



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

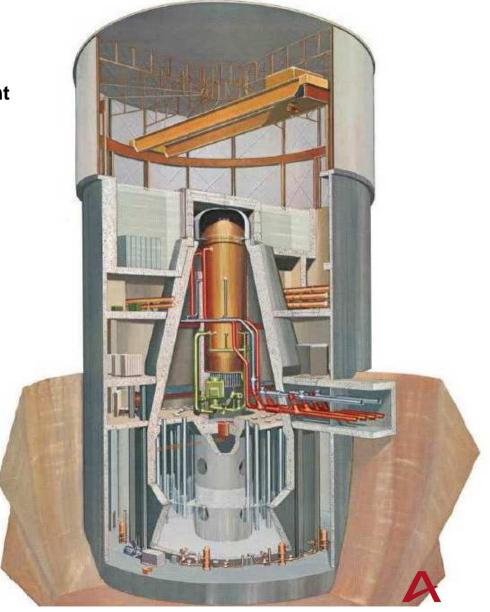
Mark II Containment Model



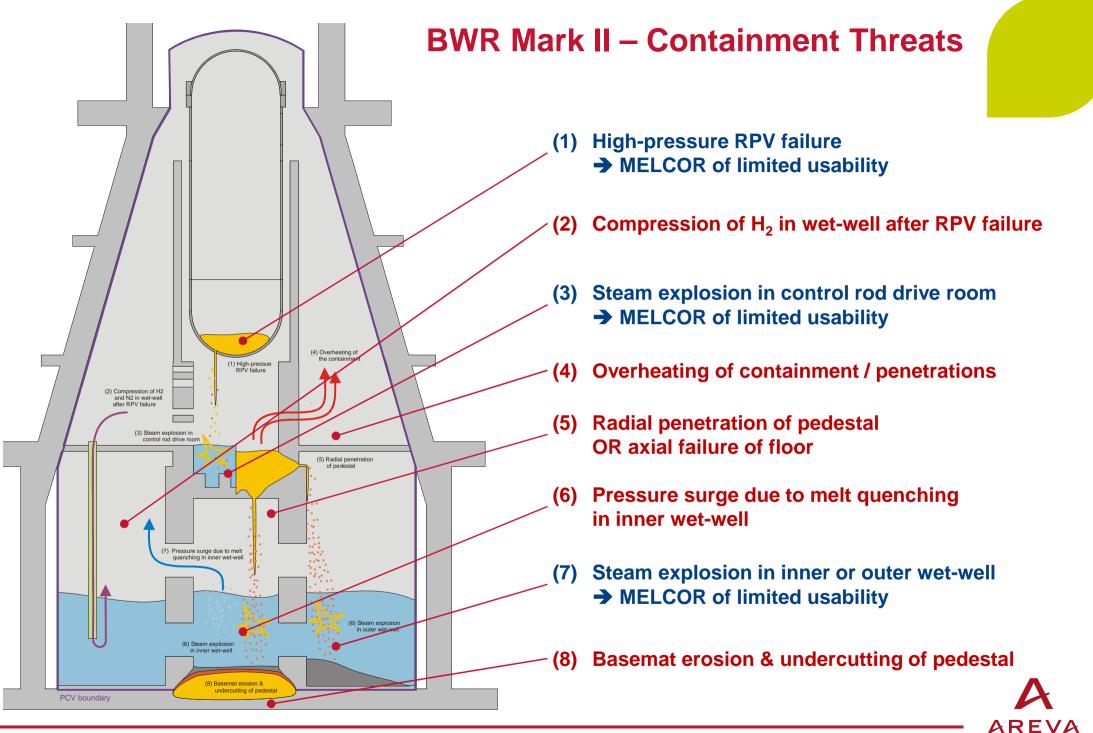
BWR Mark II – Containment Model Objective

