

**P25/26: Use of PSA in On-Line & Off-
Line Maintenance Planning**

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presentation by

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Objectives

- Illustrate how Exelon Corporation uses PSA for risk management associated with maintenance
- Demonstrate how PSA insights are applied to maintenance configurations
- Illustrate the consideration of risk using risk management tools
- Review potential for cost savings produced as illustrated by examples.

2 Sessions:

➤ P25 Approach –

- Background
- Method

➤ P26 Tool Demonstration –

- Procedures
- Computer Code

Background: Different Perspectives

- “Limited” Business Perspective:
 - Maintenance Outages are Time Shutdown
 - Time Shutdown is Money Lost
 - Thus, “Take everything out of service on-line”
- “Limited” Regulatory Perspective:
 - On-line Maintenance is Equipment Unavailable
 - Equipment Unavailable is High Risk
 - Thus, “Take nothing out of service on-line”
- In common:
 - Recognition that Maintenance must be performed
 - Tool needed to satisfy both perspectives - PSA

Background: “Maintenance Rule”

- 10CFR50.65 Section (a)(4) states, “Before performing maintenance activities (including but not limited to surveillance, post-maintenance testing, corrective and preventive maintenance), the licensee shall assess and manage the increase in risk that may result from the proposed maintenance activities.

Risk Management In Plant Operations

RISK ASSESSMENT OPTIONS

➤ QUANTITATIVE (PSA)

- Numerical Limits

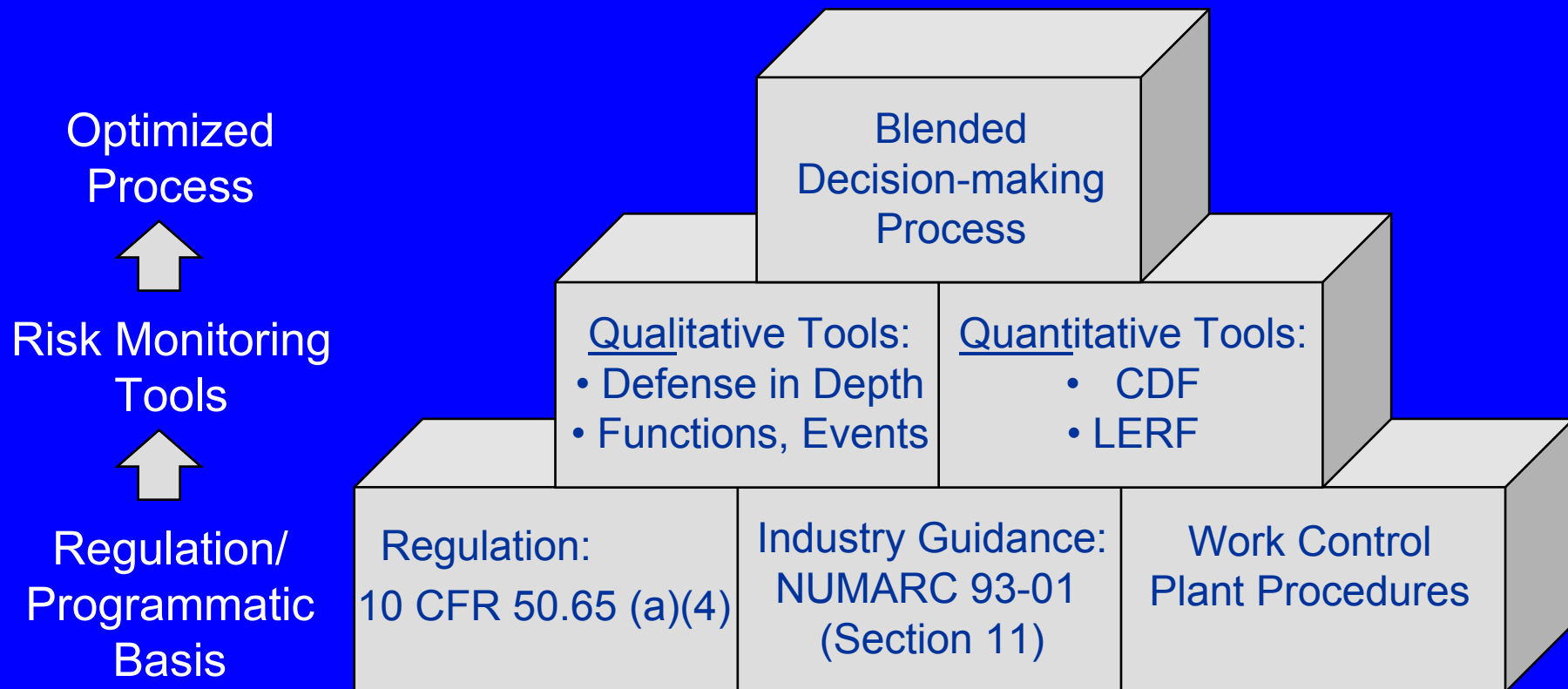
➤ QUALITATIVE (DEFENSE-IN-DEPTH)

- Equipment available for each Safety Function

➤ BLENDED APPROACH

- Both PSA and Defense-in-depth results are used
- Most adverse of PSA and Defense-in-depth is limiting
- Defense-in-depth is used if PSA results are unavailable

Risk-Informed Approach to Risk Management



Risk Management in Plant Operations -- Method Considerations

- On-line vs. Off-line maintenance
- PSA risk assessment options
- Risk acceptance criteria options
- Risk status communications

Risk Management In Plant Operations

CONSIDERATION OF ON-LINE vs. OFF-LINE MAINTENANCE

- For both, goal of Risk Management is reduction of risk consistent with maximum scheduling flexibility and reduced outage duration
 - Maintenance Rule applies to both
 - Defense-in-depth applies to both
- On-line condition is one “steady state” vs. off-line
- On-line time for operator action generally shorter than off-line
- PSA and Defense-in-Depth used for on-line risk; Defense-in-depth alone for off-line

