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EMERGENCY EXERCISE SCENARIO TOOLS

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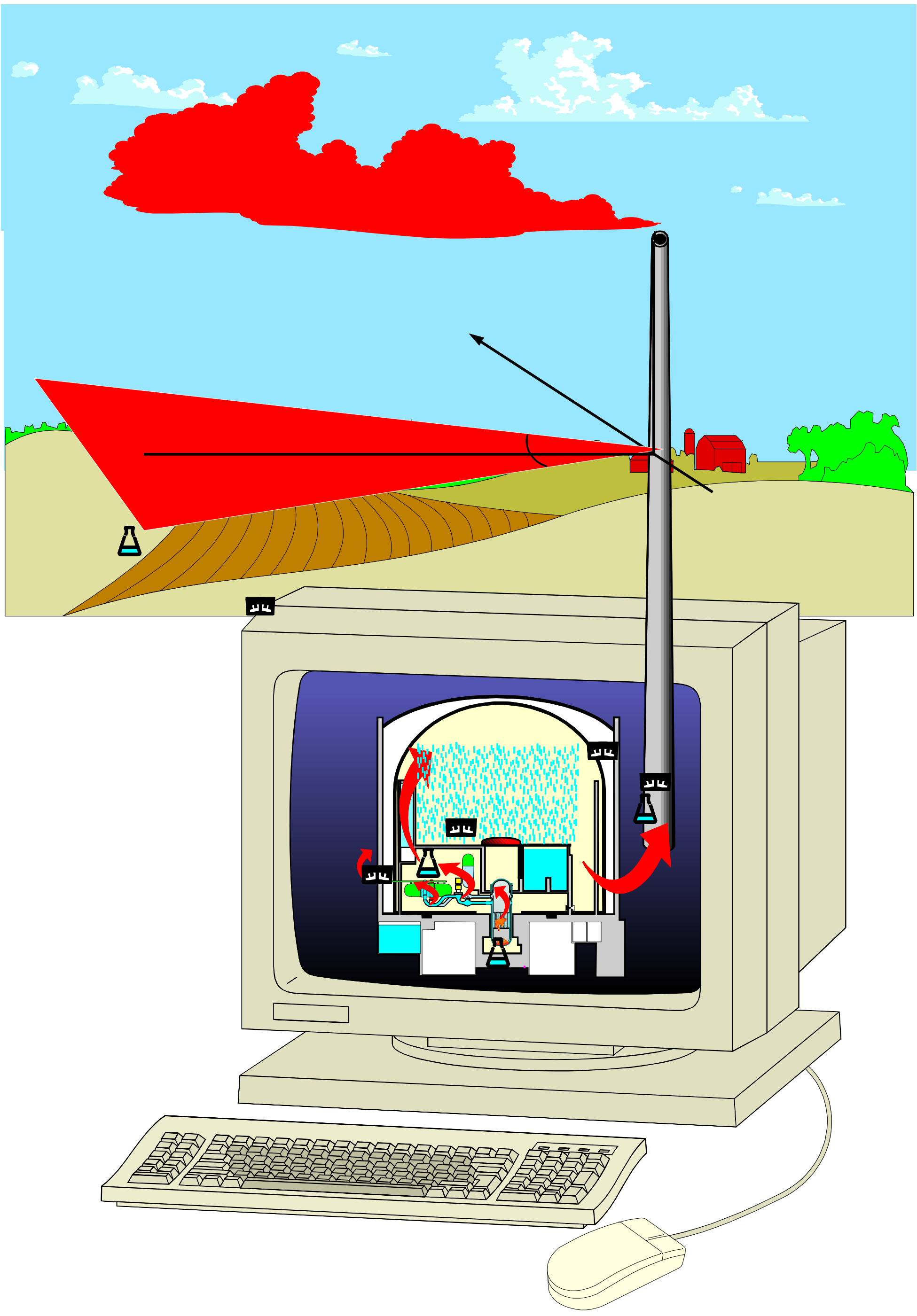

Abstract - Nuclear power plant emergency exercises require a realistically presented accident situation which includes various aspects: plant process, radioactivity, radiation, weather and people. Experiences from nuclear power plant emergency exercises show that preparing accident scenarios even for relatively short exercises is tedious. In the future modern computer technology and past experience could be used for making exercise planning more effective.

CONTENTS

1. INTRODUCTION: PREPARING FOR EXERCISES

Emergency exercises are an essential prerequisite for appropriate preparedness. However, large co-operation have been arranged relatively seldom, not always even on an annual basis. One reason is that planning and preparing these exercise requires a considerable amount of person-hours and calendar time. A large fraction of this work is related to creating accident scenarios and presenting it as realistically as possible.

To promote exercise planning and scenarios NKS included scenario development into the EKO-4 project ”Emergency exercises and information” for the years 1994-1997. The goals have been to study

- rationalizing scenario work
- increasing the realism of exercise scenario
- improving the presentation of postulated accidents

The EKO-4 -project included also a Nordic aspect in the large international emergency exercise INEX-2-FIN in April 1997; in which the postulated accident plant was Loviisa NPP. This exercise was conducted in three levels: utilty, national authorities and international (participation from 29 countries). INEX-2-FIN was favoured by good motivation by the planning and participating organizations and so it also reflected the current status of exercise scenario tools and this experience is reviewed in this report.

The INEX-2-FIN exercise reached high appreciation also by the public: According to an opinion poll[1] the public, which has different point of views of nuclear power in general, almost unanimously agrees that the rescue service authorities should exercise for radiological accidents.

1 This poll was carried out in 1997 just after a large national and international emergency exercise INEX-2-FIN, that was also included in NKS EKO-4 -project. 96-99 % of the people in Helsinki, Loviisa and Kotka agreed that this kind of exercise was needed though most of them regarded that the operation of the Loviisa nuclear power plant is safe.

2. ACCIDENT SCENARIOS

An accident scenario describes the emergency situation from the point of view of the training organization. It can contain the following entities:

1. **Power plant**
    a) Process: initiating events, defects in safety functions, human errors;
    b) Component failures: failure description, repair times;
    c) Radiology: core damage, release path, radioactivity on-site, radiation on-site;
    d) Personnel: injuries, assembly and evacuation, emergency organization;
    e) Rest of power plant: loss of electricity supply, fire, flooding etc.

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2. Environment
    a) Transportation of radioactivity: source term (nuclide types, quantities, time schedule), weather (wind direction and velocity, turbulence, precipitation), atmospheric dispersion, deposition on the ground;
    b) Radiation: dose rates & doses as a function of time and place (external, thyroid and effective whole body equivalent);
    c) Radioactivity in foodstuff (water, milk, meat, fish etc.).

3. Society
    a) Authorities: contacts, recommendations, decisions, protective actions;
    b) Newsmedia: interviews and other information, also misinformation;
    c) Population: protective actions, inquiries;
    d) Other conditions: interruption in the distribution of electricity, extreme weather conditions, disturbances in society.

3. ACCIDENT SIMULATION METHODS

There is a large variety of various more or less plant specific NPP simulators; this paper discusses only those NPP simulators that can or could simulate Nordic NPPs: Swedish, Finnish or Kola NPP. Kola NPP is located in Russia but is not far from the Norwegian or Finnish territory and has been a partner in several international co-operation projects. In addition, radiological simulators that are not as site specific, are also discussed.

Because of limited exercise planning resources the scenarios are often rather general by nature. However, the greater the level of technical expertise that is exercised the greater should be the complexity of the event sequence and scenario [IAEA SS73].

3.1 Control room replica-type simulators

Nuclear power plant process simulation has already traditions from several decades. In many countries it is even a regulatory requirement to have plant and unit specific simulators for training of all control room operators.

Loviisa Power Plant has had a ”full scale” simulator since 1980. ”Full scale” means that the simulator control room looks like the real one and most of the plant systems and redundancies have been included. The simulation grade has been improved and plant modifications have been added annually. Since 1985 the simulator has run in real time in utility level emergency exercises and also in larger rescue service exercises. During the past decade the following advances have been reached:

- The simulator computer and the simulator’s process computer have been connected to the plant process computer system;
- An Emergency Operations Facility (EOF) for emergency management, which was established in 1990, has been equipped with a terminal connected to the computers mentioned above;
- Safety parameters can be automatically reported to command posts of to the Nuclear Safety Authority (STUK) and to the engineering support organization (IVO Power Engineering) in Helsinki;
- The operators have been allowed to influence on the accident scenario.
- The simulator has increased the realism of an accident scenario compared with conservative licensing or PSA analysis. The operators´ recovery actions and non-safety systems add a valuable credit to plant safety;
- The simulating of a two-phase flow in the PWR primary circuit has gradually become more reliable regarding to both the plant parameters and the simulator availability;
- Loviisa simulator made a top perfomance in INEX-2-FIN exercise, in which the simulation lasted through the whole course of exercise — 11 hours; this accident scenario included reactor core uncovery, severe damage and rewetting!

