Updates to MRP-189 for SLR

Background, Discussion, and Summary of Results

Kyle Amberge, EPRI-Materials Reliability Program
Principal Technical Leader

Sarah Davidsaver, Framatome Inc.
Principal Engineer

Steve Fyfitch, Framatome Inc.
Technical Consultant

Ryan Hosler, Framatome Inc.
Supervisory Engineer

Background of MRP-189 (1/3)

- BAW-2248A: NRC-approved in 2000 (see ML003708443)

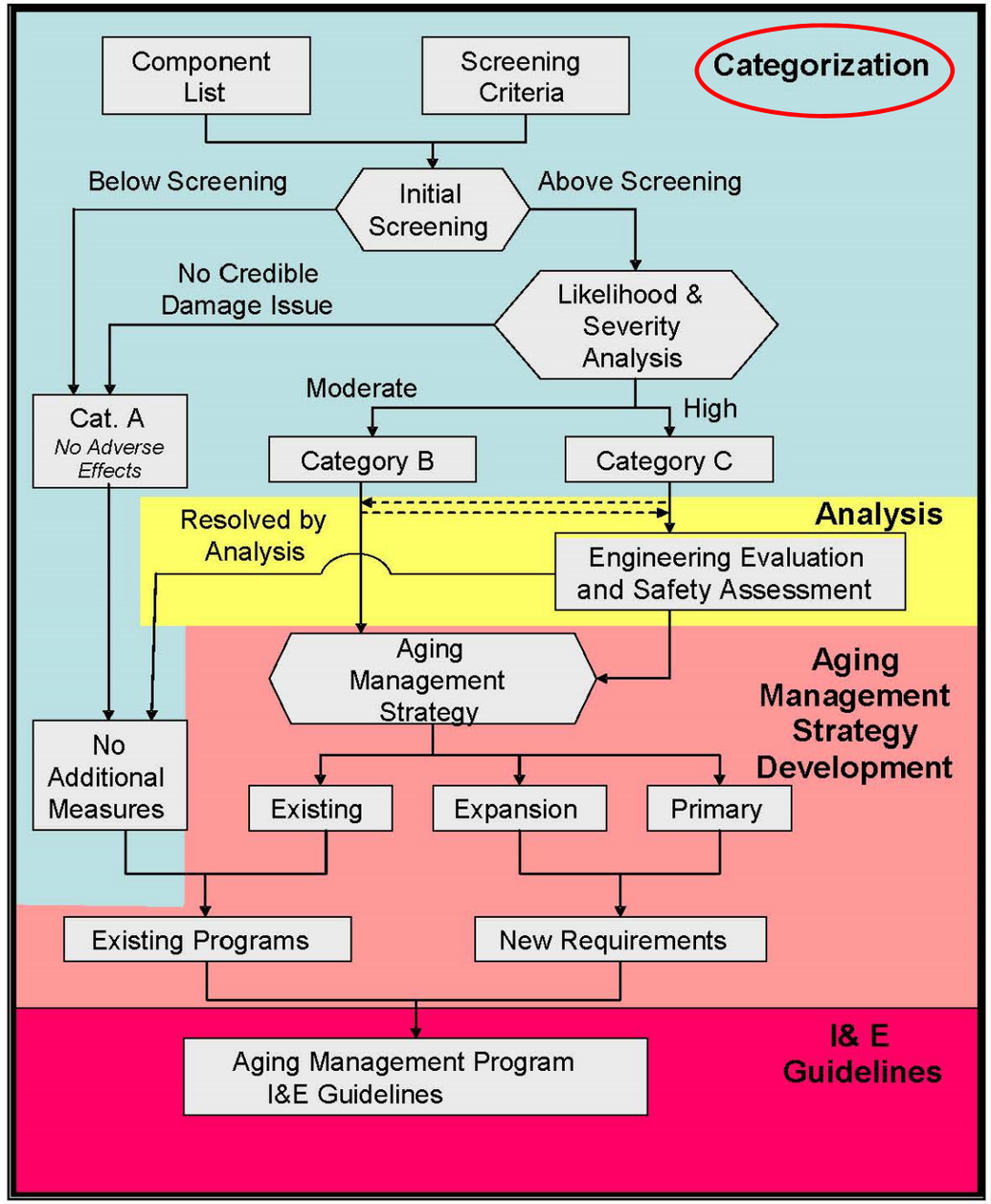
  "Demonstration of the Management of Aging Effects for the B&W Reactor Vessel Internals"
- MRP-189 Revision 0: published 2006 (not submitted to NRC)
- MRP-189 Revision 1: published 2009 (see ML091671777)
  - Purpose: include welds associated with component items
- MRP-189 Revision 2: published 2014 (see ML17289A507)
  - Purpose: update the preliminary categorization results to account for results obtained from a detailed records search for screening parameters and evaluations performed through May 2014
- MRP-189 Revision 3: published 2019 (see ML20017A345)
  - Purpose: preliminary categorization results for SLR using updated inputs

Background of MRP-189 (2/3)

- Document performs critical role in developing MRP-227
  - Lists in-scope component items and welds for Babcock & Wilcox (B&W) units (operating as of January 2019)
  - Compiles the input parameter results for the component items and welds (dose, stress, fatigue, wear, etc.)
  - Documents the results of expert panel evaluations for component item/weld susceptibility and consequences
  - Contains applicability criteria for MRP-227

Background of MRP-189 (3/3)

- MRP-189 contains everything in the 'Categorization' box
  - Provides preliminary categorization for downstream documents
  - Made updates based on new data and OE
- High safety consequence component items and welds
  - Typically receive additional engineering assessment
  - Typically become leading component items and welds ("Primary")
- Approach is the same as for MRP-227, Revision 0 and Revision 1



Differences in MRP-189 Revision 3 from Prior Revisions

- Separate lists of Preliminary Categorizations based on Safety and Economic consequences
  - Safety list used in MRP-227 development (consistent with previous MRP-227 revisions)
  - Economic list used for asset management and utility decision-making
- Operation through subsequent period of extended operation
  - Impacts accumulating time-based effects
  - Fluence-driven age-related degradation mechanisms can increase with dose
- CUF values not used since these are not available (see following slides)

Discussion of Fatigue (1/3)

- Fatigue Ranking Process
  - CUF calculations not available
  - Instead, ranking method used based on finite element model stresses
  - Stresses include:
    - Deadweight with and without fuel
    - Preload
    - Thermal transients
    - Gamma heating
    - Hydraulic loads
    - Loads associated with core clamping including reactor vessel ledge radial motions

Discussion of Fatigue (2/3)

- Fatigue Ranking Process (con't)
  - Only those component items or welds critical for core support, safe shutdown, or maintaining coolable geometry were considered
  - Internal component items that do not affect any of these three functions were only included if their presence affects the loading on a critical component item or weld
  - Also, component items that were screened in for fatigue in the previous revision (for example, baffle-to-former bolts) remain screened in for this revision and, therefore, were not modeled in detail for the fatigue ranking analysis

Discussion of Fatigue (3/3)

- Fatigue Ranking Process (con't)
  - The report lists Medium (M) and High (H) rankings
    - If not M or H, component item either was ranked as low (L) or does not support one of the three applicable functions
  - Ranking is specific to ONS-1, ONS-2, and ONS-3 but is considered representative for the B&W design
    - Unit-specific analysis is required to validate applicability to a given non-ONS unit when implementing this revision of MRP-189 or the associated downstream reports

