# A novel comparison of RODOS and LASAIR for simulation of dispersion scenarios after severe accidents in TRIGA MARK II reactors

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ABSTRACT

The TRIGA reactor at the Atominstitut Vienna (ATI) operated until 2012 with three different types of fuel elements including HEU fuel. In 2008, the Austrian Regulatory Authority responsible to supervise the safety of nuclear facilities, requested to estimate the impact of a severe reactor accident using nuclear and meteorological parameters available at that time. These calculations were performed using the PC COSYMA code.
In 2012 the TRIGA core was converted to a uniform LEU core, a meteorological station was installed at the reactor site and the RODOS simulation tool was implemented. Using these new features realistic scenarios for four types of severe TRIGA accidents were calculated. A second step was to compare the above described data to a second simulation tool, LASAIR. The results of both simulations will be presented in this paper.
The outcome of these simulations can easily be adapted for other TRIGA reactors to document the safety of this type of research reactor.

## 1. Introduction

The TRIGA Mark-II reactor (Training, Research, Isotope Production, General Atomic) in Vienna was built by General Atomic [GA] and went critical for the first time on March 7th 1962. It is a swimming pool type research reactor that operates in average 220 days per year for training and research. The maximum power output under continuous conditions amounts to 250 $kW_{th}$. The power output is very low, thus the burn-up of the fuel is small.
The fuel consists of a uniform mixture of 8 wt% uranium, 1 wt% hydrogen and 91 wt% zirconium, whereas the zirconium-hydride acts as a main moderator. The special property of this moderator is a reduced moderation at high temperatures, which permits a pulsed operation up to 250 MW of the reactor.
The safety report [1] of the reactor includes four accident scenarios and their deterministic dose consequences to the environment. Those were calculated for the old core inventory including HEU fuel. Since 2012 the reactor operates with a uniform LEU core. Therefore it was now necessary to evaluate those accident scenarios again with the current core inventory. The simulations were carried out with RODOS (see previous works [6] and [7]) and LASAIR. These are both simulation tools for dispersion calculations. This paper will show a comparison for the simulation of the above mentioned accident scenarios.

## 2. The simulation tool RODOS

After the Chernobyl accident the emergency tools, regarding the calculation of accident scenarios and the risk for general public in Europe needed to be improved. Therefore the European Commission supported the development of RODOS (Real-time On-line DecisiOn Support) to increase the knowledge and risk perception after possible accidents, and to improve communication with the public.
RODOS is a strong tool to provide decision support on 4 levels [2]:

- **Level 0**: acquisition and checking of radiological data and their presentation, directly or with minimal analysis, to decision makers, along with geographical and demographic information.
- **Level 1**: analysis and prediction of the current and future radiological situation (i.e., the distribution over space and time in the absence of countermeasures) based upon information on the source term, monitoring data, meteorological data and models.
- **Level 2**: simulation of potential countermeasures (e.g., sheltering, evacuation, distribution of iodine tablets, relocation, decontamination and food-bans), in particular, determination of their feasibility and quantification of their benefits and disadvantages.
- **Level 3**: evaluation and ranking of alternative countermeasure strategies by balancing their respective benefits and disadvantages (e.g., costs, averted dose, stress reduction, social and political acceptability) taking account of societal preferences as perceived by decision makers.

For this paper the dispersion model DIPCOT (DIsPersion over COmplex Terrain) was used [3]. The model has the ability to simulate atmospheric dispersion in both homogeneous and inhomogeneous conditions based on a Lagrangian particle model scheme.

