Introduction to PMMD Activities and Plans

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A.B. Hull & S.N. Malik (NRC)
L.J. Bond, S.R. Doctor, W.B. Taylor, T.T. Taylor, R.V. Harris, & S.M. Bruemmer (PNNL)

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Presentation at
Fracture and Reliability Research Institute, School of Engineering,
Tohoku University, Sendai, Japan

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Outline

- Proactive Management of Materials Degradation
- PMMD – Information tool – an introduction
- Conclusions/Path Forward

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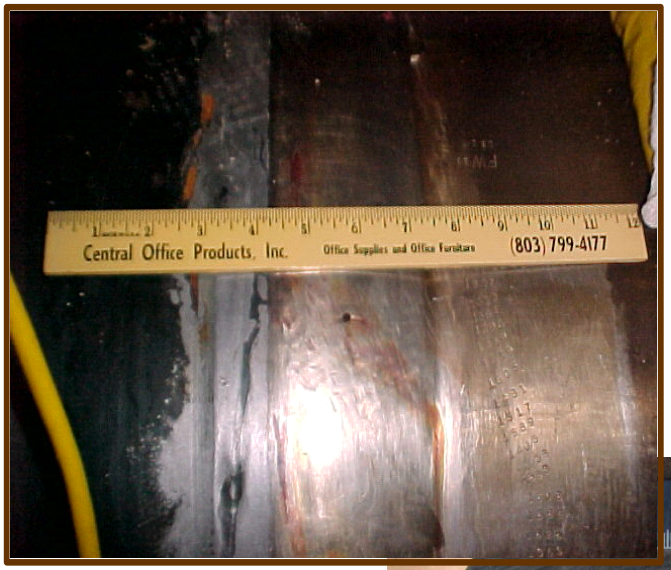
NPP Aging & Life Extension

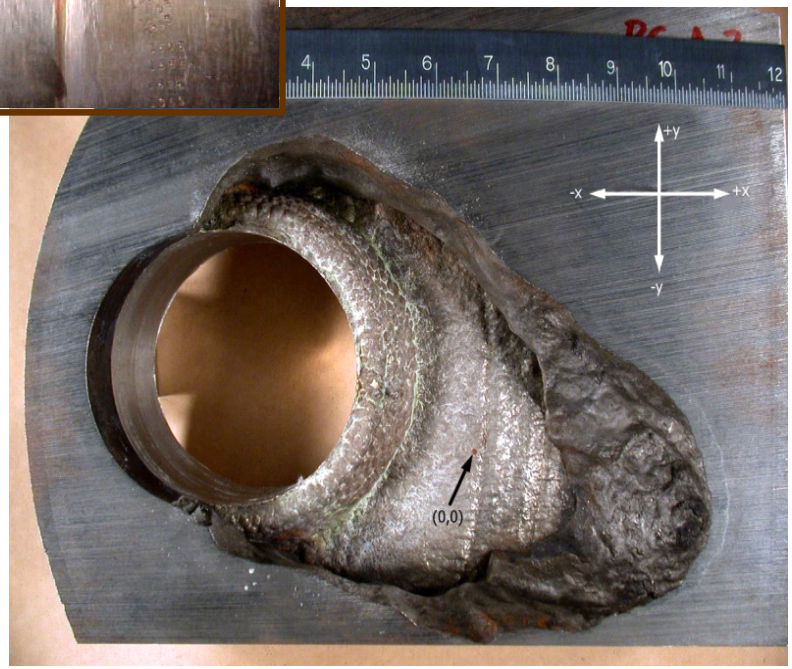
- Nuclear power plant life extension – developing since ~ 1972
  - (US supporting 40-60 years)
- NRC & DOE-NE --- "Life beyond 60" (for LWRs)
  - EPRI, INPO, NEI etc – looking at "40-60" needs.
  - NRC-DOE Workshop Feb 2008 -- Roadmap development www.energetics.com/NRCDOEFeb08.
  - DOE-NE new program --- LWR Sustainability Program
  - NRC – Proactive Management of Materials Degradation

Impetus for Proactive Management of Materials Degradation

- Develop information
  - Materials behavior
  - Mitigation or repair
  - Inspection or monitoring
- Proactively address potential future degradation
  - Avoid failures
  - Maintain integrity and safety
- Increase cooperation
  - Prioritize PMMD research with industry
  - Pursue additional international collaborations
- Evaluate existing requirements
  - Integrity of susceptible components
  - Inspection and monitoring regulations



Avoid Surprises e.g. V.C. Summer And Davis Besse



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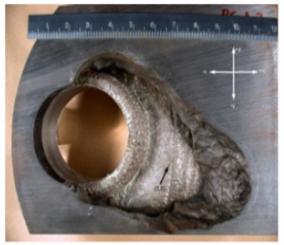
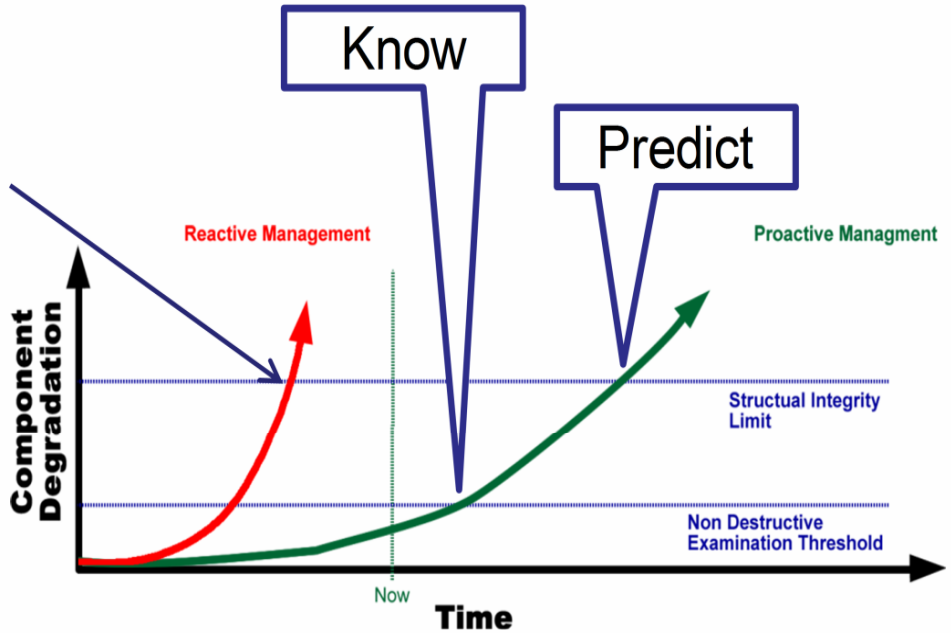
Solution: PMMD





