FAST Nuclear Emergency Tools (FASTNET project)

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Minutes of the FASTNET School

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Summary

In the framework of the FASTNET project, a School on Emergency Preparedness and Response, open to all interested stakeholders, has been organized in Bologna, Italy. Along with the standard and classical themes of Emergency Preparedness and Response, lectures on the fast-running methods and tools developed within the project, namely 3D/3P, PERSAN and RASTEP, were also given. This Deliverable collects the minutes of the FASTNET School.

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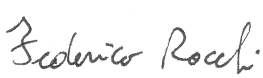
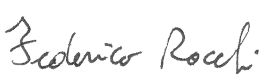
Signatures			

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Content

GLOSSARY / ABBREVIATIONS

CFD	Computational Fluid Dynamics
DSA	Deterministic Safety Assessment
DSS	Decision Support System
EP&R	Emergency Preparedness and Response
EPZ	Emergency Planning Zones
EUG	End-Users Group
FASTNET	FAST Nuclear Emergency Tools
FP	Fission Product
IEC	Incident and Emergency Centre (IAEA)
LNT	Linear No Threshold
MCCI	Molten Core-Concrete Interaction
MS	Member State
NPP	Nuclear Power Plant
PSA	Probabilistic Safety Assessment
RDD	Radiological Dispersal Device
SA	Severe Accident
SAM	Severe Accident Management
SBO	Station Blackout
SFP	Spent Fuel Pool
ST	Source Term
STV	Source Term Volume
WP	Work Package

1 INTRODUCTION

As part of the activities related to Dissemination and Education & Training within WP5 of the FASTNET project, a School dedicated to EP&R has been organized by ENEA and IRSN in Bologna in the week 21-25 January 2019. Aim of the School was to give a picture of the whole chain of competences needed to manage nuclear emergencies at NPPs, including those pertaining to the methods and tools developed within FASTNET to estimate quickly the ST. The School was open not only to FASTNET partners or members of the FASTNET End-Users Group (EUG), but also to any stakeholder potentially interested in strengthening its capabilities in the field of EP&R. 48 persons attended the School, including the lecturers; among them, also some master thesis and PhD students. All the School material has been made publicly available on the FASTNET website. What follows is a summary record of the School contents.

2 STRUCTURE OF THE SCHOOL

The Agenda of the School is reported in Appendix 1. Each lecture lasted 1 hour and 45 minutes, including a final question time. The first lecture was about the fundamentals of radiation protection and was aimed at pointing out how radiation dispersed in the atmosphere or deposited on ground surfaces induces doses, and how doses can be related to health effects. The basic idea was to pinpoint the fact that in order to estimate doses, fundamental quantities, like time-integrated air concentrations and surface depositions, need to be calculated for each isotope of radiological importance. Having set this goal, the School then proceeded to provide insights in how to estimate time-integrated air concentrations and surface depositions; this is naturally done by the numerical simulation of atmospheric transport of the ST. Therefore, two lectures were dedicated to the phenomena, which determine a release of radioisotopes from an NPP undergoing a SA, and to their best-estimate modelling. However, in order to have timely estimates of the ST, special tools need to be developed and then used during emergencies. The lectures on STs were then completed by another lecture on the fast-running methods and tools developed within FASTNET, namely PERSAN and RASTEP. One lecture was then dedicated to the basic phenomena pertaining to atmospheric transport, followed by another on the main radioisotope transfer chains and exposure pathways to take into account long-term effects in dose calculations. This first set of lectures, which treated the fundamentals of the physics of EP&R, was then followed by another set, dealing with (DSSs) typically used in Europe to perform atmospheric transport and dose calculations, JRODOS and ARGOS. The calculation framework was then complemented by a lecture on environmental monitoring techniques and data, including the European data exchange system. After that, the School proceeded in showing the international context in which EP&R activities are conducted; a lecture on the existing international conventions and exercises was given, followed by two lectures on IAEA role in EP&R and communication during emergencies. One final lecture was about health consequences of doses and the monitoring and treatment of people.

In the last part of the afternoon of January the 22nd, three videos on emergency drills performed in France and made by IRSN were shown.

