

# Nuclear Physics

Expertise in nuclear calculations, safety, radiation protection,  
fluid and structural dynamics simulations



# Safety and innovation through computations

The Nuclear Physics department in the Nuclear Technologies business unit is the specialist department for engineering services in the fields of safety and radiation protection. This includes in particular nuclear calculations and the solving of problems in fluid dynamics and structural mechanics. To ensure the safety of nuclear facilities and in our work as specialists for complex computational analyses, we draw upon our expertise and the experience gained in decades of successful work in the industry.





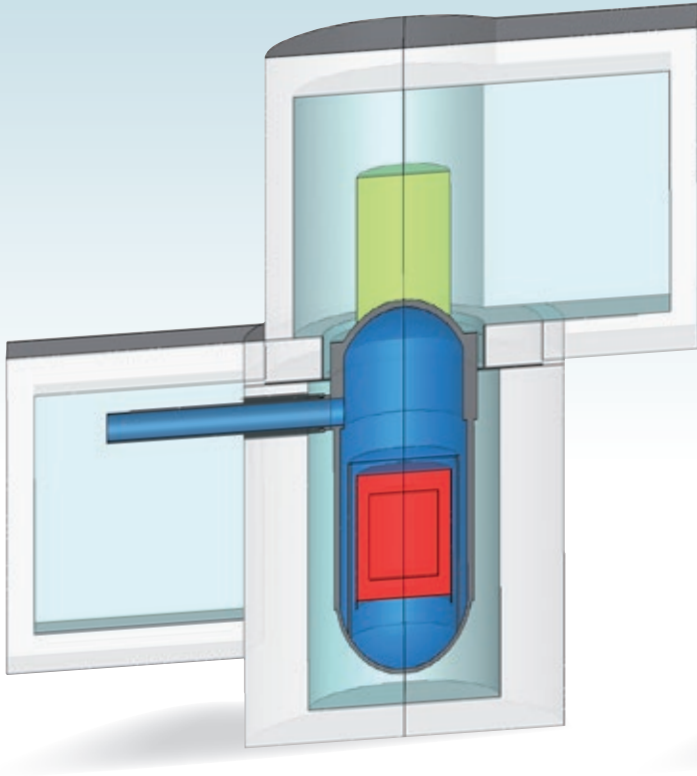
**On-site interim storage facility with spent fuel storage casks**

We apply our specialist know-how and modern computation tools not only to solve radiation protection and nuclear safety problems, but also to address issues of flow behavior, heat transport and mechanical impact on components and building structures.

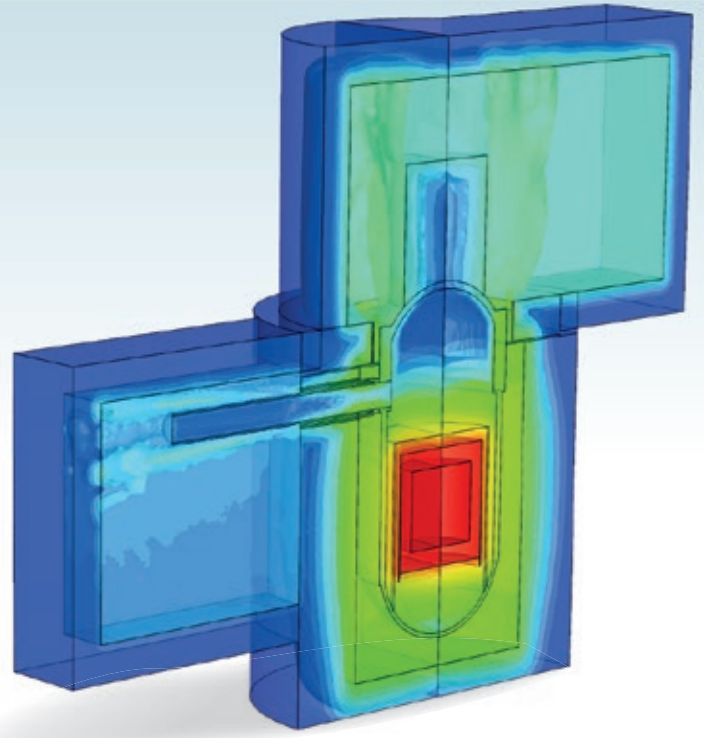
Nuclear safety and accident analyses require a multitude of scientific calculations on the dispersion of radiation and particles. For this purpose, our engineers in the Nuclear Physics department use modern, established software, and also proprietary calculation tools. As a center of expertise for physical calculations we also work for the chemical industry and conventional power plants.

Our range of services related to the safety of nuclear facilities comprises plant incident analyses, analyses of failures, and safety reviews of plants and systems. For environmentally sensitive projects we provide support during environmental impact assessment procedures and compile the required environmental impact studies.

We provide assistance for organizational and technical radiation protection during the operation of nuclear facilities or in retrofitting, decommissioning and dismantling projects. For licensing procedures we compile the necessary documentation and also support our clients by providing expertise and experts in public hearings.



