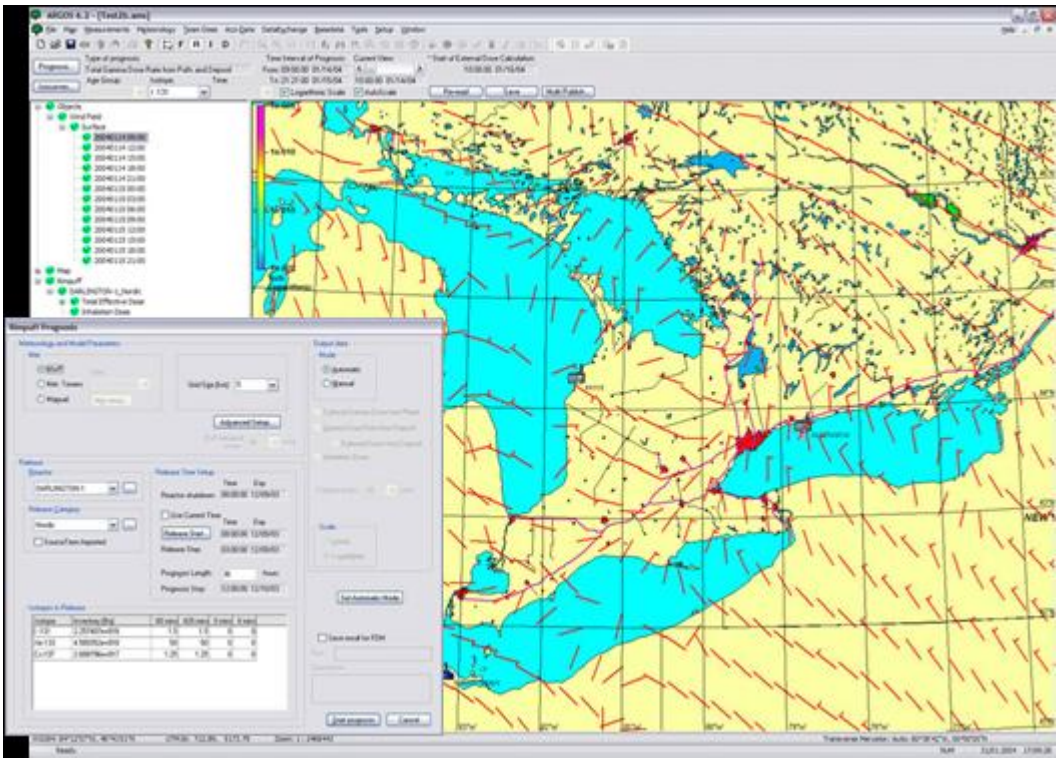
Health Canada Santé Canada

White Paper
Canadian Implementation of ARGOS

Accident Reporting and Guidance Operational System



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1. Summary

Early in 2002 a needs study was completed and found that in a serious Radiological-Nuclear (RN) event, coordinated information and actions are critical. Based on that study, Health Canada's Radiation Protection Bureau began searching for a system that could help managers make critical decisions in a short time period. This search would lead to the very successful execution of the Accident Reporting and Guidance Operational System (ARGOS) for use in Canada. ARGOS is a Decision Support System (DSS) developed by the Danish Emergency Management Agency (DEMA) and Prolog Development Centre (PDC). This white paper is a summary of the implementation of ARGOS for use in Canada and specifically for the federal government's response to an unplanned RN event

ARGOS was funded and implemented under the Chemical Biological Radiological Nuclear and Explosives (CBRNE) Research and Technology Initiative (CRTI). This program is managed by Defence and Research Development Canada (DRDC) in the Department of National Defence (DND) and is the science and research program for improving Canada's ability to prepare for and respond to CBRNE terrorist events.
In Canada, the federal government has a plan called the Federal Nuclear Emergency Plan [1](FNEP) which is administered by Health Canada and specifically the Nuclear Emergency Preparedness and Response Division (NEPRD) of the Radiation Protection Bureau (RPB).

NEPRD purchased and implemented ARGOS over a project period beginning in September 2002 and ending in May 2005. The project team included the Environmental Emergency Response (EER) Section from Environment Canada's Canadian Meteorological Centre (CMC) who integrated atmospheric dispersion models into ARGOS. A detailed description of these models is provided in this paper.

ARGOS also has data integrated into it from a national network of radiation detectors called the Fixed Point Surveillance (FPS). These are Sodium-Iodide (NaI) gamma detectors located at strategic locations near nuclear facilities, ports of entry and population centres. They are networked to the FPS communication centre at the RPB in Ottawa. Another system called the Laboratory Information Management System (LIMS) is integrated with ARGOS and provides critical information on the current and developing affect of radiological releases to the environment and on the food chain.