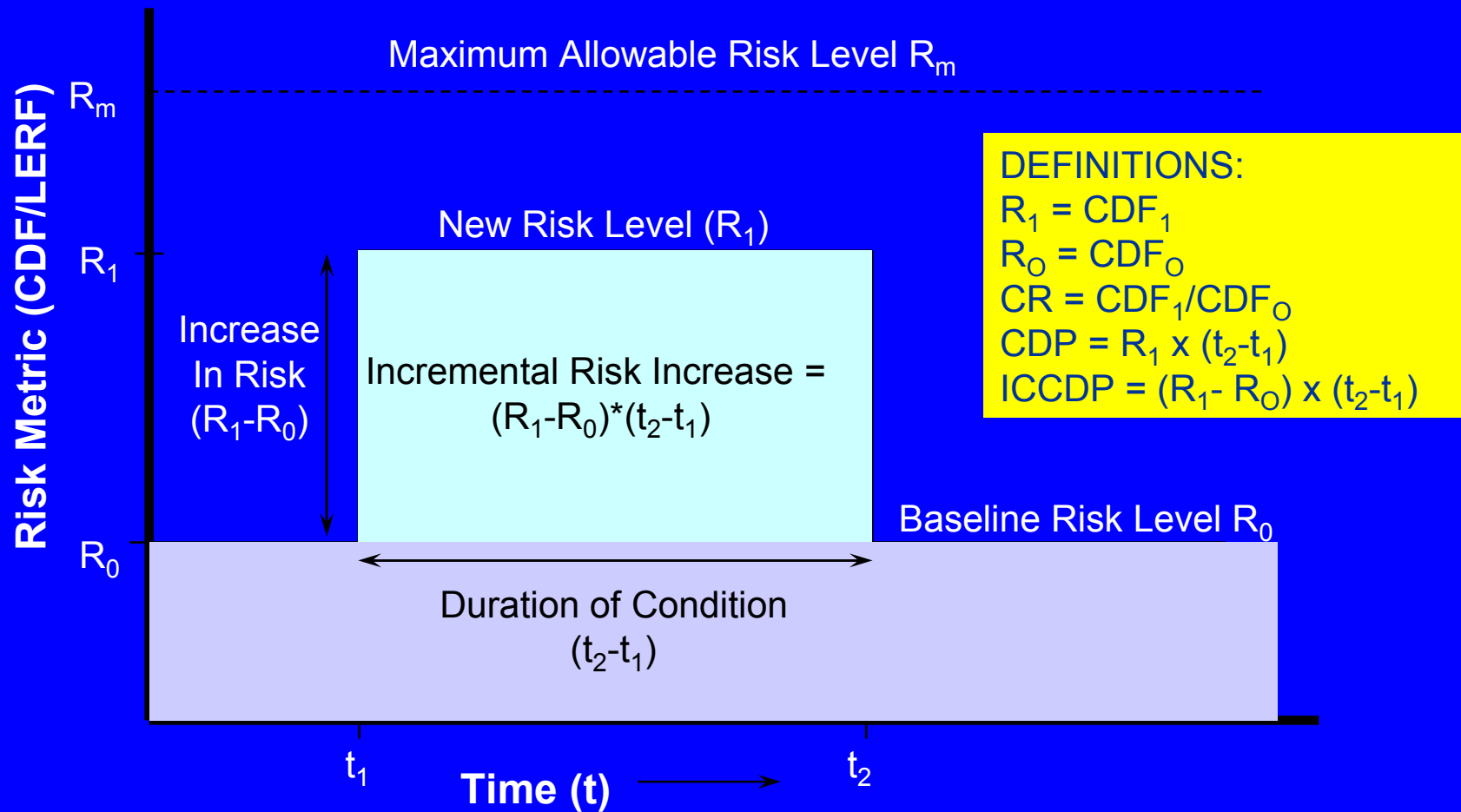
Risk Management In Plant Operations

PSA RISK ASSESSMENT CRITERIA OPTIONS

- All Require PSA Computation of Plant Configuration Risk
- Evaluation of Temporary Risk Increase
- “Speed Limit”
 - Absolute Limits
 - Relative Limits
- Cumulative Absolute Risk

