

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

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# Contents

1. Introduction
2. Integration of Event Trees and Fault Trees
3. Integration of Various PSA Scopes
4. Development of AIMS-PSA
5. Conclusion

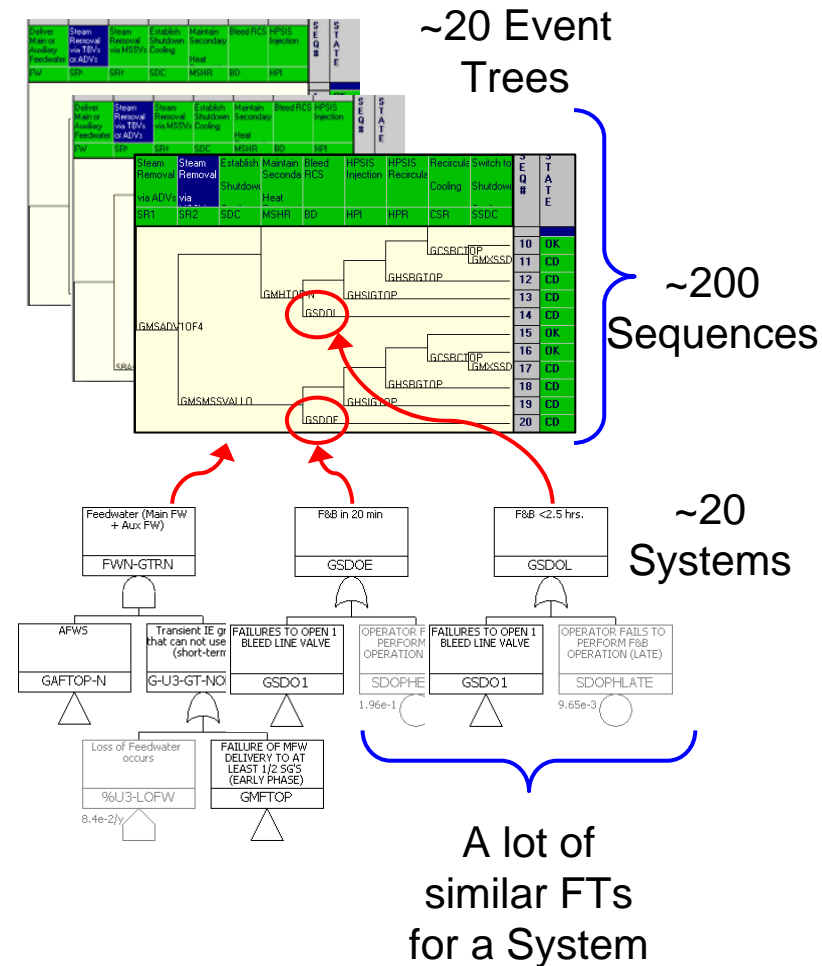
# 1. Introduction

- ◆ 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

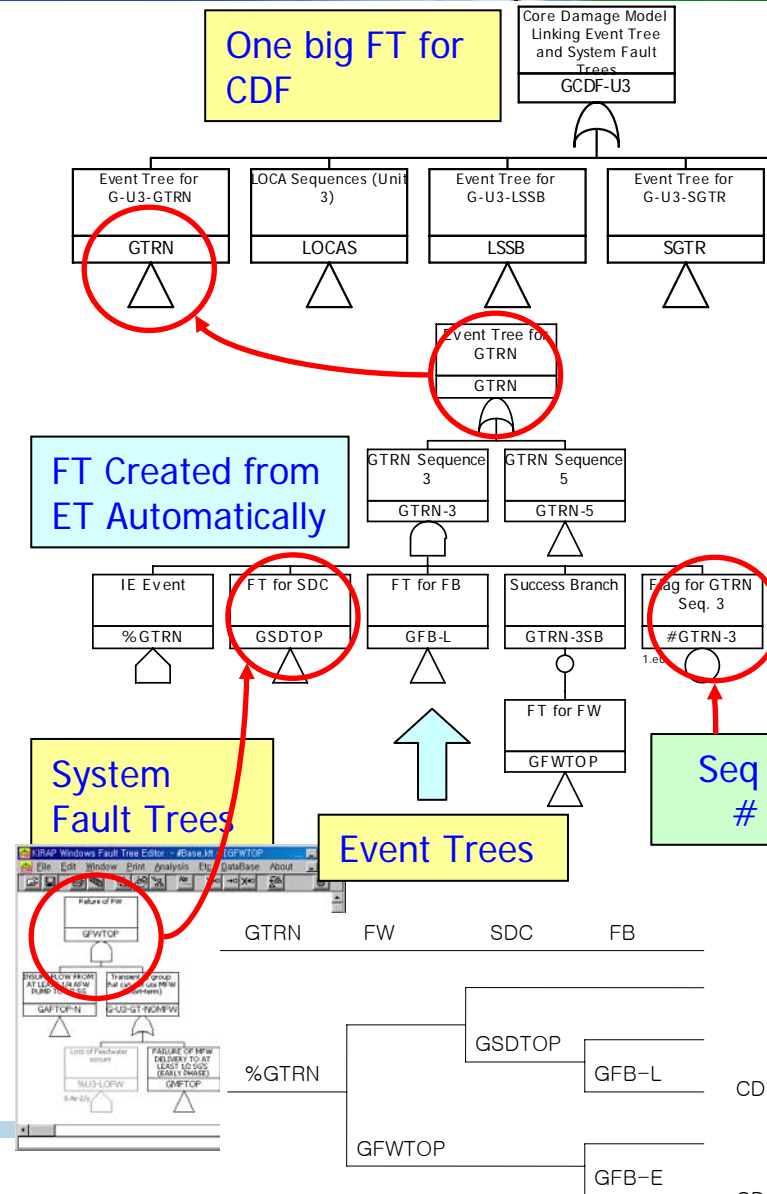
## ◆ A Typical PSA

- 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



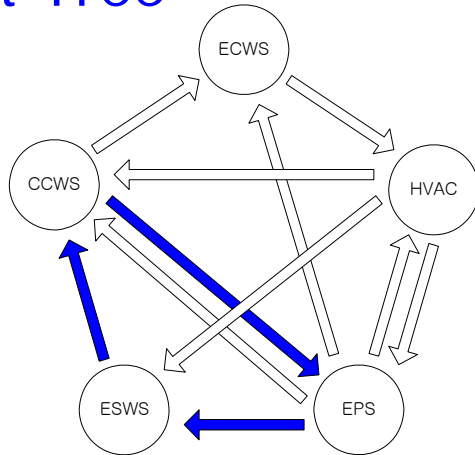
# 2.1 New Quantification Method using One Big Fault Tree Model