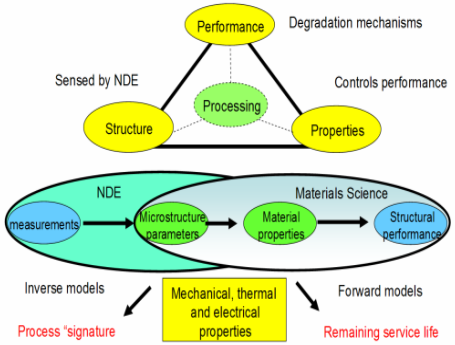
Numerous Large Reports

Distilled and Integrated via Information Tool

Help Identify Research Program Priorities

Degradation Time Line Knowledge Improved

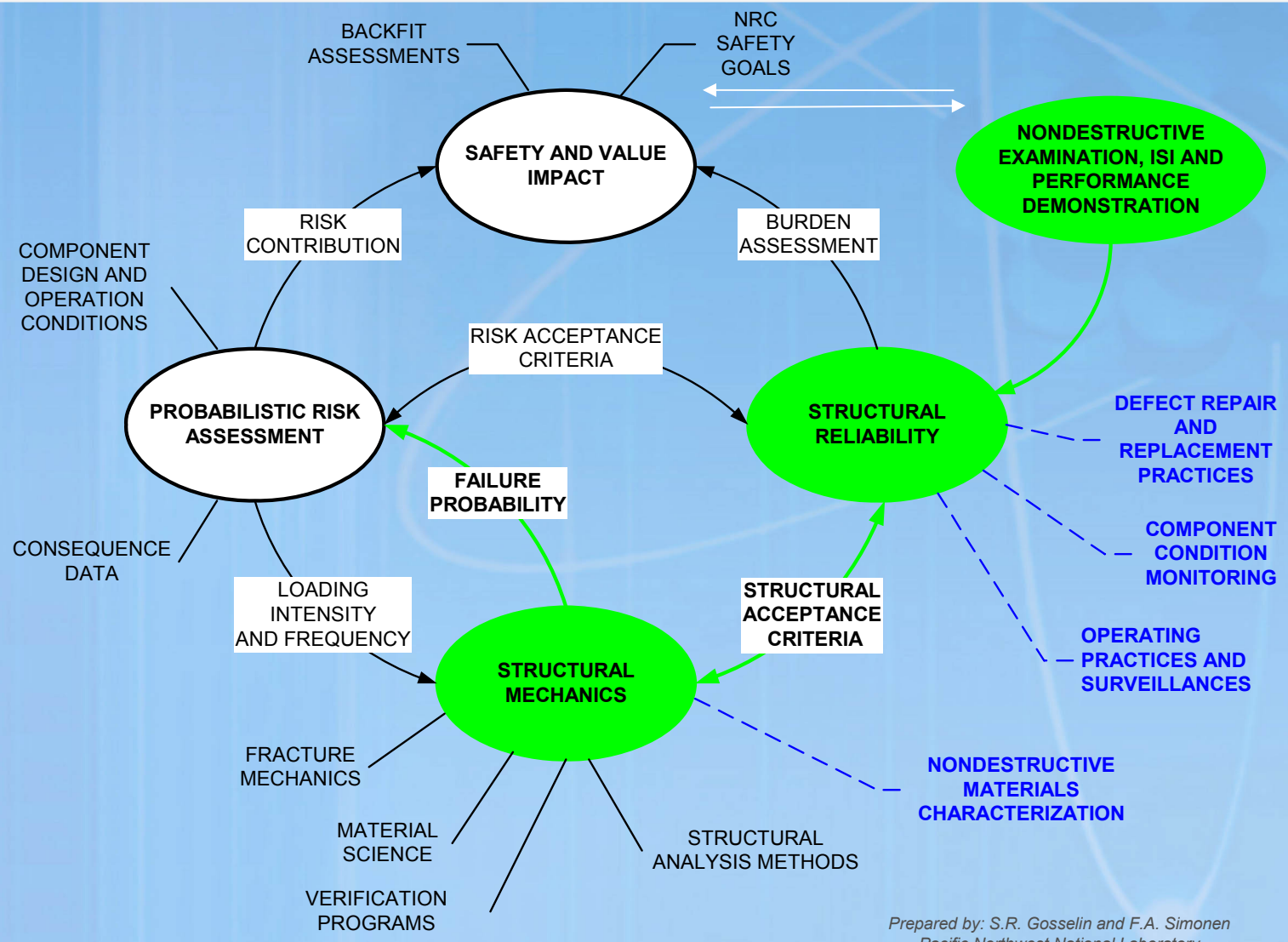
KNOW <u>SOONER</u>



PREDICT <u>ACCURATELY</u>

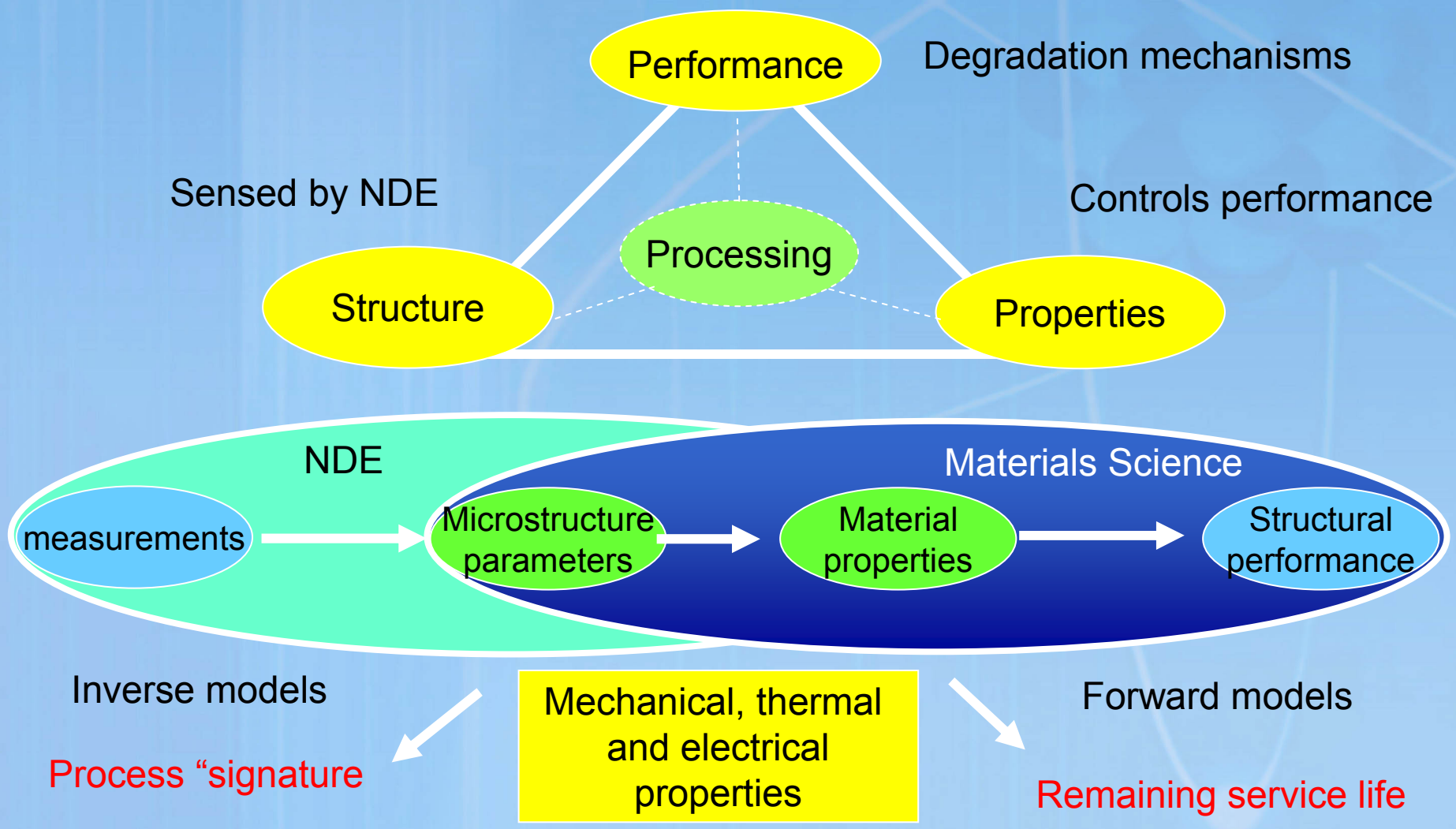
Better Regulation

Integrated Structural & Materials Reliability Program



Prepared by: S.R. Gosselin and F.A. Simonen
Pacific Northwest National Laboratory

Advanced Monitoring + Materials Science



Accomplishments from NRC Work on Proactive Approach to Assessment & Management of Materials Degradation

1. REACTOR COMPONENTS - Identify possible future degradation
   - NUREG/CR-6923 - "Expert Panel Report on Proactive Materials Degradation Assessment," 3895 pp. (published February 07)

2. ISI PROGRAMS - Assess regarding component degradation
   - NUREG "Assessment of Current Inservice Inspection and Leak Monitoring Practices for Detecting Materials Degradation in LWRs" (under revision)

3. RISK SIGNIFICANCE - Assess for component failure
   - Passive Component Conditional Core Damage Probability, Interim Report, March 2005 (John Ridgely –NRC PM)

4. FAILURE PROBABILITY - Estimate for susceptible components.
   - NUREG/CR-6936 "Probabilities of Failure and Uncertainty Estimate Information for Passive Components – A Literature Review (published May 2007, Shah Malik-NRC PM)
   - PNNL-16625 Technical Letter Report "Probabilistic Fracture Mechanics Evaluation of Selected Passive Components -- Technical Letter Report" (published May 2007, Shah Malik – NRC PM)

