Nuclear centres of excellence

by M. Osredkar*

Yugoslavia's nuclear centres have re-oriented some of their work to non-nuclear problems. Three factors have made this transition successful: good and appealing working conditions; concentration of means and of motivated scientists and engineers; and the interaction of different scientific fields and working contact with advanced science and technology.

In the years 1947 to 1951 Yugoslavia founded several research institutes to work in the development and application of nuclear energy in its widest sense. Three of them (Boris Kidrič Institute in Vinča near Belgrade, Rudjer Bošković Institute in Zagreb and Jožef Stefan Institute in Ljubljana) started with a programme broadly similar to many other nuclear centres in the world; whereas two more were established with a more narrowly defined scope, to deal with geological surveying and with the technology of basic nuclear materials such as uranium.

The idea behind the three nuclear centres was to exploit the potential of the three strongest university environments at that time. Moreover having more than one nuclear centre was in keeping with the federal character of the country. The key scientists who had the main responsibility for organizing the centres were in many cases university professors and there was mutual interaction between the universities and the institutes. The nuclear institutes were well supported and were given good oportunities for sound development.

In the 1960s the importance given to the nuclear programme and to nuclear centres gradually diminished as it became increasingly clear that the original expectations of nuclear power being an easy and inexpensive energy source were not justified, and that a strong and developed industrial background was essential for manufacturing nuclear equipment and power stations. At the same time, the price of oil and its availability were very favourable, creating an atmosphere in many circles that there was no need for nuclear power and that, if and when nuclear power was needed, it would be easily available on the market. There were also strong opinions that the "nuclear programme" should be a narrower project which did not include all "nuclear science" in its broadest meaning.

On the other hand, due to the development of Yugoslavia's political system and to the consequent decentralization of governmental responsibilities, the function of programming and financing the work of nuclear centres was transferred in part to other agencies dealing with research. However, no arrangement was made to organize in a systematic and comprehensive way, the other large projects needed for industrial development which required the work of nuclear centres. Planning of general and economic development and, within it, of research had not then been developed. Therefore, the burden of reorienting the research programme and of finding the money for it was to a great extent left to scientists in the institutes themselves. To ease this process, the institutes, were helped financially during a transition period of several years, to reorient their efforts to applicable research problems.

It is no simple matter to establish a continuous and sustained interaction and co-operation with industry and other users of research. Without going into any details, nuclear centres were more likely to be successful than other institutes because:

- They had good scientific and technical staff who were used to working in interdisciplinary teams; they had good international co-operation; they were used to interaction.
- The requirements of their research brought them into working contact with advanced science and technology.
- They had acquired good scientific knowledge in areas which were not specifically nuclear but which could be applied in many industrial branches and other fields.
- They were basically well equipped for research.
- Their scientists were strongly motivated to show the value of science and research for industrial development and had some insight into where these could be applied.

Many problems and difficulties had to be solved and overcome to achieve the situation existing today. One indication of the successful reorientation of nuclear institutes is the extent of contracted research for industry and other users. While some 10 years ago the co-operation was a practically negligible ten per cent and consisted mainly of introducing or developing "nuclear" methods or use of isotopes – which by now have become a common tool – co-operation with industry today involves almost exclusively non-nuclear problems and has grown in some institutes to 50% or more of all income. The remaining income, spent mostly on fundamental research and given by foundations.

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responsible for science, is of great importance for successful contractual research, since it provides for continuous growth of the basic scientific knowledge needed for good applied research.

Working for industry

The panel below contains a list of some of the work which the institutes have done in the non-nuclear field, using the techniques and expertise that they built up in nuclear research. For example, the materials which have been developed for industrial use are the products of laboratories which in the past were mostly oriented to work on nuclear fuel: many of the materials are being, or will be in the near future, produced industrially; several have been patented, and some licences sold for others. Although the work on heat- and mass-transfer is mainly the application of known methods – done in laboratories which used to work on reactor heat-transfer and cooling – some original work has been done and patented in the field of mass-transfer. Those laboratories working mostly in nuclear physics and chemistry have switched over to environmental work. The consultancy work on environmental impact assessment is of particular interest and has had a direct influence on investment decisions. Over 200 such assessments have been made so far. In the fast growing use of electronics and computers our nuclear centres have a significant share. Their software groups are among the strongest and most advanced.

Much of the work mentioned in the side-panel has already been industrially implemented while the rest is in some form or other on the way to implementation.