- ◆ 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



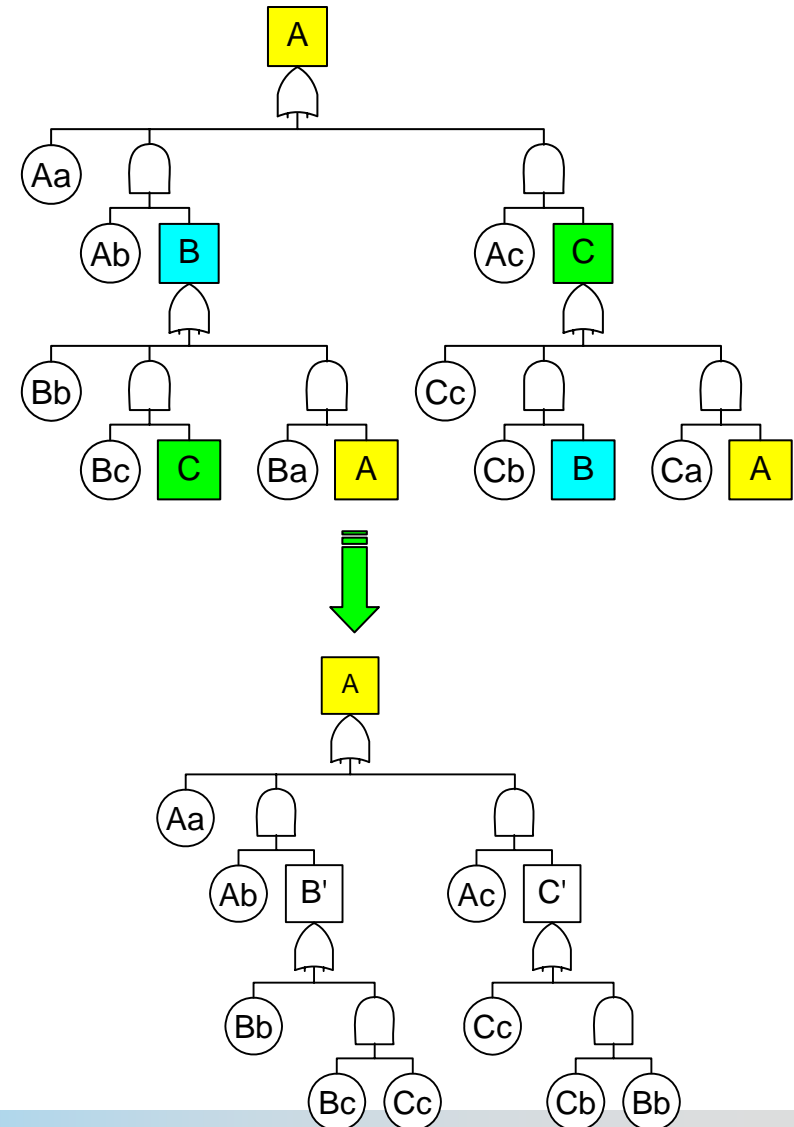
# 2.2 Circular Logics

- ◆ 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

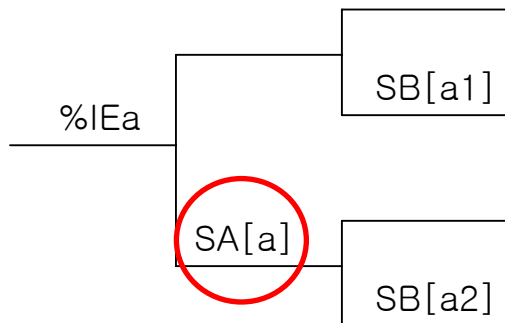
- One system FT can be used in several places with minor changes
- Most PSAs develop another FT for these cases