Yet there are many severe accident phenomena that the simulator is unable to simulate or the simulation results are less reliable, e.g. complicated core rewetting situations, containment hydrogen and pressure, fuel damage and radioactivity. So far the simulator has been oriented mainly for operator training, but it also provides other emergency management organizations with a new potential.

3.2 Other NPP process simulators

EVVEREST

The acronym EVVEREST comes from ”the European VVER Extensible Simulator for Training. The first stage of EVVEREST has been delivered to the end users at six VVER-440 -sites (including Kola) in five countries. The simulator supply contract was awarded by EC to a consortium led by France’s CORYS and included Belgatom and Siemens.

The present simulation scope includes the plant systems which are most important from the safety point of view. The simulators satisfy all state-of-the-art reequirements in terms of simultion scope and limits, fileity of modelling, tolerances, simulated incidents and accidents. The models permits major accidents including the large-break loss-of-coolant accident.

The simulator is coposed of the simulation computer, three operator stations with threee screens each, one shift supervisor station and one instructor station. The man-machine interface is a combination of interactive synoptic images, alarm images and soft panels of the real control room panels. About 100 images are available to the operators. Soft panels ensure reduced costs of hardware, as there is no need for special arrangements to accommodate the simlotr nor for developing costly control room panels. This approach also reduces the cost and the time of the software development as standard off-the shelf computers are sufficient ro run the models.

Extension to full-scope replica simulators using the EVVEREST simulators as a starting point is the next logical step in this evolutionary project. Recently a contract was awaded for the connection of the EVVEREST simulator to the existing simulator control room panels in Novovoronezh. Also this project is financed by the EC.

KOLA COMPACT SIMULATOR [Kola Finnished] & [APROS-based Kola 1 simulator]

In September 1997 IVO Power Engineering completed handover of the compact training simulator to the Kola NPP. This FIM 3 million project was Finnish financed, as part of the country’s programme of co-operation with its Eastern European neighbours.

The specialist simulator is for training operators to deal with exceptional and emergency situations and models the units 1&2 at Kola(there is also a simulator for the units 3&4 in Kola). Work stations are provided for each operator as well as for the instructior, who can subject the operators to various malfunctions. The simulator shows the operators the same information that they would get in the actual plant control room and allows them to control the same equipment as in the reality; the displays on the screen resemble the wall panels:

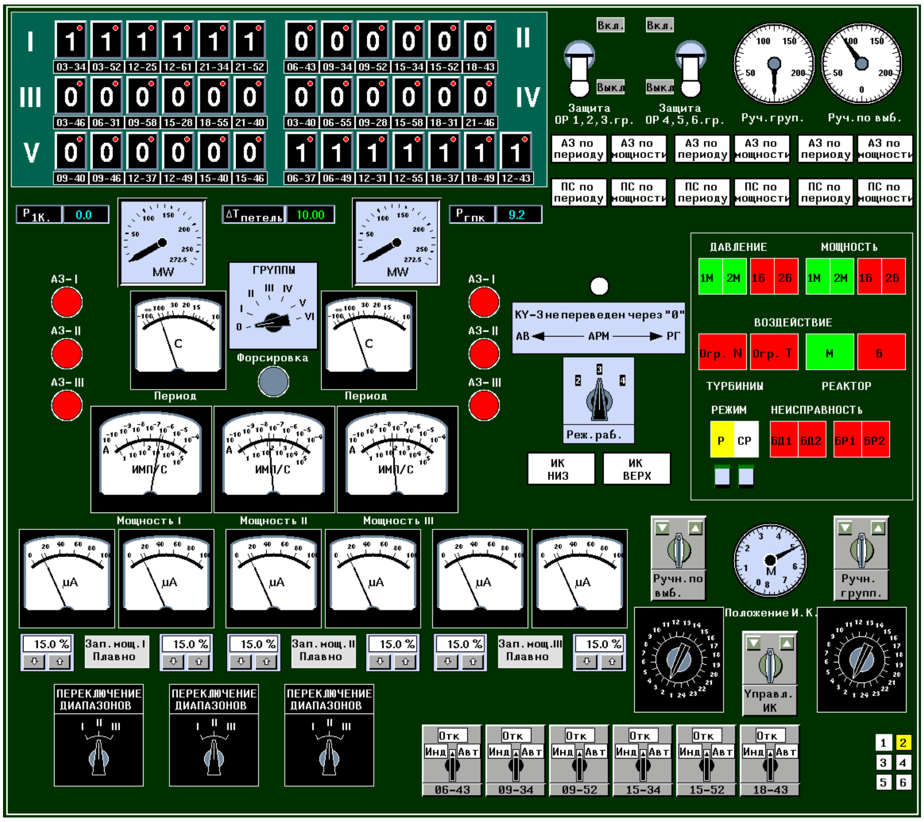


Figure 1. The PC simulator has displays that look like control room panels.

RINGHALS 1 COMPACT SIMULATOR [Skrede]

Ringhals 1 compact simulator was used in the large emergency exercise in Sweden in 1997. This simulator is made by Studsvik Enegisystem (now GES) in 1990. This compact simulator simulates major parts of Ringhals 1 (BWR); it includes advanced containment and thermohydraulic simulation for severe accidents. Yet, neither radioactive materials nor radiation is simulated.

APROS APROS (Advanced PROcess Simulation) provides a simulation environment for nuclear power plants or other processes. APROS applications include engineering and training simulators as well as comprehensive plant analyzers. APROS has been developed by VTT and IVO International, Finland. It can flexibly be adjusted to fit a specific plant. APROS models have been made e.g. for Loviisa 1&2, TVO 1&2, Forsmark 1, Ringhals 1 and Kola (both the 1&2 and 3&4) plants.

As a tool for generating emergency exercises APROS has the following benefits: existing process models and experience from training use. There are plans for using it when estimating the releases in the Loviisa PSA study. On the other hand, APROS needs a work station, and additional radiological and other sever accident models require extra work.

MELCOR / MELSIM

MELCOR is a widely used code for severe accidents. It calculates two-phase situations in the reactor and the primary circuit, fuel damage, core melt, reactor pressure vessel penetration, core-concrete reactions, hydrogen production and behaviour, and containment functions. MELCOR is neither as accurate as RELAP nor as complete as a full-scale simulator, but it can analyze severe accidents beyond core uncover. Radioactive materials are divided into six groups: Xe, Cs, Ba, I, Te and others. The amount and concentration of them in fuel, primary system, containment/deposits, containment/airborne and environment are calculated.

MELSIM is based on MELCOR but includes also a man-machine interface for interactive simulation sessions. MELSIM has been developed mainly for Technical Support (for operators) Center training rather than Emergency Operations Facility training.
MELCOR/MELSIM could benefit emergency preparedness by

- generating accident scenarios (in advance) for emergency exercises (like in Kola in 1995);
- providing an interactive plant simulator for operator training emergency exercises and
- generating releases of model accidents (quantity, quality & timing) to emergency plan.

PCTRAN

PCTRAN is a PC based NPP training simulator. It models severe accident phenomena inside a nuclear power plant. On a PC it can simulate much faster than real time (the user may use the simulation speed). PCTRAN can be used for self education. However, one shall note that PCTRAN is not a nuclear power plant analyzer.

The supplier is Micro-Soft Technology from the USA. It has a long list of clients (TVO and 16 others in 1995). A delivery can include a basic package, a plant specific model or severe accident and radiological models.

