Canadian Decision Support System for Managing a Nuclear Emergency

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For radiological and nuclear emergencies, the Federal Nuclear Emergency Plan (FNEP) supplements Canada's all-hazard Federal Emergency Response Plan (FERP) by providing extra governance and scientific/technical arrangements to address radiological public health consequences. The FNEP describes the framework used to coordinate the scientific aspects of the federal government response to a nuclear emergency affecting Canadians at home or abroad. It is a multi-departmental plan, bringing together the scientific and technical resources of 18 federal organizations into a single specialized emergency response team to support decision making at all levels of government.

Nuclear emergency response requires the integration and assessment of a large set of scientific data from distributed sources to inform actions to reduce the effects of ionizing radiation on people and the environment. To fulfill this mandate, a Decision Support System (DSS) has been developed to allow scientists analyze an incident and communicate recommendations to decision-makers. This DSS hinges on nuclear emergency functions assigned to federal departments and agencies. These functions can be grouped into the following five categories: (1) Source term characterisation: determines how much radioactive material could be/has been released and how might this change over time; (2) Hazard prediction through modelling: determines where a radioactive release might go and what the potential pathways and exposures would be; (3) Hazard assessment through measurements: determines where the radiation actually went and what the potential pathways and exposures are; (4) Hazard impact assessment: determines the impact on people and the environment and recommended protective actions; and (5) Information sharing to share data, situational awareness and recommendations with emergency management centres and decision-makers. These functions are fulfilled using various tools described below.

FNEP Emergency Response Process

Call received by the FNEP Duty Officer

Decision to respond within the FNEP scope

Emergency Operations Centre Set up

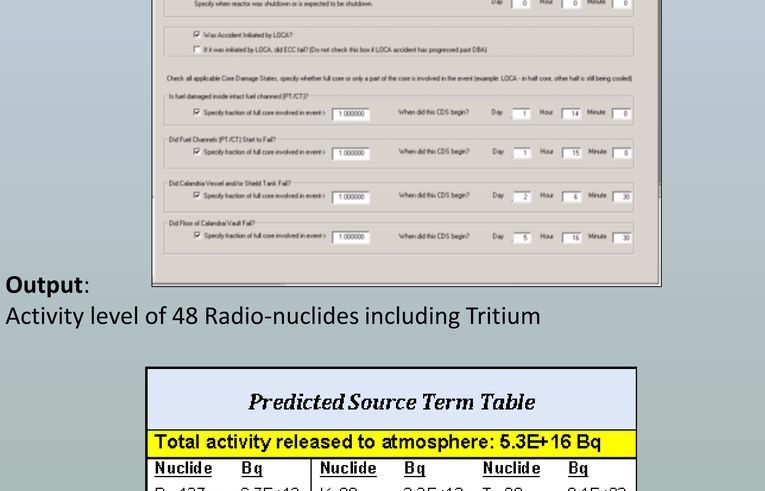
Response Implemented

FNEP TAG

Decision Support System

FNEP TAG – FNEP's Technical Assessment Group : A multi-departmental expert group activated to evaluate the radiological emergency situation (in Canada or abroad) and its potential evolution

Radiological Impact Assessment



1. Source term characterisation

VETA – CANDU specific source term estimate tool

Inputs:

- Core damage state
- Spray and filter system use
- Hold up time in containment
- Duration of release

Output:
Activity level of 48 Radio-nuclides including Tritium

Predicted Source Term Table

Total activity released to atmosphere: 5.3E+16 Bq

Nuclide	Bq	Nuclide	Bq	Nuclide	Bq
Ba-137m	6.7E+12	Kr-88	3.2E+12	Tc-99	9.1E+02
Ce-144	1.5E+12	La-140	3.2E+12	Tc-99m	4.3E+12
Cs-134	2.8E+12	Mo-99	4.3E+12	Te-127	6.8E+10
Cs-135	5.8E+03	Pr-144	1.5E+12	Te-127m	5.4E+07
Cs-136	4.9E+12	Pr-144m	1.7E+10	Te-129	1.2E+12
Cs-137	7.0E+12	Rb-88	2.2E+12	Te-129m	1.2E+12
H-3	1.9E+15	Rh-103m	1.1E+12	Te-131	2.1E+11
I-129	4.1E+00	Rh-105	1.2E+08	Te-131m	2.1E+12
I-131	2.9E+14	Rh-106	4.6E+11	Te-132	3.5E+13
I-132	3.6E+13	Ru-103	3.9E+12	Xe-131m	2.8E+14
I-133	2.1E+14	Ru-105	1.2E+10	Xe-133	4.9E+16
I-134	3.5E+02	Ru-106	4.6E+11	Xe-133m	1.1E+15
I-135	1.4E+13	Sb-127	2.3E+12	Xe-135	4.2E+14
Kr-85	5.8E+13	Sb-129	3.6E+10	Xe-135m	1.2E+13
Kr-85m	3.0E+13	Sr-89	2.6E+12	Y-90	2.9E+08
Kr-87	4.2E+07	Sr-90	5.2E+10	Y-91	3.3E+12

