How to Use PASCAL3

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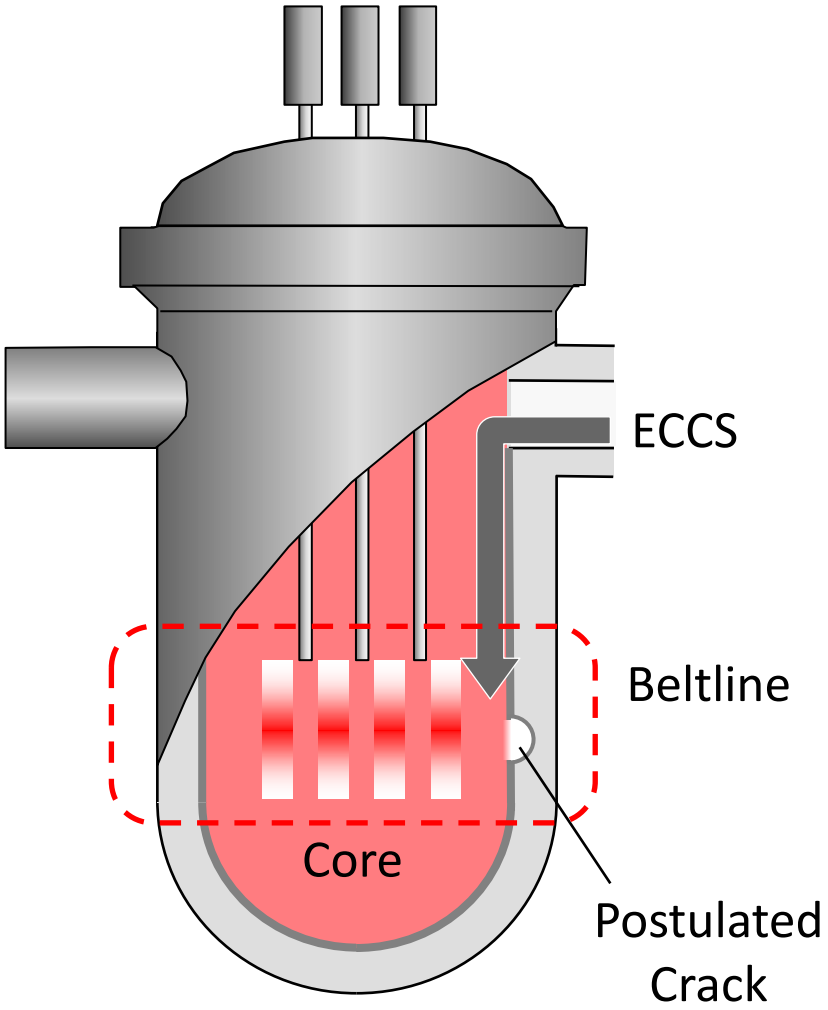
Introduction