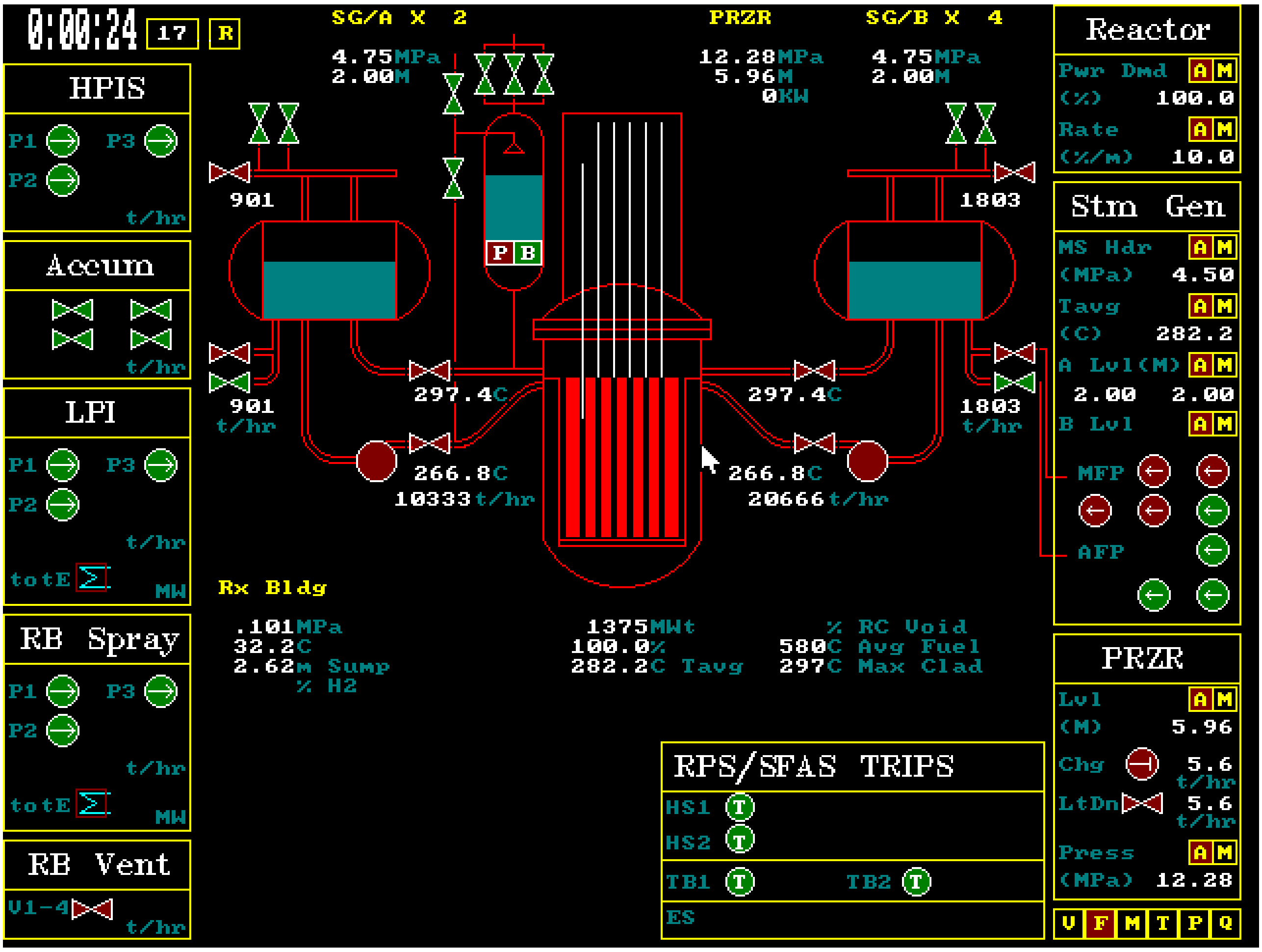


Figure 2. The PC simulator process diagrams indicate the current status of the safety systems. The user can postulate malfunctions by clicking components.

The Industrial Power Company Ltd (TVO) has used PCTRAN since 1995. It models the plant-specific features of the ABB Atom designed BWR, including its containment overpressure protection and filtered vent systems. Radiation leakage paths and dose rate distribution are presented graphically. Potential scenarios include core heat-up, hydrogen generation, core melt and vessel penetration.

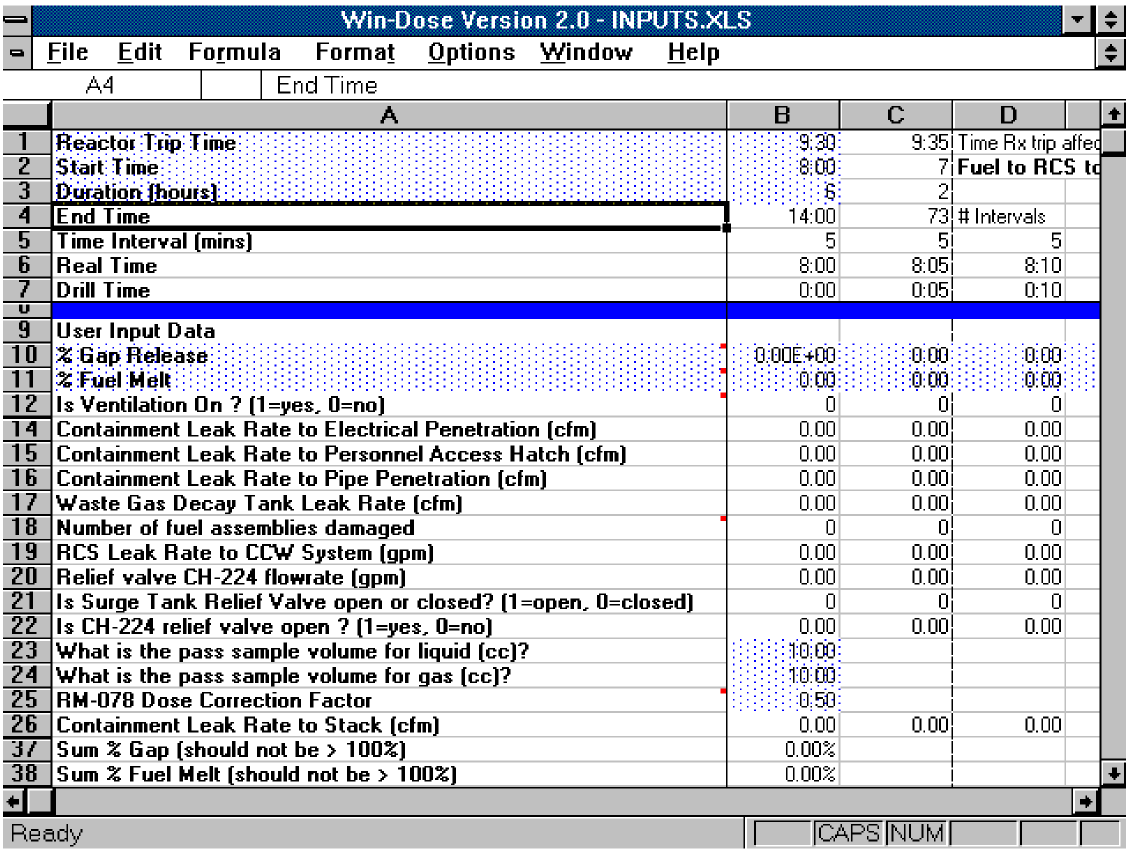
3.3 Plant radiation

Plant radiation is often simulated with rough estimates that are based on licensing calculations or simplified calculations. The transportation of radioactive materials within the plant usually lacks quantitative models. These ”hand made” scenarios have been regarded sufficient to dispatch radiation monitoring and sampling teams. However, from the point of view of a radiological analyst this kind of data can give only qualitative indication on what is happening: the magnitude and especially the time behaviour of radiological parameters cannot match real accidents.

The radiological exercise controllers may find it difficult to plan the scenario within the available man-hours and present the accident scenario in consistent way; also modifications (corrections, additions or fitting to the overal scenario) may be practically impossible during and difficult even before an exercise.

For the time being there are not many computerized applications available. For this reason this chapter names only one: Win-Dose simulates inplant contamination and dose rates, airborne radioactivity, post accident sample data and safety parameter display (SPDS) screens. It runs on a typical computer and uses specific data as accident types, source terms, radiation monitor information and compartment characteristics. Plant specific model development requires close work with plant knowledgeable staff and takes about 8 months.

As input it needs start time, duration, accident type, trip time, leak rates, leak pathway, fuel damage, plant status and operational data. Options are available to generate offsite radiological data, ingestion pathway data, accept historical meteorological data and accept downloaded data from a control room simulator and generate a file for upload to simulator.



Win-Dose Version 2.0 - INPUTS.XLS

File Edit Formula Format Options Window Help

A4 End Time

	A	B	C	D
1	Reactor Trip Time	9:30	9:35	Time Rx trip affec
2	Start Time	8:00	7	Fuel to RCS to
3	Duration (hours)	6	2	
4	End Time	14:00	73	# Intervals
5	Time Interval (mins)	5	5	5
6	Real Time	8:00	8:05	8:10
7	Drill Time	0:00	0:05	0:10
8				
9	User Input Data			
10	% Gap Release	0.00E+00	0.00	0.00
11	% Fuel Melt	0.00	0.00	0.00
12	Is Ventilation On ? (1=yes, 0=no)	0	0	0
14	Containment Leak Rate to Electrical Penetration (cfm)	0.00	0.00	0.00
15	Containment Leak Rate to Personnel Access Hatch (cfm)	0.00	0.00	0.00
16	Containment Leak Rate to Pipe Penetration (cfm)	0.00	0.00	0.00
17	Waste Gas Decay Tank Leak Rate (cfm)	0.00	0.00	0.00
18	Number of fuel assemblies damaged	0	0	0
19	RCS Leak Rate to CCW System (gpm)	0.00	0.00	0.00
20	Relief valve CH-224 flowrate (gpm)	0.00	0.00	0.00
21	Is Surge Tank Relief Valve open or closed? (1=open, 0=closed)	0	0	0
22	Is CH-224 relief valve open ? (1=yes, 0=no)	0.00	0.00	0.00
23	What is the pass sample volume for liquid (cc)?	10.00		
24	What is the pass sample volume for gas (cc)?	10.00		
25	RM-078 Dose Correction Factor	0.50		
26	Containment Leak Rate to Stack (cfm)	0.00	0.00	0.00
37	Sum % Gap (should not be > 100%)	0.00%		
38	Sum % Fuel Melt (should not be > 100%)	0.00%		

Ready CAPS NUM

Figure 3. The scenario planner can define the accident scenario by modifying the input table which is in a familiar Excel-format.