PSA Risk Assessment Criteria Options

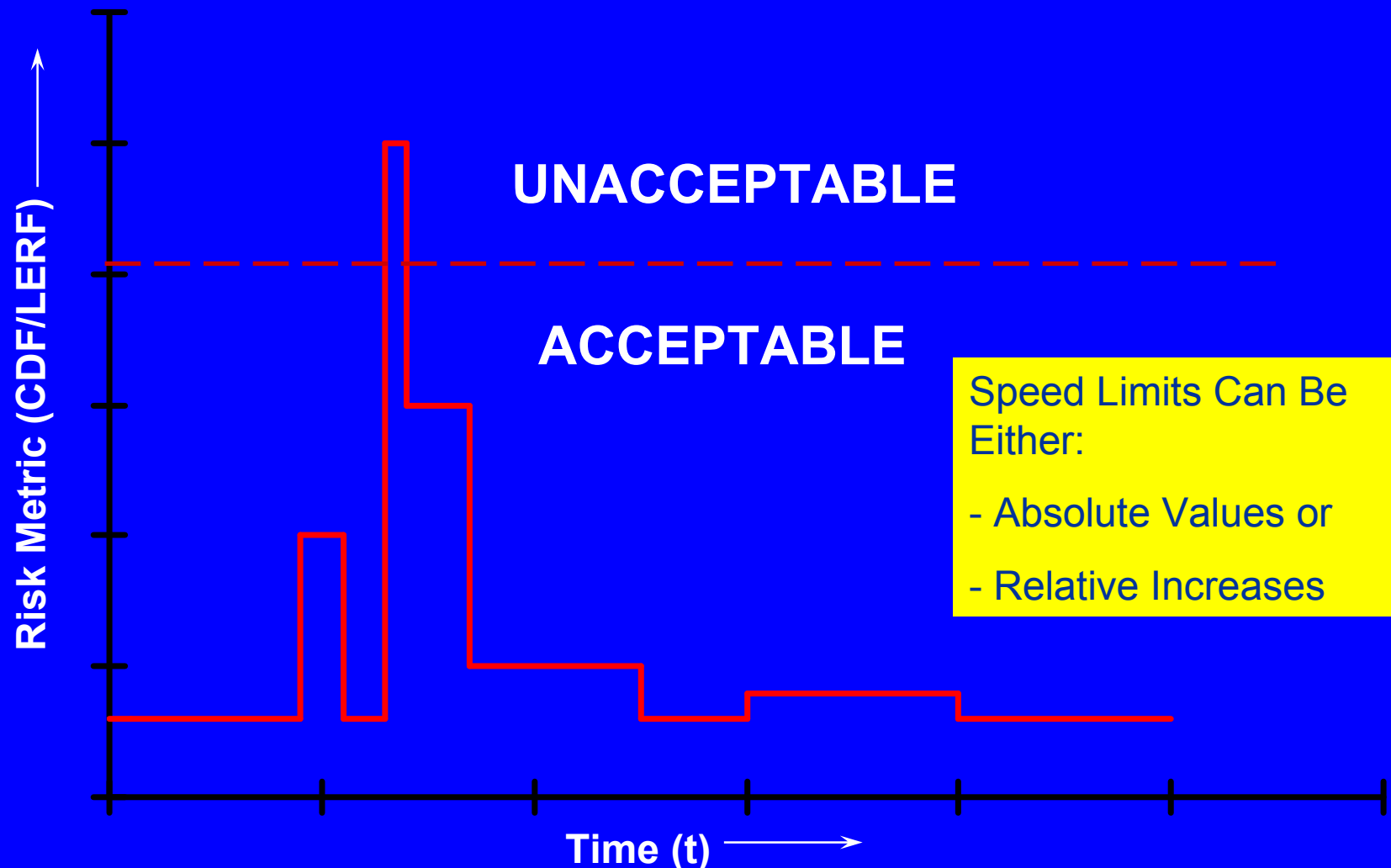
TEMPORARY RISK INCREASE DEFINITIONS



PSA in On-Line & Off-Line Maintenance Planning

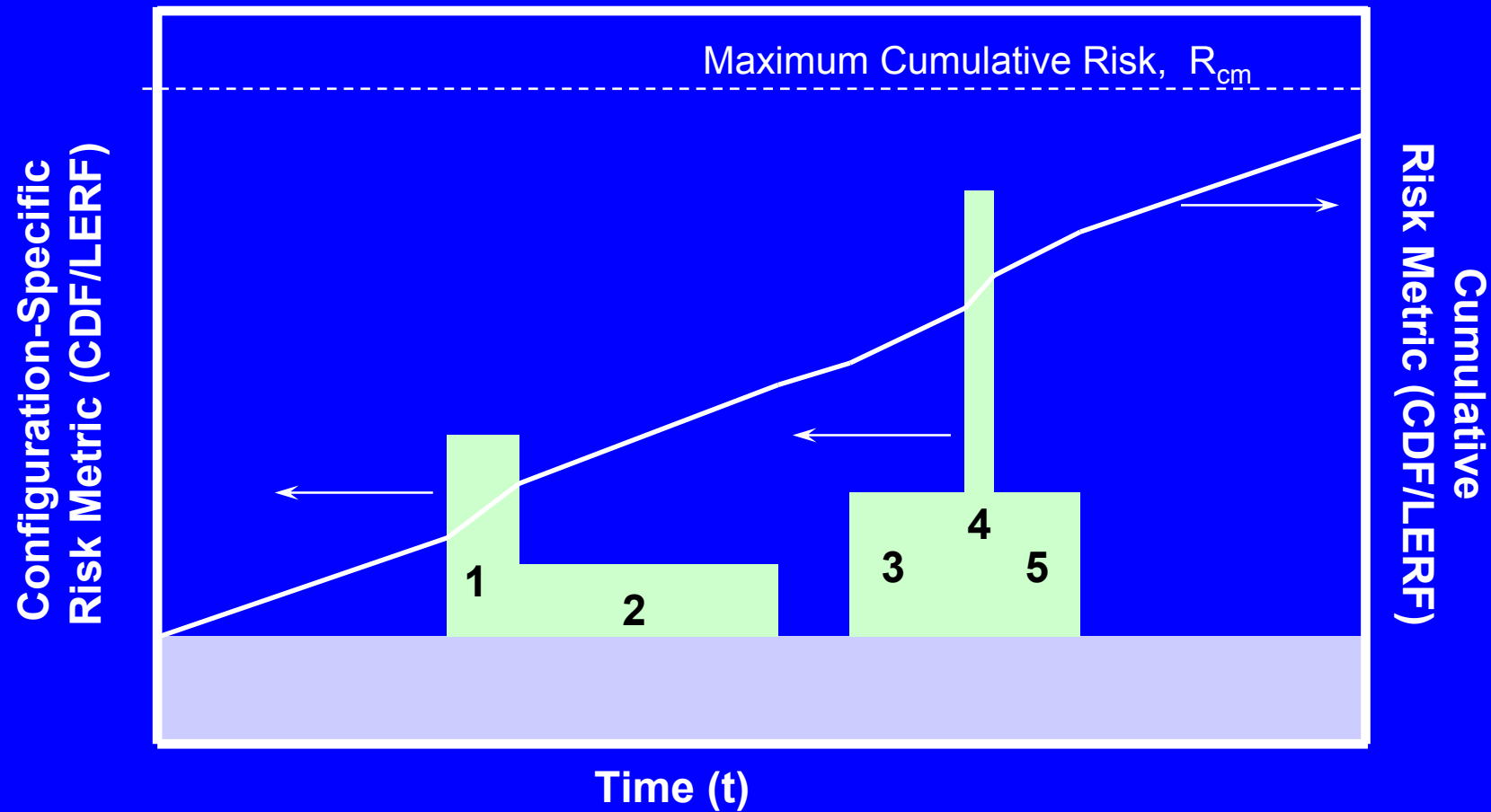
PSA Risk Assessment Criteria Options

RISK "SPEED LIMIT" APPROACH



PSA Risk Assessment Criteria Options

CUMULATIVE RISK APPROACH



PSA in On-Line & Off-Line Maintenance Planning

Risk Management In Plant Operations

RISK ACCEPTANCE CRITERIA OPTIONS

- PSA quantitative risk is numerical
- Defense-in-depth risk is qualitative
- Desire criteria:
 - Applicable to both
 - Considers uncertainty in methods
 - Can be widely applied across Exelon plants
 - Seem “reasonable” based on industry experience
- At Exelon, risk level criteria based on color

