

International Workshop: Kiev, Ukraine

Use of Probabilistic Safety Analysis in Operation of Nuclear Power Plants and Regulatory Decision Making

Applications



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Practical Applications

- ◆ **Operational Management**
- ◆ **Technical Specifications**
- ◆ **Maintenance Rule**
- ◆ **Inservice Inspection**
- ◆ **Inservice Testing**
- ◆ **Graded Quality Assurance**

Practical Applications

- ◆ Risk-informing 10 CFR Part 50
- ◆ Reactor Oversight Program
 - Significance Determination Process
- ◆ NSSL Aging & Degradation
- ◆ Event Assessment
- ◆ Notices of Enforcement Discretion

Operational Management

- ◆ **Working with NSSS Owners Groups**
- ◆ **In Accordance with Current Rules**
- ◆ **Integrated Optimum Risk Locus**
 - **Power, Transition, End Mode**
 - **Compensatory Actions vs. AOTs**
 - » **Success Paths: Lower Risk**
 - » **Identify and Avoid High Risk Situations**

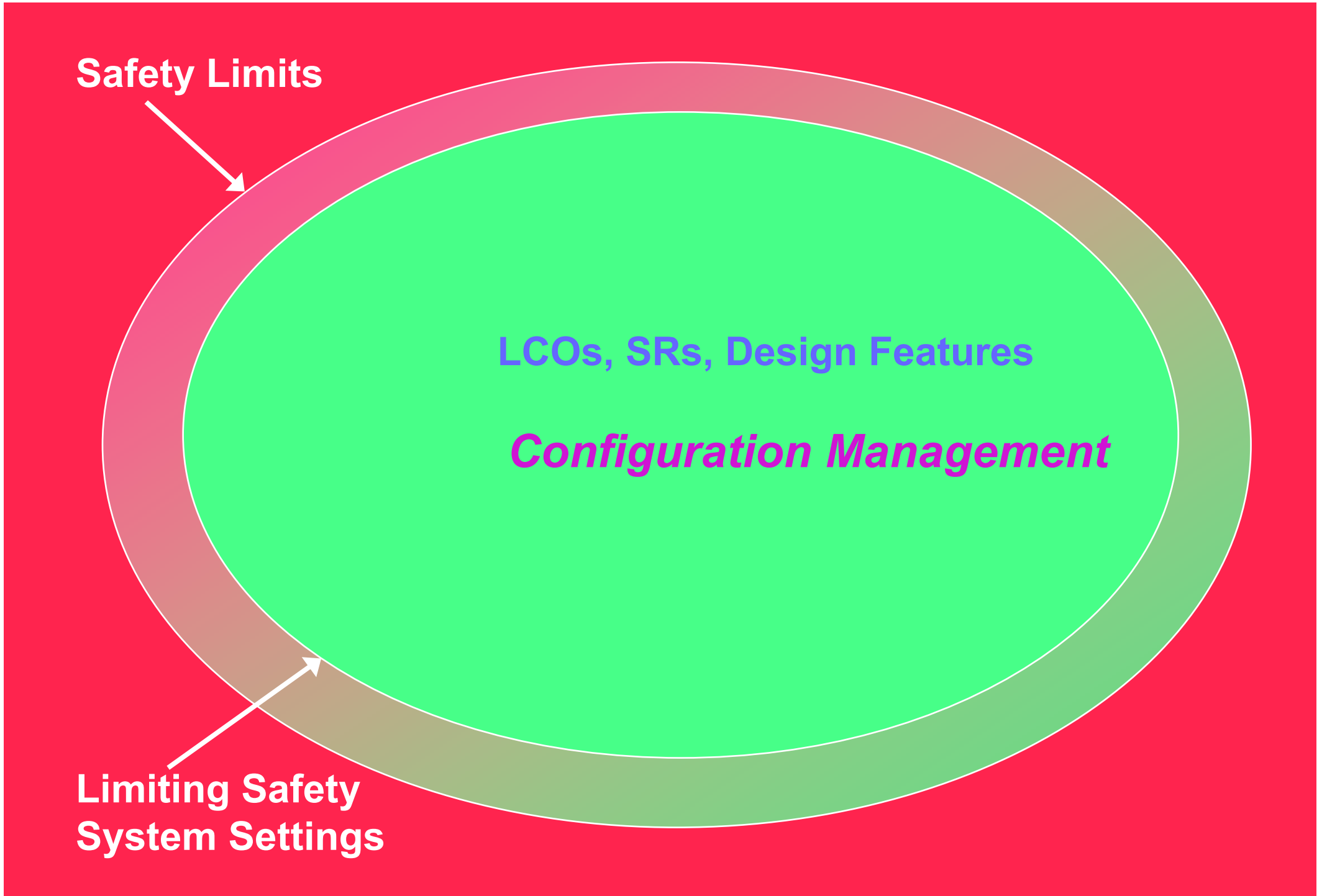
Safety Limits



LCOs, SRs, Design Features

Configuration Management

**Limiting Safety
System Settings**



Technical Specifications

- ◆ **Three tier approach**
 - Risk Measures