- 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

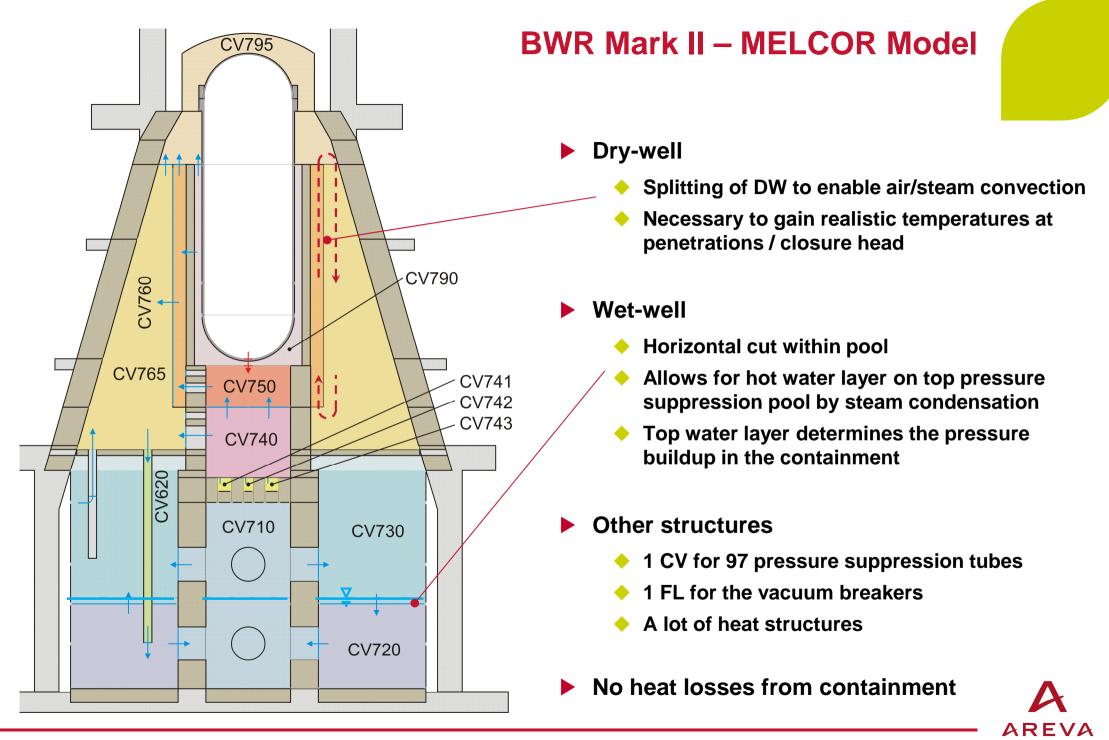
Goal of the study is the examination of possibilities for back-fitting a core catcher in a Mark II containment



forward-looking energy

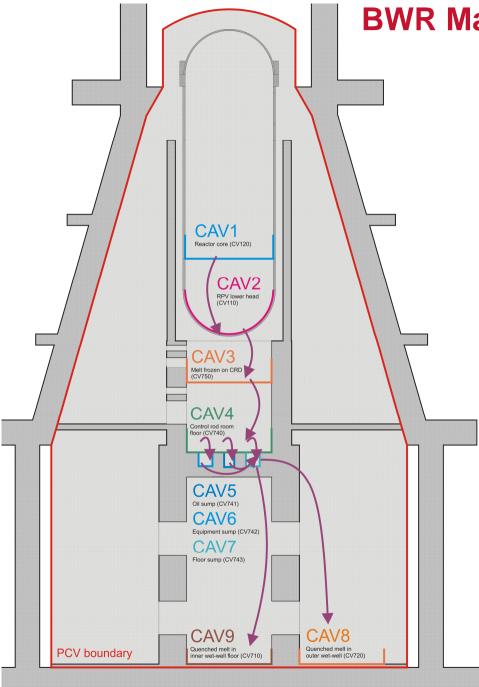


tice. forward-looking energy



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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 A

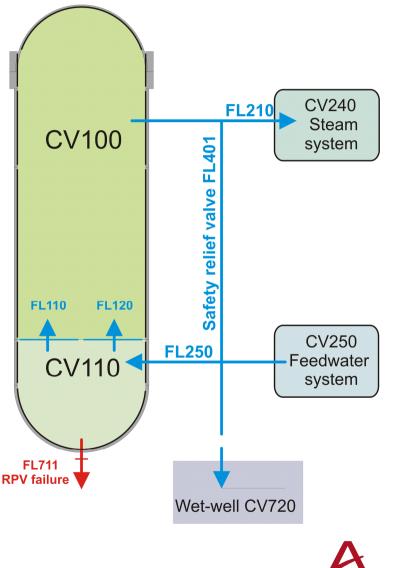
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BWR Mark II – Model Simplifications

