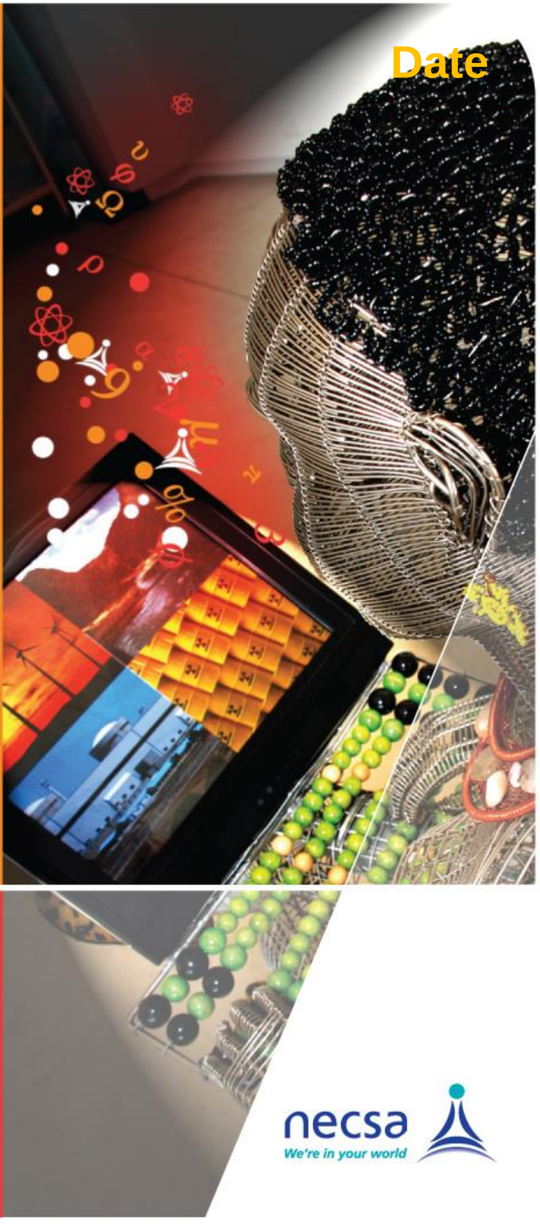
THE SAFETY CASE FOR TRANSPORTING SPENT NUCLEAR FUEL



By:

Charles Kros, Necsa

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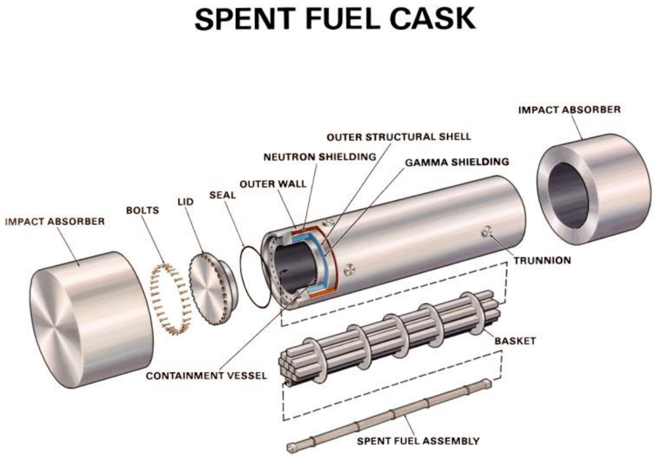
Introduction

- To discuss the experience gained in licensing the transporting of spent nuclear fuel through a spent nuclear fuel repatriation project in South Africa during 2011.

- Focus on:
  - The requirements of a transport safety case and
  - Demonstrate how this was applied in the case of this project.

- The National Nuclear Regulator (NNR) is the competent authority responsible for the regulation of transport of nuclear material in South Africa. As such, the safety case for the transporting of spent nuclear fuel needs to be submitted to and approved by the NNR prior to the transport action taking place.