On the last day, an exhibition of the experimental devices and technical vehicles in use at the Italian Fire Brigades, in charge of first response on the field during nuclear or radiological emergencies, was made. Three international companies developing specific products for EP&R were also invited to show some of their material.

3 LECTURE ON FUNDAMENTALS OF RADIATION PROTECTION

This lecture was given by Carlo Maria Castellani, of the Institute of Radiation Protection of ENEA. The specific themes dealt with were: radioactivity types and decay law, effects of radiation, quantities and units, examples of received doses, principles of radiation protection, recommendations, directives and laws, modalities of exposure, comparison of doses from different radionuclides, actions to mitigate exposure, tools for dose assessment and dose coefficients, and some examples of dose assessment based on measurements in air. This last part of the lecture was extremely important, in which it showed with practical and simple examples how to link physical quantities, like time-integrated air concentrations and ground depositions, to doses. These were the doses in Bologna due to the ^{131}I from the Chernobyl accident, the doses in Italy due to the ^{131}I and ^{137}Cs from the Fukushima accident, and the doses in iodine due to the ^{106}Ru episode of 2017.

Of particular interest was the very clear distinction between early, deterministic effects of radiation exposure and the late, stochastic effects.

The modes of exposure were also detailed, showing how the dose coefficients are calculated, as a function of age, organ, breathing rate, etc.

The efficiency in time of iodine blocking was also discussed, pointing out how the time of radioactive cloud passage should be rather well anticipated by the chain of simulations used during emergencies.

4 LECTURES ON MODELLING AND CALCULATION OF SOURCE TERMS

Two lectures were dedicated to ST modelling and calculation, and were given by N. Arnold, of BOKU University, and by E. Urbonavicius of the Lithuanian Energy Institute.

The lecture by N. Arnold was focused on SA phenomena and SA codes. It dealt with the typical issues in the “in-vessel”, “ex-vessel” and “containment” phases of SA progression. It also presented some insights in SA research and experimental programs and facilities, needed for the experimental validation of SA codes. Then, the three major SA codes, MELCOR, ASTEC and MAAP, were introduced, with special emphasis on MELCOR. Finally, a practical, detailed example of calculation with MELCOR of a long-term SBO sequence for a VVER-1000 NPP was shown.

The lecture by E. Urbonavicius was centered on the NPP containment, the last barrier to atmospheric release in case of SAs. It dealt with containment types, SA phenomena in the containment, containment failure modes, and provisions to prevent containment degradation. Attention was paid to the MCCI phenomena, and hydrogen and steam explosions. Then, the various mechanisms for the retention of fission products (FPs) were introduced, including the various, possible release pathways to the atmosphere.

5 LECTURE ON FAST-RUNNING CODES

This lecture was dedicated to show how fast-running codes can be used to calculate STs in case of emergencies, and in particular to present the two codes developed within FASTNET, namely PERSAN and RASTEP. The lecture was divided into two parts, one dealing with RASTEP, given by A. Riber-Marklund of LR, and the second dealing with PERSAN, given by O. Isnard of IRSN.

The part on RASTEP showed how PSA-1 and PSA-2 data and DSA data can be coupled through an appropriate BBN describing a given plant type. The basic principles of a BBN

were then shown through a couple of examples. For an NPP, this translates into the definition of the physical ST volumes (STV) to be considered, together with the release routes for FPs, the possible initiating events, the threatening phenomena and the systems and actions relevant to SAM. Then the generic plant models developed within FASTNET (PWR, BWR, CANDU6, VVER-440, generic out of containment SFP) were introduced. As an example of code use, some preliminary results from FASTNET WP4 Exercise 1 were given for PWR, BWR and CANDU6. Finally, the newly introduced IRIX export function was shown.

The part on PERSAN was preceded by general remarks on the role of fast and accurate ST prediction for EP&R; this was also linked to the general ideas behind EPZs. The previous French practice on this, based on a deterministic approach and on the use of three reference STs (ST1: accidents with early containment failure; ST2: accidents with delayed containment failure without filtration; ST3: accidents with delayed containment failure and with filtration) was also presented. ST3 was used for EPZ. Then, the importance of the kinetics of the release versus meteorological conditions was emphasized through the example of Fukushima. After that, the differences and the requirements during a response to a SA were discussed. An overview of the SESAME 4 system was given, and then the PERSAN code was explained. The simple conservation or balance equations for FPs were shown. A discussion on the recent developments (new reactor types and IRIX export function) of PERSAN within FASTNET concluded the lecture.

