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AREVA's Current MELCOR Activities in Germany

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Content

- **Simplified BWR Mark II containment model for MCCI with MELCOR 1.8.6**
  - **Containment model and purpose**
  - **Modeling of a core with the CAV package**
  - **Relocation between cavities**
  - **Example results**
- **AREVA's first trials with MELCOR 2.1**
  - **First experience**
  - **Challenges**
- **Visualization of PWR integral model results for SAMG training purposes (Lejla Musanovic ➔ tomorrow)**

Chapter 1

Mark II Containment Model

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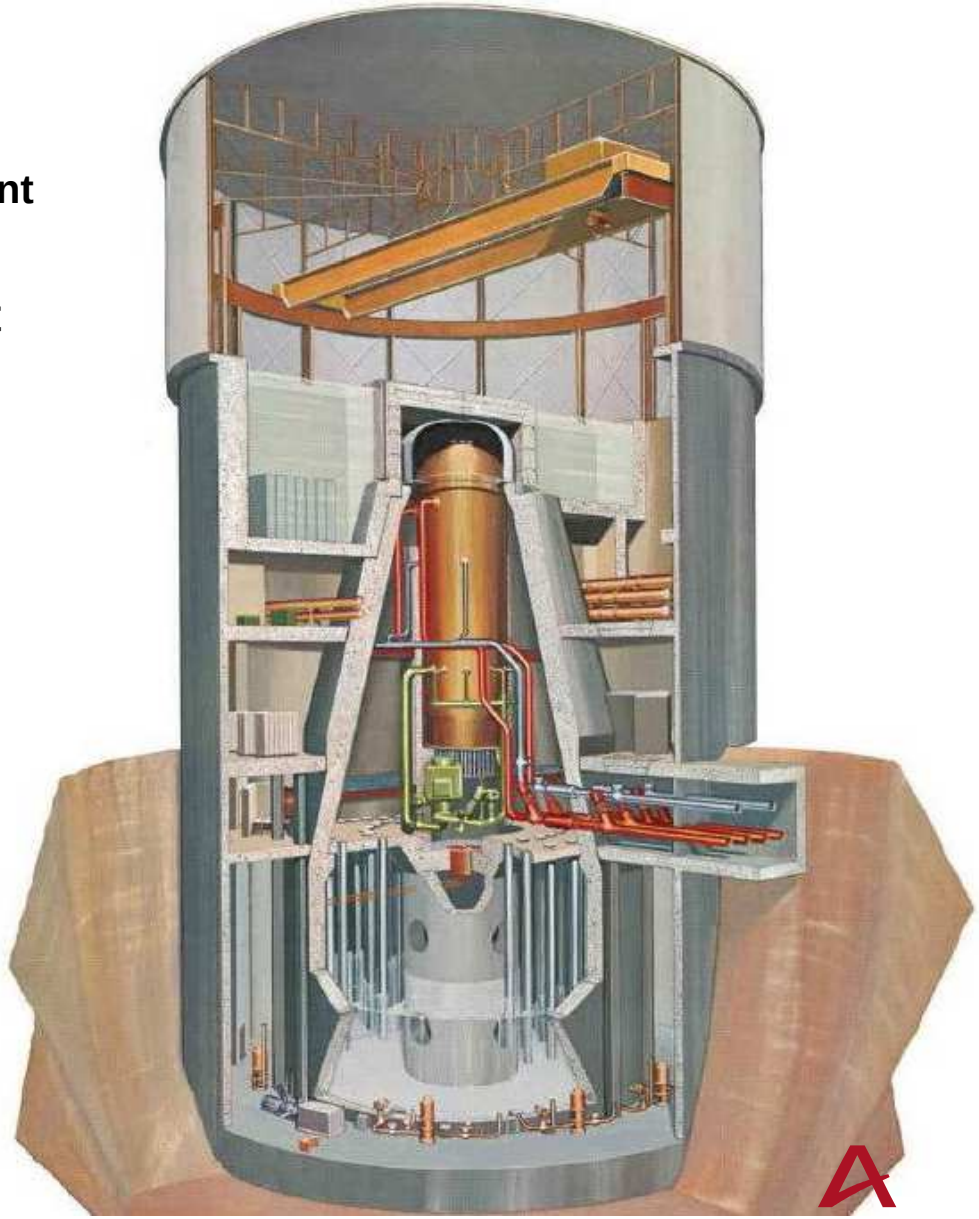
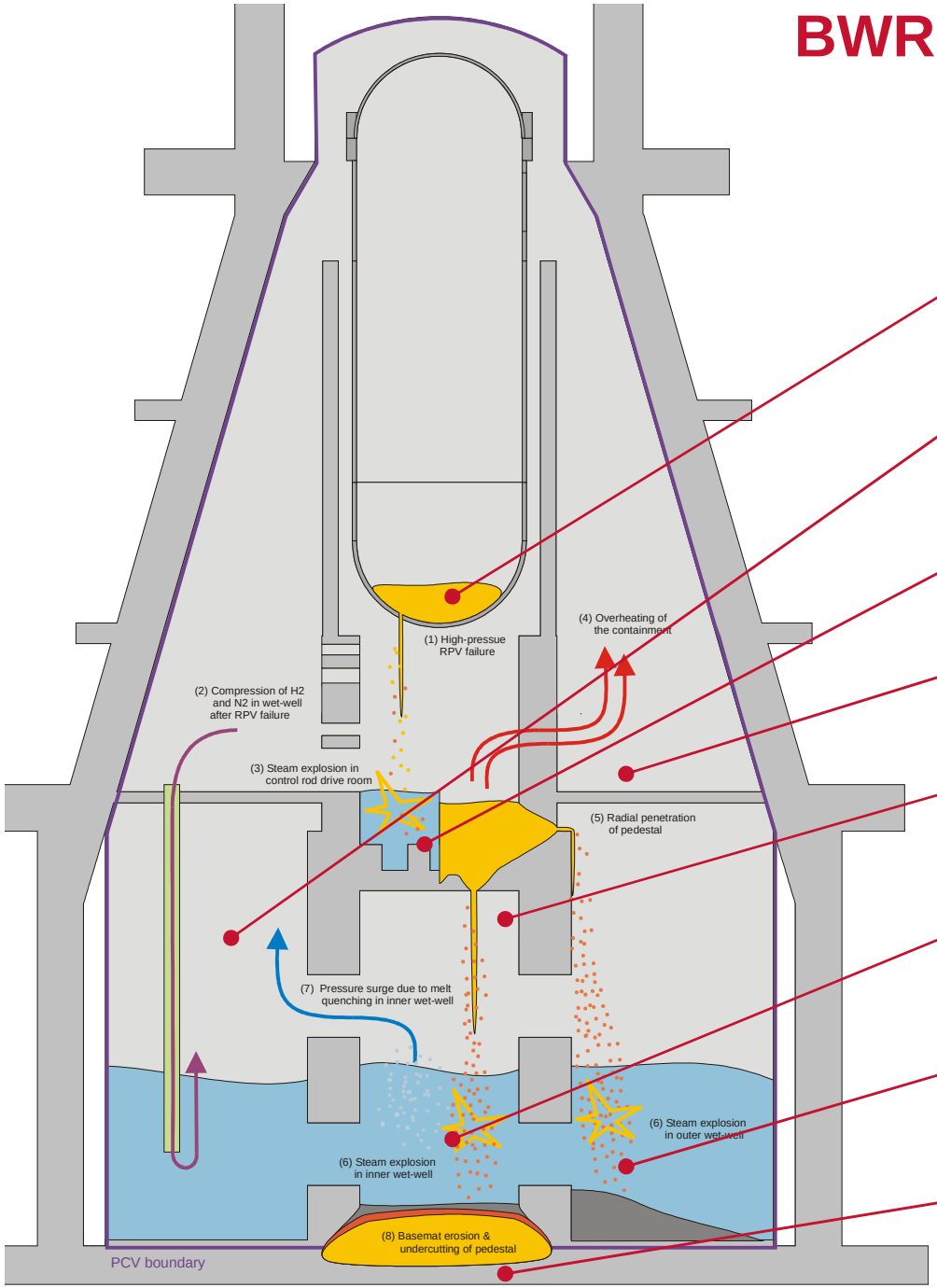
BWR Mark II – Containment Model Objective