3.4 Off-site radiation

The calculation of transportation of radioactivity and environmental radiation is relatively straightforward. There are plenty of verified models, from compact to big computer applications: RODOS, MEMBRAIN, RIMPUFF, OIVA, AINO, LENA, ROSA etc. However, a realistic presentation could still be developed especially when real weather is going to be used. One recent advance is a training version of SVO+. SVO+ is a Finnish real time radiation control system that receives and displays data also from other Nordic countries. SVO+ is managed by the Finnish Nuclear Safety Authority (STUK). The next figure shows as an example one SVO+ display.

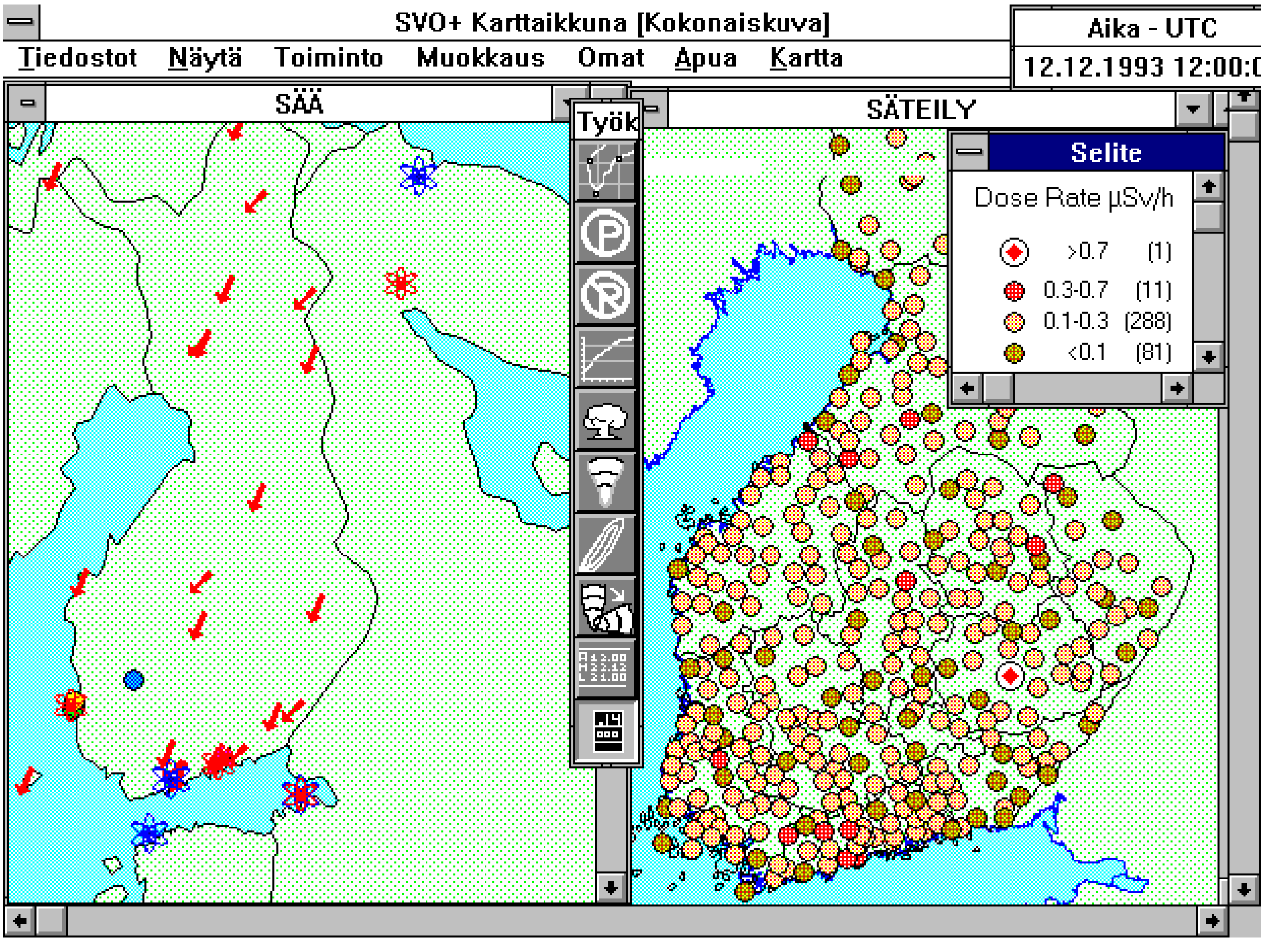


Figure 4. SVO+ displays the prevailing wind conditions and real time dose rates.

3.5 Dose rate monitoring by moving patrols

There are also — relatively new — simulating methods for moving radiation monitoring patrols. These systems make use of computerized plume calculation, global positioning system (GPS) and real-like dose rate monitor simulators:

The exercise planner defines the release or dose rates in the specific area. The moving patrols have "monitors" equipped with GPS-receivers, used for simulating dose- and dose rate measuring devices. The simulator looks like and is operated just like an ordinary dose rate meter. The GPS-receiver takes in position and time from satellites and these values are automatically fed into the simulator's computer which calculates and displays the dose rate for that specific position. By this method any change in position and/or time will give a change in the displayed dose rate.

The exercise method demands that the accident scenario including the weather have been defined in advance.

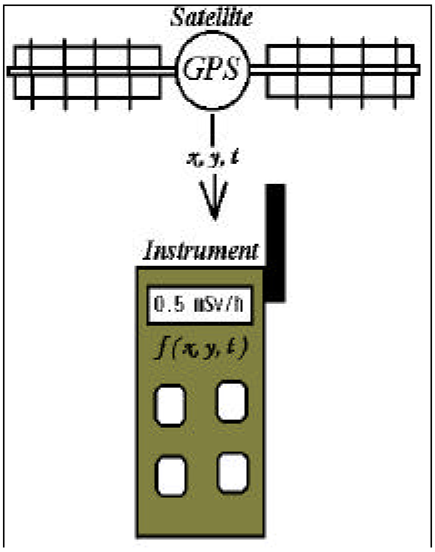


Figure 5: Schematic picture of a simulator for moving patrols.

In Nordic countries therea are (at least) two this type of systems: MARS in Sweden and KATASIMU-96in Finland.

MARS (*Ma*thematical *R*adiation *S*imulation) is developed by FOA NBC-defence with financial support from Statens Räddningsverk. The system has been used in three preparedness excercises.

KATASIMU-96 works together with a radiation survey system KATAMAP-96. KATASIMU-96 can add the postulated radiation data to the real (normal background) radiation as a function of place and time. KATASIMU-96 has been planned to be able to run in connection with the training version of SVO+. KATASIMU and KATAMAP are supplied by KATA ELECTRONICS in Finland. Emergency services college in Finland has acquired KATASIMU-96.

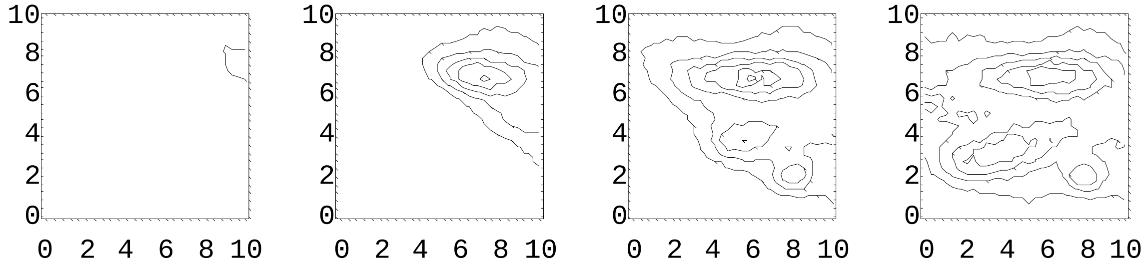


Figure 6: An example of how simulated dose rates, created by a MARS-function, evolves in an area. The area is the same in all four pictures.

3.6 Weather

Related to the off-site radiological consequences and countermeasures also the weather needs its scenario. Until now the weather has been defined in advance so that the excercise planners can prepare the simulated measurement data for the trainers of the radiation monitoring patrols. This manner has enabled also to direct the plume to the preferred geographical area.

The use of postulated weather unfortunately allows neither the use of advanced plume transportation calculation codes nor realistic weather forecasting by meteorological institutes. For these reasons the use of real weather was so desired that in the four large international INEX-2 -exercises in 1996-1999 the prevailing wind conditions are applied.

In the large international emergency exercise INEX-2-FIN in April 1997 (linked to the NKS EKO-4 project) the postulated accident plant was Loviisa in Finland and nearly 30 countries participated. The plume dispersion part of the accident scenario was made by the meteorological dispersion model SILJA. The results were presented both by SVO+ and radiation monitoring team trainees. This choice was made because SILJA models the plume transportation in a more detailed manner than any other Finnish models and it is going to be developed in the future. SILJA simulated the transportation and the consequences (dose rate and concentrations in the air and on the surface), of the (in advance postulated) radioactive release. The ambitious requirement to use real (= prevailing) weather caused the need to prepare for extensive and fast calculation. In this SILJA made success though the IAEA recommendation for one decade ago assessed this to be too time consuming [IAEA SS73]. Yet, this was a single excercise scenario and acquiring a new stable tool would require some additional work.