Scope of the assessment

- The NNR requirements on operator to demonstrate compliance.
- The NNR requires complete safety cases for the transport of radioactive material to be prepared and submitted for approval
- A graded approach is applied where the transport of small quantities and ad-hoc transport actions can demonstrate compliance through simplified methods.
- The transport of spent nuclear fuel was regarded to be a large quantity of material for which the regulator had to ensure the safety of the public. A complete safety case was prepared.

Risk assessment tools

- Through a collaborative agreement between the South African and US governments, a capacity building programme was launched to equip South African analysts to perform the required assessment as part of the licensing requirements (safety case).
- The tool chosen for quantifying the risk was the Radtran 6.0 risk assessment software.
- Dr Ruth Weiner (Sandia National Laboratories) conducted a series of training session in South Africa in 2010 and 2011.

Radtran program training elevates Necsa's skills

Front from left to right: Louis Bleidt, Louis Laubsher, Willie Basson and Charles Kros. 2nd row: Fran Dos Santos and Chris Herselman (organisers) 3rd row: Abrie Visagie, Steven Dihomo, Naomi Mokolo, Dr Ruth Weiner, Samantha Nkomombini and Carla Terblanche. Back row: Ithumuleng Kungoane, Sello Mosoeyane, Chris Melane, Josephine Thauge, Lerato Kechane, Dipuo Mphahlele and Helen Seals

Necsa recently coordinated a skills transfer programme as part of the US spent fuel repatriation project. This involved a range of training courses, presented over the course of a few months and funded by the US Department of Energy.

The skills transfer programme was designed to assist Necsa to license and execute the fuel repatriation project and to build capacity for future projects, not only at Necsa but also for other government departments.

The courses, presented in October last year and January this year, involved training in the use of the Radtran program and code. Radtran is an internationally accepted program and validated code for calculating the risks associated with transporting radioactive material, both from a routine transport and a transportation accident perspective.

The resulting transport safety reports are submitted to the National Nuclear Regulator to demonstrate compliance with regulations in order to obtain authorisation to perform the transport actions.

The course was presented by Dr Ruth Weiner from Sandia National Laboratories in the USA. Dr Weiner is internationally recognised as an expert on radioactive transport safety assessment and developed the modern version of the code. She fills the role of Adjunct Professor in the Nuclear Engineering Department at the University of Michigan and is the author of a textbook series on environmental engineering.

Introductory training, delivered by Dr Weiner and her colleague, Matthew Dennis, from 18-22 October 2010, was attended by 28 participants from the Department of Energy, Necsa (SHEQD and Licensing), NNR and ESKOM.

Dr Weiner returned from 10-14 January 2011 to present advanced training to a select group of 17 participants (10 from Necsa, 4 from ESKOM and 3 from NNR). Delegates were then required to prepare detailed independent assessments which were presented and evaluated by Dr Weiner and the group. All candidates passed this assessment.

South Africa is indebted to Dr Weiner and the US National Nuclear Security Agency (NNSA) for making this training possible. The NNSA is a division of the US DOE and the chief sponsor of Sandia National Laboratories. Sandia Laboratories holds the copyright to Radtran.

Dr Weiner enjoyed her visits and the hospitality of South Africa and hopes to maintain contact with our nuclear scientists.

