PSA Applications and Risk Monitors

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Summary of PSA Applications

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Typical/Popular PSA Applications

Application	Description	Notes
Maintenance	USNRC regulation established requirement in 2000 **to assess and manage configuration risk**. Scope of SSCs may be limited based on risk-informed evaluation process.	US NRC regulation a strong driver for US NPPs to control risk impact of maintenance. Risk Monitor is the tool of choice for compliance.
Regulatory Inspections	Use of PSA and risk Insights to improve the focus and effectiveness of inspections.	Risk ranking of components, structures, systems. Response of regulator to findings – importance?
Regulatory Reporting Requirements	NRC revised requirements for licensee reporting of events and conditions with several objectives, including elimination of reports of no risk significance.	PSA based event analysis – NPPs incentivised to analyse events and reduce reporting where risk significance shown to be low.
Plant Vulnerabilities	Use of PSA to reduce risk by implementing design, operational, and maintenance changes.	The first application of PSA!
Fire Protection	Use PSA to support improvements in fire protection and cost-effective resolution of fire protection issues.	Some problems with uncertainties in models and plant equipment capability. Currently strong uptake in US due to regulation
NRC Accident Sequence Precursor Program	This ongoing program to assess the significance of events will continue.	PSA based event analysis by regulator
Risk Monitors	Real time risk tracking. Real time risk impact of maintenance. Outage planning/maintenance scheduling.	Risk monitors often used to support other applications

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Some more PSA Applications

Application	Description	Notes
Control Room Habitability	Apply PSA and Risk-informed approaches to support resolution of radiological and toxic gas issues related to control room monitoring and in-leakage.	Assessments aim to establish the frequency of loss of control room habitability to be below 1E-6 per year. Some plants have also included an assessment of the conditional probability of core damage to demonstrate an acceptably low frequency.
Emergency Planning	Using alternate source term and PSA to improve efficiency and cost, including development of emergency plan exercises and changes to emergency plan requirements.	Use to reduce emergency planning zones and requirements was not successful. Evolving area for use in establishing Emergency Action (Response) Levels.
In-Service Inspection	NRC has approved two methods (WOG and EPRI) for weld exams. Both methods provide significant reduction in scope of RCS ISI.	
Risk Significance of Systems, Structures and Components for testing, corrective actions	Use of PSA to rank SSCs for application in programs such as IST, MOV Testing, Corrective Actions.	Routine in the US and remains key element of both Industry’s and NRC ranking of Safety Issues
Technical Specifications	PSA application to support allowed outage time (AOT) extensions.	This type of application becoming more frequent - Risk Monitors

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Less common PSA Applications

Application	Description	Notes
Alternate Source Term	Replace design basis choice of source term with risk-informed choice	Link to emergency planning / emergency planning zones
Corrective Action Program	Use of PSA to support significance assessment and disposition of events.	Link to PSA based event analysis
Graded QA	Graded Quality Assurance Program implementation on the basis of risk significance.	Possibly not as beneficial as expected.
In-Service Testing	NRC has approved risk-informed IST approach for pump and valve test interval optimization.	Benefit versus cost can vary.
Insurance	Use of PSA to reduce Insurance costs	Conservative Risk Modelling. Applications have been more for decommissioning/dismantling plants.

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PSA Quality for Applications

- Proliferation of PSA applications has been accompanied by quality standards

- ASME Standards for Level 1 PSA and LERF
- ANS Level 2 Standard

- USNRC expects compliance with Reg Guide 1.200 (mostly ASME with some comments/clarifications)

- IAEA has published TECDOC on PSA Quality

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PSA based event analysis (1)

- PSA based event analysis is the application of PSA to rank events by risk significance
- Risk significance measured by
  - CCDP: conditional core damage probability or
  - CLRP: conditional large release probability
- Sometimes called precursor analysis
- Regulatory and NPP use
  - Reporting
  - Significance determination of inspection findings

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PSA based event analysis (2)

- Applicability:
  - Any event that can be mapped to PSA model
    - Depends on scope of PSA (e.g shutdown events)
  - Usual to distinguish between condition events and precursor to initiating events
    - Condition: a degradation or unavailabililty persists for a time
    - Precursor: an event occurs which may lead to IE in PSA or maps directly to IE in PSA

PSA based event analysis (3)

- Key Points of Methodology
  - Quantification of appropriate parts of PSA with appropriate assumptions
  - Failure memory (usually the original event didn’t lead to CD!)