3.7 Human behaviour

The human behaviour of on-site personnel, near-site population, press, authorities and public forms an essential part of the accidents. In this respect the humans are still irreplaceable.

In the INEX-2-FIN exercise ”human simulators” were used extensively:

Simulation object	Simulation persons	Simulation methods
Newsmedia Radio, TV & News agencies International corresspondents	12 information students from Tampere University and 4-5 professional reporters	Telephone calls, faxes, brieflets; radio broadcasting was simulated by www-pages in internet
Local population	7+7 students from Emergency Services Institute in Kuopio	Telephone calls
Other personnel at power plant (than trainees)	4 persons from Loviisa NPP	Telephone calls
Other utility organizational units than NPP	2 persons from Loviisa NPP	Telephone calls

The personnel for simulation for human behaviour was larger than in previous Finnish rescue service exercises but still was not enough to create a realistic pressure. Yet the human simulators provided the participants with the interface to the newsmedia and radio and so fullfilled the exercise goals. The simulation task in this exercise contributed also to the education of the information and rescue service students. They had been briefed by explaining the nature of the exercise and by informing about the accident scenario and their task was to plan and conduct their intervention. The human simulators worked hard but some actors felt reliefed because they were not posed with questions requiring more thorough expertize and troubleshooting. In future the planning group could give the human simulators in advance well prepared questions and troubles to be presented to the players in due time during the exercise.

4. NEEDS FOR SCENARIO TOOLS DEVELOPMENT

The importance of emergency exercises has been recognized. However, the relative low number of repeated exercises and the large variety of emergency organization and functions limits the possibilities to invest on accident scenario tools. Nordic emergency preparedness experts at power plants and within authorities organizations have been interviewed how interested they would be to develop emergency exercise tools. From the response following conclusions can be made:

4.1 Nuclear countries and non-nuclear countries

Sweden and Finland have a long tradition to arrange large national level emergency exercises that include more or less all the levels: power plant, local emergency services, national boards and newsmedia. The threat phase before a radioactive release and the communication between nuclear power plant and nuclear safety body are essential parts in these excercises. For this reason the accident scenario must include the power plant process, release of radioactivity from the core, from the reactor water and from the plant and the environmental consequences. All these parts must be compatible with each other and the general goals of the exercise, which motivates the development of excercise scenario tools.

Denmark and Norway do not have nuclear power plants in their territory but they have a good preparedness for potential accidents in their neighbourhood. The rescue service organizations have exercised themselves; usually the emphasis has been on the consequences of a postulated release. There are sophisticated radiation monitoring and environmental assessment systems. Developing their use in real-time and real weather exercise gives more realistic accident presentation. Also the authorities in non-nuclear countries tend to activate their organizations already during the threat phase (like in INEX-2-FIN); this goal motivates to have a good understanding of nuclear power plant accident types including their time schedule.

Iceland is more a far-field country and its role has been to follow the messages sent by the authorities from the accident county and interprete this information to the local press and people.

4.2 Technical potential

The technical potential has developed rapidly; the computers have become much more effective and man-machine interface has been developed to be more user-friendly. To many extent the technical potential even exceed the reasonably justified needs.

Accident analysis codes and nuclear power plant analyzers (NPA) have been developed and knowledge on severe accident phenomena has been accumulated.
Each NPP plant or unit is going to have a full-scale simulator of its own. The word ”full-scale” has traditionally meant that the desk and wall panels are full-scale. Yet, the simulation grade of accident progression is still going forward. Applications that are run on work station or even on PC have become available. Their displays have been developed to resemble more and more control room displays. They can simulate accidents and severe accidents much more extensively than earlier.

Off-site radiation monitoring networks report to national computerized radiation control systems. These systems have terminals in many locations. It is not common to have ”exercise versions” of these displays, but this very feasible.

Calculation of off-site radiological consequences has reached a mature level. There are cheap, fast and easy to use near-site calculation systems (e.g. the Swedish LENA) and extensive computer codes that prognose the transportation and radiological consequnces of 2- or 3-dimensional plumes. The off-site radiological assessment systems have been developed rather for accident analyses or for real emergencies rather than for exercises; therefore it is recommended to use real weather with a very large number of measurements weather parameters.

4.3 Training at nuclear power plants

The NPP simulators for control room operators have a long-time history. Because the relatively large number of similar trainees and extensive training needs most NPPs have specific training simulators, usually close to the real plants. Traditionally this simulator training has been oriented to control room operators;
The focus of simulator training has been on normal operations and less severe disturbances. However, the simulators have increased their role in command post emergency exercises. First they were used to produce realistic alarm list of the initiating event and gradually also the whole course of accident.

As the capabilities have been improved the simulators have been used even in an interactive way: the operators, as part of the emergency organization, have been given the right to mitigate the accident, which has increased their motivation foremergency exercises. In large co-operation exercises the full-scale simulators. provide not only the control room but also the NPP emergency operations facility and the nuclear safety authority with extensive amount of safety related parameters.

4.4 Exercises for rescue service organizations

The large majority of people agree that the rescue service authorities need to exercise for radiological accidents. Yet, large co-operation exercises including all the most central rescue service exercises take place relatively seldom, once in 1...3 years. Therefore the internal training within each organization is an essential prerequisite of an appropriate emergency preparedness. Because the expertize within each organization is more homogenous and the number of trainees is smaller, the internal training is easier to organize than the large co-operation exercises.

The rescue service authorities execute the protective actions recommended by the radiation protection authorities. Therefore in off-site exercises the accuracy of accident scenario is not as important as in NPP exercises. However the presentation of accident scenario should be in real time, use the real displays and, in several cases also the real weather.

5. POTENTIAL DEVELOPMENT OBJECTS

The resuce service authorities and nuclear power utilities cannot have significant hands-on experience from real radiation accidents (however, the treatment of the Chernobyl accident has been very beneficial). In many respect the simulation of a real radiological emergency is either difficult or impossible: the field operations, the real stress, the massive input from newsmedia and public. Even the realistic long-time isolation conditions of command posts is often excluded from emergency exercises.

The emergency preparedness training volume must be adequate to give each organization and each person the necessary knowledge and skills. The training of substituting persons has to be ensured. When the planning of an emergency exercise has been started the time schedule is often too tight to acquire new tools for scenario work. Developing a scenario tool requires much more work than preparing a scenario for one single exercise. However, in many areas a good accident simulator can benefit so many exercise that the investment can be regarded as acceptable. Consideration should be given to the following development objects:

- ☑ The ”full-scale” NPP simulators do not, in general, display the dose rates or present the concentrations radioactive nuclides. However the node models have features that enable also the simulation of the radiological parameters; this would increase the realism of accident simulation to control room operators, radiological expterts and, in general, to the command post staff.
- ☑ Improving the simulation of accident phenomena in ”full-scale” control room simulators.
- ☑ PC-based simulators can be used for self-training by control room operators, other NPP personnel; also other organizations than NPP, e.g. nuclear safety authorities and engineering support could in this way increase their familiarity to accident dynamics.
- ☑ Developing ”exercise modes” for off-site radiological monitoring systems would increase the familiarity with the systems that otherwise would display accident conditions only in a real case.
- ☑ The use of real weather in emergency exercises is increasing; this requires reliable fast calculation methods and/or data transmission of simulated measurement results to field monitoring teams. [Rossi].
- ☑ There is one unique simulation program for in-plant radiological simulation; however this aspect of accident is very plant specific and adopting this code requires reasonable tailoring work. [Win-Dose]
- ☑ The simulation grade of ”the external world” (= population, press, non-participating organizations) must always be far below the real level but also this section could be increased. To mention one good example: INEX-1 accident scenario included several carefully planned and written simulation actions.
- ☑ During this work it has been interesting to learn how modern technology offers new opportunities to acquire accident simulation tools. The motivation for emergency exercises is high. In this field NPP utilities authorities, re-

search institutes and commercial enterprise have joint interests. A seminar or rather a workshop would provide a good opportunity to exchange opinions using discussions, presentations and forms to be filled-in.

Acquiring new exercise scenario tools requires investments that exceed the resources required for many exercises; but, in the long run, they will also benefit many exercises. It is expected that areas listed above are progressing. However the pace and ambition level will depend on decisions made at top management level.

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[APROS-based Kola 1 simulator]
APROS-based Kola 1 Nuclear Power Plant Compact Training Simulator; Kari Porkholm, Harri Kontio and Pekka Nurmilaukas (IVO Power Engineering) + Olli Tiihonen, Markku Hänninen and Jukka Ylijoki (VTT Energy) + Leonid Kumkov, Sergey Netchaev and Viktor Pirog (Kola Nuclear Power Plant).

