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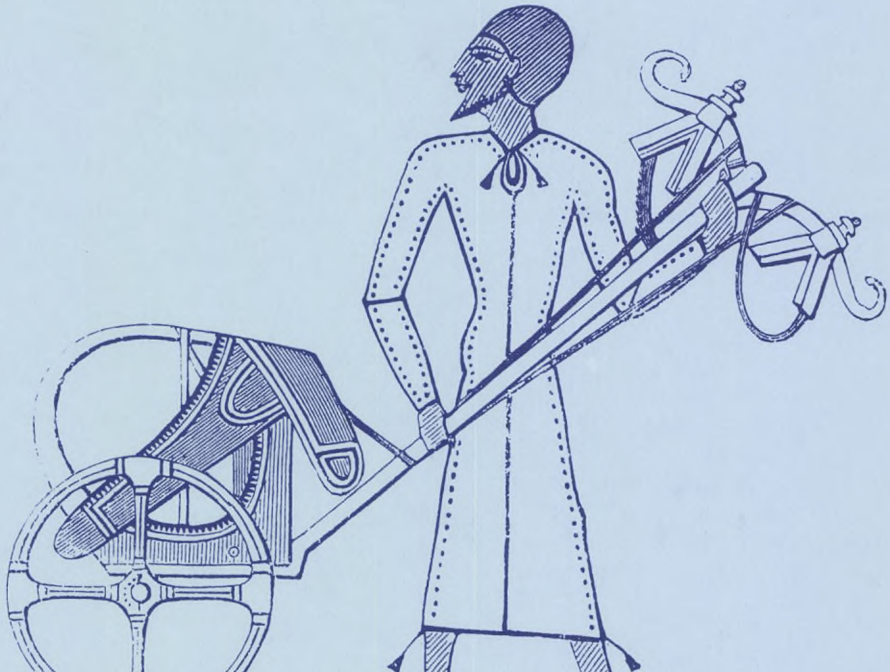

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OTTO MAYR

The Use of a Science Museum

Presented at the symposium "The History of Science and Scientific Culture in Europe", held in Firenze, Italy, December 13-14, 1991

My task at this symposium, I take it, is to talk about the role of the science museum, in a European context, in the dissemination of scientific knowledge. The question is not whether the science museums are useful for this purpose - I presume we all agree that they are: nor is the question whether they could not yet be functionally improved further - again, we probably all agree that indeed they could. The main problem of the science museums of Europe today is that they are too few, too inaccessable, and too poorly equipped. Would it be asking too much if we set as a goal that anywhere in Europe a substantial science museum should be within reach to anyone within not much more than one hour's travel time? For the moment, science museums are few in number and they are lacking personell and funds, or, more basically, public and political support. My question then is: what can be done to overcome these obstacles? What are the best arguments to persuade potential supporters to make available the necessary help?

Before we turn to that question, a few words about one of the premises of this symposium. Reading the announcements preparing for the symposium, one receives the impression that the increase and dissemination of scientific knowledge is an unquestioned value of supreme importance. I am sceptical about this premise: it is too absolute and too narrov. I doubt that there is a consensus on this point either in the history of science and technology community at large, or in this group here, or in the general public. The objectives that motivate the history of science and technology community, museum people included, are much more complex and diverse. The general public, on the other hand, will probably give the acquisition of scientific knowledge no particularly high priority: their expectations, demands, needs, concerning scientific knowledge, too, are likely to be more complex and diverse. And what is science? Is technology subsumed as a subgroup? Are the histories of science and technology no more than auxiliary disciplines, useful in the dissemination of scientific knowledge but without inherent significance of their own?

To avoid disputes about these issues, which are not crucial here, I propose the following compromises:

1. For simplicity let us use the word science in an inclusive sense, covering technology as well as the histories of science and technology: when we speak of science museums we include museums mainly devoted to technology.
2. The objectives of these science museums will be many things, the dissemination of scientific knowledge among them. Science museums are useful to society in many regards. The utility of science museums, then, is my subject.

Nobody has more experience arguing the utility of science museums than their directors. Whenever they address themselves to potential supporters, donors, sponsors, they extoll the good that science museums do to the general public: they employ all their ingenuity and imagination to find more and more powerful arguments for the support of their institutions. Such arguments are numerous: they can be found in annual reports, prefaces to catalogs, budget proposals, speeches at festive occasions etc. Science museums, it is claimed, will awaken in young people an interest in science and they will inspire them to choose professional careers in science or industry. Science museums teach the basic laws and principles of science and technology to the broad public. They persuade the public to accept the modern industrial world and to give up their hostility against technology. Historical science museums integrate science and technology into the general cultural and social history and thus promote the social acceptance of scientists and engineers in the general, traditionally literary culture. Such arguments are familiar to everyone. They are sincerely presented, and most of them are valid, but they are not always effective. For one thing, they are partisan testimony, coming from enthusiasts or from people with a personal interest. All too often such arguments are met with sceptical reception, and the desired support - normally financial support - is refused. The effect upon the defeated museum director is to go home and try to improve his argument further. He learns that rhetoric alone is not compelling. He tries to turn his arguments into scientific proof. Speaking on behalf of a scientific institution and, most likely, to a scientific audience, he feels, he should offer quantitative evidence of the utility of the science museum, hard evidence that will satisfy scientific criteria. Let us see what he may come up with.