5. COLLABORATION - develop integrated research materials reliability research per SRM M041108AB and SRM M060206A
   - Proc. 3rd Planning Meeting for International Cooperative Group and Research Program for Proactive Materials Degradation (ML070540111 and CD, Feb'07)

PMMD- International Outreach

- NRC looking at developing a multi-year international activity
  - IAEA engagement (e.g. 3 year cooperative research program on Advanced Surveillance, Diagnostics, and Prognostics Techniques used for Health Monitoring of Systems, Structures, and Components in Nuclear Power Plants – PNNL/NRC – workshop May 2008)
  - Japanese and European engagement being investigated
  - PMMD – A review of principles and programs – NUREG/CR in Draft (January 2008)
  - PMMD – PNNL activity being developed
- PHM International Conf. on Prognostics & Health Management 2008
  http://www.phmconf.org/OCS/index.php/phm
  - *Proactive Management of Materials Degradation,*
    Leonard Bond, Tom Taylor, Steven Doctor, Amy Hull, Shah Malik

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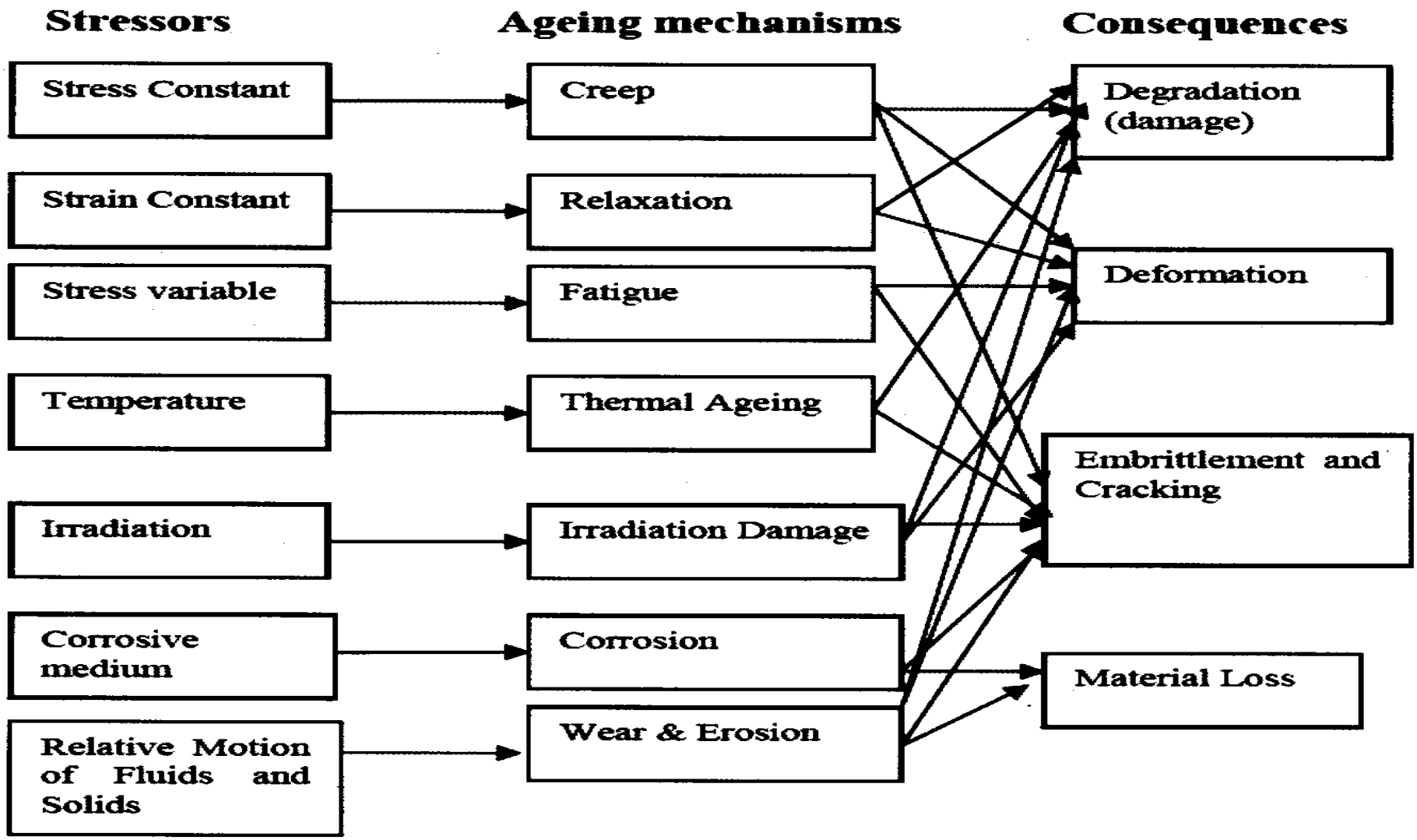
Aging Factors, Mechanisms & Possible Consequences



LWR Issue Management Tables

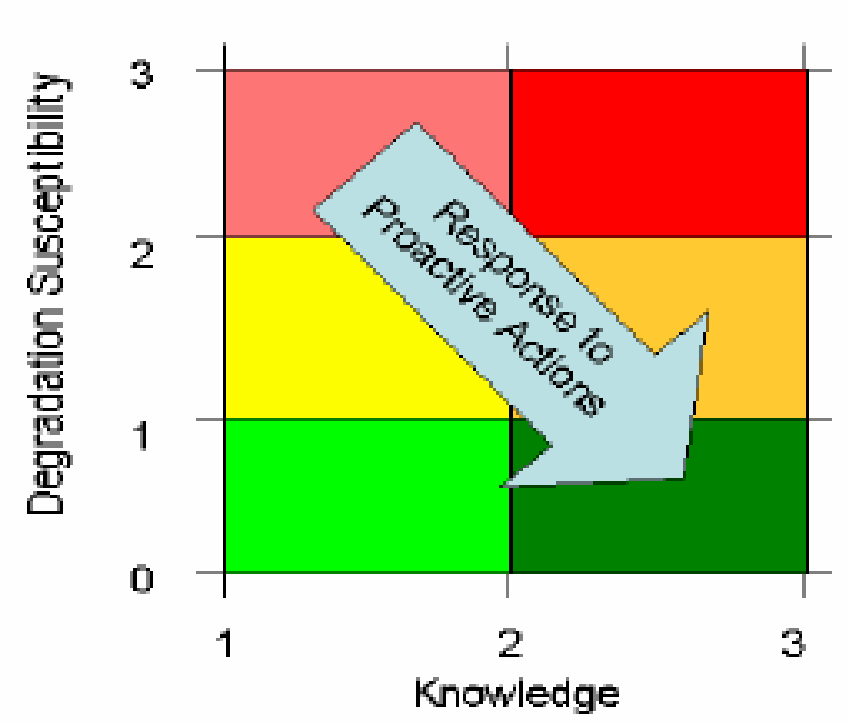
- "Bottom-up Approach" based on Materials Degradation Matrix (MDM)
  - Complementary to "Top-Down Approach" used in component-level PMDA/PIRT analysis
  - MDM and issue management tables (IMTs) to be maintained as living documents
- IMT focus on degradation of long-lived passive components
- Post-PMDA planning meetings addressed R&D on topics such as:
  - Materials and degradation mechanisms,
  - Mitigation, repair and replacement,
  - Nondestructive examination and continuous monitoring
- Common high priority R&D "gaps" identified from both PMDA and IMT evaluations
  - Inspection & evaluation (I&E) guidelines of reactor internals
  - Environmental fatigue of pressure boundary components
  - PWSCC management: Ni alloy reactor internals

Industry's Top Ten R&D Priorities
(from MRP-205)

1. Inspection & Evaluation (I&E) Guidelines: Reactor Internals (December 2008 – expected Industry Plans submittal to NRC/NRR)
2. NDE Technology: Dissimilar Metal (DM) Butt Welds
3. PWSCC Mitigation: Environmental Controls
4. I&E Guidelines: Bottom Mounted Nozzles
5. Vibration Fatigue: Small Bore Piping
6. Environmental Fatigue Issues: Press. Boundary Components
7. NDE Qualification Program: Ni-Alloy Penetrations
8. NDE Accessibility: Reactor Internals
9. PWSCC Mitigation: Stress Improvement (SI) of Butt Welds
10. Thermal & Irradiation Embrittlement: Synergistic Effects on CASS & SS Welds - Internals