- **Prediction of the overall accident progression**
  - Grace periods till and after RPV failure
  - Relocalization of molten corium within the containment
- **Identification of endangerments of the containment**
  - Temperature loads
  - Static & transient pressure loads
  - Impairing of building stability
- **Impact of accident mitigation measures**
  - Filtered venting operation



> **Goal of the study is the examination of possibilities for back-fitting a core catcher in a Mark II containment**

BWR Mark II – Containment Threats



(1) High-pressure RPV failure
➔ MELCOR of limited usability

(2) Compression of H_2 in wet-well after RPV failure

(3) Steam explosion in control rod drive room
➔ MELCOR of limited usability

(4) Overheating of containment / penetrations

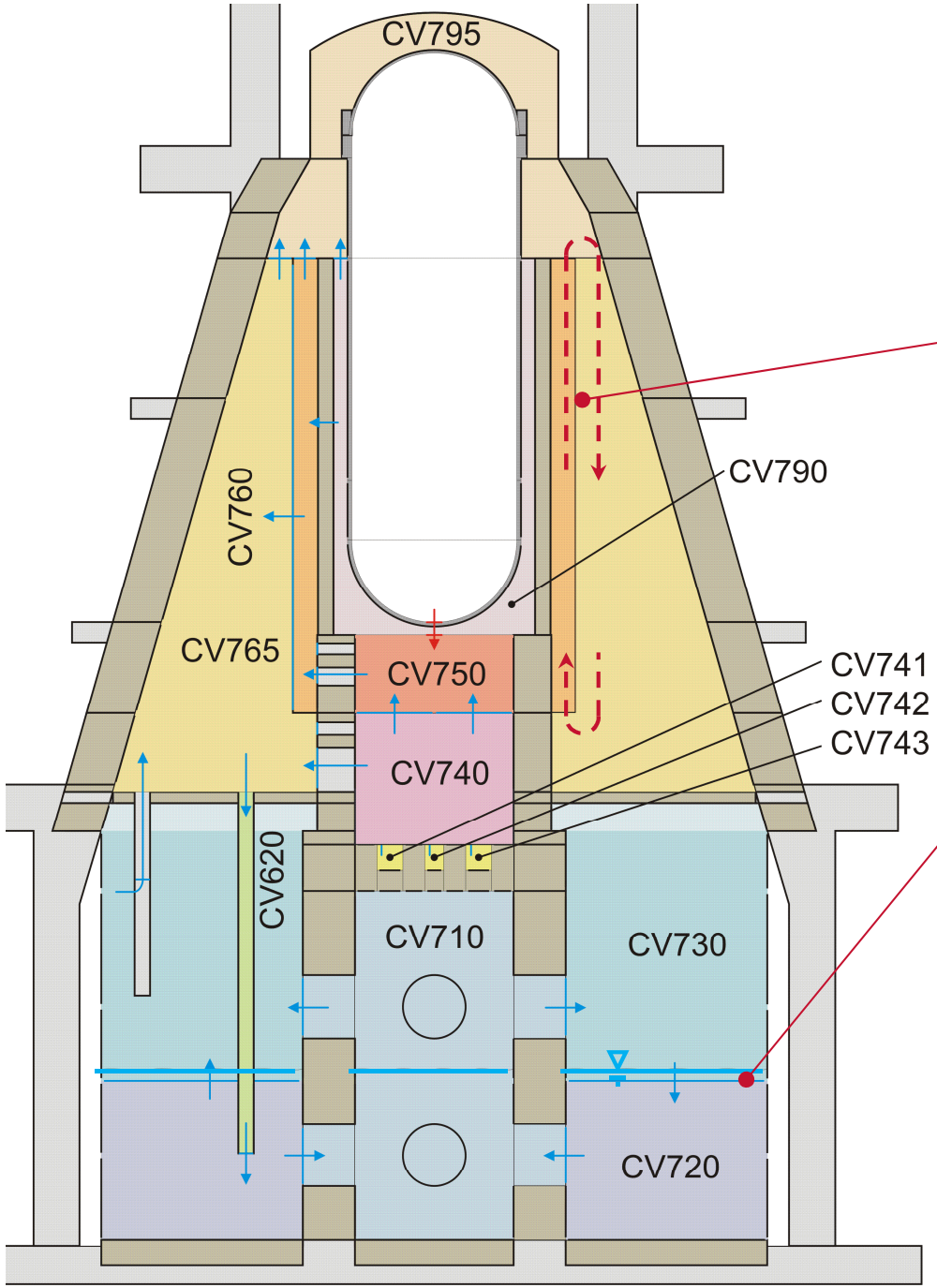
(5) Radial penetration of pedestal
OR axial failure of floor