To begin with, he will point to the attendence figures. All science museums have above average attendence rates. Some of the world's most highly frequented museums, perhaps even most, are science museums. Is this proof that they cause positive good? A sceptic can think of many objections to dilute the thrust of such statistics. In any well attended museum the majority of visitors are tourists, people spending little time and receiving only a superficial experience. Another large portion of their visitors usually are school groups. School groups, however, come to the museum only under compulsion of their teachers and are therefore not in a receptive frame of mind. The much more valuable experience of those few who study the museum thoroughly and in depth is statistically insignificant.

The modern social sciences offer more refined methods to evaluate the effectiveness of museums. They can analyse the social composition of the visitor stream, they can determine the exact nature of their interaction with specific exhibits, they can investigate the visitors's expectations before entering the museum, and they can measure the degree of their satisfaction afterwards. Empirical evaluations of visitor reactions are excellent instruments for making the museum a more effective medium of communication. But can they tell us in what way the museum visit was of value to any individual, and in what way the museum is useful to society? Empirical evaluations also suffer from other limitations: for one, they can be conducted only with a very small samples of the total visitors: and hence there remains a measure of uncertainty. For the other, they are extremely expensive and museums can seldom afford to undertake them.

What statistical evaluations of visitor samples cannot tell us, we occasionally hear from individual people. At the Deutsches Museum we are told frequently by successful scientists and engineers, Nobel Prize winners, inventors and industrialists, that the museum was for them, when they were young, the principal inspiration for their subsequent success: that as teenagers they spent weeks and months and years in the museum, and that their lives would not have been the same without it. The validity of such testimony cannot be questioned: clearly we have proof here of the utility of the museum. We have debated the question of how to quantify this evidence. It would be possible - although expensive - to interview a selection of such people - twenty or thirty or fifty? - and publish the transcriptions. This would be effective public relations material, but would it be more? Some other questions would always remain: would the lives of these achievers have been less successful without the museum? And what about cost effectiveness: running a science museum is expensive: how many success stories are required per year to justify the annual expenditure of many millions?

If the museum helps individuals, it should also help the community as a whole. Nobody really doubts this. But can we quantify it? Take the case of Munich: when the Deutsches Museum was founded, around the turn of the century, Munich was the capital of a large agricultural province with little industry and a low per capita output. Today, Munich is the high tech capital of Germany, and Bavaria is one of the most affluent of Germany's federal states. Is this, as we should like to claim, a necessary consequence of having a good science museum? Naturally, things are more complex. Many other factors have contributed, too. Probably the museum has helped. How much? There is no way of measuring it. There are even, as always, some sobering counter arguments. There are highly industrialized and affluent areas on earth without significant science museums, for example Switzerland or Silicon Valley. And there are cities with great science museums but without significant industry or even without significant scientific cultures, like Washington, D.C. Once again, what on the surface looked like a self-evident truth turns out, at closer inspection, as a reasonable opinion without empirical base.

My contention is probably clear enough now. A number of impressive arguments for the utility of science museums can be constructed: we the members of the science and technology community, or the museum community, sincerely believe in the validity of these arguments, and a significant part of our audience accepts them. Unfortunately, these arguments do not constitute proof in the scientific or legal sense. They will be accepted by those already convinced, but they will not compel the sceptical.

This is a discouraging result. What can we do about it? Where have we gone wrong?

Our mistake - I believe - is to view the science museum as a tool to do a job, as an instrument for a specific purpose: and to make the value of the science museum proportional to the efficiency with which it accomplishes these tasks. Has it ever occurred to anyone to question the utility of theaters, symphony orchestras, opera houses, art museums, churches? And to make decisions about their existence or their support dependent upon their perceived effectiveness? These are institutions that cultivate and communicate our cultural heritage, that express our imagination and our creative energy: they are supported by a broad popular consensus, and by a wide-spread belief in the implicit necessity of these institutions, a belief that is irrational and emotional.

Our mistake is to think that rational arguments are enough to generate support for science museums. When we think about it, we recognize that the support, the survival and the flourishing of science museums has the same emotional sources as the survival and flourishing of other cultural institutions - love, faith, enthusiasm.

Coming back to the original question: "what is the use of a science museum?" the answer is: "about the same as the use of an opera or a *Te Deum*".