- Replacement of core by a special constructed CAV Relocation of corium and RPV failure defined by CF CF-controlled overflow heights used to avoid CV100 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 FL110 One CV per CAV CV110 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 usage of RN or COR package

 No safety injection (limitation to Fukushima Unit 1 – like scenarios)





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	r 0.01	* of fuel rods shine on its self more than on				
CAV01U4 EMISS.SUR	R 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.Te	emp'	MAX	5	1.0	0.0	
CF5109101	500.						
CF5109111	1.0	0.0	CAV-T.HM	X.1			
CF5109112	1.0	0.0	CAV-T.HO	X.1			
CF5109113	1.0	0.0	CAV-T.LM	X.1			
CF5109114	1.0	0.0	CAV-T.LO	X.1			
CF5109115	1.0	0.0	CAV-T.ME	r.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

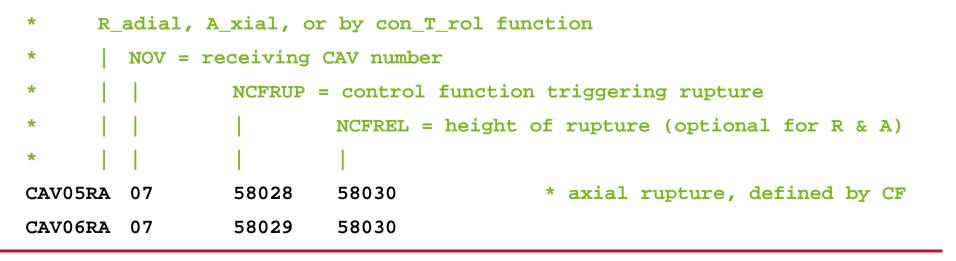
Add mass in CAV4

* 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):