The ARGOS Canada system is operational and has become a key component for RN emergency planning, exercises and CRTI's RN cluster. The objectives of the original needs assessment have been met.

[1] Refer to Appendix A in this document for definition and role of FNEP and NEPRD.

2. Background

2.1. Introduction

In the event of a serious RN event, the coordination of information and actions is critical to reduce harm to the public. Health Canada as the lead for FNEP must coordinate multi-department organizations involved in a RN response. This involves assessing considerable amounts of information from various sources and making response decisions. For an RN emergency, information on gas plume direction, radiological source terms, and meteorological conditions are critical. A decision support system that integrates atmospheric modelling and forecasting, data gathering and radiation dose and consequence assessment would help FNEP decision makers.

The results of a needs study completed by RPB and funded through CRTI, found that a system developed and used in Denmark, called the ARGOS Application Suite met the requirements for FNEP. The system developers, the Danish Emergency Management Agency (DEMA) and Prolog Development Centre (PDC) make this system available through membership in a consortium: the ARGOS Consortium.

2.2. Project Implementation

The Government of Canada through Health Canada's Radiation Protection Bureau became a member of the ARGOS Consortium in December 2002. Membership in the consortium was an early milestone in the CRTI funded project:
'Information Management and Decision Support System for Radiological-Nuclear Hazard Preparedness and Response', commonly known as the ARGOS Canada project. Funding for this project was planned at $3.3 million and over a deliverable period of three years. The project MOU was signed in September 2002.

The project required the completion of technical developments to make it viable for use in Canada. These included enhancements to support CMC weather prediction, Canadian maps, long and short-range atmospheric dispersion models and access to existing monitoring networks.

The technical enhancements were key deliverables for the project and all were met with success. The ARGOS Canada system became operational with CMC's long-range atmospheric dispersion model in January 2004. It was used in a real event in February 2005 for the FERMI-2 NPS incident. This event involved the shut-down of the FERMI-2 nuclear reactor in Michigan, USA due to a reactor coolant leak. Although no gas was released to the environment, NEPRD used ARGOS to run dispersion models as a preventative action to predict the path of a possible radioactive plume.

3. ARGOS Canada

3.1. Meteorological Data to ARGOS

The ARGOS system receives meteorological observational data in real time from the CMC. This data is received on a continuous basis through a dedicated telecommunication link. This includes the access in digital form of the instantaneous precipitation estimates derived from radar reflectivity from all Canadian and US radar sites. As well, meteorological forecast parameters are provided from the operational Global Environmental Multiscale (GEM) model at 15 km resolution (Regional configuration covering Canada and U.S.A.) and include wind speed and direction, specific humidity, geopotential height, boundary layer height and roughness length.

3.2. Regions of Interest

Radar and meteorological data are provided for three geographical domains with different resolutions in space and time, as well as projection time for the forecast data. The regions of interest are North America, Eastern Canada and Western Canada. Radar data covers North America at a spatial resolution of 12 km and a temporal resolution of 1 hour, while those for the Eastern and Western parts of Canada have a higher spatial resolution of 2 km and a temporal resolution of 20 minutes.

Meteorological data from the Regional system are updated every 6 hours. Forecast data over North America are valid for 3 specific vertical levels in the atmosphere with a 3 hour time interval and 24 hour forecast duration. Forecast data for Eastern and Western regions of Canada are valid for 10 vertical levels, 1 hour time interval and 36 hour forecast duration.

3.3. Interoperability

CMC's meteorological fields can be used by the different dispersion models implemented in ARGOS. For example, they can be used by the Local Scale Model Chain (LSMC) system which includes the local-scale dispersion model RIMPUFF (RIsø Mesoscale PUFF), developed at the Risø National Laboratory.

3.4. Emergency Exercises

The long-range transport trajectory model and both long and short-range atmospheric dispersion models MLDP0 and MLDP1 are executed through ARGOS on a regular basis for monthly, quarterly or annual tests and exercises. The participation of RPB in technical

exercises with several departments and agencies across Canada allow testing the effectiveness of ARGOS as well as all operational procedures running at CMC.

For example, both long and short-range models MLDP0 and MLDP1 were successfully executed by ARGOS on CMC's supercomputer in connection with the national Exercise Initial Thunder 2008 (ExIT-08), held in Vancouver from February 18-22, 2008.

3.5. Data Transfer and Format

Meteorological and dispersion modelling results are transferred from CMC to RPB within the ARGOS system for analysis, visualization and post-processing (radiation dose assessment) purposes. The reception of the request and the transfer of results between CMC and RPB are handled through the File Transfer Protocol (FTP) over CMC's secure server. One of the key features implemented in the Canadian ARGOS version is the use of the World Meteorological Organization (WMO) GRIB (GRIdded Binary) data format. Radar and meteorological data as well as atmospheric dispersion modelling results are provided to ARGOS in this format.

