ECONOMIC QUESTIONS ON APPLIED SCIENTIFIC RESEARCH

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I

In the course of history research has always served progress, development, and the improvement of living conditions. Its pace is sometimes faster, at other times slower, but its importance and significance is steadily increasing. Its significance is clearly shown by the effect it has on the development of sciences, economics and industry, as well as, by its social effect modifying the structure of society, and by its effect on increasing national defences. In the last decades scientific research has undergone a powerful development.

In our days the results of basic scientific research are also progressing at an ever increasing rate towards industry. For the development of industry almost unlimited possibilities can be reached in the future by *atomic research*, atomic energy. In the raw material supply of the *metallurgical industry* will start a new development for the solution of the energy problem. In the engineering industry the research in the field of *automation* may bring a vital change. *Thus, in the first place through industry, science is changing our life on an ever increasing scale.* It is evident that by the changes in technical sciences, entirely new *living conditions* and together with these new *social forms* will result in the future.

As scientific research all over the world needs enormous economic means, it is of interest to answer the following questions :

a) Are the means which are utilized based on sufficient economic considerations?

b) Is there a way to check the *efficiency of the utilization of these means*, similarly to other utilization of such means?

II

At the discussion of a given problem, however expedient it may seem, to cut short the mainly descriptive parts, at the investigation of the research work one must, however, start with its organization and with the description of the fundamental aims of these organizations. Each of the different organiza-

tions also has its own economic significance, and thus from these consequences the further investigations can be drawn.

The organization and to some extent the aim of research work is different in the capitalist countries and those having a socialist system. The largest scale research work can be found in the *Soviet Union* and in the *United States* and these are followed by some of the larger countries in Western Europe such as Great Britain, France, West Germany. The organization in the Soviet Union and that in the United States show the research organizations of the largest socialist country and that of the largest capitalist country. While in the latter country the competition of the individual industrial concerns for market and for higher profits have a decisive influence, thus it is justificable to speak about the commercialization, to a certain extent of the research work as well, in the former the research organization, the aim of research, is set and planned, and is centrally done under state control, keeping in view as a whole the interest of the people's economy. From this fundamental difference the fact also follows that while in the United States also profitableness (lucrativeness) of a great part of the research work is judged by individual concerns or by other consignors according to their own interest, in the Soviet Union the results of the research work is finally evaluated according to the interest of the socialist people's economy as a whole, and by the state control cooperating with the higher scientific councils and organizations which are concerned.

Beside university institutes and factory laboratories the research work in the Soviet Union is done by research institutes which can be classified into two large groups : to the first belong the individual scientific institutes, lead and controlled by the Academy of Science of the Soviet Union,to the other belong the industrial research institutes, under the control of the individual governmental departments concerned.

Every year the Soviet Union's state budget spends enormous funds on research of both the basic and applied sciences. These institutes utilize to the greatest advantage the extraordinary richness of its raw material, its large population, and its huge university and academy organization, which makes it possible to select good research workers. There partly academic and partly big factory laboratories are modernly equipped, and also industrial research institutes, to solve all research problems of almost every important branch of the basic, as well as of the applied sciences. Therefore, an enumeration of the individual institutes by name can be omitted here. Well-known scientists work at the head of the individual research institutes or as the leaders of their scientific boards. In the control of the individual research institutes the government departments concerned, are also aided by committees made up of scientists and the best leaders of the industry. If we take only that fact into account of the difference between the individual aims, a numerical comparison between the funds spent on research work in the capitalist and in

the socialist states this in itself cannot give us a characteristic picture. E. g. in the Sovietunion funds can only be spent on research aims of *public interest*, and the efforts as a whole of the research workers are concentrated upon the interest of the people's conomy. In the capitalist states the research funds of the *individual private concerns* can be increased by an effort to fully exploit a market situation for some such reason as e. g. to defeat a competitor in the market, or from the point of view of business propaganda. Such additional expenditures *cannot be considered useful for the whole national economy*.

Taking the possibility of such an "idle" expenditure, in view of national economy, even so a real picture cannot be obtained by a comparison between the individual capitalist states. The following few statistics given out in the USA and in some larger western European countries by the research organizations of the individual nations — may only serve as a general information for the estimation of the amount of expenditure, mainly for individual research organizations such as state, private concern, association, etc.