[Rossi] STUK-YTO-TR 114 Ydinvoimalaitosten onnettomuusharjoitusten ympäristön säteilytilanteiden suunnittelu (The planning of environmental radiological scenarios for NPP emergency exercises, in Finnish); Jukka Rossi, VTT Energy; 1996.

[Skrede] Message from Henri Skrede / Ringhals 24.10.1997.

[Win-Dose] Scenario Data Generation Model for Emergency Planning Drills; Earth Technologies; 196 Baker Avenue, Concord, MA 01742 U.S.A.

7. APPENDIX

Emergency exercise scenario tools

- Plant process
  - ”Full scale” -simulators
  - Tailor-made PC-simulators (SIPAct in France & Gösgen in the Switzerland)
  - APROS, MELCOR, PCTRAN
- Plant radiation
  - Win-Dose, completion of ”Full-scale simulators”, MARS, MELSIM
- Off-site radiation
  - RODOS, MEMBRAIN, RIMPUFF, OIVA, AINO, ROSA, SILJA, TRADOS
- Human behaviour
  - Other plant, Other world -people
  - Stored messages/tasks
  - Evacuation of the population
  - Protective actions of the population

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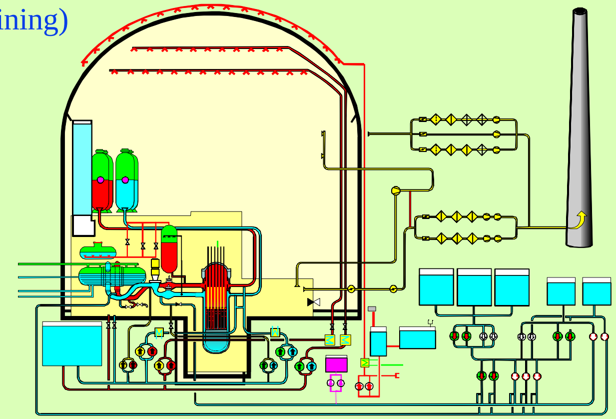
Present features of ”full-scale” simulators

- The thermohydraulics is well simulated even, in two-phase flow in PWR
- Accident simulation can be continued even after core rewetting phase
- Containment pressure can be calculated
- Simulation for operator training is realistic (licensing analysis tend to be too conservative for training)



Operation is so reliable that simulators can be used in large co-operation exercises

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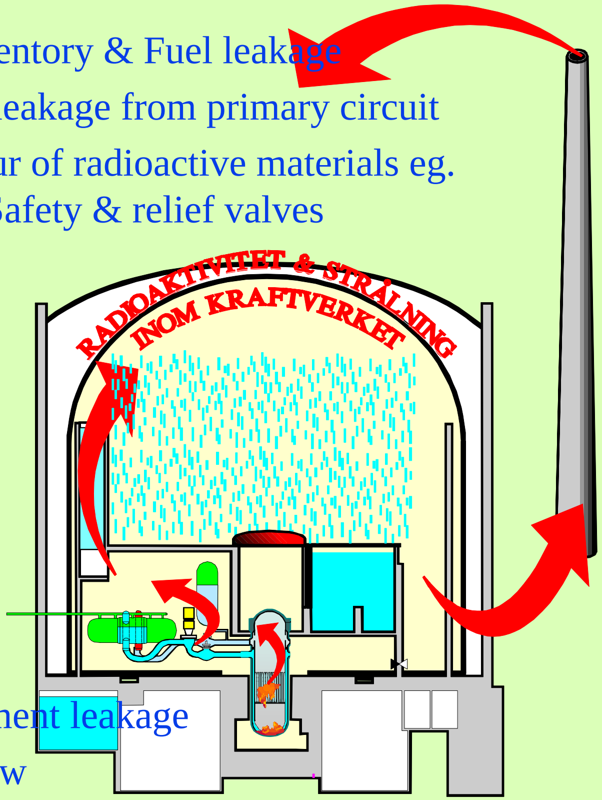
Potential features that could be added to ”full-scale” simulators

◆Core inventory & Fuel leakage

◆Coolant leakage from primary circuit

◆Behaviour of radioactive materials eg. iodine in Safety & relief valves



◆Containment leakage

◆Stack flow

◆Weather presentation

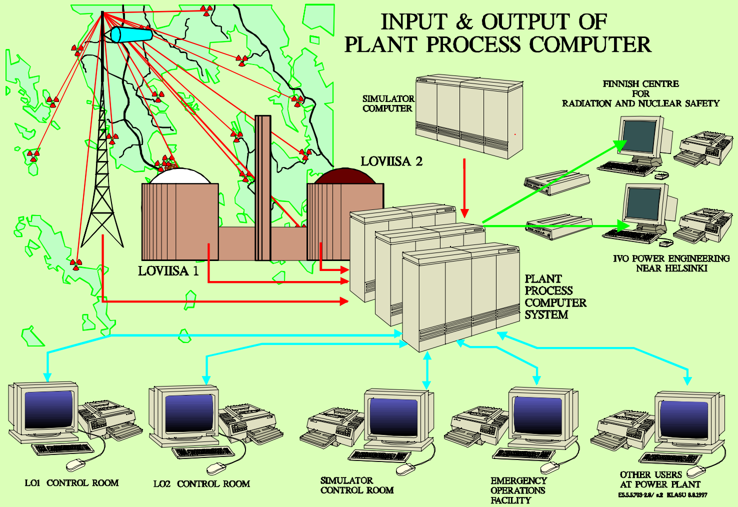
Full-scale simulators are useful for operators and for ...

◆ Technical staff at plant

◆ Plant management

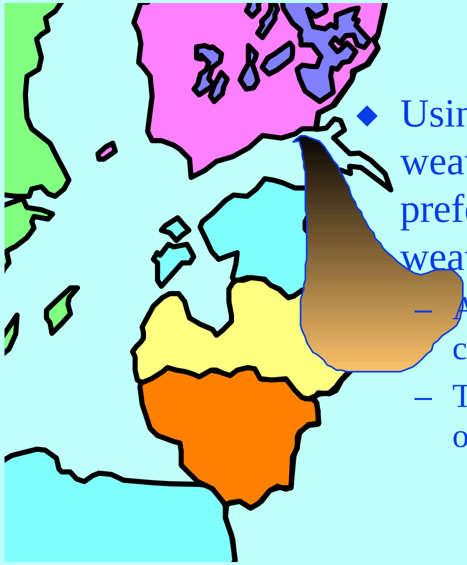
◆ Engineering support

◆ Nuclear regulatory body



Transportation of radioactivity & environmental radiation

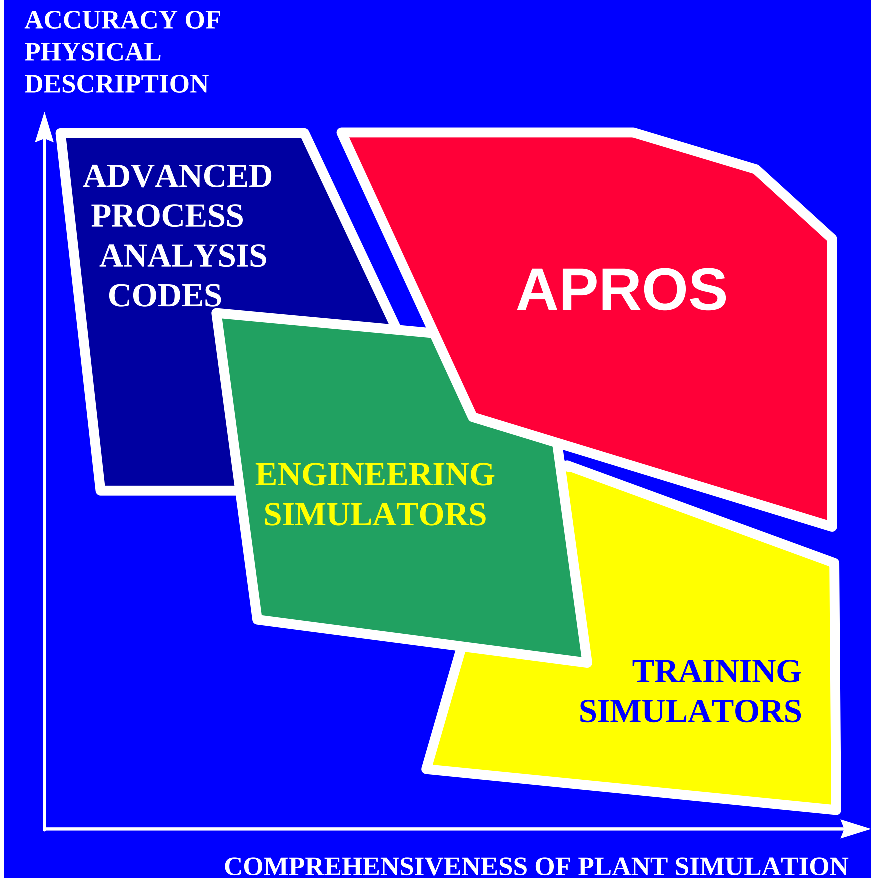
- Calculation is relatively straightforward
- There are plenty of verified models, from compact to big computer applications
- The presentation formats should be similar to those formats that are in real use



