
AREVA
forward-looking energy

AREVA Computer Codes for Radiological Consequence Analysis

Silke Torchiani, Oliver Buss, Stéphane Haussler, Oliver Ludwik, Axel Hoefer
AREVA GmbH, Offenbach, Germany

IAEA, Vienna, 20th-24th April, 2015

E&P Communications, March, 2015
PCOM 2013/14

AREVA
forward-looking energy

Agenda

1. Our Involvement
2. CompAct – Compartment Code for Source Term Evaluation
3. DOT – Dose Evaluation Tool
4. CRCS – Central Radiological Computer System

Agenda

1 **Our Involvement**

2 CompAct – Compartment Code for Source Term Evaluation

3 DOT – Dose Evaluation Tool

4 CRCS – Central Radiological Computer System

Our involvement
New builds and installed base

Our activities encompass

- **EPR™ Power Plants**
  - **Olkiluoto 3**
  - Taishan units 1 & 2
- Installed base
  - Periodic safety review
- Emergency response
  - Tools & methods

Our involvement
New builds and installed base

Our activities encompass

- **EPR™ Power Plants**
  - Olkiluoto 3
  - **Taishan units 1 & 2**
- Installed base
  - Periodic safety review
- Emergency response
  - Tools & methods

Our involvement
New builds and installed base

Our activities encompass

- **EPR™ Power Plants**
  - Olkiluoto 3
  - Taishan units 1 & 2
- **Installed base**
  - **Periodic safety review**
- Emergency response
  - Tools & methods

Our involvement
New builds and installed base

Our activities encompass

- **EPR™ Power Plants**
  - **Olkiluoto 3**
  - **Taishan units 1 & 2**
- **Installed base**
  - Periodic safety review
- **Emergency response**
  - **Tools & methods**

Our involvement
New builds and installed base

Our activities encompass

- EPR™ Power Plants
  - Olkiluoto 3
  - Taishan units 1 & 2
- Installed base
  - Periodic safety review
- Emergency response
  - Tools & methods

Preparation of the safety analyses for licensing

Safety assessments for the design of our new products

Emergency response

Codes and methods
Radiological consequences assessments

Different purposes, different objectives, different analyses: customized tools

- **Purpose**
  - **Design**
  - **Licensing**
  - **Emergency preparedness**
  - Emergency response
- **Scope**
  - **Activity releases into the environment**
  - **Activity in rooms and systems**
  - Atmospheric dispersion and dose assessment

CompAcT

DOT
Dose Evaluation Tool
AREVA

AREVA
CRCS 6.0
© 2013 AREVA GmbH

AREVA
forward-looking energy

Codes and methods
Radiological consequences assessments

Different purposes, different objectives, different analyses: customized tools

- **Purpose**
  - **Design**
  - **Licensing**
  - **Emergency preparedness**
  - Emergency response
- **Scope**
  - Activity releases into the environment
  - Activity in rooms and systems
  - **Atmospheric dispersion and dose assessment**

CompAcT

DOT Dose Evaluation Tool

AREVA

CRCS 6.0

AREVA
forward-looking energy

Codes and methods
Radiological consequences assessments

Different purposes, different objectives, different analyses: customized tools

- **Purpose**
  - Design
  - Licensing
  - **Emergency preparedness**
  - **Emergency response**
- **Scope**
  - **Activity releases into the environment**
  - **Activity in rooms and systems**
  - **Atmospheric dispersion and dose assessment**

CompAcT

DOT Dose Evaluation Tool

AREVA

CRCS 6.0

Codes and methods
Necessary features

Tools must be versatile in order to address existing and foreseeable situations for design, licensing, emergency preparedness and emergency response

Agenda

1 Our Involvement

2 **CompAct – Compartment Code for Source Term Evaluation**

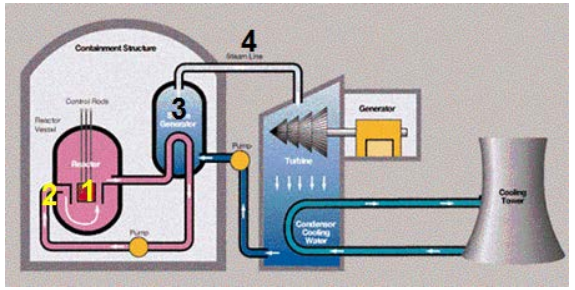
3 DOT – Dose Evaluation Tool

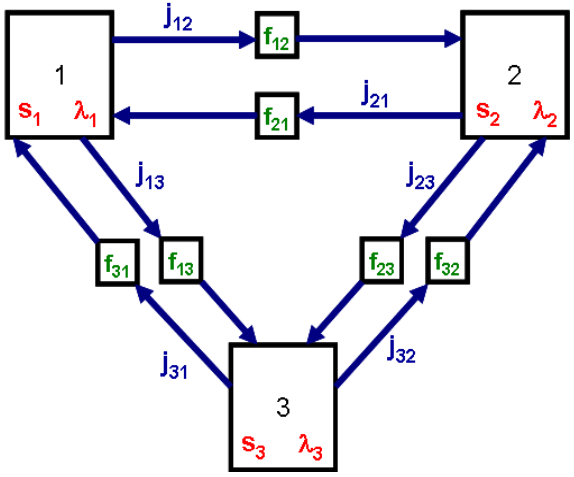
4 CRCS – Central Radiological Computer System

CompAct

Integrated compartment model

- Airborne release
  - Immediate or continuous
  - Evaporation of liquids
  - Equilibrium processes
- Multi-compartment transport
  - Active ventilation
  - Leakage pathways
  - Bypass
- Radioactive decay and ingrowth
- Removal processes
  - Filters
  - Dry deposition
  - Spray
- Individual chemical forms



