AIMS-PSA : A Software for Integrating Various Types of PSAs

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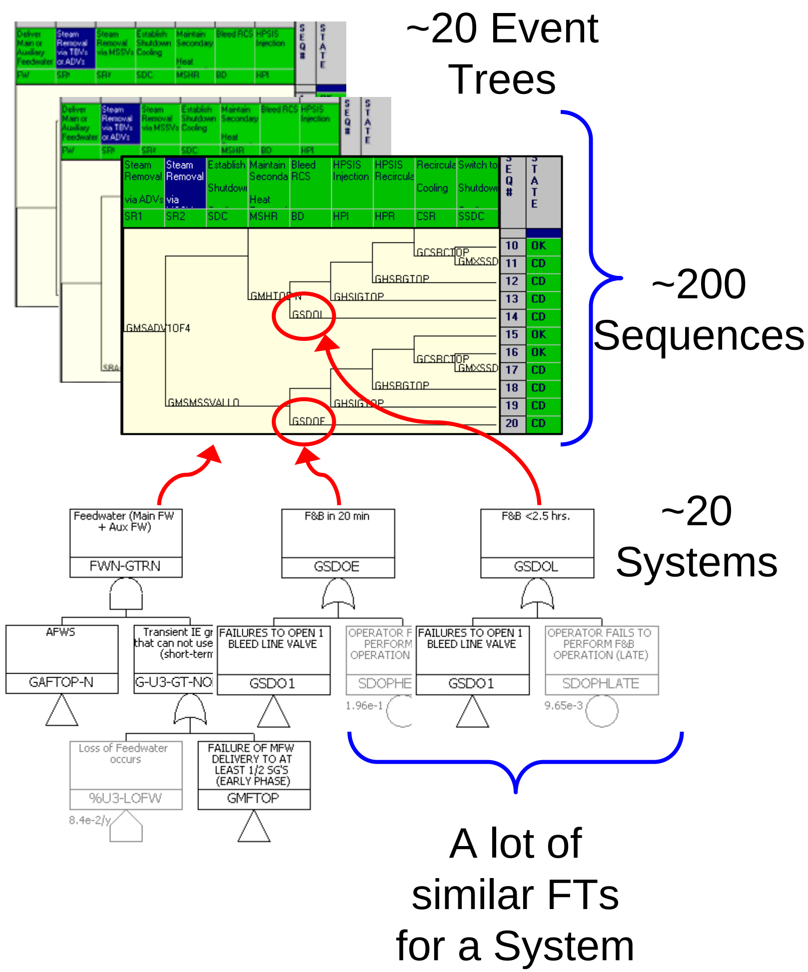
1. Introduction

- With the increased use of probabilistic safety analysis (PSA) in regulatory decision making, more accurate and integrated risk information are requested.
- Even though several PSA SW tools have successfully supported a limited scope of PSA, it is difficult to integrate all scopes of PSA.
  - The approaches applied to each scope of PSA are basically different each other
  - There are some barriers in substituting a lot of manual works for an automatic quantification to integrate all scope of PSA.
- The development of AIMS-PSA has an aim to provide a method and tool to automatically integrate all scopes of PSA.

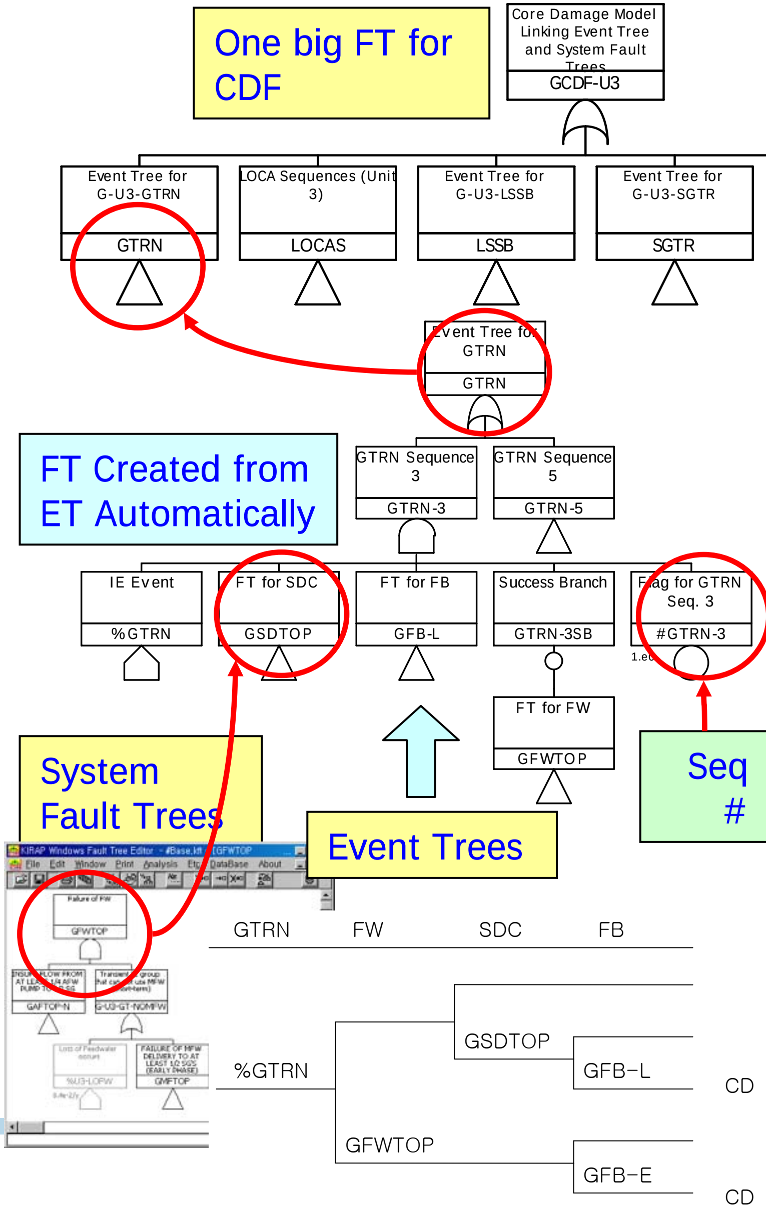
2. Integration of Event Trees and Fault Trees