In the United States besides the national research institutes there are also a number of big private research institutes. The leaders of the privately owned industrial research institutes lay a great stress on their research activities producing *positive industrial results* in the shortest possible time, because without these the existence of their institute are not firmly secured. The leaders of the research works and those of the big industrial concerns are in close cooperation, as the future leaders of many big industrial concerns are often recruited from among the directors of the industrial research institutes.

In 1930 fifteen per cent of the whole research expenditure amounting to appr. 166 million dollars was borne by the federal government.

In 1941 appr. 800 million dollars in all were spent on research and industrial development works.

In 1950 appr. 70 000 scientists and engineers were employed by the industrial research organizations.

In 1952 about half of the appr. 3 milliard dollars spent on research was covered by the government.*

National research and the development of industry, including the survey of research plans, in most cases are estimated and entrusted to two sorts of special committees. One committee investigates the general aims of the researches, the other carries out the detailed analysis of the research plans. The first committee is composed of experts who have extensive practice in *organizing work* on this field of science. These experts often modify the research plans, reject other research targets, or take up some such subject which had been so far neglected. The members of the latter committee are *mainly recruited from*

*L'organisation de la recherche appliquée en Europe, aux États-Unis et au Canada, Paris, 1954. Vol. III. p. 11 and 25.

experts in some special branch of science who discuss each plan in detail and compare them from experiences obtained earlier in similar fields.

In the private industry the raising of the funds necessary for research is done essentially through profit, or from specially issued shares. Since 1946, 66 percent of the funds newly invested in industrial research is obtained from profit and normal issue of shares, 32 percent from loans, and only two percent from the issue of preferential shares.

In America there are a *great number of independent, not state-owned research institutes* in operation. Among these the following ones are the most notable : Mellon Institute for Industrial Research (founded in 1913) ; Battelle Memorial Institute (founded in 1929) ; the Stanford Research Institute in Palo Alto (California) cooperating with the Stanford University ; the American Research Foundation, etc.*

The greater part of the institutes was established from some foundation or was founded by a special company formed for this purpose. They are the so-called non-profit institutes, which spend their revenue made by research contracts or other orders — besides the sustenance of the institute — on the development of their equipments and instruments, and on some basic research works, without order.

There are also a some independent so-called profit institutes which were essentially founded for the commercial application and exploitation of their research results. Such is the American Research and Development Corporation in Boston. This has 400 shareholders some universities included.

In Great Britain a strong *state control* is characteristic for many important fields of research. E. g. research works carried out for national defence are entirely under state control. However, the state exercises a strong influence over the other research works as well. E. g. in the year 1950—51 the state spent appr. sixteen million pounds (45 700 000 $) on research works, not affecting national defence. From this appr. 7 500 000 £ (21 400 000 $) was used for heavy industry, and two million pounds for medical science and public health purposes. In the year 1946 the independent research expenditure of the whole country amounted to appr. 30 million pounds (86 million dollars).* In the year 1956—57 the British government spent 66 million dollars on scientific research. From this sum the industry received 32 million dollars, the agriculture 19 million dollars, medical science and public health 8 million dollars. (Chemical and Engineering News, 31 Dec. 1956. p. 62—65.) The two most important state organs for the control of industrial research are the Advisory Council

*It may be interesting to note that according to the estimation of an institute of this kind in the five years preceding 1954 each 1000 $ research expenditure brought a 15 000 $ profit for the ordering companies. Naturally, the accuracy of such estimations must be regarded with reservations.

*L'organisation de la recherche appliquée en Europe, aux États-Unis et au Canada, Vol. II, p. 185.

for Scientific and Industrial Research, also the Department of Scientific and Industrial Research (D. S. I. R.). This latter institute concerns itself with the initiation and support of all industrial research works affecting the whole national economy, and also aids the university basic research, furthermore it occupies itself with the training of research workers. Connected to this authority belong many large state-owned laboratories as e. g. National Physical Laboratory, Chemical Research Laboratory, Building Research Station, Food Investigation Organization, Geological Survey, Hydraulics Research Organization, Mechanical Engineering Research Organization, Radio Research Organization, Road Research Laboratory, etc.