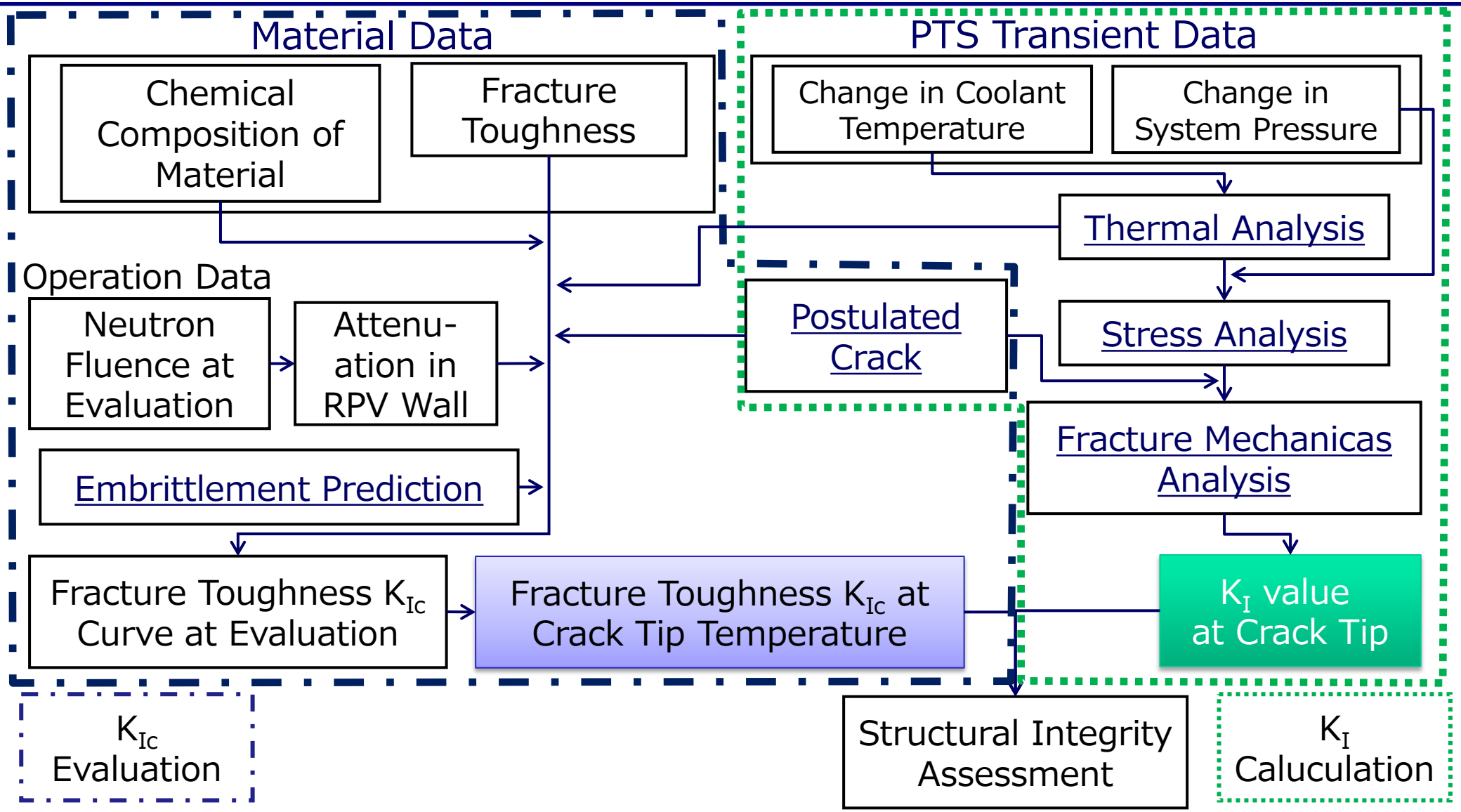
1. Overview of PASCAL3
2. Input and Output Data of PASCAL3
3. An example of PFM Analysis Using PASCAL3
4. On-going Work

1-① Structural Integrity of RPV

- Area of Interest
  - Beltline of Reactor Pressure Vessel (RPV)
  - During Pressurized Thermal Shock (PTS) Transients
  - Preventing RPV from Brittle Crack Initiation
- Deterministic Structural Integrity Assessment Prescribed in JEAC 4206-2007 (1-②)
- Probabilistic Approach of PASCAL3 (1-③, 1-④)
- Conditional Probability of Through-Wall Cracking(CP-TWC), Through-Wall Cracking Frequency(TWCF) (1-⑤)