6 LECTURE ON ATMOSPHERIC DISPERSION MODELLING

This lecture was given by W. Raskob from KIT. It included a description of the structure of the atmosphere and its main features, and of the planetary boundary layer. The terrain roughness parameter was introduced, and how it influences the wind speed vertical profiles. The important differences between the s.c. Neutral, Unstable and Stable plume conditions were given, as well as how to classify the atmospheric stability (Pasquill classes and associated plume parameters). Some basic atmospheric dispersion models were then introduced, namely the Gaussian Puff Models ATSTEP and RIMPUFF, the Puff-Particle Model DIPCOT, as well as CFD ones. Some hints on how to model plume rise were given for different release conditions. Wet and dry deposition phenomena were discussed, together with the associated cloud and source depletion. Wake from buildings was quickly presented.
Some examples of direct and backward atmospheric dispersion calculations were then given using Fukushima as reference scenario.
Finally, some considerations on how to deal with atmospheric forecast data uncertainties and weather ensembles were provided.

7 LECTURE ON TRANSFER CHAINS AND EXPOSURE PATHWAYS

This lecture was given by W. Raskob from KIT. It dealt with long-time effects of radioactive releases on human health and environment, in particular focussing on the terrestrial food chain. The basic processes of transfer in the food chain were shown, from plants to the human body, like direct consumption or through processing to foodstuff, or through animal products. Foodstuffs in the food chain model for Central Europe were then shown. The main features of the mechanisms of interception of wet deposited radionuclides on plants were introduced as a function of the time of the year for European conditions. The lecture then moved to the mechanism through which plant products become contaminated (root uptake). Examples involving several plants and vegetables, as well as milk, were reported. The case of Fukushima was presented, including the aquatic food chain (irrigation of crops, drinking water, feed water for animals, production of fish). Making then reference to the

ERMIN module of JRODOS, the contribution to the dose from contaminated buildings in an inhabited area was highlighted. The importance of shielding from external exposure from ground was also introduced, with different examples of various types of buildings.

8 LECTURE ON DECISION SUPPORT SYSTEMS

This lecture was split in two parts, one, given by W. Raskob from KIT, dedicated to JRODOS, another, given by S. Hoe from DEMA, focussed instead on ARGOS. Both presentations were targeted at introducing the two DSSs and their main features.

The main atmospheric dispersion modules of JRODOS were discussed (LSMC, Rimpuff, ATSTEP, Dipcot, LASAT, etc.), together with the modules for the calculation of doses in the early phase and the modules for the study of recovery in the long-term post-accident phase. The hydrological models recently introduced in JRODOS were also touched. The aquatic models, as applied to Fukushima, were briefly discussed. Some examples of application of JRODOS in Germany related to the update of emergency measures were given. Off-site EPZs in Germany were structured to have intake of stable iodine for children and pregnant women at distances <100 km; intake of stable iodine for adults for distances <25 km; evacuation and sheltering at distances <10 km. Three representative NPPs have been selected for the updating study: Unterweser, Grohnde and Philippsburg. Weather data covering one representative year were used, together with three different STs. Because of these calculations, new planning areas were then formulated: evacuation up to 20 km; sheltering and iodine tablets up to 100 km, and iodine tablets for the whole German territory.

As far as ARGOS, the general software architecture was presented together with its server & client and their associated functions. The dispersion models within ARGOS for the different scales (URD, Rimpuff, DERMA) and the related sources for weather data were introduced. Some examples, mainly related to Fukushima, were given. Some insights were put forward on RDDs and urban dispersion too. The import of monitoring data is also possible within ARGOS, and this was shown, for both national networks, portable devices, and EURDEP data. The standard ANSI 42.42 is used throughout the software. Uncertainty in numerical weather prediction through ensemble data is currently managed by ARGOS.

9 LECTURE ON ENVIRONMENTAL MONITORING AND EU DATA EXCHANGE SYSTEM

This lecture was divided into two parts, the first by G. Iurlaro of ENEA on Environmental Monitoring, and the second by M. Sangiorgi from JRC on the European Data Exchange System.