## ◆ New Gate Type Introduced

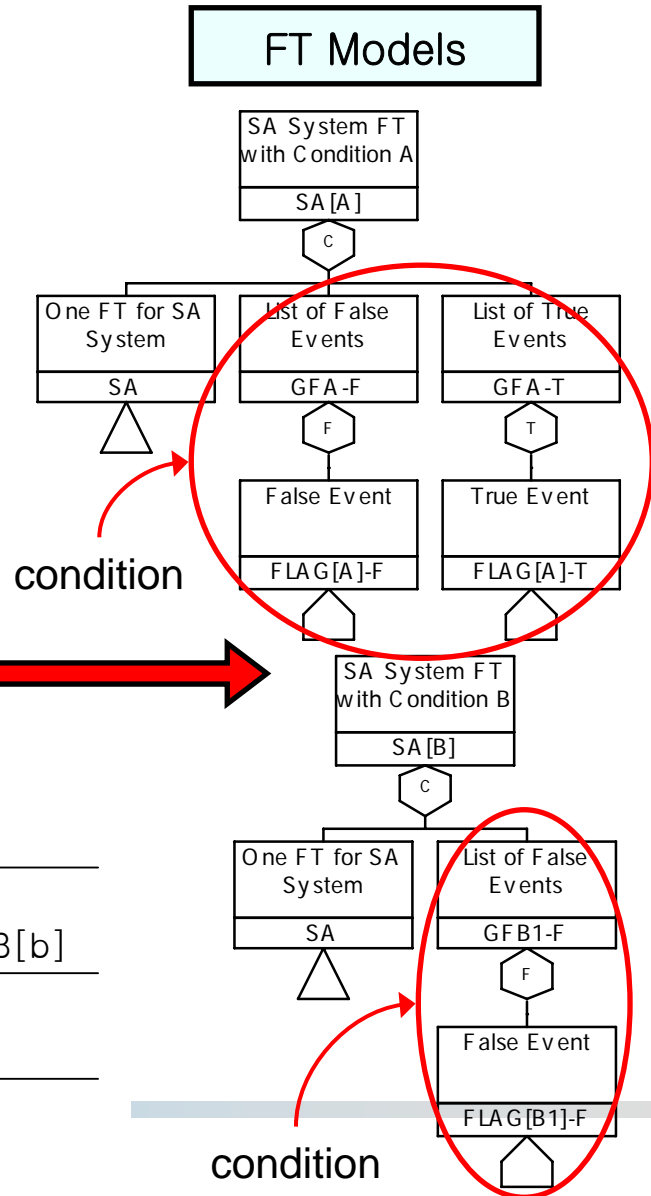
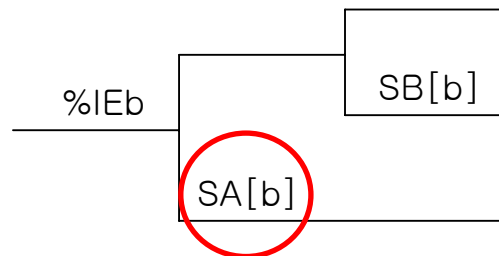
- A Gate can have the conditioning events
- AIMS-PSA automatically restructures the FT incorporating the conditioning events
- It saves the effort to develop & maintain the PSA model

