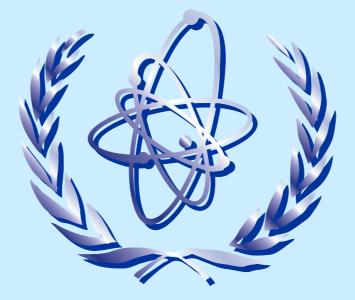
IAEA Training in level 1 PSA and PSA applications

Basic Level 1. PSA course for analysts



PSA quantification



- Impacts of truncation on the numerical results
- Importance analysis
 - Roles and definitions
- Uncertainty analysis
 - Elements of the uncertainties



- OPTIMISTIC RESULTS
- DELETED CUTSETS
- INCONSISTENT CONTRIBUTORS
- INCORRECT IMPORTANCE MEASURES
- LEVEL OF DETAIL FOR APPLICATIONS
- LEVEL 1 / LEVEL 2 INTERFACE



- DO NOT ACCEPT RECOMMENDED CUTOFF VALUES
- ADJUST TRUNCATION LIMITS UNTIL RESIDUALS ARE LESS THAN ~ 10 % OF TOTAL
 PER INITIATING EVENT
 TOTAL CORE DAMAGE
- BETTER RESOLUTION MAY BE REQUIRED FOR SPECIFIC PLANT DAMAGE STATES OR LEVEL 2 ISSUES
- BETTER RESOLUTION MAY BE REQUIRED FOR SPECIFIC APPLICATIONS / SENSITIVITY STUDIES



- PROVIDE SIMPLE ESTIMATES OF SENSITIVITY TO EXTREME VALUES FOR MODEL PARAMETERS
- PROVIDE A SIMPLE AND COARSE RANKING OF ITEMS WITH RESPECT TO RISK OR SAFETY IMPORTANCE
- CAN BE USED TO FOCUS REVIEWS AND SENSITIVITY STUDIES
- SHOULD BE VIEWED AS A SUPPLEMENT TO, NOT A REPLACEMENT FOR, CAREFUL "TOP-DOWN" ANALYSIS OF THE RISK CONTRIBUTORS
- KNOWLEDGE OF THE MODEL IS ESSENTIAL TO AVOID MISLEADING CONCLUSIONS
 Slide 5.



COMPONENTS / INDIVIDUAL BASIC EVENTS GROUPS OF BASIC EVENTS

SYSTEMS HUMAN ACTIONS

- INITIATING EVENTS
- MODEL ELEMENTS

- EARLY FATALITY FREQUENCY ANY OTHER RISK MEASURE WITHIN THE PSA MODEL SCOPE
- LARGE, EARLY RELEASE FREQUENCY
- CORE DAMAGE FREQUENCY
- **RISK INDICES**

NUMERICAL IMPORTANCE MEASURES RISK INDICES AND MODEL ELEMENTS

PSA quantification



- FRACTIONAL IMPORTANCE
- FUSSELL VESELY IMPORTANCE
- BIRNBAUM IMPORTANCE
- RISK REDUCTION WORTH
- RISK ACHIEVEMENT WORTH

PSA quantification NUMERICAL IMPORTANCE MEASURES VARIABLE DEFINITIONS

- $\begin{array}{ll} R(Q_{\chi} = N) & \mbox{Calculated value of Risk Index R with the value} \\ & \mbox{of Model Element X set equal to its nominal} \\ & \mbox{Mean Value N.} \end{array}$
- $R(Q_{\chi} = 1)$ Calculated value of Risk Index R with the value of Model Element X set equal to 1.0.
- $R(Q_X = 0)$ Calculated value of Risk Index R with the value of Model Element X set equal to 0.



- THE MATHEMATICAL FORMULAS FOR SOME NUMERICAL IMPORTANCE MEASURES ARE NOT DEFINED CONSISTENTLY IN THE LITERATURE
- THE "BASIC PHILOSOPHY" IS CONSISTENT
- DIFFERENCES PERTAIN PRIMARILY TO TREATMENT OF "SUCCESS STATES"



- MEASURE OF THE FRACTION OF RISK INDEX R THAT IS CONTRIBUTED BY FAILURE OF MODEL ELEMENT X
- GENERAL DEFINITION

 FI_{χ} = SUM (All cutsets with X failed) / R(Q_{\chi} = N)

• RISK SPECTRUM DEFINITION (SAME AS FUSSELL -VESELY IMPORTANCE)