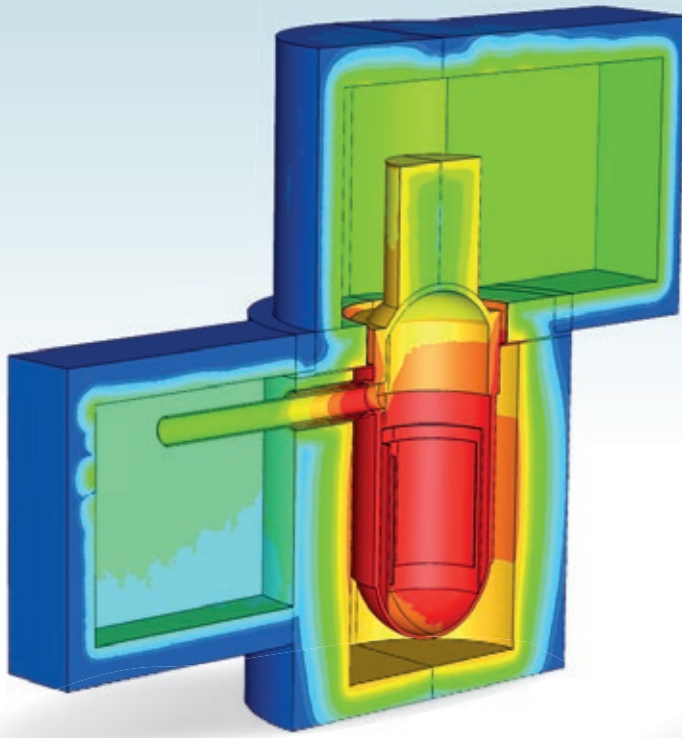
3D model of a pressurized water reactor



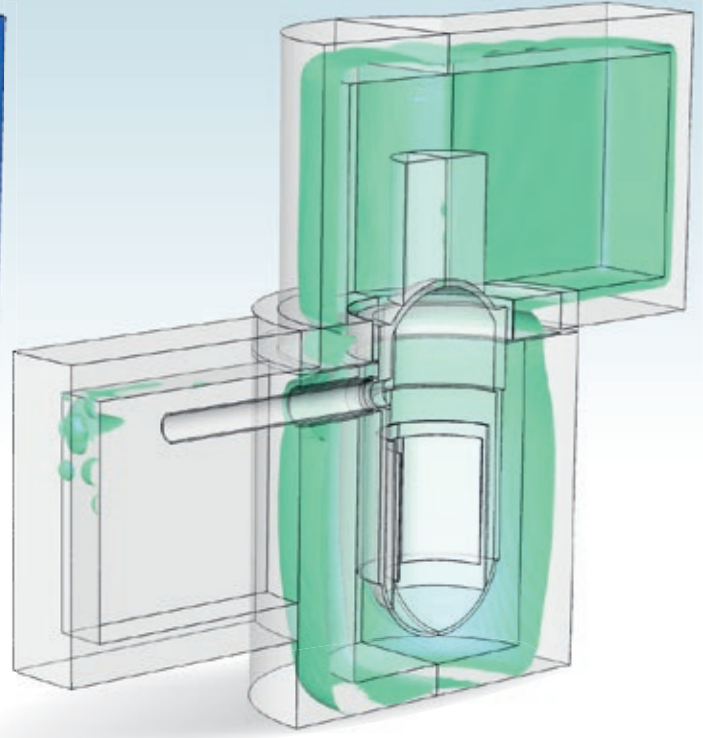
Neutron flux distribution in a pressurized water reactor

## Nuclear calculations

We use tested and proven software to perform complex scientific calculations for a diverse range of problems related to nuclear safety. These calculations form the basis of the proofs and verifications required in nuclear licensing procedures. A great many affirmative licensing notices and permits obtained testify to the high quality of the licensing application documentation provided by our specialists.



Co-60 isotope concentration after 40 years of reactor operation



Clearance measurement limit value for Co-60 (0.1 Bq/g) after 50 years, according to Appendix III of the German Radiation Protection Ordinance

### Shielding calculations

**Demonstration of compliance with permissible dose rates is an essential element of nuclear licensing procedures.**

#### Our services comprise:

- Creation of complex, three-dimensional model geometries for representation of source areas and shielding structures
- Optimization of shielding design and selection of materials for component design
- Calculation of direct and scattered radiation effects and skyshine effects
- Combined neutron and photon flux calculations
- Determination of three-dimensional dose rate distributions
- Use of internationally recognized radiation protection software, such as ATTILA®, SCALE and MCNP