  (See Section 3.2, Item H and Section 3.3, Item F in MRP-189 Revision 3)

Preliminary Categorizations Based on Economic Consequences

- MRP-189 Revisions 0, 1, and 2 treated Safety and Economic Consequences separate
  - Preliminary Categorizations based on Safety Consequence used to develop MRP-227 (Revisions 0 and 1)
  - No Preliminary Categorizations based on Economic Consequence made
- MRP-189 Revision 3 also treats Safety and Economic Consequences separate
  - Preliminary Categorizations based on Safety Consequence used to develop MRP-227 (Revision 2, consistent with previous revisions)
  - New lists of Preliminary Categorizations based on Economic Consequence

Accumulating Age-Related Degradation Mechanisms (1/4)

- Age-related degradation mechanisms with fluence as a screening criterion
  - Irradiation-assisted stress corrosion cracking (IASCC)
  - Irradiation-enhanced stress relaxation and creep (ISR/IC)
  - Irradiation embrittlement (IE)
  - Void Swelling (VS)
- Age-related degradation mechanisms increase with dose with some saturation effects
  - IASCC does not appear to saturate, but above 10 dpa, dose effects are small
  - ISR/IC does not saturate, but will decrease as remaining preload decreases
  - IE saturates between 10-20 dpa and is effectively unchanged afterwards (excluding very high VS effects)
  - VS does not saturate, but the VS rate may eventually saturate

Accumulating Age-Related Degradation Mechanisms (2/4)

- Fluence Input Development
  - Fluence values are best-estimate values at end of 80 years
  - Fluence values are projected from existing documentation
    - Example: fluence transport calculations for various components calculated to 60 years
  - Where fluence values are not available, fluence values are taken from the nearest component item, using engineering judgment

    (See Section 3.2, Item C and Section 3.3, Item B in MRP-189 Revision 3)

Accumulating Age-Related Degradation Mechanisms (3/4)

- Fluence Input Development (con't)
  - For fluence values < 3 dpa, fluence values are listed as less than the lowest applicable screening criterion that can be justified (i.e., < 1.5 dpa [IE])
    - Fluence screening criteria are as follows, consistent with MRP-175, Revision 1:
      - For bolted or spring locations, a fluence value of 0.2 dpa is applicable (ISR/IC)
      - For CASS and austenitic SS welds, a fluence value of 1 dpa is applicable (IE)
      - For austenitic SS (and other alloys that exceed this criterion), a fluence value of 1.5 dpa is applicable (IE)
      - For all alloys, a fluence value of 3 dpa is applicable (IASCC)
      - For all alloys, a fluence value of 20 dpa is applicable (VS)
  - For fluence values ≥ 3 dpa, actual estimated fluence values are listed

Accumulating Age-Related Degradation Mechanisms (4/4)

- Some degradation mechanisms have an inherent time component
  - Wear, stress corrosion cracking (SCC), IASCC, thermal aging embrittlement (TE)
  - Note that the time effect on other mechanisms is accounted for by increased fluence or increased fatigue usage
- Time aspect of these mechanisms included in MRP-175 Revision 1 screening criteria for use over the plant life
  - Wear: any component with potential relative motion
  - SCC: any component that exceeds threshold stress
  - IASCC: any component that exceeds threshold stress and dose
  - TE: any component that embrittles at reactor temperatures
- Time is already conservatively addressed by this approach

Unchanged Aspects of MRP-189 Revision 3

- Process
  - Expert panel approach
  - Consensus approach on decision making
  - Screening → Categorization → Ranking
- Assumptions affecting inputs (fuel management, base load operation, plant design changes)
- Component item and weld list
  - A few additions will be discussed
- Role of document and results in MRP-227 Revision 2 development

MRP-189 Revision 3 Revision Process

- Inputs for Expert Panel review
  - List of component items and welds and materials
  - Updated fluence and fatigue ranking inputs and initial component item and weld screening
  - Drawings, sketches, and descriptions of components and assemblies
  - Definitions for review process
- Expert Panel Review
  - Panel members covered the same MRP-189, Section 4 areas as before
  - Performed FMECA by validating or updating assigned safety and economic consequences
  - Applied a 100% consensus decision-making approach
  - Process is unchanged from previous revisions and documented in Section 4

MRP-189 Revision 3 Age-Related Degradation Mechanism Screening

- Started with the updated screening criteria in MRP-175 Revision 1
- Applied MRP-175 Revision 1 criteria directly in all but one case:
  - Directly: SCC, IASCC, Wear, Thermal Aging Embrittlement, Irradiation Embrittlement, Void Swelling, Irradiation-Enhanced Stress Relaxation and Creep
  - Not directly: Fatigue
    - As discussed previously, used a ranking process in lieu of lack of CUF values

Scope of Component Items and Welds Evaluated

- MRP-189 Revision 2 added many component items and welds identified through May 2014
  - Primarily identified through performance of MRP-227-A Applicant/Licensee Action Item (A/LAI) 2
- Additional component items and welds added in MRP-189 Revision 3
  - Component items and welds taken from completion of A/LAI 2 from MRP-227-A after MRP-189, Revision 2 was published

Input Applicability for MRP-189 Revision 3

- Assumptions were kept the same as used in MRP-227-A
  - Operation for 30 years or less with high-leakage core loading followed by low leakage loading
  - Operation as a base load unit for majority of plant life
  - No design changes beyond those identified in general industry guidance or by the OEM
- Must be verified by applicant/licensee as part of implementation (similar to MRP-227-A A/LAI 1)

Role of MRP-189 Revision 3 in Developing MRP-227 Revision 2

- Scoping – Defined the components that must be managed for extended operation (determined based on drawings and experts)
- Screening – Selected the components that could potentially experience age-related degradation (assigned based on MRP-175)
- Categorization – Determined by expert panel through FMECA
  - Susceptibility to degradation assigned (informed by OE)
  - Safety and Economic consequences assigned
  - Results in a FMECA group assignment
- Ranking – Assigned Preliminary Categories A, B, and C (from expert panel)

Role of MRP-189 Revision 3 Preliminary Categorizations in MRP-227 Revision 2 (1/2)

- Category A:
  - Components with aging effects below the screening criteria or that the panel considers to have minimal likelihood to cause failure
  - Components are screened out of further consideration for future steps in developing MRP-227 for SLR
- Category B:
  - Components above screening levels that are judged to have moderate susceptibility and potentially significant consequences, such that the effects on function cannot easily be dispositioned by screening but that do not rise to the level of lead items
  - Some components in Category B may be re-assigned to Category A if existing aging management is sufficient to preclude a concern
  - Components may require additional evaluation to be shown tolerant of the aging effects with no loss of functionality

Role of MRP-189 Revision 3 Preliminary Categorizations in MRP-227 Revision 2 (2/2)

- Category C:
  - "Lead" components with aging effects above screening levels and high or moderate likelihood and aging degradation significance
  - Engineering assessment could not demonstrate component/weld to be sufficiently damage-tolerant to remain functional during long-term operation
  - Enhanced or augmented inspections may be warranted under MRP-227
- Category C components are the primary focus for MRP-227
- Some Category C and B components will be evaluated analytically through modeling and other options (e.g., core barrel, baffle plates, former plates)