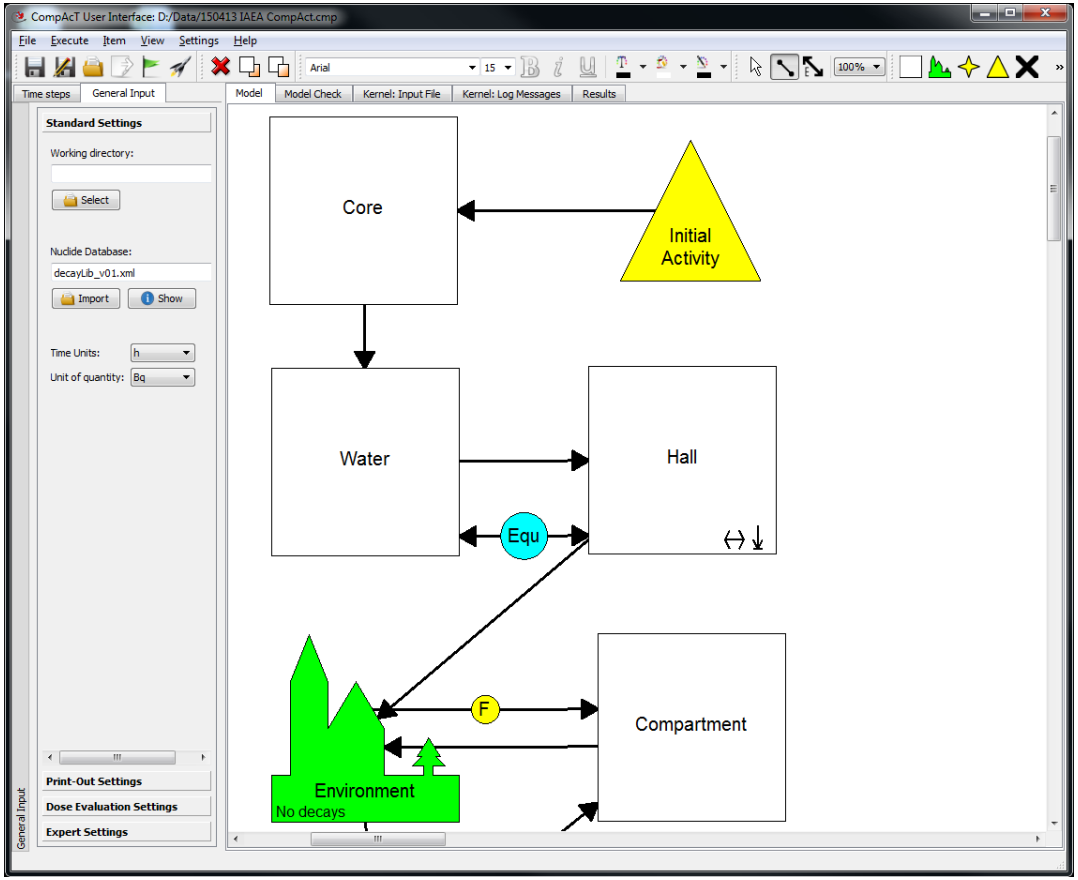


CompAcT

A few selected features

- **State-of-the art solver for large, stiff ODE systems**
- **Internal verification of numerical precision**
- **Intuitive graphical user interface**
- **Easy adaptation to various requirements**
- **Arbitrarily complex models**
- Convenient output
- Model checks itself for validity and completeness

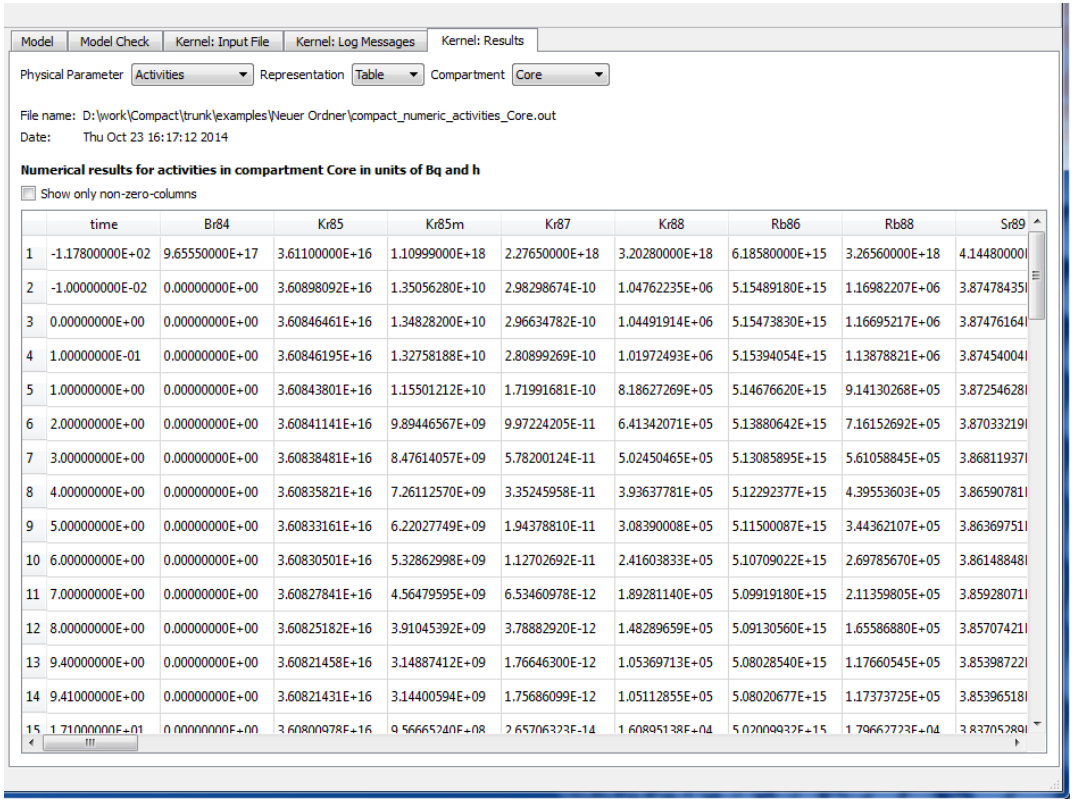
ODE = ordinary differential equation



CompAct

A few selected features

- State-of-the art solver for large, stiff ODE systems
- Internal verification of numerical precision
- Intuitive graphical user interface
- Easy adaptation to various requirements
- Arbitrarily complex models
- **Convenient output**
- Model checks itself for validity and completeness