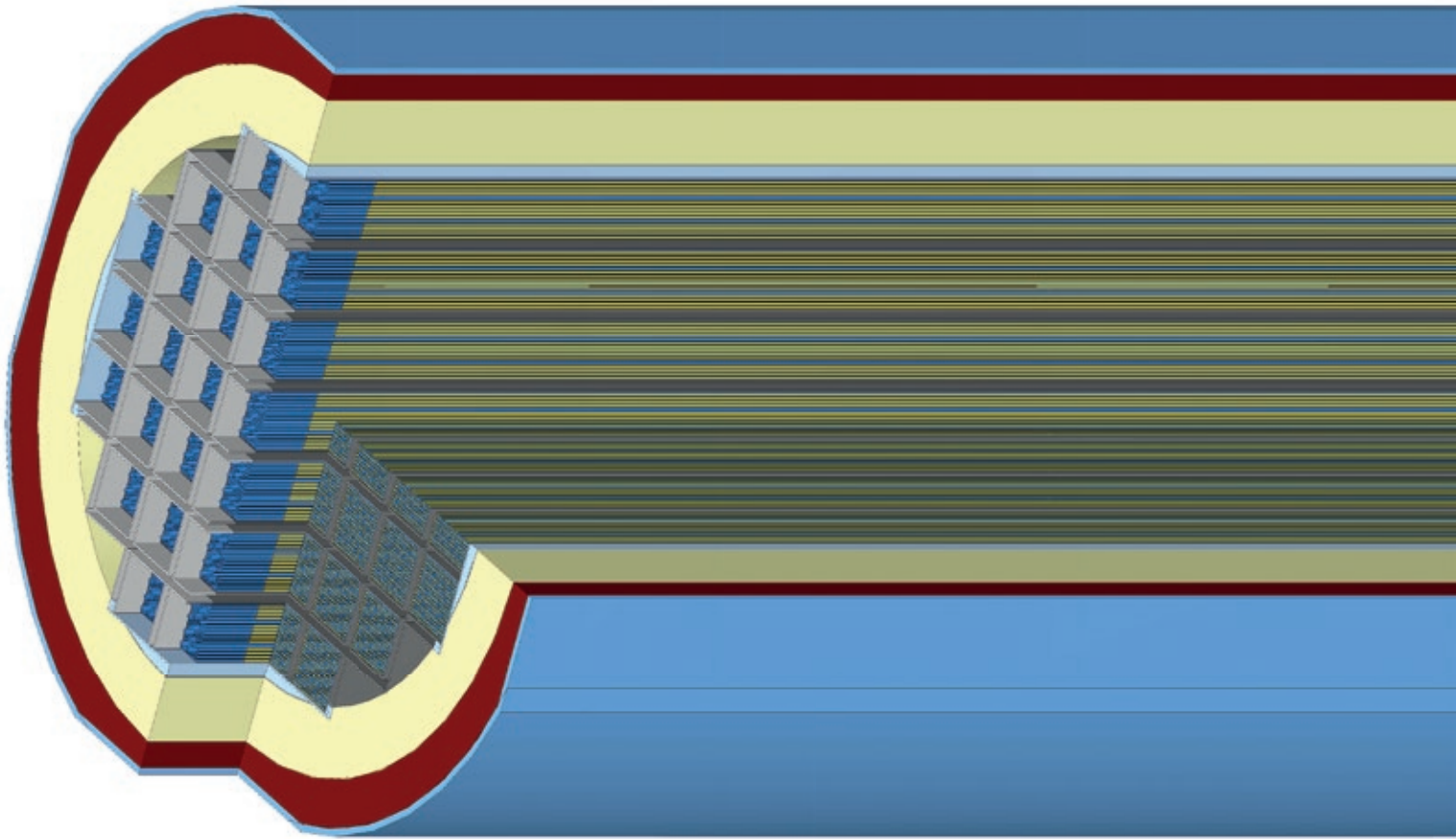
### Activation calculations

**Detailed knowledge of the radioactive inventory induced by neutron radiation is a fundamental prerequisite in devising an efficient handling of activated materials from belt-line areas of the reactor.**

#### Our services comprise:

- Simulation of the activation of the main structural materials over time
- Determination of activity source terms and inventories
- Consideration of radioactive decay of calculated nuclide inventories
- Showing of three-dimensional, nuclide-specific activity distributions (Bq/cm<sup>3</sup>, Bq/g and p/barn cm)
- Determination of the resulting three-dimensional, nuclide-specific neutron and gamma source terms
- Determination of low activity regions (eligibility for clearance measurements under paragraph 29 of the German Radiation Protection Ordinance (StrlSchV))





Model of the arrangement of fuel elements in a Type B(U) package, as used for criticality calculations

### Burn-up calculations

Calculation of burn-up is the basis for further determination of source terms.

#### Our services comprise:

- Calculation of the burn-up of fuel elements for pressurized water reactors, boiling water reactors and other reactor types
- Determination of the decay heat output of irradiated fuel elements
- Consideration of the radioactive decay for any kinds of material compositions
- Simulation of separation, feeding and mixing of radioactive mass flows
- Determination of neutron and gamma source terms

### Criticality calculations

Criticality calculations are necessary to ensure the criticality safety of arrangements of fissile materials, for instance in storage facilities.

#### Our services comprise:

- Creation of three-dimensional model geometries for representation of complex fuel arrangements
- Calculation of cell-weighted cross-sections
- Proof of subcriticality for fuel storage facilities and fuel element casks
- Proof of subcriticality for fuel production facilities