 - Importance Measures
 - Configuration Risk Management Program (CRMP) or Maintenance Rule (a)(4)
- ◆ **Flexible AOTs (Operational Management)**

Maintenance Rule

- ◆ **10 CFR 50.65 (a)(4)**
- ◆ **Evaluate Risk Significance of Proposed Maintenance Configurations**
- ◆ **Regulatory Efficiency: subsume CRMP**

Inservice Inspection

- ◆ **Focus: Piping Segments with EITHER**
 - Important Degradation Mechanisms OR
 - High Failure Consequences
- ◆ **40 Units at 30 Sites Have Adopted**
- ◆ **14 Units at 10 Sites Under Review**
- ◆ **Changes Location and Number of Welds**
- ◆ **Changes Inspection Methods: WOG, EPRI**

Inservice Inspection Benefits

- ◆ **Essentially Risk Neutral**
- ◆ **Conserve Fiscal Resources**
- ◆ **Reduce Personnel Radiation Exposure**

Inservice Testing

- ◆ **Categorize Pumps & Valves**
 - High Safety Significance (HSSC)
 - » Could include non-code components
 - Low Safety Significance (LSSC)
- ◆ **Adjust Test Frequency to risk**
 - Include some Compensatory Measures
 - Staggered Testing Reduces CCF
- ◆ **Evaluate (integrated) Risk Measures**
- ◆ **Adopted: 2 Units Full Scope; 1 Partial**
- ◆ **In Review: 1 Unit Full Scope; 1 Partial**