- A Typical PSA
  - A lot of event trees and fault trees
    - 20 ETs result in 200 sequences
    - 20 FTs are linked to each sequence
    - Quantification for each sequence ➔ 200 times quantification ➔ Slow Quantification
  - Manually build a lot of similar fault trees
    - break the circular logics between system fault trees
    - handle different conditions for one system
  - Different models for the PSA and the risk monitor



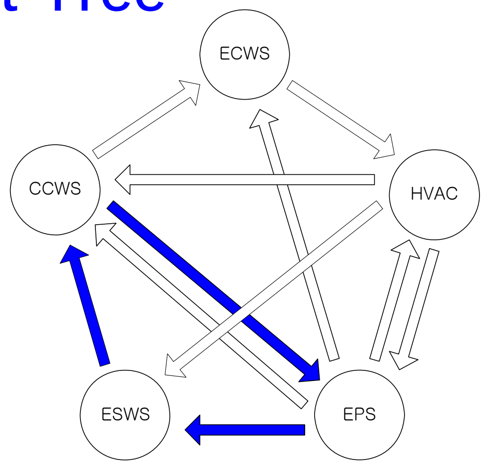
2.1 New Quantification Method using One Big Fault Tree Model

- ◆ One big fault tree Generated
  - Each sequence converted into a FT
    - A dummy event for representing a sequence number is added
- ◆ in Quantification
  - Solve NOT gate using 'delete term operation'
  - Delete the duplicated nonsense cut sets between sequences (created due to the sequence number events)
- ◆ One Time Quantification of the big FT
  - ➔ Total CDF & Cut Sets
  - ➔ CDF for Each IE & Each Sequence