Summary of Results

- Updates made to address time-based parameters for SLR
  - Fluence projections updated for 80-year life
  - Ranking process used to address fatigue
- Expert panel reviewed the components and assigned consequence ranking and categorization for SLR
  - Largest number of components remained in “No Additional Measures” Category A
  - Smallest number of components in Safety Category C
  - Larger numbers of components in Economic Categories B and C than in the corresponding Safety Categories
    - Reflects expensive nature and economic risk of materials degradation

Number of Component Items/Welds in Consequence Category, B&W Units

- Safety Category C, Economic Category C
  - 12 groupings of component items and/or welds
- Safety Category A or B, Economic Category C
  - 38 groupings of component items and/or welds
- Details can be found in Section 5.3 of MRP-189 Revision 3

B&W Safety and Economic Category C Component Items and Welds

- Table 4-2 (component items) and Table 4-3 (welds) differences:
  - Differences in final category only (A, B, C) highlighted in MRP-189, Revision 3
    - Categories are a combination of susceptibility and safety consequence
    - Differences in specific aging degradation mechanisms not highlighted

B&W Safety and Economic Category C Component Items and Welds

1. Plenum cover assembly weldment rib pads
2. Plenum cover assembly support flange
3. Plenum cover assembly support ring
4. Core support shield assembly cylinder, including top and bottom flanges and circumferential flange welds (core support shield cylinder top flange only Category C for safety in MRP-189, Revision 2)
5. Core support shield assembly upper core barrel bolts (original and replacement) (core support shield assembly lower core barrel bolts also Category C for safety in MRP-189, Revision 2)
6. Core barrel assembly cylinder and top flange, including center and top flange circumferential welds (core barrel assembly cylinder bottom flange Category C for safety in MRP-189, Revision 2)
7. Core barrel assembly core barrel-to-former plate cap screws
8. Core barrel assembly baffle-to-former bolts/screws/special shoulder screws
9. Core barrel assembly baffle-to-baffle bolts/screws (internal and external)
10. Core barrel assembly former plates (core barrel assembly baffle plates also Category C for safety in MRP-189, Revision 2)
11. Lower grid assembly lower grid rib section (lower grid assembly shell forging and flow distributor bolts also Category C for safety in MRP-189, Revision 2)
12. Lower grid assembly shock pad bolts (TMI-1 only)

B&W Safety and/or Economic Category C Component Items and Welds

Component Item or Weld	Safety Category C	Economic Category C	Component Item or Weld	Safety Category C	Economic Category C
Plenum cover assembly weldment rib pads	✔	✔	Control rod guide tube assembly flange-to-upper grid cap screws		✔
Plenum cover assembly support flange	✔	✔	Control rod guide tube assembly spacer castings		✔
Plenum cover assembly support ring	✔	✔	Control rod guide tube assembly rod guide tubes		✔
Plenum cover assembly weldment rib welds		✔	Control rod guide tube assembly rod guide sectors		✔
Plenum cover assembly base blocks for lifting lugs (except ONS-1)		✔	ANO-1 RVLMS assembly – various component items		✔
Plenum cover assembly integral lifting lugs with base blocks (ONS-1)		✔	Core support shield assembly cylinder, including top and bottom flanges and circumferential flange welds	✔	✔
Upper grid assembly FA support pad cap screws and cap screw-to-FA support pad welds		✔	Core support shield assembly cylinder vertical seam welds		✔
Upper grid assembly rib-to-ring cap screws		✔	Core support shield assembly lifting lugs		✔

B&W Safety and/or Economic Category C Component Items and Welds

Component Item or Weld	Safety Category C	Economic Category C	Component Item or Weld	Safety Category C	Economic Category C
Core support shield assembly upper core barrel bolts (original and replacement)	✔	✔	Core barrel assembly baffle-to-baffle bolts/screws (internal and external)	✔	✔
Remaining SSHT assembly item: bearing (ONS-1, ONS-2, ONS-3)		✔	Core barrel assembly former plates	✔	✔
Vent valve assembly top and bottom retaining ring		✔	Core barrel assembly lower core barrel bolts (original and replacement)		✔
Vent valve assembly original and modified locking device component items		✔	Thermal shield cylinder and vertical and circumferential welds, including plugging welds		✔
Core barrel assembly cylinder bottom flange, bottom flange circumferential weld, and vertical seam welds		✔	Core barrel assembly upper thermal shield bolts (original)		✔
Core barrel assembly cylinder and top flange, including center and top flange circumferential welds	✔	✔	Core barrel assembly remaining SSHT assembly hex head bolt (ONS-1, ONS-2, ONS-3, ANO-1)		✔
Core barrel assembly core barrel-to-former plate cap screws	✔	✔	Core barrel assembly baffle plates		✔
Core barrel assembly baffle-to-former bolts/screws/special shoulder screws	✔	✔	Core barrel assembly SSHT bolts and locking devices (tie plates, compression collars, washers, and crimped locking cups) (DB only; replacement)		✔

B&W Safety and/or Economic Category C Component Items and Welds

Component Item or Weld	Safety Category C	Economic Category C	Component Item or Weld	Safety Category C	Economic Category C
Lower grid assembly lower grid rib section	✔	✔	Lower grid weldment ribs (ONS-1)		✔
Lower grid assembly lower grid FA support pad cap screws		✔	Lower grid assembly guide block bolts (except DB)		✔
Lower grid shell forging		✔	Lower grid assembly lower thermal shield bolts, studs, and nuts (original and replacement)		✔
Lower grid assembly rib-to-shell forging cap screws		✔	Flow distributor assembly flow distributor bolts (original)		✔
Lower grid assembly shock pad bolts (TMI-1 only	✔	✔	IMI guide tube assembly IMI guide tubes		✔
Lower grid forging (except ONS-1)		✔	IMI guide tube assembly IMI guide tube nuts		✔