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

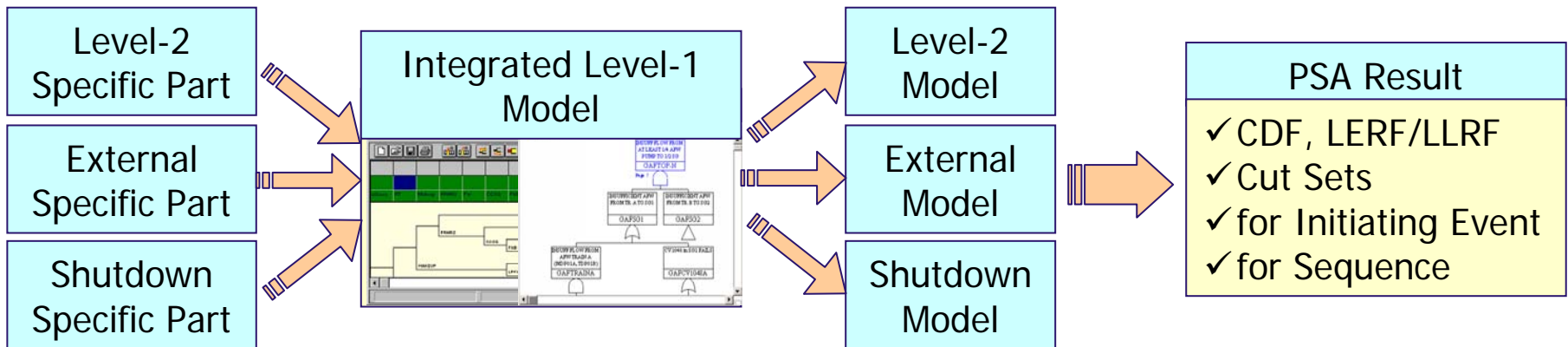
### ◆ Save the Effort for PSA modeling and quantification

- 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

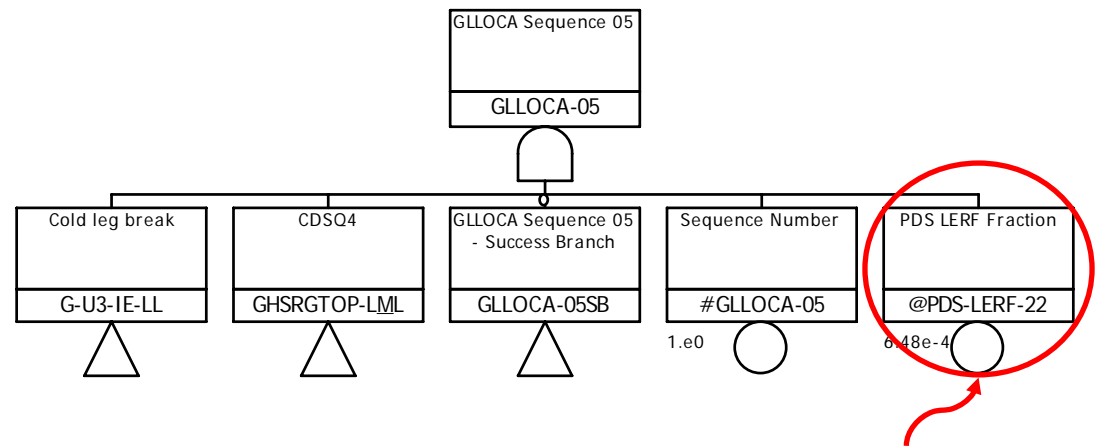
## ◆ Integration of the Level-1 & 2 PSA

- 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

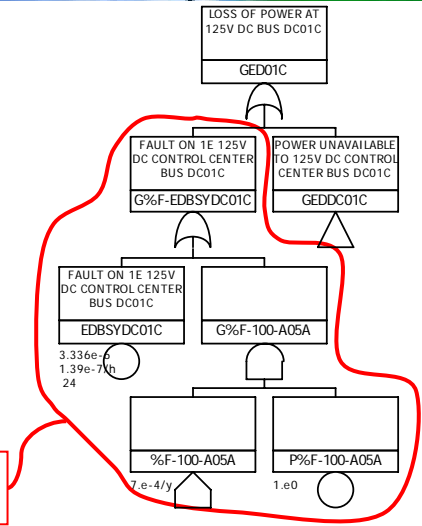
### An Example of the LERF Model



LERF Fraction for PDS

# 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.	Transferred 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