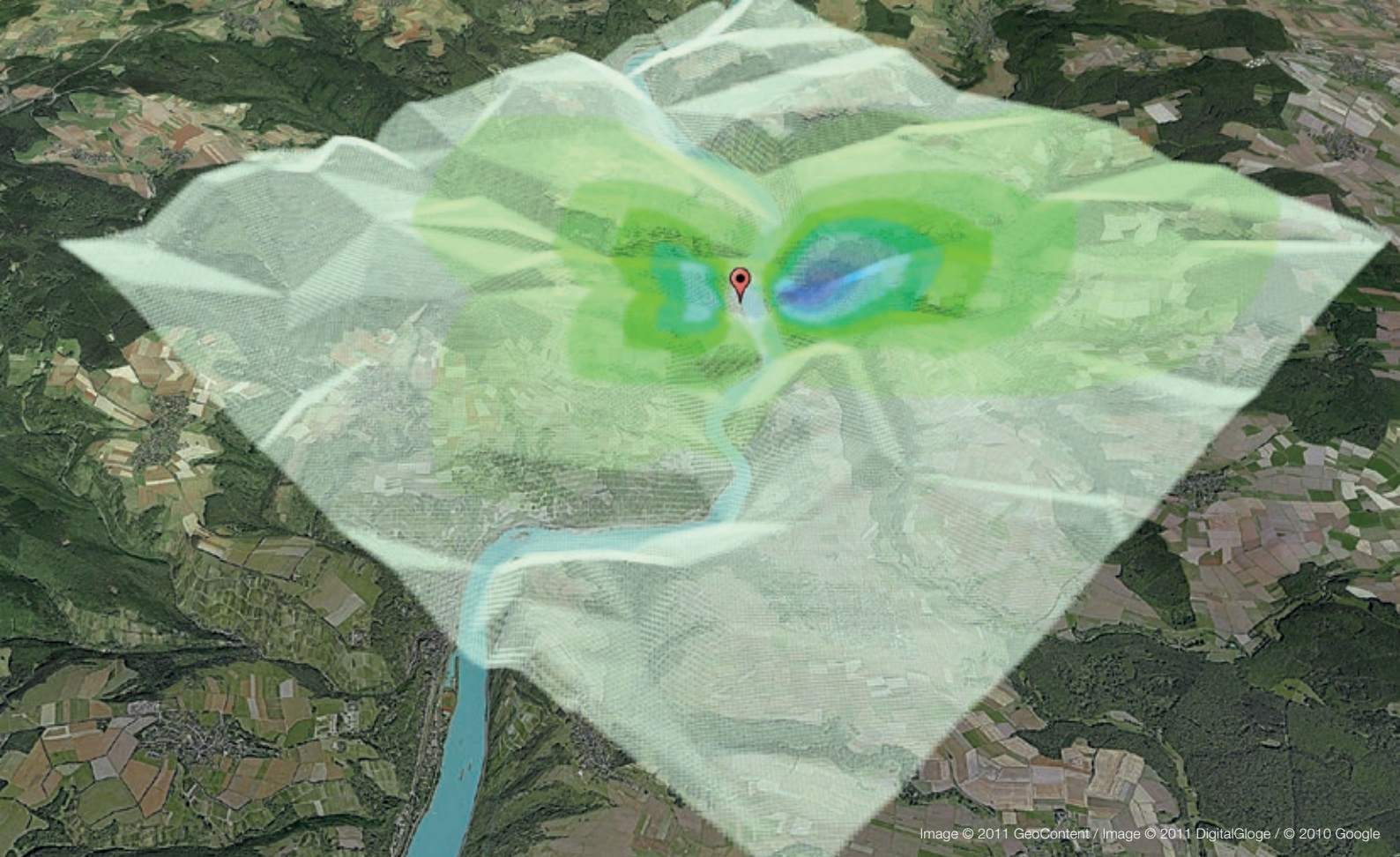


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**Modeling of local topography for consideration in radiation exposure calculations and in verification of compliance with statutory limits**

### Dispersion calculations

**In the field of dispersion calculations we perform sophisticated calculations on the dispersion of radioactive and chemical substances, for complex geometries and topographies. We apply certified software, that has been developed in house for some of these calculations.**

#### Our services comprise:

- Determination of source terms
- Demonstration of compliance with permissible radiation exposure in the environment as a result of emission or release of radioactive substances during normal operation and during accidents
- Calculation of dispersion factors for close-to-ground activity concentration and for gamma submersion and immersion
- Consideration of fallout factors and washout factors
- Determination of dose levels as function of exposure time, exposure path, nuclide, organ, age and particle size
- Consideration of lung absorption and ingestion classes
- Consideration of buildings and topography and of thermal uplift effects

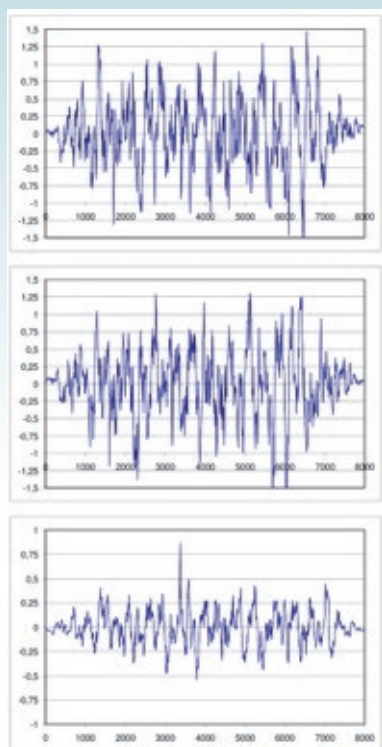
### Software products EXPO, STAR and ARTDOS

- Calculation of radiation exposure in the environment due to emissions or release from nuclear facilities
- Verification of precautions to be taken against damage caused by ionizing radiation
- Proof of compliance with statutory limits (paragraphs 47 and 49 of the German Radiation Protection Ordinance (StrlSchV))
- Consideration of the exposure paths exhaust air and waste water
- Dispersion calculations using the Gaussian plume model and the Lagrangian dispersion model
- Dose level calculations on the basis of the ARTM and LASAT dispersion modeling modules
- Software licenses in Germany, Switzerland and Spain

### Software product SAFEDIS

- Calculation of the concentration of harmful gases in the environment due to release from chemical plants





Spectrally matched time response used for dynamic calculation of earthquake impact



Geometry model of a container stack used for verification of stability in the event of the design basis earthquake



Example of storage of decommissioning waste in an interim storage facility



# Optimized packaging concepts for waste from decommissioning

Based on previous activation calculations we optimize strategies for the dismantling, packaging, transport and storage of activated materials, and generate the basis for efficient dismantling work.

## Our services comprise:

- Selection of suitable packaging in consideration of the specific transport and storage conditions
- Dismantling concept for activated components and structures
- Specifications for the composition of waste batches
- Optimization of container loading
- Checking of compliance with radiological storage and transport criteria

For optimized utilization of suitable packaging for final disposal, we use an optimization software tool which we developed ourselves:

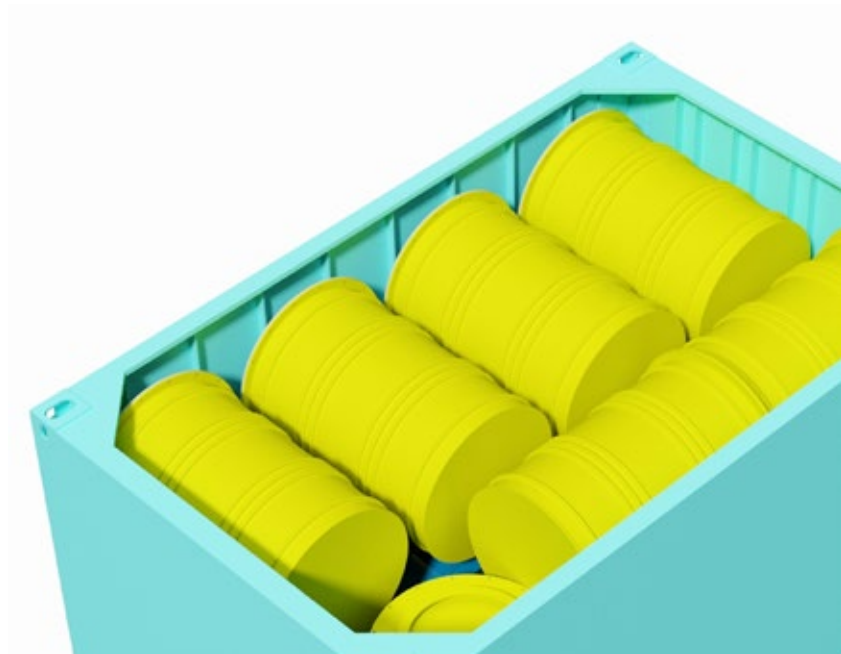
## Input parameters

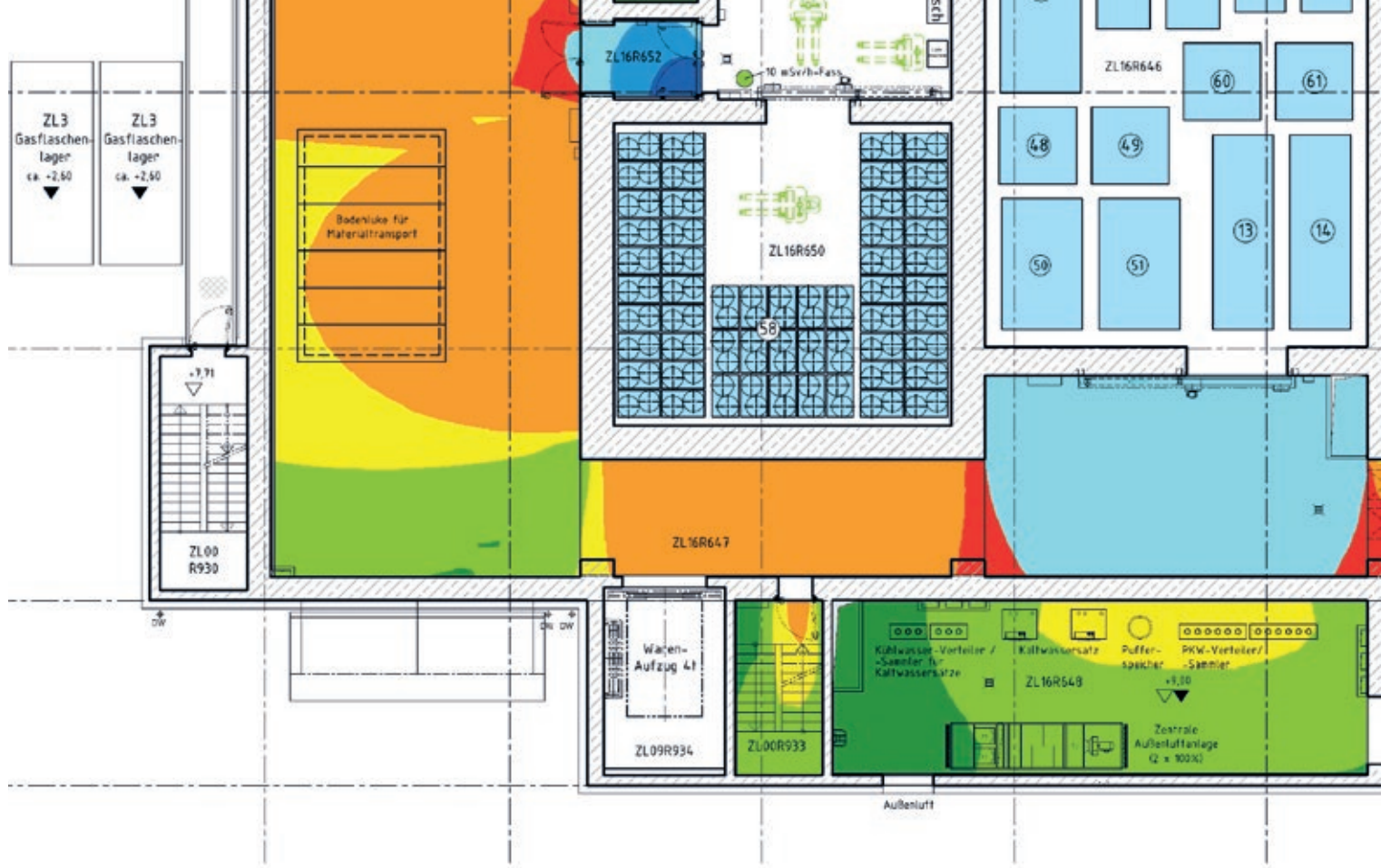
- Total mass of the waste batch
- Nuclide vector of the waste batch
- Total activity
- Waste density
- Container type
- Container cost

## Criteria considered for optimized use

- Limit values for the final repository, as defined in
  - safety analysis for normal operation
  - accident analysis
  - thermal analysis
- Dose limitation
- Criticality
- Activity limits from approval and transport
- Total mass

On the basis of a batch of radioactive waste with a given nuclide vector, we determine the respective minimum quantities for the containers available, taking account of the specific transport and storage conditions. Other results include the total container costs and the costs of transport and final disposal.





# Safety and radiation protection

We provide consulting services and support to our clients in nuclear and conventional licensing, permitting and approval procedures, and compile the required application documentation.

## Nuclear licensing procedures

- Safety and explanatory reports
- Radiation protection concepts
- Shielding reports
- Radiation exposure in the environment
- Accident analyses
- Collective dose and individual dose estimates

## Consulting and support

- Technical discussions with competent authorities and experts
- Technical support in public hearing procedures
- Technical advice on the implementation of permitting requirements
- Technical support in environmental impact assessment procedures, compiling of environment impact studies
- Technical support in amendment procedures

All engineering services associated with safety and permitting are an integral element of our range of services.

