

PUBLIC FUNDING OF RESEARCH: RESULTS VERSUS COSTS

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*Your Magnificence — Rector of ČVUT,
Spectabilis — Dean of Civil Engineering Faculty.
Honored Colleagues and Friends:*¹

I want to express my appreciation for the great honor that you have bestowed upon me, and I accept it with humility. It is for me an overwhelming moment. I would not be standing today in this ancient hall of Karolinum without the incredible, epochal political changes that happened in Central and Eastern Europe. Therefore, first of all, I want to compliment the leaders of the successful democratic revolution that took place in my native land.

But also, I realize I would not be standing here today without several other fortunate circumstances in my life. The role of my parents in my education and their moral support in facing communism were, I feel, crucial. It was to a large extent the influence of my father, as well as my grandfather, that led me to a most rewarding scientific career. To ČVUT I am deeply indebted for my basic engineering education. I want to thank a number of outstanding teachers that I was fortunate to have, particularly professors Rektorys, Hruban, Koloušek, Tesar, Faltus and Pachner at ČVUT, and Brdička at Charles University. I was fortunate to settle in the United States, a country of truly equal opportunity. I want to thank the United States, and Northwestern University in particular, for providing excellent conditions for my research. I also want to thank several American funding agencies and private firms for providing funds for that research. Finally, I want to thank the many dedicated assistants and coworkers who have helped me with my research, in which I have tried to elucidate the laws that govern the stability, fracture, creep and plasticity of engineering structures — laws that must be understood in order to build better and safer bridges, nuclear power plants, high-rise buildings, dams, ocean structures, underground structures, airplanes, rockets and ships.

Having had the good fortune to pursue my research in the United States for 22 years, I believe that I have

¹English translation of the acceptance speech of an honorary doctorate, delivered in Czech in the Great Hall of Karolinum to the faculty of the Czech Technical University in Prague (ČVUT).

some words of wisdom to share with you on this occasion — some new perspectives or insights on a subject of great concern to all of us: how to organize and promote research, so that it will bring optimum benefits to Czechoslovakia.

1 The Problem

My native country, devastated by 41 years of communist dictatorship, now faces a formidable task — how to recreate its social, economic and educational structures within the framework of a democracy and free market economy. After so many years, a return to the old pre-communist structures is impossible. Recent examples must be examined, new ideas implemented.

One area of change in which difficult decisions must be made is the system of public funding of research in science and engineering. In view of the precarious economic situation inherited from communism, it is crucial to adopt the most productive system possible. One must realize that simply allocating funds is not enough. Such funds can be put to good use — or can be wasted. Indeed, experience has shown that research results achieved in various countries have been far from proportional to the taxpayers' monies spent.

The aftermath of the velvet revolution presents a special opportunity. While countries with established social structures often find changes slow and cumbersome to implement, Czechoslovakia has the chance to make drastic improvements right away. She can immediately institute a system of funding that combines the best from the experiences of various democratic countries. But caution is necessary, because some of these countries offer a better model than others.

2 Examples to Avoid

A little history is instructive here. Before the second world war, scientific research was generally conducted on a much smaller scale, with modest governmental funding, and in a more individualistic manner. This system, in which Germany excelled, did not require educating large numbers of scientists and could rely on the small number of geniuses naturally occurring in a population. Such geniuses manage to educate themselves despite inadequacies in the educational system. They manage to produce outstanding doctoral dissertations without advisors and without formal graduate-level courses.

Later, many countries greatly expanded their funding of research. Unencumbered by the opinion of voters, the communist Soviet Union was able to quickly set up a number of large research institutes, most of which were independent of the universities. Young researchers, some very bright, seized the opportunity to get leading positions in these institutes, making them initially quite successful.