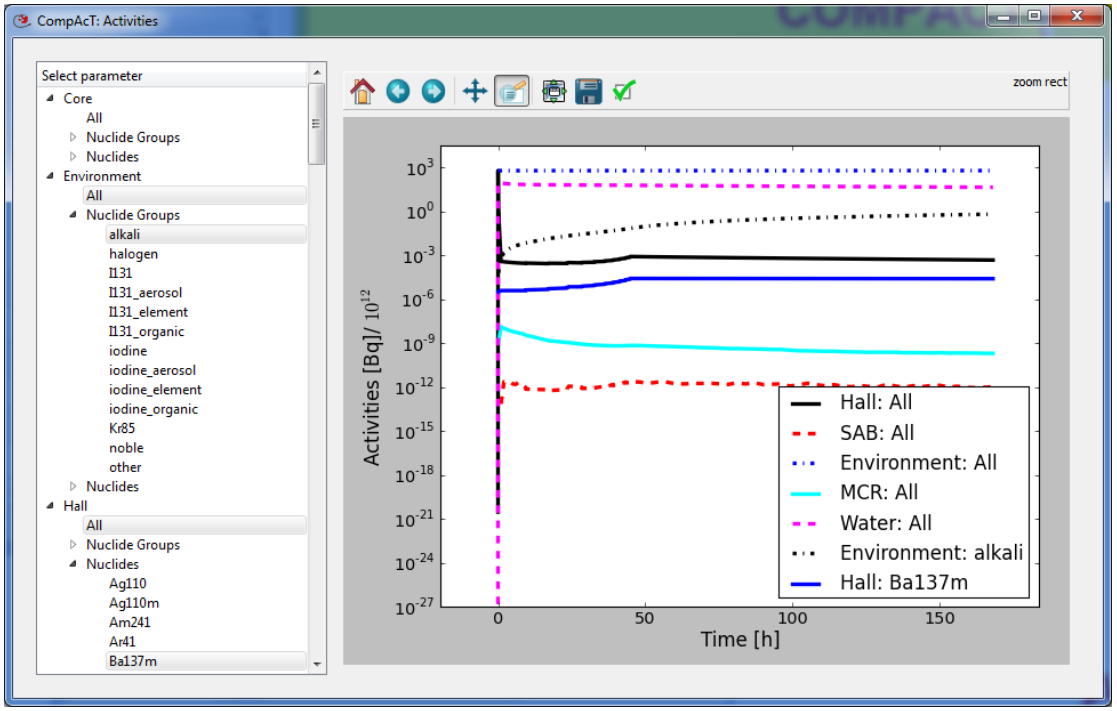


	time	Br84	Kr85	Kr85m	Kr87	Kr88	Rb86	Rb88	Sr89
1	-1.17800000E+02	9.65550000E+17	3.61100000E+16	1.10999000E+18	2.27650000E+18	3.20280000E+18	6.18580000E+15	3.26560000E+18	4.14480000
2	-1.00000000E-02	0.00000000E+00	3.60898092E+16	1.35056280E+10	2.98298674E-10	1.04762235E+06	5.15489180E+15	1.16982207E+06	3.87478435
3	0.00000000E+00	0.00000000E+00	3.60846461E+16	1.34828200E+10	2.96634782E-10	1.04491914E+06	5.15473830E+15	1.16695217E+06	3.87476164
4	1.00000000E-01	0.00000000E+00	3.60846195E+16	1.32758188E+10	2.80899269E-10	1.01972493E+06	5.15394054E+15	1.13878821E+06	3.87454004
5	1.00000000E+00	0.00000000E+00	3.60843801E+16	1.15501212E+10	1.71991681E-10	8.18627269E+05	5.14676620E+15	9.14130268E+05	3.87254628
6	2.00000000E+00	0.00000000E+00	3.60841141E+16	9.89446567E+09	9.97224205E-11	6.41342071E+05	5.13880642E+15	7.16152692E+05	3.87033219
7	3.00000000E+00	0.00000000E+00	3.60838481E+16	8.47614057E+09	5.78200124E-11	5.02450465E+05	5.13085895E+15	5.61058845E+05	3.86811937
8	4.00000000E+00	0.00000000E+00	3.60835821E+16	7.26112570E+09	3.35245958E-11	3.93637781E+05	5.12292377E+15	4.39553603E+05	3.86590781
9	5.00000000E+00	0.00000000E+00	3.60833161E+16	6.22027749E+09	1.94378810E-11	3.08390008E+05	5.11500087E+15	3.44362107E+05	3.86369751
10	6.00000000E+00	0.00000000E+00	3.60830501E+16	5.32862998E+09	1.12702692E-11	2.41603833E+05	5.10709022E+15	2.69785670E+05	3.86148484
11	7.00000000E+00	0.00000000E+00	3.60827841E+16	4.56479595E+09	6.53460978E-12	1.89281140E+05	5.09919180E+15	2.11359805E+05	3.85928071
12	8.00000000E+00	0.00000000E+00	3.60825182E+16	3.91045392E+09	3.78882920E-12	1.48289659E+05	5.09130560E+15	1.65586880E+05	3.85707421
13	9.40000000E+00	0.00000000E+00	3.60821458E+16	3.14887412E+09	1.76646300E-12	1.05369713E+05	5.08028540E+15	1.17660545E+05	3.85398722
14	9.41000000E+00	0.00000000E+00	3.60821431E+16	3.14400594E+09	1.75686099E-12	1.05112855E+05	5.08020677E+15	1.17373725E+05	3.85396518
15	1.71000000E+01	0.00000000E+00	3.60800978E+16	9.56665240E+08	2.65706323E-14	1.60895138E+04	5.02009932E+15	1.79662723E+04	3.83705289