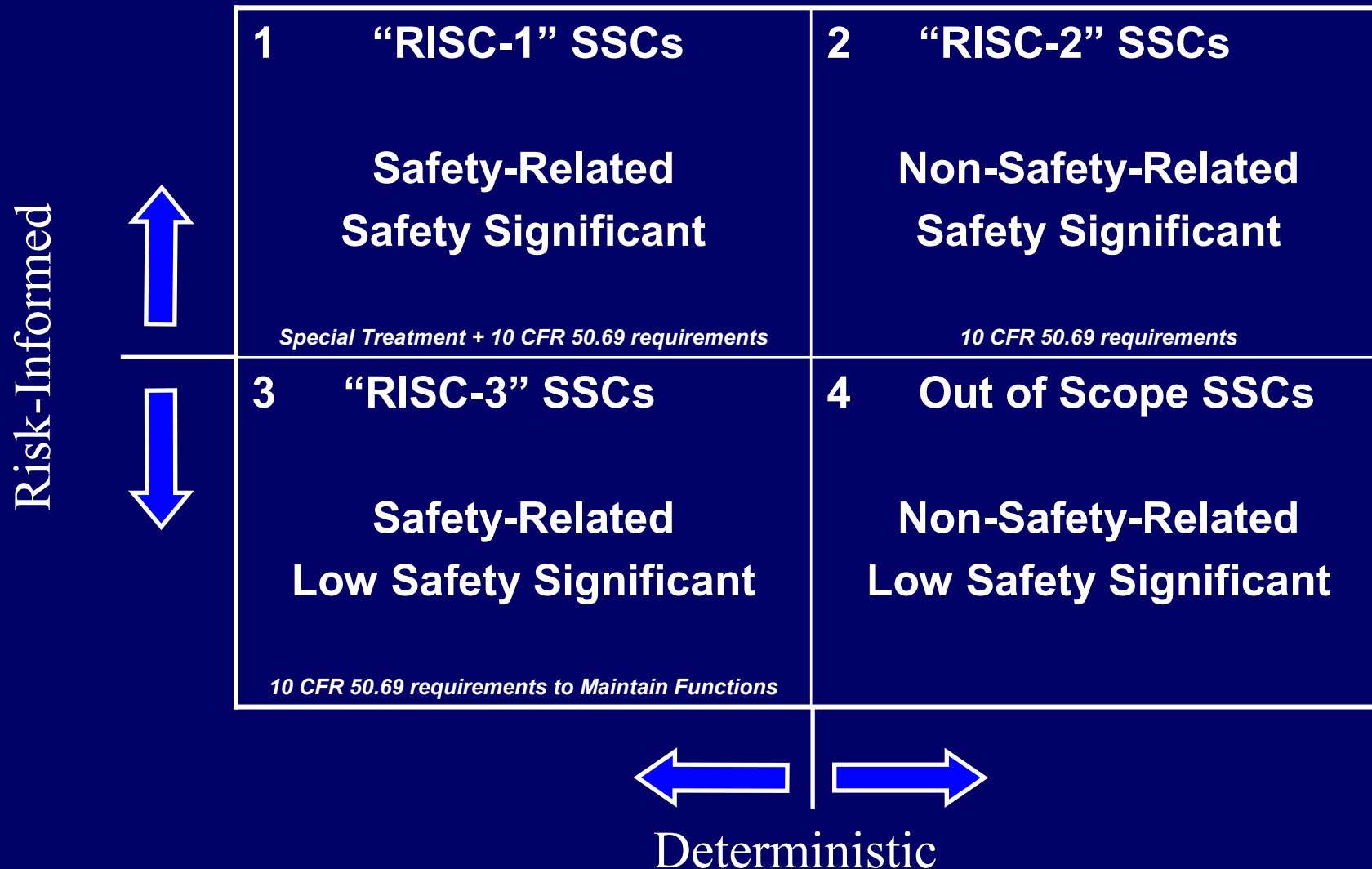
Inservice Testing Benefits

- ◆ **Focus On More Safety Significant Issues**
- ◆ **Reduce Operator Burden**
- ◆ **Reduce Off-Normal Configurations**
- ◆ **Conserve Fiscal Resources**
- ◆ **Commence Peak Full Scope Program**
 - **Quantitative: $<10E-6$ / year CDF increase**
 - **Qualitative: Risk Neutral**
 - » **Added risk-important components to program**
 - » **Fewer tests & fewer realignment errors**

Graded Quality Assurance

- ◆ **South Texas Project**
 - Less QA Effort for 15 of 18 Criteria
 - Implement Equipment Monitoring
 - Risk Neutral
- ◆ **Other Regulations Complicated Implementation**
 - To be resolved in RIP 50 Technical Requirements Phase

Categorization of Structures, Systems, and Components



Risk Informing 10 CFR 50 (RIP50)

- ◆ **Continue with Applications**
- ◆ **Special Treatment Requirements**
 - Proposed Rule, 10 CFR 50.69
 - » Four quartiles
- ◆ **Technical Requirements**
 - Containment Combustible Gas Control
 - Large Break LOCA
 - Future?

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Reactor Oversight Program (ROP) Significance Determination Process (SDP)



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ROP and SDP Program

- ◆ **NRC Inspection Manual Chapters**
 - 0305, ROP Program
 - 0307, ROP Self-Assessment Program
 - **0308, ROP Basis**
 - 0350, Plants Shutdown — Performance Problems
 - 0608, Performance Indicator Program
 - 0609, SDP (Also Attachments & Appendices)
 - 0612, Power Reactor Inspection Reports
- ◆ <http://www.nrc.gov/reading-rm/doc-collections/insp-manual/manualchapters.html>