B&W Safety Heat Map

A1-D1 shown in detail on Slide 30

A2-D2
A3-D3 shown in detail on Slide 31
A4-D4

B&W Safety Category Heat Map

Increasing Safety Consequence from 1 to 4

Increasing Susceptibility from A to D

	A	B	C	D
1		P.1.1 PC Weldment Ribs P.1.3 PC Bottom Flange P.1.6 PC Cover Plate P.1.8 PC (Except ONS-1) Base Blocks for Lifting Lugs P.1.11 PC (ONS-1) Integral Lifting Lugs with Base Blocks P.1.12 PC Letter Plate (Letter W) P.2.1 Plenum Cylinder P.2.2 Plenum Cylinder Top Flange P.2.3 Plenum Cylinder Bottom Flange P.2.4 Plenum Cylinder (Except DB) Reinforcing Plates P.2.8 Plenum Cylinder Bottom Flange-to-UG Bolts P.4.10a-P.4.10m ANO-1 RVLMS Items S.5a,b (TMI-1, DB) UCB Compression Collars S.5b (ANO-1, DB) UCB Crimped Locking Cups S.6a (Except ONS-3, DB) CSS Outlet Nozzles S.16 CSS Flow Deflectors S.17 CSS Lifting Lugs S.18-S.21 Remaining SSHT Assembly Items (ONS, ANO-1) S.7 VV Nozzles S.11k VV Modified Locking Device: Spec. Hex Head Screw B.5b (DB) LCB Crimped Locking Cups B.16 TS Upper Restraint Cap Screws (not exposed) L.1.10 LG Shell Forging L.1.7 LG FD Plate L.1.9a (Except ONS-1) LG Forging L.1.9b (ONS-1) LG Weldment Ribs L.1.13 (Except DB) Guide Blocks (Mating with Guide Lugs on RV) L.1.22 (DB) Guide Blocks (Mating with Guide Lugs on RV) L.1.18 LG Support Post Pipes L.1.19 LG Support Post Pipe Bolting Plugs L.1.12 (ONS) LTS Replacement Stud/Nut Crimped Locking Cups L.1.12 (DB, ANO-1) LTS Replacement Crimped Locking Cups L.2.1 FD Head L.2.2 FD Flange L.2.6 IMI Guide Support Plate Clamping Ring L.3.2 IMI Guide Tube Gussets	P.3.5 UG FASPs P.3.6 UG FASP Dowels P.3.7 UG FASP Cap Screws P.3.3 UG Rib-to-Ring Cap Screws P.4.3 CRGT Flange-to-UG Cap Screws P.4.5 CRGT Spacer Castings P.4.10f ANO-1 RVLMS Brazement Guide Assembly—J-Bolt and Nut S.22 Remaining SSHT Assembly Item: Bearing (ONS) S.10 VV Top Retaining Ring S.10 VV Bottom Retaining Ring S.11a –S.11e and S.11g VV Original Locking Device Items S.11h,i and S.11l VV Modified Locking Device Items B.3 CB Bottom Flange B.4b (ONS-1) LCB Original Type 304 Bolts B.4c (TMI-1) LCB Original Bolts B.4d (DB) LCB Replacement Bolts B.5a,b (TMI-1, DB) LCB Compression Collars B.10 TS Cylinder B.6a (Except TMI-1) UTS Original Bolts B.6b (TMI-1) UTS Original Bolts B.28a-B.28f Remaining SSHT Assembly Items (ONS) B.28g Remaining SSHT Assembly Hex HD Bolt (ONS, ANO-1) B.20 CB-to-FP Cap Screw Locking Pins B.21 CB-to-FP Dowels B.8b (DB) Replacement SSHT Bolts B.9 (DB) Replacement SSHT Bolt Locking Device Items L.1.5 LG Rib-to-Shell Forging Cap Screws L.1.14a (Except DB) Guide Block Bolts (Mating with Guide Lugs on RV) L.1.20 LG Support Post Pipe Cap Screws L.1.11b (ONS) LTS Replacement Studs L.1.11b (ONS) LTS Replacement Nuts L.1.11c (DB, ANO-1) LTS Replacement Bolts L.3.1 IMI Guide Tubes L.3.4 IMI Guide Tube Nuts L.3.6 IMI Guide Tube Spider Castings	B.4a (ANO-1, DB, ONS) LCB Original Bolts B.23 (Except ONS-1, TMI-1) BF Bolt Locking Pins (except F4) B.23 (ONS-1, TMI-1) BF Screw Locking Wires (except F4) B.25 BF Shoulder Screw Locking Dowels (F4) B.27 (Except ONS-1, TMI-1) Internal and External BB Bolt Locking Rings B.27 (ONS-1, TMI-1) Internal BB Screw Locking Wires B.27 (ONS-1, TMI-1) External BB Screw Locking Washers B.27 (ONS-1, TMI-1) External BB Screw Locking Wires L.1.2-L.1.4 LG FA Support Pads and items L.1.11a (TMI-1) LTS Original Bolts L.2.3a (Except TMI-1) FD Original Bolts L.2.3b (TMI-1) FD Original Bolts
2		P.4.8 CRGT Rod Guide Tubes P.4.9 CRGT Rod Guide Sectors B.17 BPs	P.1.2 PC Weldment Rib Pads P.1.4 PC Support Flange P.1.5 PC Support Ring B.18 FPs B.19 CB-to-FP Cap Screws B.22 (Except ONS-1, TMI-1) BF Hex Head Bolts (except F4) B.22 (ONS-1, TMI-1) BF Button Head Socket Cap Screws (except F4) B.24 BF Shoulder Screws (F4) B.26 (Except ONS-1, TMI-1) Internal and External BB Bolts B.26 (ONS-1, TMI-1) Internal BB Socket Head Cap Screws B.26 (ONS-1, TMI-1) External BB Socket Head Cap Screws (Design A) B.26 (ONS-1, TMI-1) External BB Socket Head Cap Screws (Design B) L.1.1 LG Rib Section	L.1.17b Shock Pad Bolts (TMI-1 only)
3		S.1 CSS Cylinder S.2 CSS Top Flange S.3 CSS Bottom Flange	S.4b (TMI-1) UCB Original Bolts S.4c,d (ANO-1, DB) UCB Replacement Bolts B.2 CB Top Flange	S.4a (ONS) UCB Original Bolts B.1 CB Cylinder
4				

Initialisms: ANO-Arkansas Nuclear One, BB-Baffle-to-Baffle, BF-Baffle-to-Former, BP-Baffle Plate, CB-Core Barrel, CRGT-Control Rod Guide Tube, CSS-Core Support Shield, DB-Davis-Besse, FASP-Fuel Assembly Support Pad, FD-Flow Distributor, FP-Former Plate, IMI-In-core Monitoring Instrumentation, LCB-Lower Core Barrel, LG-Lower Grid, LTS-Lower Thermal Shield, ONS-Oconee Nuclear Station, PC-Plenum Cover, RV-Reactor Vessel, RVLMS-Reactor Vessel Level Monitoring System, SSHT-Surveillance Specimen Holder Tube, TMI-Three Mile Island, TS-Thermal Shield, UCB-Upper Core Barrel, UG-Upper Grid, UTS-Upper Thermal Shield, VV-Vent Valve