CompAcT

A few selected features

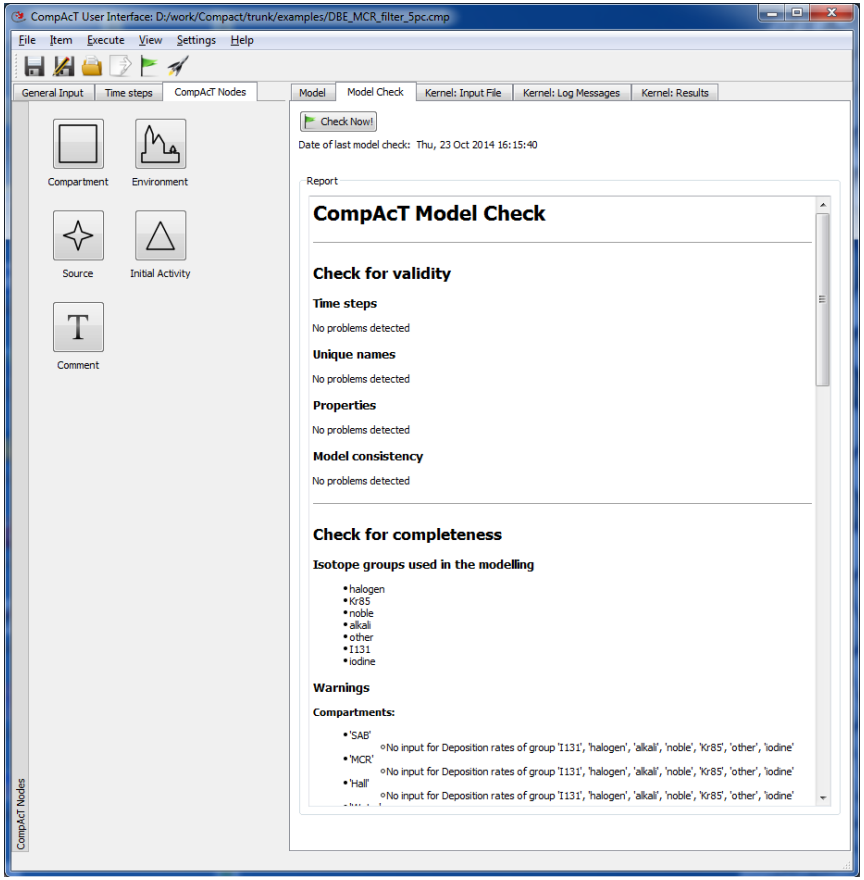
- State-of-the art solver for large, stiff ODE systems
- Internal verification of numerical precision
- Intuitive graphical user interface
- Easy adaptation to various requirements
- Arbitrarily complex models
- **Convenient output**
- Model checks itself for validity and completeness



CompAcT

A few selected features

- State-of-the art solver for large, stiff ODE systems
- Internal verification of numerical precision
- Intuitive graphical user interface
- Easy adaptation to various requirements
- Arbitrarily complex models
- Convenient output
- **Model checks itself for validity and completeness**



Agenda

1 Our Involvement

2 CompAct – Compartment Code for Source Term Evaluation

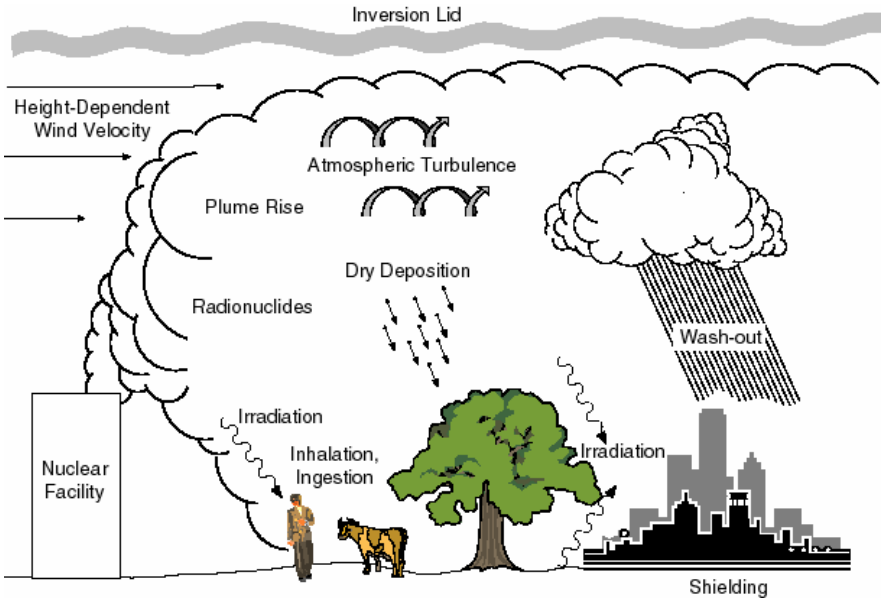
3 **DOT – Dose Evaluation Tool**

4 CRCS – Central Radiological Computer System

DOT
Dose Evaluation Tool

Radiological consequences assessments for design & licensing

- Gaussian atmospheric dispersion
- Dose calculations
  - Cloud-shine
  - Inhalation
  - Beta submersion
  - Ground-shine
  - Ingestion
- Contamination of foodstuff

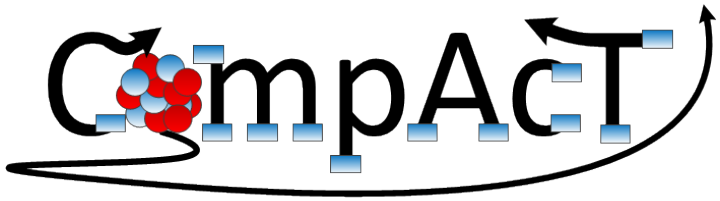


Source: MACCS2 Computer Code Application Guidance for Documented Safety Analysis, 2004