Performance Goals

- ◆ **Maintain a Low Frequency of Events that could lead to a Nuclear Reactor Accident**
- ◆ **Zero Significant Radiation Exposures resulting from Civilian Nuclear Reactors**
- ◆ **No Increase in the Number of Offsite Releases of Radioactive Material from Civilian Nuclear Reactors that Exceed 10 CFR Part 20 Limits**
- ◆ **No Substantiated Breakdown of Physical Protection that Significantly Weakens Protection against Radiological Sabotage, or Theft or Diversion of Special Nuclear Materials**

Exhibit 1: REGULATORY FRAMEWORK

NRC's Overall Safety Mission

PUBLIC HEALTH AND SAFETY AS A RESULT OF CIVILIAN NUCLEAR REACTOR OPERATION

Strategic Performance Areas

REACTOR SAFETY

RADIATION SAFETY

SAFEGUARDS

Cornerstones

INITIATING EVENTS

MITIGATING SYSTEMS

BARRIER INTEGRITY

EMERGENCY PREPAREDNESS

PUBLIC RADIATION SAFETY

OCCUPATIONAL RADIATION SAFETY

PHYSICAL PROTECTION

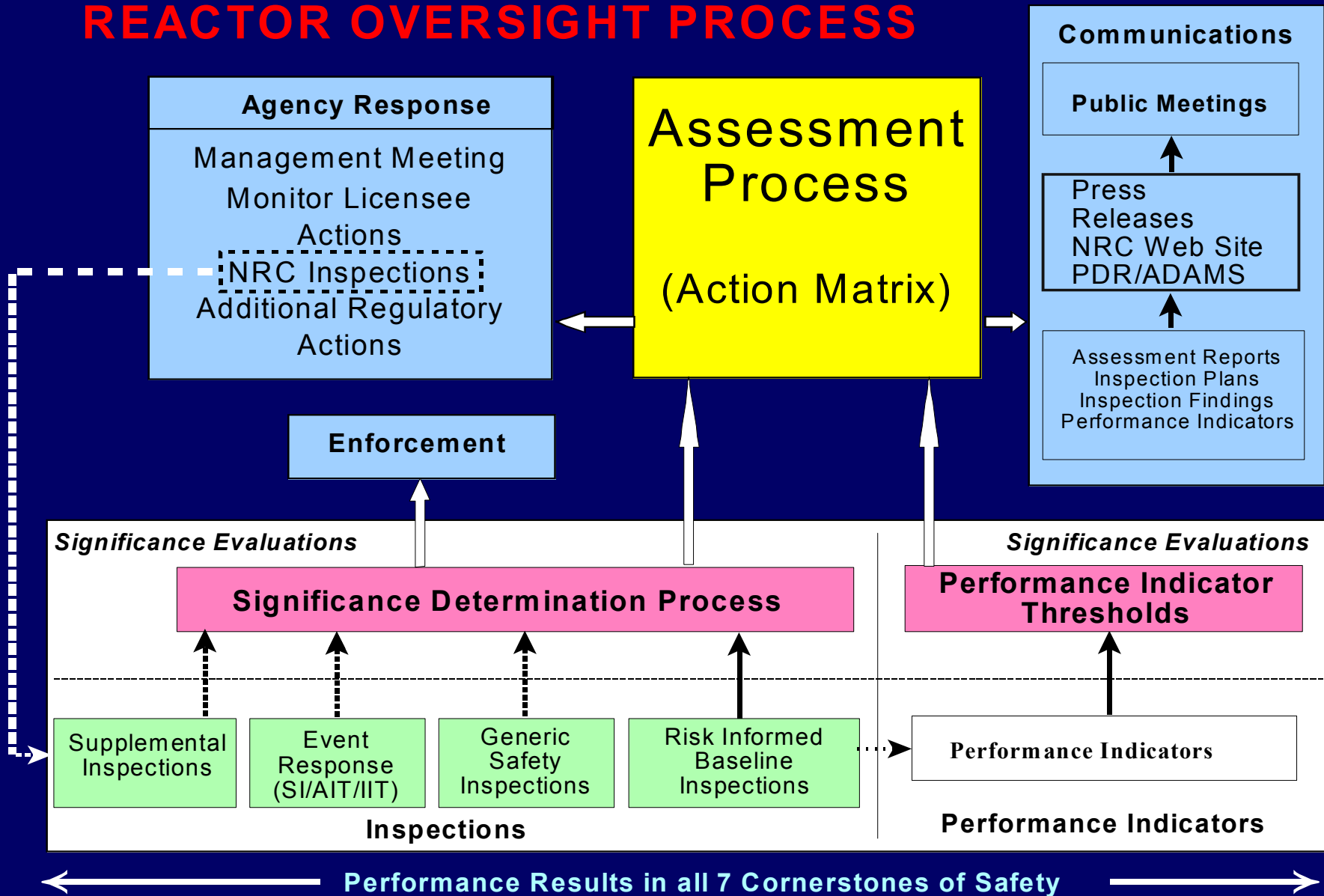
HUMAN PERFORMANCE

SAFETY CONSCIOUS WORK ENVIRONMENT

PROBLEM IDENTIFICATION AND RESOLUTION

Cross-Cutting Areas

REACTOR OVERSIGHT PROCESS



Significance Determination Process

- ◆ **Supports Reactor Oversight Program**
- ◆ **Determine Safety Significance:**
 - **Inspection Findings (Performance Deficiencies)**
 - **Performance Indicators**
 - **Risk Guidelines Comparable to Other R-I Activities**
 - » **RG 1.174 Guidelines**
- ◆ **Four levels**