Risk Management In Plant Operations

PSA RISK ACCEPTANCE CRITERIA BY COLOR

Green

Insignificant Risk Increase

Yellow

Significant Risk Increase

Orange

Very Significant Risk Increase

Red

Unacceptable Risk Increase

Risk Characterization Using Colors

EXAMPLE PSA RISK LIMITS

Risk Level	ICCDP (C)	CDF/CDF ₀ (CR)
Green	$C < E-06$	< 2
Yellow	$E-06 < C < E-05$	$2 < CR < 10$
Orange	$C > E-05$	$10 < CR < 20$
Red	$C > E-03/\text{yr}$	$CR > 20$

Risk Characterization Using Colors

EXAMPLE DEFENSE-IN-DEPTH RISK LIMITS

(N = Minimum Equipment Required for each Key Safety Function)

Two Equipment Availability Options (more are possible)

Green	$> N+1$ (or 2)	All
Yellow	$N+1$ (or 2)	All - 1
Orange	N	$N+1$
Red	$N-1$	N

PSA in On-Line & Off-Line Maintenance Planning

Risk Characterization Using Colors

RESPONSE TO RISK COLORS

Green

Information only

Yellow

Heightened awareness required; may limit unavailability time or take compensatory actions

Orange

Required compensatory actions and equipment protective measures; Sr. Mgmt. approval required to enter voluntarily

Red

Not to be entered voluntarily; if emergent, immediate actions required to reduce risk

Risk Management in Plant Operations -- Procedures and Demonstration

➤ On-line

- Basis is 13 Week “Template”
 - Separates units
 - Separates “divisions” of equipment
 - Procedures define actions each week
- Risk evaluation part of work planning
- Operators review risk and determine “emergent” risk

➤ Off-line

- Basis is known work
 - Past Schedules
 - Defense-in-Depth
- Risk evaluation fine-tunes schedule
- Risk evaluation updated for changing conditions

Plant Staff Responsibilities

Work Planning/Management

- **REVIEW** schedules for configuration impacts
- **ASSESS** risk using ORAM-SENTINEL and **CREATE** risk assessment profiles
- **REASSESS** risk for emergent conditions

Operations

- **ENSURES** plant configurations match planned risk assessment.
- **REASSESS** risk if an emergent condition results in a plant configuration that has not been previously assessed (“WHAT-IF”).

RISK Management Engineer

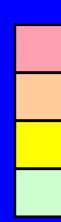
- **ADVISE & SUPPORT** Work Management and Operations for risk & software.
- **RUN** ORAM-SENTINEL CDF cases for unanalyzed conditions (WHITES).
- **REVIEW** work week risk profiles
- **TREND** risk

Risk Monitor Examples

ORAM-SENTINEL™ BLENDED RISK ASSESSMENT – On-Line

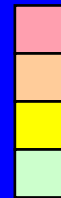
Safety Function Assessment

- Degree of Defense In Depth
- Susceptibility to Undesirable (Non-Core Damage) Endstates



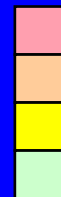
Plant Transient Assessment

- Susceptibility to Plant Transient
- Combination of Transient Potential and/or Safety Function Degradation

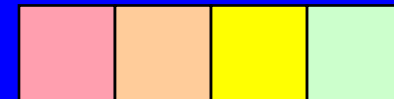


Probabilistic Assessment

- CDF & LERF
- Thresholds Based On Relative Change & Peak CDF



Decision Basis:







Risk Management In Plant Operations

RISK MONITOR EXAMPLES - ORAM-SENTINEL™





ORAM-SENTINEL Application Mode

Please select the desired mode of operation from the available options by clicking the associated button.

On-Line Evaluations

-   **SCHEDULE PLANNING**
Provides monitoring of Safety Functions, Plant Transients, and PSA evaluations during on-line maintenance.
-   **WORK RELEASE**
Single configuration monitor.

Outage Evaluations

-   **SCHEDULE PLANNING**
Provides monitoring of Safety Functions, Integrated Safety, and PSSA evaluations during outage-based maintenance.
-   **WORK RELEASE**
Single configuration monitor.

Date Frame Selection

	Date	Time
Starting at	01-JUN-00	00:00
Ending at	30-JUN-00	24:00

Risk Monitor Examples

ORAM-SENTINEL™ OPERATOR SCREEN

The screenshot displays the ORAM-SENTINEL interface with the following components:

- Overall Status:** Indicated by a green bar at the top right of the main display area.
- PSA Results:** A section on the right showing risk factors:

CDF RISK INCREASE FACTOR	1.010E+000
LERF RISK INCREASE FACTOR	1.020E+000
- Safety Fns Status:** A list on the left under 'Safety Functions Status' including:
 - PSA RESULTS
 - CONTAINMENT PRESSURE CONTROL
 - 125V DC POWER
 - AC ELECTRIC POWER
 - HIGH PRESSURE INJECTION
 - CONTAINMENT HEAT REMOVAL
 - LOW PRESSURE INJECTION
 - PRESSURE CONTROL
 - REACTIVITY CONTROL
- Transients Status:** A list in the middle under 'Plant Transients Status' including:
 - ATWS
 - LOSS OF BALANCE OF PLANT SYS
 - LOSS OF OFFSITE POWER
 - MEDIUM LOCA
 - LOSS OF DC
- Equipment List:** A table at the bottom showing safety systems categorized by function:

High Pressure	Low Pressure	Decay Ht Removal	Pressure Control	Reactivity
HPCI System	RHR/LPCI	RHR/RHRSV Div. 1	ADS/SRYs	SBLC
RCIC	Core Sprag	RHR/RHRSV Div. 2	RCIC	RPS/ARI/RPT
SSMP		Shutdown Cooling		
CRD				
Room Cooling				