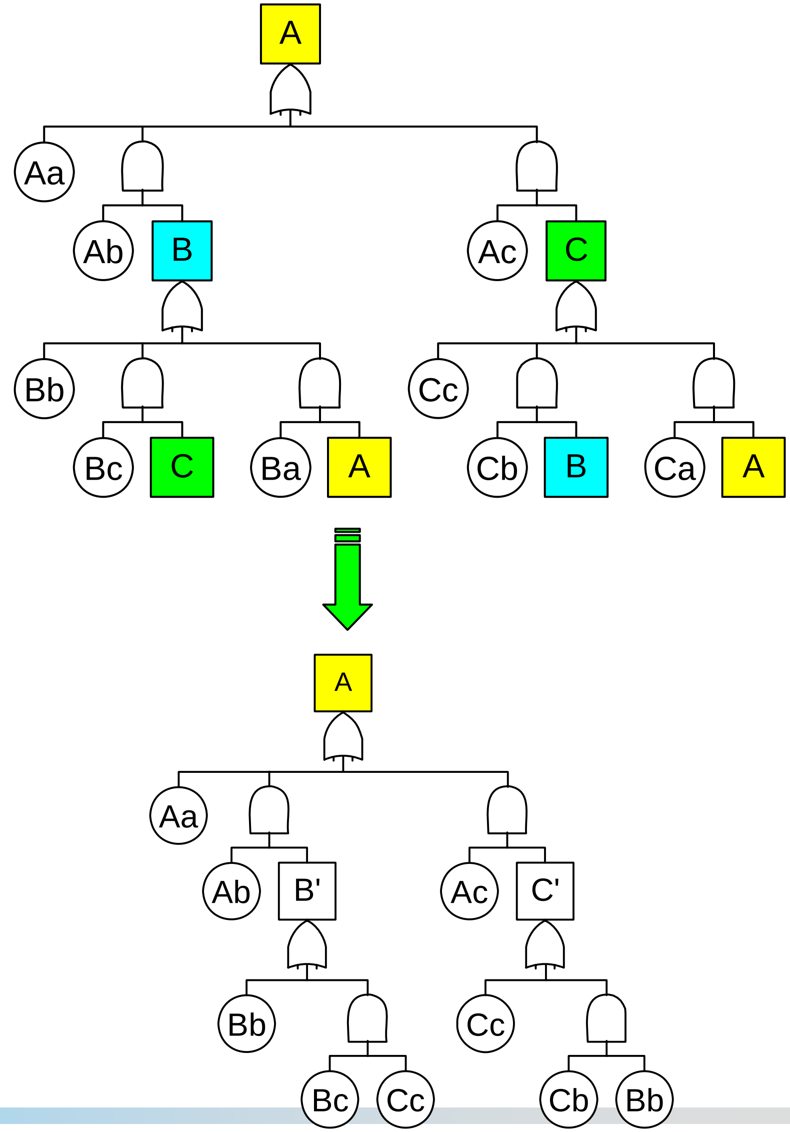


2.2 Circular Logics

- Most PSA has Circular Logics in the Fault Tree

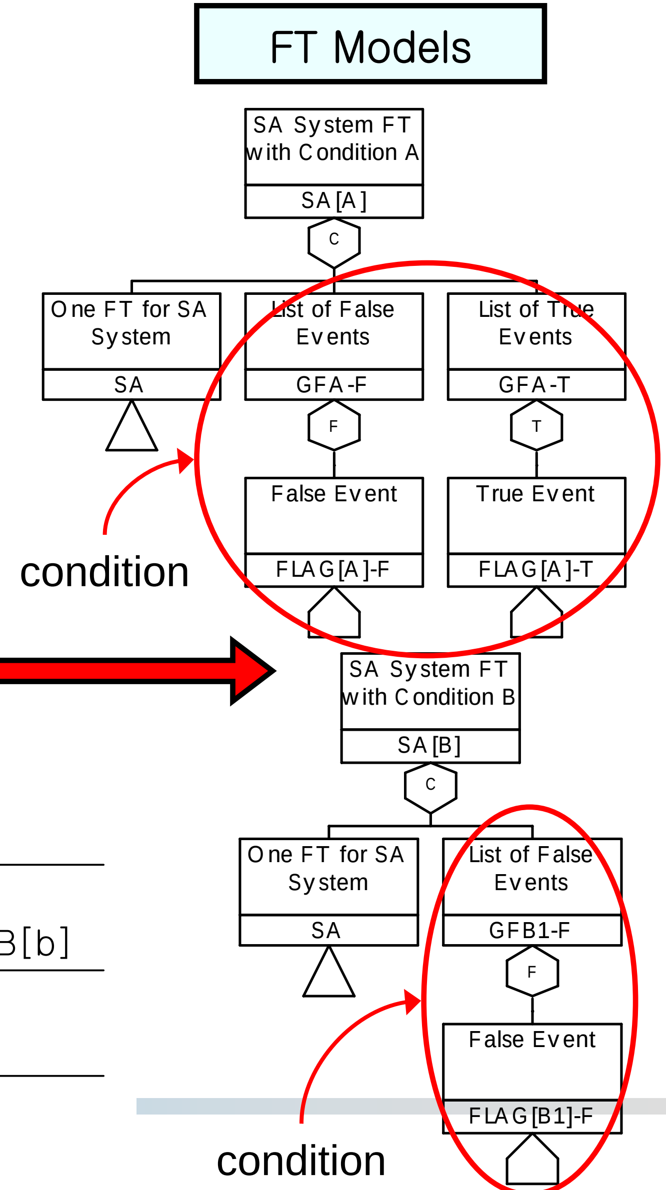


- Analytic Solution of Circular Logic
  - Yang's Algorithm
  - Convert a Fault Tree which has Circular Logics into a Logically Equivalent Fault Tree which has no Circular Logic
  - Implemented in the Cut Set Generation Engine FTREX



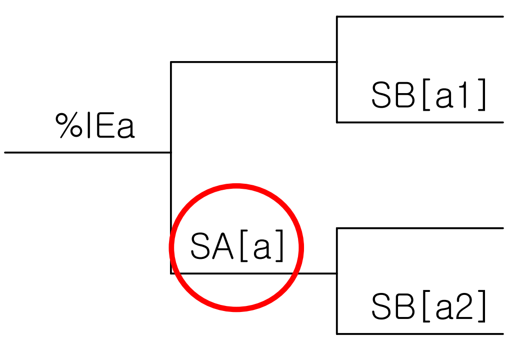
2.3 Condition Gate

- Typical PSAs
  - One system FT can be used in several places with minor changes
  - Most PSAs develop another FT for these cases
- New Gate Type Introduced
  - A Gate can have the conditioning events
  - AIMS-PSA automatically restructures the FT incorporating the conditioning events
  - It saves the effort to develop & maintain the PSA model

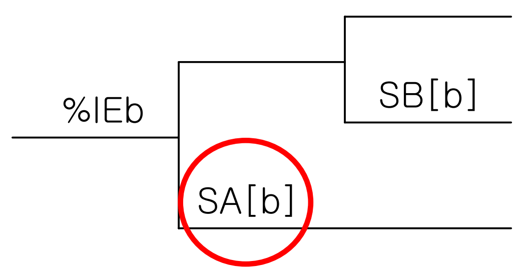


SA[a] = SA(FLAG[A]-F = False, FLAG[A]-T = True)
SA[b] = SA(FLAG[B1]-F=False)

Event Tree (a)