But these institutes were less than successful in the long run, and it is important to understand why. Due to their authoritarian, politicized organizational structures, most of these institutes gradually ossified. No doubt one reason is that many of these original leaders still directed their institutes in Moscow as they grew into old age, completely controlling the research direction of everyone in their institute. No wonder, the direction often remained the same as forty years earlier. One institute, for example, that worked in 1950 on the so-called "aging viscoelastic" analysis of behavior of concrete structures under long-time loads, was still working on the same subject in 1990. These geriatric directors often went so far as to prevent anyone from embarking on certain radically new directions whose potential they did not appreciate — or which they saw as a threat to their own records. Some of these directions were later proven elsewhere to be extremely fruitful. In my experience, twenty years ago I decided to start working on the so-called "strain-softening" theory of damage of structural materials — an unconventional but useful mathematical approach whose pursuit, as I heard, was actually prohibited to any soviet scientist by an omnipotent committee of their Academy!

To avoid this kind of stagnation of basic scientific research, the new Czechoslovakia should, I believe, draw principally from the experience of the U.S. and Western Europe but, as I will explain, emulate more the former than the latter. In applied industrial research, Japan must, of course, be con-

sidered to be at least on a par. However, I will focus solely on the government-sponsored basic research, because I think this is the kind of research that should be undertaken mainly at universities. The system must be democratic, but even in democratic countries some systems have more drawbacks than others. The old communist system is not the only one to avoid.

During various study trips to western countries, I have had the opportunity to become acquainted with the way of life in many university departments or governmental institutes, renowned because of the research results of the scientists who attracted me there. While I greatly benefited from my interactions with these scientists, I was often surprised by the inefficiency I saw — for example, by the large staff of the institute, distinctly larger than that of a typical institute of comparable output in the U.S. I wondered what it must cost to fund these institutions. To give a nonspecific, but realistic, example, let me sketch the atmosphere in such an institute.

Imagine an institute in which the working hours are apparently interpreted by most of the research staff as the upper (rather than lower) bound on the hours one should actually work. The institute is deserted after five o'clock (which might not a problem if the research staff worked at home, but that does not seem to be the case). Trying to be there in the evening, or on a Saturday or Sunday, requires some determination and courage. One has to wander through unlit corridors and grope in the dark for the light switches and keyholes.

There are scheduled work breaks in the morning and afternoon, but these are regularly extended to hour-long coffee or tea sessions with lively chat, only rarely concerned with research. These sessions are defended by the need to discuss departmental problems. Some of the research staff even have a breakfast session immediately after arriving — late — to work. Of course, the few productive and renowned members of the department are not frequently seen at these sessions; but no one finds it wise to boycott them completely. He would miss the gossip or be accused of not playing with the team.

None of this seems to matter in this hypothetical institute, since the funds come from the government more or less automatically. The institute director, a hardworking man with a solid international reputation, sees the problem, of course. But he is unable to remedy it, for it originates from the socialist system pervading the universities and governmental institutions, which is in striking contrast to the country's private industry. The professor-director

cannot change the salaries of his research assistants, secretary, or technician. He cannot fire them, even if they do next to nothing. His assistant can work on his doctorate for five, or even ten years, displaying curiously little interest in finishing (his salary is not too bad and, of course, secure). The secretary, chronically ill with a tennis elbow, pursues lengthy cures in a spa. In the meantime, the professor is left with no secretarial assistance at all. Every petty problem must be decided by meetings of the employees. The labor union dominates, but seems interested mainly in the well-being of its local members, and not in the productivity which affects the well-being of the nation as a whole (in the U.S. the unions have been trying hard to unionize the employees of the universities and research institutes, but so far none of the places where they have succeeded is a major university — and the academic rating of each such university went even lower).

Dear colleagues, the system I just depicted is not actually undemocratic. It can and does exist in democracies. But it is not a system you want — especially after enduring 41 years of a politicized, authoritarian research establishment. Some western countries, after first becoming rich through private enterprise, might subsequently afford the luxury of accepting and tolerating such a system. But the new Czechoslovakia can not.

3 Principles that Have Worked

I would like to suggest *ten principles* which, in my opinion, it is wise to follow, insofar as possible, and which will prevent over-socialization, over-regulation, and authoritarian tendencies in the research establishment, with the low productivity that results. I have worked for 22 years under a system in which these principles were implied, and I can vouch for them first-hand.