(6) Pressure surge due to melt quenching in inner wet-well

(7) Steam explosion in inner or outer wet-well
➔ MELCOR of limited usability

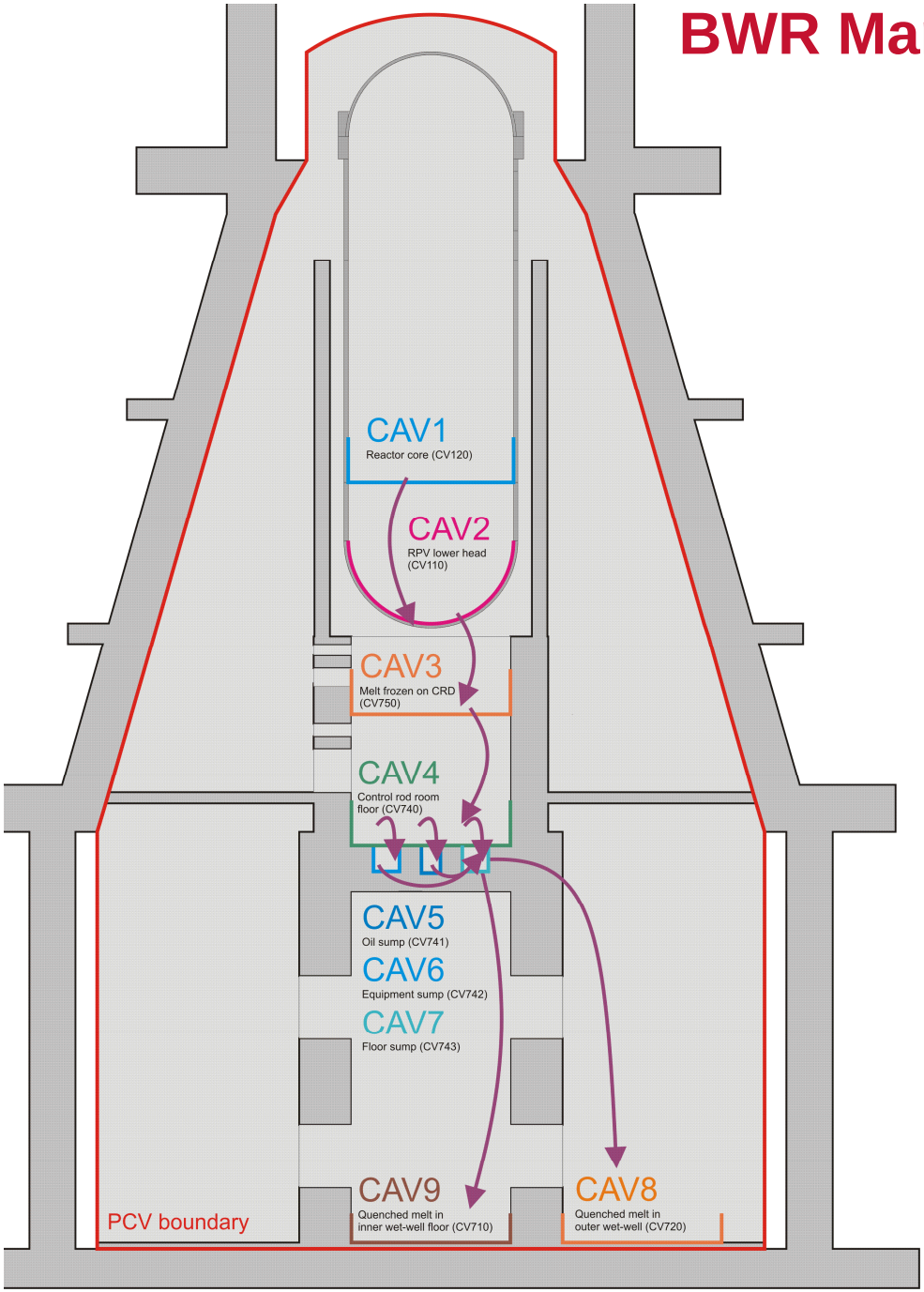
(8) Basemat erosion & undercutting of pedestal

BWR Mark II – MELCOR Model



- **Dry-well**
  - Splitting of DW to enable air/steam convection
  - Necessary to gain realistic temperatures at penetrations / closure head
- **Wet-well**
  - Horizontal cut within pool
  - Allows for hot water layer on top pressure suppression pool by steam condensation
  - Top water layer determines the pressure buildup in the containment
- **Other structures**
  - 1 CV for 97 pressure suppression tubes
  - 1 FL for the vacuum breakers
  - A lot of heat structures
- **No heat losses from containment**

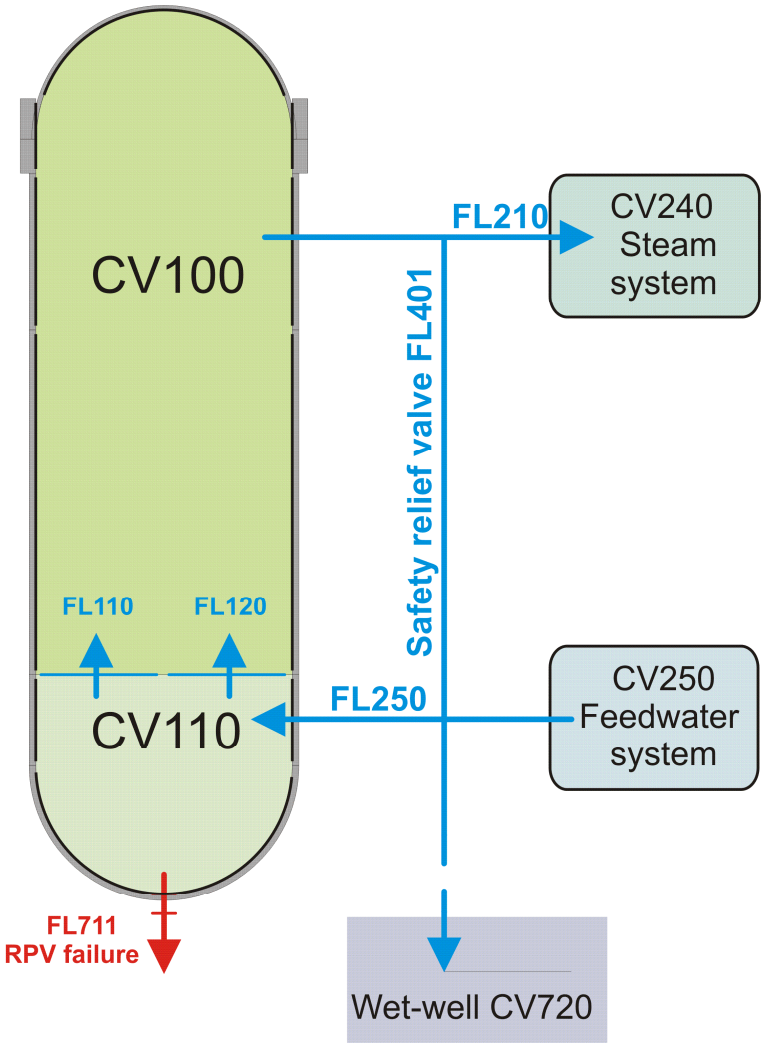
BWR Mark II – Corium Relocation Paths



- **CAV1 – Intact core**
- **CAV2 – Corium in RPV lower head**
- **CAV3 – Corium stuck on control rod drives**
  - **~ about 10^{-2} m thickness on 10 rods**
- **CAV4 – Control rod drive (CRD) room**
  - **Mass of 10 drives added to melt**
  - **Mass of control rod changing machine added**
- **CAV5+6+7 – Sumps within the CRD room**
  - **Oil sump, Equipment sump, & Drain sump**
  - **Sequential filling of sumps if CAV4 layer thickness > 10 cm / > 15 cm / > 20 cm**
- **CAV8 – Outer wet-well floor**
  - **After radial penetration of RPV pedestal**
- **CAV9 – Inner wet-well floor**
  - **After axial penetration of CRD room floor**