AREVA
forward-looking energy

A few selected features

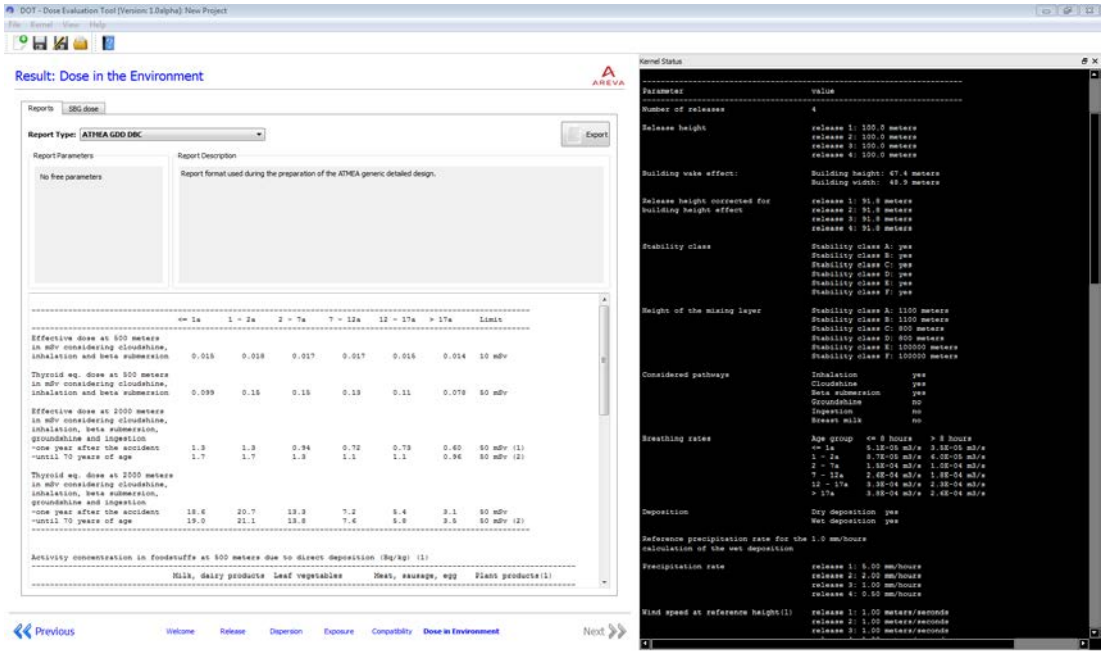
- **Independent kernel and graphical user interface (GUI)**
  - **DOT kernel is a library (.dll)**
  - **The kernel can be re-used**
- **Interface with CompAcT**
- Simplify
  - Calculations
  - Documentation
- User-friendly GUI



DOT
Dose Evaluation Tool

A few selected features

- Independent kernel and graphical user interface (GUI)
  - DOT kernel is a library (.dll)
  - The kernel can be re-used
- Interface with CompAcT
- **Simplify**
  - **Calculations**
  - **Documentation**
- **User-friendly GUI**



AREVA
forward-looking energy

Agenda

1 Our Involvement

2 CompAct – Compartment Code for Source Term Evaluation

3 DOT – Dose Evaluation Tool

4 **CRCS – Central Radiological Computer System**

Motivations

A real life accident will not follow a fixed scenario and will deviate from the assumptions of the safety analysis report

- What is the radioactive source term of a design-exceeding event?
- What is the impact of such an event on the surrounding areas?
- How can the impact on the population be assessed and minimized?

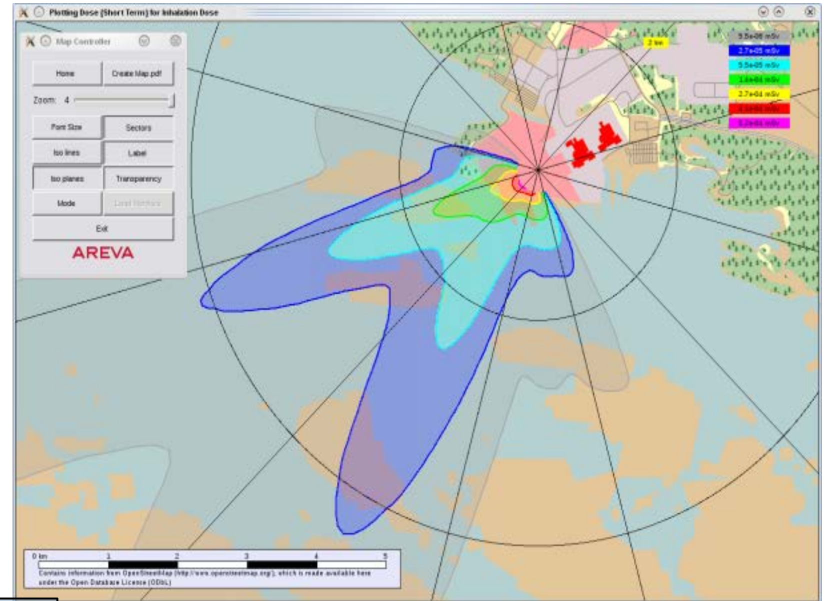
Objective, Benefits, and Application of CRCS