1. *Government funds for basic research should be spent mainly in the form of research grants to individual principal investigators (university faculty members), based on their unsolicited proposals.*

Experience in the U.S. has proven that such grants, introduced on a large scale in the late 1960's, are very cost-effective and most likely to lead to original ideas. I am convinced that this system has enabled my newly adopted country to do well in civil engineering research despite the fact that financial outlays in this field have,

in fact, been much smaller than in some other countries.

Since the proposals are unsolicited, does the government have any control of the research direction? — Yes, but only in a very general way. The relative emphasis on various fields, such as robotics, high-performance materials, AIDS, etc., is controlled by the amount of funds wisely (or unwisely) allocated by the government to each field.

2. *The individual principal investigator who succeeds in receiving a grant should be the director of the funded project*

— in the full sense of the word, even if he is a 27-year old assistant professor. In the American system, the director alone is responsible to the government agency for the technical aspects; he alone decides whom to hire as his research assistant, whether to use an in-house or outside secretary for typing, and whether to attend a conference abroad (provided, of course, there are sufficient funds in his grant). A project director is normally allowed considerable freedom to reallocate funds from one subaccount of the grant to another, for example from technician salaries to computer purchases or from postdoctoral stipends to conference travel. He is free to tell his assistants that he does not care about their working hours, *provided that they work hard enough to be able to demonstrate good progress at the weekly research sessions.* Treated this way, many graduate students are sufficiently motivated to be at the computer or in the lab even at 11p.m.! Senior faculty members, the department chairman and the dean, cannot forcibly intervene in scientific matters of the grant. This is in stark contrast to some West European, as well as former East-European, institutes, in which the senior professor-director totally controls the type of research undertaken by the junior faculty members, whether or not they can travel to a conference, and so forth. The responsibility of the university, which has previously examined and approved the detailed proposal for the grant, is to provide the means for carrying out the research (rooms, equipment, an academically stimulating environment, accounting, etc.), while ensuring that no rules are violated and preventing conflicts with teaching, other university business, or other research projects.

3. *En-bloc funding of large research centers or institutes should be exceptional.*

Such funding is appropriate only when there is a particular need for a rapid advance regardless of cost, or when it is necessary to have a mandated, rather than a spontaneous, collaboration of many scientists with different specializations. Typically, such large centers distribute funds to their members on the basis of in-house reviews which tend to be superficial and tainted by local politics, buddy systems, and personal animosities. While a few principal investigators in the center may be outstanding, many others would often be unable to get funding on their own and thus get a "free" ride. Even if the center does achieve a significant advance, the cost-to-result ratio is normally higher than that of individual grants.

The worst effect of funding entire centers through a single grant is that it siphons away most of the funds that would otherwise be available for grants to individual investigators. In the U.S., there has recently been considerable polemics on this subject, and the politicians who generally favor governmental regulation of the economy won a great expansion of such en-bloc funded large centers, similar to those in Europe and Japan; however, the overall consequences, in my opinion, have not been gratifying.

4. *Although every known system has some faults, the anonymous peer review is the best for selecting basic research proposals for funding.*

In this system, anonymous reviewers — peers in the profession selected as leading specialists in the subject — evaluate both the research proposal and a report on the accomplishments under the previous grant. They also scrutinize the overall research record of the proposer.

The officers of the granting agency who select the reviewers have great power. While they need not be specialists in the same narrow subject, they must have broad research experience themselves. They attend many conferences and stimulate research workshops, at which they can hear the researchers argue and criticize each other.