BWR Mark II – Model Simplifications

- **No usage of RN or COR package**
  - **Replacement of core by a special constructed CAV**
- **Relocation of corium and RPV failure defined by CF**
  - **CF-controlled overflow heights used to avoid unphysical (MELCOR-typical) instantaneous relocalization**
- **Simplified modelling of the reactor coolant system**
  - **Time independent CVs as sources/sinks for feed water and steam system**
  - **One safety relief valve**
  - **One CV per CAV**
- **Limited modelling scope for safety systems**
  - **Filtered containment venting system as one FL with TF mass flow vs. containment pressure**
  - **Fire protection system modelled as spray (SPR)**
  - **No safety injection (limitation to Fukushima Unit 1 – like scenarios)**



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BWR Mark II – CAV as COR Substitute (I/II)

- **Cavity instead of core input:**

```
CAV01C0  INERT
...
CAV01C1  ZRO2     1.0                 * ZrO2 to prevent ablation
* Layer content
CAV0110  TEMP     550.
CAV0111  UO2      158.E3
CAV0112  FE       21.8E3
CAV0113  ZR       38.2E3
CAV0114  ZRO2     51.6E3              * no reactor poison possible
...
CAV01U2  EMISS.OX          0.01       * only very small emissivity as large surface area
CAV01U3  EMISS.MET         0.01       * of fuel rods shine on its self more than on
CAV01U4  EMISS.SUR         0.01       * other structures
                                      * but: CAV02U2   EMISS.OX 0.8
```

BWR Mark II – CAV as COR Substitute (II/II)

- **Hydrogen production during core destruction:**

```
* Hydrogen addition
*--------------------------
* If CAV1 reaches 1200°C, then add 1675 kg hydrogen at 1200°C with 1 kg/s
CF5109100         'CAV.1.Temp'      MAX      5         1.0      0.0
CF5109101         500.
CF5109111         1.0      0.0      CAV-T.HMX.1
CF5109112         1.0      0.0      CAV-T.HOX.1
CF5109113         1.0      0.0      CAV-T.LMX.1
CF5109114         1.0      0.0      CAV-T.LOX.1
CF5109115         1.0      0.0      CAV-T.MET.1
```

- **Relocation from CAV 1 to CAV 2 at 1700 K in CAV 1 (melting SS structures):**

```
CAV01RA  02       51012              * axial rupture, defined by CF-controlled rupture,
                                     * axial rupture & no height CF = full dump in CAV2
```

BWR Mark II – CAV Package

- **Add mass in CAV4**

```
* Initial layer content
*-------------------------
* Assumption: 5% of control rods drop down
* Mass CRD changing machine [kg]  10.E3    * estimate
CAV0410  TEMP     333.15                   * = 60+273.15
CAV0412  FE       13.0E3                   * 10% of RPV internals below the core
```

- **One cavity can only drain in up to three cavities**

- **Cavity CAV 5 + 6 drain into CAV7 (example):**

```
*     R_adial, A_xial, or by con_T_rol function
*     |  NOV = receiving CAV number
*     |  |        NCFRUP = control function triggering rupture
*     |  |        |       NCFREL = height of rupture (optional for R & A)
*     |  |        |       |
CAV05RA  07       58028    58030            * axial rupture, defined by CF
CAV06RA  07       58029    58030
```

BWR Mark II Containment Model – CAV Package

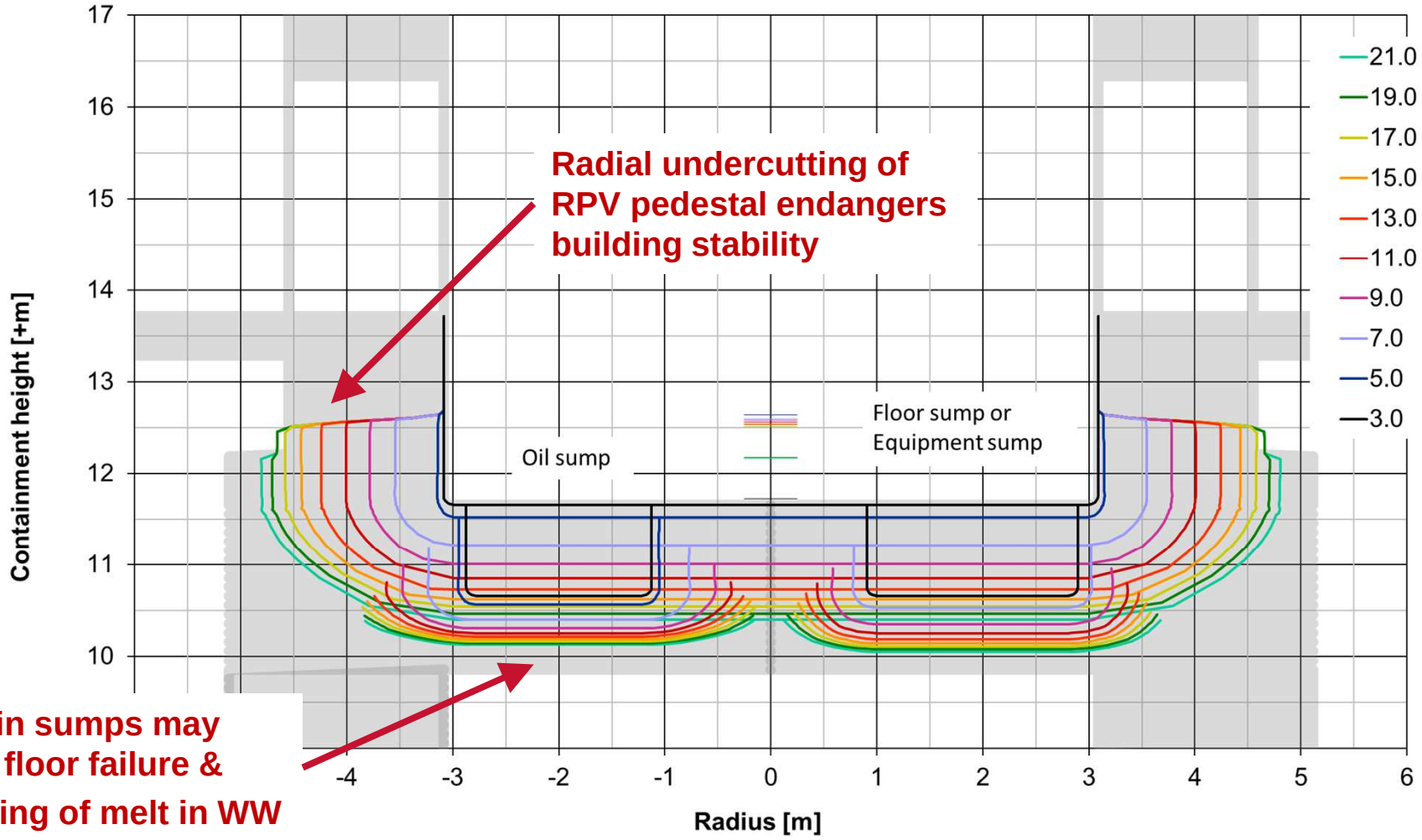
- **Quenching in CAV 8 + 9 after relocation from CAV 4 + 7 as conservative assumption for PCV loads**

```
* spread on 40 m radius disk > 5000 m² to ensure coolability
*       ZT - top edge height (in RG0)
*       |       RAD - radius
*       |       |       HIT - height of cylindrical cavity
*       |       |       |       RADC - radius of corner
*       |       |       |       |       RW - external radius
*       |       |       |       |       |       HBB - bottom thickness
*       |       |       |       |       |       |       NBOT - no
*       |       |       |       |       |       |       |       NCORN
*       |       |       |       |       |       |       |       |
CAV08G2 3.760   40.     1.0     0.1     50.     10.     10      3
```