Post release source term reconstruction:
Estimates of source term in short cycle time using field and surveillance network measurements and atmospheric transport and dispersion modeling tools

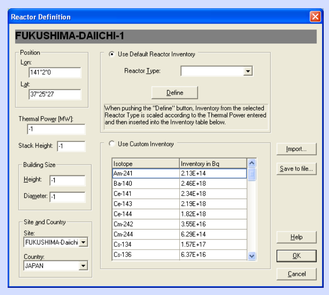
2. Radiological hazard prediction through modelling

ARGOS - Accident Reporting Guidance and Operational System

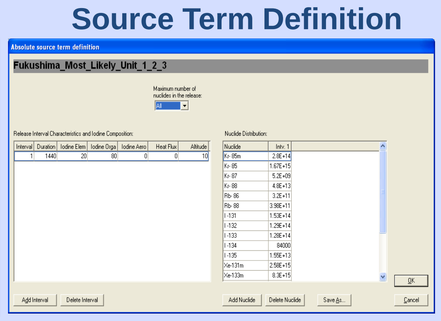
Expert System for

- Interfacing with the Canadian Meteorological Centre (CMC) for radiological atmospheric dispersion modeling
- Activity & dose assessments
- Radionuclides concentration in the air
- Radionuclides deposition on the ground
- Cloudshine, groundshine, inhalation & ingestion doses

Reactor Definition



Source Term Definition

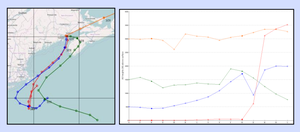


Atmospheric Transport and Dispersion Models

Canadian Meteorological Centre Models

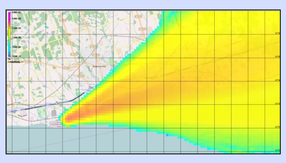
Trajectory

- Simple 3D trajectory calculations
- Horizontal and vertical advection only
- Simple trajectories for a few air parcels released from different vertical levels
- No diffusion, no radioactive decay, no deposition
- Forward & backward modes



MLDP0 & MLDP1 – Modèle Lagrangien de Dispersion de Particules d'ordre 0 et 1

- 3D Lagrangian particle models
- Horizontal diffusion: order 1 (Mesoscale fluctuations)
- Meteorology: Full 3D fields
- Multiple sources
- Radioactive decay
- Dry and wet deposition
- Forward or inverse mode

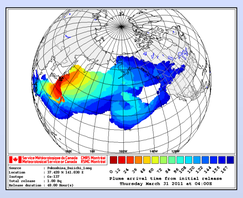


MLDP0

- Order 0: Random displacements in the vertical
- Trajectories calculated based on increments in the particle displacements
- Turbulence effects modelled according to a vertical diffusion coefficient
- Gravitational settling and particle size distribution

MLDP1

- Order 1: Langevin stochastic equations for velocities
- Trajectories calculated according to increments in particle speeds
- 3D wind fluctuations based on partition of TKE
- Off-line model
- Sophisticated emission scenario module
- Concentrations more accurate near the source than for MLDP0



3. Radiological hazard assessment through measurements

- Federal government support for radiological consequence management
- Scientific reach-back to Municipal, Provincial and Federal Emergency Operations Centres
- Provision of expert scientific advice for radiation protection matters

Fixed Point Surveillance System

- There are 77 fixed point surveillance stations distributed across the country, including around nuclear power generating stations and near ports that host nuclear powered vessels. The stations are operated on a 24/7 basis and data can be downloaded to a centralized database in near real-time
- Specialized software is used to analyze and identify the source and the composition of potential releases of radioactive material

Aerial Survey

- Aerial radiation surveys deliver a rapid way to characterise the extent, severity, and isotopic content of deposition
- Initial post-incident surveys following a serpentine path give a general outline of the contaminated area
- Followed up by surveys on close line spacing to provide a detailed map and indicate hotspots, and repeating surveys indicate time evolution of the contamination

Ground survey

- Gamma vehicle borne survey with real time data synchronization into a web mapping application
- Light portable fix point detectors with batteries that can be quickly deployed to report information from distance through satellite communication
- In situ measurements with high purity germanium detectors for characterisation of contaminated areas
- Rapid Response Kit of detection equipment ready to be deployed across the country

