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Taking CAIRE

20 Years of Experience with the Advanced Emergency Guidance System CAIRE for Nuclear Facilities

For emergency response forces, the Fukushima accident raised the question how appropriate radiation protection measures can be planned and implemented when there are no data available anymore from the affected plant – radiation protection measures both, for the own workforce trying to mitigate the course of the accident and for the general public.

For these cases, the company Brenk Systemplanung GmbH (BS) in Aachen developed the advanced emergency guidance system CAIRE (Computer Aided Response to Emergencies), a self-sufficient system, combining actual radiological measurements with mathematical model calculations to obtain a diagnosis of the source term and the actual radiation exposure as well as dose projections within the endangered area.

The system CAIRE was installed at four ports of the French navy about 20 years ago, and is still working reliably and stable. In the aftermath of the Fukushima accident, a revised and modernised version of the system is planned to be installed also at a nuclear power plant in the northern part of Germany.

To this special issue

It has now been almost 20 years that we, at **Brenk Systemplanung GmbH (BS)**, triggered by the accidents at "Three Mile Island" in 1979 and at "Chernobyl" in 1986, have developed the emergency decision aid system CAIRE (Computer Aided Response to Emergencies) to assist decision makers to stand the high pressure of responsibly managing and mitigating a nuclear accident. The system is designed to work automatically on the basis of telemetric monitoring networks and started operation for the first time at 4 port sites of the French navy in 1992. In cases of incidents or accidents, it has to answer the following questions automatically:

- Where did the incident/accident occur?
- Which radionuclides are being released?
- What are the release rates?
- What is the actual radiation exposure?
- How will the incident/accident develop?

Due to the Fukushima accident, these functionalities have reached sad relevance. Based on the demand of our client, a large NPP of a German power utility company, we are planning a modernised CAIRE system to be installed at this NPP and the Nuclear Emergency Service (KHG). Currently, the conceptional work is under way.

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MANAGING EMERGENCIES

Whatever the specific reason for a nuclear emergency may be, a quick and accurate estimate of the consequential radiation exposure must be made before decisions about protective measures as well as on-site and off-site emergency management can be made. With these facts in mind, the importance of remote, telemetric monitoring systems has increased at least after the Chernobyl accident as an inherent part of environmental surveillance installations in many European countries. Most of the existing systems are designed to cover both, routine operation and emergency situations, normally providing site-specific meteorological data, gross effluent dose rates, and dose rate measurements on-site and at approximately 30 off-site locations near the source. In some cases there may also be off-site concentration measurements for gaseous iodine, aerosols and noble gases. Based on such telemetric surveillance networks, about 20 years ago the system CAIRE was developed by BS for the French navy and is being used at four sites as a real-time emergency response tool since 1992. This tool is designed to provide decision makers with precise radiation exposure data for the on-site workforce and the population at risk.

Fig. 1: Self-sufficient dose rate measurement device

A NEED FOR ACCURACY

The accuracy requirements for the radiological evaluations performed by CAIRE are defined by national and international emergency response guides. Most guides use order-of-magnitude estimates to differentiate between various possible protection measures, such as: taking shelter, ingesting iodine tablets or arranging evacuation. Thus, the reliability of the assessment given by CAIRE must be significantly better. This requirement cannot be accomplished by mathematical model calculations or by measurements alone but can only be fulfilled by a combination of both approaches.

The development of CAIRE has therefore been based on some key considerations: mathematical model calculations have the advantage of supplying consistent interpretations of real and potential radiation impacts as a consequence of emergencies, but the accuracy of their assessment is limited; actual measurements are free from large uncertainties and assumptions, but their decisive disadvantage is the fact that a steadily growing quantity of measurements, different in their physical character and taken at a variety of locations and during various periods of time, can hardly be interpreted without the support provided by interpolating model calculations.

