



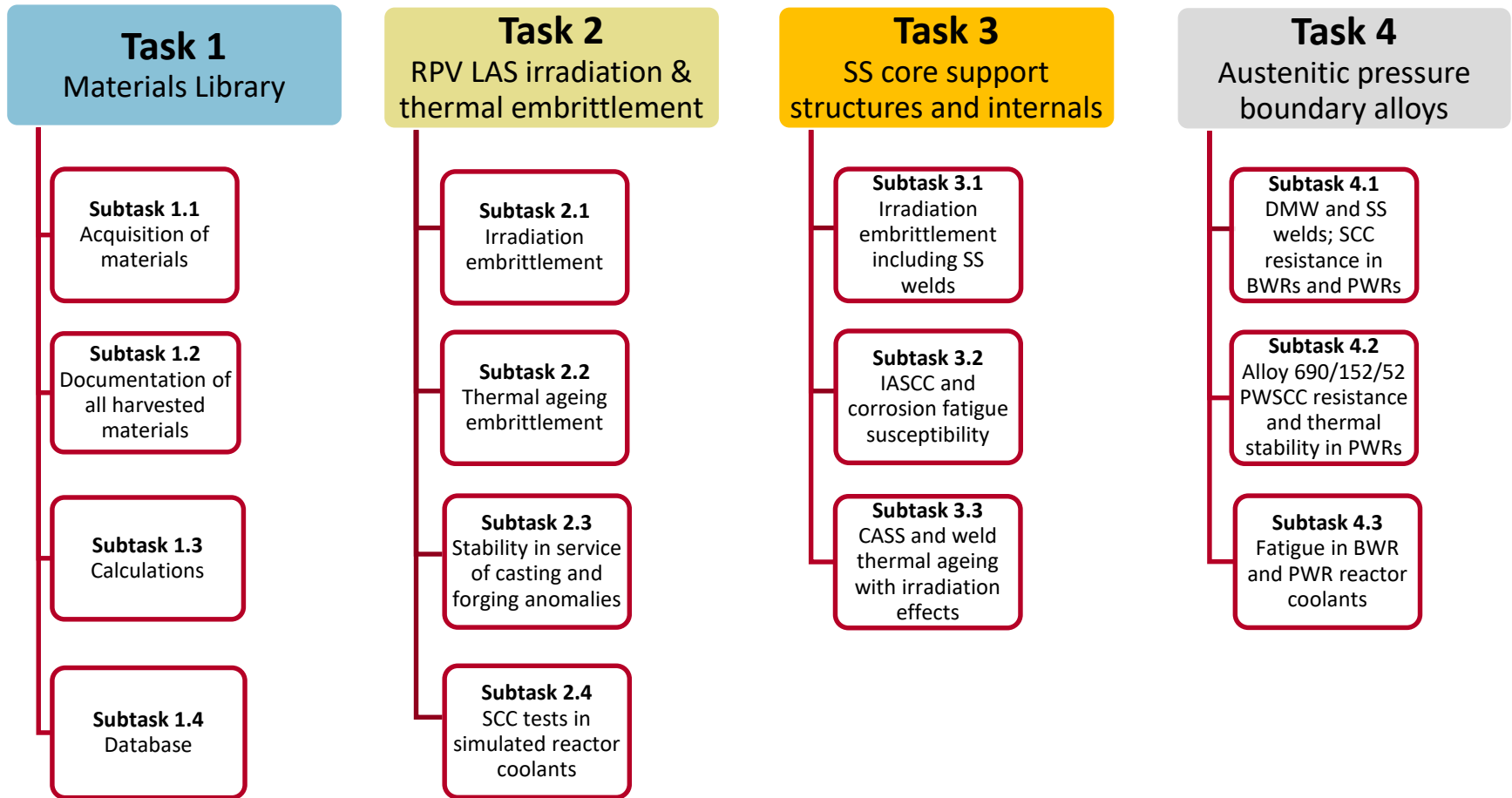
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Context of the SMILE Project Knowledge Gaps and Uncertainties