Universities

When discussing other non-nuclear uses of nuclear centres in Yugoslavia one should not by-pass their relation to university teaching. In the beginning, scientific leaders and senior scientific staff of the centres were largely university professors, since there were very few other scientists available at that time. These university scientists transferred their research to the centres, or started research there where the circumstances were more favourable. In time, scientists in nuclear

Some results of work on non-nuclear problems

Materials for industrial use

Dielectric ceramics for electronic elements and circuits
Magnetic ceramics
Hard ceramics for mechanical tools
High-temperature ceramics for various uses
Porous high-temperature ceramics for thermal insulation
Copper alloys of high conductivity
Copper alloys of high mechanical resistance
Sparkless tools
Metallic filters
Al alloys
Ni alloys
Composite materials
Carbon deposits and fibres
Metallic deposits for abrasion resistance
Liquid crystals
Non-destructive testing

Heat- and mass-transfer

Cooling tower design and experimental verification (small and medium size)
Thermal pollution assessment, verification and avoidance
Drying kinetics and facility design for agricultural products
Characterization of coals for optimal combustion
Ash fouling and depositing problems in furnaces
Waterside deposits in boiler tubes
Thermophysical characterization and standarization of metallic and non-metallic materials
Design and experimental verification of industrial ovens
Minimization of liquid fuel consumption in thermal stations
Fluidized bed combustion of coal, shales and biomass
Fluidized bed conveying of powders, granular materials and grains

Environment

Pollution measurements and control: inorganic (heavy metals), organic, radioactive
Pollution control instrumentation and automatic systems for data collection and processing
Sea pollution measurements and control
Consulting work on environmental impact assessment of industrial production plants, existing and future, for use of administration and banks

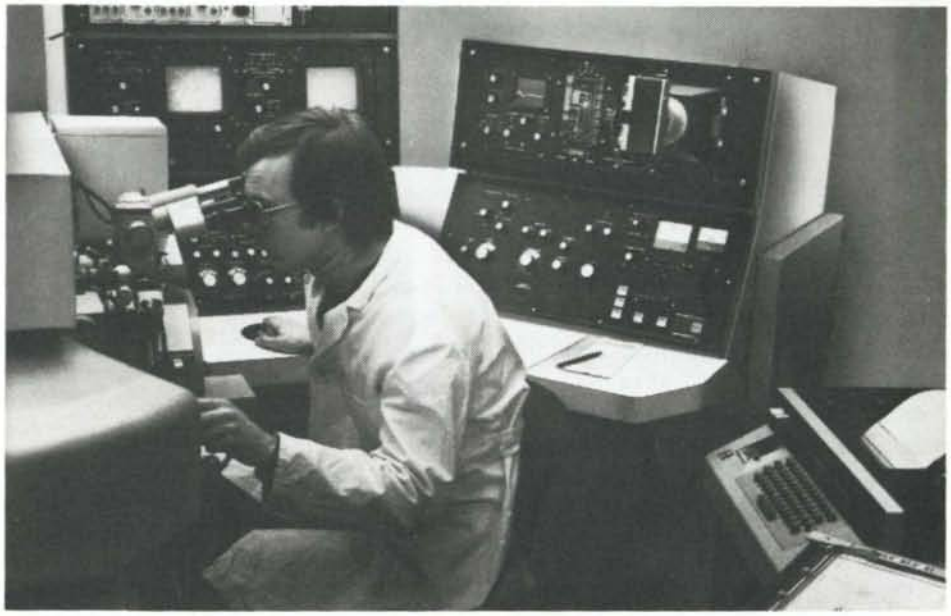
Chemistry

Development and adaption of technologies related to industrial wastes (sulphates, pharmaceutical wastes, waste gases, etc.)
Development for pharmaceutical industry (synthesis, testing, proteins, antibiotics, enzyme production)
Radiation sterilization
Radiation treatment (curing) of polymers (shrinkable tubes)