 $FI_{\chi} = [R(Q_{\chi} = N) - R(Q_{\chi} = 0)] / R(Q_{\chi} = N)$

 $FV_{\chi} = [R(Q_{\chi} = N) - R(Q_{\chi} = 0)] / R(Q_{\chi} = N)$

RISK SPECTRUM DEFINITION

 $FV_{\chi} = [R(Q_{\chi} = N) - R(Q_{\chi} = 0)] / R(Q_{\chi} = N)$

GENERAL DEFINITION

PSA quantification

MEASURE OF THE FRACTION OF RISK INDEX R THAT IS CONTRIBUTED BY FAILURE OF MODEL ELEMENT X

NUMERICAL IMPORTANCE MEASURES **FUSSELL - VESELY IMPORTANCE**



- RISK SPECTRUM DEFINITION NOT CALCULATED
- $BI_{\chi} = [R(Q_{\chi} = 1) R(Q_{\chi} = 0)] / R(Q_{\chi} = N)$
- GENERAL DEFINITION
- **CONTRIBUTION TO RISK INDEX R FROM FAILURE OF MODEL ELEMENT X. (SOMETIMES CALLED THE PARTIAL RISK DERIVATIVE FOR ELEMENT X.)**
- **BIRNBAUM IMPORTANCE** MEASURE OF THE MAXIMUM POSSIBLE FRACTIONAL





- MEASURE OF THE AMOUNT BY WHICH RISK INDEX R MAY BE REDUCED IF MODEL ELEMENT X IS PERFECT
- GENERAL DEFINITION (INVERTED IN SOME REFERENCES)

 $RRW_{\chi} = R(Q_{\chi} = N) / R(Q_{\chi} = 0)$

• **RISK SPECTRUM DEFINITION**

 $RRW_{\chi} = R(Q_{\chi} = N) / R(Q_{\chi} = 0)$



 $RAW_{\chi} = R(Q_{\chi} = 1) / R(Q_{\chi} = N)$

PSA quantification

$$RAW_{\chi} = R(Q_{\chi} = 1) / R(Q_{\chi} = N)$$

- GENERAL DEFINITION (INVERTED IN SOME REFERENCES)
- MEASURE OF THE AMOUNT BY WHICH RISK INDEX R MAY INCREASE IF MODEL ELEMENT X IS ALWAYS FAILED
- NUMERICAL IMPORTANCE MEASURES



- USED TO IDENTIFY COMMON CONTRIBUTORS THAT APPEAR IN MANY SEQUENCES AND CUTSETS
- USED FOR RANKING PLANT FEATURES BY RISK SIGNIFICANCE (E.G., FOR FOCUSED TESTING OR MAINTENANCE)
- RISK ACHIEVEMENT WORTH IS USEFUL FOR ESTIMATING THE RISK SIGNIFICANCE OF EQUIPMENT THAT IS REMOVED FROM SERVICE
- RISK REDUCTION WORTH IS USEFUL FOR BOUNDING THE RISK BENEFITS FROM PROPOSED IMPROVEMENTS
- IMPACTS FROM SOME PRECURSOR EVENTS CAN BE EVALUATED BY EXAMINATION OF IMPORTANCE MEASURES
- EXAMINATION OF GROUPS CAN PROVIDE INSIGHTS ABOUT COMPOUND IMPACTS AND DEPENDENCIES NOT EVIDENT FROM SINGLE-COMPONENT ANALYSES



PSA quantification

NUMERICAL IMPORTANCE MEASURES COMMON PROBLEMS IN USE OF RISK IMPORTANCE

- IMPACTS FROM NUMERICAL TRUNCATION
- ARTIFICIAL ASYMMETRIES IN MODELS FOR NORMALLY RUNNING EQUIPMENT
- LIMITATIONS IN SIMULATING EQUIPMENT OUT OF SERVICE (GUARANTEED FAILED)
- LIMITATIONS IN SIMULATING "SUCCESS STATES"
- NO CONSIDERATION OF UNCERTAINTIES; DETAILED NUMBERS IMPLY THAT ALL VALUES ARE KNOWN PRECISELY
- FOCUS TOO MUCH ATTENTION ON NUMERICAL COMPARISONS OF FINE STRUCTURE, RATHER THAN "BIG PICTURE" UNDERSTANDING OF RISK CONTRIBUTORS



- HAZARD VS. RISK
- BOUNDING VS. REALISTIC
- DECISION MAKING
- ROLE OF COMMUNICATION IN RISK ASSESSMENT



- DATA
- MODEL
- APPLICATION OF THE MODEL



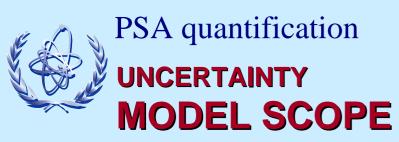
- INTERPRETATION AND CLASSIFICATION OF FAILURE EVENTS
- DETERMINATION OF SUCCESS DATA (NUMBER OF DEMANDS, OPERATING HOURS, EXPOSURE TIME, ETC.)
- SIZE OF DATA SAMPLE (STATISTICAL UNCERTAINTY)
- APPLICABLE POPULATION
- MATHEMATICAL MODELS FOR DATA ANALYSIS



- COMMON DATA FOR SEVERAL COMPONENTS / FAILURE MODES
- INDEPENDENT SAMPLING REDUCES OVERALL
 UNCERTAINTY
- ACCOUNT FOR CORRELATION TO MAINTAIN CORRECT UNCERTAINTY
- MEAN VALUE OF $(A)^2 = /= (MEAN VALUE OF A)^2$