In Great Britain in 1953 forty so-called "*Research Associations*" were in activity which were established mainly on the initiative of private concerns. The whole annual expenditure of these exceeds 3,4 million pounds (9 700 000 $).* From this sum the state subsidy run to 1,25 million pounds (3 570 000 $).**

Further significant, special-basic research work is done at the *English universities*. About 140 years ago Britain had only two universities: one at Cambridge and the other at Oxford. At the present moment it has 18 universities. In 1953 more than half of the total expenditure of the universities was met by the state. This research work is exclusively under the control of the autonomous universities. In the year 1949—50 the normal expenditure of the universities and university institutes was appr. 22 million pounds (63 million dollars). About 64 percent of this sum was supplied by the state, from a subsidy passed by Parliament, and 4,6 percent was provided by the local communities. Besides this, the state additionally supplied appr. six millions pounds (17 200 000 $) for the purpose of single investments (as for new buildings). Since the war till the beginning of this year, from the total of 686 million dollars assigned for buildings, 450 million dollars were spent on buildings for university and research purposes.

In Great Britain the state control of research is fairly centralized, whereas *in Sweden* it is rather decentralized. Five research councils, ten special state research laboratories, four research institutes under state subsidy, six so-called state technical services, divided among five different ministries, are functioning. They are in no special coordination with each other.

The results of applied (industrial) scientific research are *generally* lagging behind those of basic research, in spite of the fact e. g., in 1955 the Imperial Chemical Industry spent more than 26 million dollars for research purposes.

Of the larger privately owned research institutes, which are so numerous in America, only a very few are to be found in Britain. Notable among these are the Fulmer Research Institute and the Sondes Place Research Institute.

*Which is about seven times as much as the sum spent in 1939.

**L'organisation de la recherche appliquée en Europe, aux États-Unis et au Canada, Paris, Vol. II, p. 198 and 193.

The former has researches in the field of metallurgical and also in physical and chemical problems.

The significant role that the Royal Academy in Britain plays must specially be mentioned, particularly in the development of basic research. Many famous research workers cooperated in the past as well as in the present in their research works with the Academy. In their time Sir William Bragg and Lord Rutherford carried out their researches also in cooperation with the research institutes of the Academy.

In France research work is done by the following institutes :

a) national research institutes and laboratories,

b) factory research laboratories of large nationalized concerns,

c) organs working under the authority of the Ministry of Education, in the first place are the *universities*, and the government organ named *Le Centre National de la Recherche Scientifique* (C. N. R. S.) which plays a large role in the forwarding and control of research work in France. Groups and subgroups composed of scientists for the cultivation and promotion of almost all the important branches of science. The normal annual estimate (budget de fonctionnement) for this organization totalled e. g. in 1951 three milliard Frs (8 580 000 $). In the same year 600 million Frs (1 720 000 $) were spent on equipments.* On one hand this organization supports by a considerable sum the research work of higher education and also employs a good number of research workers — among these many young men and scholars with stipends — on the other hand it also controls and sustains its own research institutes. Fifteen large laboratories are controlled by this institute, the most known is the so-called Bellevue Laboratory which has also further twenty specialized sub-laboratories.

d) The research institutes of *private concerns* are of two kinds :

1. The *factory laboratories* of private concerns of the big industry e. g. Le Centre Technique de l'Aluminium (founded by the Société de l'Aluminium Français). The Société Neypric, in Grenoble is such a Factory laboratory, which accepts research orders under research contracts from others — even from rival — concerns.

2. *Independent research institutes* for individual branches of industry, maintained by a certain branch of industry or by a group of them. Such are e. g. Le Centre Technique de la Fonderie, l'Institut Français du Pétrole, l'Institut de Recherches Sidériques, l'Institut Textile de France.

Some branches of industry founded *research associations* for the solution of *common research problems* for the whole branches of the industry concerned or for individual concerns within certain branch of industry. The organizations greatly differ in these associations. Their expenses are covered mostly

*L'organisation de la recherche appliquée en Europe, aux États-Unis et au Canada, Paris. Vol. II, p. 67.

from contributions of the members of the association, or from profits made by the association from their research results, and finally from grants and subsidies.

In *Western Germany* during the last year a total of appr. 300 million dollars was spent on non-military research purposes. About half of this sum was spent on industrial research aims. In the year 1954—55, the total expenditure used for scientific research was increased by 2,3 million dollars, as compared to preceding years. The same year 158 million dollars were gained by public and private contributions, five per cent of which were donated by private persons, 4 per cent by communities, 77,7 per cent by the federal government, 13,3 per cent by the provincial governments. Basic research is mainly done by the *Max Planck Institute* in Göttingen (founded in 1948) which has *several* large scientific *research institutes* in different parts of the country. In 1953 the annual estimate of the institute was 17 800 000 DM (4 240 000 $).