- PSA status / quality
  - Simplifications in PSA – fit for **this** purpose? (event analysis)
  - Representative / up-to-date PSA
  - General quality, completeness of PSA
    - Affects results!

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PSA based event analysis (4)

- Insights
  - Quantitative – CCDP, CLRP
  - Quantitative: likely paths to core damage / release, importances
  - Qualitative: study alternate similar scenarios, possible evolutions of event

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Introduction to Risk Monitors – some history

THE ORIGINAL RISK MONITOR INTERFACE

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1988 - ESSM

- Installed at Heysham 2 Power Station to assist the operator in managing outages of safety related plant.
- Addresses compliance with the station's operating rules; carry out an 'on-line' risk assessment to demonstrate that the risk is acceptable.
- Available to operator and maintenance staff
- has the level 1 reactor PSA programmed within it in the form a single large logic tree.

1994 - Safety Monitor

- Installed at many plants in four countries after first installation at San Onofre.
- Core is PSA model (Level 1 and 2) for all plant operating modes and dual units.
- Carry out ‘on-line’ and off line risk assessment for current and future configurations.
- Available to all plant staff
- User group and continuous upgrading to meet user requirements
- has rule tracking for safety functions, tech spec, etc.
- Fast solution engine for each configuration

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1998 - NRC Initiatives

- USNRC purchases Risk Monitor for use in training site inspectors and other staff. Develops models for each of the reactor types in US
- Issues Regulatory Guide 1.174 An Approach for Using Probabilistic Risk Assessment in Risk-informed Decisions on Plant Specific Changes to the Current Licensing basis.
- Maintenance Rule implementation and expansion
  - Assess & manage the risk increase - Full Power and Shutdown
  - Scope of structure, systems, and components (SSCs) may be limited
    - Risk-informed evaluation process
    - Significant to public health & safety

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Key features (1)

- Usable by NPP staff such as control room staff, maintenance staff
  - Day to day use
  - Planning and evaluation of hypothetical situations
- Generate reports for plant management
- No detailed PSA knowledge should be required

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Key features (2)

- NPP staff should be able to work with NPP terminology
  - Component names
  - Maintenance tags
  - Operational modes
  - RM hides details of PSA model

- Rapid feedback: model quantification typically < 1 minute

- Promotes understanding of risk leads to a reduction in risk of plant operation. Key example: refuelling outages of light water reactors.

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RISK MONITOR MODES

– Schedule mode for planning risk management throughout an outage (longer term future timeframe)

– Real mode for assessing real time plant risk and recording past configurations and risk

– Hypothetical mode for looking at long and short term future timeframes, I.e., what-if maintenance scenarios and assessment of alternatives

– Different users may have access to different modes

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DUAL UNITS

- A number of RMs are used at dual unit plants
- Risk tracked on both units
- Software should ensure consistency for availability of shared equipment
  - Shared items set as on maintenance by operator using Unit 1 Risk Monitor model
  - Consistency best achieved if software ensures that this equipment is marked as on maintenance in unit 2 model also

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ENVIRONMENTAL AND TESTING FACTORS

- Modified IE frequencies when tests are in progress or under particular external environmental conditions
  - Maintenance induced initiating events more likely in certain shutdown states (e.g., loss of supports due to maintenance error, draindown or overdraining for a PWR, etc)
  - Bad weather increasing loss of offsite power frequency
  - etc

- These effects are typically smoothed out into averages in the Living PSA
  - Particularly full-power portion of LPSA

- Risk Monitor represents point-in-time situation by allowing application of environmental/testing factors