Event Tree (b)



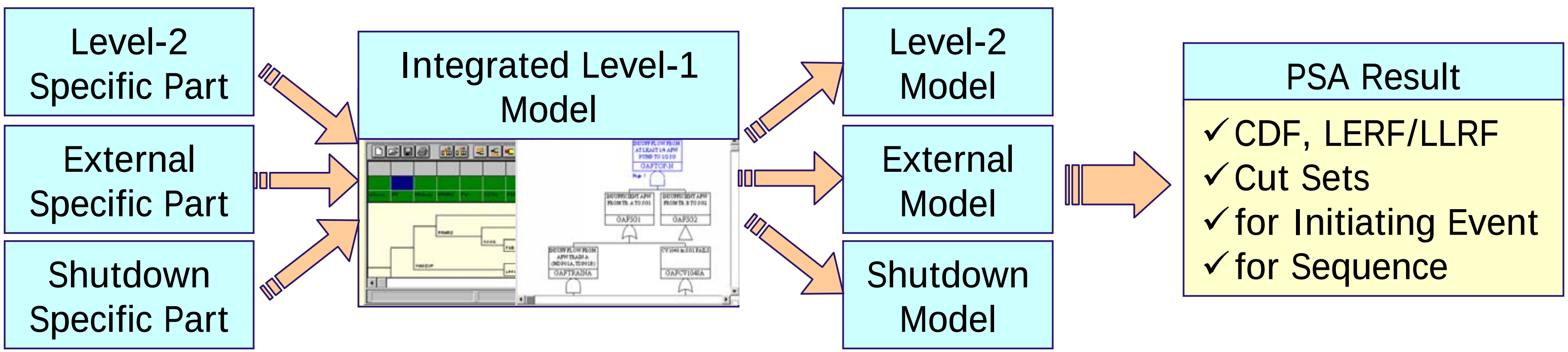
2.4 Summary : Integration of ET/FT

- Unique Features
  - Quantification using One Big Fault Tree Model
  - Automatic Solution of Circular Logics
  - Condition Gates

- One Model for PSA and Risk Monitor
- Save the Effort for PSA modeling and quantification
  - 20 – 50% for Level-1 Full Power Internal PSA Model
    - 3400 gates .vs. 6700 gates
  - One Time Calculation for a PSA
    - Few seconds for UCN34 Level-1 PSA Model

3. Integration of Various PSA Scopes

- Typical External & Shutdown PSA
  - Different Data & Analysis Method with Level-1 Internal PSA
  - A lot of manual works
- Each Scope of PSA Integrated
  - Based on Level-1 Internal PSA Model
  - Tabularize Information in each PSA scope
  - Builds a model for each PSA scope
  - ➔ Minimize the effort to prepare the model



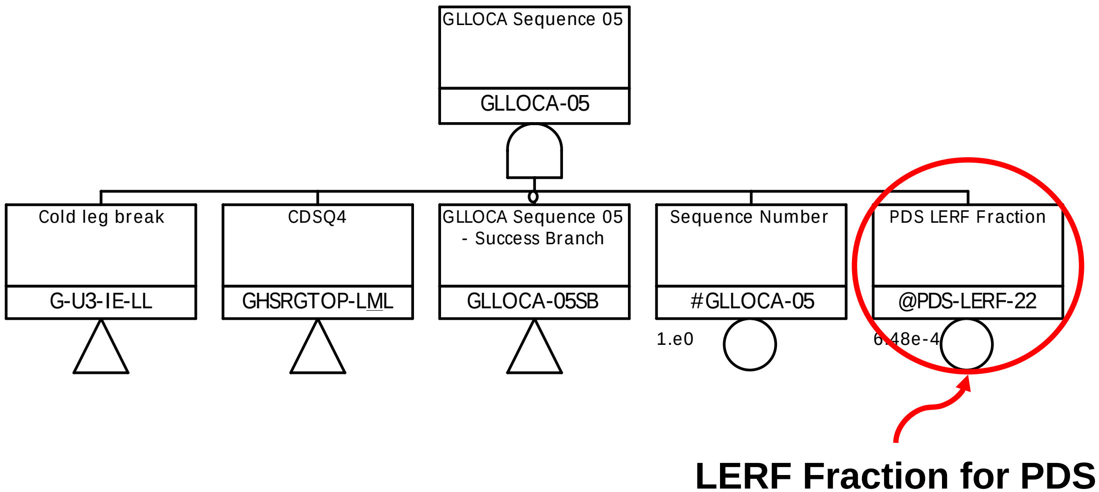
3.1 Level-2 PSA

- Integration of the Level-1 & 2 PSA
  - LERF fraction/frequency table is the interface for Level-1 & 2
  - Automatically Build the One Big Fault Tree for the LERF
  - PDS Frequency Table is transferred to the Level-2 PSA