## Safety analyses

- Analyses regarding internal and external impacts
- Verifications regarding criticality safety, shielding, safe enclosure of the radioactive inventory
- Development of scenarios and determination of source terms for accident analyses
- Dispersion of harmful substances
- Analyses on dose minimization at plant perimeter and in the surroundings

## Safety reviews

- Safety reviews in nuclear fuel cycle facilities
- Contribution to periodic safety reviews

## Other studies and analyses

- Decommissioning studies
- Disposal studies
- Studies on the dispersion of radioactive substances in water bodies
- Optimization of handling processes for dose minimization





**In the field of radiation protection, we support our clients with a comprehensive range of services.**

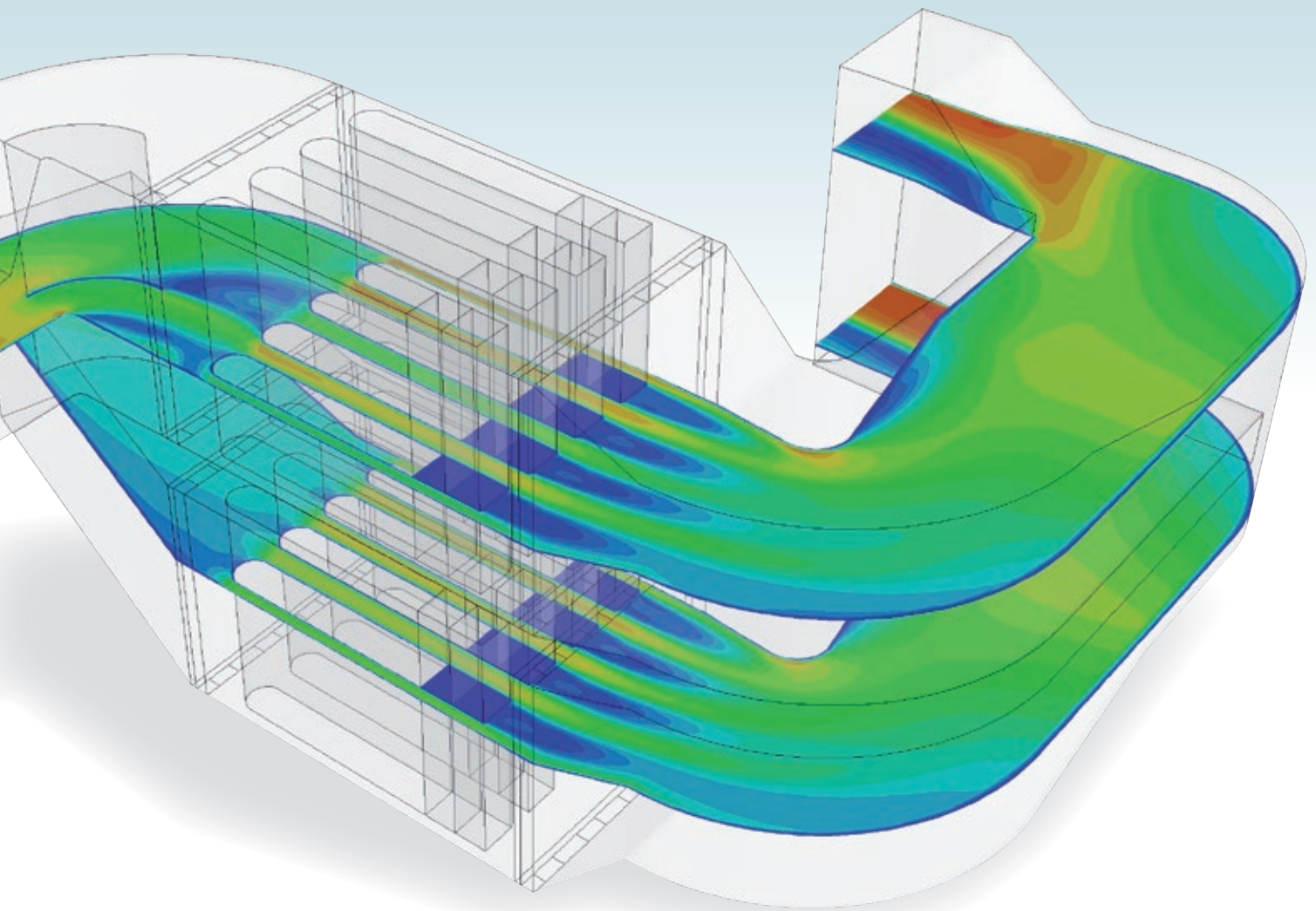
### Radiation protection engineering

- Radiation protection concepts
- Access control concepts for controlled areas
- Layout planning for radiation protection components
- Operating manual
- Radiation protection procedures
- Concepts for releases under paragraph 29 of the German Radiation Protection Ordinance (StrlSchV)
- Radiation protection software
- Radiation protection instrumentation
- Shielding design of components and building structures
- Support of plant radiation protection officer
- Radiographic testing

**Based on our experience with international projects we are familiar with the application of international standards and local laws, directives and standards.**

### International

- Planning and reviewing on the basis of national radiation protection legislation and the associated codes of practice (e.g. United Kingdom, Brazil, Switzerland)
- Using of internationally recognized codes and standards (e.g. KTA, EN, ISO, ENSI, ANSI, NUREG, CFR, IAEA, ICRP, WENRA, CNEN)