- **Reheating in wet-well not possible, because only 9 cavities allowed**
- **Molten corium is submerged with water if a pool exists in the connected CV**
- **Test with stratified corium: Increased radial ablation but “noisy” cavity shape**

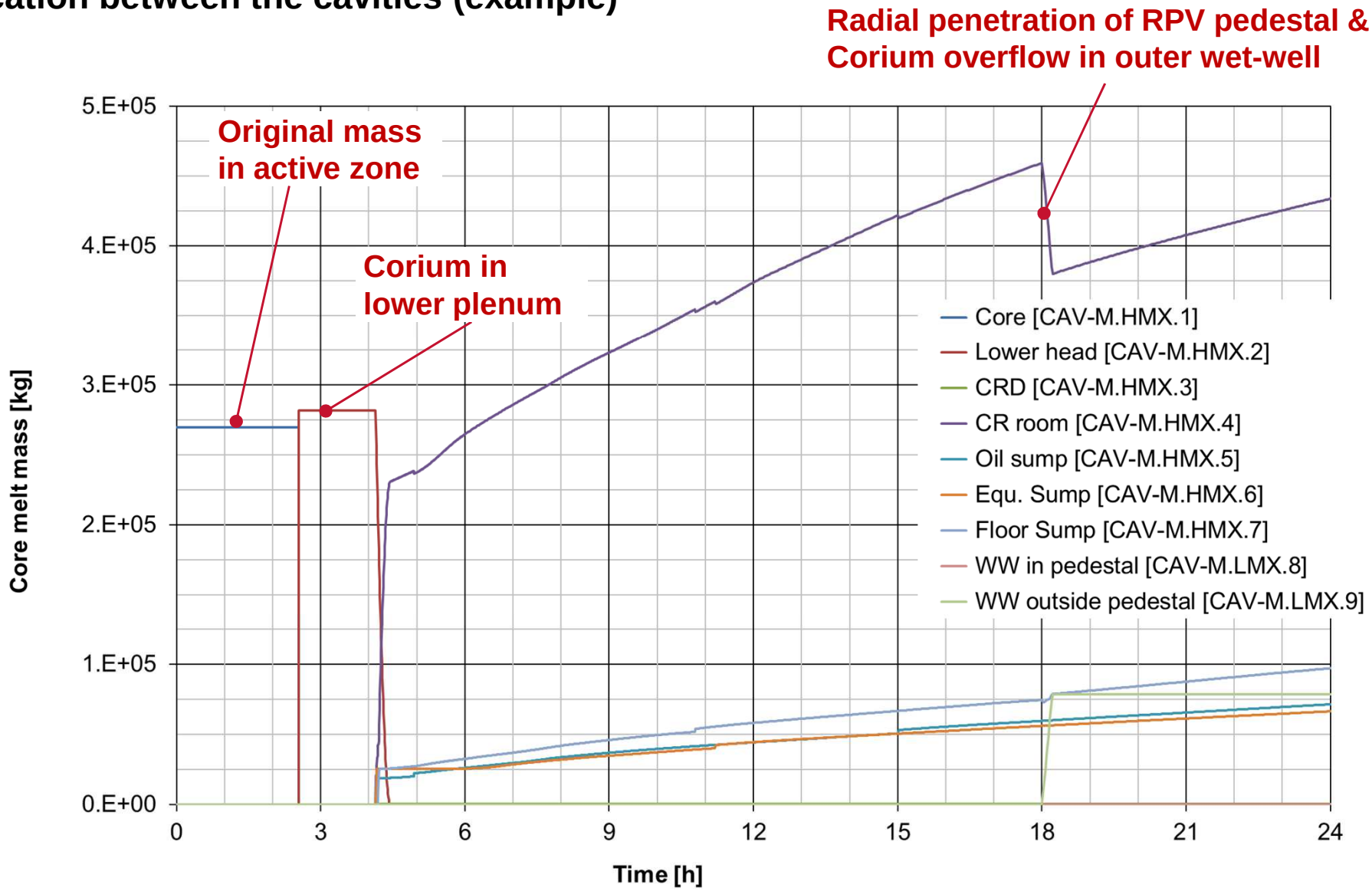
BWR Mark II – Predicted Cavity Shape

- **Cavity shape (example)**
  - **Shape generated by overlay of the three CAV of the three sumps (Excel)**
  - **Assumption: enforced mixing of melt**



