Some aspects of the realization of high-energy projects in CERN*

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ABSTRACT

General features of high-energy projects are outlined. It is indicated that although these projects are normally large, complicated, and technologically advanced, in general they meet the cost and time estimates rather well. The aspects discussed include: project set-up and control at CERN; the kind of staff, their work and motivation; collaboration with industry and the possibility of "fall-out" products.

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Several aspects of high-energy physics projects have already been discussed yesterday by Dr. Hine and Dr. Carreras, and to-day I would simply like to say a few words about the way in which we realized these projects and the role of industry in this. I shall not go into the subject of collaboration with other laboratories, although this is an important point for CERN; but this afternoon Dr. Adams will certainly talk about this matter.

1. HIGH ENERGY PHYSICS PROJECTS

You will have seen or at least heard that the projects that we talk about are very big -- big in size, i.e. they may be of the order of 100 metres up to kilometres; big in money, they cost hundreds of millions, up to a milliard francs; and also they should be considered as technologically advanced.

In 1959, when the present Proton Synchrotron became ready, it was the first of this type working in the world, and the same was true for the Intersecting Storage Rings when they were starting up three years ago. These Rings, by the way, are still the only ones; no others exist, neither are any being constructed. And the "big machine", when ready, will be the largest of its type again, and it will certainly be full of technical novelties. What I want to say is that these projects, from the point of view of technical advancement, can be considered at the same level as, say, large rockets, or supersonic airplanes, or new types of reactors. The projects that we discuss here, when put into operation, generally worked immediately up to the performance specifications that we promised; but, moreover, when you look at the construction, you find that we have done rather well in keeping to the time-scale and to the cost estimates.

The largest project so far finished in CERN was the Intersecting Storage Rings project, which was approved at the end of 1965. At that time we told our Council that we would build it for 332 MSF (at 1965 prices), and that the machine would be in operation by the middle of 1971. In reality the machine worked four months earlier and, when we made the accounts, we found that approximately 5 MSF of the project money were still left over; so we under-spent on this project. This is, of course, quite a different affair if you compare it with some of the other advanced projects I have mentioned, or even some of the more conventional

*) Adapted from tape recording.
projects such as underground railways, abattoirs, airports, or Olympic games, and even simply motorways, where sometimes large over-expenditures and delays have occurred. Admittedly we do not always underspend on our projects. We also have sometimes an over-expenditure of 5% or maybe even 10%. But I have never, never, in our field seen a factor of 2 to 5 over-expenditure that you sometimes find in other fields. This discipline of sticking to your promise -- because that is what it is -- this discipline is not limited only to CERN, but it is rather typical of high-energy physics I would say. To give one other example: in 1960, the Alternating Gradient Synchrotron in Brookhaven, USA, which was a sister machine of our PS, was finished, and at that time their project leader was able to hand back a sum of money to the Atomic Energy Commission saying: "Well, the machine is finished and this money is left. Thank you very much."

2. PROJECT SET-UP AND CONTROL

I should now like to mention a few points which we believe are of importance for making these projects, not only a technical success -- which means that they work according to the specifications -- but also a success from the management point of view, which means that you stick to the time-table and to the cost estimates. Let me start with a point that I believe is not so essential, but I want to mention it because it is so fashionable that even big conferences are held about it. It is what is called "project control", the management "tools". It is of course important to control the project. In the ISR we had PERT, a critical path system to control this, and it worked very nicely. I am sure that in the new "big machine" there will be a system that is even more complicated, and I am sure that this will also work very well. But I still remember the old PS which was finished in 1959, at which time these systems did not yet exist. All that one had at that time was common sense, and yet the PS was ready six weeks before schedule. I therefore believe that of course one would be stupid not to use the tools when they are available, but I do not believe that they are so essential that a project would be doomed without them. I think there are more essential things. For instance there is the project set-up; and here we have always been rather clear in CERN, and also I think in other laboratories. A project leader has always been given very great liberty in devising his own set-up, and when we talk about big projects of the size of the large accelerators, we have always created a special project division which was, from the technical point of view, almost self-supporting; that is, it had its own magnet group, its own vacuum group, even its own electronics workshop, its own mechanical workshop, certainly its own drawing office, even its own buildings group. Therefore for technical matters the project leader never had to rely on general services from the Laboratory; he of course used general services from the administrative point of view, such as for the cleaning of the buildings, payment of salaries, and so on, but the technical matters were always within his own hands and, if something went wrong he could only blame himself or his own people. And we believe that this is an essential point: to give a great independence to the project, and therefore the full responsibility to the project leader.