In contrast to the Max Planck Institute, the Deutsche Forschungsgemeinschaft to which are connected some universities and the most important German scientific institutes, *do not do research work themselves*, but usually entrust individual scientists, or scientific institutes to carry them out. It mostly works with state or community subventions. In 1953 its annual estimate was 11 million DM (2 622 400 $).* On questions concerning individual research requests, the so-called, Fachausschuss-es make decisions. In 1953, 131 such Fachausschusses were in action. Every Fachausschuss is composed of two university professors. The Fachausschusses are elected by a college for four years dealing with all scientific research questions and composed of university professors.

The *Frauenhofer Gesellschaft* in Bavaria mainly works on applied scientific research questions. The members of the company pay its expenses but it also gets support from the state.

Also individual big industrial concerns spend great sums on research. We bring as an example the Farbenfabrik Bayer (the former IG Farbenindustrie) which spent 62 million DM in 1955 on research. (This sum is more than four per cent of the annual turnover.) The central laboratory in Leverkusen in which basic as well as applied research work is done, cost 17,7 million DM. It is one of the most modern research laboratories in Europe.*

Private concerns having no factory laboratories of their own form a so-called *Forschungsgemeinschaft* for the furthering of their common aims.

Thus, research organizations, both in the larger Western European countries and in the United States show a *greatly differing, inhomogeneous picture*. Research is done by different organs and by differently organized institutes. In the larger Western European countries and in the United States research is usually con-

*Chemical and Engineering News, 31st Dec. 1956. p 62—63.

* Chemical and Engineering News, 31st Dec. 1956. p. 62—63.

trolled by the government of the state, and by the different organizations or representatives of *industrial concerns*. The state undertakes researches which are concerned with national defence, atomic energy and public health. In general, the state finances the basic researches of greater importance, and also those scientific institutes where research workers are trained.

The *place of research work* or the organization of the institute doing such work can be classified as follows :

1. University institute
2. Factory laboratory of an industrial concern
3. Independent research institute

The independent research institute may be

a) state-owned

b) in capitalist economic system : non-state-owned such as

α) maintained by some associations

β) private institute that make *research contrats* or accept *research orders*.

In accordance with the *aim of the research*, the above-mentioned institutes can be divided into the following three large groups which, however, are not clearly limited from each other :

1. Basic research
2. Applied research
3. Industrial development work.

According to the *research organization*, all three kinds of research works may finally work with several research teams (then it is called "team work" large independent research organizations or a big factory laboratory) or may be the work of a usually smaller research group (e. g. university institute) lead by a research leader.

In the following chapter the starting point of the discussion will be of the relationship between basic and applied researches. From the above described organization of the research work, facts ensue which are also important in their economic effect.

III

If we want to discuss — in this case *only in general* — the question of the lucrativeness of applied research, it is evident that we must start with a consideration based on a comparison of research expenditure and profit expressed in money ensuing from the results of the research. In this respect *three fundamental questions* must be answered.

1. Can such *methods* be found which can be *generalized*, and could give real results, by the use of which the *expected lucrativeness from the applied research* could be measured *in advance*, and be estimated with approximate accuracy?

2. Is it possible, *in the the course of applied research work* or more precisely during one of its phases, to *estimate* with approximate accuracy *economic lucrativeness of the research work?*

3. Can be determined from the *results of a research work* which had already been done and brought profit, *how much of this profit is due to the result of the research work* (e. g. the profit gained by new manufactures put on the market as the results of the research, and how much is due to different market conditions and economic fluctuations, that are independent of the research work done?

Every serious *applied research* which is not *simply* development work also contains *more or less basic research elements*. Before starting to answer the questions, which is our final aim, it should be investigated, whether lucrativeness of basic research above-mentioned in points 1 and 2 can be evaluated.

It is a proved fact that basic research *as a whole* is profitable and economical. To prove this it is enough to refer to two simple and well-known examples : *one* is the *ever increasing*, almost secular trend of the lucrativeness of basic research. *The other* is in fact continually certified by practice that far the greater part of the results of basic research becomes, sooner or later, directly or indirectly, economically useful because it streams into the industry, contributes to the development of industry, and to the increase of the latter's being profitable. In spite of basic research *as a whole* being economical based on empirical perceptions, the economic results of an *actually given* basic research work — as mentioned in points 1 and 2 — *can by no means be determined.* Just as at the time when Euclide's geometry was established no one could have made conclusions as to the economic significance of the atomic energy based on the theory of space curvature and the theory of relativity.