PSA in On-Line & Off-Line Maintenance Planning

Risk Monitor Examples

ORAM-SENTINEL™ SAFETY FUNCTIONS

TYPICAL BWR

- » Containment Integrity
- » Pressure Control
- » Electric Power
- » Reactivity Control
- » High Pressure Injection
- » Low Pressure Injection
- » Heat Removal
- » Secondary Containment

TYPICAL PWR

- » Containment Integrity
- » Vital Power Sources
- » Subcriticality
- » Core Cooling
- » RCS Integrity
- » Heat Sink
- » Component Cooling

Risk Monitor Examples

ORAM-SENTINEL™ TRANSIENTS

TYPICAL BWR

- » Reactor / Turbine Trip
- » Loss of Offsite Power
- » ATWS
- » LOCA
- » Loss of FW

TYPICAL PWR

- » Reactor / Turbine Trip
- » Loss of Offsite Power
- » LOCA
- » Loss of Support System(s)

Risk Monitor Examples

ORAM-SENTINEL™ TYPICAL RISK STATUS

ORAM-SENTINEL - All Modes Maintenance and Safety Function Advisor - [Operations Plant Status View]

File Edit Results Reports Tools View Window Help

UNITE ACTUAL

12-MAY-04 16:28 Now! Duration: 200d 07h 32m Overall Overall

SFAT SFAT PTAT PTAT PSA PSA

Safety Functions Status

- PSA RESULTS
- CONTAINMENT PRESSURE CONTROL
- 125V DC POWER
- AC ELECTRIC POWER
- HIGH PRESSURE INJECTION
- CONTAINMENT HEAT REMOVAL
- LOW PRESSURE INJECTION
- PRESSURE CONTROL
- REACTIVITY CONTROL

Plant Transients Status

- ATWS
- LOSS OF BALANCE OF PLANT SYS
- LOSS OF OFFSITE POWER
- MEDIUM LOCA
- LOSS OF DC

PSA RESULTS

CDF RISK INCREASE FACTOR 3.690E+000

LERF RISK INCREASE FACTOR 2.100E+000

ReturnToService RemainInService CompActions

0SSD - SAFE SHUTDOWN PUMP AND MOT

IHPC - U1 HPCI PUMP/TURBINE

Export Schedule View All Activities Worksheet Current Agts WHAT-IF Save Reset

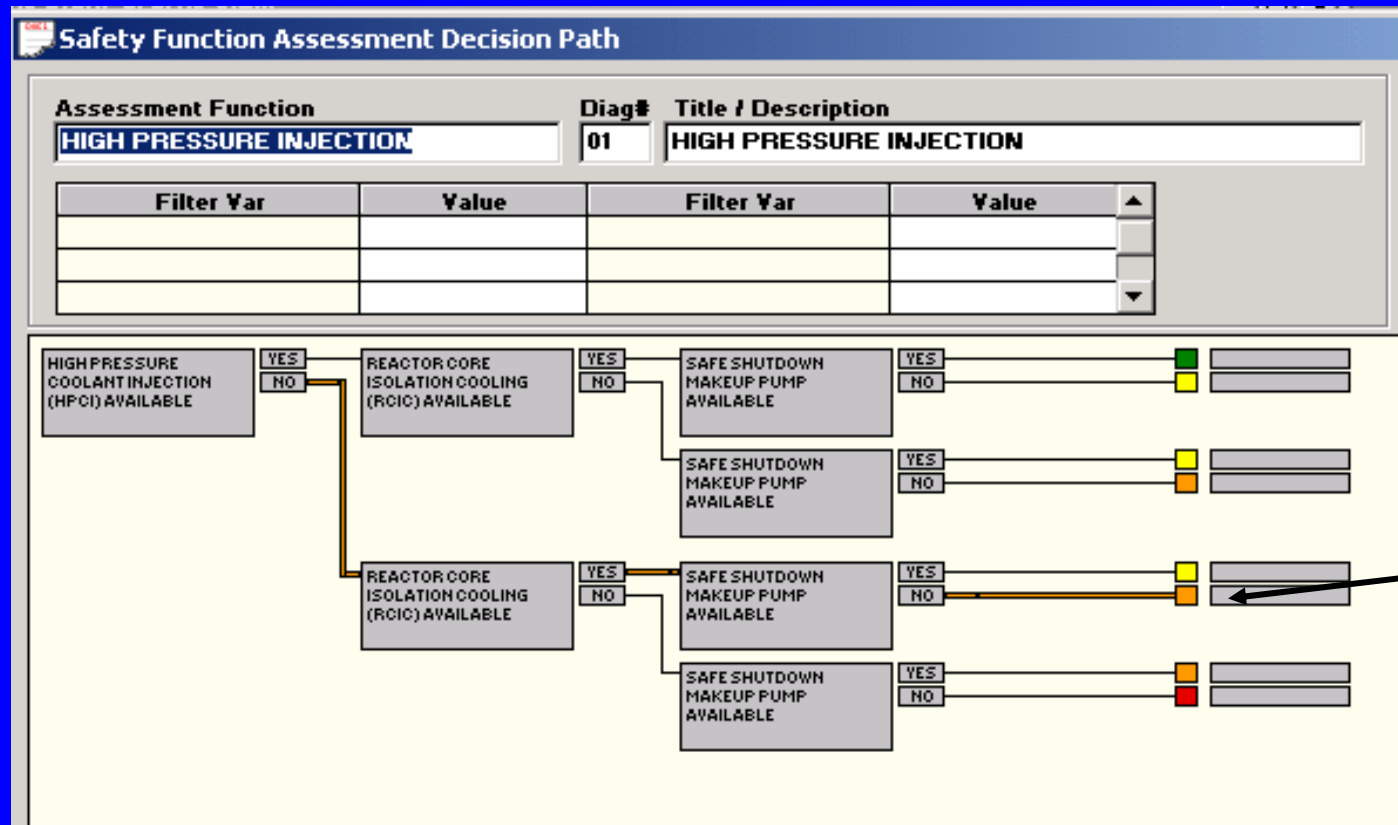
Safety Systems

High Pressure	Low Pressure	Decay Ht Removal	Pressure Control	Reactivity
HPCI System	RHR/LPCI	RHR/RHRSV Div. 1	ADS/SRVs	SBLC
RCIC	Core Sprag	RHR/RHRSV Div. 2	RCIC	RPS/AR/RPT
SSMP		Shutdown Cooling		
CRD				
Room Cooling				