3. STAFF

Of course the quality of the staff must be good, and we have been lucky in CERN that we were allowed to hire our staff within Europe from wherever we wanted it. We have a very good Convention, and we have a marvellous Council, and they allow us to hire people without
considering their nationalities. They do not insist that we distribute the posts in accordance with the contributions of the Member States; we can take the best man that we can find for a specific job.

What may be even more important is the motivation of the staff, and here we come to a point that I should like to call the "continuity of the staff" throughout the project. This is the following: once you decide that you want to start a new project, the very first step is to set up a "design study group", as we call it, which may be composed of 10 or 20 senior engineers and physicists. We work together for a year or so, in order to produce what we call the Design Study Report. This is a rather thick book containing the reasons why you are going to propose this project, and how to go about it. It gives the first drawings of the layout and the first technical drawings; it mentions where difficulties can be expected, and it contains the cost estimate and the time-table. It is with this book that we have to go to our Governing bodies for approval. It is very important that the senior staff, when making the design study, know that they will stay on later to actually do the work. This senior staff will form the nucleus of the project division, and therefore a man who, under the design study, has estimated the magnet to cost a certain amount of money, knows that if the project is approved he will have to do it for that money, and this of course motivates him to make a proper cost estimate. And making a proper cost estimate is of course half the job, because you have two figures which you want to balance, one is the cost estimate and one is the total cost. If you make a bad error in the cost estimate, you cannot correct it any more. So it is extremely important at an early stage to motivate the people by letting them know that they will stay with the project.

There is another facet of staff continuity that is interesting, and which again refers to our type of equipment: once these big accelerators or detectors start to function, we know from experience that we need more people to run them -- that is to operate, maintain, and develop them -- than to construct them. This may seem strange, but if you think about it, it becomes obvious, because this equipment will have a long life and a very busy life. It will, in the first place, run 24 hours a day, 7 days a week, and therefore for each operator you need five or six posts, which means that you need a large operating staff. Then as you know, this is advanced precision equipment which needs a lot of maintenance, and since at the same time it is very large in size, it also needs a big maintenance staff. We cannot avoid it. Finally, because it is so expensive, you want this equipment to last a long time, say 25 years. And 25 years is an enormously long time. If you simply look back 25 years, you see that computers, transistors, and printed circuits did not exist. So during the lifetime of an accelerator the technology can change completely. Also the physics interest may change during these 25 years, and therefore you need to have continuous development of this equipment. So you require a large operating staff, a large maintenance staff, and a sizeable development staff -- all of which adds up to a very big staff figure.

It is interesting if a fairly large percentage of the staff that works throughout the construction stage stays on with the project, having become familiar with it during this time. This gives the same sort of motivation for doing a good job. If you know that you have to run something, you will not do a sloppy job when making it. Because of the need for a large number of staff to run this equipment, we can afford to have a sizeable staff during the construction period without having to fear laying-off large numbers of people.
This brings me to the next point, which is how we deal with industry and what is our contracts philosophy. This is related to the fact that we can have a sizeable project group.