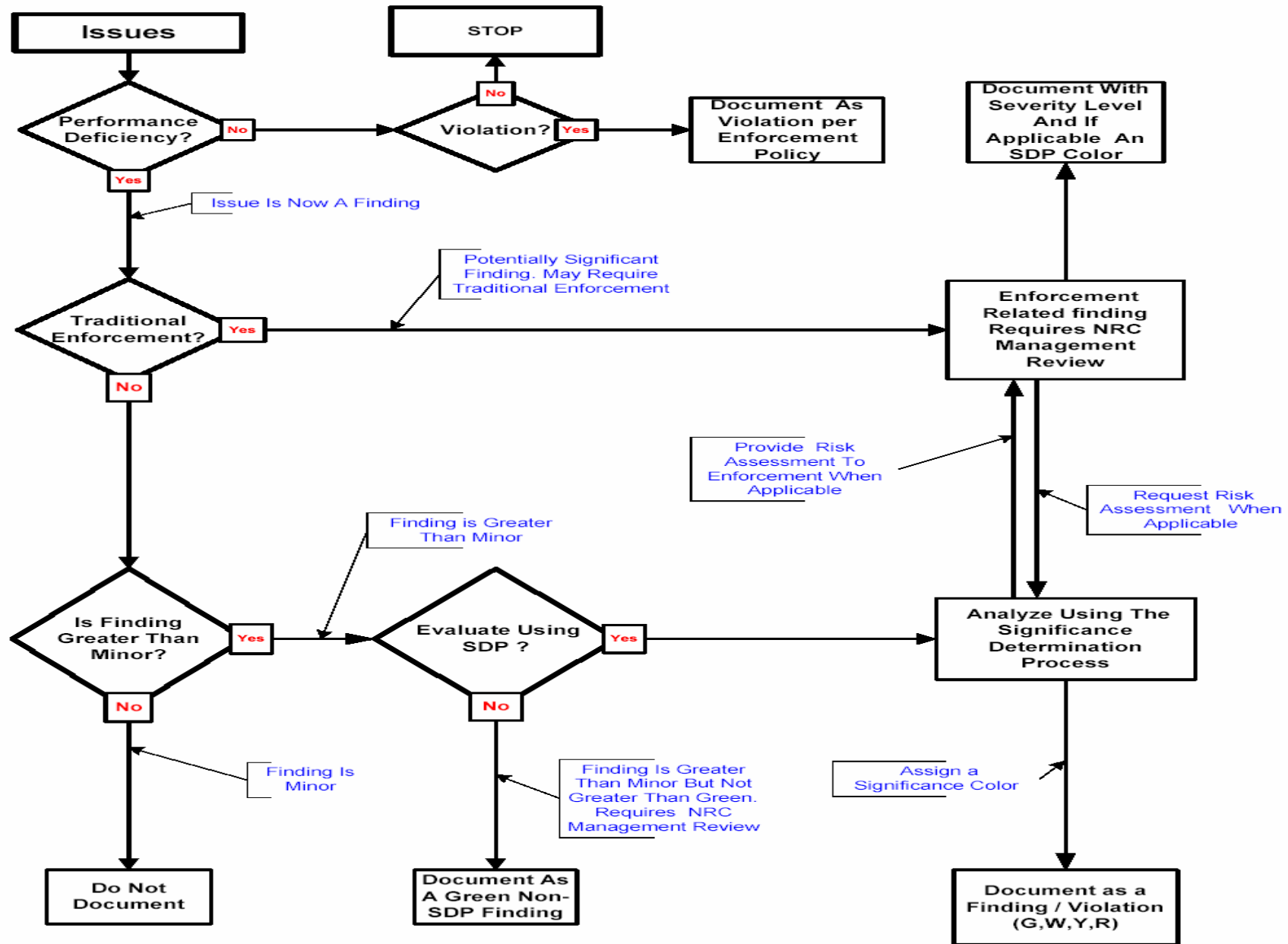
Risk-Informed Significance Levels

Color	① CDF (/yr)	② LERF (/yr)	Description
Red	$\geq E-4$	$\geq E-5$	Unacceptable
Yellow	$< E-4$	$< E-5$	Required Regulatory Response
White	$< E-5$	$< E-6$	Increased Regulatory Response
Green	$< E-6$	$< E-7$	Licensee Response Corrective Action Program

Inspection Findings

- ◆ **Inspection**
 - Performance Deficiency
 - » SDP
- ◆ **SERP**
 - Preliminary “Color”
- ◆ **Licensee Interface**
- ◆ **Final “Color”**
- ◆ **Assessments: Quarterly, Semi-Annually, Annually**
 - Roll Up for Each Cornerstone
 - “Color” Inspection “Windows”
- ◆ **Action Matrix**
 - Determine Regulatory Action

Issue Disposition Screening



Performance Indicators (PIs)

- ◆ **18 PIs**
- ◆ **Risk-Informed**
 - Initiating Events
 - Mitigating Systems
 - Risk-Informed Thresholds
- ◆ **Non Risk-Informed**
 - Other Cornerstones
 - Traditional Engineering Thresholds
- ◆ **Future: Mitigating System Performance Index (MSPI) ?**
- ◆ **Assessments: Quarterly, Semi-Annually, Annually**
 - Roll Up for Each Cornerstone
 - “Color” Inspection “Windows”
- ◆ **Action Matrix**
 - Determine Regulatory Action

Assessment

Level of Review	Frequency Timing	Participants (* Chair)	Desired Outcome	Communication