Selecting unbiased reviewers is, of course, a difficult and sensitive task. After some experience, one inevitably finds that there exist certain experts who usually recommend rejection and others who usually recommend ap-

proval of any proposal. Such reviewers should not be selected. Furthermore, the reviewers must be neither enemies nor close friends of the proposer. In my experience, however, most reviewers are motivated to do an honest job. Moreover, they do so without a fee, because they consider it a moral duty of an active scientist and because they want to achieve a good image for themselves with the granting agency. Nevertheless, not all the reviewers are impartial, and for this reason it is desirable for a country to have a variety of granting agencies, so that if a proposer thinks the evaluation from one agency has been unfair he could try his luck with another agency. In the U.S., this variety is helped by the fact that the branches of the military fund much basic research whose application is not only military (military officers are often excellent administrators, and in this manner they are able to do something useful in peace-time). Recently, evaluations by a panel of experts after peer review have been added at the U.S. National Science Foundation to mitigate the consequences of a possible poor job by a reviewer.

There is a danger that can wipe out the benefits of a good review system — egalitarianism. There exist countries where, despite peer review, nearly every faculty member somehow receives a research grant, but never a large grant (by our standards). It is important for the governmental agencies to realize that getting a research grant must not be an entitlement of any professor.

For small countries, such as Czechoslovakia, there is an additional problem. The number of researchers in a particular subject is often so small that the reviewer must expect the proposer to correctly guess his identity. This would, of course, defeat the system. Thus, it will probably be necessary to solicit anonymous reviews from other countries; but in this case it might be difficult to get a reviewer to respond without offering him an honorarium (this is actually done, for example, by Saudi Arabia). Requesting reviews from abroad, on the international scale, is already practiced in Western Europe, Australia, and Canada.

In this regard, we, emigrants, can of course help our native country, and it will feel wonderful to do so. The experience of countries such as Korea or Taiwan provides an interesting comparison. They suffered massive emigration of

their brightest scientists to the U.S., but they never regarded these emigrants as traitors. Rather, they cultivated their friendship. Later, after acquiring a wealth of experience, many of these scientists started joint projects or served as consultants for their native country; they returned as well-paid professors or institute directors, bringing with them their experience. Many Ph.D. alumni of our department are professors or directors in Taiwan and Korea. The result has been an economic miracle.

5. *Research grants should pay the full cost of research, not just the incremental costs.*

This means that the grant to a professor should substitute for a part of his academic salary. It should also provide him additional salary (which is done in the U.S. in the form of the so-called "summer salary"). It should pay for his assistants, technicians, and possibly an outside consultant such as a specialist in a vitally related subject. It should pay for the proportional costs of his secretary, conference travel, health and retirement insurance, computer and testing equipment, office supplies, mail, phone and fax, and, of course, the administrative overhead, which is essential for the well-being of a private university. Without this, the full cost of research is not known to the government and cannot be compared to other financial outlays according to the principles of market economics; when the country's system includes both public and private universities, fairness in the relative treatment of both is impossible without such knowledge.

6. *Outstanding research should be rewarded, especially financially.*

Financial rewards are a tremendous stimulus for most people, including researchers. By winning a grant, an American professor can earn additional salary (which is at Northwestern University limited to one-third of his academic salary). His salary level, as well as promotion, depend heavily on his research accomplishments (even though the amount of granted funds does not measure these accomplishments precisely). These rewards provide a powerful incentive for productivity. The number of research proposals submitted by Northwestern faculty members nearly doubled after the university introduced a system in which one-half of the professor's salary paid from his research grant is returned to him as discretionary

monies, from which he can freely buy a computer to use at home, pay for a study trip abroad, or hire an additional assistant or typist.

Bureaucrats can destroy these incentives. They have an innate urge to prevent any academic from gaining extra income, regardless of performance. It is a curious mind-set; they consider it normal when a singer or a boxer is rewarded for top performance by millions of dollars, but they envy a successful scientist every petty honorarium, consulting fee, "slush" fund, or other perk. Whether in the West or the East, bureaucrats constantly try to smuggle into the system a variety of new restrictions, even when the paperwork to enforce them costs more than a researcher's honoraria or fees.