Identification of Components with Highest Susceptibility to Degradation

- Materials degradation is highly likely, with limited knowledge for mitigation (pink zone)
  - 21 scenarios for PWRs
  - 1 scenario for BWRs.
- Materials degradation is highly likely, but knowledge exists for mitigation (red zone)
  - 24 scenarios for PWRs
  - 62 scenarios for BWRs



Work on Internals Testing Supported by Analyses of PMDA Scenario Results – high degradation susceptibility with limited knowledge for mitigation

System	Subgroup (Structure and/or Component)	Location on Structure and/or Component	Material	Environment	Aging Mechanism	LWR Type	Susceptibility
RCS	12.11 (reactor vessel internals)	Cold-worked austenitic reactor vessel internals	Type 316 austenitic SS	PWR primary water, >0.5 dpa (high fluence); 556°F to 620°F, 2250 psia	Irradiation creep (IC)	PWR	Pink
RCS	12.11 (reactor vessel internals)	Cold-worked austenitic reactor vessel internals	Type 316 austenitic SS	PWR primary water, >0.5 dpa (high fluence); 556°F to 620°F, 2250 psia	SCC	PWR	Pink
RCS	12.11 (reactor vessel internals)	Cold-worked austenitic reactor vessel internals	Type 316 austenitic SS	PWR primary water, >0.5 dpa (high fluence); 556°F to 620°F, 2250 psia	Swelling	PWR	Pink

Process to Develop Plan for Cooperation on PMMD Research

- Focus only on safety-significant items that correspond to high susceptibility, low knowledge, of relevance to operating and new reactors
  - Draw <u>as appropriate</u> upon draft overview program plan (OPP) w/ 62 work plans
    - ❑ Materials degradation (46)
    - ❑ Mitigation strategies (7)
    - ❑ NDE techniques (5)

Topic #	NUREG/CR-6923 Issue	OPP Chapter	OPP Section	PMDM Work Plan ID	OPP Title (NRC PMDM)	PWR IMT counterpart (from MRP-2005, Oct. 2006)	EPRI '07 Portfolio	MRP Project & Task Descroptions for 2007-2008 (Nov.06)
9	high susceptibility to SCC and wear for Alloy 600 MA SG tubes secondary side including crevices, PWR secondary water,544-620F, 1000psia (subgroups 11.6 and 11.14)	component	steam generators	5.1.1.10	SCC and mitigation for Alloy 600TT and 690TT in lead and sulfur contaminated solutions	MT-04 - ODSCC: Ni-Alloy SG Tubing ---- Investigate potential impact of impurities, most notably Pb on the SCC initiation and propagation in Ni Base Alloy Steam Generator Tubes (rated at medium priority) Resolution of this gap will involve development of	P41.01.02.02.01 Steam Generator Management Program (SGMP) Advanced Water Chemistry; P41.01.02.02.04 SGMP Materials and Thermal/Hydraulics -- Secondary-side steam generator tubing degradation continues in both recirculation and once-through steam generato	Although MT-04 was not referenced, a number of projects were generically related to Alloy 600.

Application: NRC Work on Proactive Approach to Assessment & Management of Materials Degradation

- Developing research plan for continued effort
- Customers: Regulators, Industry
- Results may lead to:
  - Modifying (if needed) 10 CFR 50.55a to ensure the integrity of degradation-susceptible components
  - Modifying (if needed) regulatory requirements for inspection and monitoring programs for risk-significant components
  - Implementing appropriate regulatory actions to keep materials degradation from adversely impacting safety (by performing calculations on failure probabilities and uncertainties for the reactor components as a function of operating time to quantify the likelihood of postulated failure mechanisms and their consequences)

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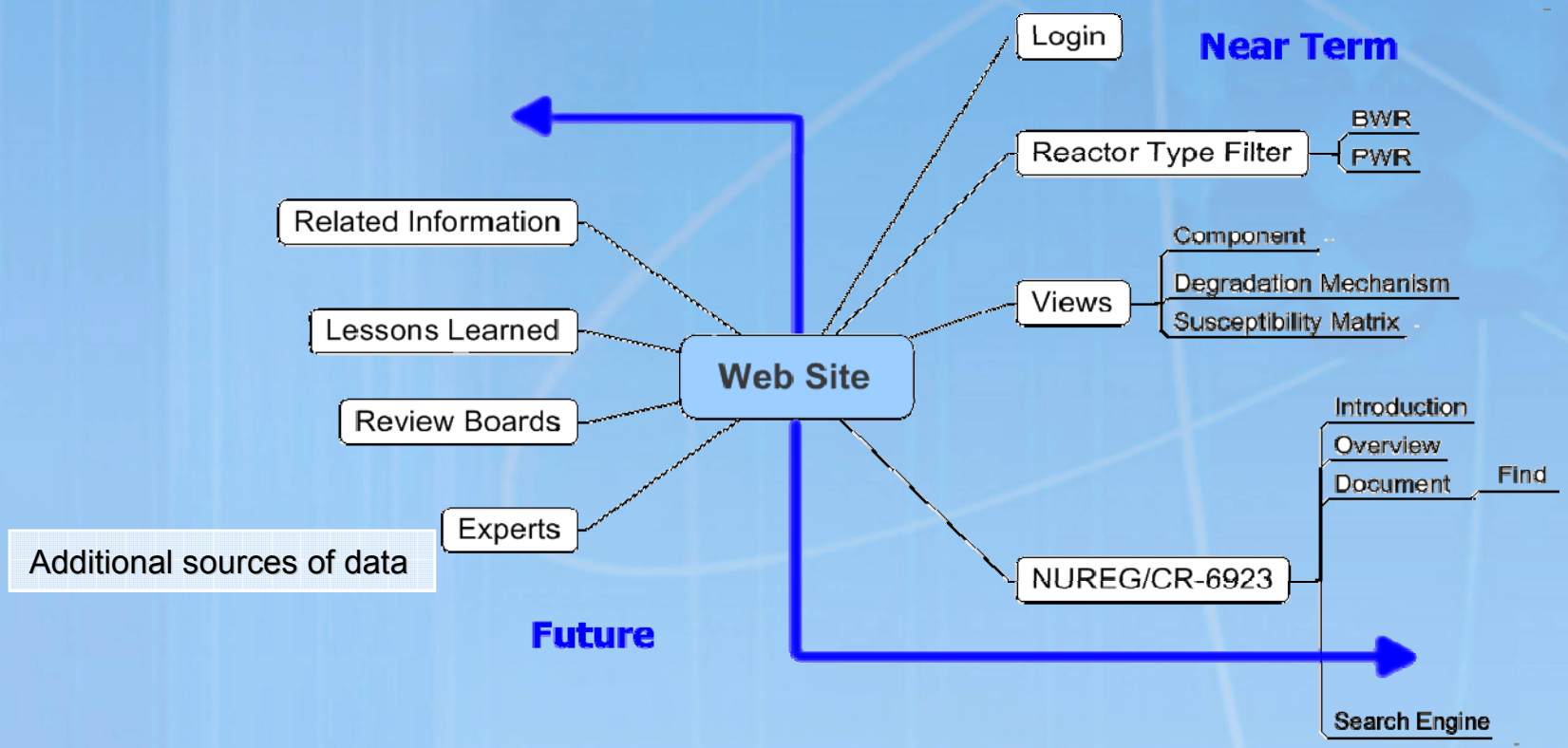
PROACTIVE MANAGEMENT OF MATERIALS DEGRADATION:

Information Tool: an introduction.