## 3. The simulation tool LASAIR [8]

LASAIR was developed by the German Federal Office for Radiation Protection as a graphical interface for the model LASAT. LASAIR is mainly used for the dispersion simulation of explosion scenarios and fires containing radioactivity. LASAT was developed for the simulation of the dispersion of conventional particles. It is based on a Lagrangian particle model for an instantaneous or short term release. It calculates for a group of representative particles their dispersion in the atmosphere. A random process initiates this simulation. The model was developed in the 1980s, since 1990 it's an open software tool. It can simulate the dispersion up to 2000 m into the atmosphere, in local and regional areas, up to 200 km. Depending on the time, it simulates the following procedures:

- transport through average wind
- dispersion in atmosphere
- sedimentation of heavy aerosols
- deposition on soil (dry deposition)
- washing out of particles through rain and wet deposition
- chemical change of first order

## 4. Simulation input

Previous works ([4], [6] and [7]) showed the simulation for four different accident scenarios: Exposure of one fuel element, whole core exposure, small airplane crash and large airplane crash. The outcome showed that the exposure of one fuel element, the whole core exposure and the small airplane crash had only very little impact on the environment, hence this work considered for the comparison with LASAIR only the scenario of the large airplane crash.

LASAIR offers a smaller variety of input parameters compared to RODOS: The user has only the possibility to include 5 nuclides at one release time, whereas RODOS offers flexibility with the number of nuclides and the release time of nuclides. The wind direction and wind speed are fixed parameters for LASAIR simulations, for RODOS weather data information are flexible input data, and can be inserted with any needed granularity. For the simulation in this work, the value is 1 h.

Precipitation is not included in the simulation, it is only added as a parameter after the simulation in LASAIR. In RODOS it is a simulation parameter with possible input data for each time step.

For the LASAIR simulation the input data from RODOS had to be altered. The source term for LASAIR was minimized to five nuclides. For the input data of wind speed, wind direction and rain rate an average data had to be calculated for the LASAIR input.

The average wind direction was calculated with equation 1:

$$\bar{\alpha} = atan\left(\frac{\sum sin\alpha}{\sum cos\,\alpha}\right) \qquad (1)$$

With $\alpha$ the wind direction in degree and $\bar{\alpha}$ the mean wind direction. LASAIR does not allow a scenario without wind, the minimum wind speed is 0.5 m/s. The foggy day scenario was altered from 0.22 m/s to 0.5 m/s. For the thunderstorm scenario the wind speed, wind direction and rain rate at the time of the thunderstorm were taken. The release time was 10 min for the LASAIR simulations (in order to achieve reasonable simulation times), and 1h for the RODOS simulations to stay consistent with previous works.

## 5. Calculated Scenarios

Seven different weather scenarios were taken into consideration since our previous works showed the strong influence of the weather scenario on the results (see [7]).The reactor has its own weather station, which continuously measured the wind speed, wind direction, the rain rate and the temperature over three years. Those measurements were taken to define the seven scenarios:

- spring day - this scenario describes an average spring day
- summer day - this scenario describes an average summer day
- autumn day - this scenario describes an average autumn day
- winter day - this scenario describes an average winter day
- thunderstorm day - this scenario describes a thunderstorm day
- foggy day - this scenario describes a foggy day
- hot day - this scenario describes a hot summer day

## 6. Results

Table 3 shows the dose results for the average weather scenarios of a spring day, a summer day, an autumn day and a winter day for the large airplane crash scenario. The results show the maximum dose received after 1 year of exposure, including all exposure paths (except ingestion) for RODOS and the calculated γ-ground dose after 1 year for LASAIR results. Precipitation is not included in the outcome results for LASAIR.

| Scenario | LASAIR | RODOS |
|---|---|---|
| | [mSv] | [mSv] |
| Spring | 0.61 | 2.70 |
| Summer | 0.64 | 3.18 |
| Autumn | 2.47 | 3.20 |
| Winter | 0.59 | 1.83 |

Table 1: Comparison of maximum dose after large airplane crash scenarios after 1 year for average weather scenarios

Table 4 shows the maximum dose received after 1 year of exposure, including all exposure paths (except ingestion) for specific weather scenarios (thunderstorm, foggy and hot day) for RODOS and the calculated γ-ground dose after 1 year for LASAIR results. Precipitation is not included in the outcome results for LASAIR.

| Scenario | LASAIR | RODOS |
|---|---|---|
| | [mSv] | [mSv] |
| Hot Day | 0.724 | 2.65 |
| Foggy Day | 0.521 | 12.5 |
| Thunderstorm Day | 0.161 | 11.5 |