PDS vs. LERF Fraction Table

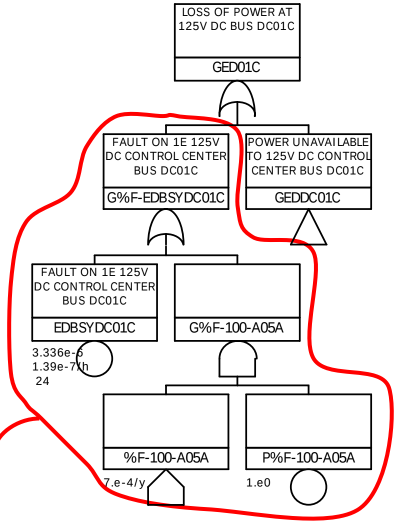
PDS #	LERF Fraction
01	1.00
03	2.09E-02
22	6.48E-02

An Example of the LERF Model



3.2 External PSA

- Automatically Build an External Model using
  - Internal PSA Model and
  - Hazard Information Table & Specific Model
- Easy and Fast Modeling and Quantification
  - Enables the analyst to concentrate on the External Specifics



Modified by Software

Room	IE Freq.	Trans-ferred Area	ET	Fail Proba	Failed Equip.
100-A05A	7e-4		GTRN	1.0	EDBCY01C AFMVO44A
100-A05A	7e-4	100-A13A	LCCW	0.01	EMBSY03A SWMVT67A

Level-1 Internal PSA Model
- Event Tree
- Fault Tree

Hazard Information Table

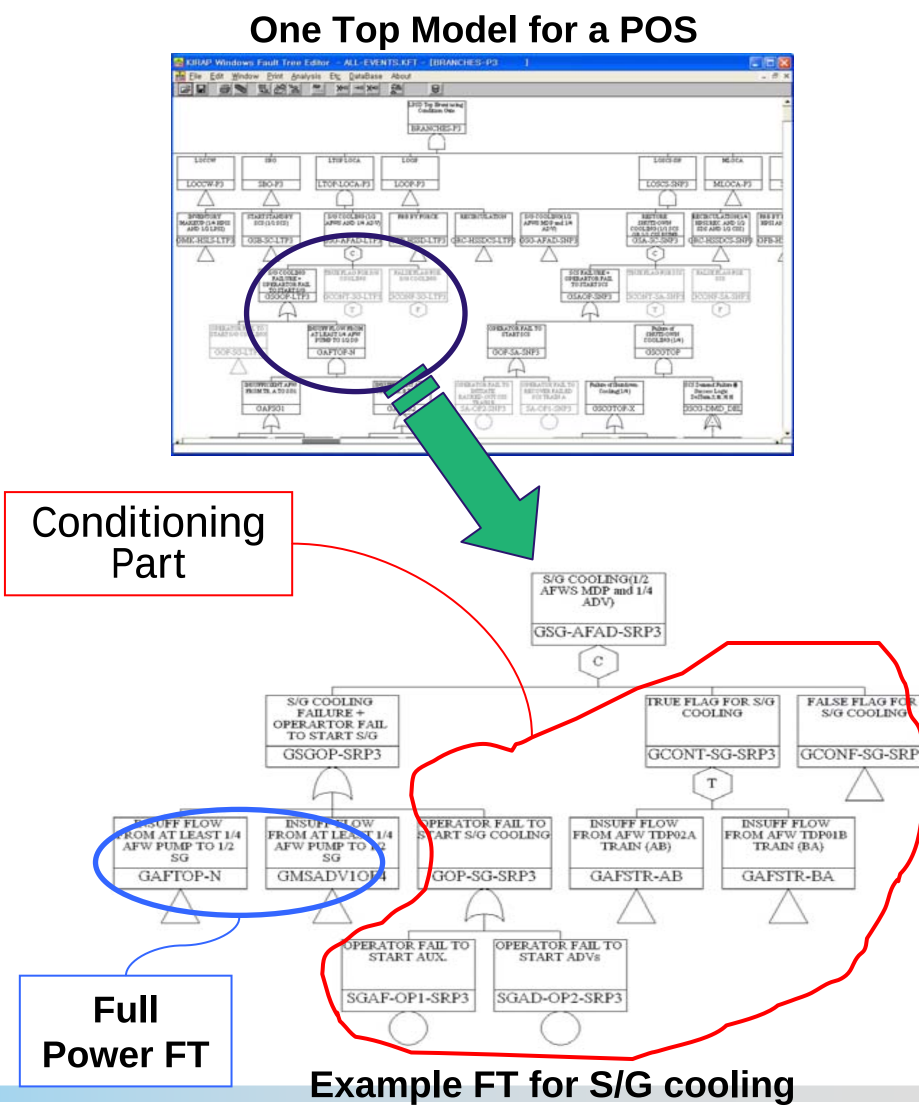
External Specific Model
- Event Tree
- Fault Tree