First Step: Developed from data in appendices of NRC NUREG/CR-6923 (2007)

Functional View of PMMD Website



Loaded locally on PNNL computer until any possible security issues are resolved

Using PMMD Tool: Reports

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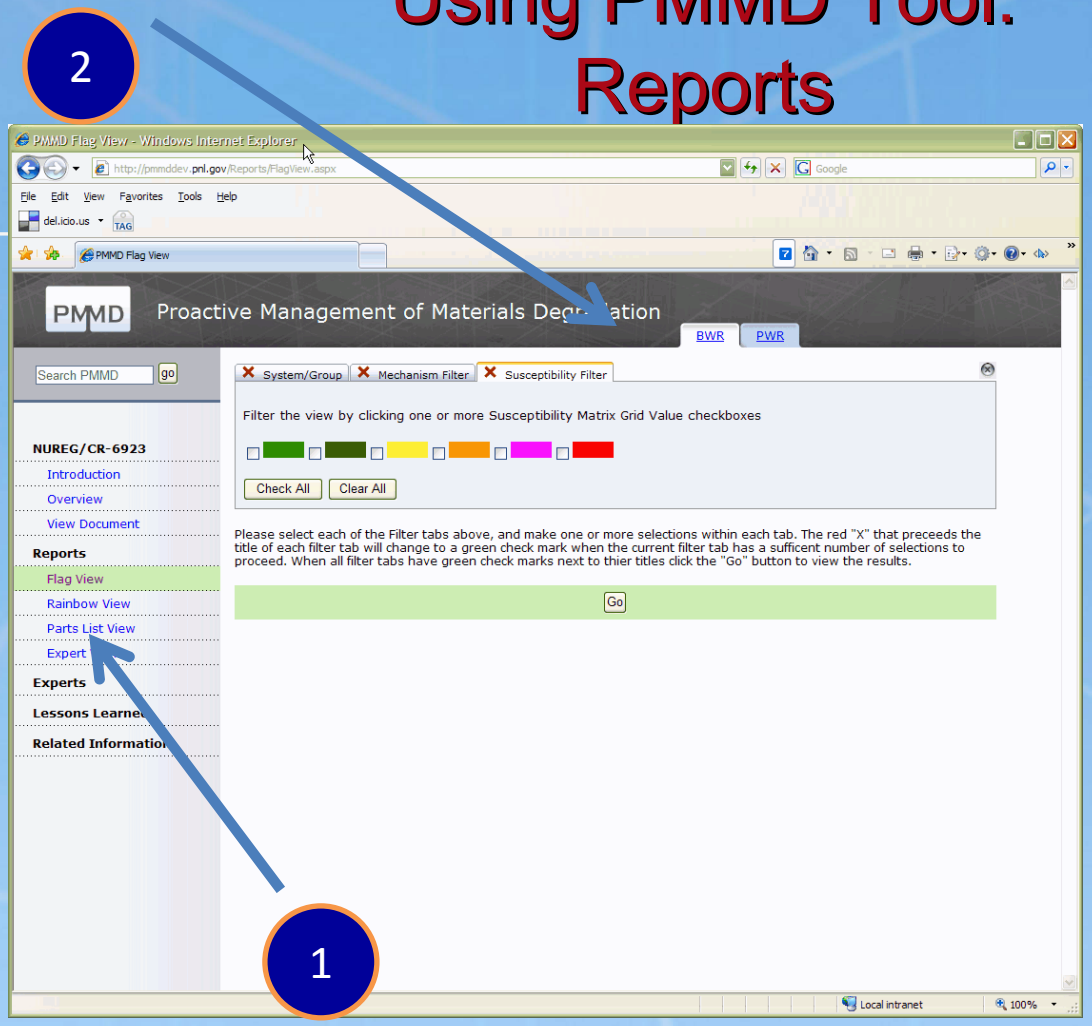
The Reports group in the left hand navigation column presents information from NUREG/CR-6923 that can be tailored by the user dynamically. Selecting "criteria" to filter within each of the reports is done using "Filters". Each type of filters functions identically in each of the reports but not all filters are available for each of the reports. Results match content "style" published in the original report but the information is a subset and focused based on filter choices made by the user. To get Started…



Click a report type. For purposes of illustration we have chosen "Flag View" in this example.

Select the type of Reactor you are interested in from the tabs at the top of the page. Choices are: Boiling Water Reactor (BWR) and Pressure Water Reactor (PWR). In this example we have chosen BWR

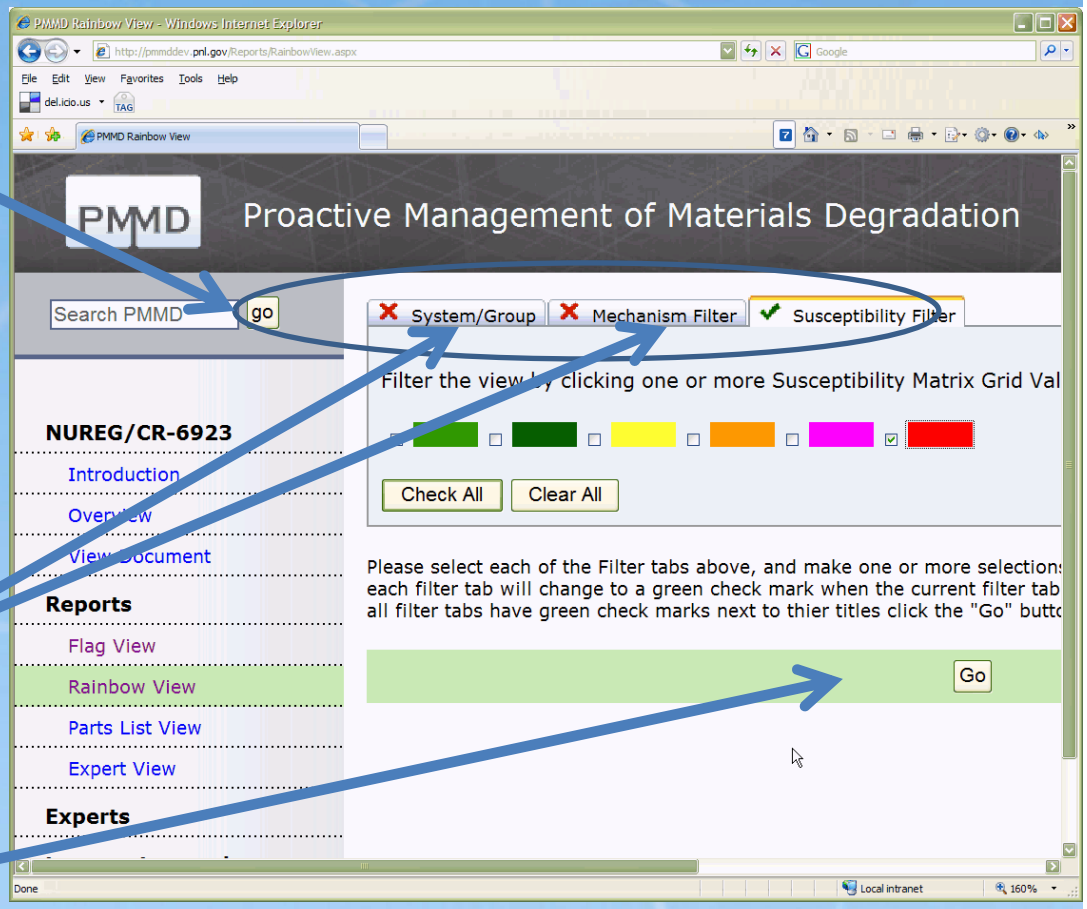
Using PMMD Tool: Using Filters

Report Filters are represented as "Tabs" which are displayed across the top of the main content area of the tool.

The user must select at least one criteria item from each of the filters by clicking on the tab and selecting "criteria" from each filter before they can get results.

A visual clue in the form of a red "X" or a green "check mark" indicates if the filter has enough selected criteria to generate a report.

When each filter tab has a green "check mark" the report can be generated by pressing the "Go" button.