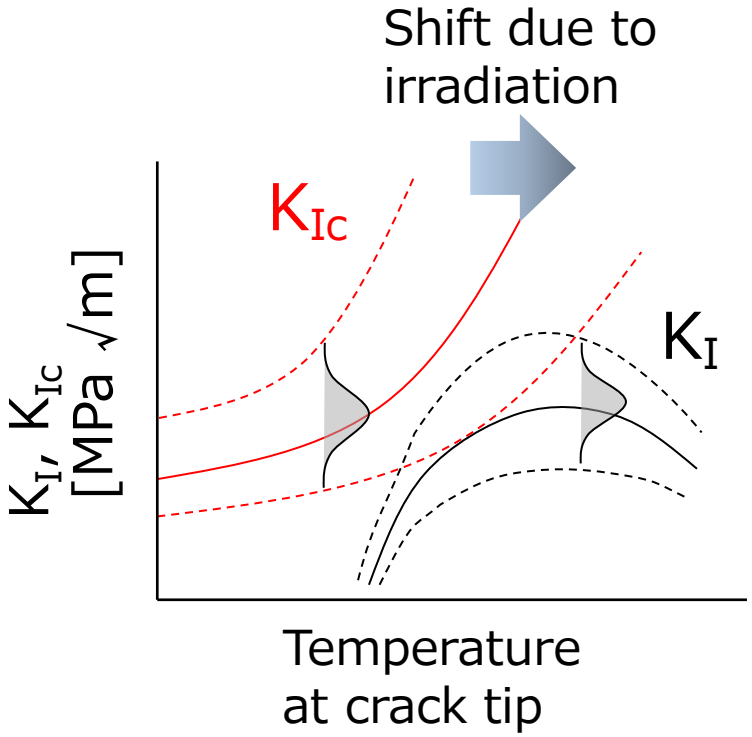


1-② Structural Integrity Assessment in JEAC4206



1-③ Probabilistic Approach

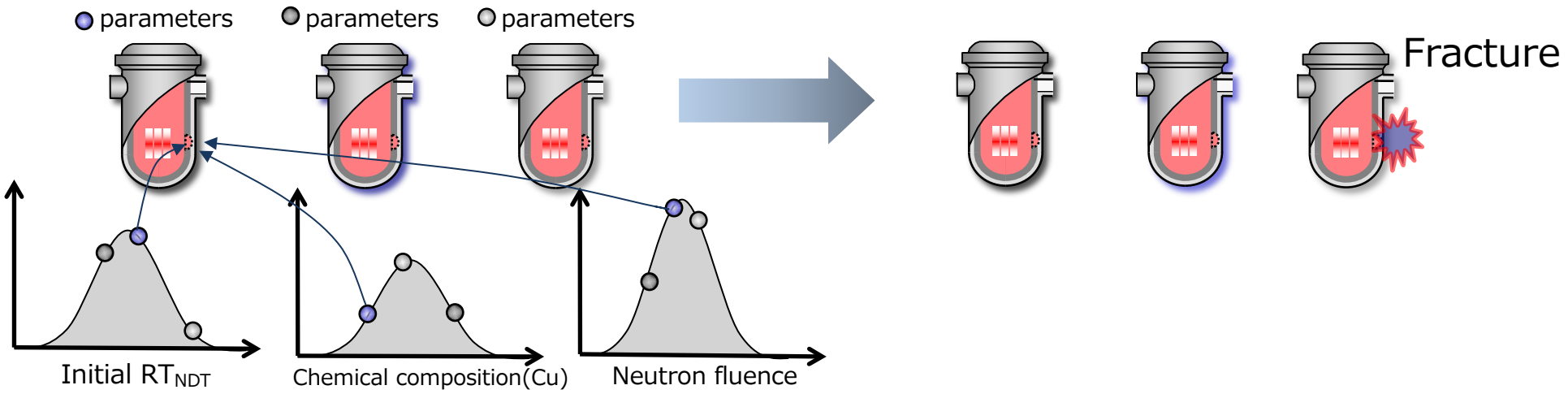
K_I and K_{Ic} curves during PTS



- ✓Structural integrity (against brittle crack initiation) is maintained if K_I is smaller than K_{Ic} in deterministic approach.
- ✓If uncertainties in K_I and K_{Ic} are taken into account, probabilities of crack initiation can be evaluated.

1-④ Monte Carlo Method

Schematic of PFM analysis by Monte Carlo simulation

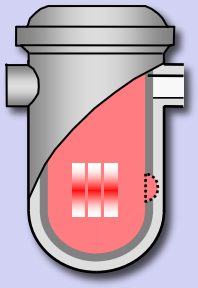


- ✓ Users need to input mean value and standard deviation for parameters of normal distribution such as initial RT_{NDT}, chemical composition, fast neutron fluence.
- ✓ A different value is used for each RPV sample.
- ✓ Each calculation of the integrity evaluation is performed in deterministic fracture mechanics approach.
- ✓ The fracture probability is calculated from the number of fractured vessels and number of calculated samples.

