

KANT, THE ASN PROBABILISTIC SOFTWARE FOR L2 PSA

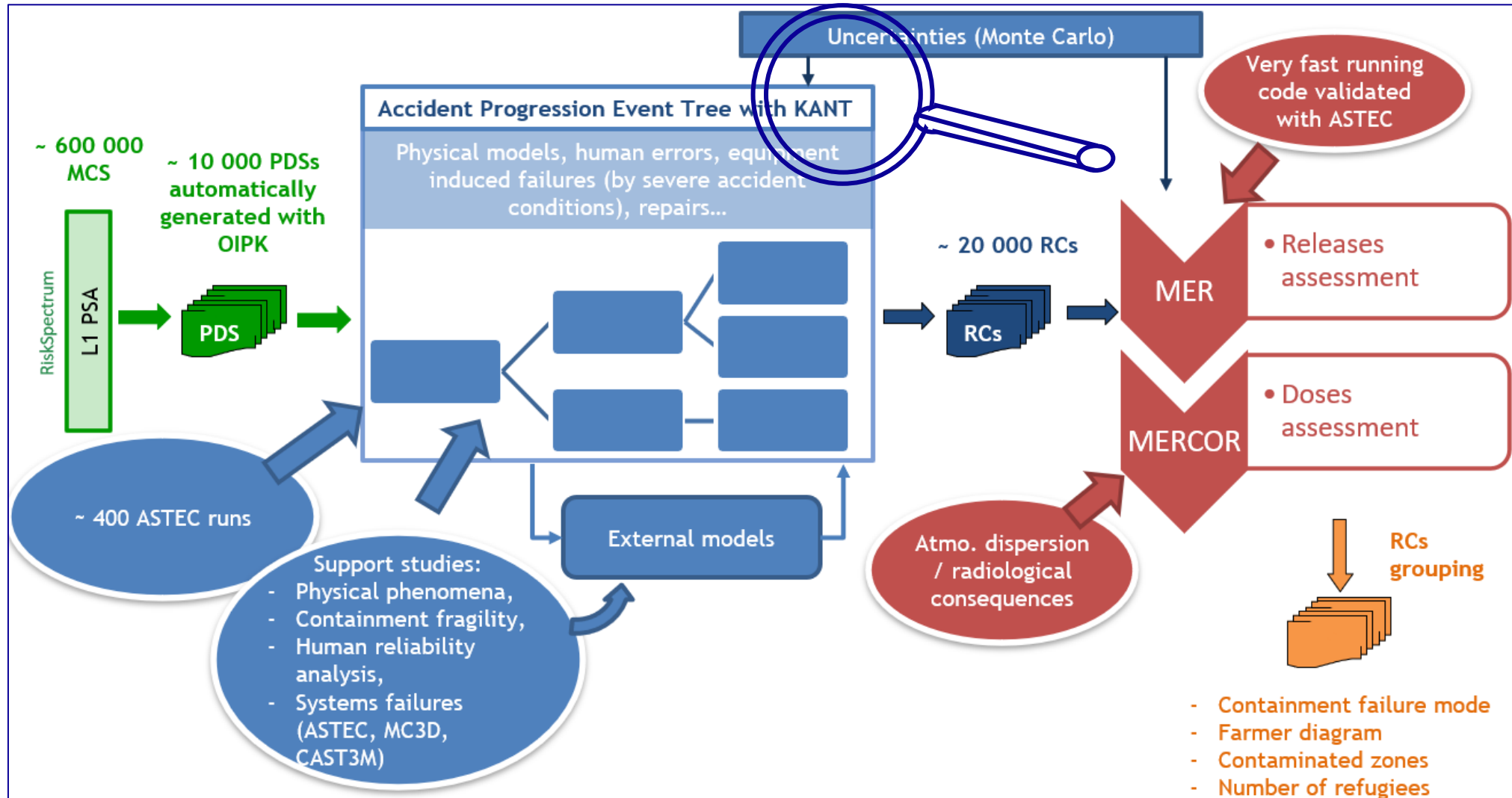
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PREAMBLE