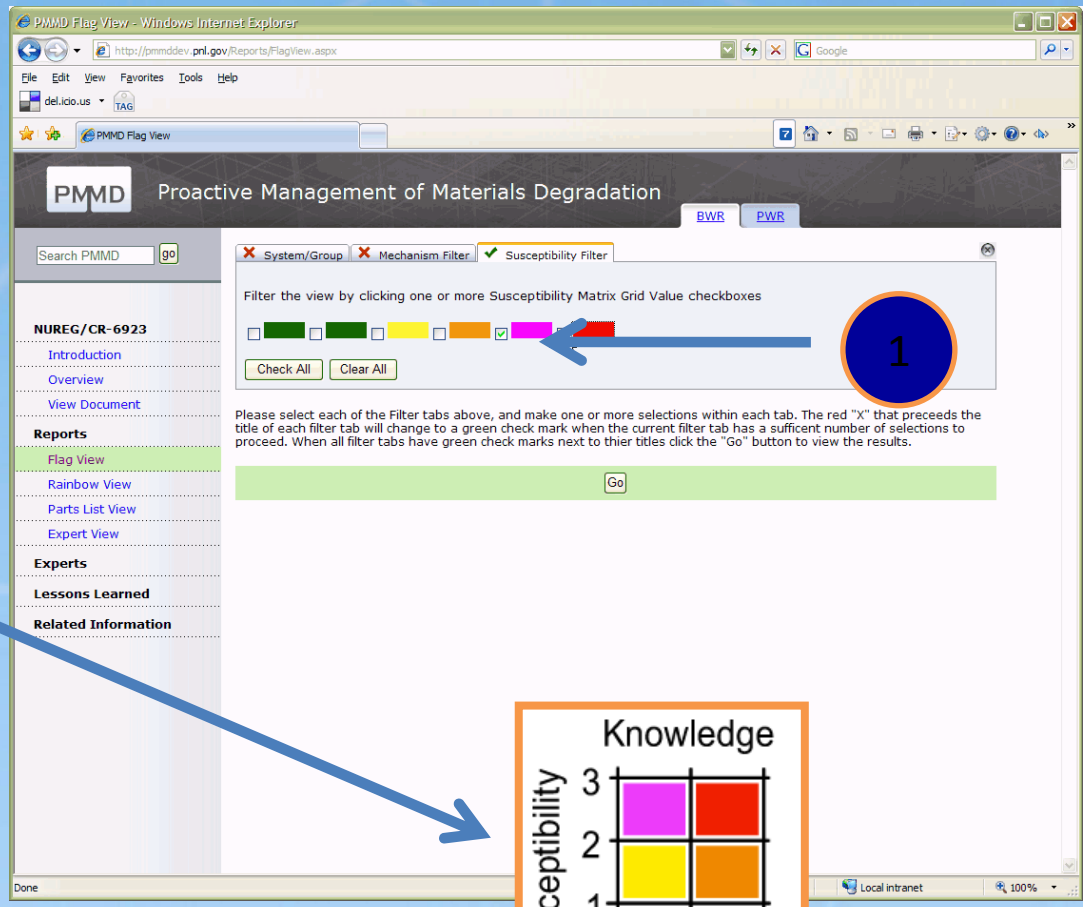


Using PMMD Tool: Susceptibility Filter

The Susceptibility filter allows the user to select a subset of the possible data based on the susceptibility matrix values

1) Select one or more Susceptibility Matrix Quadrant values in the Susceptibility Filter by clicking on the check box next to each possible value. (Note: future version of this tool will have a picture of the Susceptibility Matrix in this filter for greater clarification.)

The "Check All" will select all available options when clicked. The "Clear All" button will deselect all criteria that is currently selected. Both buttons only work in the context of this filter (i.e. criteria in other filters will not be affected by clicking these buttons)



Using PMMD Tool: Mechanism Filter

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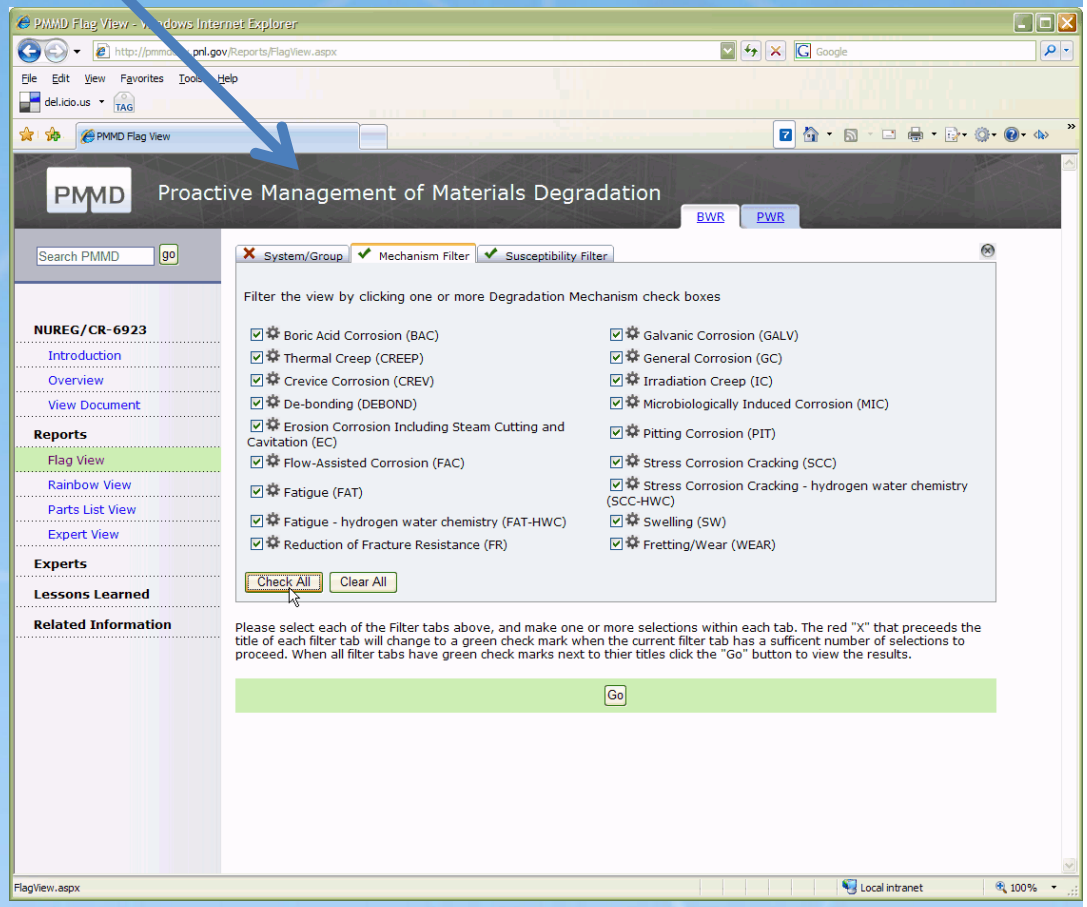
The Mechanism Filter is a simple list filter and represents the types of Degradation identified in NUREG/CR-6923

1) Clicking on the “Mechanism Filter” tab the user can select one or more Mechanisms by clicking the check box next to the desired mechanism description(s).

The “Check All” button will select all available options when clicked. The “Clear All” button will deselect all criteria that is currently selected. Both buttons only work in the context of this filter (i.e. criteria in other filters will not be affected by clicking these buttons)



Using PMMD Tool: System/Group Filter

The System/Group Filter is a “tree” control which means the choices are hierarchical in nature. The top level choice (System) can be further filtered to specific “children” (Groups).

1) To view the Groups within a system click on the folder icon next to the System name or the text describing the system name to display its groups.

