD) of silicon


OPAL Reactor Building and Visitors' Centre


OPAL Reactor Pool

My Responsibilities...

...in my former role with Engineering

As a *Mechanical Systems Engineer* I was responsible for reactor systems including: Control Rod Drives; Fuel Assembly Clamps; and pool internal components. Each Systems Engineer performs the following duties for their assigned systems:

1. Develop and implement **maintenance optimisation strategies** based on the Reliability Centred Maintenance (RCM) framework:
   - Preventative maintenance
   - Corrective maintenance
   - Spares management
2. Plan work to be performed during **shutdowns**
3. Perform day-to-day **systems engineering** tasks:
   - Review designs of custom components
   - Develop and review technical documents (e.g. maintenance instructions)
   - Develop engineering solutions to improve safety and effectiveness of operational and maintenance tasks
   - Respond to events and provide support to Operations
4. Manage **minor projects** for plant modifications

...in my current role with Operations

As a *Reactor Engineer* I work a 12-hour rotating shift roster with a crew under the leadership of a Shift Manager. As a shift team we:

1. **Operate** the reactor:
   - Remotely via the Reactor Control & Monitoring System (RCMS)
   - In the field
2. Conduct routine **surveillances** and ensure compliance with Operational Limits and Conditions by performing:
   - Plant and equipment inspections and functional tests (remote and in-field)
   - Sampling of process fluids for analysis
3. **Respond** to alarms / faults / external events (e.g. offsite power outages)
4. **Prepare plant** for maintenance (i.e. configure and isolate)
5. Participate in routine **shutdowns** in co-operation with Engineering and Maintenance personnel

Reactor Engineers also manage **projects** aimed at optimising reactor systems' performance and safety.

Relationship between Engineering/Maintenance and Operations

The Operations–Engineering/Maintenance relationship can be viewed as either a customer–supplier relationship or as a genuine partnership.*

- Teams' goals are not necessarily well-aligned.
- Maintenance is viewed as an inconvenient expense rather than as an essential resource.
- Maintenance work and engineering fixes tend to be reactive rather than preventative.

- There is a clear focus on the common goal of **reliability**.
- Maintenance work and engineering improvements are viewed as crucial to achieving the common goal.
- Teams work closely and communicate well.

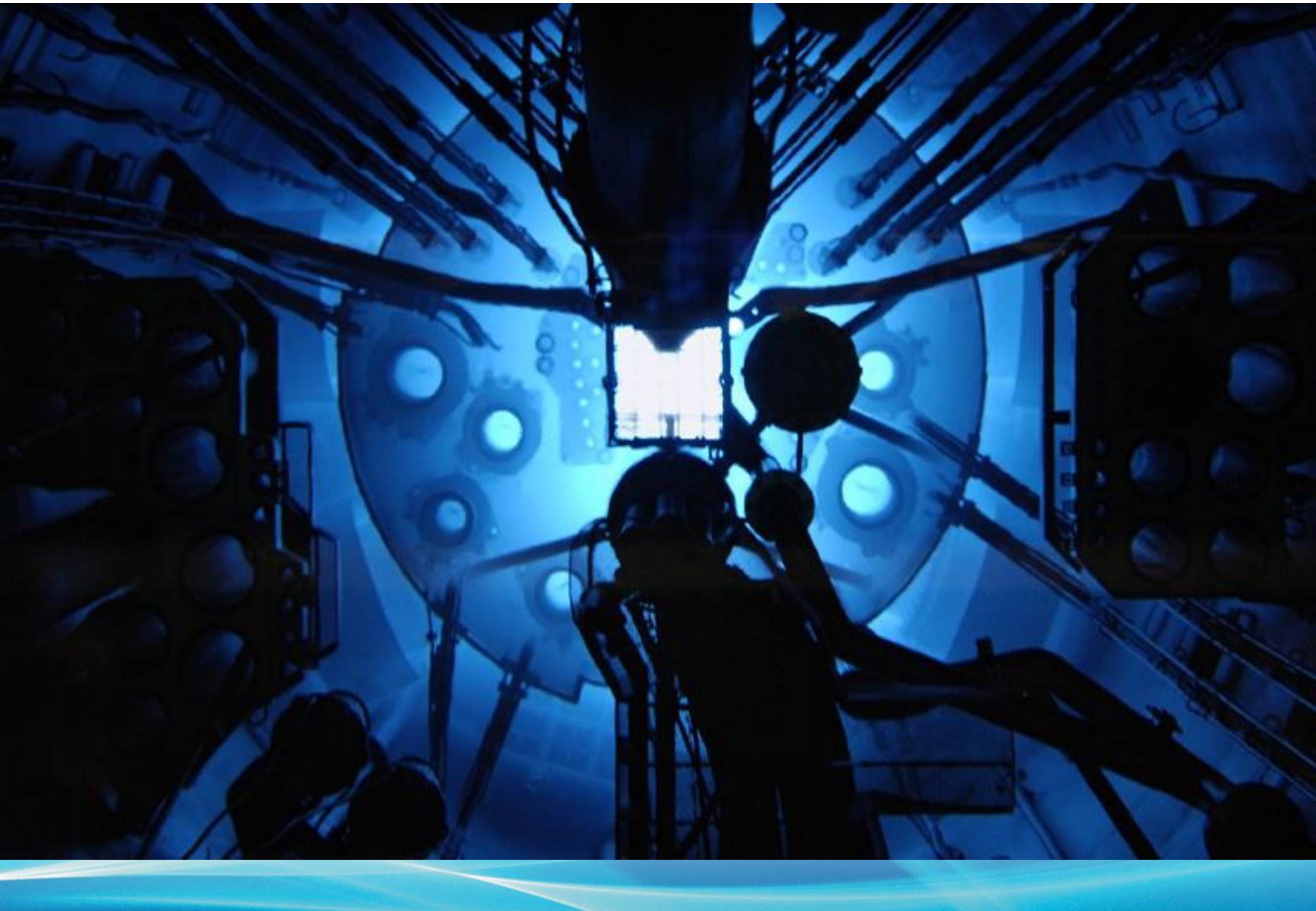
Positive Practices used at OPAL to Foster a Genuine Partnership

- Daily morning meetings with representatives from all teams
- Operational and production schedules available for reference by all staff
- Shutdowns planned by Operations in close consultation with all teams
- Use of a single, joint shutdown schedule
- Extensive use of SAP (Computerised Maintenance Management System) by all teams
- Joint implementation and ongoing review of maintenance strategies

* See several articles regarding this topic at www.sloan.com/resource-library/articles/operations-and-maintenance

ourvalues


TRUST + RESPECT. CURIOSITY. LEADERSHIP. EXCELLENCE. WORKING TOGETHER.
Safe. Secure.
Sustainable.

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