If, however, the expected results from a given basic research work in general can only with great difficulties or not at all be measured by economic-means, it remains to be determined whether any considerations of general validity can be found on which the lucrativeness of the basic research could be increased. Three principles can be enumerated that quite are well-known, although little followed in practice.

a) *The first* and most important principle is that there is a *close relationship* between basic research and the *area, density of population, national resources* (e. g. richness or shortage of raw materials), and *national income* of the country concerned. The omission to draw the right conclusions from this relationship is a great mistake, even in economic respects. In other words a small and poor country cannot dispose either of such economic means or such a selection of research personnel, as a big and rich country. Basic research, however, particularly in some branches as nuclear physics, etc., needs a great amount of expenditure and a great number of research workers.

The second and in its economic effect, also significant question is to bring about a *proper proportion* of necessary basic and applied sciences being cultivated, in the first place in those countries where the possibilities of basic research are very limited, owing to the limited resources of the country. This proportioning means that a country of limited resources — if following the right economic policy — will evidently endeavour to produce such goods of which a great quantity or a significant value produced can be put on the market, either at home or abroad. The subsidy spent or to be spent on basic research, particularly the *investment* must logically be made use of in the interest of this aim, therefore it is to be spent on *basic research closely connected to the necessary applied research* and not arbitrarily chosen subjects not related to it.* This statement *does not apply to purely theoretical fields of research* which need no expensive instruments and equipments such as e. g. some parts of mathematical research or some fields of theoretical physics, etc.

c) *Thirdly* owing to the continual reciprocal effect that nature and man have on each other, man perceives, understands and solves the secrets of nature, and in doing this, he himself also creates many new things in nature. This work is, however, in the first place a *creative work* depending on the talent of man, and up to a certain point, it *cannot be planned, timed and valued* in advance, and even its trend cannot always be exactly determined.*

The right course as well from the economic side is to suitable "*credit*" a research scientist. Under credit is understood that when giving research orders the decisive factor should be in the first place the research worker in person doing or leading it, and his aptitude for it justified by previously obtained results. (The results achieved by a scientist can be measured e. g. by the echo of his work from abroad.) *The best results are likely to be obtained from the best scientists* whereas the epitaphs in the cemetery of the badly used or wasted large sums are carved by bad scientists usually.

Coming now to the main subject of our discussion, i. e. to applied research, it usually originates either from a scientific discovery, a new invention or some development aim, and finally from a combination of all three.

Answering to the *first question* put at the beginning of this chapter, it is mostly the *short-range* development works, the expected results of which can be estimated with approximate accuracy. This is so, because such works can usually be finished within 1 to 5 years and their results can also be realized. The estimation of the lucrativeness of research works taking up longer time is rather inaccurate, if only, as we have seen, on account of the uncertainty of judging the occasional supplementary basic research.

*A country may digress to a certain extent from this principle for the sake of developing the culture of its basic science or for the sake of some of its great scientists.

* E. g. Ziegler while doing research work in some entirely other field, succeeded to produce polietilen without pressure which was achieved before only at a pressure of 1500 at.

As to the *second question, the checking up of the profitableness of* a *long-range* research work *already in progress* is likewise a difficult task, and its estimation is considered rather uncertain. In the laboratories of the Bell Telefon Company — as known — a great number of researchers worked on the solution of different applied research problems. At the same time researchmen *Bardeen* and *Bratain* discovered the transistor effect during their measurements in the field of basic research. Owing to its significance, this discovery changed the trends and aims of all the applied research done up till then.

The answer to the *third question* whether *the result of applied researches of longer range can be measured* is likewise unfavourable. The economic appraisal of the results of such researches is difficult for the following reasons :

a) On account of the *long duration of the research.* Taking the known example of the electronic tube it appears that it was discovered about 50 years ago, but from the time of its discovery, until its industrial production a time of appr. 25 years elapsed.

b) Because *the gain* obtained by the results of research is due in many cases *not only to the results of the research,* but to the changing market conditions or economic fluctuations, and occasionally to some particular behaviour of the competitors.

c) Finally, it is *difficult to even ascertain a negative result* because the amount of further material and mental sacrifice cannot be precisely established by means of which a research so far giving no results, could be turned into a successful one. In 1939 Kipping said that the industrial application of organic silicon compounds was hopeless, and yet in 1943 the silicons already appeared in the market.