B&W Safety Heat Map, A1-D1

Safety Consequence of 1

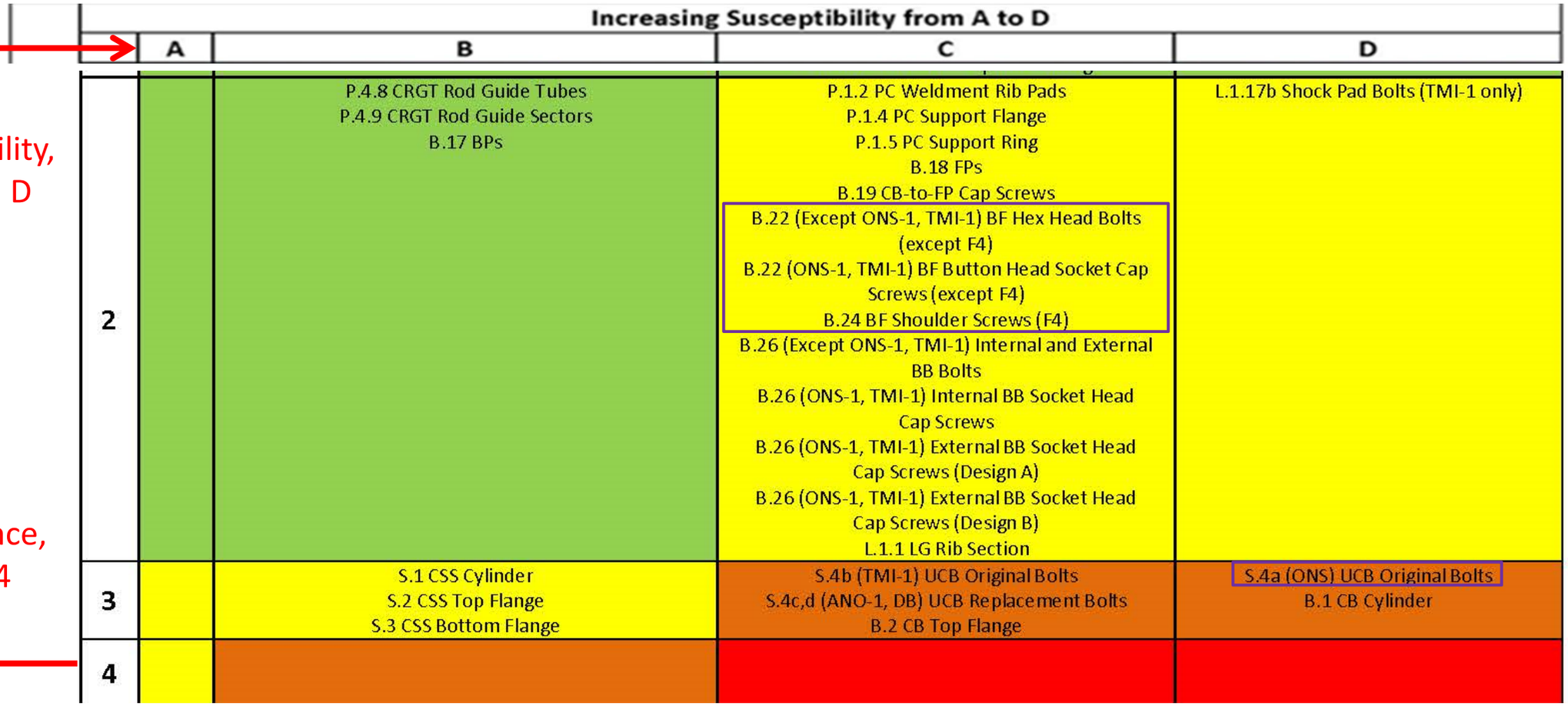
Susceptibility, A through D

Increasing Susceptibility from A to D				
	A	B	C	D
1		P.1.1 PC Weldment Ribs P.1.3 PC Bottom Flange P.1.6 PC Cover Plate P.1.8 PC (Except ONS-1) Base Blocks for Lifting Lugs P.1.11 PC (ONS-1) Integral Lifting Lugs with Base Blocks P.1.12 PC Letter Plate (Letter W) P.2.1 Plenum Cylinder P.2.2 Plenum Cylinder Top Flange P.2.3 Plenum Cylinder Bottom Flange P.2.4 Plenum Cylinder (Except DB) Reinforcing Plates P.2.8 Plenum Cylinder Bottom Flange-to-UG Bolts P.4.10a-P.4.10m ANO-1 RVLMS Items S.5a,b (TMI-1, DB) UCB Compression Collars S.5b (ANO-1, DB) UCB Crimped Locking Cups S.6a (Except ONS-3, DB) CSS Outlet Nozzles S.16 CSS Flow Deflectors S.17 CSS Lifting Lugs S.18-S.21 Remaining SSHT Assembly Items (ONS, ANO-1) S.7 VV Nozzles S.11k VV Modified Locking Device: Spec. Hex Head Screw B.5b (DB) LCB Crimped Locking Cups B.16 TS Upper Restraint Cap Screws (not exposed) L.1.10 LG Shell Forging L.1.7 LG FD Plate L.1.9a (Except ONS-1) LG Forging L.1.9b (ONS-1) LG Weldment Ribs L.1.13 (Except DB) Guide Blocks (Mating with Guide Lugs on RV) L.1.22 (DB) Guide Blocks (Mating with Guide Lugs on RV) L.1.18 LG Support Post Pipes L.1.19 LG Support Post Pipe Bolting Plugs L.1.12 (ONS) LTS Replacement Stud/Nut Crimped Locking Cups L.1.12 (DB, ANO-1) LTS Replacement Crimped Locking Cups L.2.1 FD Head L.2.2 FD Flange L.2.6 IMI Guide Support Plate Clamping Ring L.3.2 IMI Guide Tube Gussets	P.3.5 UG FASPs P.3.6 UG FASP Dowels P.3.7 UG FASP Cap Screws P.3.3 UG Rib-to-Ring Cap Screws P.4.3 CRGT Flange-to-UG Cap Screws P.4.5 CRGT Spacer Castings P.4.10f ANO-1 RVLMS Brazement Guide Assembly—J-Bolt and Nut S.22 Remaining SSHT Assembly Item: Bearing (ONS) S.10 VV Top Retaining Ring S.10 VV Bottom Retaining Ring S.11a –S.11e and S.11g VV Original Locking Device Items S.11h,i and S.11l VV Modified Locking Device Items B.3 CB Bottom Flange B.4b (ONS-1) LCB Original Type 304 Bolts B.4c (TMI-1) LCB Original Bolts B.4d (DB) LCB Replacement Bolts B.5a,b (TMI-1, DB) LCB Compression Collars B.10 TS Cylinder B.6a (Except TMI-1) UTS Original Bolts B.6b (TMI-1) UTS Original Bolts B.28a-B.28f Remaining SSHT Assembly Items (ONS) B.28g Remaining SSHT Assembly Hex HD Bolt (ONS, ANO-1) B.20 CB-to-FP Cap Screw Locking Pins B.21 CB-to-FP Dowels B.8b (DB) Replacement SSHT Bolts B.9 (DB) Replacement SSHT Bolt Locking Device Items L.1.5 LG Rib-to-Shell Forging Cap Screws L.1.14a (Except DB) Guide Block Bolts (Mating with Guide Lugs on RV) L.1.20 LG Support Post Pipe Cap Screws L.1.11b (ONS) LTS Replacement Studs L.1.11b (ONS) LTS Replacement Nuts L.1.11c (DB, ANO-1) LTS Replacement Bolts L.3.1 IMI Guide Tubes L.3.4 IMI Guide Tube Nuts L.3.6 IMI Guide Tube Spider Castings	B.4a (ANO-1, DB, ONS) LCB Original Bolts B.23 (Except ONS-1, TMI-1) BF Bolt Locking Pins (except F4) B.23 (ONS-1, TMI-1) BF Screw Locking Wires (except F4) B.25 BF Shoulder Screw Locking Dowels (F4) B.27 (Except ONS-1, TMI-1) Internal and External BB Bolt Locking Rings B.27 (ONS-1, TMI-1) Internal BB Screw Locking Wires B.27 (ONS-1, TMI-1) External BB Screw Locking Washers B.27 (ONS-1, TMI-1) External BB Screw Locking Wires L.1.2-L.1.4 LG FA Support Pads and items L.1.11a (TMI-1) LTS Original Bolts L.2.3a (Except TMI-1) FD Original Bolts L.2.3b (TMI-1) FD Original Bolts
		P.4.8 CRGT Rod Guide Tubes	P.1.2 PC Weldment Rib Pads	L.1.17b Shock Pad Bolts (TMI-1 only)

