PERSPECTIVES IN NUCLEAR REACTION RESEARCH IN YUGOSLAVIA

I. Šlaus

Institute "Rudjer Bošković", Zagreb

I assume that research, education and scientific approach to decision making are essential factors in achieving progress and better quality of life."To inquire and to create - these are the centres around which all human pursuits ... revolve" (Humboldt) and "All men by nature have a desire to know" (Aristotle). Therefore, I argue that research and knowledge are the basic human needs like food, energy and health, and not just means or techniques how to satisfy human demands. "The main thing needed to make men happy is intelligence. And this is our optimistic conclusion, since intelligence can be fostered by known methods of education." (Russell).

Through science policy we ought to make a programmatic endevour to achieve better quality of life. What we really do is concentrate to solve certain problems which we believe are national and social priorities. We should not overlook that relationship between those priorities and quality of life requires more understanding and consequently more research.

Developing countries going now through a phase that highly developed countries have gone through 30 to 100 years ago are not necessarily immune from repeating the same mistakes and unfortunately there are many additional pitfalls.

Therefore, for a developing country the definition of a sound science policy is of paramount importance and it has to be done in a face of at least three disturbing factors: *i)* desire to uncritically copy more advanced countries, *ii)* nervousness and urgency to narrow the technological gap and *iii)* fast rate of development which inhibits many correction feedback mechanisms that were effective previously.

After the II. World War nuclear research centres have been established in several developing countries. The unavoidable question is - whether these countries needed and need nuclear research centres? Probably, in many cases it would have been better to establish different research centres, e.g. in agriculture, metallurgy, medicine, In most cases nuclear research centres have been organized entirely disconnected from the existing universities, and often these centres were in no position to influence education. One should not conclude that establishment of research centres is or was mistake. On the contrary, there are many arguments in favour of such centres: a) to give a special momentum to a given field, b) to achieve a technological breakthrough, c) originality of the field makes it impossible to develop a field within university structure, d) to use such a centre as a nucleus which one intends to develop a modern university.

Whenever one or more of these reasons exist, it is desirable to build a research centre. In many cases nuclear research centres were and often are centres of excellence.

The scientific and educational institutions obviously benefit if there is a good research centre. Apparently the benefit for industrial institutes is much smaller and it is smaller the less developed the country is. The solution of this problem is one of the most important tasks of science policy and strategy in developing countries. Let me just mention some aspects of this problem:

i) impatience to produce profit. Many industries treat scientists in about the same way as medieval nobility treated alchemists often keeping them in prison until they would make gold. But let me tell a more humourous story about two partners in a factory who employed a research chemist. About 11 a.m. of his first day one partner said to the other "Shall we go see whether that research fellow has discovered anything yet?" The other replied "No, let s wait until after lunch."

ii) successful research and even discoveries do not necessarily lead to profit, particularly not for an undeveloped economy and for a small market so typical for developing countries. Research that brings a large profit to highly developed countries might have a very small effect for the economy of a developing country. It is instructive to contemplate what effect would have a discovery of a transistor, or penicillin if it were made in a developing country. I argue that the overall effect, though quite significant, would be comparable to the effect made by the discovery of parity nonconservation or special theory of relativity.

iii) often industries in developing countries emphasize demand for applied research and development while what they really need is consulting. Consulting should be an integral part of the education process and ideally it should be organized in connection with implementation of permanent education.

iv) "the unnecessary and unwanted people" syndrome develops in the nuclear research centre.

It almost looks as if nuclear centres in many developing countries were established before nuclear energy became a real need, almost a necessity. This situation could have contributed to an "unnecessary and unwanted institution" syndrome. However, nuclear energy is now vital for many developing countries and it would be a grave mistake to denuclearize nuclear centres. On the contrary, we might be faced with a shortage of nuclear specialists, engineers and technicians and it seems most convenient to incorporate nuclear centres within universities and use their mutual expertise. The first and the most important duty of any scientific and educational institution is to achieve and maintain an outstandig level of excellence. Developing countries cannot afford second rate scientific activities. If a developing coutry has a nuclear research centre which has indeed achieved a high level of excellence, I argue that it should maintain it even if nuclear energy is not its highest priority. The nuclear centre is engaged in an active dialogue with the economy of a country through consulting and permanent education, if its expertise is used in decision making, it will significantly contribute to the progress of the country.