As to the possibility of the economic evaluation of long-range applied research work — before its completion or industrial application — *the opinions are also sceptical in the literature.** The individual research institutes and concerns have different evaluating and checking methods, in which they trust, but these methods cannot come into consideration when looking for principles of general validity. (Unfortunately, the literature on this question was not completely accessible.)

Fig. 1 shows the history of a period in the technology of steel production. It is evident from the figure that when a new industrial process starts being developped (in this case the stirred iron marked "b"), the earlier process after having gone through its production peak begins to decline. (Charcoal pig iron marked "a".) It also appears from the Gauss' curve-shaped lines in the figure, that when a new industrial process starts on its way to success, the earlier process has a certain *run-out time,* during which a complete decline of this process

*„Comitée d'organisation européenne de cooperation économique" has this opinion. L'organisation de la recherche appliquée en Europe, aux États-Unis et au Canada, Paris, 1954. Vol. I, p. 32.

has not yet set in. This is a good example to prove that even if it cannot be exactly determined, whether a long-range research work brings forth economic results, according to the questions given under points 1, 2 and 3 in chapter III, yet a big industrial concern neglecting research is left behind in competition. Therefore, a big manufacturing concern must spend on research from the profit at its disposal, or from some other means, a sum which is proportional to its resources, and to the probability of success of the subject under research. From the point of view, of business establishments, however, it must be accepted

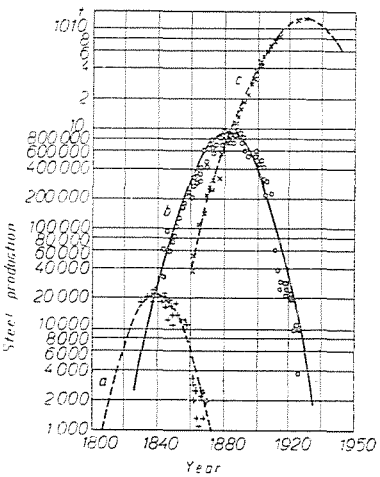

Fig. 1. a Charcoal pig iron, *b* Stirred iron, *c* Mild steel

as a general principle that the research is *only a way* to the goal and not the goal itself. This fact also helps to determine what percent of the profit or the total annual turnover should be spent in a year on research. In order that its economic effect should also show itself *in time*, the actual results of the research are to ensue, not later than within the run-out time mentioned above.

IV

As to the foregoing discussions as we have seen yield negative results, not more than a few *economic* and closely connected *organizational principles* can be summed up — for improving the economic efficiency as well of the long-range applied research work.

1. *Decisive are the arguments resulting from economic considerations* and the economist — the originator of these arguments — must also be listened to when the question is : *What* should be the subject of research, considering the interest of *the national economy as a whole?* Because the right decision of this question depends, in the first place, on the adoption of a correct general

economic policy. When the individual business establishment is about to decide the question of what should be the subject of the research, the different economic considerations of the management must also have a role, such as the amount of annual profit, the results of market-research at home and abroad, etc. A further question closely connected to the question of the *research target* is *what resources* are available to attain the set aims. A reasonable distribution of available resources among the fixed aims, is a task that also needs economic considerations. Such an economic consideration is e. g. that only so many research targets should be fixed to the attainment of which the *appropriate means* are, *to a necessary extent*, entirely available.

The decisions of the question *of how the research should be carried out*, is in the first place a scientific question, although it also contains a number of purely economic tasks. This questions can be devided into two parts :

The first part is the settlement of *general* questions, mainly those concerning science organization, which is the task of the *science organizer*. The second part is the decision on questions of *detail*, which mainly belong to the *scientific research worker*. The organizer and the research worker are, as is well-known, two different types of men. (The research worker does not need to have organizing ability, but the science organizer must also be a scientific researcher who is inclined to leave his laboratory — the seat of his limited work — to obtain wider horizons.)