One Top Model for External Event

CDF
- for Each Fire Event

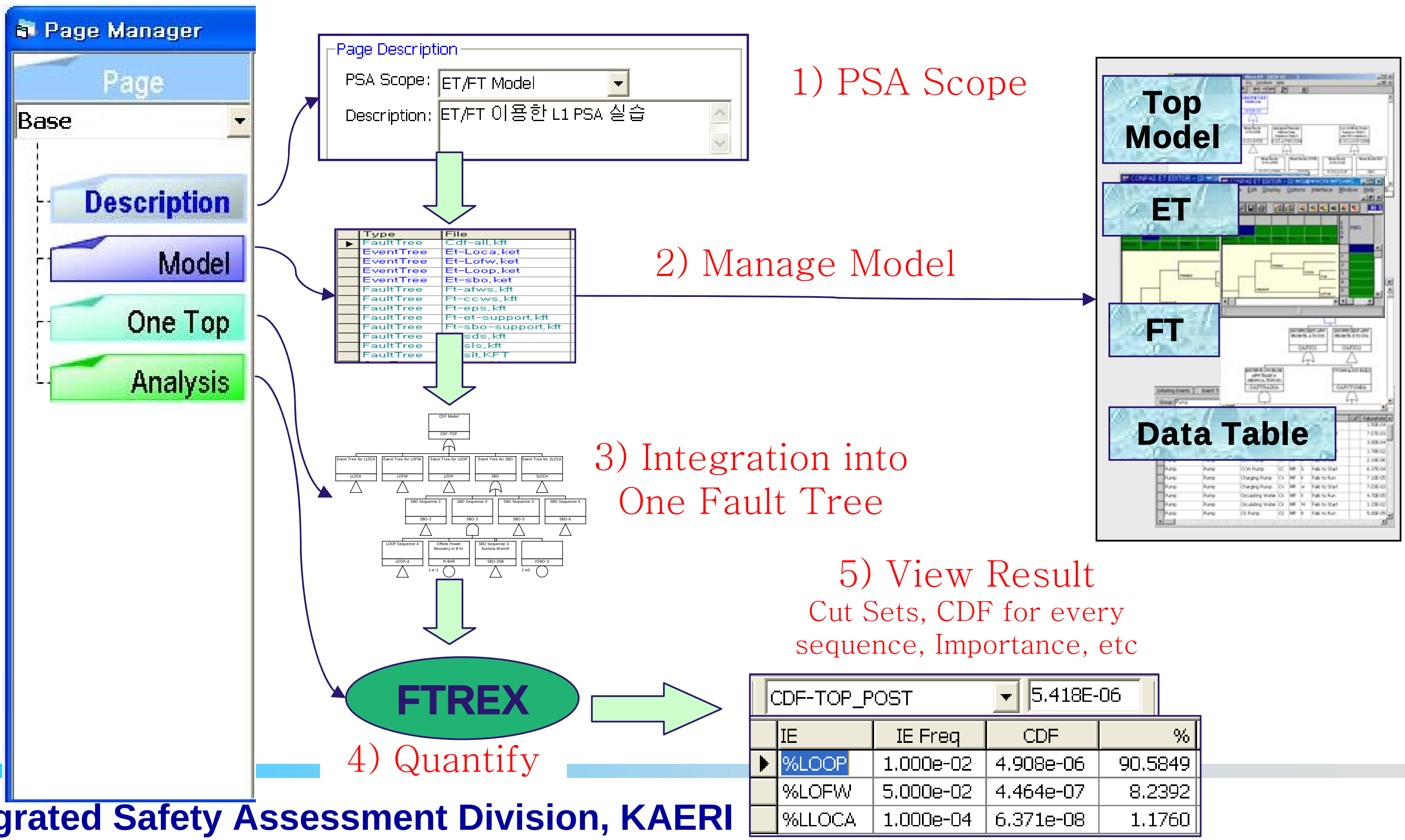
3.3 Shutdown PSA

- Use the Condition Gate
  - to incorporate the component's state changed for each POS compared to the full power model
  - Minimize the effort to build the shutdown PSA model
- Easy to Build and Maintain the model
  - Enables the analyst to concentrate on the shutdown Specifics



4. Development of AIMS-PSA

- Simple Analysis following the Work Flow
- Just Click few Buttons to Produce the Results



5. Conclusion

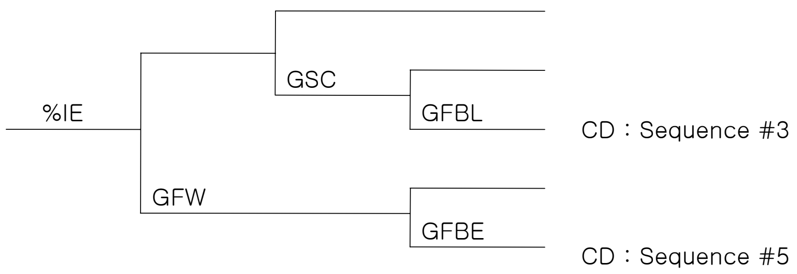
- AIMS-PSA
  - Save the effort for PSA modeling & quantification
    - Save the number of gates
      - 20-50% for Level-1 full power internal PSA model : 3400 gates .vs. 6700 gates
    - Minimize the Effort for Modeling Various PSA Scopes compared to the Traditional PSA Softwares.
  - Easy and Useful tool for the inexperienced users as well as the PSA experts
    - The User Interface is designed to follow the Work Flow
    - Easy to review & reproduce the PSA