BWR Mark II – Melt Masses and Positions

- **Relocation between the cavities (example)**



BWR Mark II – Summary

- **Simple model**
  - **Economic model generation**
  - **Short project time (several weeks)**
  - **Fast running model (2 CPU-hr per 24 hr problem time on standard Windows PC)**
- **Model sufficient to answer the following questions**
  - **Accident grace periods (for SBO scenarios)**
  - **Containment pressure build-up & pressure peaks**
  - **Containment temperatures**
- **Should-knows of the CAV package**
  - **One CAV can drain only in 3 other CAV (`CAVxxRA`, `CAVxxRR`, `CAVxxRT`)**
  - **Only 9 cavities do work (even so 100 CAV can be defined)**
  - **Corium is perfectly submerged with water as long as a pool exists in the connected CV (no height information transmitted between CAV and CVH)**
  - **Stratified corium gives understandable but "noisy" cavity shape (raises doubts about model reliability)**

The MELCOR code is very flexible and can easily be adapted to specific questions

Chapter 2

First Trials with MELCOR 2.1

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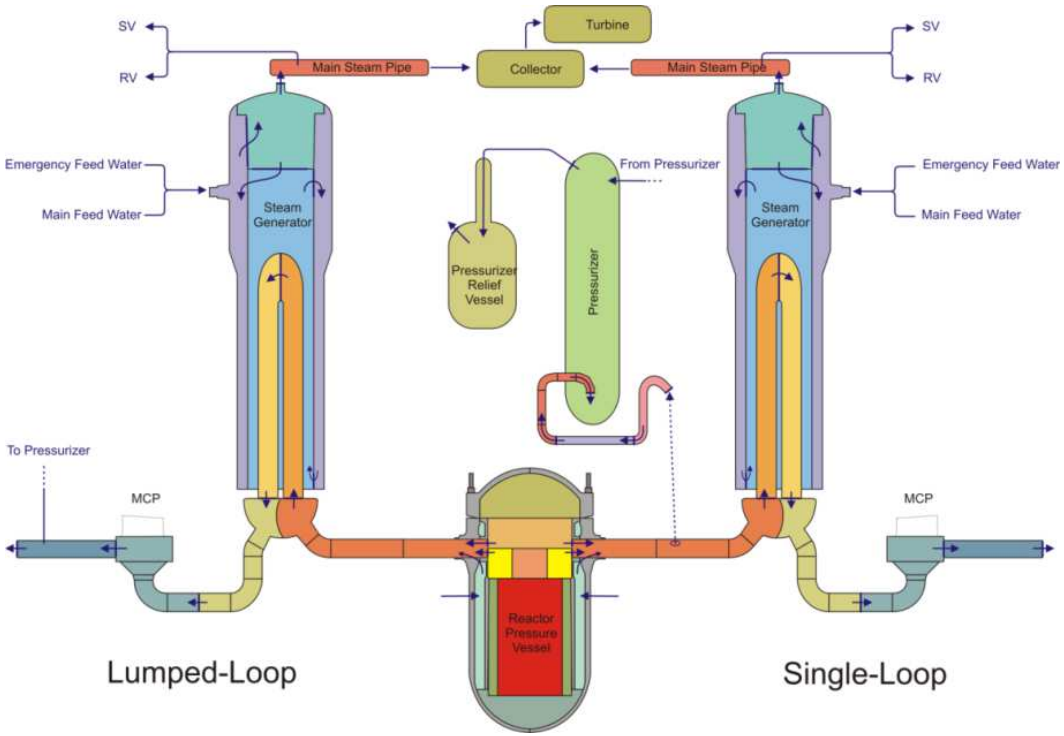
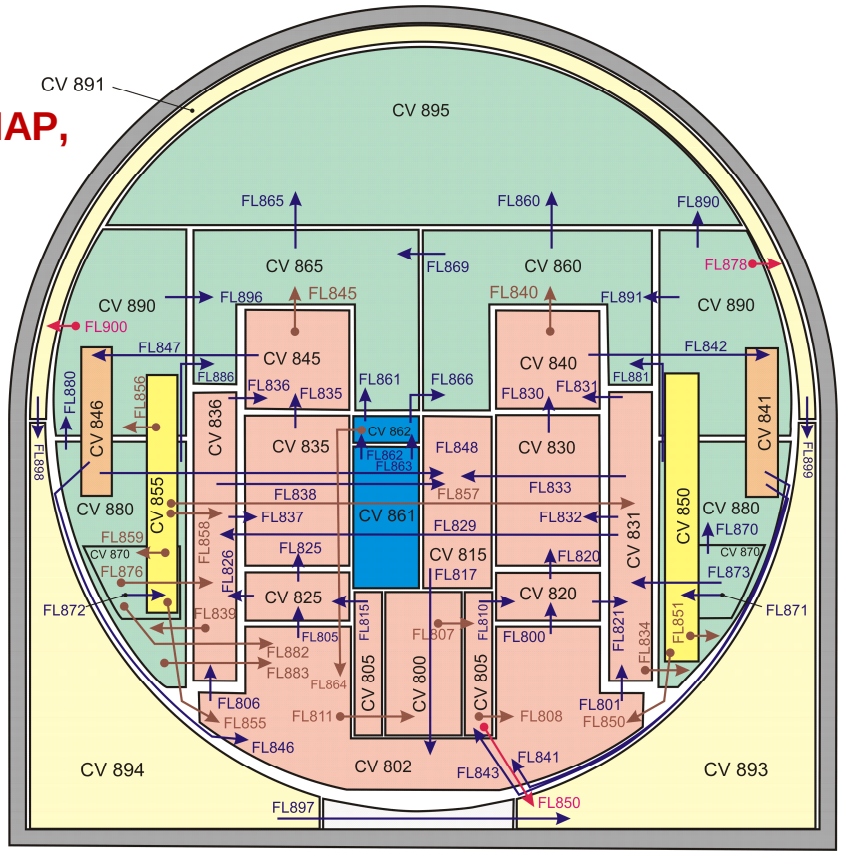
First Trials with MELCOR 2.1 –Task and Challenges