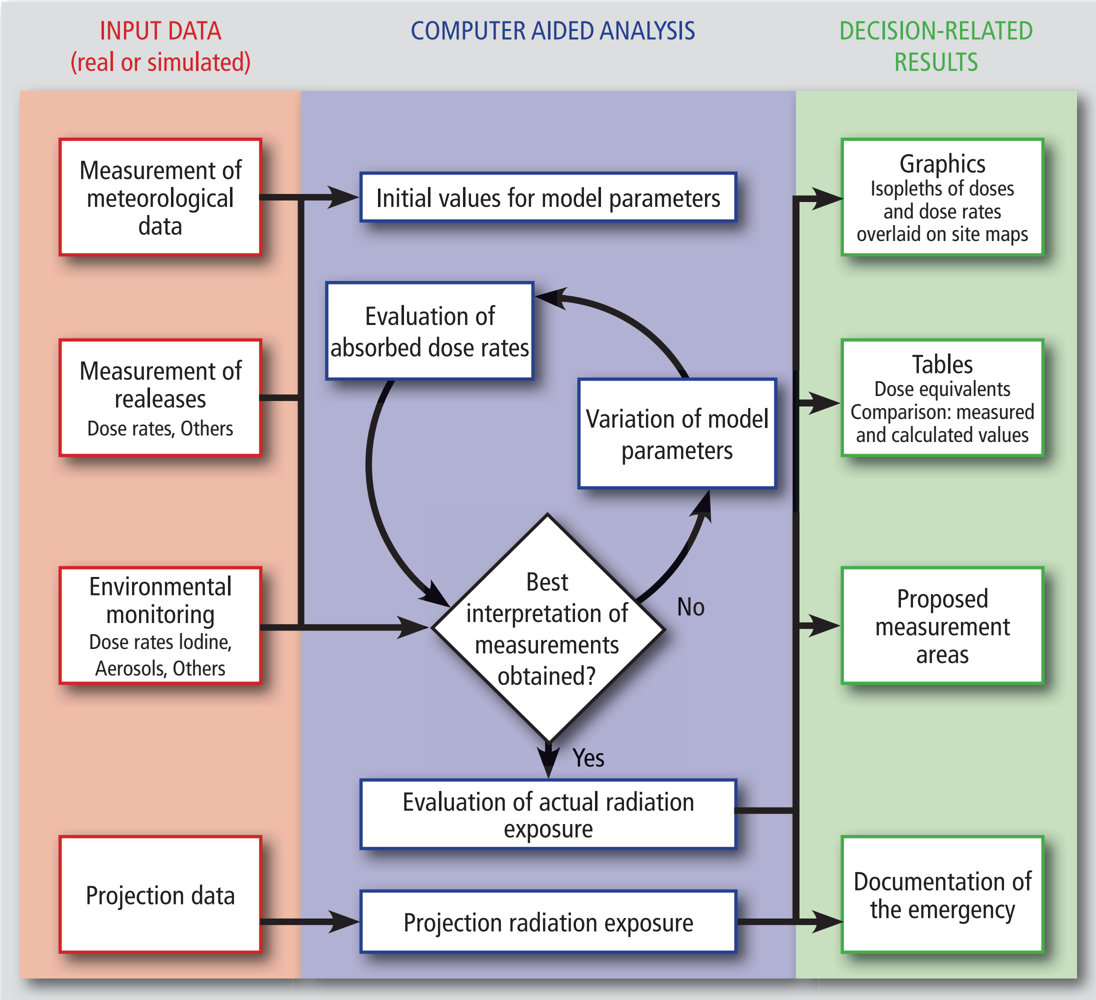

Fig. 2: Logical structure and data flow in the decision aid system CAIRE

The advantages and disadvantages of measurements and model calculations are essentially complementary. It therefore was an obvious step to merge the two decision aids so that the deficiencies are mutually compensated. This is achieved in CAIRE by a continuous feedback of actual measurements into model calculations in order to bring calculations and measurements into the best possible correspondence, and to supply consistent information about the actual exposure situation in the endangered area (see fig. 2). This procedure also forms the best basis for further projections of the radiological situation. Moreover, decision-makers cannot wait, so all the relevant information has to be supplied in real time, i.e. before any decision is necessary, and before significant changes in the radiological situation occur.

Depending on the layout of the telemetric networks connected, CAIRE is able to fulfil the following main functions. It automatically:

- identifies the source location,
- determines the source term (amount, composition and time-dependence),
- diagnoses the actual radiological situation and
- identifies the endangered area.