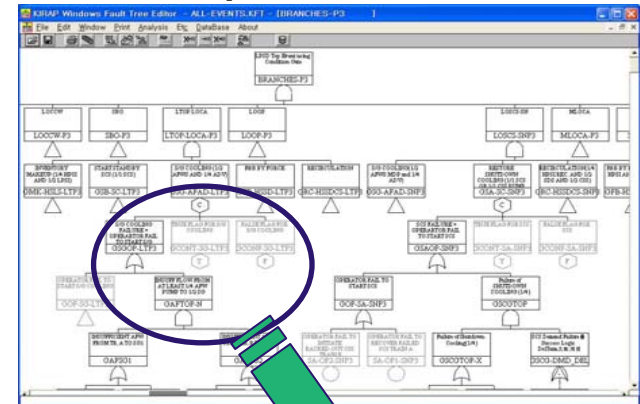
## ◆ Use the Condition Gate

- 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

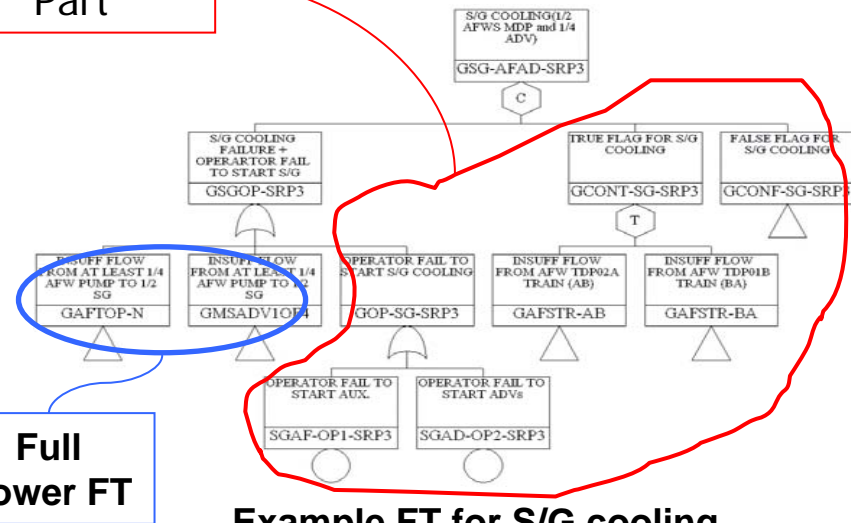
## ◆ Easy to Build and Maintain the model