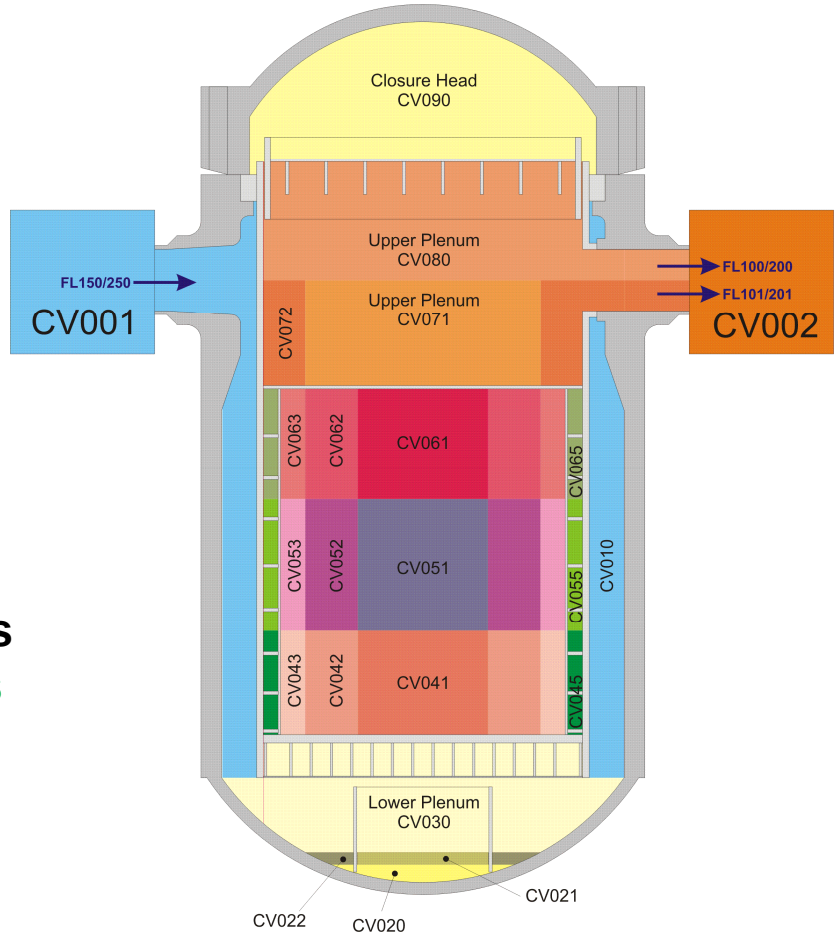
- **Task:** Translation of input decks for different KWU PWRs for validation purpose to use MELCOR 2.1 in future (BWRs possibly later)
  - The models comprise 25,000–29,000 lines in MELCOR 1.8.6 (without comments)
  - Excessive in-code comments for quality assurance
  - The input is divided into ~42 modular files
  - To learn more about the challenges of translation with SNAP, we have started with the latest model “C.N. Trillo”





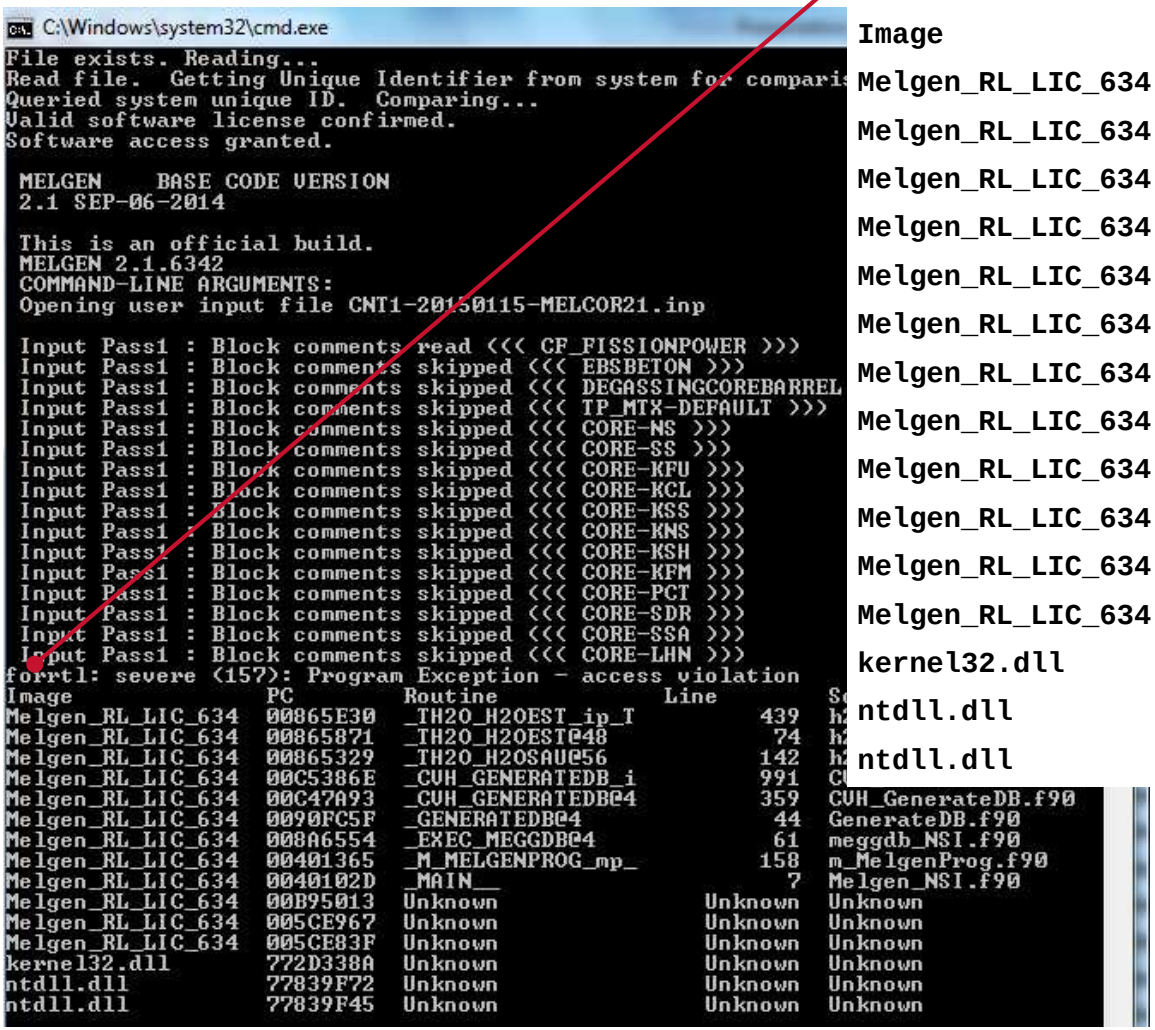
First Trials with MELCOR 2.1 – Approach

- **Combining all files into a single one (required for unique names)**
- **Translation with SNAP**
  - **Minor changes especially for global parameters, MELGEN and MELCOR directives**
- **First trial to run the input**
  - ➔ **crash during building the restart file**
- **Splitting input into modules and reduction**
  - ➔ **crash**
- **Further reduction of the input:**
  only an RPV with time independent boundary volumes
  - ➔ **running, although it contains complex input files**