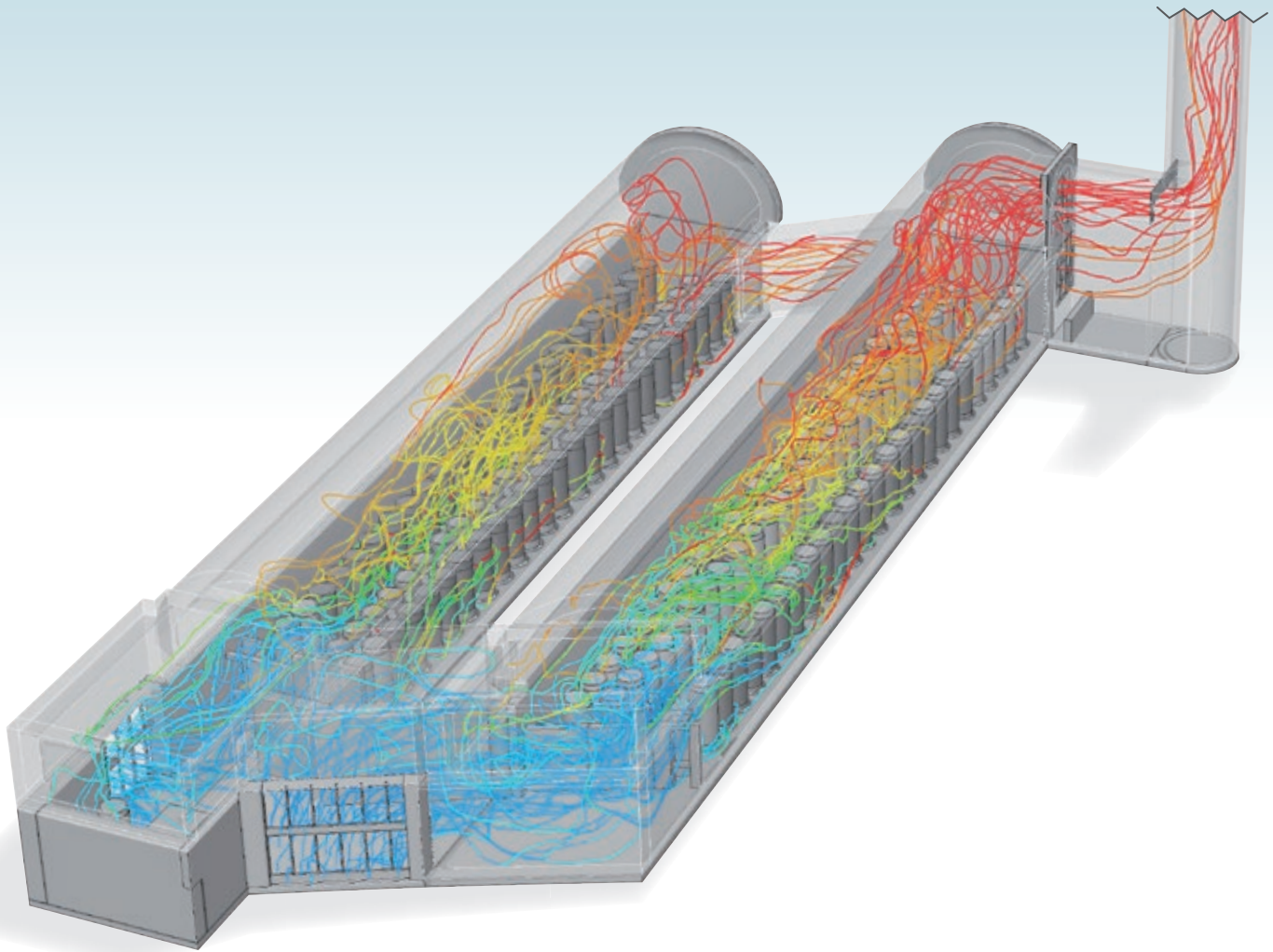


Isocontours of flow velocity in a flue gas treatment system

## Computational fluid dynamics (CFD)

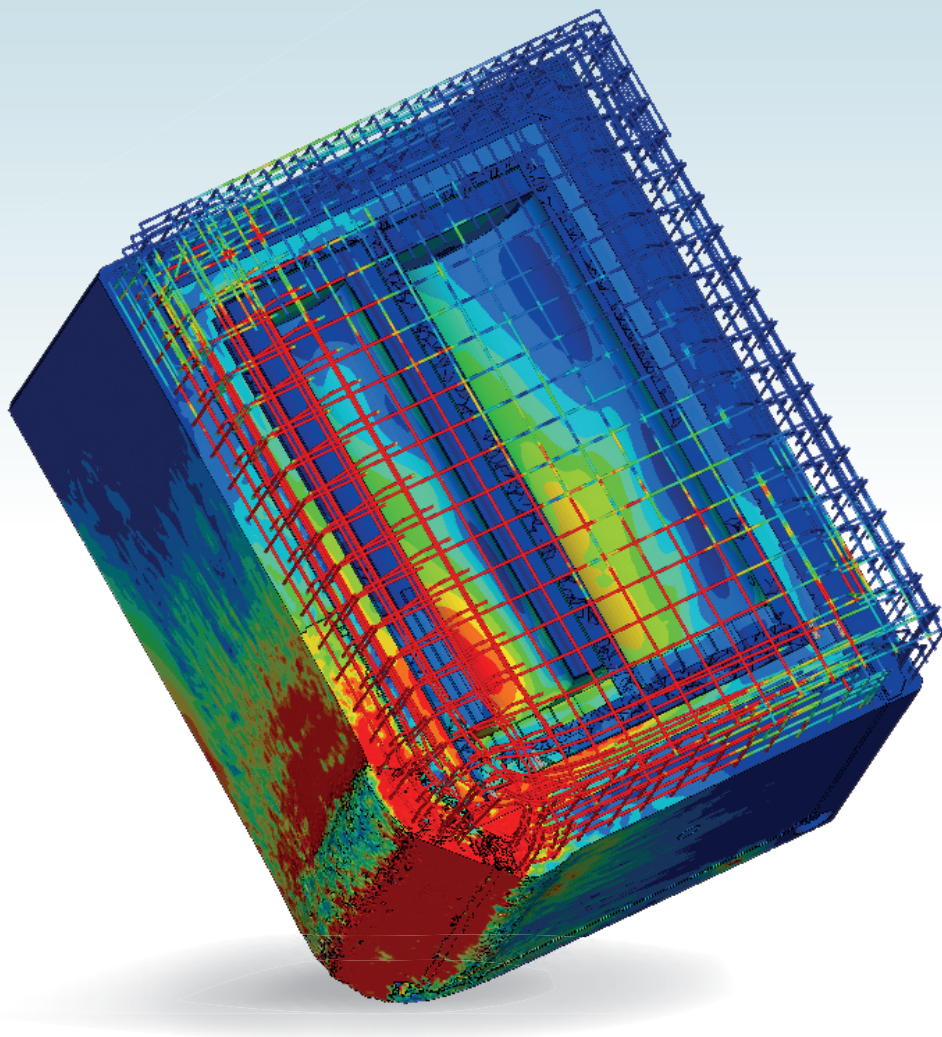
Using leading specialist software we offer a wide range of computational services in the various fields of fluid mechanics, both for nuclear facilities and for fossil-fueled power plants. We perform complex verifications, we design components and structural elements, and we optimize processes.