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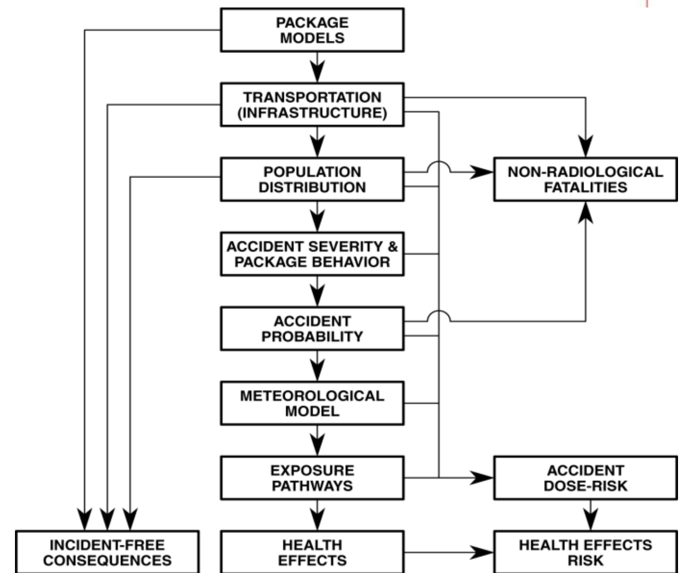
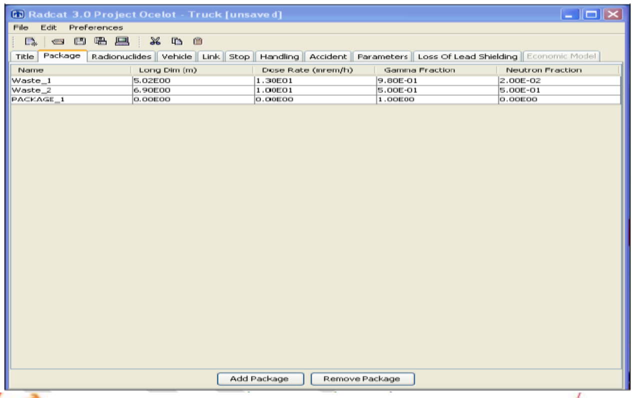
RADTRAN 6.0

- RADTRAN is an internationally accepted program and code for calculating the risks of transporting radioactive material both deterministically and probabilistically.
- Almost all input parameters are user-defined, therefore the user needs a certain familiarity with the appropriate values and the use of the programme.
- The output of the code is highly dependent on the selection of appropriate input parameters. Much reliance was placed on default parameters and internationally available studies.
- Notwithstanding, the challenge of any computer model is the balance between realism and conservatism.





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Qualitative Aspects

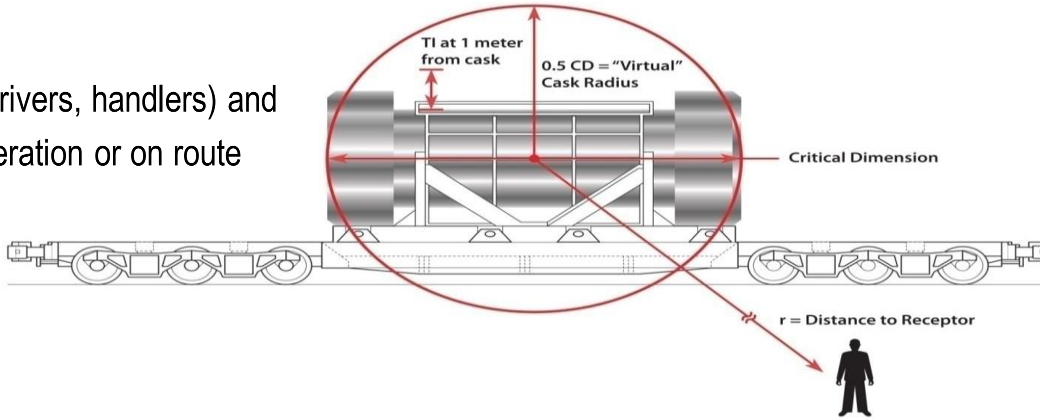
- The safety case contains aspects of a qualitative nature most of which is very prescriptive in its requirements. In South Africa requirements are a combination of local and international requirements:
  - Transportation regulations, for example content limits for packages, package design criteria
  - Radiation dose limits for exposure of members of the public
  - Role of the transportation package to ensure safety by means of the transportation package certification process which should adequately demonstrate compliance throughout design, manufacture and maintenance,
  - Procedural arrangements including those for training, emergency response, preparation, consigning, loading, carriage, in-transit storage, unloading and receipt of radioactive material and packages,
  - Security provisions as required by local and international authorities.