4. COLLABORATION WITH INDUSTRY

Our philosophy in this is very simple. It is that in order to make the total cost balance as closely as possible with our cost estimate, we make an attempt to obtain the equipment we need for as low a price as possible. This is the simple philosophy that we try to follow. In order to do this, we have at least two rules: the first is that we give to industry specifications that are as precise as possible for the equipment we need, in the hope that they can make better price calculations with a minimum of unknowns, and therefore a minimum of risk for them. The other rule is that we see to it that for each tender there is sufficient competition. We believe that these two rules help industry very much in their attempts to give CERN interesting offers.

The placing of only a very limited number of extremely large and complicated orders with only one or two big firms or consortiums of firms, such as is sometimes done in space work, is obviously not in accordance with the two rules I have mentioned, and this is why we do not do it. Actually we do the opposite: we tend to break down the whole project into a relatively large number of contracts, each of which is relatively simple in itself, and in most cases therefore suitable for medium-size or even smaller firms. In this way, of course, we increase the number of firms that we can interest, thus increasing the competition.

The equipment we need can be of various types: in the first place, it can be standard equipment, e.g. a power transformer. There are plenty of factories that make transformers, and these factories exist in most countries. So we know that when we need a transformer, there are experts in these firms -- much better experts than we have here ourselves -- who can design this equipment. Thus for standard equipment we never think of setting up our own design group; but we make performance specifications, possibly giving outside dimensions, or how much cooling we have available, and so on; but we do not make a detailed design. In this same class there are many other items: computers for instance, vacuum pumps, cranes, switch-gear, and many instruments.

There is a second type of equipment which is a sort of extension of what already exists. Suppose there is on the market a high-frequency tube of 2 MW, and we want to have something very similar but for 5 MW. Here again we do not try to set up a special group to develop this, but we try to interest a certain number of firms in making us an offer to develop, from their existing standard model, something that suits us. Of course we ask them to develop it at a fixed price. Actually very much of our work is in this category -- that of trying to get a firm to develop something further, something more difficult than what they usually make for the normal market. And in these contracts we quite often have a good relationship with the firms; for instance, we help them to do tests, or even to advance the work.

Then there is a third type of equipment. This consists of all the equipment that normally is not made in factories; for example, there does not exist a factory for synchrotron
vacuum chambers, or for synchrotron magnets, etc. For this type of equipment we insist on having our own experts within the Organization; we want to have them also for later developments and we set up small design sections who work out the specifications, with detailed drawings that are sent out to those firms who we believe can do this type of job, even if this is not their normal speciality. And in this way we are sure that we can get lower prices than if we go to the specialist firms only. To give an example: the vacuum chamber of the PS was made by a factory manufacturing washing machines, which had the right type of production facilities and was therefore cheaper than the specialized vacuum firms -- much cheaper actually -- and they made a very good job of it. But of course we would never have trusted this firm to do the design work. So, to summarize this question of design, we are perfectly happy to let industry do the designing for the normal equipment or for any extension of normal equipment; but for specialized equipment where firms have little or less experience than we have, it is considered more effective to concentrate the technical efforts for the design within our Organization. In this way we form a group of our own specialists for coping with further developments, and at the same time we avoid the setting-up of a number of design groups in various firms where people would normally spend only part of their time on these jobs.

For CERN this philosophy also fits in very well with our financial rules, which like our Staff Rules were made by the people who form our Council, or rather those who formed our early Council. Contrary to what is generally the rule in international organizations, we do not have a system of what is called "juste retour" or "fair return", i.e. if a country contributes 20% of the budget, it does not insist on getting back 20% of the money. Our rule is extremely simple: there is no geographical distribution; we have to accept the lowest offer that meets the technical requirements and delivery time. We believe that the technical judgement of these offers cannot be done better than by the staff who made the detailed design and who will be responsible for the realization. This freedom of spreading out the orders throughout the Member States, without having to worry about "juste retour", is of great importance to us, as you can imagine, and it certainly helps us in getting low prices. But we believe it is not advantageous to CERN alone. We have noticed, for instance, that sometimes a certain firm or factory is temporarily not fully occupied, and therefore it can make a lower offer, accepting to reduce the fixed cost in its price calculation. If this firm gets the order, it is obvious that more than one party will be satisfied. In the first place there is the firm itself that gets the order; they should be very happy because they really needed the work. And CERN should be happy too, because it gets a lower price. But not only that: we know from experience that firms in this situation also give us very good attention. Firstly, they are not so busy at that moment; and secondly -- since they do not make much profit -- they at least try to get a maximum propaganda value out of their contract. And the Member States, even those who did not get the contract, ought to be very happy because they know that they get good value for their taxpayers' money.