BWR Mark II Containment Model – CAV Package

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 *

Quenching in CAV 8 + 9 after relocation from CAV 4 + 7

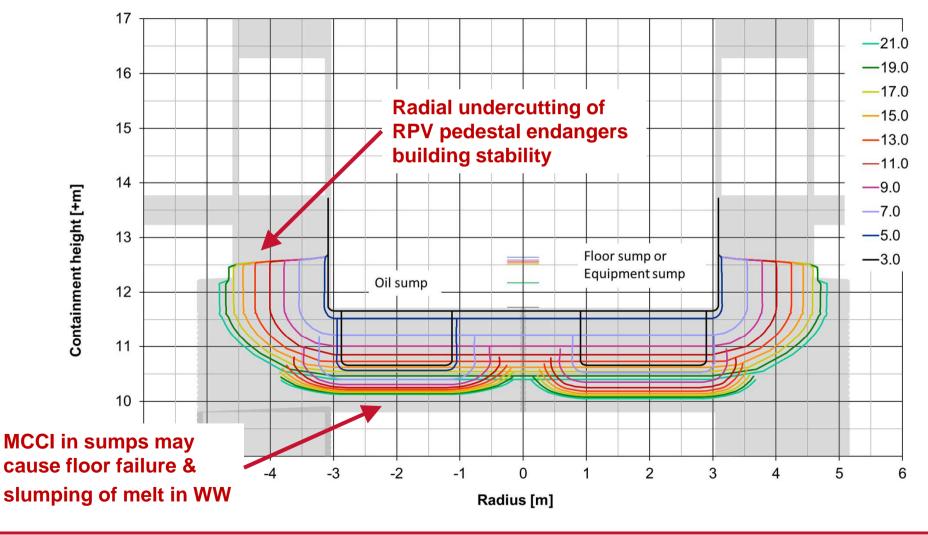
*

- 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

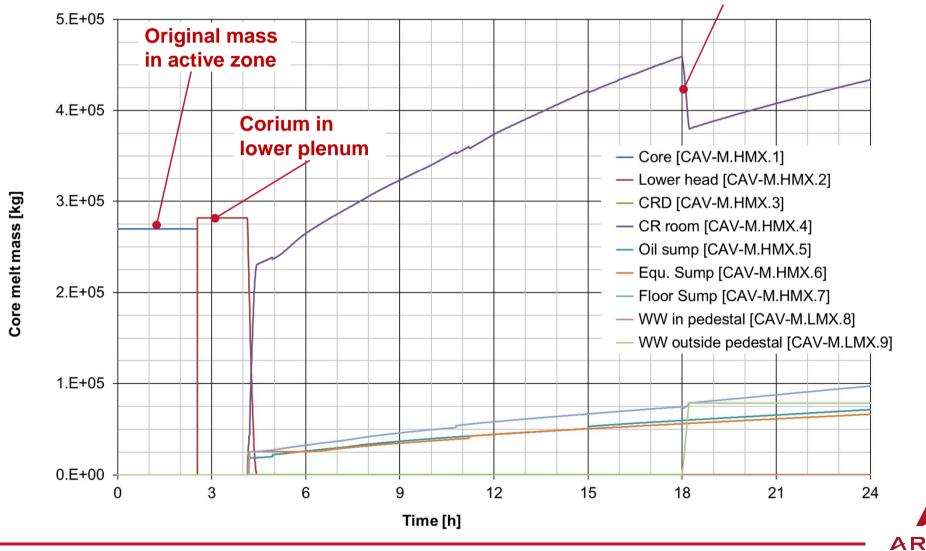


BWR Mark II – Melt Masses and Positions

Relocation between the cavities (example)

Radial penetration of RPV pedestal & Corium overflow in outer wet-well

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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





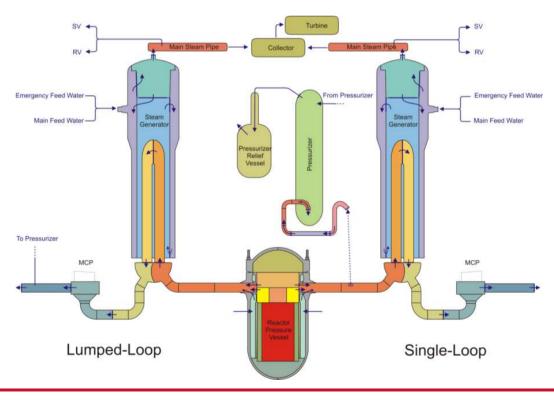
Chapter 2

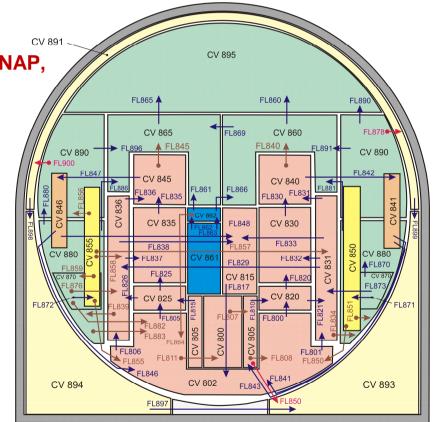
First Trials with MELCOR 2.1



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"