Quantitative Aspects

- The safety case contains quantitative aspects which supports the qualitative descriptions and facilitates the demonstration of conformance.
- The common denominator is the radiation doses accrued by members of the public and workers during the transport operation. The Transport Regulations defines three general severity levels:
  - Routine conditions of transport (incident free);
  - Normal conditions of transport (minor mishaps); and
  - Accident conditions of transport.
- The consequence of these severity levels (or conditions of transport) needs to be quantified for the transport operation.
- This was achieved by the use of RADTRAN.

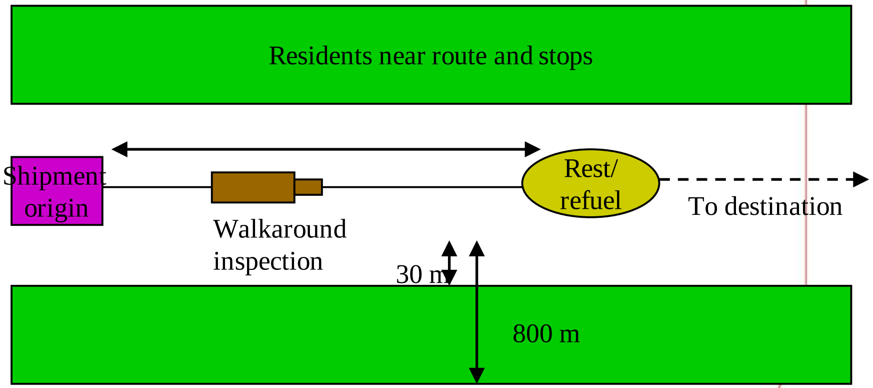
Routine Transport Doses (1)

- Risks associated with routine conditions (incident free) of transport are limited to external exposure scenarios
- Principally, since no accidents are anticipated, no loss of any radioactive material and therefore no contamination is anticipated
- The radiation dose rates for spent fuel shipments are measured before each shipment and kept within regulatory limits
- The radiation dose from this external radiation to any member of the public during routine transportation, including stops, is barely discernible compared to natural background radiation
- Exposure scenarios are limited to:
  - Workers involved in the transport operation (drivers, handlers) and
  - Members of the public in the vicinity of the operation or on route



Routine Transport Doses (2)

- Routes are divided into rural, suburban, and urban segments according to the population per square kilometre (population density).
- Given the complexity of calculating doses from for example moving vehicles, RADTRAN provided a suitable solution.



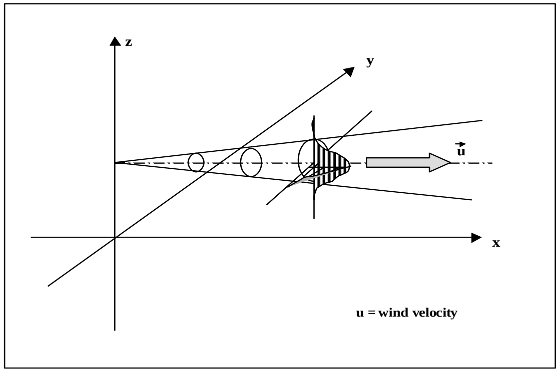
- Input parameters of transport in RADTRAN are:
  - Package external dose rate,
  - Crew details, ie number of crew, distance from package,
  - Vehicle and package dimensions,
  - Vehicle speeds to calculate exposure times;
  - Vehicle external dose rate for dose calculations;
  - Route characteristics, ie distances, population densities (RADTRAN assumes the exposed population is in a 800 meter wide band on either side of the route), vehicle densities, persons per vehicle;
  - Stop characteristics for exposure scenarios during stops at re-fuelling, compulsory stops, etc;
  - Handling characteristics for exposure scenario during handling.