ANDRÉ WEGENER SLEESWYK

The development of the earliest wheels: a viewpoint

Introduction

The development of the early wheel probably started at the end of the 4th millennium BC. It would be an illusion to think that today one can reconstruct that development with more than a limited probability. Nevertheless, it is possible to present a scenario for it, which seems more probable than any other which comes in view; at the very least, the result may have some value as a provisional historical description. In what follows, such an outline is presented for the development of the wheel prior to the advent of the wheel with a central nave and uniformly shaped spokes.

While establishing that scenario, one runs the risk of reading too much history in the archaeological artifacts, but that can be alleviated to a considerable extent by the use of other data and supplementary knowledge. One can think of the following points as aids to a proper methodology:

1. Technological data on construction, materials and usage. In what follows, elementary mechanics essentially contributes to understanding the merits of different types of friction. In addition, the grain of the wood of which it is made is found to play a prominent role in the development of the wheel, at least in the interpretation presented here. The basic mechanical property which is important is that wood is some ten to twenty times stronger when pulled along the run of the grain then when it is pulled in a direction perpendicular to it.

2. Study of the survival of 'living technological fossils'. It is not rare that an innovation, when its useful life seems to have reached its end as it is being replaced by a new one, continues to linger on in isolated regions as a technological relict or fossil. The fact renders it impossible to describe the development of technology as a linear process, and it greatly hampers the arrangement of a chronology of development. On the other hand, the technological fossil may be regarded - with caution - as a record of an earlier stage.

3. Experimental archaeology. Reenactment of technological usage often brings to light unsuspected properties and problems of technological artifacts. Regarding

transport technology, that has been true in particular of experiments with summer sledges, i.e. sledges not sliding over snow or ice.

4. Searching for proper intermediate steps in the development, which in general should not incorporate more than one modification of a previous stage at a time. Such intermediate stages are sometimes hidden in the record, sometimes they may be inferred without being entirely speculative. The following will contain examples of both.

5. The record of cultural anthropology, even if it does not document a relevant technological fossil or an intermediate stage, but another development. Sometimes it becomes clear from the record why under different circumstances a different option was chosen, which may be a most valuable piece of information.

The foregoing should enable us largely to avoid the 'armchair invention', the phenomenon which used to arouse - rightly - the deepest scorn of the late A.G. Drachmann, a predecessor along this line of research in the field of ancient technology, who combined historical erudition and technical insight with the rare ability of 'penser avec les mains', a combination which is most useful in this type of work. If the armchair invention cannot be avoided, it is often possible to render it harmless by combining all available knowledge on the problem.

The origin of the wheel.

In the past, there has been no lack of speculation on the origin of the wheel. It started with the 'Royal Bavarian Inspector of Carriage Construction' in the kingdom of Bavaria, Johann Christian Ginzrot, who published in 1817 a book on the history of land transport[1]. He suggested that the wheel originated from the roller which had been used under load platforms which were pushed, or pulled by ropes. This hypothesis is of a sympathetic rationality compared with Robert Forrer's theory (1932) that the origin of the wheel must be sought in a rotating symbol of the sun worshipped in prehistory[2]. The idea was distilled from a proposal earlier in the century by the historian of economy Eduard Hahn which was somewhat more elaborate. A priest of the Babylonian cult of the sun - of which practically nothing is known with any certainty - watching the whorls being used in spinning, would have transformed these into wheels supporting carriages bearing images of the sun god[3]. Kaj Birket-Smith[4] in 1948 convincingly demolished the argument, which had been defended most vigorously by Hahn.

From these speculations emerge two proposed origins for the wheel which merit being taken seriously: the spindle whorl and the roller. It does not seem that

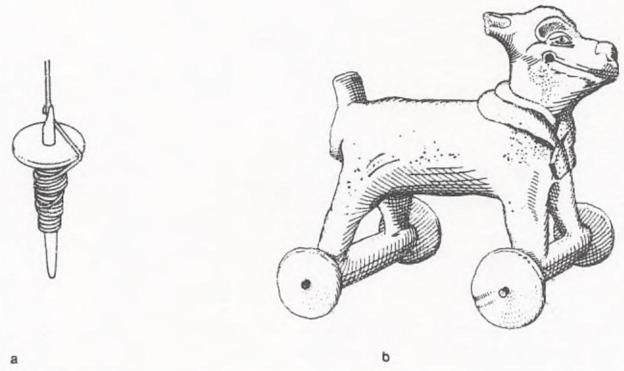


Fig. 1. a: spindle with pottery whorl. b: pre-Columbian toy figure, found at Tres Zapotes, Mexico. (After Ekholm)

other proposals need to be taken into consideration; the first appearance of evidence of the potter's wheel, for instance, is later than that of the carriage wheel[5].