Sampling and sample analysis

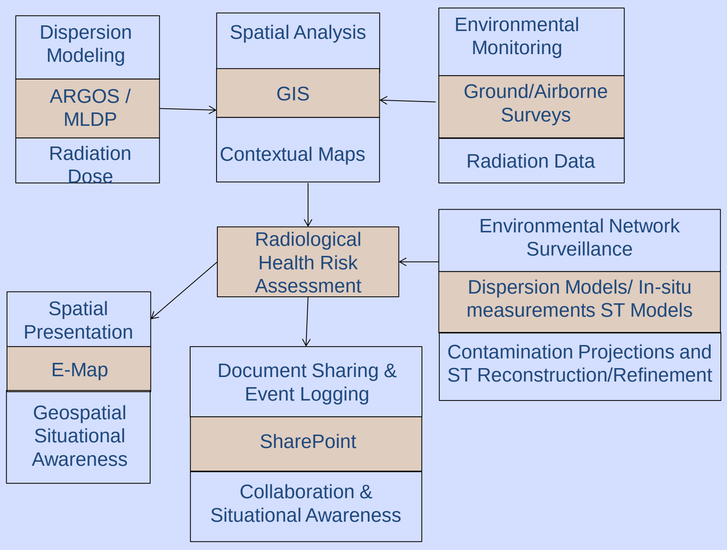
- Capability to collect and analyse samples of air, soil, water, vegetation and swipe.
- Identification and quantification of the radioisotopes in the samples with the Mobile Nuclear Laboratories (high purity germanium detectors)
- Samples are then sent to head quarters laboratory for automated, high throughput

Contamination control

- Quick deployment of tents, portal monitors and pancake detectors to monitor field team officers and set up a decontamination line
- Equipment, vehicles and samples are monitored when the scientific teams are coming back from contaminated zones

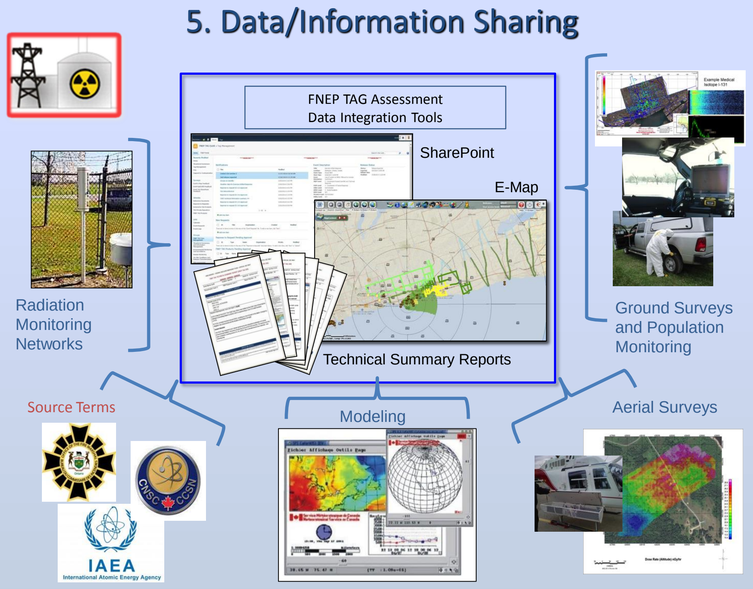
4. Radiological hazard impact assessment

Data Integration and Analysis



- Prior to a release, dose projections are compared to pre-determined criteria to inform decisions about protective actions
- After a release, measurement data from fixed detector networks and updated models are used to reassess the appropriateness of protective actions and revise guidance if necessary
- Reassessment continues as more measurements are collected
- As the situation stabilizes, more detailed assessments of exposure pathways and long-term dose projections guide decisions on longer-term protective actions as well as recovery operations
- Assessments also inform responses to specific questions from stakeholders, which may include reassuring people that they are not at risk of significant exposure

5. Data/Information Sharing



- All geospatial data collected during a nuclear emergency are consolidated in a geographical information system for spatial analysis and radiological impact assessment
- Results of the assessment are presented to emergency responders and decision-makers through a web mapping application
- Non spatial data and technical summary reports are shared with FNEP partners through a SharePoint site

Gaps and Future Development

While the Canadian Decision Support System (DSS) for managing a nuclear emergency is mature, there are still some areas that need further development and/or improvements

- Automated integration of field data into the analysis and long term dose projections
- Managing continuous release events
- Source term reconstruction: further development of rapid and automated tools to improve the data integration process and reconstruction speed
- Use of a probabilistic approach to estimate uncertainties in dose projection assessments

Conclusion

The Canadian Decision Support System for managing a nuclear emergency is a mature system that was developed in collaboration between many federal departments. It has been tested through regular exercises and drills. In particular, it was successfully used during the Fukushima Daiichi Nuclear accident of March 2011 and in a recent full scale exercise in Canada which consisted of responding to a major (beyond design basis) at the Darlington Nuclear Generating Station. In both cases, outputs from the system were used by emergency response organisations to inform their decision-making process.