First Trials with MELCOR 2.1 – Crash 1

- **Access violation**

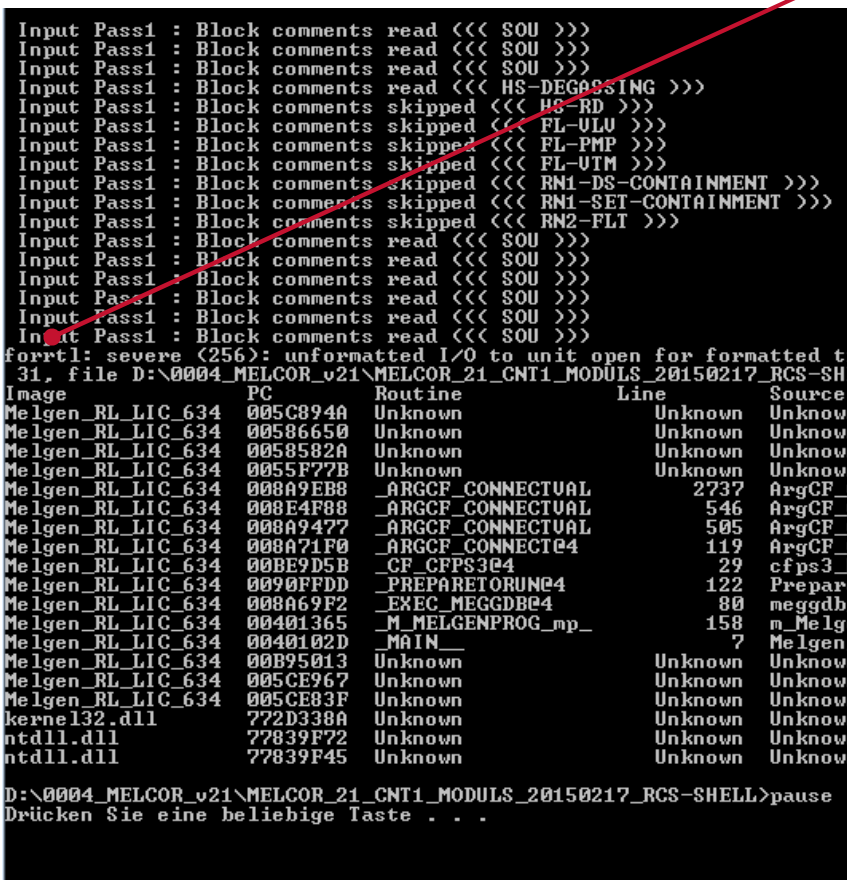


forrtl: severe (157): Program Exception - access violation

Image	PC	Routine	Line	Source
Melgen_RL_LIC_634	00865E30	_TH2O_H2OEST_ip_T	439	h2oest_NSI.f90
Melgen_RL_LIC_634	00865871	_TH2O_H2OEST@48	74	h2oest_NSI.f90
Melgen_RL_LIC_634	00865329	_TH2O_H2OSAU@56	142	h2osat_NSI.f90
Melgen_RL_LIC_634	00C5386E	_CVH_GENERATEDB_i	991	CVH_GenerateDB.f90
Melgen_RL_LIC_634	00C47A93	_CVH_GENERATEDB@4	359	CVH_GenerateDB.f90
Melgen_RL_LIC_634	0090FC5F	_GENERATEDB@4	44	GenerateDB.f90
Melgen_RL_LIC_634	008A6554	_EXEC_MEGGDB@4	61	meggdb_NSI.f90
Melgen_RL_LIC_634	00401365	_M_MELGENPROG_mp_	158	m_MelgenProg.f90
Melgen_RL_LIC_634	0040102D	_MAIN__	7	Melgen_NSI.f90
Melgen_RL_LIC_634	00B95013	Unknown	Unknown	Unknown
Melgen_RL_LIC_634	005CE967	Unknown	Unknown	Unknown
Melgen_RL_LIC_634	005CE83F	Unknown	Unknown	Unknown
kernel32.dll	772D338A	Unknown	Unknown	Unknown
ntdll.dll	77839F72	Unknown	Unknown	Unknown
ntdll.dll	77839F45	Unknown	Unknown	Unknown

First Trials with MELCOR 2.1 – Crash 2

- I/O



forrtl: severe (256): unformatted I/O to unit open for formatted transfers, unit 31, file D:\0004_MELCOR_v21\MELCOR_21_CNT1_MODULS_20150217_RCS-SHELL\R35.GOUT

Image	PC	Routine	Line	Source
Melgen_RL_LIC_634	005C894A	Unknown	Unknown	Unknown
Melgen_RL_LIC_634	00586650	Unknown	Unknown	Unknown
Melgen_RL_LIC_634	0058582A	Unknown	Unknown	Unknown
Melgen_RL_LIC_634	0055F77B	Unknown	Unknown	Unknown
Melgen_RL_LIC_634	008A9EB8	_ARGCF_CONNECTVAL	2737	ArgCF_Connect.f90
Melgen_RL_LIC_634	008E4F88	_ARGCF_CONNECTVAL	546	ArgCF_Connect.f90
Melgen_RL_LIC_634	008A9477	_ARGCF_CONNECTVAL	505	ArgCF_Connect.f90
Melgen_RL_LIC_634	008A71F0	_ARGCF_CONNECT@4	119	ArgCF_Connect.f90
Melgen_RL_LIC_634	00BE9D5B	_CF_CFPS3@4	29	cfps3_NSI.f90
Melgen_RL_LIC_634	0090FFDD	_PREPARETORUN@4	122	PrepareToRun.f90
Melgen_RL_LIC_634	008A69F2	_EXEC_MEGGDB@4	80	meggdb_NSI.f90
Melgen_RL_LIC_634	00401365	_M_MELGENPROG_mp_	158	m_MelgenProg.f90
Melgen_RL_LIC_634	0040102D	_MAIN__	7	Melgen_NSI.f90
Melgen_RL_LIC_634	00B95013	Unknown	Unknown	Unknown
Melgen_RL_LIC_634	005CE967	Unknown	Unknown	Unknown
Melgen_RL_LIC_634	005CE83F	Unknown	Unknown	Unknown
kernel32.dll	772D338A	Unknown	Unknown	Unknown
ntdll.dll	77839F72	Unknown	Unknown	Unknown
ntdll.dll	77839F45	Unknown	Unknown	Unknown

First Trials with MELCOR 2.1 – Summary

- **All users should have a Bugzilla account**
  - ➔ **At least for reading the discussions**
- **The translation with SNAP seems to be very easy but not without issues**
- **The splitting of the converted input into modules and re-adding the comments is very exhausting**
- **The collected input, e.g. for `HS_RD`, `FL_FLSH`, `FL_VLV`, `FL_VTM`, and `FL_PMP`, complicates the modularization of the input**
- **Searching for errors is difficult if these are not recognized by MELGEN**

> **“Translation is relatively easy, but maybe it is better to start with smaller input decks”**

Thank you for your attention!

End of Presentation: AREVA's Current MELCOR Activities in Germany

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