As justification and legal basis for the provisions for environmental monitoring, it was remembered that article 35 of the Euratom Treaty specifies that Member States must ensure that an appropriate programme to monitor the level of radioactivity in the environment is in place. Moreover, article 36 asks that Euratom Treaty Member States report the results of such monitoring to the European Commission. The final aim of these two articles is of course the protection of the public and the environment. The differences between routine and emergency monitoring were pointed out, as well as those between site monitoring and national/regional monitoring. Sampling strategies and measurements were noted, for airborne particulate, soil, surface water, drinking water, milk and other foodstuff. Laboratory measurements were then compared to direct measurements. Examples from national, yearly reports were also shown. Then, environmental radioactivity monitoring networks were introduced, dealing with both air sampling stations and gamma

dose rate stations, and pointing out advantages and disadvantages of both. European national networks were described, together with typical alert and alarm thresholds (fixed or relative); usual values are 300 nSv/h for the Alert threshold, and 400 nSv/h for the Emergency threshold, this being about 3-4 times higher than natural background. Finally, the fundamentals of environmental monitoring during emergencies were introduced.

The presentation on the EU Data Exchange System was introduced by a description of the activities carried out by the JRC/REM Unit to deal with the aforementioned articles of the Euratom Treaty. In particular, the following four main activities were detailed: REMdb (Euratom art. 36 database), EANR (European Atlas of Natural Radiation), ECURIE (European Community Urgent Radiological Information Exchange), and EURDEP (European Radiological Data Exchange Platform). The first two activities are related to routine cases, while the second two are related to emergencies. The Radioactivity Environmental Monitoring Databank (REMdb) was created in 1988 in the aftermath of the Chernobyl accident to keep a historical record of the Chernobyl fallout and to store the radioactivity monitoring data gathered through the national environmental monitoring programs of the EU MSs. It is a unique collection of environmental radioactivity measurements from 1984 onwards (air, water, foodstuff), which contains more than 5 million measurements. The ECURIE system is the practical implementation of the Council Decision 87/600. It is the early notification system for nuclear/radiological accidents of the EC. When a Member State decides to take counter-measures, it shall forthwith notify the Commission and the affected MSs. This Council Decision was taken to assure better preparedness and response to transboundary events as caused by the Chernobyl accident. It is similar to the USIE system of the IAEA IEC. EURDEP was created to favour the timely and free exchange among MSs and other European participants of information relevant to the radiological situation to support nuclear emergency response. It consists in storage and further dissemination of gamma dose rates and airborne radioactivity concentration measured by the networks described in the first part of the lecture. The European Atlas of Natural Radiation is a collection of maps displaying the levels of radioactivity caused by different natural sources in Europe. It is intended to familiarise the public with the radioactive environment.

10 LECTURE ON INTERNATIONAL CONVENTIONS AND EXERCISES

This lecture was given by P. Zeppa of ISIN. It provided the international legal framework for EP&R, in particular the two international conventions under IAEA, namely the Convention on Early Notification, and the Convention on Assistance. Both conventions were quickly put in place after the Chernobyl accident in 1986. It then moved on to show the European framework, followed by some details on the recent case of ^{106}Ru in Europe, as well as on the existing international exercises and drills.

The Convention on Early Notification places obligations on MSs and IAEA in the event of any accident involving facilities or activities of a MS from which a release of radioactive material occurs or is likely to occur, and which has resulted or may result in an international transboundary release that could be of radiological safety significance for another MS. As a counterpart to the EURDEP system described in the previous lecture, the IAEA IEC USIE system was introduced, together with the EMERCOM forms to share information on emergencies. The EP&R categories, as specified in IAEA GSR Part 7, were explained in detail, and emphasis was given to Category V, in which transboundary cases are enveloped. In addition, the types and typical distances for emergency zones (PAZ, UPZ, EPD, ICPD) according to IAEA EPR-NPP Public Protective Actions document were listed.

The Assistance Convention states that MSs shall cooperate between themselves and with the IAEA to facilitate prompt assistance in the event of a nuclear accident or radiological emergency in order to mitigate its consequences. If a MS needs assistance, it may call for

such assistance from any other MS, directly or through IAEA; each MS receiving the request shall promptly decide and notify the requesting MS, whether it is in a position to render the assistance requested, and the scope and terms of the assistance, that might be rendered. As a consequence of this Convention, the IAEA RANET Network has been established to implement rapid actions, both in terms of Field Assistance Teams (FAT) and External Based Support (EBS).