- ▶ Created in 2025, ASNR groups the French Safety Authority ASN and its technical support organization IRSN
- ▶ In France, 32 PWRs 900, 20 PWRs 1300, 4 PWRs 1450, 1 EPR are operated by EDF which develops all reference safety studies, for example PSA
- ▶ ASNR maintains “detailed” L2 PSAs for the French PWRs 900 and 1300 that
 - include all knowledge from severe accident research program or accident simulations
 - reduce use of expert's judgments
 - provide containment failure modes frequencies and release categories frequencies associated to kinetic and amplitude of releases
- ▶ ASNR develops L2 PSA for other types of facilities
- ▶ ASNR develops and uses **the probabilistic software KANT** for these L2 PSAs.
- ▶ **This presentation provides an overview of the status of KANT**

GLOBAL APPROACH FOR ASNR L2 PSA (PWR EXAMPLE)



PRESENTATION PLAN



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OVERVIEW OF KANT

OVERVIEW OF KANT

► KANT is a user-friendly tool able to

- integrate all information from L1 PSA (initiating events, minimal cut-sets)
- implement representative information about accident scenarios
- reflect the chronology of the severe accident and integrate models for physics, human errors and systems → dynamic event trees can be modeled if needed
- model all dependencies between events
- integrate uncertainties and perform uncertainty analysis by Monte-Carlo simulations
- consider all the containment failure modes
- quantify the frequency and the radiological consequences of severe accident sequences

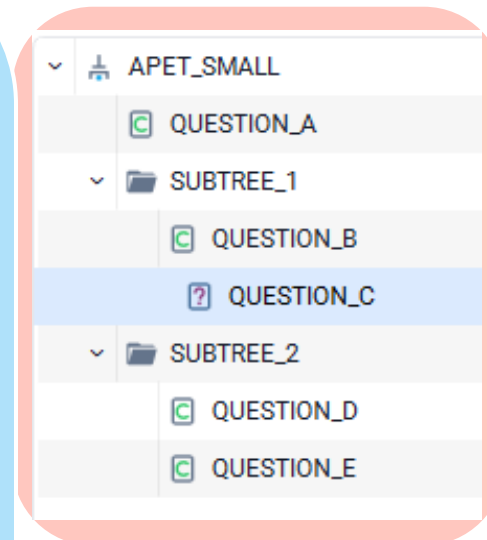
OVERVIEW OF KANT - WORKFLOW

- ▶ KANT represents the progression of a severe accident with a probabilistic tree : Accident Progression Event Tree or **APET**
- ▶ APET's entries are PDSs (Plant Damage States) coming from the L1-L2 interface process

- ▶ KANT explores the APET for every PDS and generates **L2 PSA sequences**
 - **series of events (or questions)** representing systems behaviour, physical phenomena, human actions
 - several answers per question, with conditional probability depending on the input variables
 - questions programmed in «KANT» language : flexible enough to cover all the reactor states and PDSs with a single APET
 - KANT groups similar L2 PSA sequences into **RCs** (Release Categories)

- ▶ KANT computes release and radiological consequences for each RC (with fast running codes)

- ▶ For Monte-Carlo quantification, KANT repeats the process



OVERVIEW OF KANT – SOME SPECIFICITIES

SEVERAL WAYS OF MODELING PHYSICAL PHENOMENA

- Grids of deterministic precomputed results
- Mathematical models written in the KANT language
- External libraries for more complex models

IMPLEMENTATIONS

- Supported systems : Windows, Linux
- Parallel processing : MPI* library
- For KANT language : Lua to improve performance / maintenance
- User interface framework : QT