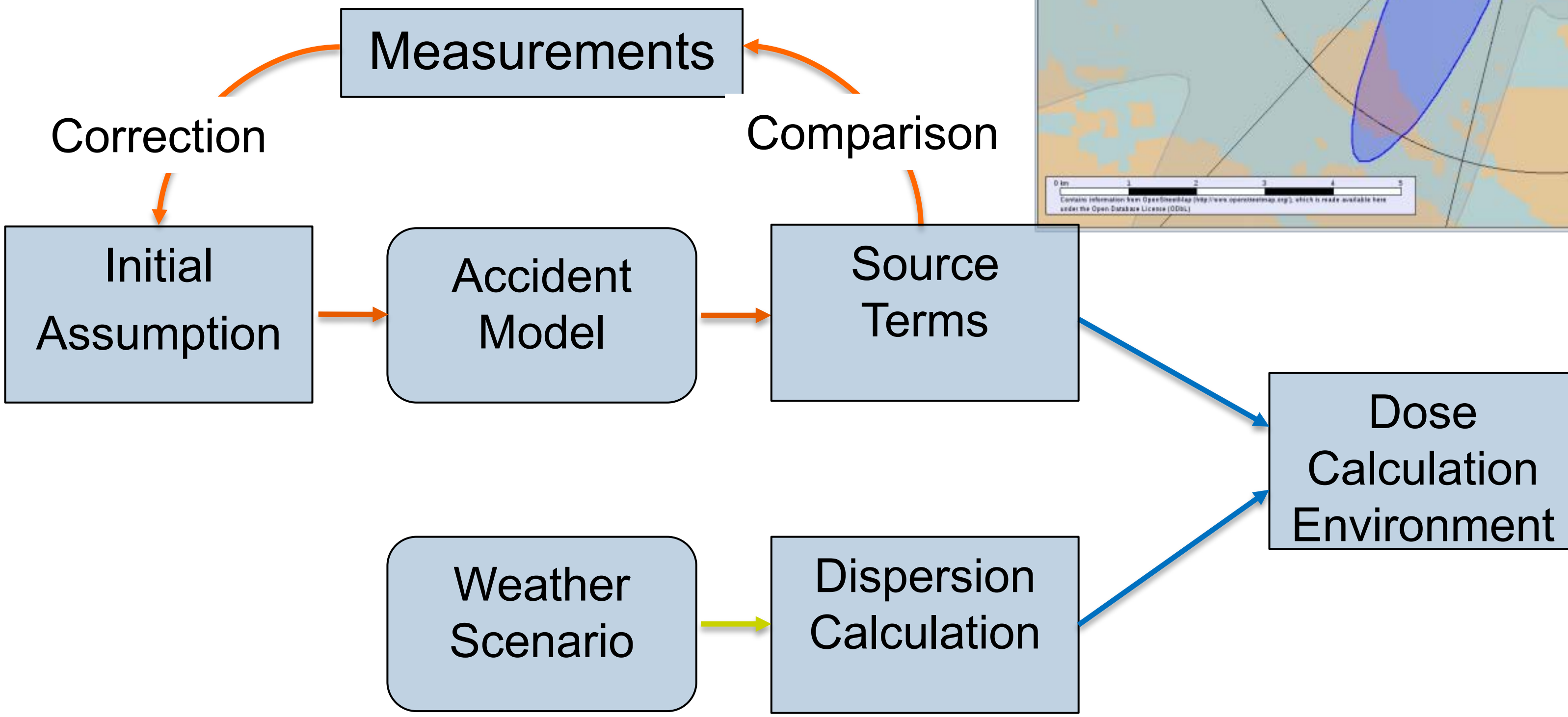
- **CRCS** is a modular tool for supporting the radiological staff of a Nuclear Power Plant with Radiological Surveillance and Emergency Preparedness (Crisis Center)
- **CRCS** is part of the EPR™ Design for Taishan 1+2 and Olkiluoto 3
- **CRCS** is easily adaptable to site-specific needs

Approach

- Starting Point
  - Power-plant-specific **activity source term** (PC, core, etc.), **system parameters** (ventilation rates, leakage rates, etc.) and thermo-hydraulic data (core release fractions, deposition fractions, etc.)
  - Modelling the **accident sequence** in terms of a system of differential equations
  - Definition of modifiable key parameters for adaptation of the release calculation to real case

- **Adaptation** of model parameters to reproduce **measurements**
  - Real sequence is reflected by the model
  - Activity measurements and system parameters within the plant
  - Meteorological and dose rate measurements (environment)





Accident selection among pre-defined scenarios

Activity releases into the environment

Meteorological conditions

Radiological consequences assessment

– Large Break Loss of Coolant Accident

– Small Break Loss of Coolant Accident

– Rod Ejection Accident

– Steam Generator Tube Rupture

– Loss of Condenser Vacuum

– Long Term Loss of Offsite Power

– Locked Rotor Accident

– Loss of Coolant outside Containment

– Leakage in the Gaseous Waste Processing System

– Fuel Handling Accident

– Effect of Earthquake on Nuclear Auxiliary Building / Waste Building

– Core Melt Sequence: initiated by a Large-Break Loss of Coolant Accident

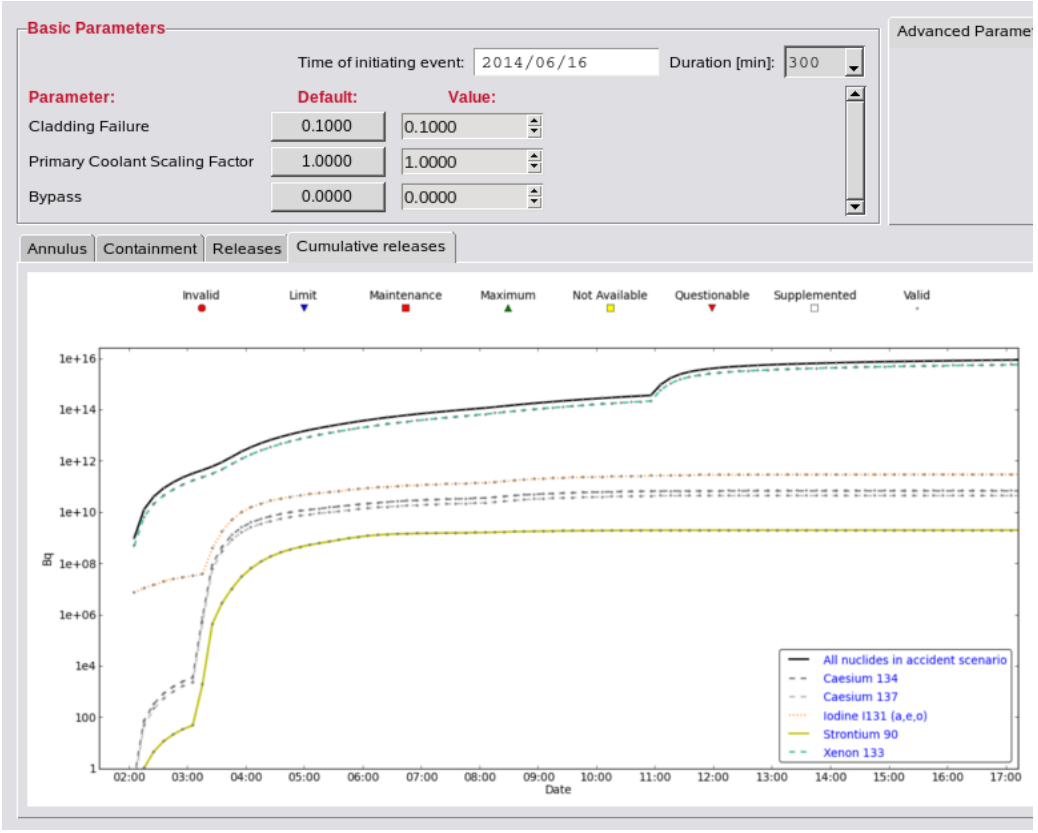
– Core Melt Sequence: initiated by a Loss of Offsite Power