1-⑤ Probability / Frequency

"Conditional Probability of Through-Wall Cracking"(**CP-TWC**)
- ✓One crack in the RPV
- ✓Under one PTS transient

Transient(a) Once

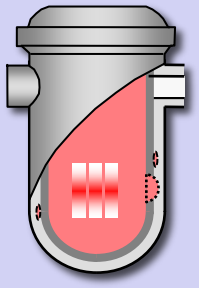


One Crack

"Through-Wall Cracking Frequency"(**TWCF**)
- ✓Multiple cracks
- ✓Multiple PTS transients with occurrence frequencies

Transient(b) n_b events/year

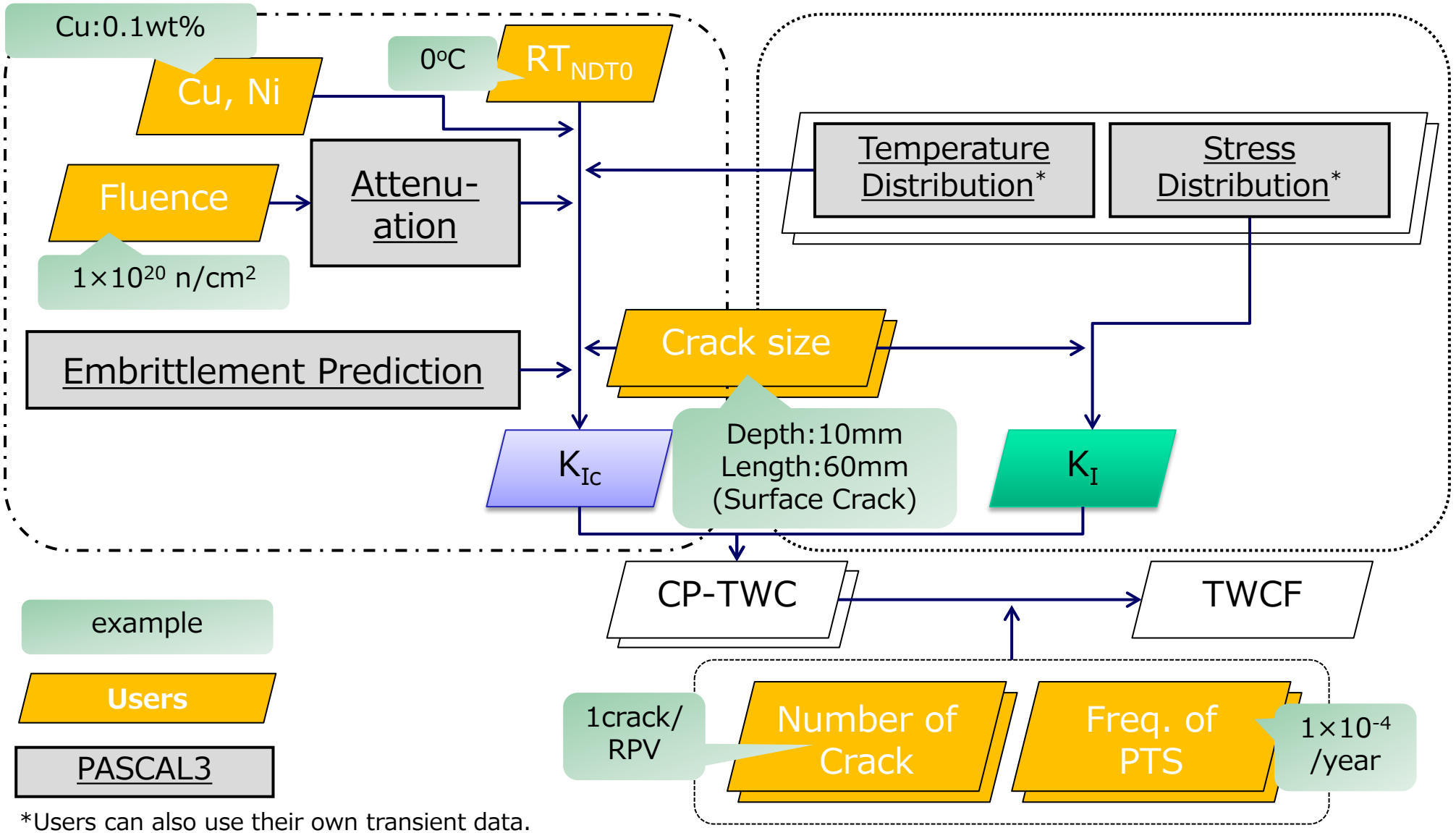
Transient(a) n_a events/year



N Cracks

- ✓Number of cracks
- ✓Varieties of PTS transients & occurrence frequencies

2-① Input Data by Users



*Users can also use their own transient data.