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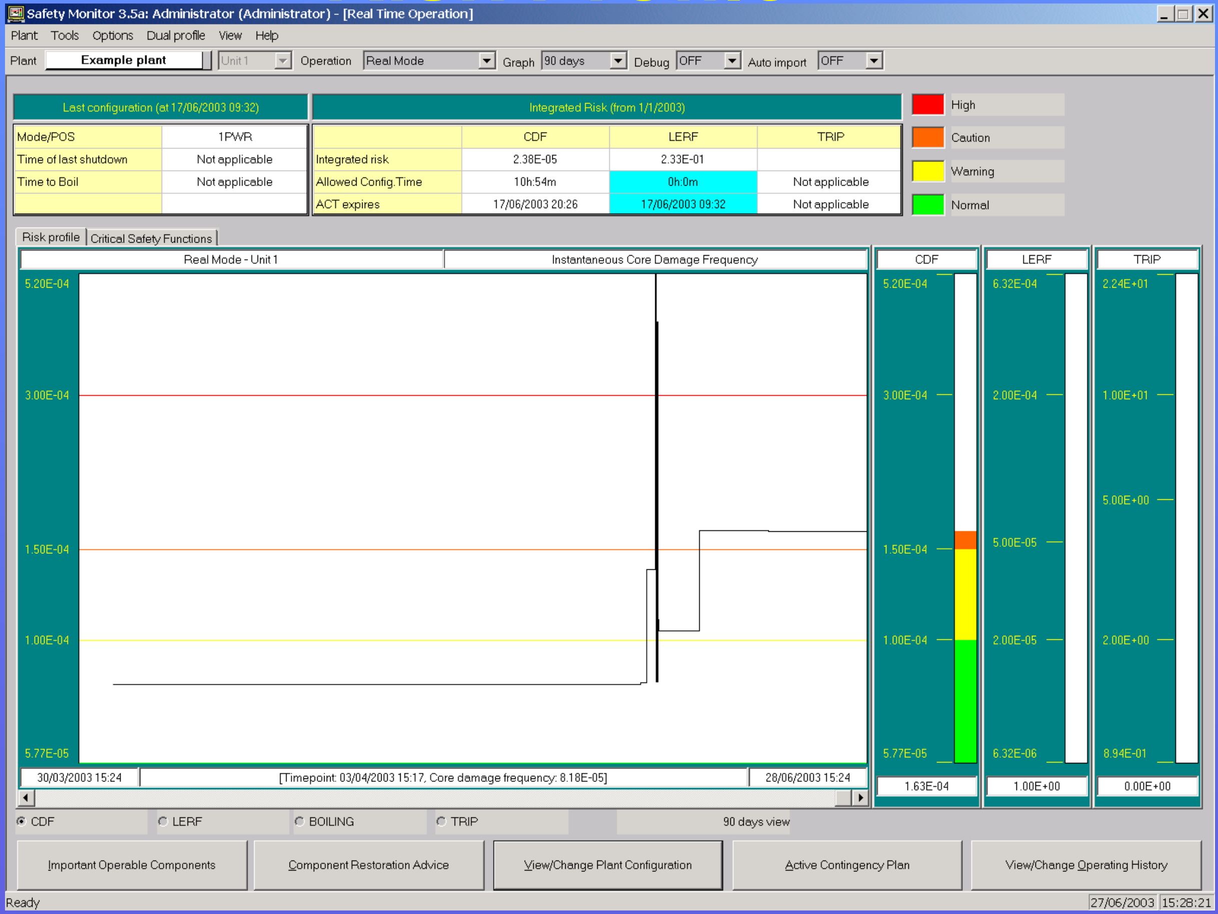
Risk Monitors Now: EXAMPLE SCREENSHOT - Risk Profile



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Defense in depth

- Status views in RMs extended to deterministic system status
  - Colour coding of status – trains available, partial degradation of supports
  - Implemented by flexible safety function status trees
    - User defined