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SMILE

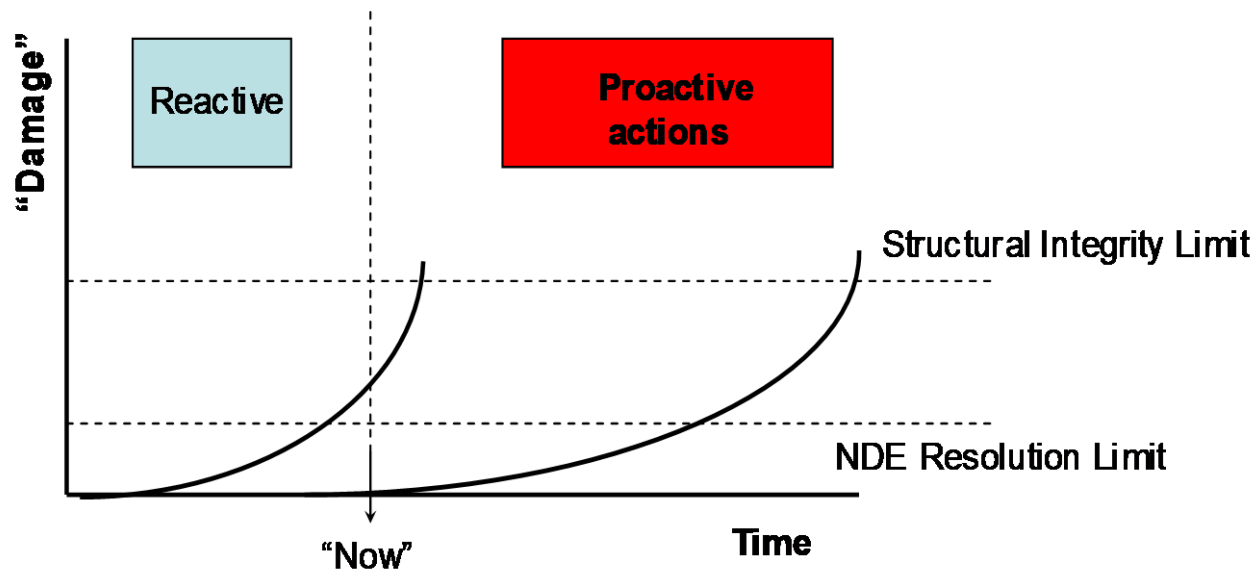


SUMMARY OF IAEA, USNRC AND EPRI AGEING MANAGEMENT: APPROACHES & KNOWLEDGE GAPS

- Proactive Materials Degradation Assessments and perceived R&D needs by expert panel elicitation (NRC, EPRI and NISA, now NRA).
- Ageing Management Plans (AMPs):
 - USNRC Generic Aging Lessons Learned (GALL) report (NUREG-1801, Rev2, 2010) details its evaluations of LWR ageing management programmes for US plants, (broader in application to plant safety than just NSSSs) and where they should be augmented for LTO.
 - IAEA, building on the USNRC GALL report, issued its guidance for international LWR (and CANDU) operators on how to manage existing and potential future ageing and degradation considered important to safety (IAEA Safety Reports Series N°. 82, 'IGALL', 2015).
 - EPRI PWR Issue Management Tables (IMTs) that identify, prioritize and describe R&D gaps for PWR NSSS ageing degradation issues, PWR IMTs – Revision 3 (MRP-205), 2013, and BWR IMTs for R&D gaps for the BWR Vessel and Internals Project (VIP), BWR VIP-167NP, Revision 3, 2013.

PROACTIVE MATERIALS DEGRADATION ASSESSMENT

- Independent studies by NRC, EPRI and the Japanese regulators (NISA, now NRA):
 - *NRC Proactive Materials Degradation Assessment*, USNRC NUREG /CR 6923, 2007 – Updated during 2013
 - *Primary System Corrosion Research Program: Materials Degradation Matrix, Revision 4*, EPRI Report 3002013781, May 2018 (Includes CANDU and VVER systems)
 - T. Shoji, T. Takeda, J. Kuniya, P. Ford, P. Scott, N. K. Das, *Proactive Materials Degradation Management (PMDM) and long term operation*, Proceedings of the 16th Int. Conf. on Environmental Degradation of Materials in Nuclear Power Systems-Water Reactors, 2013



MAPPING SMILE TO EPRI PWR IMTs (2013)