PSA in On-Line & Off-Line Maintenance Planning

Risk Monitor Examples

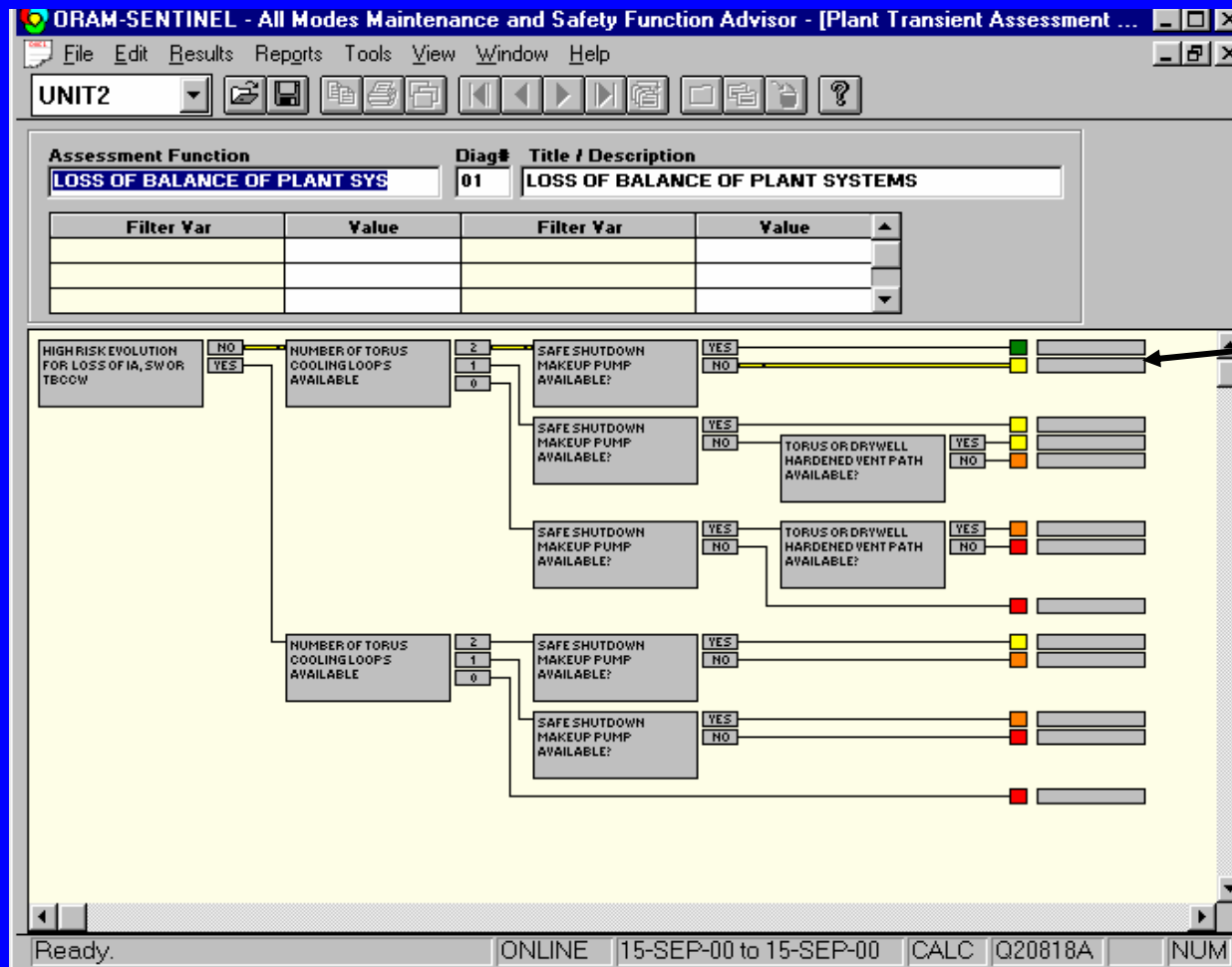
ORAM-SENTINEL™ SAFETY FUNCTION STATUS



Limiting Logic Path

Risk Monitor Examples

ORAM-SENTINEL™ TRANSIENT SUSCEPTIBILITY

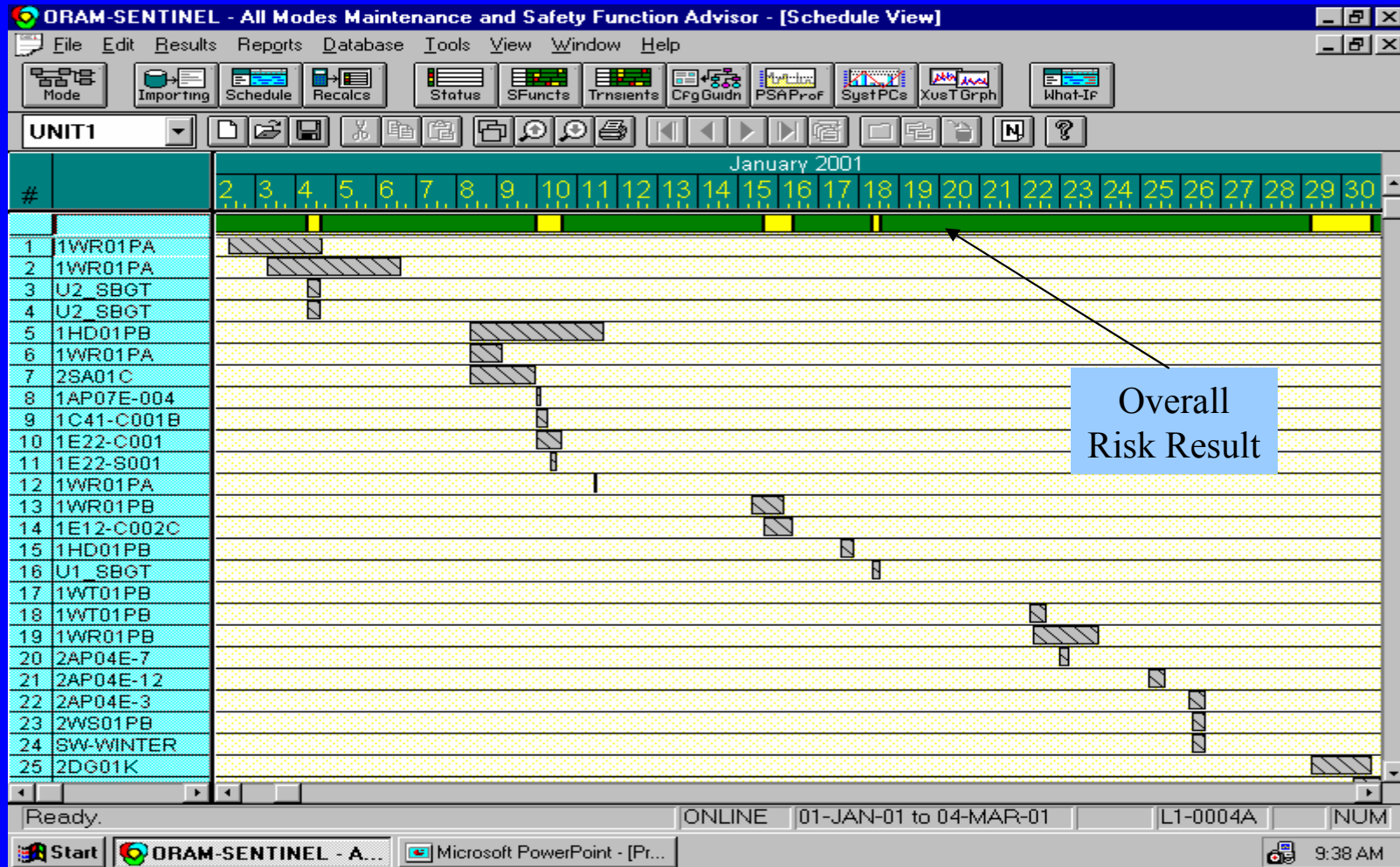


Limiting Logic Path