- Enables the analyst to concentrate on the shutdown Specifics

One Top Model for a POS



Conditioning Part



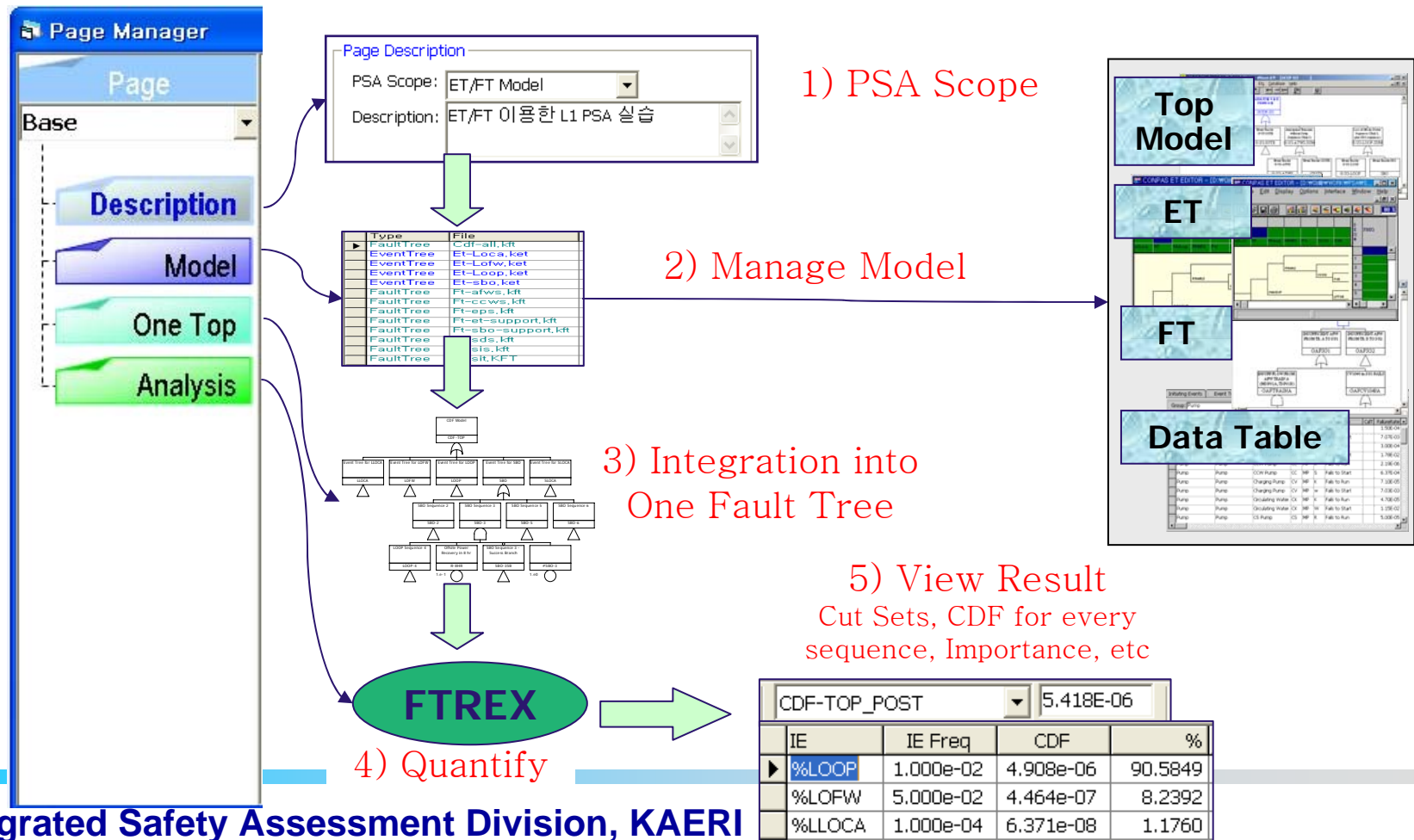
Full Power FT

Example FT for S/G cooling



# 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



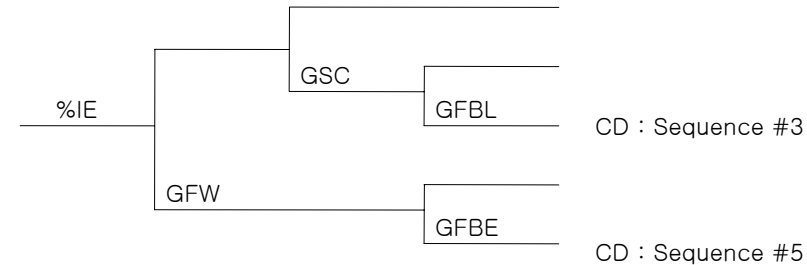


# Quantification of Event Sequences (FTREX)

## - 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
    - $\text{Seq-3}' = \%IE * \text{GSC} * \text{GFBL}$
  - Step 1.2 : Delete nonsense cut sets from the cut sets obtained in the step 1 using the 'delete term operation'
    - $\text{Seq-3}'' = \text{Seq-3}' / \text{GFW}$
- Step 2 : Delete nonsense cut sets in sequences
  - $\text{Si}' = \text{Si} // \Sigma \text{Sj}, (j < i)$
  - $\text{Si}'' = \text{Si}' / \Sigma \text{Sj}, (j > i)$



### ◆ Notation

- $\text{Si}$  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  $P_i = 1$ , or
  - Set the Event as True
- ◆ Option for CCF treatment
  - No Treatment for CCF Event
  - Set Value for a CCF Event = CCF Factor

The screenshot shows the AIMS-PSA software interface. At the top, there are input fields for 'Base CDF' (1.886e-05) and 'New CDF' (2.734e-05), along with 'ReCalculate' and 'Show CutSet' buttons. Below this, there are tabs for 'OOS', 'Run/Standby', 'Result', and 'Options'. The 'OOS' tab is active, showing a 'Type' section with radio buttons for 'Component' (selected), 'Train', and 'System'. A 'Select Component' list on the left contains various system components, with '3441M-PP01A' selected. To the right, an 'OOS Component' list shows 'C 3593-DG01E' and 'C 3441M-PP01A'. Navigation buttons '>>', '<<', and 'Re' are also visible.