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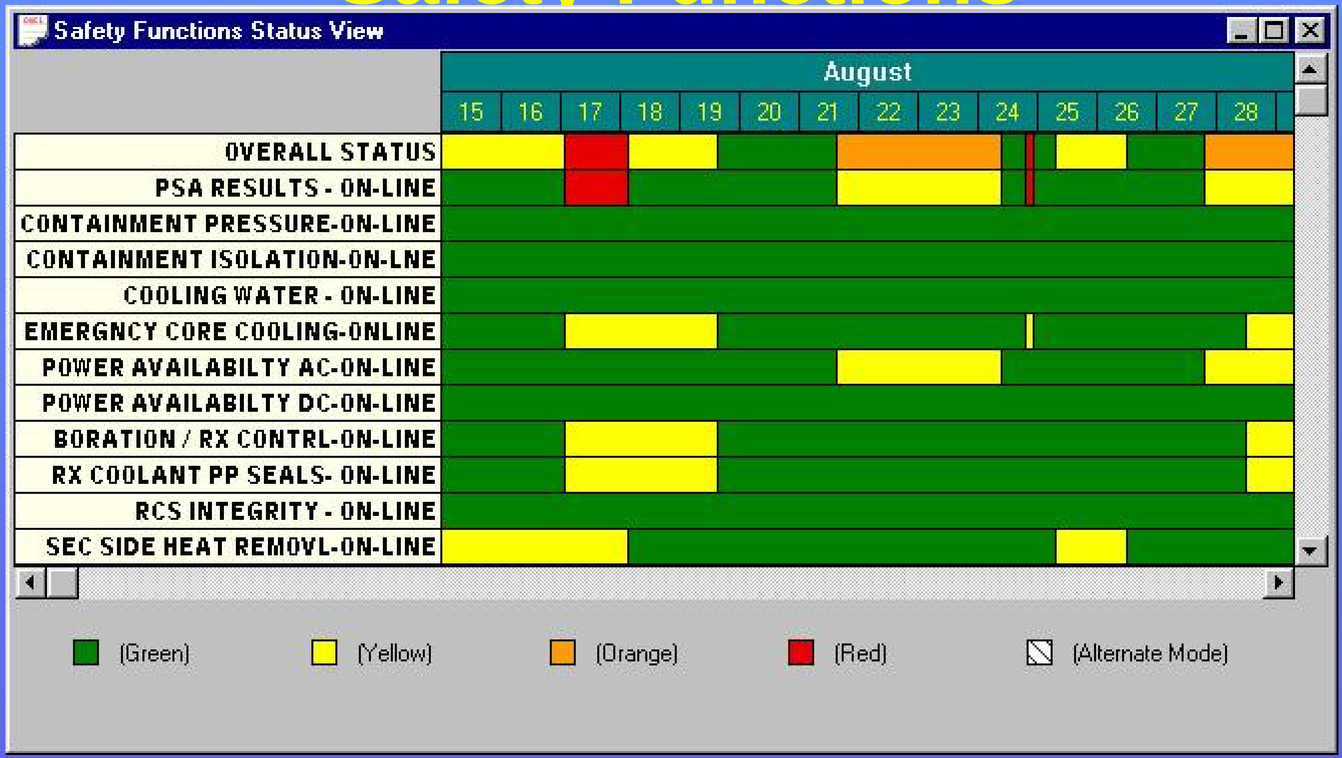
Risk Monitors Now: EXAMPLE SCREENSHOT - Safety Functions