PSA in On-Line & Off-Line Maintenance Planning

Risk Monitor Examples

ORAM-SENTINEL™ OOS PLANNING SCREEN



PSA in On-Line & Off-Line Maintenance Planning

Risk Monitor Examples

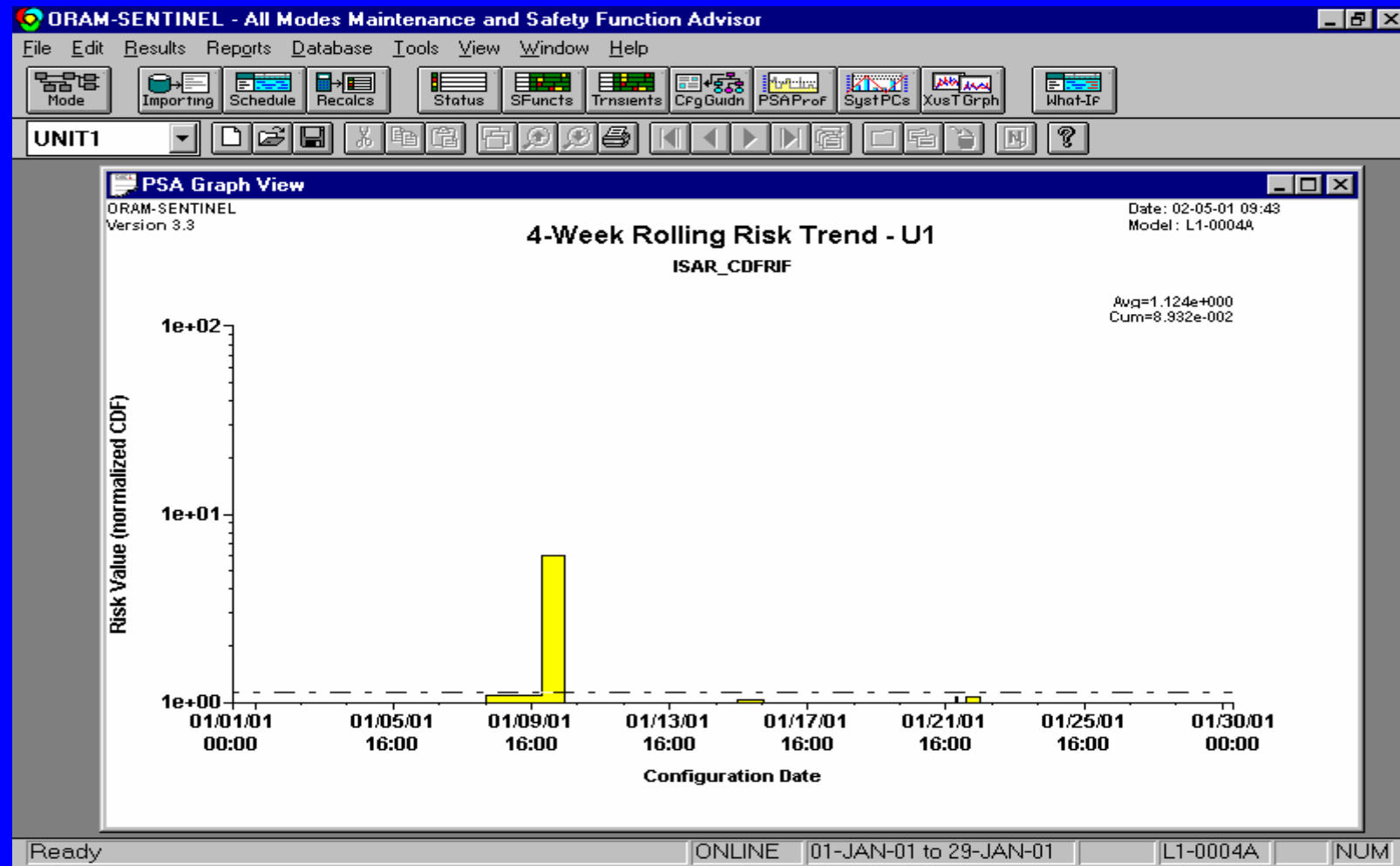
ORAM-SENTINEL™ SCHEDULE RESULTS SCREEN (Equipment OOS Increased for Illustration)