Canada requested that GRIB become the official binary data format within the ARGOS system in order to handle more easily large data sets exchange between CMC and RPB, and processing (reading, visualization) within ARGOS. It was a Canadian requirement for ARGOS to be able to manage efficiently the voluminous data sets involved for the wide geographical areas under Canadian responsibility. The use of an international and well documented binary format like the WMO GRIB format was deemed appropriate.

3.6. Atmospheric Transport and Dispersion Modelling

Requests for atmospheric dispersion modelling can be automatically sent out to CMC through ARGOS. RPB is authorized to trigger the execution of long and short-range transport and dispersion models on CMC's supercomputer in order to respond to any radiological or nuclear emergency situation occurring in North America. All modelling requests are processed automatically at CMC. The models available include a multi-level long-range trajectory model and two full 3-D Lagrangian particle dispersion models MLDP0 and MLDP1 developed for long-range and short-range problems. The long and short-range dispersion models are coupled to source term modules (for specific events, reactors and release categories) integrated into the ARGOS database.

The modelling requests are categorized according to different launching modes implemented in ARGOS and are used to trigger the execution of the model on CMC's supercomputer. These modes have specific computing priorities, configurations and resources which are function of the type of emergency. For a real nuclear emergency, ARGOS requests would be given access to computer resources with the highest priority and dispersion modelling would be available to RPB through ARGOS in less than 10 minutes. The ARGOS' user at RPB has also the option to contact CMC's 24/7 Operations

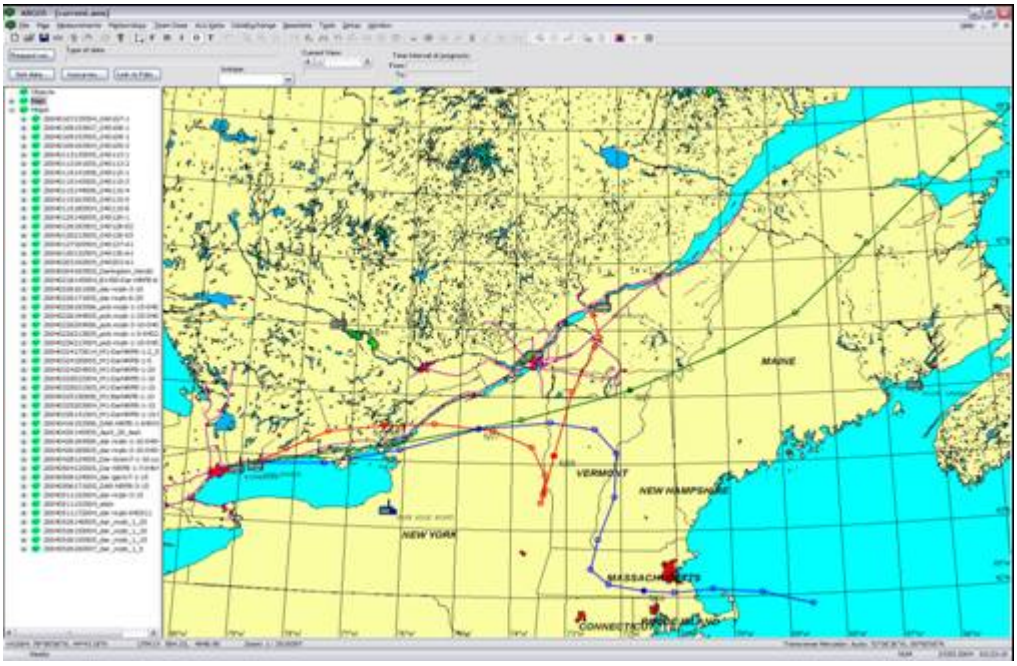
shift meteorologist supervisor or environmental emergency response duty officer for immediate modelling assistance.

3.7. Trajectory Model

The trajectory model is a simple tool designed to calculate the trajectory of a few air parcels moving in the 3-D wind field of the atmosphere. Only transport by the winds is considered without taking into account any other physical or atmospheric processes.