2-② Sample of Input File of PASCAL3

```
#TITLE
 P01_standard_f10
#FLAG
     0     1     1     1     0     1     0     1     1     1
     0     1    11     1    20    20     0    47    71    31
     1     2     8     5    11     0     0     0     0
   100     1     2     0     0     0     0     0     0     0
     1     0
#VESSEL
     0.2050      1.995       10.0        9.4      0.005
        288          0
#MATRAL
     2.10e5         0.3         0.0        9.4        0.0
          5        0.14        0.04       0.04       0.25
        0.8        0.02        0.74       0.86      0.016
      0.002       0.010       0.022       0.20       0.02
       0.14        0.26        0.15          5       0.10
          5       0.131         220        500
                                  :
                                  :
```

Selection of Analysis Type

Geometry of RPV

Material

```
                                  :
#TRANS
       90.0        3.00           0        2.00         1.0         0.8
    80
       0.10        0.20        0.30        0.40        0.50
       0.60        0.70        0.80        0.90        1.00
                                  :
#TEMP
                                  :
#STRS3D
                                  :
#PRESPT
                                  :
#CDEPTH
    80   10000000   300         0.0
#CRKFIX
      0.015       0.030
                                  :
#CONT2
                                  :
                                  :
#END
```

PTS Transient

Sampling Number

Crack Size

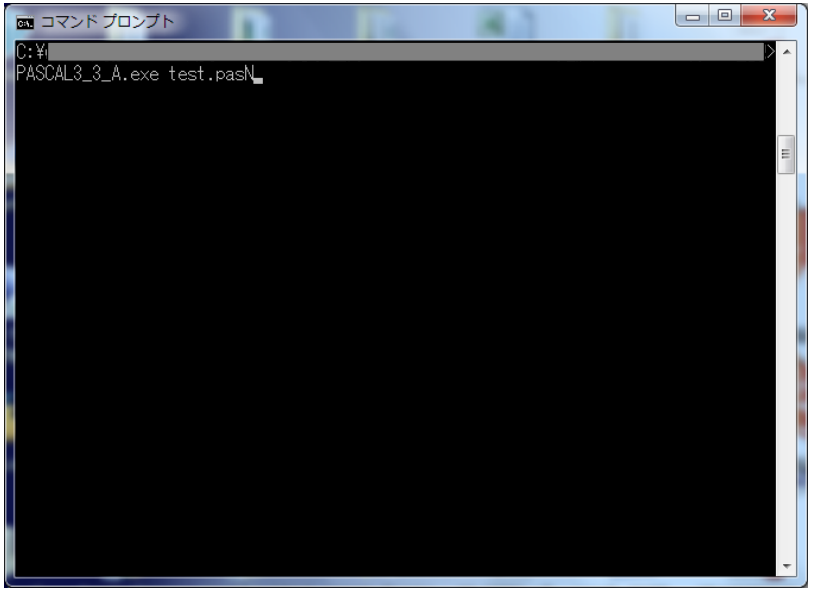
Multiple Analysis Cases

- ✓ A sample input file and some typical example files will be distributed (with manuals on the ways to change the sample input file into the examples).
- ✓ Detailed manual (JAEA-Data/Code-2010-033) can be downloaded for free from http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAEA-Data-Code-2010-033.pdf (in Japanese)

2-③ How to Run PASCAL3

- Environment
  - ✓ Windows 7 32bit/64bit
  - ✓ Text editor for input and output files
  - ✓ Acrobat reader for manuals

- Run
  - ✓ MS-DOS command prompt
    (or make and run ”*.bat” file)
  - ✓ Main output file
    “ ’(inputfilename)’.rsl” file