B&W Safety Heat Map, A2-D2, A3-D3, A4-D4

Susceptibility, A through D

Safety Consequence, 2 through 4



	Increasing Susceptibility from A to D			
	A	B	C	D
2		P.4.8 CRGT Rod Guide Tubes P.4.9 CRGT Rod Guide Sectors B.17 BPs	P.1.2 PC Weldment Rib Pads P.1.4 PC Support Flange P.1.5 PC Support Ring B.18 FPs B.19 CB-to-FP Cap Screws B.22 (Except ONS-1, TMI-1) BF Hex Head Bolts (except F4) B.22 (ONS-1, TMI-1) BF Button Head Socket Cap Screws (except F4) B.24 BF Shoulder Screws (F4) B.26 (Except ONS-1, TMI-1) Internal and External BB Bolts B.26 (ONS-1, TMI-1) Internal BB Socket Head Cap Screws B.26 (ONS-1, TMI-1) External BB Socket Head Cap Screws (Design A) B.26 (ONS-1, TMI-1) External BB Socket Head Cap Screws (Design B) L.1.1 LG Rib Section	L.1.17b Shock Pad Bolts (TMI-1 only)
3		S.1 CSS Cylinder S.2 CSS Top Flange S.3 CSS Bottom Flange	S.4b (TMI-1) UCB Original Bolts S.4c,d (ANO-1, DB) UCB Replacement Bolts B.2 CB Top Flange	S.4a (ONS) UCB Original Bolts B.1 CB Cylinder
4				

B&W Economic Heat Map

A1-D1
A2-D2 shown in detail on Slide 33

A3-D3
A4-D4 shown in detail on Slide 34

B&W Unit Economic Category Heat Map

Increasing Economic Consequence from 1 to 4 / Increasing Susceptibility from A to D

	A	B	C	D
1		P.1.12 PC Letter Plate (Letter W) S.5a,b (TMI-1, DB) UCB Bolt Compression Collars S.5b (ANO-1, DB) UCB Bolt Crimped Locking Cups S.16 CSS Flow Deflectors B.5b (DB) LCB Bolt Crimped Locking Cups L.1.19 LG Support Post Pipe Bolting Plugs L.1.12 (ONS) LTS Replacement Stud/Nut Crimped Locking Cups L.1.12 (DB, ANO-1) LTS Bolt Replacement Crimped Locking Cups L.2.6 IMI Guide Support Plate Clamping Ring	P.3.5 UG FASPs P.3.6 UG FASP Dowels B.4b (ONS-1) LCB Original Type 304 Bolts B.5a,b (TMI-1, DB) LCB Bolt Compression Collars B.28a-B.28f Remaining SSHT Assembly Items (ONS) B.20 CB-to-FP Cap Screw Locking Pins B.21 CB-to-FP Dowels L.1.20 LG Support Post Pipe Cap Screws L.3.6 IMI Guide Tube Spider Castings	B.23 (Except ONS-1, TMI-1) BF Bolt Locking Pins (except F4) B.23 (ONS-1, TMI-1) BF Screw Locking Wires (except F4) B.25 BF Shoulder Screw Locking Dowels (F4) B.27 (Except ONS-1, TMI-1) Internal and External BB Bolt Locking Rings B.27 (ONS-1, TMI-1) Internal BB Screw Locking Wires B.27 (ONS-1, TMI-1) External BB Screw Locking Washers B.27 (ONS-1, TMI-1) External BB Screw Locking Wires L.1.2-L.1.3 LG FASP and items
2		P.1.1 PC Weldment Ribs P.1.3 PC Bottom Flange P.1.6 PC Cover Plate P.2.1 Plenum Cylinder P.2.2 Plenum Cylinder Top Flange P.2.3 Plenum Cylinder Bottom Flange P.2.4 Plenum Cylinder (Except DB) Reinforcing Plates P.2.8 Plenum Cylinder Bottom Flange-to-UG Bolts P.4.10a-P.4.10h ANO-1 RVLMS Items S.6a (Except ONS-3, DB) CSS Outlet Nozzles S.18-S.21 Remaining SSHT Assembly Items (ONS, ANO-1) S.7 VV Nozzles S.11k VV Modified Locking Device Spec. Hex Head Screw B.16 TS Upper Restraint Cap Screws (not exposed) L.1.7 LG FD Plate L.1.13 (Except DB) Guide Blocks (Mating with Guide Lugs on RV) L.1.22 (DB) Guide Blocks (Mating with Guide Lugs on RV) L.1.18 LG Support Post Pipes L.2.1 FD Head L.2.2 FD Flange L.3.2 IMI Guide Tube Gussets	WC-28 PC Weldment Ribs to Each Other Weld WC-23 Cap Screw Weld to UG FASP P.3.7 UG FASP Cap Screws P.3.3 UG Rib-to-Ring Cap Screws P.4.3 CRGT Flange-to-UG Cap Screws P.4.5 CRGT Spacer Castings P.4.10f ANO-1 RVLMS Brazement Guide Assembly—J Bolt and Nut S.22 Remaining SSHT Assembly Item: Bearing (ONS) S.10 VV Top Retaining ring S.10 VV Bottom Retaining Ring S.11a-S.11e and S.11g VV Original Locking Device Items S.11h,i and S.11l VV Modified Locking Device Items B.6a (Except TMI-1) UTS Original Bolts B.6b (TMI-1) UTS Original Bolts B.19 CB-to-FP Cap Screws B.8b (DB) Replacement SSHT Bolts B.9 (DB) Replacement SSHT Bolt Locking Device Items L.1.1 LG Rib Section L.1.4 LG FASP Cap Screws L.1.5 LG Rib-to-Shell Forging Cap Screws L.1.11b (ONS) LTS Replacement Studs L.1.11b (ONS) LTS Replacement Nuts L.1.11c (DB, ANO-1) LTS Replacement Bolts L.3.1 IMI Guide Tubes L.3.4 IMI Guide Tube Nuts	B.17 BPs B.18 FPs B.26 (Except ONS-1, TMI-1) Internal and External BB Bolts B.26 (ONS-1, TMI-1) Internal BB Socket Head Cap Screws B.26 (ONS-1, TMI-1) External BB Socket Head Cap Screws (Design A) B.26 (ONS-1, TMI-1) External BB Socket Head Cap Screws (Design B) L.1.17b Shock Pad Bolts (TMI-1 only) L.1.11a (TMI-1) LTS Original Bolts
3		P.1.8 PC (Except ONS-1) Base Blocks for Lifting Lugs P.1.11 PC (ONS-1) Integral Lifting Lugs with Base Blocks P.4.8 CRGT Rod Guide Tubes P.4.9 CRGT Rod Guide Sectors P.4.10i-P.4.10m ANO-1 RVLMS Items S.17 CSS Lifting Lugs B.10 TS Cylinder	P.1.2 PC Weldment Rib Pads P.1.4 PC Support Flange P.1.5 PC Support Ring B.28g Remaining SSHT Assembly Item: Hex Head Bolt (ONS, ANO-1) L.1.14a (Except DB) Guide Block Bolts (Mating with Guide Lugs on RV)	B.22 (Except ONS-1, TMI-1) BF Hex Head Bolts (except F4) B.22 (ONS-1, TMI-1) BF Button Head Socket Cap Screws (except F4) B.24 BF Shoulder Screws (F4)
4		S.1 CSS Cylinder S.2 CSS Top Flange S.3 CSS Bottom Flange L.1.10 LG Shell Forging L.1.9a (Except ONS-1) LG Forging L.1.9b (ONS-1) LG Weldment Ribs	S.4b (TMI-1) UCB Original Bolts S.4c,d (ANO-1, DB) UCB Replacement Bolts B.2 CB Top Flange B.3 CB Bottom Flange B.4c (TMI-1) LCB Original Bolts B.4d (DB) LCB Replacement Bolts	S.4a (ONS) UCB Original Bolts B.1 CB Cylinder B.4a (ANO-1, DB, ONS) LCB Original Bolts L.2.3a (Except TMI-1) FD Original Bolts L.2.3b (TMI-1) FD Original Bolts