Concerning Europe, the Council Decision 87/600/Euratom of 14 December 1987 was explained and linked to the ECURIE system presented in the previous lecture.

As an example of the weaknesses of the current existing conventions, the recent case of ^{106}Ru in Europe was shown.

International exercises were then described, with special emphasis on the IAEA IEC CONVEX series, the ECURIE ECUREX series and the NEA INEX series.

11 LECTURE ON IAEA ROLE IN EP&R

This lecture was made of three parts, all of them given by video-conference by F. Stephani from the IAEA IEC. The first part was on the international EP&R framework as shaped by the two conventions mentioned in the previous lecture. The role and responsibilities of the national Competent Authorities were shown. As regards to the operational arrangements, the lecturer introduced the IEComm Manual, the JPLAN, the RANET, and the REPLIE. Then, the IAEA IEC was described. The second part of the presentation dealt with the roles of IEC in EP&R. In particular, the 45 IAEA EPREV Missions conducted so far were introduced. The five key missions of IEC were then given: 1) Notification and official information exchange; 2) assessment of potential emergency consequences and prognosis of possible emergency progression; 3) provision of public information; 4) provision of assistance on request; and 5) coordination of inter-agency response. The three modes of operation of IEC were also described: normal/ready mode; basic response mode; full response mode. Finally, in the third part of the lecture an overview of IAEA Safety Standards for EP&R was given. A historical picture of the evolution of such standards from 1966 to the present days was illustrated. Among the Safety Fundamentals, SF-1, Principle 9 was recalled, in that it states “Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents”. The very recent publication (2015) of General Safety Requirements Part 7 on EP&R was discussed. It supersedes GS-R-2 which dated back to 2002. The importance of GSR Part 7 lays also in the fact that it was co-sponsored and co-endorsed by FAO, IAEA, ICAO, ILO, IMO, Interpol, OECD/NEA, PAHO, UNEP, UNOCHA, WHO, WMO and CTBTO. The Safety Guides GS-G-2.1 “Arrangements for Preparedness for a Nuclear or Radiological Emergency” and GSG-2 “Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency” were also quoted. The concept of graded approach for Preparedness, in particular through the five Categories I to V, was likewise shown.

12 LECTURE ON COMMUNICATION

P. Kaiser of IAEA gave this lecture, again through videoconference from the IAEA IEC. The importance of communication for both Preparedness and Response was stressed. Communication in fact directly influences human behaviour and the associated welfare. It is intimately associated to the communication of risk, which, for the public, is to estimate the likelihood of losing something valuable. Alongside this, the perception of risk is something which is overlaid over psychological and cultural factors, different from country to country, driving the human behavioural response. The role of Preparedness in Communication is that of 1) correcting misperceptions of risks, and 2) building trust and credibility. In this regard, IAEA GSR Part 7 states that governments shall establish a

national coordination mechanism for effective communication with the public in preparedness for a nuclear or radiological emergency. Additionally, governments shall periodically assess the effectiveness of public information arrangements. Information shall be given in plain and understandable language. The engagement of many stakeholders is also fundamental so that communication can bridge the gap between what people believe and what they really need to know. A way to build effective and efficient communication channels is the establishment of sound relations with media, schools, employers, public health authorities, etc. Moreover, when people know what to do, they can better cooperate with emergency responders on the field. Communication ops manuals should be drafted and exercised, with the objective of providing useful, timely, true, clear and appropriate information while, at the same time, protecting sensitive information. Frequent updates in communicating emergencies are vital, as well as the constant monitoring of information channels: no uncertainty, fear or anger about lack of control should be transmitted. Theory of speed and initial message was also introduced in the lecture. A public information centre should facilitate the transfer of messages.