Accident selection among pre-defined scenarios

Activity releases into the environment

Meteorological conditions

Radiological consequences assessment



Accident selection among pre-defined scenarios

Activity releases into the environment

Meteorological conditions

Radiological consequences assessment

Distribution of wind directions and speeds

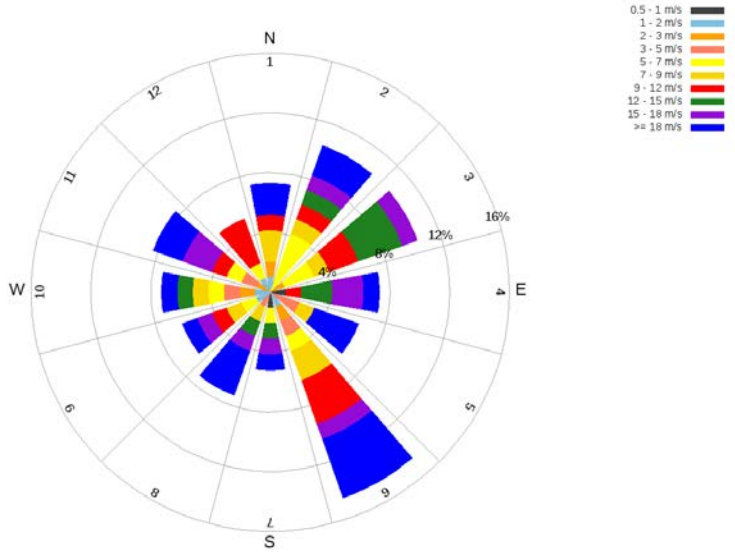
WindRose
relative frequency of wind directions per sector

2011.01.01 00:00 - 2011.01.05 00:00
60-minutes average values

Wind measurement height: reasonable -> 100m

Availability:		
Dates:	96	
Available:	96	(100.0%)
Substitution values:	0	(0.0%)
Not available:	0	(0.0%)
Wind calm:	4	(4.2%)