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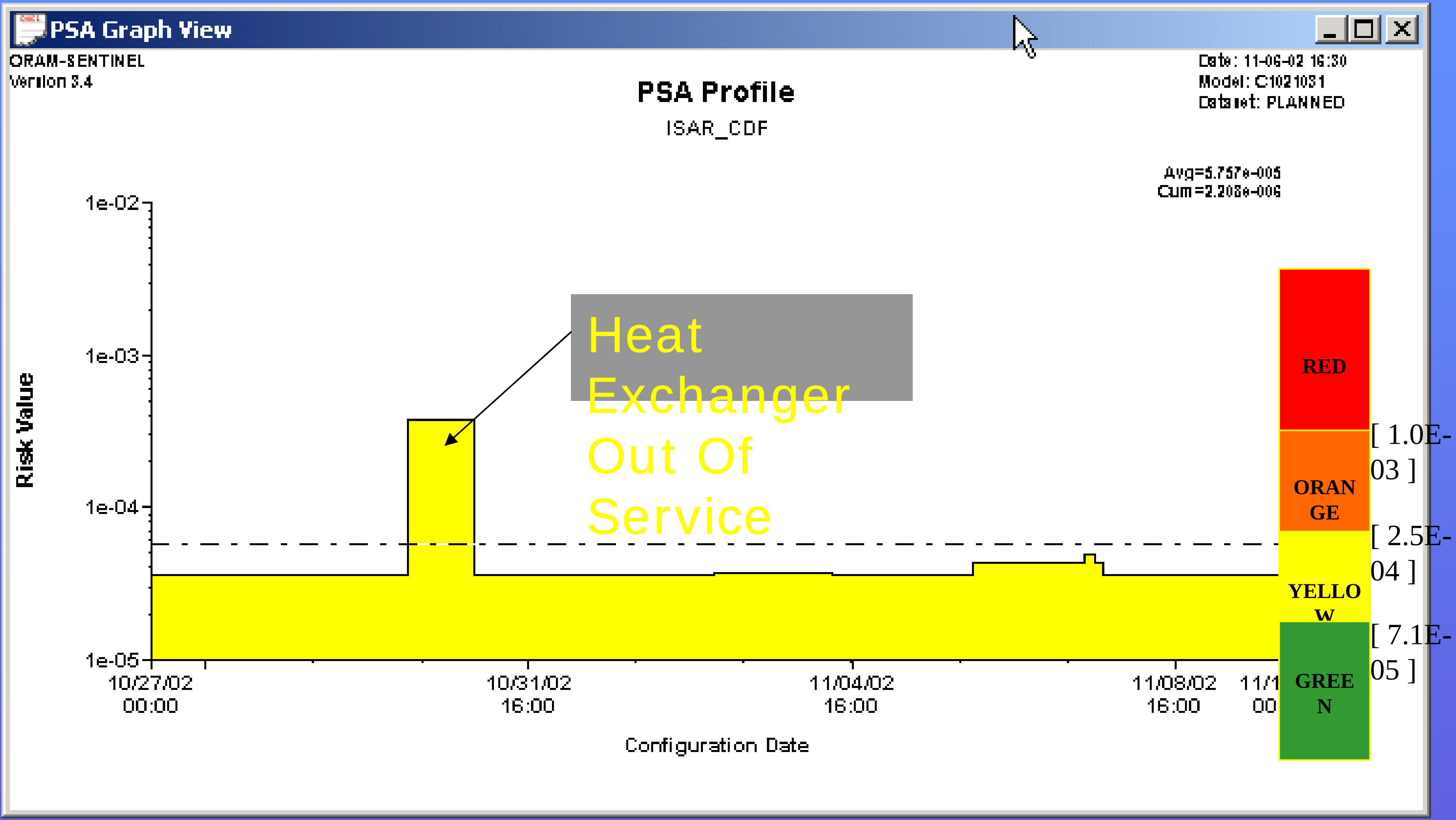
Example risk profile report for management



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Trends: Model Solution

- Processors getting faster & engines improving
  - Solution times reduced

- Multi-core PCs:
  - Standard solution engines use one core at a time
    - No speed up on multi-core
  - Solution: multi-threaded engine
    - Multi-threaded psimex in Safety Monitor
    - 2 cores – twice as fast
    - 4 cores – four times as fast
    - Etc

- Benefits of all this:
  - Little need for model optimisation/simplification
  - Huge benefit for schedule optimisation (volume of runs to analyse schedule)

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Trends: Switch to Risk Informed Completion Times

- RMs traditionally generated an **Allowed Configuration Time** using a simple “allowed delta risk” / risk level calc
- Problems seen with clock resetting; clock started again if configuration changed
- Regulatory impression that use was not formalised
- In practice seen that many NPPs didn’t use ACTs
- **Safety Monitor** moving to Risk informed completion time – avoids clock resetting. Cumulative configuration risk will be used to generate limits – precise methodology likely to take account of NRC view
- In US this is driven by USNRC. NRC wants reporting of time in riskier configurations and targets applied and compliance with targets. (Initiative 4b)

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SUMMARY OF KEY POINTS

- PSA Applications:
  - Variety of applications
  - PSA quality

- Risk monitors
  - access to risk calculations through an interface for non-specialist use
  - Risk profile taking account of equipment unavailabilities and environmental/testing/activity influences
  - Deterministic status (safety functions) also monitored
  - Can support applications, especially most “popular”
  - Many detailed features:
    - Scheduling
    - Hypothetical (what if) mode
    - Consistent treatment of dual units
    - Fast solution

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