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

Select  
 %U3-GTRN And  Mark Event Select 3.930E-1606 / 14730 (0.043)  
 Propagate a Cut Set Copy Selected Lines Quit

No	Value	F-V	Accu	BE# 1	BE# 2	BE# 3	BE# 4	BE# 5	BE# 6
1	4.730e-16	0.005	0.005	%U3-GTRN	MTC	RPMCF	#GATWS-34		
2	4.710e-16	0.005	0.010	%U3-GTRN	MFMPM07P	SDOPHEARLY	AFFPWALL	#GGTRN-26	
3	3.320e-16	0.003	0.013						
4	2.734e-16	0.002	0.016						
5	2.408e-16	0.002	0.019						
6	2.016e-16	0.002	0.021	%U3-GTRN	EDIRK01CD	MXOPHMSTR	#GGTRN-07		
7	9.586e-17	0.001	0.022	%U3-GTRN	MFMP07P	SDOPHEARLY	AFFPWALL	#GGTRN-26	
8	9.436e-17	0.001	0.023	%U3-GTRN	SDOPHEARLY	AFFPWALL	MFISAMV093	#GGTRN-26	
9	9.436e-17	0.001	0.024	%U3-GTRN	SDOPHEARLY	AFFPWALL	MFISAMP07P	#GGTRN-26	
10	9.436e-17	0.001	0.025	%U3-GTRN	SDOPHEARLY	AFFPWALL	MFISAMV058	#GGTRN-26	

## Total Cut Sets & CDF

Name	Ty	Desc	Mean	C	Lamda	La	Tau	T	Fact
%U3-GTRN	H	General Transient Occurs	0.946	4	0.946		0		
AFFPWALL	B	QUADRUPLE CCF(DEMAND) OF ALI	0.00005	0	0.00005		0		
MFMPM07P	B	MFWS S/J FWP 07P UNAVAILABLE	0.0254	0	0.0254		0		
SDOPHEARLY	B	OPERATOR FAILS TO PERFORM F	0.276	0	0.276		0		

## CDF for Initiating Events

IE	IE Freq	CDF	%	CDP	Cut Set
%U3-LOOP	.000e+00	71e-16	2.5828	902e-16	3098
%U3-LSSB-SG1	.500e-01	758e-16	1.3570	560e-16	469
%U3-LSSB-SG2	.500e-01	758e-16	1.3570	560e-16	469
%U3-LOCCW	.28				

## CDF for Sequences

IE	Sequence	IE Freq	CDF	%	CDP	Cut Set
%U3-LOFW	#GLOFW-04	.400e-01	225e-16	0.0101	798e-16	10
%U3-SGTR-SG1	#GLOFW-05	.400e-01	194e-16	0.0003	302e-16	2
%U3-SGTR-SG2	#GLOFW-06	.400e-01	194e-16	0.0003	302e-16	2
%U3-GTRN	#GLOFW-07	.46				
%U3-LOFW	#GLOFW-08	.40				
%U3-LOFW	#GLOFW-09	.40				
%U3-LOFW	#GLOFW-10	.40				
%U3-LOFW	#GLOFW-11	.40				
%U3-LOFW	#GLOFW-12	.40				

## LERF for PDS

PDS	CDF	%	CDP	Cut Set
@PDS-LERF-37	.023e-01	89.3058	.400e-01	997e-16
@PDS-LERF-36	.350e-01	5.2953	.400e-01	137e-16
@PDS-LERF-16	.896e-01	2.8661	.400e-01	638e-16
@PDS-LERF-09			.400e-01	796e-16
@PDS-LERF-07			.400e-01	313e-16
@PDS-LERF-02	.388e-01	0.2358	.400e-01	139e-16
@PDS-LERF-12	.190e-01	0.2167	.400e-01	785e-16
@PDS-LERF-15	.311e-01	0.0823		
@PDS-LERF-03	.976e-01	0.0789		
@PDS-LERF-01	.094e-01	0.0702		
@PDS-LERF-19	.619e-01	0.0358		

Cut Set Comparison  
 Comparison Result:  No Relation  Same  Absorbed  Absorb  
 Load Cut Sets for Comparison: GCDP-U3  
 Compare 2 Cut Sets Quit