CRCS Rev: 7481 on Devel0L3. Created: 2014/07/14/15/29

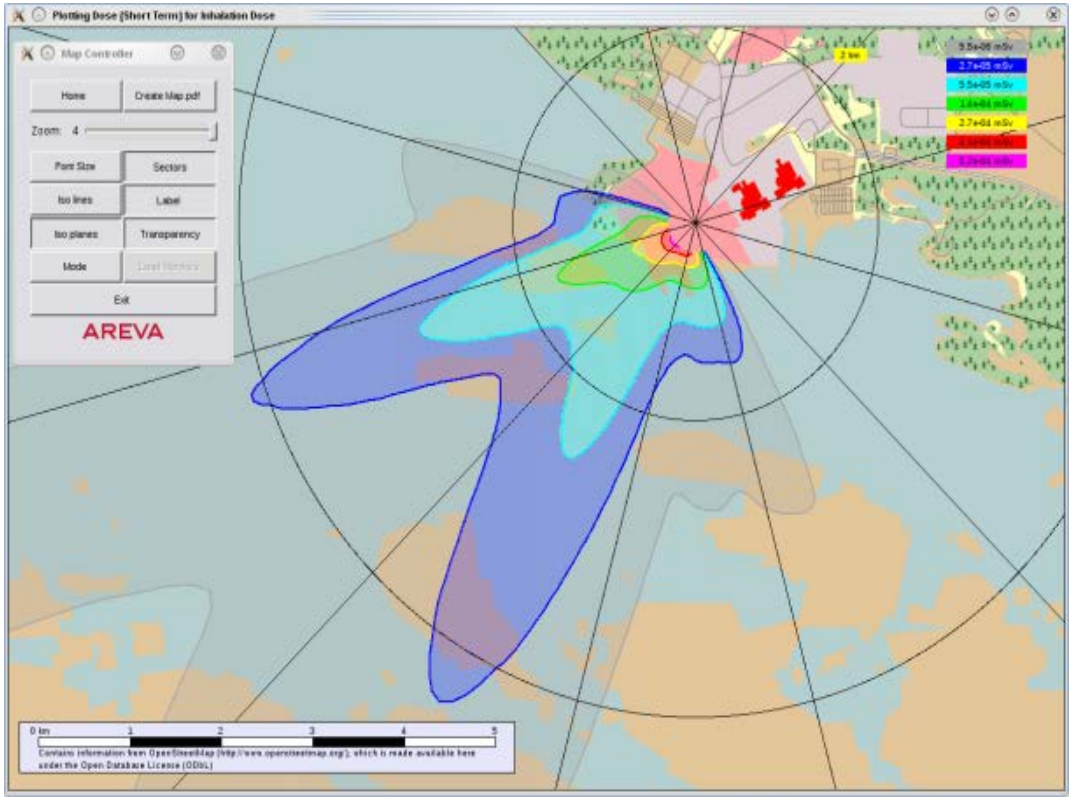


Accident selection among pre-defined scenarios

Activity releases into the environment

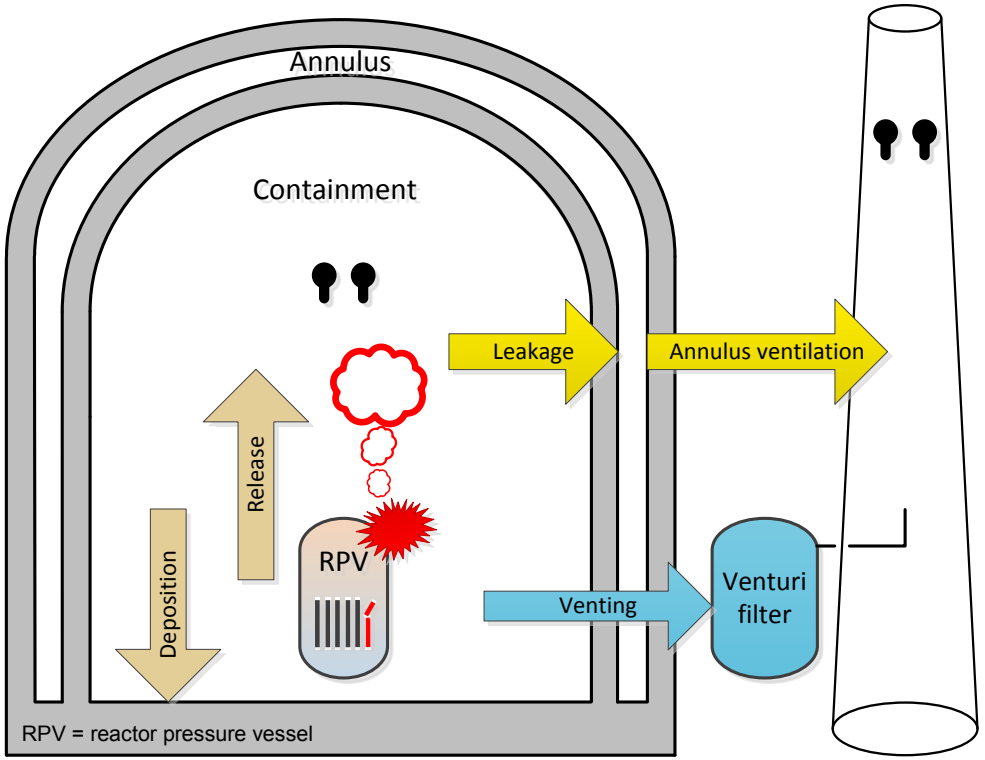
Meteorological conditions

Radiological consequences assessment



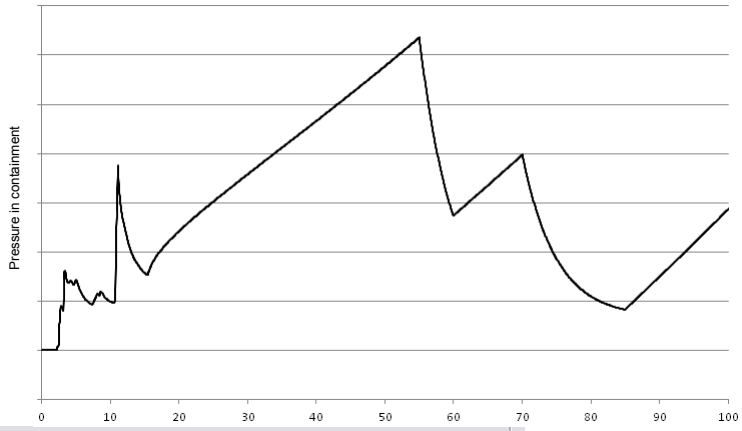
Special Tool: e.g. for Venting

- Pre-calculated accident sequence and correction due to venting process and real conditions (measurements: pressure, dose rate)
- Release fractions and depositions taken from thermo-hydraulic calculations
- Transport calculation of venting and leakage into the annulus



Special Tool: e.g. for Venting

- Display of pressure and dose including measurements in the containment
- Release rates and integral release



Scenario

Time of shut down: 2014/06/04/00/00
Time of initiating event: 2014/06/04/00/00
Accident scenario: Open RVP + LUHS

Venting

	Start	End	Enable
Venting phase 1:	2014/06/05/16/00	2014/06/05/21/00	☑
Venting phase 2:	2014/06/06/06/00	2014/06/06/21/00	☑
Venting phase 3:	----/--/--/--/--	----/--/--/--/--	☐

Filter factors for venting

	Default	
Aerosol (0.0-1.0)	0.99	0.99
Elemental iodine (0.0-1.0)	0.99	0.99
Organic iodine (0.0-1.0)	0.99	0.99

Leakage to Annulus

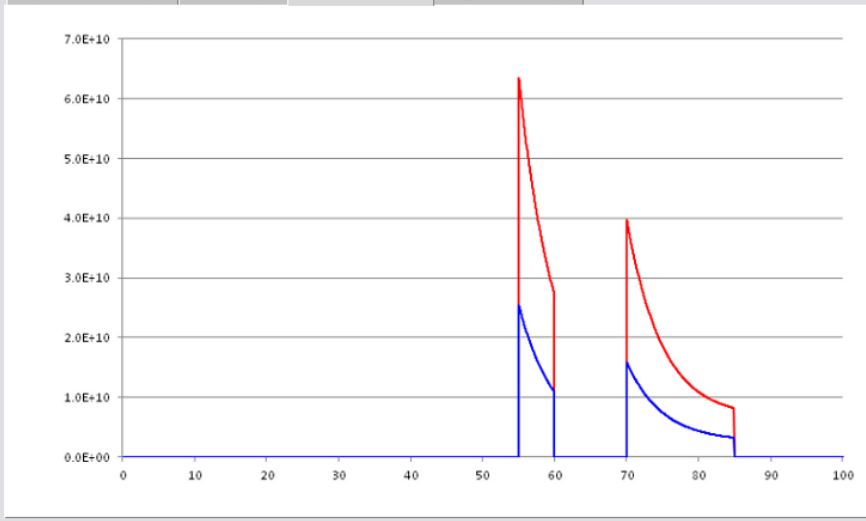
☑ Calculate leakage to annulus

	Default	
Leakage rate at design pressure (5.3 bar abs.) in 1/s	5.780e-08	5.780e-08
Annulus volume in m³	6000	6000
Annulus vent rate	Containm. leak rate	
Vent rate in m³/h (200-2000 m³/h)		

Filter factors for annulus ventilation system

	Default	
Aerosol (0.0-1.0)	0.99	0.99
Elemental iodine (0.0-1.0)	0.99	0.99
Organic iodine (0.0-1.0)	0.99	0.99

Physical Properties [bar] | Dose Rate [Sv] | Release Rate [Bq/s] | Integral Release [Bq]



Plot options:

☑ Aerosol
☑ Noble Gas

Time period: 1 h | DGL time step [minutes]: 1 | Replot

Summary
Codes and methods

Different purposes, different objectives, different analyses: customized tools

- Purpose
  - Design
  - Licensing
  - Emergency preparedness
  - Emergency response
- Scope
  - Activity releases into the environment
  - Activity in rooms and systems
  - Atmospheric dispersion and dose assessment

CompAcT

DOT Dose Evaluation Tool

AREVA

CRCS 6.0

Note

AREVA
forward-looking energy