When deciding the question of how to carry out the research only *the good coordination* of the two tasks can bring good economic results both at the setting of the aims, at their attainment and in the course of checking.*

First of all, for the sake of a successful research the science organizer, if he is at the same time a research leader, must solve the fundamental *contradictions of research work*. This contradiction is due to the fact that discovery, invention, the finding of new processes and methods, are usually a question of individual inclination and working method. On the other hand the elaboration of details of most of such results, their application in technical practice is the result of a strenuous work precisely organized and ready to comply with the nstructions of this organization.

* Sometimes the role of the science organizer, sometimes that of the research worker is assumed by that dangerous type that can be called *science administrator*. They are also economically, really harmful to the research, because they work with the lowest efficiency and usually do more harm than good. *J. P. Bardin*, the vice-president of the Academy of Science of the Sovietunion characterizes such science administrators as follows : „There are such research workes who have no merit whatever in the field of science, and that by obtaining certain administrative posts they try to secure a scientific position for themselves. It sometimes happens that workers of this sort are at the same time leaders at university department, heads of a section at a scientific institute, or a member of an examination board, a member of the editorial staff of a periodical. As the amount of titles in itself cannot substitute qualifications, therefore in scientific disputes with antagonists he takes administrative measures instead of using scientific arguments." (Academy Bulletin of Hungary 1951 : Against the over-administration of science for the creative-minded scientific work. p. 341—345.)

Military tactics and strategy are taught *from books* and even generals were taught in this way. Nevertheless, generals are not judged by their books knowledge, but *by the way* they make use of their knowledge *in a given case*, by mustering their individual talents and aptitude. Thus, the research leader should give opportunity to research workers cooperating with him to follow in some given cases their inclinations, and make use of their individual aptitude even, if this involves certain risks not estimated beforehand or expenses never to be recovered. But he must be able to counter every lack of discipline thus masked, as the wasting of time is incompatible with serious research work.

2. In order to increase the lucrativeness of research, the most important task of the science organizer or the research leader is *to regularly check the costs and results of research*. In the course of checking the costs, the *way of checking the expenditure utilization*, has a special importance. Besides receiving all necessities to complete his work successfully the researcher must also get accustomed to a *strong financial discipline*. This can be done in the individual phases of the research plan, by comparing the results obtained by means already used and with those still necessary in the future. In other words it is necessary to *evaluate every important phase of the researcher's work*. The individual phases of the evaluation may be e. g. as follows :

a) *A previous checking* of the expenditure laid out for the laboratory *research plan*. (This is necessary only when planning expensive researches on large scale.)

b) *An interim checking of the results :* a balancing of the costs already spent, and those still necessary and their comparison with further result plans. In the course of investigating the partial results, it is advisable to have, as soon as possible, a *forecast* made from the means which are necessary until completion, from the economic value of the final results, furthermore from the time likely to be necessary until completion.

c) A detailed preliminary investigation of the costs and expected results of the proposal for pilot-plant production.

d) Based on the data of successful pilot-plant production a *previous* assesment of costs and expected economic results of the *industrial realization*.

A not cumbersome and hindering, but *reasonable maintenance of pecuniary discipline*, usually has a favourable effect on the research workers. Not all of the several good ideas are feasible in practice, as they may happen to be uneconomical. On the other hand the researcher upholds his idea and is often childishly blind to its defects, and thus he is reluctant to acquiesce it to its fate i. e. if its practical realization is not economical. A later idea of the same research worker can sometimes to be worth gold, therefore he should not be discouraged in his researches. The checking of the individual phases of research

work is already known in practice and its significance concerning the present investigation is as follows :

This *necessary checking should be carried out in view of its educational effect* on the individual, particularly on young research workers. In the course of these checking conversations the researchers who often do not know practical life well enough, should learn the relationship of idea and practice by the well-meaning explanation by those best qualified for this. They should be convinced of this by themselves, and should not lose their creative spirits, and endeavour in the future to harmonize theory and practice, idea and its realization, technical perfection and lucrativeness.

For measuring efficiency of the research, good leading principles are given by the German patent law, especially in its determining the idea of *novelty* and *steplike development*.