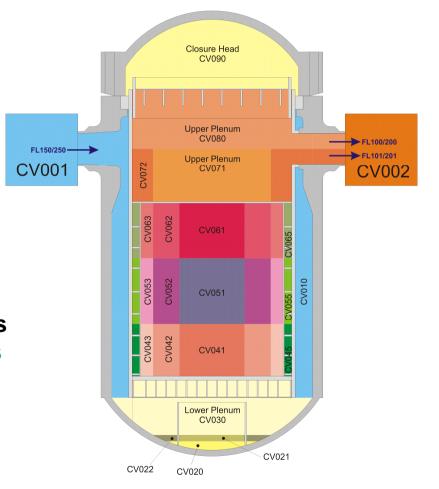






First Trials with MELCOR 2.1 – Approach

- 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

C:\Windows\system32\cmd.exe	Image	PC	Routine	Line	Source
File exists. Reading Read file. Getting Unique Identifier from system for compari		00865E30	TH20 H20EST ip T	439	h2oest_NSI.f90
Queried system unique ID. Comparing Valid software license confirmed. Software access granted.			 TH2OH2OEST@48	74	h2oest_NSI.f90
MELGEN BASE CODE VERSION	-		 _TH2O_H2OSAU@56		h2osat_NSI.f90
2.1 SEP-06-2014 This is an efficient build	Melgen_RL_LIC_634	00C5386E	_CVH_GENERATEDB_i	991	CVH_GenerateDB.f90
This is an official build. MELGEN 2.1.6342 COMMAND-LINE ARGUMENTS:	Melgen_RL_LIC_634	00C47A93	_CVH_GENERATEDB@4	359	CVH_GenerateDB.f90
Opening user input file CNT1-20150115-MELCOR21.inp	Melgen_RL_LIC_634	0090FC5F	_GENERATEDB@4	44	GenerateDB.f90
Input Pass1 : Block comments read (((CF_FISSIONPOWER))) Input Pass1 : Block comments skipped (((EBSBETON))) Input Pass1 : Block comments skipped (((DECOSSINCCODEBORDED)))	Melgen_RL_LIC_634	008A6554	_EXEC_MEGGDB@4	61	meggdb_NSI.f90
Input Pass1 : Block comments skipped (<< DEGASSINGCOREBARREI Input Pass1 : Block comments skipped (<< TP_MTX-DEFAULT >>> Input Pass1 : Block comments skipped (<< CORE-MS >>> Input Pass1 : Block comments skipped (<< CORE-MS >>>>	Melgen_RL_LIC_634	00401365	_M_MELGENPROG_mp_	158	m_MelgenProg.f90
Input Pass1 : Block comments skipped (((CORE-SS))) Input Pass1 : Block comments skipped (((CORE-KFU)))	Melgen_RL_LIC_634	0040102D	_MAIN	7	Melgen_NSI.f90
Input Pass1 : Block comments skipped (((CORE-KCL))) Input Pass1 : Block comments skipped (((CORE-KSS))) Input Pass1 : Block comments skipped (((CORE-KNS)))	Melgen_RL_LIC_634	00B95013	Unknown	Unknown	Unknown
Input Pass1 Block comments skipped (((CORE-KNS))) Input Pass1 : Block comments skipped (((CORE-KSH))) Input Pass1 : Block comments skipped (((CORE-KFM))) Input Pass1 : Block comments skipped (((CORE-PCT)))	Melgen_RL_LIC_634	005CE967	Unknown	Unknown	Unknown
Input Pass1 : Block comments skipped (((CORE-SDR)))	Melgen_RL_LIC_634	005CE83F	Unknown	Unknown	Unknown
Imput Pass1 : Block comments skipped (((CORE-LHN))) forrtl: severe (157): Program Exception - access violation	kernel32.dll	772D338A	Unknown	Unknown	Unknown
Image DC Douting	ntdll.dll	77839F72	Unknown	Unknown	Unknown
Melgen_RL_LIC_634 00865329 _TH20_H20SAU056 142 H Melgen_RL_LIC_634 00C5386E CVH_GENERATEDB i 991 0	ntdll.dll	77839 F 45	Unknown	Unknown	Unknown
Melgen_RL_LIC_634 00C47A93 _CVH_GENERATEDB04 359 (Melgen_RL_LIC_634 0090FC5F _GENERATEDB04 44 (CUH_GenerateDB.f90 GenerateDB.f90				
Melgen_RL_LIC_634 00401365 _M_MELGENPROG_mp_ 158 m	neggdb_NSI.f90 n_MelgenProg.f90 1elgen_NSI.f90				
Melgen_RL_LIC_634 00B95013 Unknown Unknown U Melgen_RL_LIC_634 005CE967 Unknown Unknown U	Inknown Inknown				
kerne132.dl1 772D338A Unknown Unknown U	Inknown Inknown Inknown				Λ
ntdll.dll ??839F45 Unknown Unknown U					K



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First Trials with MELCOR 2.1 – Crash 2

► I/O

Input Pass1 : Block comments read (((SOU)))