Thank You
for Your Attention

Appendix

Quantification of Event Sequences (FTREX) - to Utilize One Top Model Method -

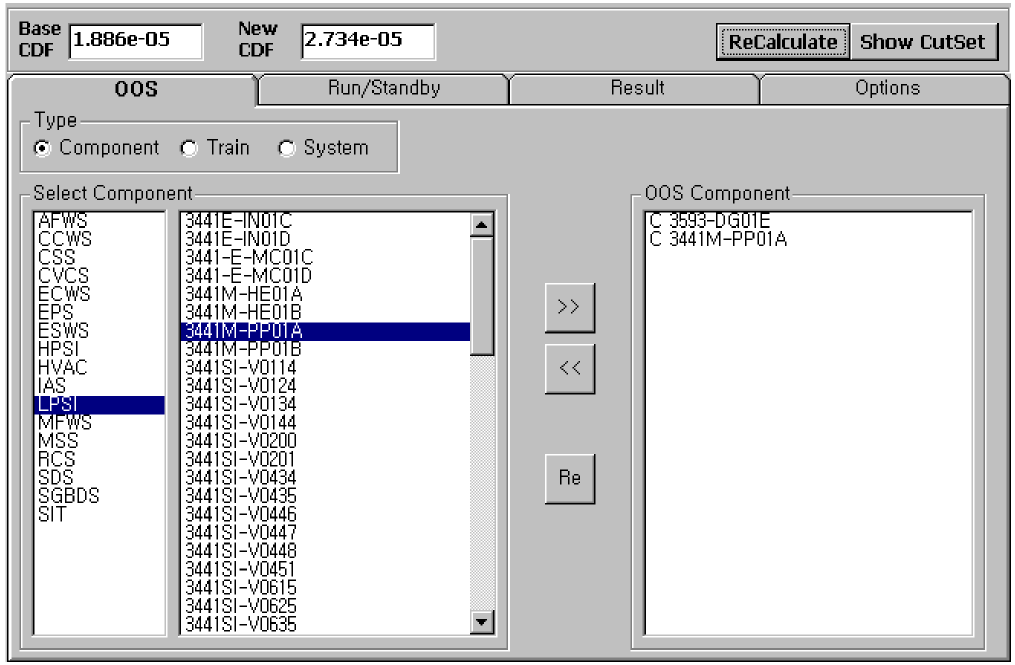
- Procedures to solve sequences
  - Step 1 : solve each sequence
    - Step 1.1 : Generate cut sets for a sequence where success branches are excluded
      - Seq-3’ = %IE * GSC * GFBL
    - Step 1.2 : Delete nonsense cut sets from the cut sets obtained in the step 1 using the ‘delete term operation’
      - Seq-3’’ = Seq-3’ / GFW
  - Step 2 : Delete nonsense cut sets in sequences
    - $S_i' = S_i \,//\, \Sigma S_j, (j < i)$
    - $S_i'' = S_i' \,/\, \Sigma S_j, (j > i)$



- Notation
  - Si is the result of Steps 1 for the i-th sequence, (a sequence having larger i is located in the lower part of an event tree)
  - A / B is to delete any cut set in A if the cut set is a superset of a cut set in B. (Delete Term Operation)
  - A // B is to delete any cut set in A if the cut set is a proper superset of a cut set in B

Analysis for Component Out of Service (AIMS-PSA)

- Analysis of Component OOS
  - A Feature of the Risk Monitor
- Support PSA Analysts to Perform the Case Studies for the Risk Monitor
- Option for OOS Component
  - Set the Pi = 1, or
  - Set the Event as True
- Option for CCF treatment
  - No Treatment for CCF Event
  - Set Value for a CCF Event = CCF Factor