3. When examining the place and method of research work, and the significance of its organization the following can be stated :

a) The *basis*, and at the same time the *starting point* of scientific research are the *universities* and university institutes. This is so because the fate of the *future replacement* of research workers of both the independent research institutes and the big factory laboratories, are decided upon from year to year, in the first place, mainly at the universities. This is also the reason why these institutions have a key position for developing research work in the whole country. The *economic utilization* of the university research works is good because all the buildings, equipments and personnel are used for the double purpose of teaching and research. It is because the selection of the research workers can be made out of a great number of enthusiastic and still comparatively cheap workers. Finally, because the universities through the cooperation of their different departments afford an unparalleled possibilitiy for a good and comparatively cheap coordination of the most different basic and applied researches. This good coordination is secured by the professors themselves, each of whom leads a smaller individual research team and also works in the field of both teaching and research. Very often it is much cheaper to locally expand the above-mentioned cooperating university institutes, to repair and complete their equipments or to increase to a certain extent their personnel in the interest of some important research works, than to have one or more independent institutes built for this purpose. Those arguments are not quite valid, brought against the more economical utilization described above that, in the interest of research success, it is necessary to be free of every other work at an institute used solely for this purpose. Because when necessary this seclusion can be carried out also at the universities, partly by employing personnel solely occupied with research, partly by establishing a few large institutes closely cooperating with the universities and located in their proximity. (There are,

naturally, such research works for which big independent research institutes are really necessary. These will later be dealt with.)

b) If the universities mentioned as having the key position of applied research, in order to obtain good economic results, the *factory laboratories of the big industrial concerns* can also bring forth an *ideal cooperation* where theory and practice, the aims of scientific research and the interest of management, are of equal value. (To avoid any possible misunderstanding under the term factory laboratory, not a laboratory of some section of the works are understood, but the central research laboratory of the whole concern.) The factory laboratory may select its research personnel according to the importance attached to the solution of one or two of its different problems. Accordingly, it may to some extent to employ practiced research workers in basic or applied research, or those who have practice in industrial development. Cooperation can be simple and usually very profitable between a management knowing well the aims, endeavours, economic results, as well as the possibilities of the concern, and between the leader of the research laboratory and his co-workers who are aware of the state, outlooks and possibilities of the research. To these circumstances can be mainly attributed, usually, the excellent economic results of the big factory laboratories.

c) An *independent industrial research laboratory* is necessary when :

some larger-scale research work of concerns *having no separate factory laboratories* is in question,

if the nature of the research requires the *cooperation of big scientific teams* with the *employment* of such *expensive* and *special* equipments, the setting up of which is not expedient at university institutes or factory laboratories.

To these belong some basic research works usually done by state orders, owing to their extraordinary expensiveness, works of public interest, for national defence and public health, furthermore some researches of great importance possibly concerning whole branches of industry, or necessary for the establishment of some new branches of industry. For these purposes either a separate institution is established, or a so-called research contract is made, or a research order is given to one or more already existing appropriate research institutes.

In the work of an independent research institute the *planned control* (by state or other controlling organs) and the *checking of results* may also help to obtain maximum economic results. The individual research aims properly used in the research plan or order, should in the first place be checked by the consignor (business establishment) concerned. In the course of this checking, in order to carefully coordinate the aims and possibilities, a close and permanent cooperation is also necessary between the *consignors* and *those doing the research work*. In the course of its work the rese-arch institute not only accepts orders (e. g. through research contracts or other

research agreements made)* but knowing the aims of its consignors or the possibilities and needs of its field of research, may themselves make some proposals toward the consignors who having accepted these proposals, may carry them out. *Thus the independent research institute becomes the thinking central brain of its research field* and its consignors, which not only gives answers to the question put to them, but also takes up proposals where possible and necessary. Therefore, the independent research institute performs each of its tasks in the best possible way, if it does not lay stress upon its *independence* but upon its *readiness for a permanent cooperation* with its consignors. In view of a given order it should act like the *factory laboratory of the consignor*, in order to obtain a better coordination of research and the economic questions.

The economic efficiency of the work of the independent private research institute can be measured by the *actual results* of the *performed* research contracts and other research orders.

Without claiming sufficient actual results a private research institute cannot exist unless it can cover its expenses by profits made through its results.

The checking of the actual results of a state research institute is a much more complicated task. This question will be *separately* dealt with at a later date.

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* The advantage of a research contract or order, is that the placer of the order need not procure material and equipment or employ personnel. It has no administration, nor is burdened by the rather complicated detail-work of checking the research. On the other hand, the contractor institute through a quick and satisfactory performance of research contracts may make a profit that not only helps to cover its running expenses, but may sometimes make it possible to procure some more expensive instrument or other important equipment, for investigation of such useful scientific questions, that are not provided for in the budget, but are thought necessary by the institute.

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