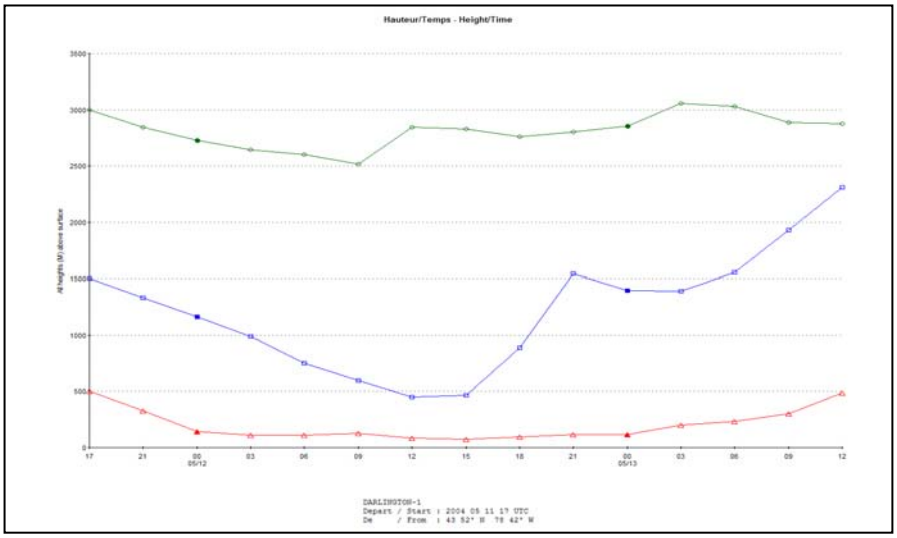
Figure 1 shows the trajectories for three air parcels released at different heights (500, 1500 and 3000 m) from the Darlington Nuclear Power Plant (NPP) near Toronto, Ontario.

Figure 1:



The three elevations of the trajectories are graphically shown over time as indicated in Figure 2.

Figure 2:

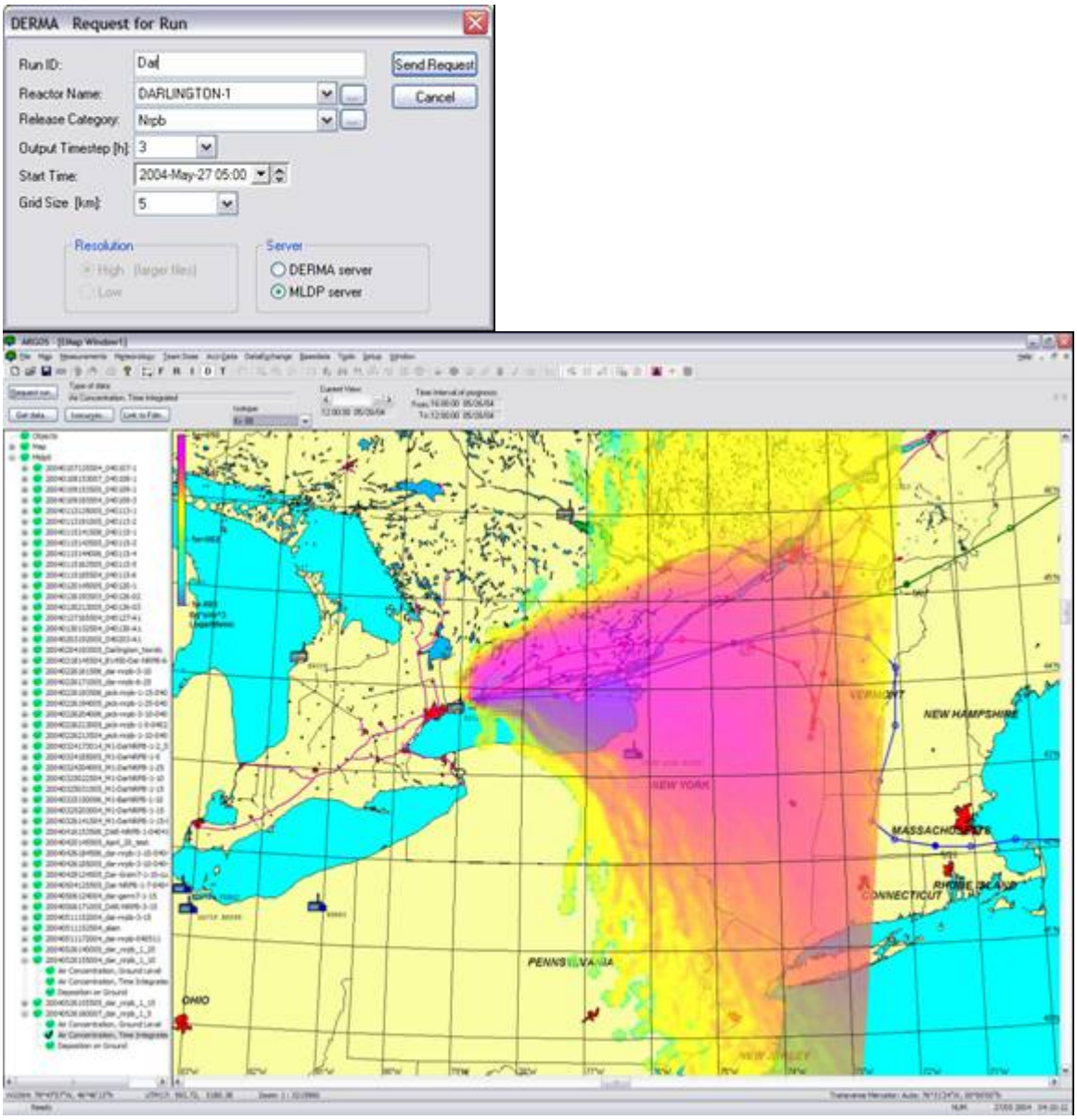


3.8. Long-Range Dispersal Model

The *Modèle Lagrangien de Dispersion de Particules d'ordre zéro* (MLDP0) is a Lagrangian particle dispersion model of zeroth order designed for long-range dispersion problems occurring at regional and global scales. Dispersion is estimated by calculating the trajectories of a very large number of air particles (or parcels). Large scale transport is handled by calculating the displacement due to the synoptic component of the wind field and diffusion through discretized stochastic differential equations to account for the unresolved turbulent motions. Vertical mixing caused by turbulence is handled through a random displacement equation based on a diffusion coefficient. This coefficient is calculated in terms of a mixing length, stability function, and vertical wind shear. Lateral mixing (horizontal diffusion) is modeled according to a first order Langevin Stochastic Equation for the unresolved components of the horizontal wind (mesoscale fluctuations).

Figure 3 illustrates the results of a simulation from the long-range dispersion MLDP0 model based on a release from the Darlington NPP. The information required to generate the model is shown in the GUI (request for run).

Figure 3:



3.9. Short-Range Dispersion Model

Modèle Lagrangien de Dispersion de Particules d'ordre un (MLDP1) is a first order Lagrangian particle dispersion model presently applied to problems on horizontal domains of 100 to 200 kms, with a time horizon of 12 hours. In this stochastic dispersion model, the fluctuating components of the turbulent wind are obtained by partitioning the Turbulent Kinetic Energy (TKE) calculated in the driving NWP models. Concentrations are expected to be estimated more accurately near the source with a first order model.

MLDP1 is parallelized and runs on several nodes on the IBM supercomputer at CMC. It uses both distributed and shared-memory standards. Distributed-memory parallelism is implemented with MPI (Message Passing Interface) library while shared-memory parallelism relies on OMP (Open Multi-Processing) directives.

3.10. Other Modelling Features

Both the MLDP0 and MLDP1 are off-line models and use the full 3-D meteorological fields provided by an NWP system. Therefore, fields of wind, moisture, temperature and geopotential heights must be provided to the models, which are obtained, for ARGOS, from the GEM data assimilation and forecast system in the Regional configuration.

Dry deposition is modeled in term of a deposition velocity. The deposition rate is calculated by assuming that a particle contributes to the total surface deposition flux in proportion to the tracer material it carries when it is found in a layer adjacent to the ground surface. Wet deposition will occur when a particle is presumed to be in a cloud. The tracer removal rate is proportional to the local cloud fraction.

The source term is controlled through an emission module which takes into account the different release rates of several radionuclides over time as they come from the ARGOS release scenarios.

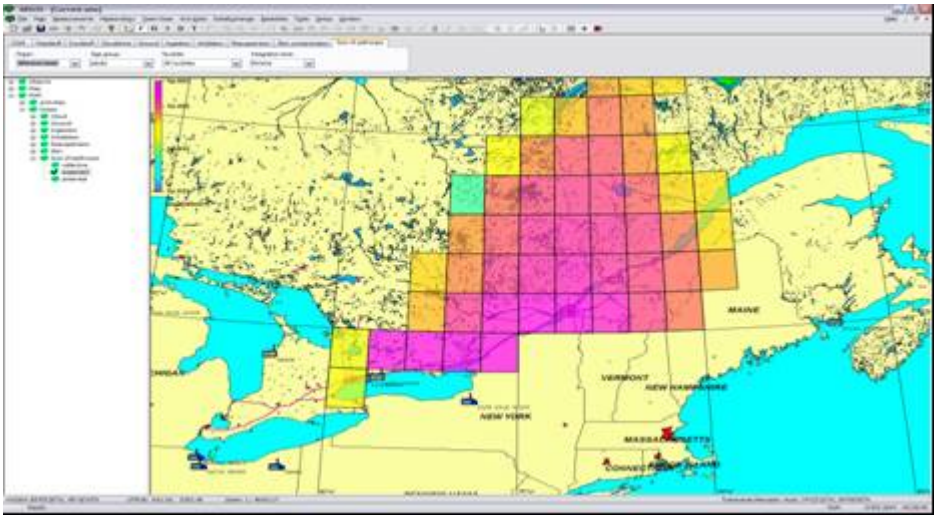
3.11. Food Chain and Dose Module (FDM)

Surface air concentrations, time-integrated concentrations and total ground depositions are important fields produced by the long and short-range atmospheric dispersion models. The results generated by MLDP0 and MLDP1 can be fed into the radioecological model, Food chain and Dose Module (FDM), which is integrated within ARGOS in collaboration with another European radiological decision support system called RODOS (Real-time On-line DecisiOn Support). This post-processing model is designed to simulate the food chain transfer and estimate doses to humans from ingestion of contaminated food.