2-④ Typical Output

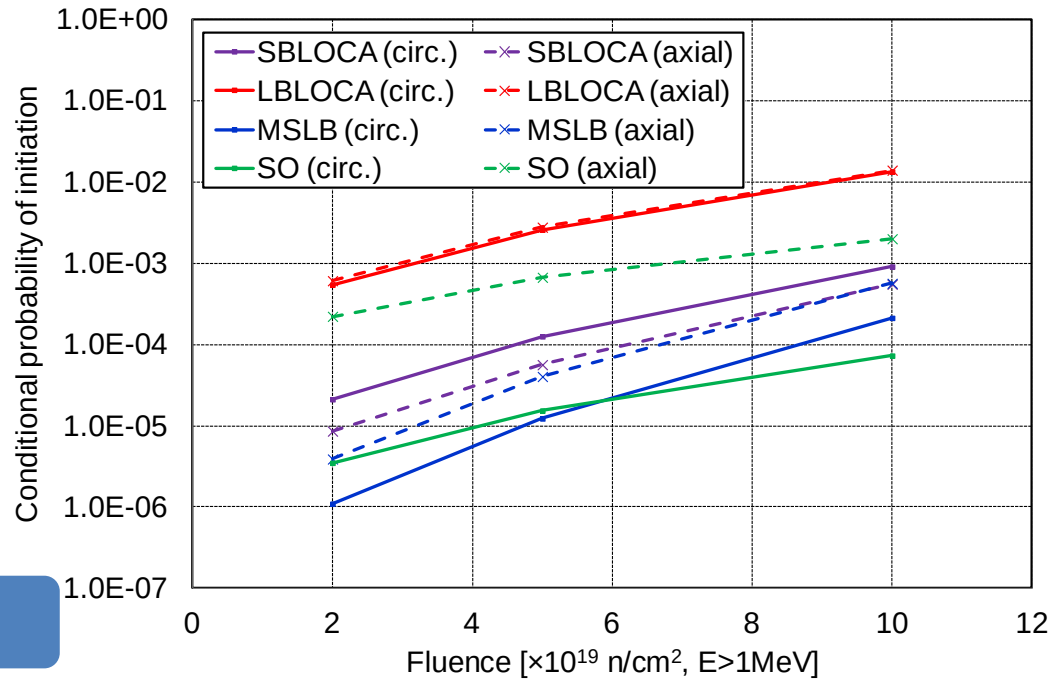
```
                                                :
fluence (x10^19 n/cm2)                          =      10.000
fluence after annealing (x10^19 n/cm2)          =       0.000
Monte Carlo method                              = importance

Number of simulation                            =    10000000
Vessel failure (through-wall cracking)          =  0.00000E+00   0.00000E+00
Crack initiation (total )                       =  1.34382E+05   1.34382E-02
Crack arrest (total )                           =  1.34382E+05   1.34382E-02
                                                :
```

Fast neutron fluence

CP-TWC

CP-CI
(Conditional Probability of Crack Initiation)

Text editor



Microsoft Excel

3-① Analysis Conditions (1/2)

➢ Typical Input Items

Item	Condition
■ Geometry of RPV	ID:4m, Thickness of Base Metal:200mm, Thickness of cladding:5mm, Height of Beltline : 4m
□ Types of PTS Transients and ■ Occurrence Frequencies	LBLOCA : 7.1×10^{-6} [events/year] SBLOCA : 5.9×10^{-4} [events/year] MSLB : 2.2×10^{-3} [events/year] SOV : 9.9×10^{-4} [events/year]
■ Fast Neutron Fluence	Mean : 1×10^{20} n/cm^2, E>1MeV SD : 0.131 of Mean Value
■ Chemical Composition	Cu Mean0.16%, SD0.01% Ni Mean0.61%, SD0.02%
□ Embrittlement Prediction	JEAC4201-2007 (SD10°C)
■ Initial RT_{NDT}	Mean0°C, SD9.4°C
□ Fracture Toughness K_{Ic}	PASCAL Weibull Type
□ Crack Arrest Toughness K_{Ia}	ORNL Weibull Type
□ Warm Pre-Stress	Considered

■ Users □ PASCAL3

3-② Analysis Conditions (2/2)