7. *The conduct of research at a university should be objective-oriented.*

The only thing that matters in research is what is achieved. Thus, the progress of the team members toward the objectives must be regularly evaluated. It is counterproductive to dwell on formalities such as adherence to working hours. Naturally, an assistant must attend research meetings and classes, but if he wants to sleep till noon or take a day off, he should be told — fine, *provided that he is self-disciplined enough to work for a sufficient number of hours and be able to meet the objectives by demonstrating good progress at weekly research meetings.* To succeed, our assistants often voluntarily work over 60 hours a week, at nights and on weekends. The professor, too, may be much more effective by doing research at home. The only thing that matters is what is achieved. Such an approach helps motivation and healthy competition.

8. *Universities are, on the average, more efficient in basic research than institutes that do no teaching.*

A critique of the Institute for Advanced Studies by American Nobel-prize winner Feynman² is a case in point — even an assembly of the greatest brains did not guarantee great results. How many professors have had the experience that a new idea, or previous error, comes to mind while writing on the blackboard in front of a class? Students often ask surprising questions

²R.P. Feynman, "Surely you are joking, Mr. Feynman!", W.W. Norton & Co., New York 1985

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and challenge the professor. If no good new idea is coming to the professor's mind, at least he has a feeling of usefulness if he teaches, and with such a feeling a good idea is more likely to come to his mind eventually.

9. *Relevance of scientific research to industry needs to be fostered in certain fields by incentives for collaboration.*

Certainly it is inappropriate to grant taxpayers' funds to profit-oriented industrial firms. However, cooperation of university researchers with industry does not happen automatically and needs to be encouraged. This is particularly important in all fields of engineering and applied science. Cooperation with industry is best promoted by various incentives — for example, by allocating additional funds solely for that purpose.

10. *Finally, it is beneficial if the country's system includes not only public but also private universities engaged in research.*

Obviously, the latter provide competition to the former, and thus force them to be equally efficient. For example, if a private university can thrive with an overhead rate of 52%, it is unlikely that a government auditor would approve a rate of 80% for a state university.

4 Some Reservations

After articulating these ten principles, I wish to emphasize that a wholesale adoption of the American system, or any foreign system, would not be advisable. As always, the wisest path is to change no more of an existing system than necessary. The problem is how to achieve cost-effectiveness with the least amount of disruption.

No system is perfect. As British statesman Winston Churchill once said of democracy, it is a terrible political system—except that no better system has yet been discovered. The same applies here. Indeed, the system of research I advocate has shown some shortcomings, but I know of no better system.

Many of my colleagues believe that the American system creates a conflict between research and teaching, but I think this has been overstated. The same is true, I think, of the publish-and-perish attitudes induced by this system.

Presently we are having great difficulties in attracting American students, especially very good ones, to pursue doctoral studies. This problem is

particularly acute in engineering, and even more so in civil engineering. One reason, of course, is that employment and salary prospects are, on the average, not much better for engineers with a doctoral degree, and another is that higher incomes attract students to law, business, and medicine. However, another important reason, in my opinion, is that adherence to the free market ideas underlying the principles I just outlined tends to depress research assistant stipends; because outstanding foreign students are willing to come to America in large numbers for relatively low pay. In this case, these principles need to be violated to some extent — e.g. by special incentives. Governmental funding agencies should grant the best American students special stipends for doctoral study. Indeed, this is already being initiated in the U.S.

5 Conclusion

On balance, however, the principles that I recommend represent the most efficient system known at present. They motivate researchers by giving them the maximum possible freedom. They exploit free market ideas, which are the opposite of socialism. Socialism is not incompatible with democracy, but socialistic measures are an expensive luxury. It is said that socialism is like medicine — a small dose is healthy, but an overdose is harmful.

The new Czechoslovakia, at this moment largely freed from bondage to the past, has a unique opportunity to take a big step forward by choosing for its scientific research the best system possible. I trust that the new leadership in Czechoslovakia will make the right choice. I also hope that my opportunity to address the distinguished faculty of ČVUT on this solemn occasion is a harbinger of more cooperation in the future with my newly adopted country.

Dear friends, I appreciate the privilege of sharing my ideas with you today, and I sincerely hope they might be of some help in setting new directions for engineering and scientific research in Czechoslovakia.

Thank you for your attention!