Agricultural, land use and population density information is provided to ARGOS from the respective provincial departments. This data is part of a geographical grid that is used by ARGOS for radiological dose modelling. ARGOS can project the affects of radioisotopes on the food chain over a period of time. These affects include metabolized contamination of plant life.
The model is dependant on updated information on land use, agricultural types, population densities etc.

Figures 4 and 5 show the dose distribution over a region in Eastern Canada from the affects of a release of Cs-137.

Figure 4:



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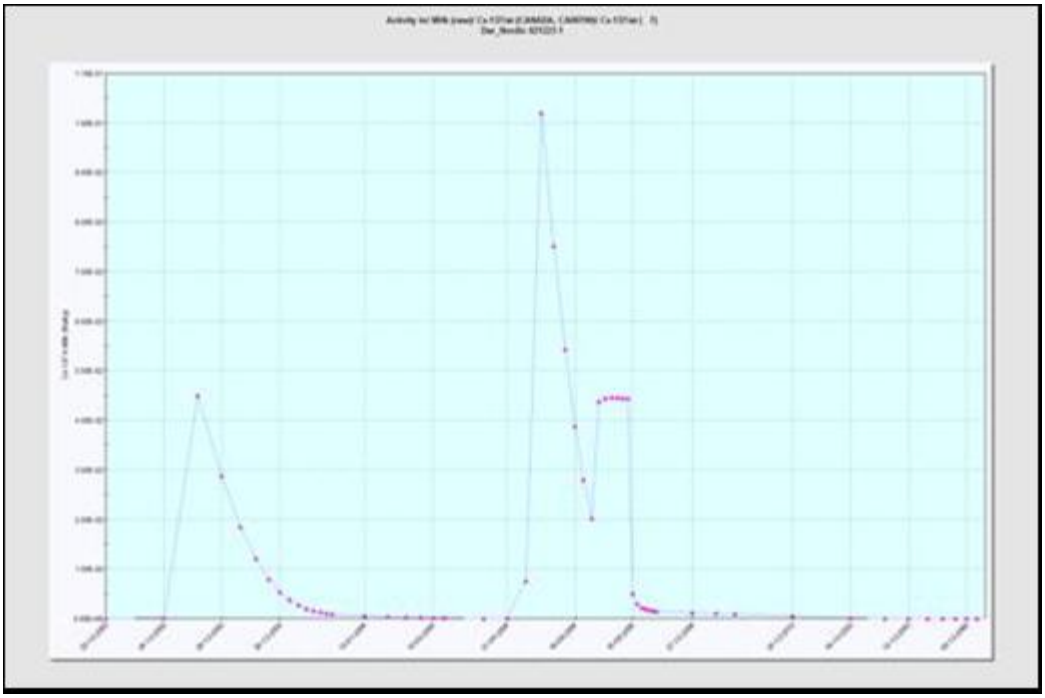


4. ARGOS Canada Inputs

4.1. Fixed Point Surveillance Network (FPS)

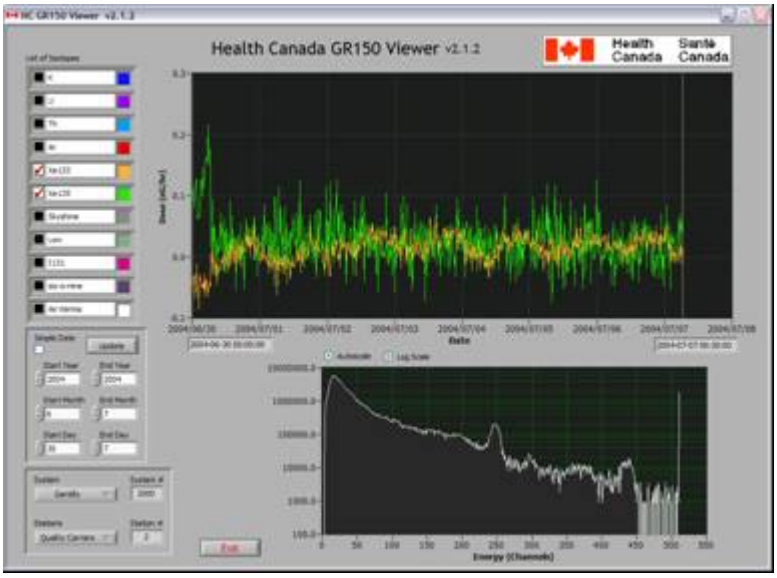
The RPB has established a network of gamma detectors in various Canadian locations. The detectors are Sodium-Iodide (NaI) crystals housed in a protective aluminium casing. The role of the network of detectors is to monitor the environment for exposure to radiation sources. The detectors are located near nuclear facilities, in cities and sea ports where nuclear powered vessels may berth.