In my opinion nuclear research in Yugoslavia has achieved a level of excellence and thus it should be continued.

It seems that there are four possible ways: 1. to have adequate accelerators in each nuclear centre; 2. to have a regional or subregional centre; 3. to form user groups; 4. to continue a present routine characterized by inadequate facilities with several outstanding researchers working on a part time basis in very good foreign accelerator centres. Table 1. summarizes the relative merits of these four ways.

TABLE 1.

CHARACTERISTICS	1	2			3	4
		city	country	abroad		
Number of published paper/physist. year	0.7	0.7	0.7	0.7	0.4	1 - 2
value of reserach	← average →				← maybe outstanding →	
duration	← life of accelerator →			life of contract	uncertain	
interdisciplinary value	100	100	100	10	1	1
number of researchers included	all	all	all	all	≤50%	≤20%
other personnel included	all	all	≤50%	≤10%	≤10%	0
dependence on technical support	100	100	100	10	20	0
effect on local technology	100	100	100	10	20	0
extra cost	≤30%	← ≤50% →			≤40%	0

It is often argued that accelerators are too expensive. It is certainly reasonable if the extra cost EC due to the establishment of the accelerator centre is kept not to be much larger than the nonproductive cost of research (NC) (overhead which supports nonscientists not directly connected with research). Typically NC is 30% of the financial support for research SR. The EC is composed of the initial investment (II) and the yearly expenses for the accelerator (YEA). Assuming that 10 years is a lifetime of an accelerator one obtains:

$$II + 10 \times YEA > 10 \times NC \simeq 10 \times 0.3 \times SR \qquad (1)$$

SR is of the order of a number of nuclear scientists (NS) divided by all scientists (S) and multiplied by the total support for research (TSR).

It can be argued that accelerators are useful to other nonnuclear scientists and that it is also reasonable to allocate more funds to nuclear scientists than to an average researchers. This yields

$$NS' = 2 \times NS \tag{2}$$

also, accelerators can be used for isotope production, cancer therapy, metallurgy research etc. and thus the yearly expenses could be partly (up to 30%) covered from these other sources:

$$YEA' = 0.7 \times YEA \tag{2.2}$$

Using typical values: $NS = 50$, $S = 2000$, $TSR = 200$ M*din*, one obtains from (1):

$$II > 5M\,din, \qquad YEA = 1M\,din \tag{1a}$$

and from (1) with (2.1) and (2.2)

$$II > 16\ M\,din, \qquad YEA = 2M\,din \tag{2a}$$

This is already a good accelerator, anyway much better than what we now have. If one contemplates about the regional centre obviously a more powerful accelerator is needed. However,

$$\frac{NS}{S} \cdot TSR = NS_{eff}$$

is increased, and additional values might make it acceptable to increase EC up to twice NC, yielding as a solution from (1) with (2.1), (2.2) and $NS_{eff} = 170$:

$$II > 100\ M\,din, \qquad YEA = 10\ M\,din \tag{2b}$$

a quite powerful accelerator!

Finally, one has to answer whether there is worthwhile research to be done with accelerators, and aren't there enough accelerators in the world already. Fundamental problems e.g. nuclear interaction on (particularly $T = 0$ states, and $n - n$ interaction) and off energy shell, three body force, symmetries (charge independence, parity nonconservating strong interaction), and discoveries: heavy ion physics, isotopes far from stability line, isobar components in nuclear wave functions etc. are still in front of us. Nuclear physics is certainly a very active and existing field and more accelerators, particularly evenly geographically distributed, are necessary.