New in 2026

**Message Passing Interface*

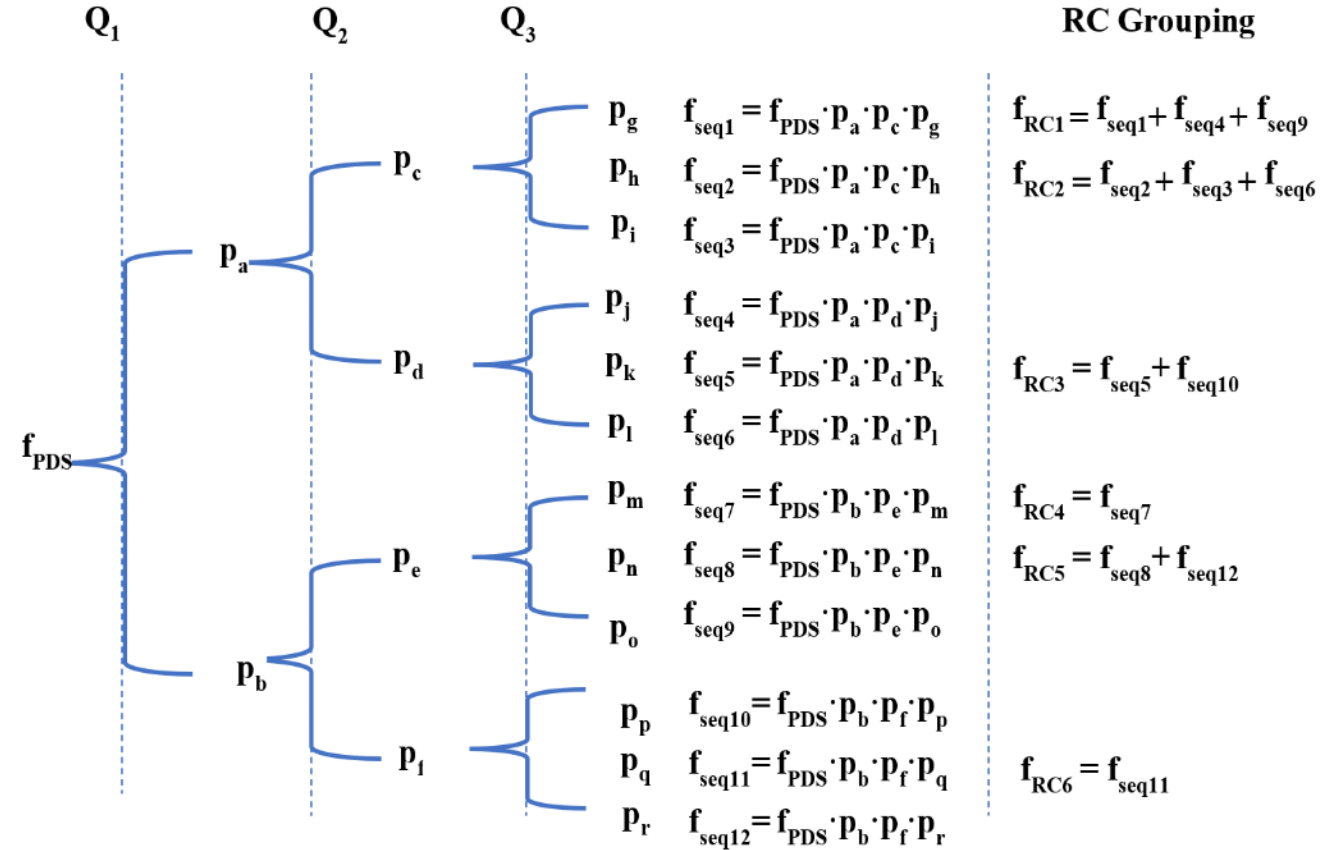
02

ALGORITHM AND LANGUAGE

APET EXPLORATION ALGORITHM

Principle:

- KANT explores the questions and their possible answers recursively
- After each question, the frequency is updated
- Explored branches are discarded when frequency < cutoff value
- This is repeated for each PDS
- This is repeated for each sample in Monte-Carlo mode