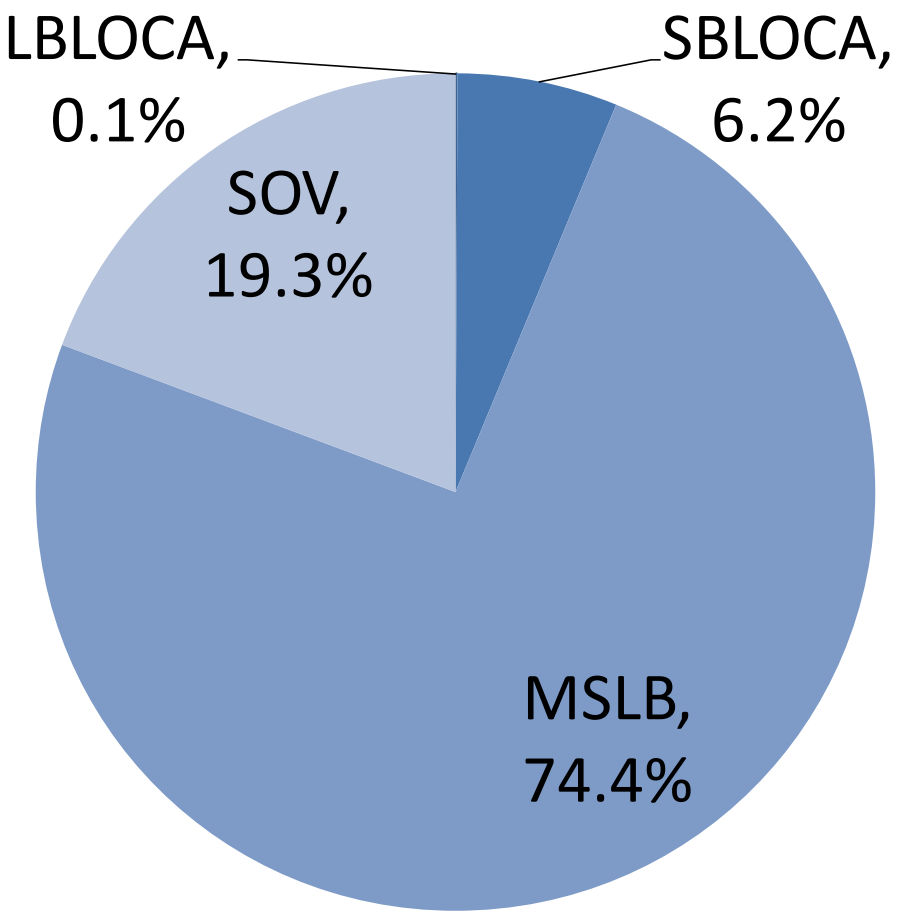
➢ Initial Crack

Item	Condition
Surface Crack	Circumferential Semi-Elliptical Crack Crack Depth, Crack Aspect Ratio, Crack Density :Sample Data of VFLAW (Crack Depth, a : 6mm) (Crack Aspect Ratio, L/a : 2, 6, 10, 20)
Inner Crack	Circumferential and Axial Elliptical Crack Crack Depth, Crack Aspect Ratio, Crack Density :Sample Data of VFLAW Position in the RPV : 1/8×t from Inner Surface (t:thickness)
Crack Geometry after 1st Initiation	Circumferential Crack : Circumferential 360 degree Crack Axial Crack : Axial Infinite Length Crack
K_I Solution	Semi-Elliptical Surface Crack : CEA (Solution for Through Clad Crack) Elliptical Inner Crack : JSME Circumferential 360 degree Crack : JSME Axial Infinite Length Crack : JSME