Continuous	Continuous	Senior Resident Inspector (SRI)*, Resident Inspector (RI), regional inspectors, senior reactor analysts (SRAs)	Performance awareness	None required Notify licensee by an Assessment Follow-Up letter only if thresholds crossed
Quarterly	Once per quarter 5 weeks after end of quarter	DRP: Branch Chief (BC)*, Project Engineer, SRI, RI	Input and verify PI and PIM data Detect early trends	Update data set Notify licensee by an Assessment Follow-Up letter only if thresholds crossed
Mid-Cycle	At mid-cycle 6 weeks after end of second quarter	DRS or DRP Division Director (DD)*, DRP and DRS BCs	Detect trends Plan inspection	Mid-Cycle letter with an inspection plan through the next 12 months
End-of-Cycle	At end-of-cycle 6 weeks after end of assessment cycle	DRS or DRP DD, Regional Administrator (RA)*, NRR representative, BCs, principal inspectors, SRAs	Assessment of plant performance Oversight and coordination of regional actions	Annual Assessment Letter with an inspection plan through the next 12 months
Agency Action	Review Annually 2 weeks after end of cycle review	EDO*, Director of NRR, RAs, DRS/DRP DDs, Inspection Program Branch, OE, OI, other HQ offices as appropriate	Oversight and coordination of agency-level actions	Commission briefing, followed by public meetings with individual licensees to discuss assessment results