Heat removal from an interim storage facility filled with spent fuel storage casks

- Steady and non-steady flow field calculations
- Multi-phase flows with solid particles and droplets
- Flows with simultaneous heat transfer
- Calculation of combustion processes and chemical reactions
- Dispersion of contaminants and gases
- Proof of compliance with specified component temperatures and proof of safe heat removal
- Temperature rise in soil and groundwater
- Determination of friction coefficients of components
- Fluidic optimization of components
- Use of internationally recognized CFD software, e.g. ANSYS® FLUENT®

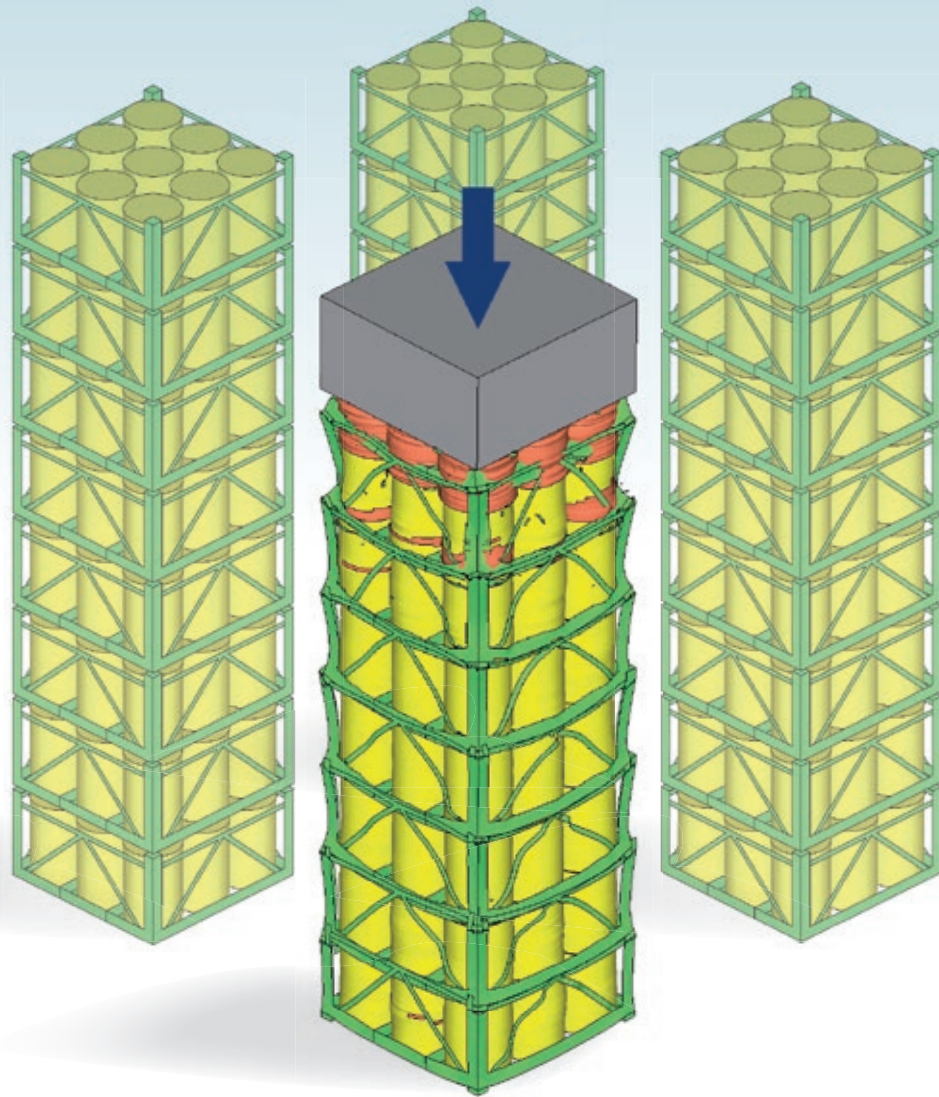


Simulation of the degree of damage to a concrete cask induced by a crash

## Finite element methods (FEM)

Our range of services in the field of structural mechanics calculations comprises crash simulations, such as analyses of airplane impact on buildings, drop analyses for drums or other packages containing radioactive residues, and earthquake analyses.





**Modelling of mechanical impact of falling debris on a stack of drums**

- Non-linear, non-steady-state calculations
- Dynamic earthquake simulation for structures, plants and components
- Calculation of damage to components and systems
- Load crash simulations
- Design of shock absorbing elements
- Strength and stress analyses
- Airplane crash calculations
- Use of internationally recognized FEM software, e.g. RADIOSS™ and HyperMesh® / HyperCrash™

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