The data from the detectors is downloaded at the data centre in Ottawa every 15 minutes. This data provides gamma spectroscopy information for the area around the detector. Abnormal spectral data such as peaks not part of the normal background radiation are tagged and alerted to the FPS network. The data is shared with CMC for validation of atmospheric dispersion models. ARGOS Canada has constant access to the data and is stored on a separate layer.

During an emergency, the FPS network spectral data can provide crucial information to NEPRD and/or FNEP staff regarding gamma radiation levels and type observed.

Figure 6 illustrates a GUI for the FPS network showing the gamma spectroscopy for a NaI detector at a Canadian nuclear power station.

Figure 6:



4.2. Aerial Radiometric Survey

Data collected from airborne gamma spectrum monitoring can be loaded into ARGOS to provide information regarding ground deposition. Natural Resources Canada (NRCan) has various sized liquid sodium iodide detectors that can be mounted into aircraft. The aircraft fly over an area of interest at an elevation of between 100 to 150 meters using the NaI detectors to create a spectral map.

The data from the gamma monitor is downloaded into NucInfo which is integrated with ARGOS. The time from data integration to evaluation in the food dose model can be as fast as one hour.

4.3. Laboratory Information Management System (LIMS)

LIMS is a system that manages processes related to samples, instruments, laboratory users and results within a laboratory setting. The samples include air sampling filters, cow's milk, water and human food chain consumables. The results from the analysis performed are centralized in the LIMS database within RPB which is located in Ottawa and is integrated with the ARGOS Canada system.

When used by ARGOS, the LIMS database provides NEPRD and FNEP TAG members with critical information on the current and developing affect of radiological releases to the environment and on the food chain. This information can be used with the Food Chain and Dose Module described in paragraph 3.11 of this document.

5. ARGOS Canada Outputs

5.1. EMap

ARGOS is made available to a large group of users through a companion system called eMAP. EMAP is a web-based geographic information system (GIS) that provides the user with all the necessary information related to the plume. The database includes a complete map of Canada including listings of city streets, hospitals, schools and nuclear facilities. The user can see the current and projected direction of a plume. This information is the current and real-time data being generated by ARGOS.
Users with access to eMAP can include emergency responders, FNEP TAG members and other government officials.

Figure 7 is an illustration of an eMAP display of a plume resulting from a unplanned release at a Canadian sea port.

Figure 7:

6. Future Developments

6.1. CBRN Hazard Prediction and Assessment for the Urban Environment

This is a prototype modelling system being developed by the CMC that will predict the transport and dispersal of CBRN materials in an urban environment. Its implementation will result in the improved emergency preparedness and management of CBRN incidents in Canadian cities. The outputs from this system will be integrated into ARGOS Canada.

6.2. Canadian Health Integrated Response Platform (CHIRP)

CHIRP is a project being lead by Health Canada that will integrate the existing Canadian Network for Public Health Intelligence (CNPHI) with the ARGOS system. The CNPHI is a decision support system used by the public health community in Canada to help identify risks, initiate responses and build response capacity.
Having both systems integrated will provide interoperability between the RN and biological clusters systems and improve emergency response.

6.3. Assessment of CBRN Releases

A model has been completed and is being implemented with the ARGOS Canada system that will provide decision makers with real-time assessment and forecasts of the timing, location and amount of deposited CBRN material in the event of a terrorist attack. The enhanced model will: (i) Forecast the trajectory and concentration of CBRN material in the air; (ii) Forecast the location, duration and intensity of precipitation; (iii) Estimate the amount of airborne material deposited on the ground when it is raining or snowing; (iv) Calculate deposition in the absence of precipitation.
The ARGOS Canada system can access the model which is operated by the CMC to provide an estimation of the amount of hazardous material released in the air and deposited on the ground.

7. References

Paragraph

2.2 RPB (2005): Memorandum to the Assistant Deputy Minister. Subject: Coolant leak shuts down U.S. nuclear power reactor near Canada/U.S. border. Jean-Patrice Auclair, NEPRD Health Canada

3.1 – 3.10 CMC (2008): Description of Meteorological Data and Dispersion Modelling Implemented in the Canadian Version of ARGOS. Alain Malo, Réal D'Amours, Richard Hogue, René Servranckx. CMC, Environment Canada

6.1 CRTI 02-0093: An Advanced Emergency Response System for CBRN Hazard Prediction and Assessment for the Urban Environment. Abstract (2008) by Richard Hogue, CMC, Environment Canada. Presented at the 2008 Centre for Security Science symposium in Edmonton, Alberta.