Gap ID N°		R&D Gap Description Excluding Mitigation Gaps, Inspection & Evaluation Gaps, Repair / Replacement Gaps, Regulatory Gaps and Closed Gaps	Priority 2013	Task 1 Materials Library	Task 2 RPV LAS irradiation & thermal embrittlement				Task 3 SS core support structures and internals			Task 4 Austenitic pressure boundary alloys		
					2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1	4.2	4.3
Degradation Mechanism Understanding Gaps	P-DM-09	Environmental Effects on Fracture Resistance	Medium					X						
	P-DM-10	Thermal Embrittlement of RPV Steels [LTO]	Low			X								
	P-DM-11	SCC of Thermally Aged CASS PB Components [LTO]	Low								X			
	P-DM-13	Long-Term SCC Susceptibility [LTO]	Low	X										
Assessment Gaps	P-AS-02	Environmental Effects on Fatigue: PB Components [LTO]	High	X										X
	P-AS-04	Neutron Embrittlement of RPV Steels [LTO]	Medium	X	X		X							
	P-AS-05	Fluence Spectra and Dose Rate Effects on RPV Steels [LTO]	Medium	X	X									
	P-AS-09	SCC of SS Exposed to Primary Water [LTO]	High									X		
	P-AS-12	PWSCC Characterization for Alloys 690, 52, and 152	High										X	

2.1 Irradiation embrittlement
 2.2 Thermal ageing embrittlement
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3.1 Irradiation embrittlement including SS welds
 3.2 IASCC & corrosion fatigue susceptibility
 3.3 CASS & weld thermal ageing with irradiation effects

4.1 DMW and SS welds; SCC resistance in BWRs and PWRs
 4.2 Alloy 690/152/52 PWSCC resistance & thermal stability
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P-AS-13a	Thermal & Irradiation Embrittlement Synergistic Effects on CASS [LTO]	High	X						X				
P-AS-13b	Thermal & Irradiation Embrittlement Synergistic Effects on SS Welds [LTO]	High	X					X					
P-AS-14a	IASCC Characterization: Generic Data Needs [LTO]	High	X						X				
P-AS-14b	IASCC Characterization: Baffle Bolting [LTO]	High	X						X				
P-AS-15	Void Swelling of Stainless Steels [LTO]	Medium	X					X					
P-AS-16	Env. Effects on Fatigue: Reactor Internals [LTO]	Medium	X						X				
P-AS-19	PWSCC Management for Ni-base Alloy Reactor Internals [LTO]	High						X	X				
P-AS-22	SG Tubes & Internals Wear & High-Cycle Fatigue	High	X									X	
P-AS-28	Neutron Embrittlement of Nozzle Forgings and Upper Shell Course [LTO]	High	X	X									
P-AS-38	Fluence Impact on SS Mechanical Prop. (FT, YS) [LTO]	High	X					X					
P-AS-46	CASS Piping Component Thermal Aging Embrittlement & Long-Term Integrity Assessment [New] [LTO]	High	X							X			

Assessment Gaps

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MAPPING SMILE TO EPRI BWR IMTs (2013)

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				2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1	4.2	4.3
Degradation Mechanism Understanding Gaps	B-DM-03	Low Temperature Crack Propagation	Low			X							
	B-DM-06	Environmental Effects on Fracture Resistance	Medium			X	X						
	B-DM-07	Chloride Transient Effects on Low Alloy Steel Crack Growth Rates	Medium				X						
	B-DM-08	Long-Term Neutron Fluence Effect on Low Alloy Steel Cracking Susceptibility [LTO – indirect]	Low	X				X					
	B-DM-09	Long-Term SCC Susceptibility (Late Life SCC Initiation) [LTO – Indirect]	Low					X				X	