Routine Transport Doses (3)

- RADTRAN calculates the doses assuming a probability of 100% and the results is normally a very small external radiation dose, presented as:
  - Collective external dose to residents along route;
  - Collective external dose to public at stops;
  - Collective external dose to urban non-residents;
  - Collective dose to occupants of vehicles sharing route;
  - Occupational external doses; and
  - Maximum individual in-transit dose.

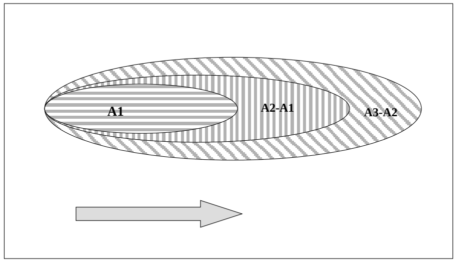
Transport Accident Doses(1)

- The calculation of risks associated with transport accident is more complex. Given that the deterministic doses might exceed the criteria due to over-conservatism in assumptions, RADTRAN provides for the probabilistic assessment of these doses.
- The different types of accidents that can interfere with routine transportation of spent nuclear fuel are:
  - Accidents in which the spent fuel cask is not damaged or affected
  - Accidents in which the spent fuel cask is affected
- If a spent fuel cask is in a severe enough accident, material can be released into the environment and dispersed. RADTRAN uses a Gaussian dispersion model.



Transport Accident Doses (2)

- Input parameters for accident conditions of transport are:
  - Radionuclide inventory which, for spent fuel, can be very elaborate thus requiring a screening analysis to determine most important radionuclides based on relative dose contribution to be included;
  - Accident rate (route characteristic) similar to routine conditions of transport but includes accident statistics and land farming fractions;
  - Accident specific parameters such as the conditional probability of accident (severity for Type B containers) obtained from available studies, particle settling velocities;
  - Meteorological parameters.
- Provided that the parameters were selected appropriately, the output of these calculations will yield results for the various kinds of accidents possible for example accidents involving a release and/or dispersion of material:
  - Number of expected accidents (per link);
  - Collective dose and/or population risk from inhalation, resuspension, groundshine and cloudshine;
  - Maximum dose and/or risk for individual;
  - Doses and dose risks per radionuclide and
  - Critical group doses and dose risks



Interpretation of Results

- The safety case presented to the competent authority needs to include the aspects addressed in this paper.
- The safety case for the repatriation of spent fuel from South Africa included all the required aspects including a cask validation report, procedures, detailed assessments of the actions in the work procedures and a complete transport safety assessment.
- The transport safety assessment was performed using RADTRAN computer code and the most important outcomes are summarised:
  - The radionuclide screening assessment confirmed the 10 most important nuclides would be representative of >99.9% of the radiological impact;
  - The spent fuel was 'old' (over 26 years since removal from core) and significantly less material (inventory) were loaded into the casks than it was designed for;
  - Doses from routine conditions of transport were extremely low (as a result of the low activity of the spent fuel) with the maximum individual in-transit dose calculated to be less than 5.5E-06 Sv;
  - Notwithstanding the availability of a probabilistic module in RADTRAN, it was possible to demonstrate deterministically (assuming a probability of 1 for the accident to occur) compliance to dose criteria for accident conditions; as a result of the low activity of the spent fuel as a result of its age.

Conclusions

- The safety case for the transport of spent fuel has several aspects for which compliance to regulatory requirements needs to be demonstrated.

- Through the use of the RADTRAN computer code it was possible to demonstrate that for normal and accident conditions of transport the doses and risks were extremely low and in compliance to regulatory requirements.

Acknowledgements

- Dr Ruth Weiner, Sandia National Laboratories, for training, guidance and support
  - US National Nuclear Security Agency for funding training and attendance .
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