- SCOPE
- COMPLETENESS
- SUPPORTING DOCUMENTATION AND ANALYSES
- SUCCESS CRITERIA
- ASSUMPTIONS
- ERRORS



- LEVEL 1, LEVEL 2, LEVEL 3
- FULL-POWER OPERATION, LOW POWER, SHUTDOWN
- INTERNAL EVENTS, EXTERNAL EVENTS



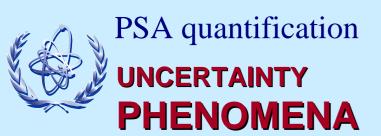
• WE CAN MAKE VERY LIMITED STATEMENTS ABOUT OUR STATE OF KNOWLEDGE WITH RESPECT TO PUBLIC HEALTH RISK IF WE HAVE PERFORMED ONLY A LEVEL 1 PSA THAT ESTIMATES THE FREQUENCY OF CORE DAMAGE DUE TO INTERNAL INITIATING EVENTS DURING FULL-POWER OPERATION.



- INITIATING EVENTS
- PHENOMENA
- **DEPENDENCIES**
- HUMAN PERFORMANCE



- SUPPORT SYSTEMS
- "INSIGNIFICANT" INITIATORS
- RECOMMENDED TREATMENT
 - ESTIMATE FREQUENCY
 - DETERMINE FUNCTIONAL IMPACTS
 - ALLOW PSA MODEL TO QUANTIFY ITS SIGNIFICANCE



- FAILURE TO SCRAM (ATWS)
- OVERCOOLING (PTS)
- TRANSIENT-INDUCED EVENTS (LOCA, LOSP, ETC.)
- CONTAINMENT PHENOMENA (HYDROGEN, STEAM, AEROSOLS, ETC.)
- RECOMMENDED TREATMENT
 - INCLUDE IN MODEL, IF POSSIBLE
 - BOUND FUNCTIONAL IMPACTS IF NOT MODELED EXPLICITLY
 - SENSITIVITY STUDIES CAN ESTIMATE NUMERICAL CONSERVATISM



- PHYSICAL
- FUNCTIONAL
- LOCATION / ENVIRONMENTAL
- DATA-BASED
- HUMAN



UNCERTAINTY SUPPORTING DOCUMENTATION AND ANALYSES

- PLANT DESIGN INFORMATION
- OPERATING, TESTING, MAINTENANCE PROCEDURES
- DESIGN-BASIS ACCIDENT ANALYSES
- BEST-ESTIMATE THERMAL / HYDRAULIC ANALYSES
- RECOMMENDED TREATMENT
 - "FIRST PRINCIPLES" CALCULATIONS
 - DOCUMENT AND QUANTIFY UNCERTAINTY
 - BOUND FUNCTIONAL IMPACTS IF NOT MODELED EXPLICITLY
 - SENSITIVITY STUDIES CAN ESTIMATE NUMERICAL CONSERVATISM



- SYSTEMS
- OPERATOR ACTIONS
- RECOMMENDED TREATMENT
 - BEST-ESTIMATE ANALYSES
 - BOUNDING ASSUMPTIONS
 - SENSITIVITY STUDIES CAN ESTIMATE NUMERICAL CONSERVATISM

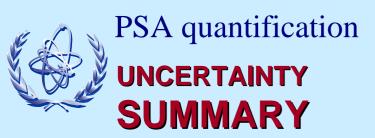


• DOCUMENT ALL ASSUMPTIONS

 SENSITIVITY STUDIES CAN ESTIMATE NUMERICAL CONSERVATISM



- THERE ARE ERRORS IN YOUR STUDY
- SOME ERRORS PRODUCE CONSERVATIVE RESULTS, AND SOME PRODUCE OPTIMISTIC RESULTS
- TYPICAL REVIEWS TEND TO FIND ERRORS THAT PRODUCE CONSERVATIVE RESULTS
- TYPICAL REVIEWS TEND TO MISS ERRORS THAT PRODUCE OPTIMISTIC RESULTS
- REVIEWS SHOULD EXAMINE "WHAT IS NOT IMPORTANT" WITH EQUAL EMPHASIS AS "WHAT IS IMPORTANT"
- DEVELOP CONFIDENCE AND UNDERSTANDING <u>WHY</u> SPECIFIC INITIATING EVENTS, SCENARIOS, AND CONDITIONS ARE NOT IMPORTANT
- ANALYST KNOWLEDGE, SENSITIVITY STUDIES, AND IMPORTANCE ESTIMATES CAN HELP TO FOCUS EXAMINATION



- COMMUNICATION IS A CENTRAL ELEMENT OF RISK ANALYSIS AND DECISION MAKING
- WE HAVE NOT COMPLETED OUR JOB AS RISK ANALYSTS UNTIL WE HAVE ADDRESSED UNCERTAINTY
- BETTER A SIMPLIFIED QUANTITATIVE, OR EVEN QUALITATIVE, UNCERTAINTY ANALYSIS THAN NOTHING