KANT PROGRAMMING LANGUAGE

- ▶ English and French keywords
- ▶ Usual language features
 - Control instructions : `if ... switch ... for ... while ...`
 - Operators : `+ - * / % and or not = < > <= >= <>`
 - Types and arrays : `integer, real, boolean, string [size]`
 - Debug : `break, stop`
- ▶ Domain-specific keywords and features
 - APET branching : `go_to, go_to_end_apet`
 - APET exploration information: `answer, answer(), write_sequence`
- ▶ Built-in functions : `MIN, MAX, power, log ...`
- ▶ User functions, external function calls

03

GRAPHICAL USER INTERFACE

THE GRAPHICAL USER INTERFACE

► The GUI is organized in **pages**, one page per step in development and quantification of an APET

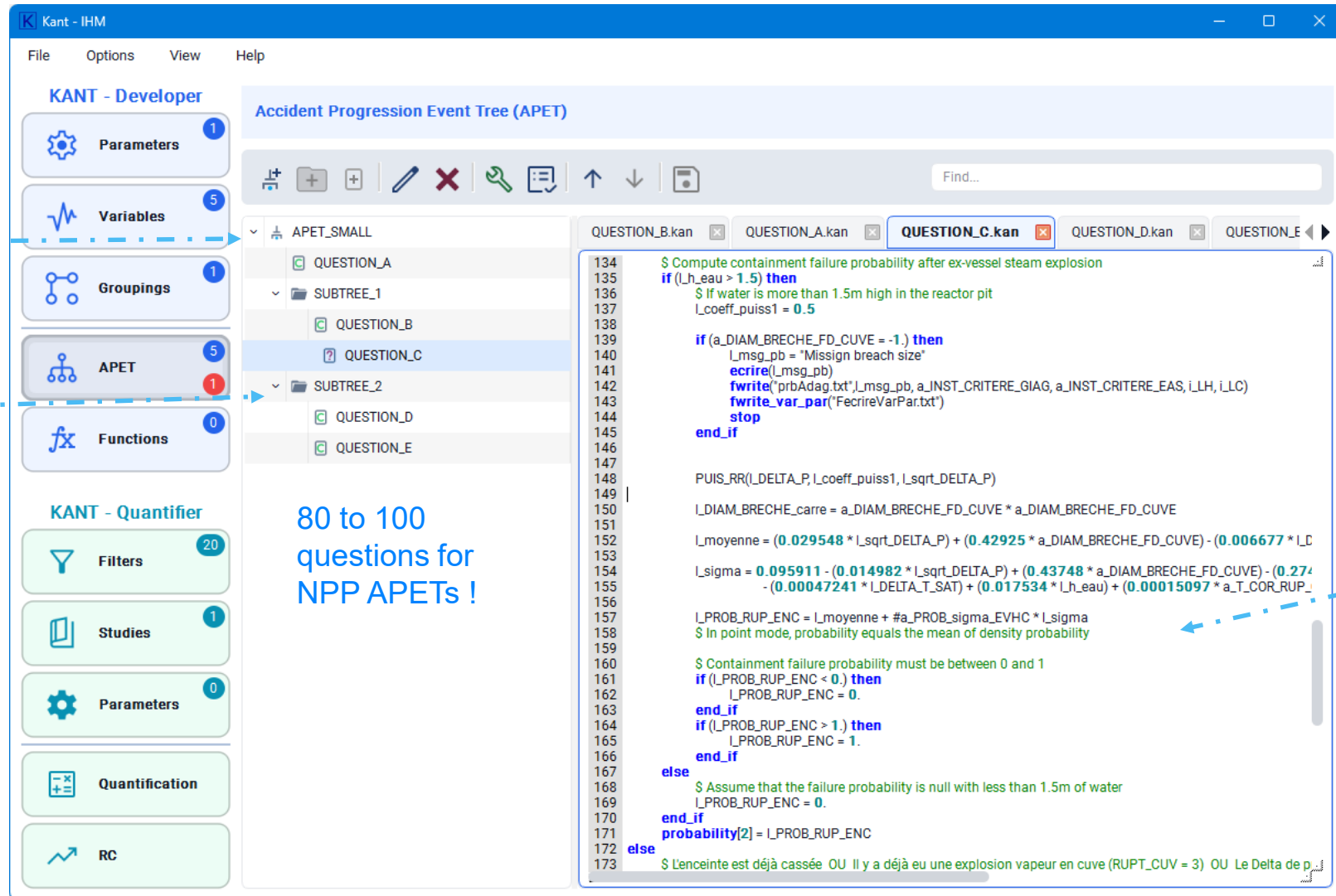
- KANT Developer pages:

- Variables : type, name, attributes (PDS variables, release variables, others)
- Parameters : type, name, unit, description
- Groupings rules: variables considered, allowed values
- APET : tree construction and programming in KANT language

- KANT Quantifier pages:

- PDS filters : boolean expressions to restrict the PDSs to consider, if needed
- Study definition : APET, PDS file
- Parameters values : fixed values or probability laws (for each study)
- Quantification : running parameters (cutoff frequency ...)

GUI : APET REPRESENTATION EXAMPLE



KANT - Developer

- Parameters (1)
- Variables (5)
- Groupings (1)
- APET (5)
- Functions (0)

KANT - Quantifier

- Filters (20)
- Studies (1)
- Parameters (0)
- Quantification
- RC

Accident Progression Event Tree (APET)

QUESTION_B.kan | QUESTION_A.kan | **QUESTION_C.kan** | QUESTION_D.kan | QUESTION_E

134 \$ Compute containment failure probability after ex-vessel steam explosion
 135 if (L_h_eau > 1.5) then
 136 \$ If water is more than 1.5m high in the reactor pit
 137 L_coeff_puiss1 = 0.5
 138
 139 if (a_DIAM_BRECHE_FD_CUVE = -1.) then
 140 L_msg_pb = "Missign breach size"
 141 ecrire(L_msg_pb)
 142 fwrite("prbAdag.txt", L_msg_pb, a_INST_CRITERE_GIAG, a_INST_CRITERE_EAS, i_LH, i_LC)
 143 fwrite_var_par("FecireVarPar.txt")
 144 stop
 145 end_if
 146
 147 PUIS_RR(L_DELTA_P, L_coeff_puiss1, L_sqrt_DELTA_P)
 148
 149 L_DIAM_BRECHE_carre = a_DIAM_BRECHE_FD_CUVE * a_DIAM_BRECHE_FD_CUVE
 150
 151 L_moyenne = (0.029548 * L_sqrt_DELTA_P) + (0.42925 * a_DIAM_BRECHE_FD_CUVE) - (0.006677 * L_D
 152
 153 L_sigma = 0.095911 - (0.014982 * L_sqrt_DELTA_P) + (0.43748 * a_DIAM_BRECHE_FD_CUVE) - (0.274
 154 - (0.00047241 * L_DELTA_T_SAT) + (0.017534 * L_h_eau) + (0.00015097 * a_T_COR_RUP_
 155
 156 L_PROB_RUP_ENC = L_moyenne + #a_PROB_sigma_EVHC * L_sigma
 157 \$ In point mode, probability equals the mean of density probability
 158
 159 \$ Containment failure probability must be between 0 and 1
 160 if (L_PROB_RUP_ENC < 0.) then
 161 L_PROB_RUP_ENC = 0.
 162 end_if
 163 if (L_PROB_RUP_ENC > 1.) then
 164 L_PROB_RUP_ENC = 1.
 165 end_if
 166 else
 167 \$ Assume that the failure probability is null with less than 1.5m of water
 168 L_PROB_RUP_ENC = 0.
 169 end_if
 170 probability[2] = L_PROB_RUP_ENC
 171 else
 172 \$ L'enceinte est déjà cassée OU Il y a déjà eu une explosion vapeur en cuve (RUPT_CUV = 3) OU Le Delta de p
 173

Questions

Subtrees for
APET legibility

80 to 100
questions for
NPP APETs !