Users PASCAL3

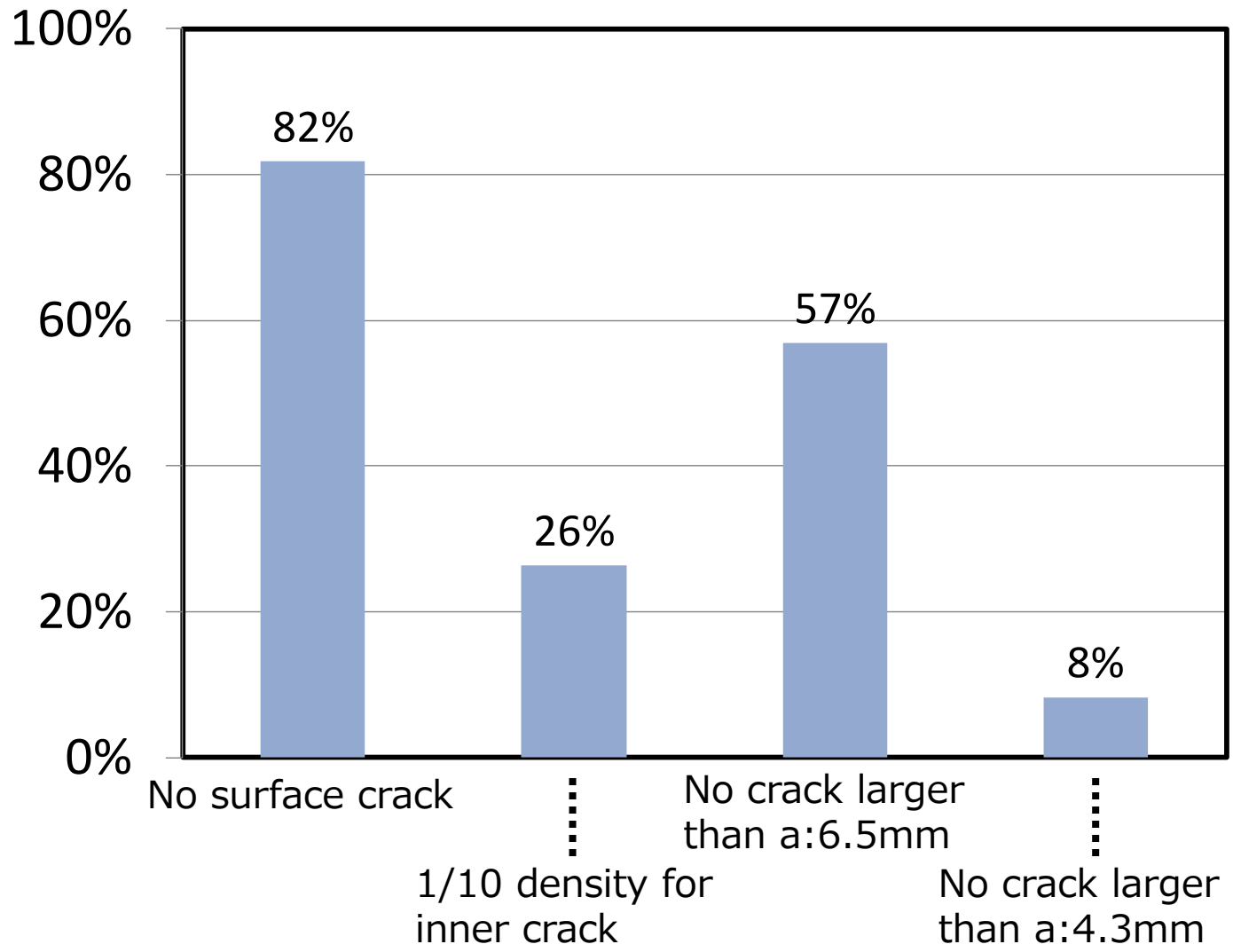
3-③ Analysis Results (Effect of PTS Transients)

- Percentage of TWCF of Each PTS Transient to the Total TWCF



3-④ Analysis Results (Effect of Initial Crack Size)

- Percentage of TWCF of Other Crack Densities to the Original TWCF



4 On-going Work

- Update of User's Manuals
  - ✓ Theory and detailed input manual (JAEA Data/Code 2010-033)
  - ✓ Preparing simplified manual, manual on PTS transient and more

- Research on Utilization of PASCAL3
  - ✓ Guideline for general procedures of PFM analysis
  - ✓ Selection of typical input data and analysis functions of PASCAL3
  - ✓ Verification of PASCAL3

5 Conclusion

- ✓ The main analysis flow of PASCAL3,
- ✓ Typical input and output data of PASCAL3,
- ✓ An example of a PFM analysis using PASCAL3 for different crack densities,

are introduced.

6 Deliverable List

- ✓ Load module of PASCAL3
- ✓ Samples of input/output files
- ✓ Manuals

※How to access is as presented by JAEA.

Demonstration

- ✓ Demonstration of PASCAL3
- ✓ Samples of input/output files
- ✓ Manuals
- ✓ References

References

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