13 LECTURE ON MONITORING AND TREATMENT OF PEOPLE

This final lecture was given by R. Brancaleoni of Catholic University of Sacred Heart in Rome.
Dr Brancaleoni introduced first the concept of risk for cancer, as induced by ionizing radiations or other agents (alcohol, smoke, diet, etc.). She showed how, according to IAEA, the level of risk associated to ionizing radiation can be up to a factor 20 lower than that associated to other agents. Then, the full chain of physical phenomena leading to biological effects on humans, from the ionization of atoms up to whole body symptoms, was described, paying attention to the disruption of DNA chains. Also the timing of these phenomena was touched, ranging from some seconds to years or even human generations. Clear distinction was made between stochastic and deterministic effects of ionizing radiation, with special attention to the problem of the existence or not of a minimum dose threshold for the appearance of deterministic effects. The rather old and well-established theory of adaptive cell response was introduced, to show the shortcomings and limitations of the LNT hypothesis. The acute radiation syndrome was discussed, together with its clinical patterns and course. Then, the hematopoietic, gastrointestinal, neurovascular, cutaneous and multi-organ syndromes were treated. After that, the lecture went through typical medical management procedures for contaminated persons, including first aid measures. Contamination survey techniques for injured persons were also discussed. Finally, hospital plans, including triage actions, were introduced.

14 PICTURES

The following pictures show a moment of a lecture in Aula Magna (Fig. 1), a moment of the Fire Brigades demonstration of vehicles and devices (Fig. 2), and a moment of the social dinner (Fig. 3).

Fig. 1. A moment of a lecture in Aula Magna.

Fig. 2. Fire Brigades exhibiting and demonstrating vehicles and devices.

Fig. 3. Social dinner

15 APPENDIX

Agenda of the FASTNET School

Monday, 21st January	
10:15 - 11:15	**Arrival of participants and registration**
11:15 - 13:00	**Fundamentals of Radiation Protection (C. M. Castellani, ENEA)**
13:00 - 14:00	*Lunch in ENEA canteen*
14:00 - 15:45	**Modelling and Calculation of Source Terms 1 (N. Arnold, BOKU & E. Urbonavicius, LEI)**
15:45 - 16:15	*Coffee break*
16:15 - 18:30	**FASTNET: Introduction to PERSAN and RASTEP tools (O. Isnard, IRSN & A. Riber-Marklund, LR)**
Tuesday, 22nd January	
09:00 - 10:45	**Modelling and Calculation of Source Terms 2 (N. Arnold, BOKU & E. Urbonavicius, LEI)**
10:45 - 11:15	*Coffee break*
11:15 - 13:00	**Atmospheric Dispersion Modeling (W. Raskob, KIT)**
13:00 - 14:00	*Lunch in ENEA canteen*
14:00 - 15:45	**Transfer Chains and Models and Exposure Pathways (W. Raskob, KIT)**
15:45 - 16:15	*Coffee break*
16:15 - 18:00	**Videos on Emergency Drills (IRSN)**
Wednesday, 23rd January	
09:00 - 10:45	**Decision Support Systems and other Codes (S. C. Hoe, DEMA & W. Raskob, KIT)**
10:45 - 11:15	*Coffee break*
11:15 - 13:00	**Environmental Monitoring and EU Data Exchange System (M. Sangiorgi, JRC & G. Iurlaro, ENEA)**
13:00 - 14:00	*Lunch in ENEA canteen*
14:45 - 19:00	**WP4 Meeting (restricted to FASTNET Partners)**
20:00 - 22:30	*Dinner offered by ENEA*
Thursday, 24th January	
09:30 - 10:45	**FASTNET : Feedback from Exercise 1 (M. Dowdall, DSA)**
10:45 - 11:15	*Coffee break*
11:15 - 13:00	**International Conventions and Exercises (P. Zeppa, S. Scarpato, ISIN)**
13:00 - 14:00	*Lunch in ENEA canteen*
14:00 - 15:45	**IAEA Role and Activities in EP&R (F. Stephani, IAEA)**
15:45 - 16:15	*Coffee break*
16:15 - 18:00	**Communication during emergencies and INES Scale (P. Kaiser, IAEA)**
Friday, 25th January	
09:00 - 10:45	**Monitoring and Treatment of People (R. Brancaleoni, Università Cattolica)**
10:45 - 11:15	*Coffee break*
11:15 - 13:00	**Exhibitors**
	End of the School
13:00 - 14:00	*Lunch in ENEA canteen*