The “Check All” button will select all available options when clicked. The “Clear All” button will deselect all criteria that is currently selected. Both buttons only work in the context of this filter (i.e. criteria in other filters will not be affected by clicking these buttons)

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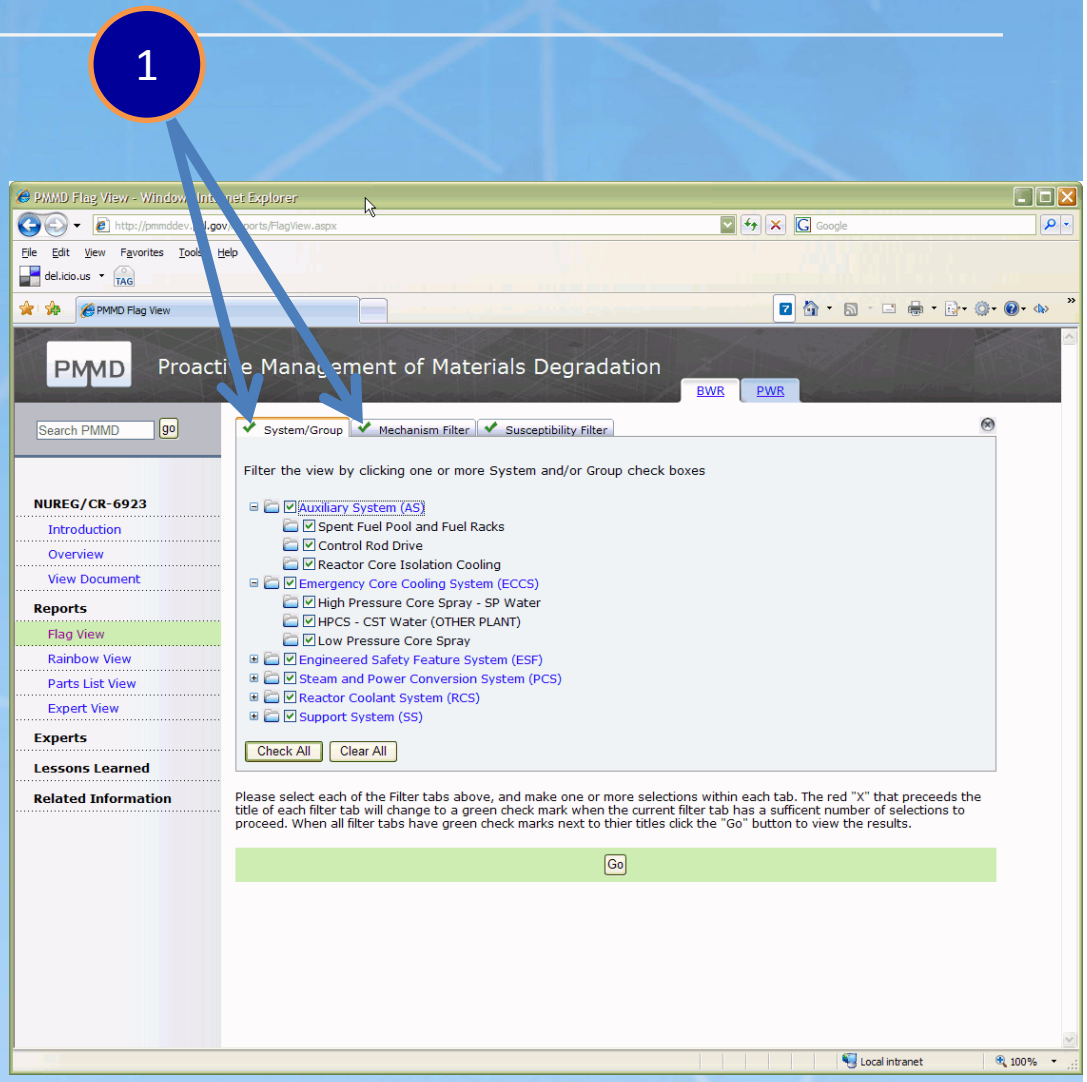
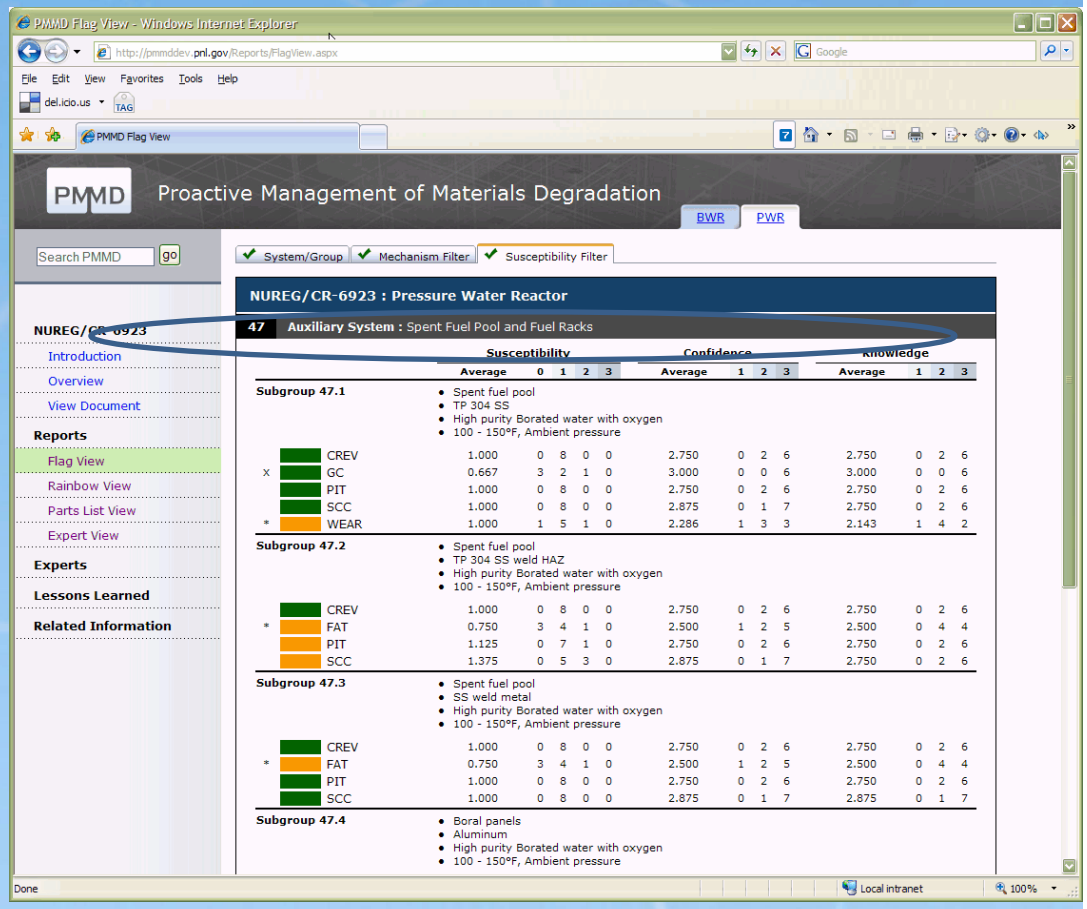