It also:

- projects the radiological situation with and without protective measures, and
- delivers all this information in the form of easily understood computer graphics.

OPERATING EXPERIENCE

In 1991, the French navy decided to install remote monitoring networks together with CAIRE at four French sea-ports where nuclear submarines and aircraft carriers are built and maintained. Three of the harbours are at the Atlantic Ocean, while the fourth is at the Mediterranean Sea. All four sites comprise densely built-up areas, but with completely different orography. While one site is rather flat, the others have large hills, steep cliffs, up to 40 m high, and deep river valleys. The Mediterranean site is even adjacent to 600 m high mountains. Consequently, the question arose as to whether CAIRE, with its comparatively simple homogeneous wind field and Gaussian puff dispersion model, would nevertheless, be able to provide sufficiently accurate and reliable results. Thus parallel to

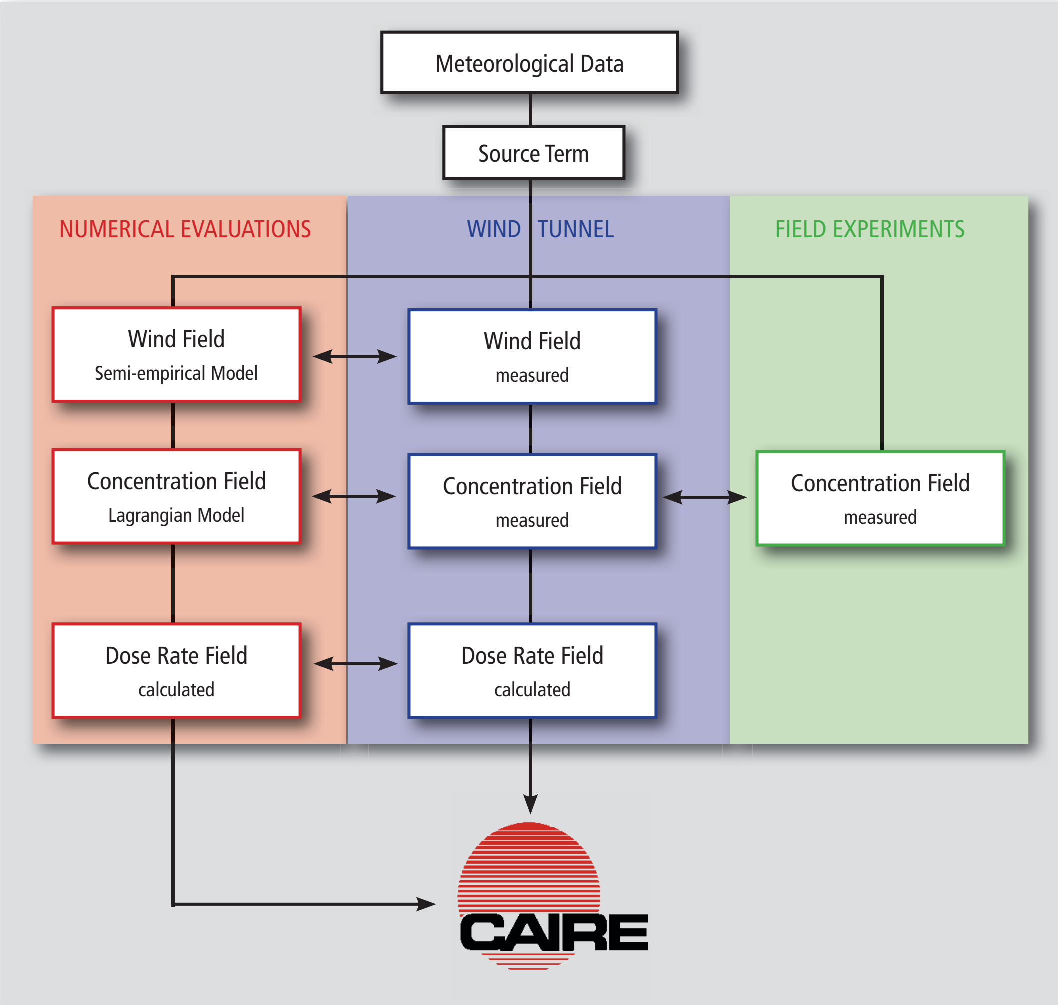

Fig. 3: The three branches of the validation procedure

the installation of CAIRE, an extensive validation / adaptation program was set up to address this question in particular.
The performance of the nuclear surveillance system for the French navy as a whole depends significantly, among other things, on the layout of the remote monitoring network. The operation of the system was optimised by optimal siting of each of the measurement devices, considering the neighbouring orography, building structures, vegetation and potential radiation sources. Because of its experience in this field, BS was responsible for this part of planning work.