Question code
in KANT
language

GUI : RUNNING A QUANTIFICATION

The screenshot displays the KANT - IHM software interface, which is divided into several sections. On the left, a vertical sidebar contains icons for various functions: Parameters (153), Variables (955), Groupings (2), APET (98), Functions (45), Filters (22), Studies (40), Parameters (0), Quantification, and RC. The main window is titled 'KANT - Developer' and features a menu bar with 'File', 'Options', 'View', and 'Help'. Below the menu bar, the 'Quantification' section is active, showing 'Compute mode' with 'Mode' set to 'Point', 'Samples' set to 'Number of samples (integer)', and 'Method' set to 'Simple method'. The 'Debug' section includes checkboxes for 'Debug', 'Traces', 'Validation', 'Forced parameters', and 'Forced sample'. The 'Compute options' section shows 'Study' set to '900_tous_etats_V5_0', 'Cutoff frequency' set to '1e-7', and 'Nb of sequences' set to '5'. The 'Output options' section includes checkboxes for 'Releases', 'Samples matrix', 'Sequence file', and 'By Sample'. The 'Start Computation' button is visible. On the right, the 'Execution messages' panel displays the following text: '# FPA's produites', 'Total: 2 FPA', 'Nom | Frequence | F.Seq.Prepondérantes | Nb.Zeros', a table of data, 'Total | 1.97252e-06', 'Frequence perdue par les coupures : 8.19106e-06', '# Statistiques des rejets', 'Le calcul des rejets est désactivé', '# Statistiques', 'Temps 0 Secondes => 00:00', 'Temps 0.375 Secondes', and two error messages: '[ERR] MOTEUR : STOP a la Question init_appoint_cuve Ligne 256' and '[ERR] MOTEUR : La valeur -1 de la variable AP_B de regroupement n'est pas con'. The interface is annotated with blue dashed lines and text labels: 'Fixed values or sampled values' points to the 'Parameters' icon; 'Debug/Replay options' points to the 'Groupings' icon; 'Study selection' points to the 'Studies' icon; 'Cutoff frequency' points to the 'Cutoff frequency' input field; 'Output options' points to the 'Quantification' icon; 'Execution messages' points to the 'Execution messages' panel; and 'Errors and warnings' points to the error messages in the 'Execution messages' panel.

04

RESULTS

KANT RESULTS



Frequency	Min cutset in L1PSA	PDS			Release Cat.			Release (Bq/s)			Dose (mSv)	
		HPSI	SG	...	BS	CSS	...	Aerosols	Mol. Iodine	...	Eff.	Thyr. ...
1.38145e-6	I_LOCA SI_FAIL ...	2	3	...	1	1	...	2.5e+10	8.2e+11	...	450	8100
4.38546e-7	I_LOCA CSS_FAIL ...	1	4	...	1	5	...	5.1e+9	7.1e+10	...	120	1980
3.38678e-8	I_LOOP DG_FAIL ...	1	1	...	2	2	...	3.1e+10	3.1e+11	...	20	10
...	...	...	...	...	...	...	...	...	...	...	...	...

- ▶ The results are post-processed with a dedicated ASNR tool : PEPS (Post-procEssing for PSA)
- ▶ The analyst can examine results from L1 PSA to L2 PSA

HPSI : High Pressure Safety Injection
SG : Steam Generator status

BS : (Containment) Breach Size
CSS : Containment Spray System

Eff. : effective dose
Thyr. : Thyroid dose

05

CONCLUSION

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- ▶ KANT is a user-friendly software used to perform ASNR's L2 PSA
- ▶ KANT is continuously improved for calculation performances, user interface / functions and maintainability
- ▶ KANT allows users to trace the results (frequencies/releases/consequences) back to the root causes (initiating events, systems failures, human failures, severe accident phenomena ...) modeled in L1 PSA and L2 PSA
- ▶ ASNR will continue to use KANT for NPPs PSAs and also other facilities like fuel cycle facilities or SMRs

THANK YOU FOR YOUR ATTENTION