Table 2: Comparison of maximum dose after large airplane crash scenarios after 1 year for specific weather scenarios

## 7. Discussion

LASAIR is optimized for quick calculations after explosion or fire scenarios. This is also represented with the low flexibility of its input data. It has no long term prognostic results. RODOS offers a wider variety of input parameters which can be altered for small time steps. A quantitative comparison of the above calculated results is not justifiable. The input data for the simulation had to be altered for make calculation with LASAIR possible. The lack of flexibility regarding LASAIRs' input data does not lead to reasonable comparable results. Especially for the specific scenarios the input data had to be adapted in such a way that a comparison of the results is not possible. For the average scenarios a comparison in a qualitative way is possible: Looking at the graphical results, both simulation tools show a release with the main wind direction.

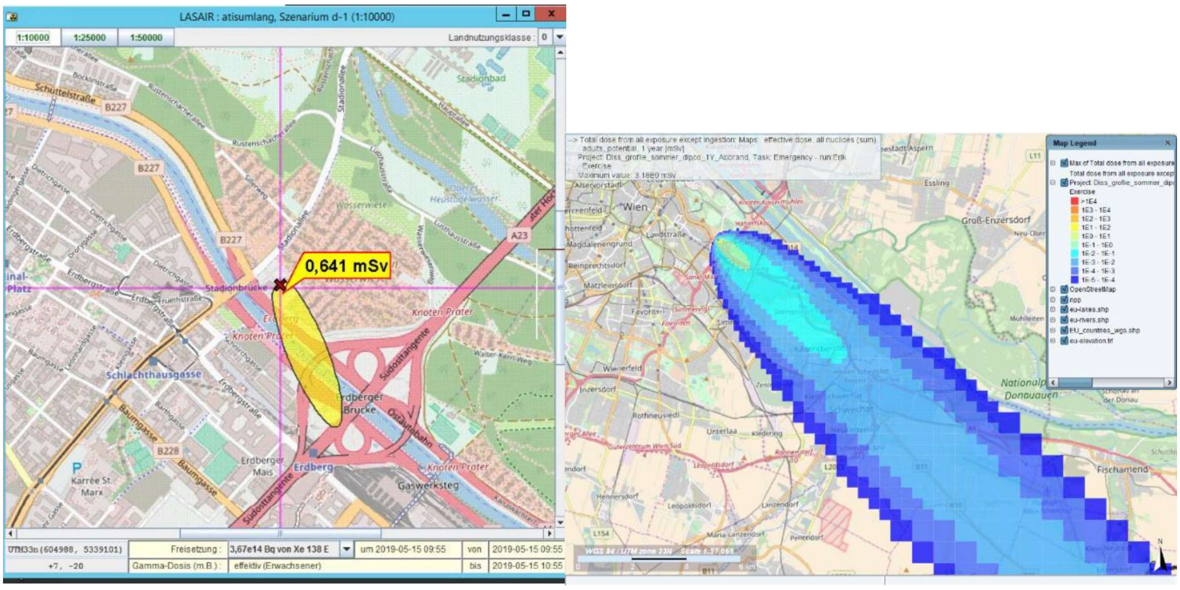


Figure 1. Comparison of Graphical results for LASAIR and RODOS simulations: Left side graphical outcome for summer day scenario simulated with LASAIR; right side graphical results for summer day scenario simulated with RODOS

RODOS was developed after the Chernobyl accident as a communication tool.
With its fast calculation times and its graphical output it is an ideal tool to simulate consequences after big NPP accidents.
LASAIR was developed as a tool for consequence simulation after nuclear explosions or fires. A research reactor poses a special case for simulation programs of radionuclide dispersion after accidents. LASAIR underestimates the release and possible consequences, as its input parameter are not suitable in flexibility and variety (weather data and nuclides) to represent a research reactor accident. RODOS results lie in accordance with previous works ([4]).

## 8. References


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