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

Input Pass1 : Block commen							
Input Pass1 : Block commen Input Pass1 : Block commen	ts read (((SOU))) ts read (((HS-DEGA95II	NG >>>	Image	PC	Routine	Line	Source
Input Pass1 : Block commen Input Pass1 : Block commen Input Pass1 : Block commen	ts skipped (((HS-RD)) ts skipped (((FL-ULU)	>>>	Melgen_RL_LIC_634	005C894A	Unknown	Unknown	Unknown
Input Pass1 : Block commen Input Pass1 : Block commen Input Pass1 : Block commen	ts skipped (((FL-FMF) ts skipped (((FL-UTM) ts skipped (((RN1-DS-(/// /// CONTAINMENT ////	Melgen_RL_LIC_634	00586650	Unknown	Unknown	Unknown
Input Pass1 : Block commen Input Pass1 : Block commen Input Pass1 : Block commen	ts skipped (((RN1-SET- ts skipped (((RN1-SET- ts skipped (((RN2-FLT	-CONTAINMENT >>>	Melgen_RL_LIC_634				Unknown
Input Pass1 : Block commen	ts read (((SOU)))	///	Meigen_RL_LIC_034	005656ZA	UIIKIIOWII	Unknown	UIIKIIOWII
Input Pass1 : Block commen Input Pass1 : Block commen	ts read (((SOU))) ts read (((SOU)))		Melgen_RL_LIC_634	0055F77B	Unknown	Unknown	Unknown
Input Tass1 : Block commen	ts read (((SOU)))		Melgen_RL_LIC_634	008A9EB8	_ARGCF_CONNECTVAL	2737	ArgCF_Connect.f90
In e t Pass1 : Block commen forrtl: severe (256): unfor	natted I/A to unit oner	n for formatted				- 1 -	
31, file D:\0004_MELCOR_v2 Image PC	L\MELCOR_21_CNT1_MODULS	S_20150217_RCS-S ine Source	Meigen_RL_LIC_034	008E4F88	_ARGCF_CONNECTVAL	546	ArgCF_Connect.f90
Melgen_RL_LIC_634 005C894A Melgen_RL_LIC_634 00586650	Unknown	Unknown Unknow Unknown Unknow	Melgen PL LTC 634	008A9477	_ARGCF_CONNECTVAL	505	ArgCF_Connect.f90
Melgen_RL_LIC_634 0058582A Melgen_RL_LIC_634 0055F77B	Unknown	Ilakaowa Ilakao		00827150	ARGCF CONNECT@4	119	ArgCF Connect.f90
Melgen_RL_LIC_634 008A9EB8	_ARGCF_CONNECTUAL	2737 ArgCF					
Melgen_RL_LIC_634 008E4F88 Melgen_RL_LIC_634 008A9477	_ARGCF_CONNECTUAL	505 AraCF	Melgen_RL_LIC_634	00BE9D5B	_CF_CFPS3@4	29	cfps3_NSI.f90
Melgen_RL_LIC_634 008A71F0 Melgen_RL_LIC_634 00BE9D5B	_CF_CFPS304	119 ArgCF 29 cfps3	Melgen_RL_LIC_634	0090FFDD	_PREPARETORUN@4	122	PrepareToRun.f90
Melgen_RL_LIC_634 0090FFDD Melgen_RL_LIC_634 008A69F2	_EXEC_MEGGDB04	122 Prepa 80 meggd	Melgen_RL_LIC_634	00826952	_EXEC_MEGGDB@4	80	meggdb_NSI.f90
Melgen_RL_LIC_634 00401365 Melgen_RL_LIC_634 0040102D	_M_MELGENPROG_mp_ _MAIN	7 Melge	n				meggaa_ner.re
Melgen_RL_LIC_634 00B95013 Melgen_RL_LIC_634 005CE967	Unknown Ilnknown	Unknown Unknown Unknown Unknow	Melgen RL LIC 634	00401365	$M_MELGENPROG_mp_$	158	m_MelgenProg.f90
Melgen_RL_LIC_634 005CE83F kerne132.dl1 772D338A	Unknown Unknown	Unknown Unkno Unknown Unkno	Melgen_RL_LIC_634	0040102D	_MAIN	7	Melgen_NSI.f90
ntdl1.dl1 77839F72 ntdl1.dl1 77839F45	Unknown Unknown	Unknown Unknov	Melgen_RL_LIC_634		Unknown	Unknown	Unknown
D:\0004_MELCOR_v21\MELCOR_2		_RCS-SHELL>pause	Melgen_RL_LIC_634	00505967	Unknown	Unknown	Unknown
Drücken Sie eine beliebige	faste		Mergen_RL_LIC_034	00505907	UIKIIOWII	UIIKIIOWII	UIKIIOWII
			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

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Thank you for your attention!

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

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