- Using the present real weather in exercises is preferred (to a postulated weather):
  - Advanced calculational codes can be used
  - There is motivation to rely on weather prognoses

APROS

EXTENSIVE RANGE OF APROS APPLICATIONS



APROS

READY-MADE MODELS FOR SEVERAL NUCLEAR POWER PLANTS

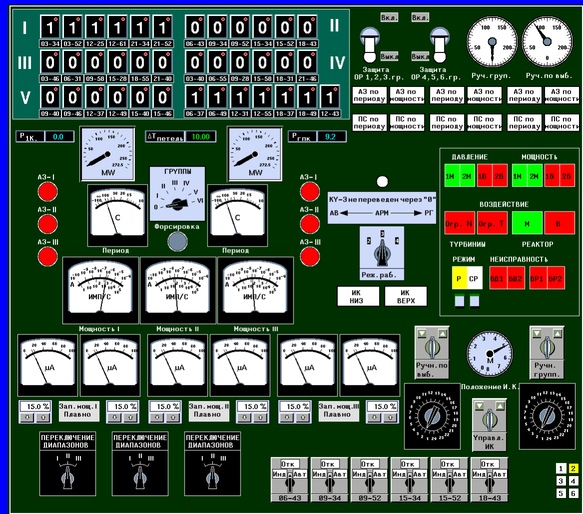
1993	Loviisa 1&2	VVER-440/213
1992	Ringhals 1	BWR
1992-	VVER-91	VVER-1000
1993-	Forsmark 1	BWR
1993	TVO 1&2	BWR
1995	Paks	VVER-440/213
1993	Kola 3&4	VVER-440/213
1994	Kola 1&2	VVER-440/230
1997	Kola compact training simulator	

... and to even more numerous other thermal power plants

KOLA NPP COMPACT TRAINING SIMULATOR

- an extension of the Kola 1 NPP analyzer

- Has been tested: comparison with other calculation results and plant measurements
- Includes about 50 displays that are similar to control room panels:



- Field operator actions taken into account
- Faster than real time

APROS
GENERATING EMERGENCY EXERCISE SCENARIOS?

BENEFITS:

- PROCESS MODELS ARE READY
- HAS BEEN USED IN PLANT SPECIFIC ANALYSIS FOR LOVIISA & TVO NPPS; eg. POWER UPRATING AND PLANT MODIFICATION PROJECTS
- IN TRAINING USE AT KOLA NPP

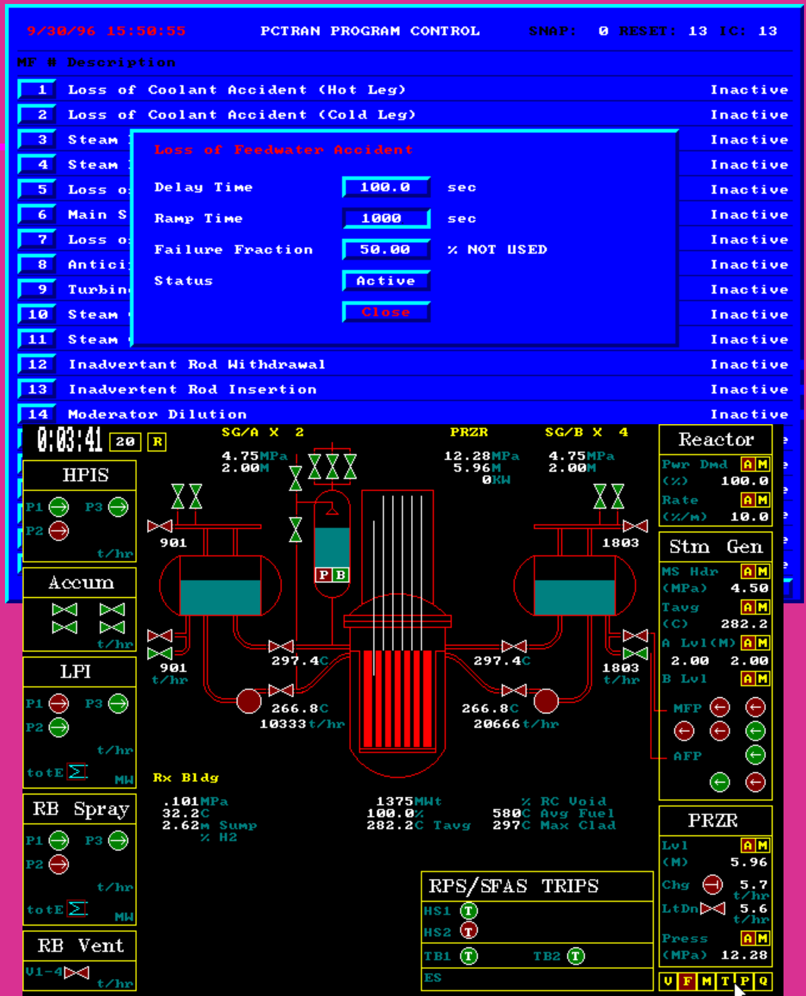
STILL TO DO:

- NOT YET SEVERE ACCIDENT PHENOMENA
- RADIOACITIVITY AND RADIATION MODELS ARE NOT YET INCLUDED BUT CAN BE ADDED
- UNTIL NOW REQUIRES WORK STATION

PCTRAN -
NUCLEAR POWER PLANT TRAINING SIMULATOR

- Models severe accident phenomena inside a nuclear power plant
- Runs on PC
- Much faster than real time
- Not a nuclear power plant analyzer
- Can be used in self studies
- MST (from U.S.A.) has a long list of clients (TVO and 16 others in 1995)
- A DELIVERY CAN INCLUDE:
  - ✓ A basic package
  - \+ Plant specific model
  - \+ Severe accident & radiological models

PCTRAN - displays:



MELCOR is a widely used code for severe accidents

- MELCOR analysis two-phase situations in the reactor and primary circuit, fuel damage, core melt, reactor pressure vessel penetration, core-concrete reactions, hydrogen production & behaviour and containment functions.
- MELCOR is neither as accurate as RELAP nor as complete as full-scale simulators but can analyze severe accidents beyond core uncovery.
- Radioactive materials are in six groups: Xe, Cs, Ba, I, Te and others; their amount and concentration in fuel, primary system, containment/deposits, containment/airborn and environment are calculated

MELSIM - SIMULATOR FOR SEVERE ACCIDENTS

- MELSIM is based on MELCOR but includes also man-machine interface for interactive simulation sessions.
- MELSIM has been developed mainly for Technical Support (for operators) Center training rather than Emergency Operations Facility training (TSC and EOF are American terms defined by NRC).
- Radiological training would require units of radioactivity and dose rate instead of mass units.

MELCOR/MELSIM could benefit emergency preparedness by

- generating accident scenarios (in advance) for emergeny preparedness exercises (like in Kola in 1995);
- providing an interactive plant simulator for operator training
- providing an interactive plant simulator for emergency preparedness exercises;
- generating releases of model accidents (quantity, quality & timing) to emergency plan.

Real time tools for emergency preparedness

ROSA:

- Automatic/interactive dose prediction and follow-up
- Within 20 km.
- In operative use at both Finnish nuclear power plants.
- Could be compared with the Swedish LENA.

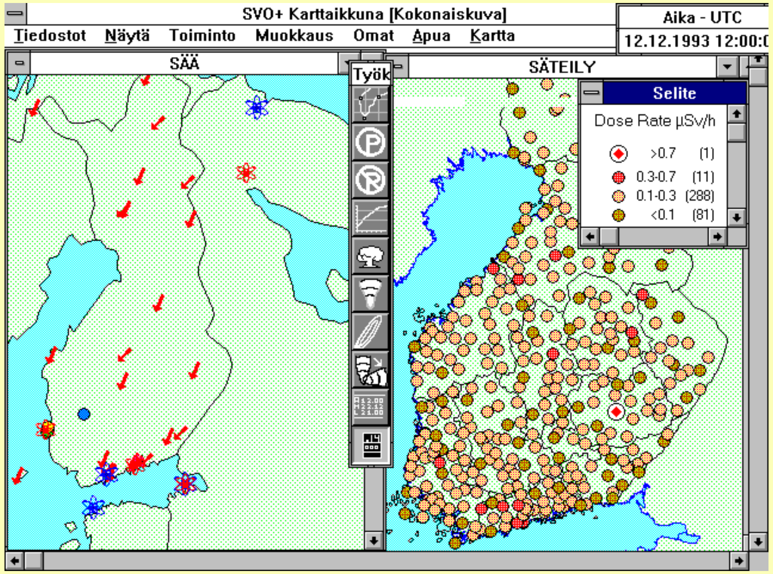
TRADOS:

- Long-range evaluation of trajectories,
- dispersion and external & internal doses;

SILJA:

- Advanced model for atmospheric dispersion and dose analyses
- based on fine-grid HIRLAM under development in co-operation with FMI.