PSA in On-Line & Off-Line Maintenance Planning

Risk Monitor Examples

ORAM-SENTINEL™ PSA RESULT TREND SCREEN



PSA in On-Line & Off-Line Maintenance Planning

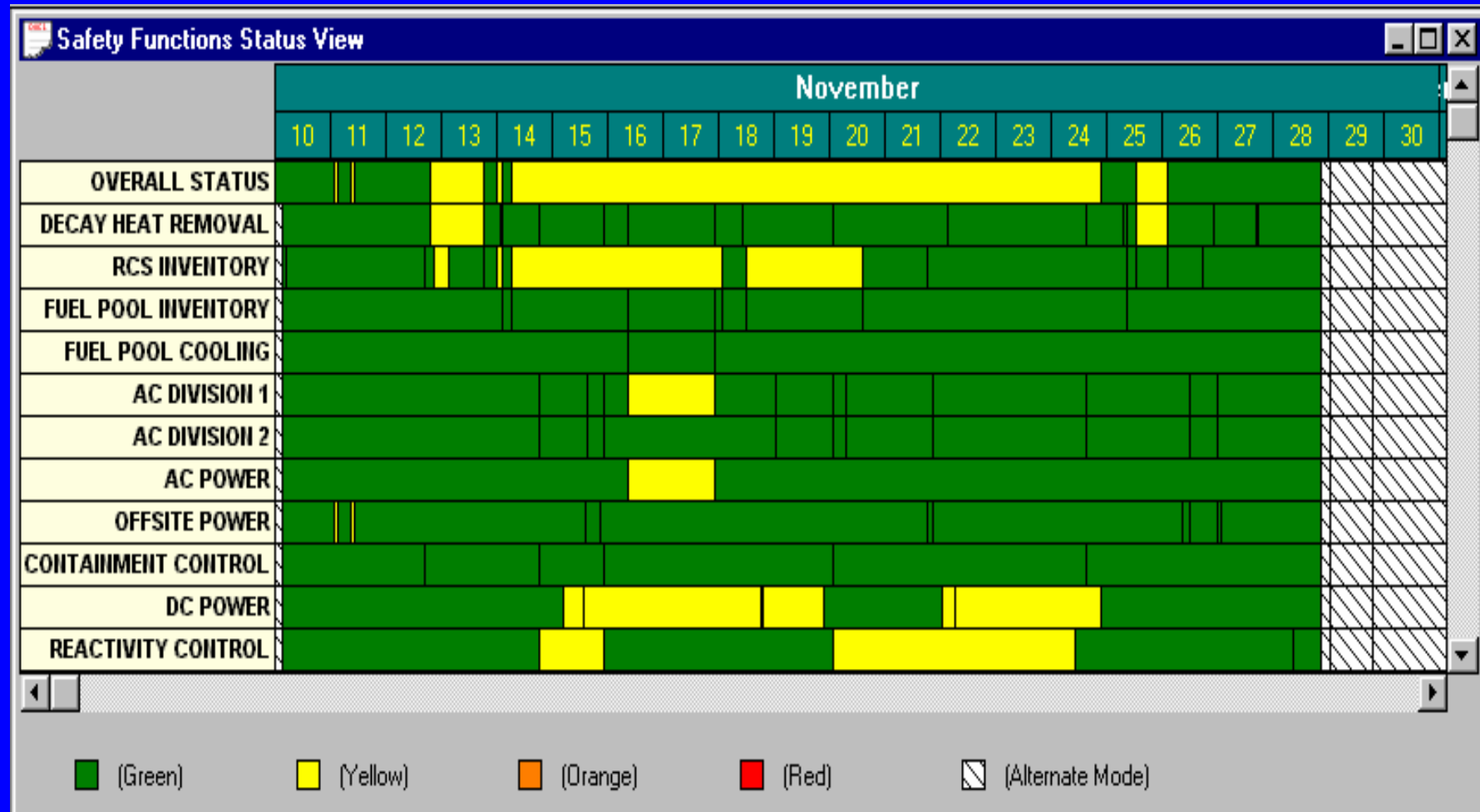
Risk Management In Plant Operations

SHUTDOWN RISK MANAGEMENT

- U.S. utilities follow NRC-endorsed guidance
- Applies to all shutdown modes of operation
- Actions and Responsibilities are proceduralized
- Monitors Defense-in-depth for all safety functions
- Generally does not involve PSA
- Identifies protected equipment
- Requires contingency plans
- Requires authorizations and communications

Shutdown Risk Management

TYPICAL OUTAGE DEFENSE-IN-DEPTH RISK PROFILE



PSA in On-Line & Off-Line Maintenance Planning

Shutdown Risk Management

SHUTDOWN PSA ISSUES

- Risk measure: CDF, LERF, both, alternative end states
- Plant operating states (POSs) to be assessed
 - Modes and equipment configurations
 - Transition between modes
- Plant configurations to be assessed
 - Criteria for differentiating between configurations
- Definition of LERF applied to LPSD

Risk Management In Plant Operations

RISK STATUS COMMUNICATIONS

- Plant risk status is generally displayed to all employees on the website and in the plant
- Plant risk status is reported in daily operations and plan-of-the-day reports/telecons/meetings
- Contingency plans and protected equipment are reported for higher plant risk status levels
- Planned changes in plant risk status are reported including contingency plans and protected equipment

Use of PSA in Optimizing On-Line and Off-Line Maintenance Planning

CONCLUSIONS

- PSA is used daily in maintenance decision making by all Exelon plants
 - Required by regulation
 - Accepted by Work Planners and Operations
- Risk management tools are available to assist decision making
- Applying risk insights from PSA reduces costs
 - Permits acceptable on-line maintenance
 - Avoids unacceptable risk and resulting operational consequences (events, shutdown)