		Licensee Response Column	Regulatory Response Column	Degraded Cornerstone Column	Multiple Degraded Cornerstone Column	Unacceptable Performance Column
Results		All Assessment Inputs (Performance Indicators (PIs) and Inspection Findings) Green. Cornerstone Objectives Fully Met.	One or Two White Inputs (in different cornerstones) in a Strategic Performance Area. Cornerstone Objectives Fully Met.	One Degraded Cornerstone (2 White Inputs or 1 Yellow Input) or any 3 White Inputs in a Strategic Performance Area. Cornerstone Objectives Met with Moderate Degradation in Safety Performance.	Repetitive Degraded Cornerstone, Multiple Degraded Cornerstones, Multiple Yellow Inputs, or 1 Red Input. Cornerstone Objectives Met with Longstanding Issues or Significant Degradation in Safety Performance.	Overall Unacceptable Performance. Plants Not Permitted to Operate Within this Band, Unacceptable Margin to Safety.
	Regulatory Performance Meeting	None	Branch Chief (BC) or Division Director (DD) Meet with Licensee	DD or Regional Administrator (RA) Meet with Licensee	RA (or EDO) Meet with Senior Licensee Management	Commission meeting with Senior Licensee Management
Response	Licensee Action	Licensee Corrective Action	Licensee root cause evaluation and corrective action with NRC Oversight	Licensee cumulative Root Cause Evaluation with NRC Oversight	Licensee Performance Improvement Plan with NRC Oversight	
	NRC Inspection	Risk-Informed Baseline Inspection Program	Baseline and Supplemental Inspection Procedure 95001	Baseline and Supplemental Inspection Procedure 95002	Baseline and Supplemental Inspection Procedure 95003	
	Regulatory Actions ¹	None	Supplemental Inspection only	Supplemental Inspection only	-10 CFR 2.204 DFI -10 CFR 50.54(f) Letter - CAL/Order	Order to Modify, Suspend, or Revoke Licensed Activities
	Assessment Letters	BC or DD review/sign Assessment Report (w/ Inspection Plan)	DD review/sign Assessment Report (w/ Inspection Plan)	RA review/sign Assessment Report w/ Inspection Plan)	RA review/sign Assessment Report (w/ Inspection Plan)	
Communication	Annual Public Meeting	SRI or BC Meet with Licensee	BC or DD Meet with Licensee	RA (or designee) Discuss Performance with Licensee	EDO Discuss Performance with Senior Licensee Management	
	Commission Involvement	None	None	None	Plant discussed at AARM	Commission Meeting with Senior Licensee Management
	Increasing Safety Significance →					

Significance Determination Process

- ◆ **Operation**
- ◆ **Shutdown**
- ◆ **Fire Protection**
- ◆ **Maintenance**
- ◆ **Containment**
- ◆ **NSSS Aging & Degradation**
- ◆ **External Events**

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Shutdown Risk



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Unfamiliar Plant Configurations

- ◆ **Plant Different From Learned & Operated**
 - **RCS Configuration Not Normal**
 - » **Lineups**
 - » **Coffer Dams**
 - » **Freeze Seals**
 - » **No Bubble in Pressurizer**
 - **Some Mitigation Equipment Unavailable**
 - **Electrical Lineup Not Normal**

Regulatory Considerations

- ◆ **Very Few Technical Specifications**
- ◆ **Compensatory Measures Voluntary**
- ◆ **Key Shutdown Functions**
 - **Reactivity Control**
 - **Liquid Makeup**
 - **Level Control**
 - **Decay Heat Removal (DHR)**
 - **Containment**
 - **Electrical Power**

Plant Operational States (POS)

- ◆ POS 1 RCS Closed
- ◆ POS 2 RCS Open
- ◆ POS 3 Refueling Cavity Flooded

Shutdown Initiating Events

- ◆ **Loss of Offsite Power**
- ◆ **Loss of Inventory**
- ◆ **Loss of Level Control**
- ◆ **Loss of DHR Operating Train**

Human Reliability

- ◆ **Dominated by Human Actions**
 - **If Lose RHR for Any Reason**
 - » Need **Human Action** to Recover
 - » A Human Has to Take Some Action
 - **Instrumentation, Plant Access, Time, Training, Procedures**

Quantitative Risk

- ◆ **Comparable to Full Power Risk**
- ◆ **High Risk Outage Periods**
 - **Example: Mid-Loop**
 - **Instantaneous CDF**
 - » **SD Can Be $>$ Full Power**