6.2 CRTI 04-0127RD: Canadian Health Integrated Response Platform Abstract (2008) by Kendra Shaw, NEPRD Health Canada Presented at the 2008 Centre for Security Science symposium in Edmonton, Alberta.

6.3 CRTI 02-0041RD: Real-time Determination of the Area of Influence of CBRN Releases. Abstract (2007) by Jian Feng and Richard Hogue, CMC, Environment Canada.

8. Acronyms

ARGOS	Accident Reporting and Guidance Operational System
CBRNE	Chemical Biological Radiological Nuclear Explosive
CHIRP	Canadian Health Integrated Response Platform
CMC	Canadian Meteorological Centre
CRTI	CBRNE-Research and Technology Initiative
DEMA	Danish Emergency Management Agency
DND	Department of National Defence
DRDC	Defence Research and Development Canada
EEC	Environmental Emergency Response
FDM	Food chain and Dose Model
FNEP	Federal Nuclear Emergency Plan
FPS	Fixed Point Surveillance
GEM	Global Environmental Multiscale
GIS	Geographic Information System
GRIB	GRIdded Binary data format
GUI	Graphical User Interface
LIMS	Laboratory Information Management System
LSMC	Local Scale Model Chain
MLDP0	Modèle Lagrangien de Dispersion de Particules d'ordre zéro
MLDP1	Modèle Lagrangien de Dispersion de Particules d'ordre un
MOU	Memorandum of Understanding
MPI	Message Passing Interface
NaI	Sodium Iodide detector
NEPRD	Nuclear Emergency Preparedness and Response Division
NPP	Nuclear Power Plant
NRCan	Natural Resources Canada
NWP	Numerical Weather Prediction
OMP	Open Multi-Processing
PDC	Prolog Development Centre
RIMPUFF	Riso Mesoscale PUFF
RN	Radiological-Nuclear
RODOS	Real-time On-line Decision Support
RPB	Radiation Protection Bureau
TKE	Turbulent Kinetic Energy
WMO	World Meteorological Organization

Appendices

A. Role of FNEP and NEPRD

Protection of Canadians from the health effects due to exposure from uncontrolled sources of radiation rests with Health Canada. The Government of Canada has a plan in place that describes the authority and framework for emergency preparedness policies called the Federal Nuclear Emergency Plan (FNEP). The FNEP is under the administration of Health Canada and specifically the Radiation Protection Bureau (RPB). Within the RPB all administrative and coordinating actions are tasked with the Nuclear Emergency Preparedness and Response Division (NEPRD).

The scope of the FNEP includes the following nuclear or radiological emergencies:

- An emergency at a nuclear facility in Canada or in the United States along a shared border,
- Nuclear-powered vessels or vessels containing radioactive materials visiting Canada or in transit through Canadian waters,
- A nuclear facility in the southern United States or in a foreign country,
- Any serious radiological event such as:
    - Malevolent acts involving improvised nuclear devices or the use of conventional explosives at a facility that stores or uses radioactive materials,
    - The re-entry of a nuclear-powered satellite.

The goal of the FNEP is to provide the structure for federal nuclear emergency preparedness and response in order to:

- Protect the public from the immediate and delayed health effects due to exposure to uncontrolled sources of radiation,
- Minimise the impacts of a nuclear emergency on property and the environment,
- Maintain public confidence in the ability of responsible authorities to protect public health.

The roles for NEPRD are for the administration of the FNEP which involves leading and coordinating federal preparedness and response to a radiological nuclear emergency and also to develop and deliver training and exercise programs. These exercise programs are completed to mitigate the effects of an unplanned RN event.
Roles for NEPRD include supporting other government programs that relate to anti-terrorism including the National Counter-Terrorism Plan and the Chemical Biological Radiological Nuclear Explosives Research and Technology Initiative (CRTI).

RPB is located in a facility that is licensed for low concentrations of radioisotopes and in Ottawa, Ontario. The facility consists of offices and also laboratories equipped for radioactive materials.

B. The ARGOS Consortium

The ARGOS consortium is a collection of 11 national organizations that use ARGOS. The objective of the consortium is to maintain and develop ARGOS as an expert decision making tool, and to share expertise. The consortium is managed through DEMA and PDC in Denmark and the consortium meets in Copenhagen once per year for meetings and workshops.

In December 2002, Canada became the first non-European member of the consortium. The membership now includes (August 2008): Australia, Brazil, Canada, Denmark, Estonia, Ireland, Lithuania, Montenegro, Norway, Poland and Sweden.
Canada is represented by the Nuclear Emergency Preparedness and Response Division of the Radiation Protection Bureau, Health Canada.