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				2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1	4.2	4.3
Assessment Gaps													
B-AS-05	Assess Neutron Dose Rate Effects on Embrittlement of C&LAS [LTO – Indirect]	Medium	X	X									
B-AS-07	Environmental Effects on Fatigue Resistance: PB Components [LTO – Direct]	High	X				X						
B-AS-09	Assess the Impact of High Fluence on FT [LTO – Indirect]	High	X					X					
B-AS-10	Assess the Impact of High Fluence and HWC Mitigation Technologies on SCC CGR [LTO - Indirect]	High	X						X				
B-AS-12	Thermal & Irradiation Embrittlement: Synergistic Effects (on CASS BWR Reactor Internals) [LTO - Indirect]	Low	X							X			
B-AS-14	Environmental Effects on Fatigue Resistance: Reactor Internals [LTO - Direct]	Low	X						X				
B-AS-22	High-Cycle Thermal Fatigue: Piping Locations	Medium	X									X	
B-AS-26	High Strength Alloys [LTO - Indirect]	High							X				
B-AS-27	Alloy 182 / Creviced Alloy 600 SCC Susceptibility & Irradiation Effects [LTO - Indirect]	Medium							X		X		
B-AS-29	Steam Dryer Evaluation Methodology	High	X										
B-AS-33	Equivalent Margins Analysis for BWR Nozzles [new gap] [LTO - Direct]	Medium	X	X									
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MAPPING SMILE TO GALL & IGALL AMPs FOR BWR & PWR

IGALL/GALL AMP ID N°	IGALL AMPs for Mechanical Components	Task 1 Materials Library	Task 2 RPV LAS irradiation & thermal embrittlement				Task 3 SS core support structures and internals			Task 4 Austenitic pressure boundary alloys		
			2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1	4.2	4.3
AMP 101/M1	Fatigue Monitoring	X										X
AMP 105/M4	BWR Vessel ID Attachment Welds						X	X		X		
AMP 106/M5	BWR Feedwater Nozzle							X				X
AMP 107/M7	BWR Stress Corrosion Cracking in Coolant Pressure Boundary Components									X		
AMP 108/M8	BWR Penetrations									X		X
AMP 109/M9	BWR Vessel Internals	X					X	X	X			
AMP 111/M11B	PWR Cracking of Nickel-alloy Reactor Coolant Pressure Boundary Components									X	X	
AMP 112/M12	Thermal Ageing Embrittlement of Cast Austenitic Stainless Steel								X			
AMP 113/M16A	PWR Vessel Internals	X					X	X	X			
AMP 116/M19	Steam Generators										X	
AMP 118/M31	Reactor Vessel Surveillance	X	X	X	X	X						
AMP 123/M6	BWR Control Rod Drive Return Line Nozzle									X		X
AMP 154	PWR Pressurizer			X		X				X	X	
AMP 161	High Cycle Fatigue Monitoring	X										X

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MAPPING SMILE TO GENERIC IGALL TLAAS FOR BWR & PWR

IGALL TLAA ID N°	TLAAs for Mechanical Components	Task 1 Materials Library	Task 2 RPV LAS irradiation & thermal embrittlement				Task 3 SS core support structures and internals			Task 4 Austenitic pressure boundary alloys		
			2.1	2.2	2.3	2.4	3.1	3.2	3.3	4.1	4.2	4.3
TLAA 101	Low-cycle Fatigue Usage	X										X
TLAA 102	RPV Neutron Embrittlement	X	X									
TLAA 103	Crack Growth Analyses	X				X		X		X	X	
TLAA 106	Environmentally Assisted Fatigue	X				X		X				X
TLAA 107	High-cycle Fatigue for SG Tubes	X										X
TLAA 109	PWR RPV Internals Swelling						X					
TLAA 110	Thermal Ageing of CASS						X		X			
TLAA 114	Flaw Tolerance Calculation due to Thermal Ageing and Fatigue	X		X	X	X					X	
TLAA 115	Fatigue and Thermal Ageing Analysis of Manufacturing Flaws	X		X	X	X					X	
TLAA 116	Thermal Ageing of Low Alloy Steels		X	X								
TLAA 117	Underclad Cracking	X										
TLAA 119	High-cycle Thermal Fatigue	X										X
TLAA 121	IASCC Fluence Limit for Stainless Steels	X						X	X			

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SUMMARY

- Mapping of SMILE Tasks/Subtasks to EPRI IMTs, GALL/IGALL AMPs and TLAAAs for PWRs and BWRs has shown where the data and mechanistic insights obtained should aid the development/validation of the predictive models required for managing materials ageing and plant life extension
- Subtask priorities will be established in order to match SMILE participants priority requirements to the timetable of availability of harvested materials and project budget