SVO+ is a Finnish national real time radiation control that recieves and displays data also from other Nordic countries



A SIMULATION VERSION of real time SVO+ is at a development stage

Win-Dose is a Radiological Scenario Data Generation Tool

- Microsoft Excel and/or Visual Basic application; **Win-Dose** runs faster in **Visual Basic** than in **Excel**
- Simulates radioactive materials and dose rates inside the plant
- Based on site specific data:
  - Accident types
  - Source terms
  - Radiaton monitor information (eg. the relation of dose rate and radioactive concentrations)
  - Compartment characteristics
  - Output formats

Win-Dose:

the exercise planner defines input for each scenario and the trainees see the output:

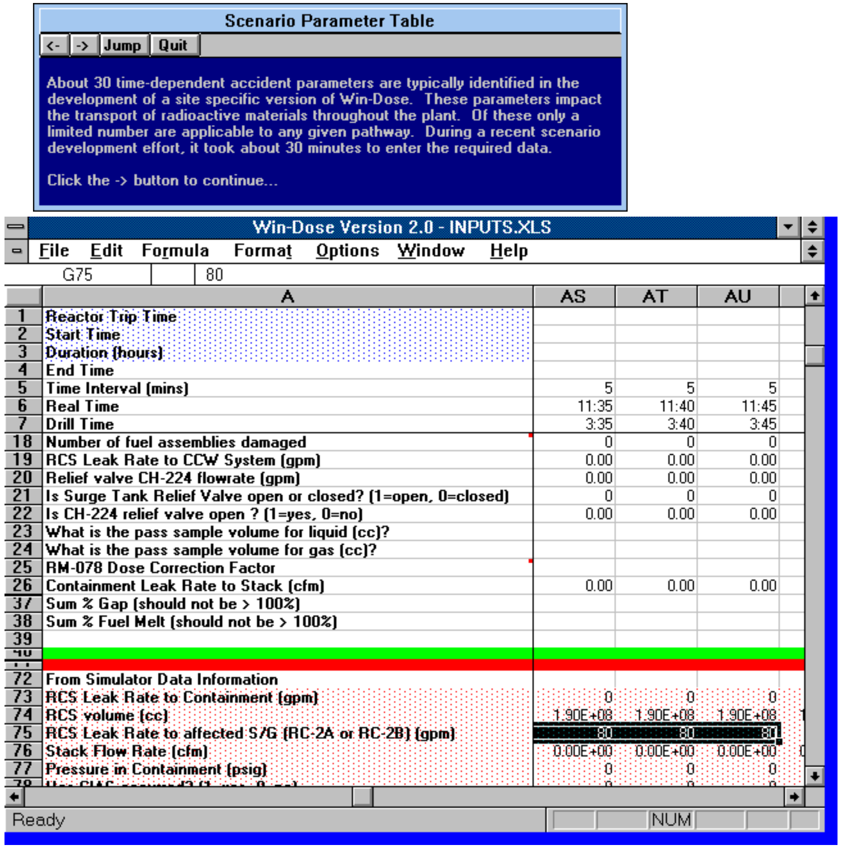
INPUT:

- **Start time**
- **Duration**
- **Accident type**
- **Trip time**
- **Leak rates**
- **Leak pathway**
- **Fuel damage**
- **Plant status**
- **Operational data**

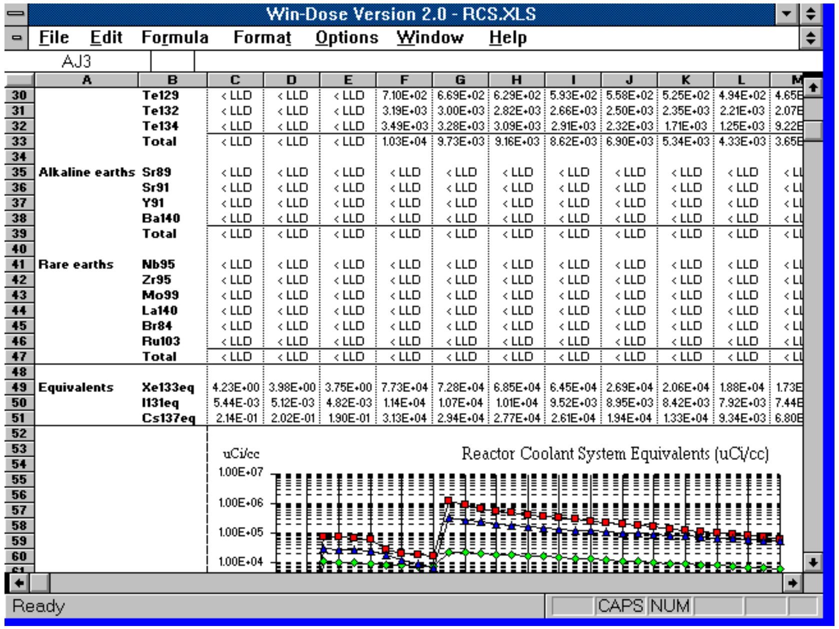
OUTPUT:

- **Inplant contamination**
- **Airborne data**
- **Dose rates**
- **Post accident sample data**
- **SPDS screens**

Win-Dose input will be given by modifying Excel-files:



Win-Dose output in Excel-tables and -graphs:



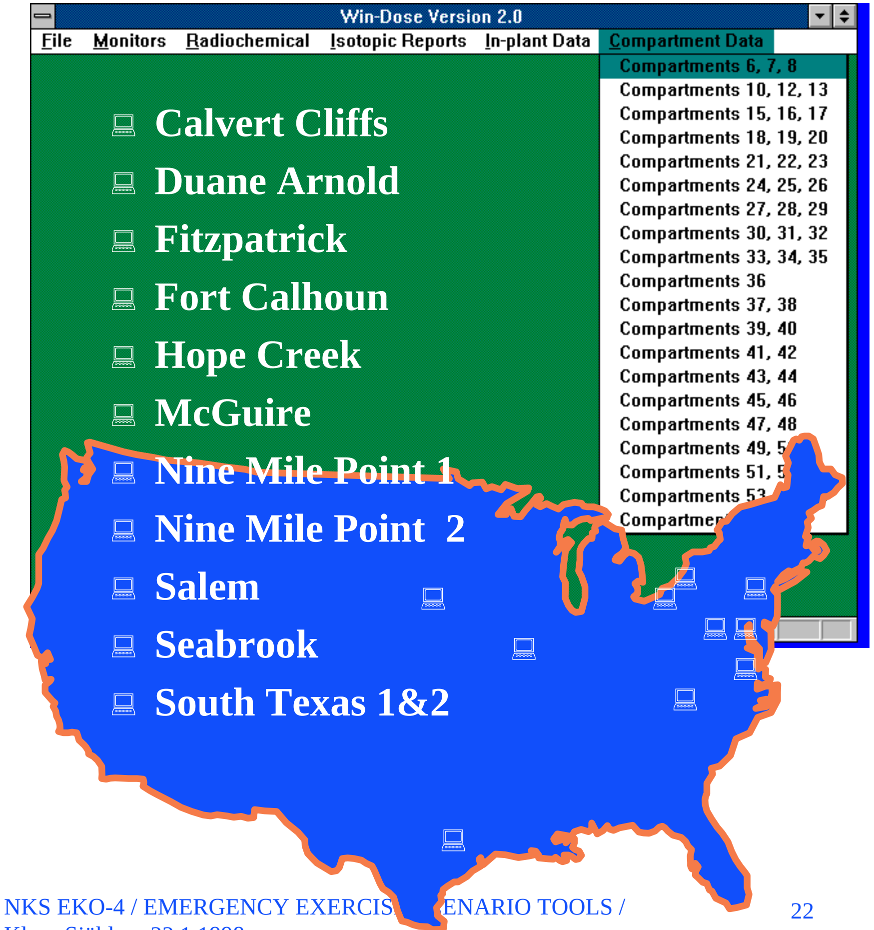
Win-Dose
Plant specific development requires

- data about plant lay-out, ventilation systems, source term inventories etc.
- close work with plant knowledgeable staff
- about 8 months
- The price depends on desired features and the complexity of the outputs.

Options are available to generate

- offsite radiological data,
- ingestion pathway data
- accept downloaded data from a control room simulator and
- generate a file four upload to simulator

Win-Dose users (until winter 1998)**:**
11 plant specific models for:



BENEFITS OF DEVELOPING EMERGENCY EXERCISE SCENARIO TOOLS:

- ☑ Radiation to ”Full scale” -simulators
  - Fits well with the plant process
  - Provide comprehensive accident scenario presentation
  - Can use existing modelling
- ☑ Tailor-made PC-simulators
  - Less expensive alternative
  - For plant operator self-studies
  - For off-site organizations (nuclear safety authorities, research institutes, technical universitys); increases understanding of NPP safety functions and describes the threat phase of an accident

BENEFITS OF DEVELOPING EMERGENCY EXERCISE SCENARIO TOOLS:

- ☑ Plant radiation simulator (like Win-Dose)
- ☑ Off-site radiation with real weather
- ☑ Human behaviour (personnel, population, other organizations)
  - Control room simulators