Initialisms: ANO-Arkansas Nuclear One, BB-Baffle-to-Baffle, BF-Baffle-to-Former, BP-Baffle Plate, CB-Core Barrel, CRGT-Control Rod Guide Tube, CSS-Core Support Shield, DB-Davis-Besse, FASP-Fuel Assembly Support Pad, FD-Flow Distributor, FP-Former Plate, IMI-In-core Monitoring Instrumentation, LCB-Lower Core Barrel, LG-Lower Grid, LTS-Lower Thermal Shield, ONS-Oconee Nuclear Station, PC-Plenum Cover, RV-Reactor Vessel, RVLMS-Reactor Vessel Level Monitoring System, SSHT-Surveillance Specimen Holder Tube, TMI-Three Mile Island, TS-Thermal Shield, UCB-Upper Core Barrel, UG-Upper Grid, UTS-Upper Thermal Shield, VV-Vent Valve

B&W Economic Heat Map, A1-D1 A2-D2

Economic Consequence, 1 or 2

B&W Unit Economic Category Heat Map

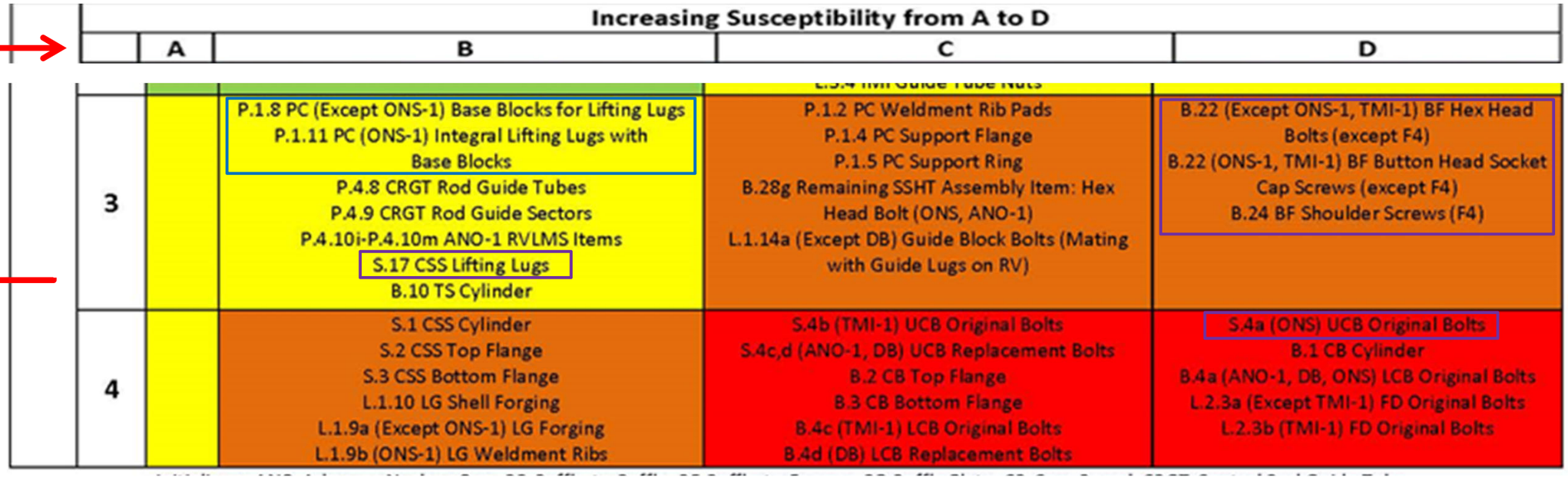
Increasing Economic Consequence from 1 to 4

Increasing Susceptibility from A to D

	A	B	C	D
1		P.1.12 PC Letter Plate (Letter W) S.5a,b (TMI-1, DB) UCB Bolt Compression Collars S.5b (ANO-1, DB) UCB Bolt Crimped Locking Cups S.16 CSS Flow Deflectors B.5b (DB) LCB Bolt Crimped Locking Cups L.1.19 LG Support Post Pipe Bolting Plugs L.1.12 (ONS) LTS Replacement Stud/Nut Crimped Locking Cups L.1.12 (DB, ANO-1) LTS Bolt Replacement Crimped Locking Cups L.2.6 IMI Guide Support Plate Clamping Ring	P.3.5 UG FASPs P.3.6 UG FASP Dowels B.4b (ONS-1) LCB Original Type 304 Bolts B.5a,b (TMI-1, DB) LCB Bolt Compression Collars B.28a-B.28f Remaining SSHT Assembly Items (ONS) B.20 CB-to-FP Cap Screw Locking Pins B.21 CB-to-FP Dowels L.1.20 LG Support Post Pipe Cap Screws L.3.6 IMI Guide Tube Spider Castings	B.23 (Except ONS-1, TMI-1) BF Bolt Locking Pins (except F4) B.23 (ONS-1, TMI-1) BF Screw Locking Wires (except F4) B.25 BF Shoulder Screw Locking Dowels (F4) B.27 (Except ONS-1, TMI-1) Internal and External BB Bolt Locking Rings B.27 (ONS-1, TMI-1) Internal BB Screw Locking Wires B.27 (ONS-1, TMI-1) External BB Screw Locking Washers B.27 (ONS-1, TMI-1) External BB Screw Locking Wires L.1.2-L.1.3 LG FASP and items
2		P.1.1 PC Weldment Ribs P.1.3 PC Bottom Flange P.1.6 PC Cover Plate P.2.1 Plenum Cylinder P.2.2 Plenum Cylinder Top Flange P.2.3 Plenum Cylinder Bottom Flange P.2.4 Plenum Cylinder (Except DB) Reinforcing Plates P.2.8 Plenum Cylinder Bottom Flange-to-UG Bolts P.4.10a-P.4.10h ANO-1 RVLMS Items S.6a (Except ONS-3, DB) CSS Outlet Nozzles S.18-S.21 Remaining SSHT Assembly Items (ONS, ANO-1) S.7 VV Nozzles S.11k VV Modified Locking Device Spec. Hex Head Screw B.16 TS Upper Restraint Cap Screws (not exposed) L.1.7 LG FD Plate L.1.13 (Except DB) Guide Blocks (Mating with Guide Lugs on RV) L.1.22 (DB) Guide Blocks (Mating with Guide Lugs on RV) L.1.18 LG Support Post Pipes L.2.1 FD Head L.2.2 FD Flange L.3.2 IMI Guide Tube Gussets	WC-28 PC Weldment Ribs to Each Other Weld WC-23 Cap Screw Weld to UG FASP P.3.7 UG FASP Cap Screws P.3.3 UG Rib-to-Ring Cap Screws P.4.3 CRGT Flange-to-UG Cap Screws P.4.5 CRGT Spacer Castings P.4.10f ANO-1 RVLMS Brazement Guide Assembly—J Bolt and Nut S.22 Remaining SSHT Assembly Item: Bearing (ONS) S.10 VV Top Retaining ring S.10 VV Bottom Retaining Ring S.11a-S.11e and S.11g VV Original Locking Device Items S.11h,i and S.11l VV Modified Locking Device Items B.6a (Except TMI-1) UTS Original Bolts B.6b (TMI-1) UTS Original Bolts B.19 CB-to-FP Cap Screws B.8b (DB) Replacement SSHT Bolts B.9 (DB) Replacement SSHT Bolt Locking Device Items L.1.1 LG Rib Section L.1.4 LG FASP Cap Screws L.1.5 LG Rib-to-Shell Forging Cap Screws L.1.11b (ONS) LTS Replacement Studs L.1.11b (ONS) LTS Replacement Nuts L.1.11c (DB, ANO-1) LTS Replacement Bolts L.3.1 IMI Guide Tubes L.3.4 IMI Guide Tube Nuts	B.17 BPs B.18 FPs B.26 (Except ONS-1, TMI-1) Internal and External BB Bolts B.26 (ONS-1, TMI-1) Internal BB Socket Head Cap Screws B.26 (ONS-1, TMI-1) External BB Socket Head Cap Screws (Design A) B.26 (ONS-1, TMI-1) External BB Socket Head Cap Screws (Design B) L.1.17b Shock Pad Bolts (TMI-1 only) L.1.11a (TMI-1) LTS Original Bolts