Between July and December 1992, CAIRE started operation at each of the four sites, having passed the obligatory acceptance tests. Additional acceptance tests included testing the results of the accompanying adaption and validation programme.

ADAPTION AND VALIDATION

Clearly, a rigorous validation of an emergency guidance system like CAIRE would preferably be achieved on the basis of a comprehensive set of measurement data from a real incident or accident at the respective site or data from comparable field experiments with radioactive tracers. Since this is no viable option, the French navy initiated a validation programme which was designed to meet, as closely as possible, the rigorous requirements mentioned. To this end a three-branch strategy was defined (see fig. 3) to simulate site-specific quasi-measurement data as input information for CAIRE in lieu of real accident data. This was achieved with the aid of numerical evaluations, wind tunnel experiments and tracer experiments in the field.

Numerical evaluations

The first branch (see fig. 3), performed by BS, was used to simulate hypothetical emergency scenarios with a Lagrangian dispersion (or particle) model together with a diagnostic (semi-empirical) wind field model which takes into account building clusters and the orography of the sites. The advantages of this method are that it provides complete sets of input data for dynamically changing site-specific weather conditions and releases of radionuclides. These simulations result in values for dose rates and radionuclide concentrations at the respective locations of the dose rate monitors and concentration measurement devices in the telemetric networks. These data are used as quasi-measurement input data normally supplied by the telemetric networks in the case of an actual emergency. In order to quantify the performance of CAIRE, these input data are compared with the respective data generated by CAIRE's feedback procedure. The results of this comparison are discussed later.

Wind tunnel experiments

The second branch relies on wind tunnel experiments with non-radioactive tracers being performed by the Centre Lyonnais d'Ingénierie (CLI) of Electricité de France (EdF). These produce values of pollutant concentrations in air and information about the wind field at several hundred points for each site. In order to generate adequate input data for CAIRE, the experimental results are completed by numerical evaluations of dose rate fields made by the French navy. In comparison with the dynamic numerical evaluations of the first branch, the second branch is limited to steady-state situations only.