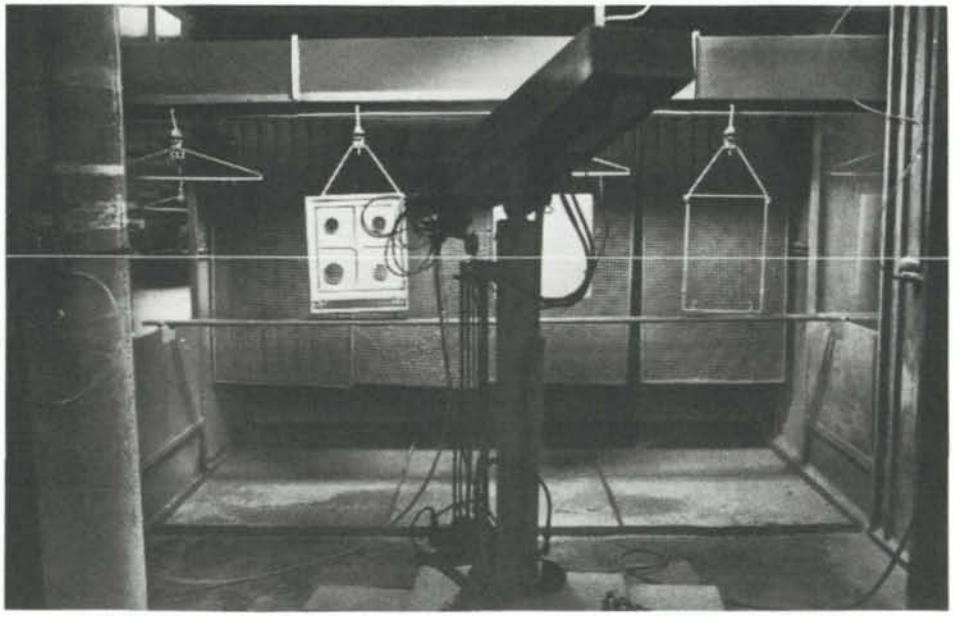
Electronics and computers

Mathematical modelling
Process instrumentation and control
Computerized data and control systems for industrial use
Microprocessor systems for different applications in processes and equipment (fermentation, concrete production, scenic illumination, hotel services, etc.)
Microprocessor networks (meteorological and environmental monitoring, communication, etc.)
Computer networks (RRC, universities, etc.)
Computerized information systems (government, press agency, federal assembly)
Optoelectronics
Biocybernetics and electrical stimulation of muscles
Robots
Software systems

A view of the laboratory for developing ceramic materials in the Jožef Stefan Institute.



A scanning electron microscope in use in the ceramics laboratory.



An industrial robot for painting metal components of domestic appliances (refrigerators etc.), designed and built by the Jožef Stefan Institute.

centres have become numerous and very well qualified to compete for university postions. When appointed in universities they very often continued their research in nuclear centres and increased mutual co-operation and interaction to a very significant extent. They also created channels for students and postgraduates to use opportunities and equipment in centres for their scientific education. Yugoslavia's nuclear centres, through such a process, contribute to university education, particularly at postgraduate level and have in part acquired the status of postgraduate schools or something similar to it. The number of scientists in our country who have started their career in nuclear centres and became university teachers is more than 300 and there is a similarly high number of postgraduates who have worked at nuclear centres (the Jožef Stefan Institute alone now has around 100 postgraduates out of 300 scientific staff). The contribution of Yugoslavia's centres to the development and growth of the country's universities is significant.

Re-orientation to some non-nuclear areas does not mean that the institutes have not remained active in the nuclear field. They still do important nuclear work mostly, however, on contractual short-term basis – particularly in nuclear safety – and they play an important role as part of Yugoslavia's regulatory body for nuclear energy. They are involved and have provided most man-power and expertise for the safety evaluation of the country's first nuclear power station. The closed-cycle technology for production of yellow-cake from uranium ores was developed in the nuclear centres. The use of conventional technology, as suggested by foreign consultants, would have ruined the environment in the mining area. It seems that most mining and ore processing in the world is being done in deserts while Yugoslavia's site is in a beautiful valley used largely for farming and recreation.

Work related to fuel cycle and fuel management for the nuclear power station is also being done as is work on problems of radioactive waste disposal and dosimetry. Of particular importance for power stations is education and training of technical personnel and operators which might eventually lead to the establishment of a nuclear technology training and educational centre for domestic and other uses. Consultancy work for government, governmental agencies and other organizations is of importance.

Centres of excellence

What conclusions could one draw from Yugoslavia's experience? Although the ideas and expectations which existed at the time of creation of the nuclear centres were not – as can be seen today – very realistic, at that time in Yugoslavia the challenge of nuclear energy which gave rise to the centres was the only stimulus able to accelerate the development of natural science and technology. This can very well be seen by comparing the development of nuclear institutes with the past development of other institutes and universities. Today "nuclear science" in Yugoslavia and elsewhere could not play the same role as it did 30 years ago. One hardly could advocate today what was believed 30 years ago by many: for instance, that work in nuclear physics in general is essential for the development of nuclear power in a country.

Nevertheless, the example of Yugoslavia's nuclear centres, their role in the past, and particularly their present role might be very significant and instructive to those who find themselves today in conditions similar to Yugoslavia's 30 years ago, and who want to create and promote their scientific infrastructure so important for social and economic progress. It is essential for them to find ways, subject to the specific circumstances and traditions of the country: of creating favourable, above-average conditions and concentrations of means for research, and concentrations of experienced creative as well as young scientists; and of accumulating equipment. It is essential to create conditions, attractive for scientists and engineers, which offer an active and interactive environment in touch with advanced work elsewhere: in other words to create, within universities or elsewhere, so-called *centres of excellence* to work on some appealing research areas relevant to national development. It is certainly not an easy task, and it is particularly difficult to find people to fill leading positions in such centres who, besides being good scientists and teachers, are able to provide the necessary organization and leadership. It is very important to note that such centres in the world, regardless of the country, have always been exposed to attacks from many quarters and that they need the appropriate protection. I believe, however, that no scattered research, as is often found in universities, even if top level, can achieve the same results as centres offering opportunities for interaction among different research fields and among good, motivated scientists.