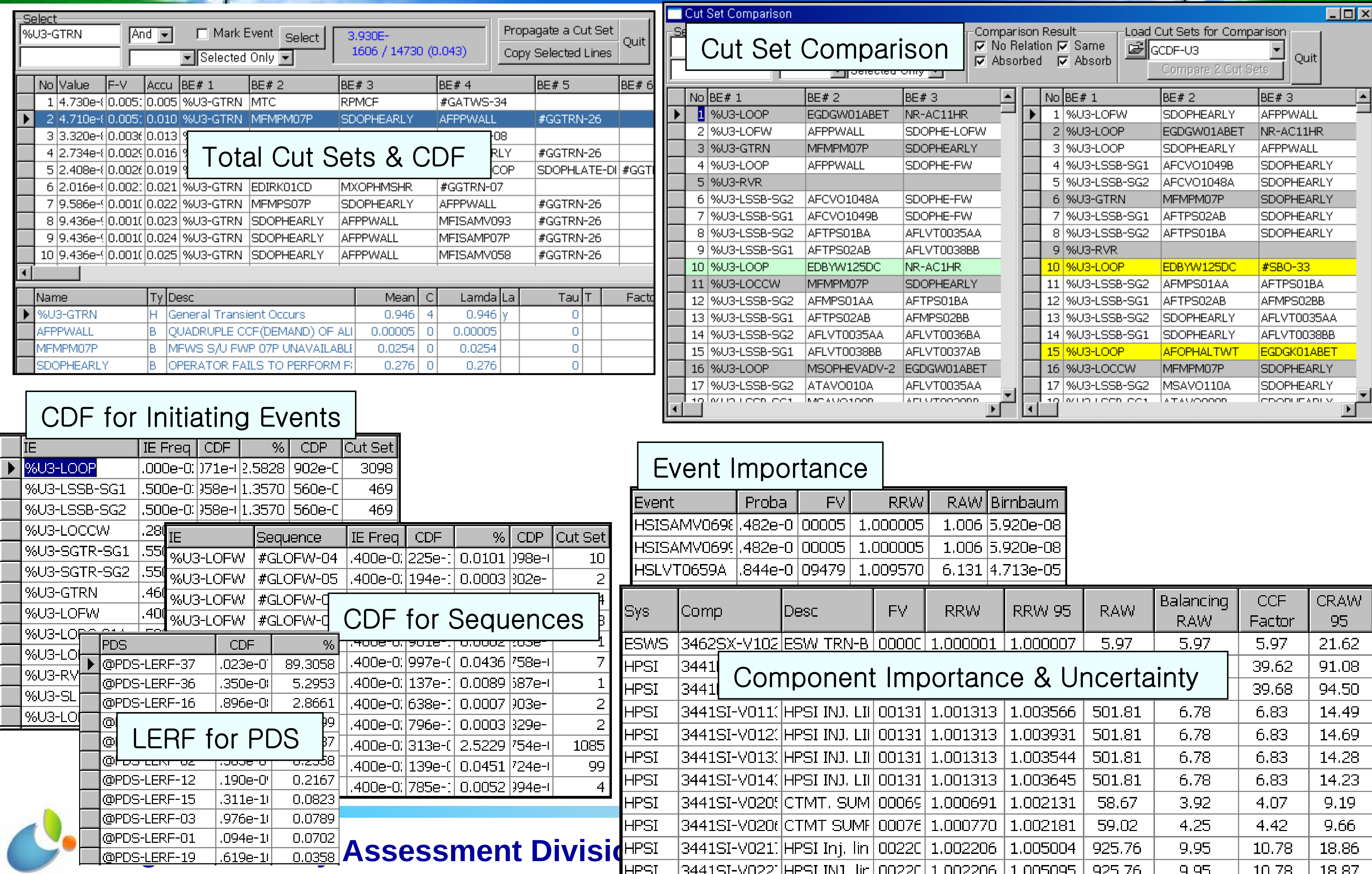


OOS | **Run/Standby**

System	Component	State
CCW	CCW HX 01A	Running
CCW	CCW HX 01B	Running
CCW	CCW HX 02A	Standby
CCW	CCW HX 02B	Standby
CCW	CCW MP 01A	Running
CCW	CCW MP 01B	Running
CCW	CCW MP 02A	Standby
CCW	CCW MP 02B	Standby
CVCS	CVCS Charging PP01	Running
CVCS	CVCS Charging PP02	Standby
CVCS	CVCS Charging PP03	Standby
CVCS	CVCS Charging PP04	Backup

Page	OOS Component	Base Value	New Value	Date
Base	3591-DG01B , 3593-DG01E	1,314e-05	2,36e-05	2005-07-02 오후 6:21:50
Base	3441M-PP01B	1,314e-05	1,901e-05	2005-07-02 오후 6:26:21
Simple-No Recovery		1,886e-05	1,886e-05	2005-07-04 오전 9:17:29
Simple-No Recovery	3441M-PP02A	1,886e-05	5,765e-05	2005-07-04 오후 4:36:34
Simple-No Recovery	3593-DG01E , 3441M-PP01A	1,886e-05	2,734e-05	2005-07-04 오후 4:37:09

AIMS-PSA : Results



Component Importance (AIMS-PSA : Result)

- **Component Importance**
  - Importance for Grouped Events
  - Fussell-Vesely Importance
  - Risk Reduction Worth
  - Risk Achievement Worth
- **Uncertainty Analysis of Component Importance**
  - Monte Carlo Simulation
  - 5%, 50%, Mean, 95%, 99%

- **3 Kinds of RAWs**
  - Basic RAW : too Conservative
    - Pi = 1 for every Event included in a Component
  - Balancing RAW
    - RAW = 1 + [(1-P)/P] * FV, (P = ΣPi)
  - CCF Factor Adjusting RAW
    - Pi(Independent Event) = 1
    - Pi(CCF Event) = CCF Factor

Comp	FV	RRW		RAW (CCF = 1)		Balacing RAW		CCF Factor RAW	
		RRW	95%	RAW	95%	BRAW	95%	CRAW	95%
HPSI PUMP-1	0.0327	1.034	1.099	1028.7	2487.2	8.9	25.5	39.6	91.1
HPSI PUMP-2	0.0327	1.034	1.094	1028.8	2492.4	8.9	26.9	39.7	94.5
HPSI Pump Disch. CV SI-404	0.0038	1.004	1.010	507.1	1233.9	17.6	62.8	18.0	41.9
HPSI Pump Disch. CV SI-405	0.0038	1.004	1.011	507.1	1235.1	17.6	59.9	18.1	42.4
Sump Iso. MOV SI-675	0.0006	1.001	1.001	13.6	33.7	1.3	1.8	1.6	2.3
Sump Iso. MOV SI-676	0.0009	1.001	1.002	14.0	34.2	1.5	2.1	2.0	3.5