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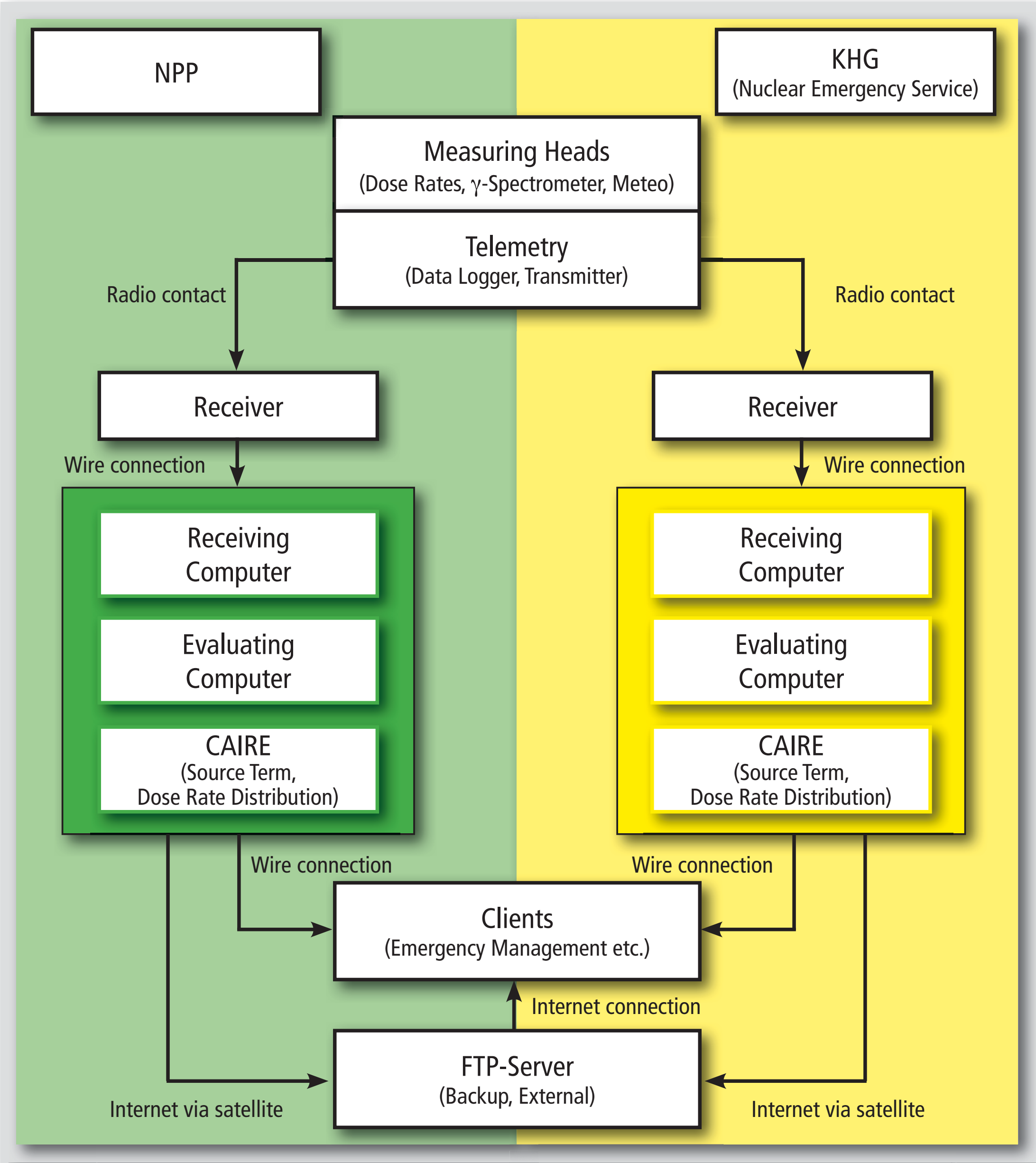

Fig. 4: Layout of the planned wireless telemetric monitoring network with the emergency guidance system CAIRE

Field experiments

The third branch is given by field experiments at each site, under the guidance of the Institut de Protection et de Sureté Nucléaire (IPSN), using SF_6 as a tracer. The experiments determined concentrations at about 20 points close to the ground in the dispersion direction. To be comparable with the wind tunnel results, neutral weather conditions with nearly constant wind direction have been chosen.

To control the particular deficiencies of each of the specific branches in the diagram, field experiments were used to validate the wind tunnel results by comparing the concentrations. The wind tunnel experiments, on the other hand, served to validate the numerical branch. This was done in three stages by comparing the measured wind fields with the calculated ones and the measured concentration fields with the calculated ones. In the third stage, the dose rate fields evaluated on the basis of the measured concentration fields were compared with those based on the calculations. Having ensured in this way the reliability of the input data for CAIRE, the next step was carried out: the simulation of emergency situations as explained above. The total amount of simulated emergency data per site used in CAIRE corresponds to time periods of up to about six hundred hours.

EVALUATING THE RESULTS

Generally speaking, the quality of CAIRE's results, after adaption, depends only slightly on the complexity of the site. The validation results show for both flat sites and for complex sites that the typical deviations between calculated and "measured" dose rates remain well within one order of magnitude. "Measured" here denotes those dose rates fed into CAIRE as a result of the numerical branch (see fig. 3) of the work.

Concerning the source term assessment of CAIRE based on impact measurements, the validation results show an accuracy much better than one order of magnitude. In fact, the typical deviations of the cumulated releases are within factors of about two at flat sites and three at orographically complex sites.

CURRENT PLANS AT GERMAN NPPs

It is currently planned to install an updated version of the system CAIRE of Brenk Systemplanung GmbH, Aachen, together with a telemetric wireless monitoring network of Saphymo GmbH, Frankfurt, as a completely self-sufficient system in a form shown in the figure above. (see fig. 4)