No	BE# 1	BE# 2	BE# 3	No	BE# 1	BE# 2	BE# 3
1	%U3-LOOP	EGDGW01ABET	NR-AC11HR	1	%U3-LOFW	SDOPHEARLY	AFFPWALL
2	%U3-LOFW	AFFPWALL	SDOPHE-LOFW	2	%U3-LOOP	EGDGW01ABET	NR-AC11HR
3	%U3-GTRN	MFMPM07P	SDOPHEARLY	3	%U3-LOOP	SDOPHEARLY	AFFPWALL
4	%U3-LOOP	AFFPWALL	SDOPHE-FW	4	%U3-LSSB-SG1	AFCV01049B	SDOPHEARLY
5	%U3-RVR			5	%U3-LSSB-SG2	AFCV01048A	SDOPHEARLY
6	%U3-LSSB-SG2	AFCV01048A	SDOPHE-FW	6	%U3-GTRN	MFMPM07P	SDOPHEARLY
7	%U3-LSSB-SG1	AFCV01049B	SDOPHE-FW	7	%U3-LSSB-SG1	AFTPS02AB	SDOPHEARLY
8	%U3-LSSB-SG2	AFTPS01BA	AFLVT0035AA	8	%U3-LSSB-SG2	AFTPS01BA	SDOPHEARLY
9	%U3-LSSB-SG1	AFTPS02AB	AFLVT0038BB	9	%U3-RVR		
10	%U3-LOOP	EDBYW125DC	NR-AC11HR	10	%U3-LOOP	EDBYW125DC	#SBO-33
11	%U3-LOCCW	MFMPM07P	SDOPHEARLY	11	%U3-LSSB-SG2	AFMPS01AA	AFTPS01BA
12	%U3-LSSB-SG2	AFMPS01AA	AFTPS01BA	12	%U3-LSSB-SG1	AFTPS02AB	AFMPS02BB
13	%U3-LSSB-SG1	AFTPS02AB	AFMPS02BB	13	%U3-LSSB-SG2	SDOPHEARLY	AFLVT0035AA
14	%U3-LSSB-SG2	AFLVT0035AA	AFLVT0036BA	14	%U3-LSSB-SG1	SDOPHEARLY	AFLVT0038BB
15	%U3-LSSB-SG1	AFLVT0038BB	AFLVT0037AB	15	%U3-LOOP	AFOPHALTWT	EGDGK01ABET
16	%U3-LOOP	MSOPHEADV-2	EGDGW01ABET	16	%U3-LOCCW	MFMPM07P	SDOPHEARLY
17	%U3-LSSB-SG2	ATAVO010A	AFLVT0035AA	17	%U3-LSSB-SG2	MSAV0110A	SDOPHEARLY
18	%U3-LSSB-SG1	ATAVO010A	AFLVT0038BB	18	%U3-LSSB-SG1	ATAVO010A	SDOPHEARLY

## Event Importance

Event	Proba	FV	RRW	RAW	Birnbaum
HSISAMV069C	.482e-01	00005	1.000005	1.006	5.920e-08
HSISAMV069S	.482e-01	00005	1.000005	1.006	5.920e-08
HSLVT0659A	.844e-01	09479	1.009570	6.131	4.713e-05

## Component Importance & Uncertainty

Sys	Comp	Desc	FV	RRW	RRW 95	RAW	Balancing RAW	CCF Factor	CRAW 95
ESWS	3462SX-V102	ESW TRN-B	00000	1.000001	1.000007	5.97	5.97	5.97	21.62
HPSI	3441								39.62
HPSI	3441								91.08
HPSI	3441								39.68
HPSI	3441SI-V011	HPSI INJ. LII	00131	1.001313	1.003566	501.81	6.78	6.83	14.49
HPSI	3441SI-V012	HPSI INJ. LII	00131	1.001313	1.003931	501.81	6.78	6.83	14.69
HPSI	3441SI-V013	HPSI INJ. LII	00131	1.001313	1.003544	501.81	6.78	6.83	14.28
HPSI	3441SI-V014	HPSI INJ. LII	00131	1.001313	1.003645	501.81	6.78	6.83	14.23
HPSI	3441SI-V020	CTMT. SUM	00069	1.000691	1.002131	58.67	3.92	4.07	9.19
HPSI	3441SI-V020	CTMT SUMF	00076	1.000770	1.002181	59.02	4.25	4.42	9.66
HPSI	3441SI-V021	HPSI Inj. lin	00220	1.002206	1.005004	925.76	9.95	10.78	18.86
HPSI	3441SI-V022	HPSI Inj. lin	00220	1.002206	1.005095	925.76	9.95	10.78	18.87



# 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
  - $P_i = 1$  for every Event included in a Component
- Balancing RAW
  - $RAW = 1 + [(1-P)/P] * FV$ , ( $P = \sum P_i$ )
- CCF Factor Adjusting RAW
  - $P_i(\text{Independent Event}) = 1$
  - $P_i(\text{CCF Event}) = \text{CCF Factor}$

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