Susceptibility, A through D

B&W Economic Heat Map, A3-D3, A4-D4



Susceptibility, A through D

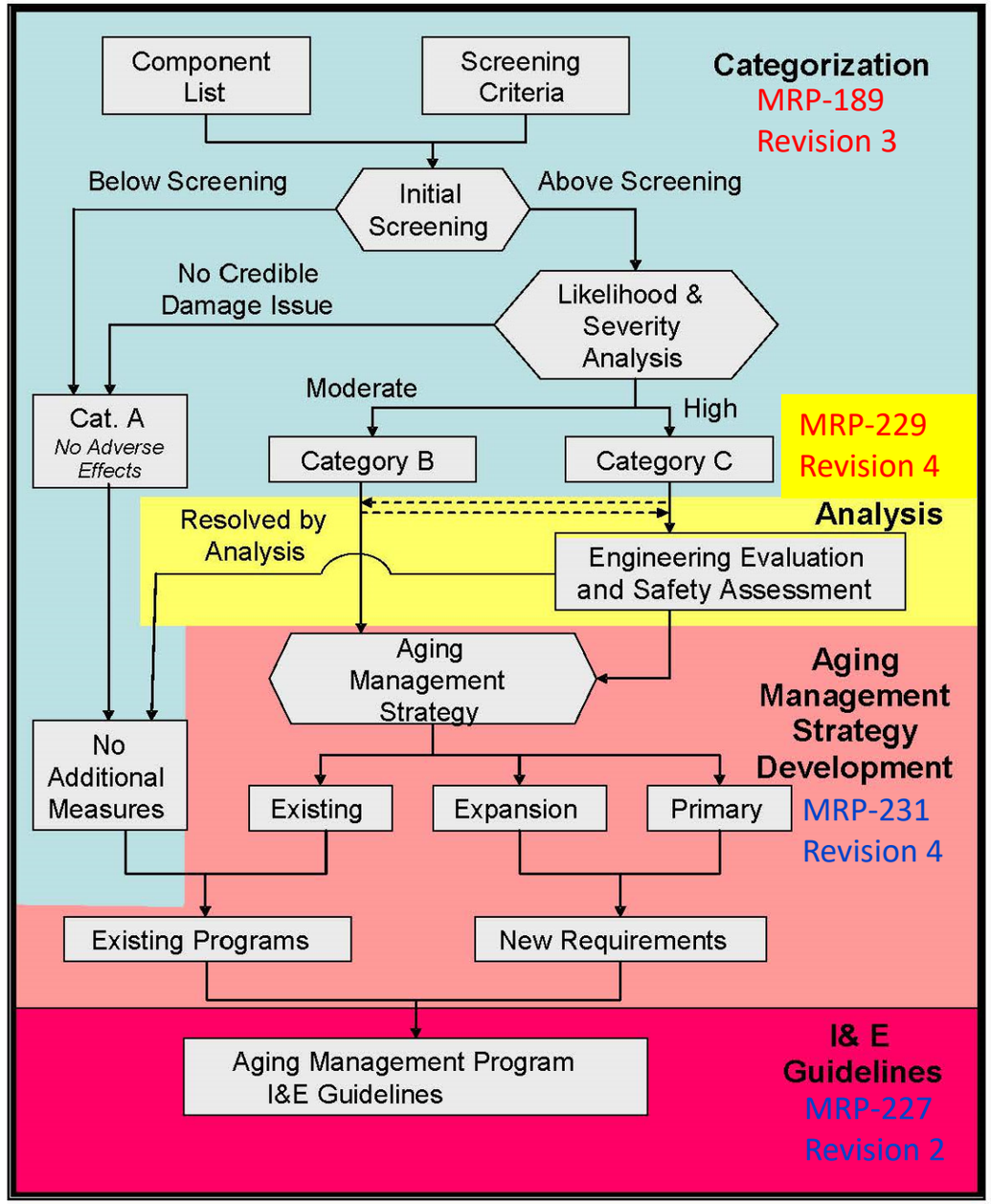
Economic Consequence, 3 or 4

Conclusions of MRP-189 Revision 3 for SLR

- Differences in preliminary screening category (A, Not A) due to the following primary reasons:
  - Changes in fatigue screening
  - Increase in fluence 60→80 years (ISR/IC)
  - Increase in fluence 60→80 years (IE)
  - PWR Owners Group CASS statistical assessment (PWROG-15032-NP)
- Degradation mechanism data from MRP-211 and MRP-175 clearly show that no failure “cliffs” are imminent
- Sampling inspection strategy used in MRP-227-A/MRP-227-Rev.1-A is the fundamental foundation and is still valid for SLR aging management
- Evaluation has not identified across-the-board increases in materials age-related degradation susceptibility

Next Steps

- MRP-189 Revision 3 updated the "Categorization" box for SLR
  - Provides key input to downstream steps
  - Made updates based on new data and OE
- Next steps for 2020 include updates associated with engineering analysis, inspection strategies and establish final I&E guidelines
- Goal is single I&E guideline of MRP-227 Revision 2 by end of 2020
  - Guidance is independent of license period
  - MRP-227 remains a "living program"



Together…Shaping the Future of Electricity