The points that I have mentioned are very important for the proper realization of our projects; but you may ask how do the firms see this. Do they feel victimized? You could even partly answer the question yourselves of course -- at least those of the firms who have done business with us. I have talked with a number of firms, and the answer seems in general to be that they believe this is a pretty good system -- except for a few of the very big
firms. Most firms actually like the way in which we work with them. This holds true parti­
cularly for the special equipment design, where complicated development contracts are avoided,
the tenders follow precise specifications, and the projects are split up into a number of
smaller contracts. It is true that very large contracts or complete projects, which involve
much development work, may bring good profits to the few firms that are big enough to handle
them, but also the risks can be very high. On the other hand, when the firms must work to
precise specifications they can calculate their prices much more precisely, thus eliminating
the risk of losses, and can therefore make an advantageous offer.

Up to now I have been speaking about the design of the equipment. However, the really
big help that CERN gets from industry, for the specialized equipment, is not in the design
work itself but in the realization of it, the construction work. And we all know very well
that this involves an enormous amount of work, of thinking, changing, developing; and it is
also here that we have the closest collaboration with industry, which then gives its real
contribution, and where we often really make friends because we are fighting on the same
front. This collaboration with industry is very important because, after all, industry ac­
tually builds 95% of our equipment. We only build about 5% ourselves within the Organization.
Of course industry can live without us, but we could not live without them. I would not go
so far as to say that without industry we would be a zero, but, as I have said, we would only
be 5%. Therefore, to the representatives of the industry, I would say: "You can look around
in this laboratory and think: 'this is our work!'".

5. "FALL-OUT"

I would like to finish by mentioning something that is connected with the work we do
with industry; this is called "fall-out". We have been created as an Organization to do
research on high-energy physics. But we have slowly come to realize that industry may gain
something else form our efforts than just the immediate orders they get from us. And this
is something we are now investigating. Dr. Schmied is at present making an investigation
to follow up what has happened to firms that have had big contracts with us. Sometimes a
firm has a contract with CERN from which they do not make any profit; but in the course of
doing the job, it may be that they introduce a new product that they did not have before
(think of the washing-machine factory that now knows how to make vacuum chambers). Or may­
be they gained experience in doing tests in ways they had not thought about before but which
were introduced by CERN. Or they used CERN as a test-bed because CERN, having been in opera­
tion day and night for 10 years, could be useful for testing equipment in a radiation field.
Or they used CERN simply as a reference. Dr. Schmied has been working' on this project for,
I think, nine months. He has talked with a certain number of firms, and two things have
emerged from this: in the first place, that there is actually this "fall-out". You can
made a list of firms that have had advantages afterwards, which were not immediately related
to the contract; it was not profit on the contract but related to the contract. This exists
to a greater extent than we had thought. I was even more surprised in the beginning at the
way in which the firms were willing to collaborate in this investigation, how they were en­
thusiastic about giving us all the information. Only recently have I understood, I believe,
why this is so: we have noticed that often we have contracts with a firm because the tech­
nical people in the firm were interested, but not necessarily the commercial people. And
then it is of course interesting later on for the technical people also to justify to their commercial colleagues that they were right after all in making this contract with CERN, and so that also for them it may be of interest to get these figures out for their firm. As I said, we are in the middle of this study and that is why we do not want to give a talk about it now, but if anyone here would like to know a little more about the methods being used, then you could contact Dr. Schmied and he could arrange to have a talk with you.