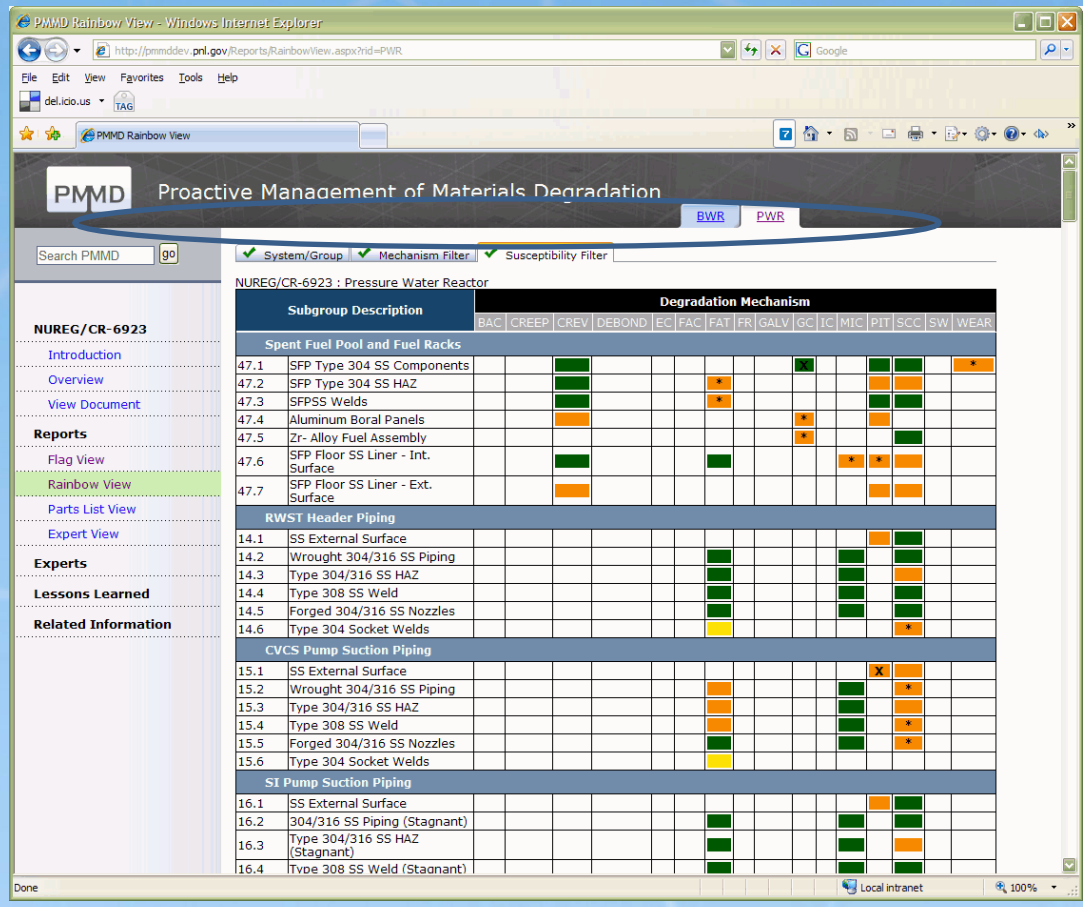
Using PMMD: The Flag View Report

The Flag View Report replicates information found in Appendix D sections 1 and 3 of NUREG/CR-6923. It summarizes susceptibility matrix ratings for degradation mechanisms and organizes them by System then Group and finally by Subgroup. It reports the aggregated values awarded by each of the experts for Susceptibility, Knowledge, and Confidence for each subgroup based on applicable degradation mechanisms for the "Components" in the subgroup. Those values are averaged and the Susceptibility Matrix coordinate is assigned to the Subgroup. Example: In Subgroup 47.1 of the Spent Fuel Pool and Fuel Racks group (a member of the Auxiliary System) the degradation mechanism "Crevice Corrosion (CREV)" received a Susceptibility rating of "Low" (1) from 8 experts. 6 experts rated their confidence in the possibility of CREV effecting the component as "High" (3) and 6 experts indicated the knowledge about CREV affecting this components is "High" (3).



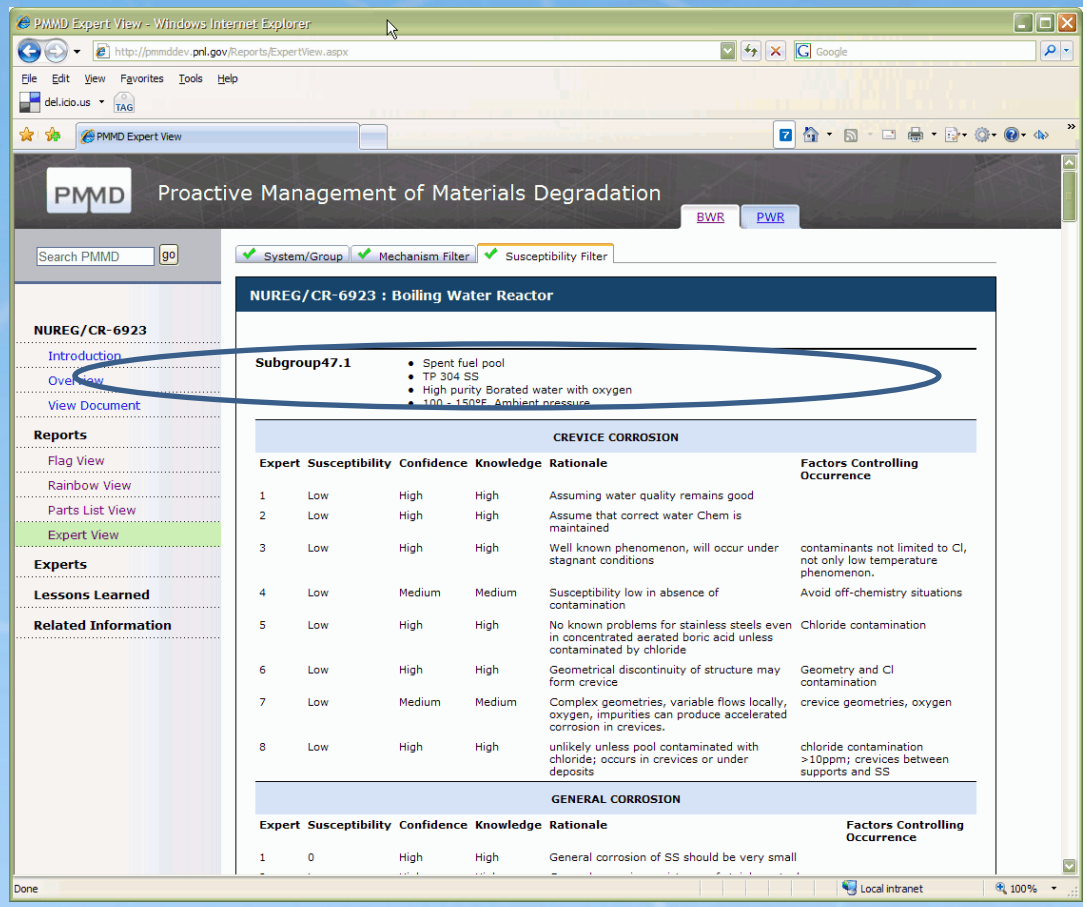
Using PMMD: The Rainbow View Report

The Rainbow View Report replicates information found in Appendix D sections 2 and 4 of NUREG/CR-6923. It lists specific subgroups within their “Group” and all of the degradation mechanisms with the susceptibility matrix coordinates that effect them. Example: Subgroup 47.1 (SEP Type 304 SS Components) within the Group “Spent Fuel Pool And Fuel Racks” has been evaluated to have the following degradation mechanisms Crevice Corrosion(CREV), General Corrosion (GC), Pitting Corrosion(PIT), Stress Corrosion Cracking (SCC) and Fretting/Wear (WEAR). CREV,GC,PIT, and SCC have Low Susceptibility with High Knowledge (Dark Green) and WEAR has Medium Susceptibility with High Knowledge (Dark Orange).



Using PMMD: The Expert View Report

The Expert View Report replicates information found in Appendix E sections 4 and Appendix F section 4 of NUREG/CR-6923. It presents the actual values each expert gave to each subgroup along with "Rational" and "Factors Controlling Occurrence" assessments from each expert. Example: In the Subgroup 47.1 Expert No. 1 ratted the Susceptibility as "Low", had "High" confidence in his/her Susceptibility rating and has "High" knowledge regarding the degradation mechanism "Crevice Corrosion (CREV)" effects on the subgroup. A comment about the Rational in that experts ratings is also presented.



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Path Forward & Conclusions

- Complete the 5-year PMMD Research Plan
- NRC is investigating how to best develop a PMMD international program.
- The PMMD Information Tool, and original NUREG/CR-6923, form a core element in this program.
  - Other sources of information will include, as appropriate and publicly available:
    - IMTs
    - OPDE Piping Database
    - Operating experience
    - NUREGs, GALL, other NRC sources
    - SCAP & PINC International activities

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Acronyms

- ADAMS — Agency-Wide Document Access and Management System
- CASS — Cast austenitic stainless steel
- DOE-NE — Department of Energy Office of Nuclear Energy
- EPRI — Electric Power Research Institute
- IAEA — International Atomic Energy Agency
- INPO — Institute of Nuclear Power Operations
- I&E — Inspection and Evaluation
- IMT — Issue Management Table
- ISI — Inservice Inspection
- LWR — Light Water Reactor
- NEI — Nuclear Energy Institute
- MDM — Materials Degradation Matrix
- NPP — Nuclear Power Plant
- NRC — Nuclear Regulatory Agency (U.S.)
- NRR — Nuclear Reactor Regulation (Office in NRC)
- OPDE — OECD Pipe Failure Data Exchange
- PINC — Program for Inspection of Nickel-Alloy Components
- PIRT — Phenomena Identification and Ranking Table
- PMDA — Proactive Material Degradation Assessment
- PMMD — Proactive Management of Materials Degradation
- PNNL — Pacific Northwest National Laboratory
- RIC — Regulatory Information Conference
- RIS — Regulatory Information Summary
- SCAP — SCC and cable aging project
- SKC — Susceptibility Knowledge-Confidence
- SRM — Staff Requirement Memorandum