The spindle whorl (Fig. 1) is probably connected with the reinvention of the wheel which took place in Middle America; the only known instance, *inter alia*, of such a reinvention. In that region, pottery toy animals, often of a most charming execution (Fig. 1), have been found in debris of habitation from the pre-Columbian era going back to the Early Classical period (300-600 AD). Horizontal holes traversing the ends of the legs of these toys often showing traces of wear, lead to the supposition that these holes once contained small wooden axles, which carried wheels at their ends[6]. In a number of cases, pottery discs were in fact found in the vicinity, but the archaeologists who discovered them very properly hesitated identifying these as wheels, as they were indistinguishible from the pottery whorls used in the same culture. These doubts were put to rest in 1944 by the closed find at Tres Zapotes in Mexico of three such toy figurines together with twelve pottery discs, which indeed could have functioned as their wheels.

The conclusion that the invention of these wheels was based on the whorl seems inescapable. But if so, it must immediately be remarked that these toy wheels were in continuous use for more than a thousand years before Columbus' fateful landing, yet there is no evidence whatever for use of the wheel in transport in the

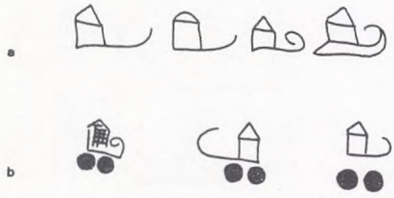


Fig. 2. Pictographs from Uruk, 3200-3100 BC. a: sledges, b: wagons, or sledges on rollers. (After Falkenstein)

Americas during the pre-Columbian period. Ekholm[6] explained this apparent anomaly by the absence of an appropriate draught animal in Meso-America, although the lama and the alpaca might perhaps have been used as such. But, as Stuart Piggott remarked[7], the weight they could have transported in this way is not significantly more than if they had been used as pack animals, about 50 kilograms. But the latter usage did not require nearly as many additional provisions in the way of construction of vehicles and roads. Moreover, these animals would have been totally unfitted as draught animals before a war chariot, such in contrast to the horse. The development of the horse-drawn war chariot probably provided a strong stimulus to the diffusion of the wheeled vehicle across the Eurasian continent, from China to Britain[8] around the middle of the second millennium BC.

No similar connection between the spindle whorl and the wheel is suggested by the remains from Mesopotamia, where the oldest indications of the wheel are to be found. The latter consists of pictographs on clay tablets from Uruk (3200-3100 BC)[9] showing sledges both with and without two circles underneath the runners (Fig. 2). Most likely, these circles represent rollers, and at first sight one is tempted to see in these pictographs a confirmation of the hypothesis of Ginzrot - who never saw these pictographs - that the roller must be the progenitor of the wheel. The question which then arises is what type of roller it could have been. Best-known among scholars is the unguided passive roller under a load platform which is drawn or pushed forward, but the less well-known active rollers which are man-powered by means of handspikes were probably used more commonly in the past. We now proceed to compare the two methods briefly.

Practical experience and archaeological experimentation both indicate that it is not a simple matter to use unguided passive rollers. It is not only that, when they are under the load platform, the spacing of the rollers has to be carefully regulated lest two successive rollers touch each other and bind, but in addition the circulation of the rollers around the load platform has to be well-organised. The Dalmatian engineer Marin de Carbus tried the system when he had to transport the 1600 ton monolith on which Falconet's bronze statue of Peter the Great stands at St. Petersburg, but he abandoned it because the rollers under the load platform were pushed into the earth and did not rotate. He finally chose a method in which bronze spheres rolled in massive bronze-clad wooden gutter sections. Using that system, he managed to bring the monolith from the marsh in which it had been discovered, over a distance of 6.5 kilometres to the bank of the Newa river in the winter of 1769 -'70[10]. During the next summer the monolith was shipped from that point to the town.

In 1979 the archaeologist Jean-Pierre Mohen directed an experiment in which a 32 ton monolith was transported using wooden rollers[11]. These, the wooden track over which they moved and the load platform were all made of unpeeled oaken logs. The ropes which were used in the experiment for drawing the megalith and the load platform were made from the same type of vegetable material as those used in prehistory. The principal result of the experiment was that about two hundred men were needed at a minimum for moving the load. The average force exerted by each of these individuals was estimated by the experimenters at around one hundred kilograms, which would imply a total force of approximately 20 tons. A force of 20 tons to move a weight of 32 tons indicates a 'friction coefficient' of 20/32, or 0.625. The friction coefficient is a useful concept, because it may be regarded as a constant when the load is larger or smaller in situations where the same type of friction occurs. It allows us, therefore, to compare the friction of various different systems, even if the loads transported were different. We distinguish here friction coefficients for sliding and for rolling.

The situation which must be considered for comparison with results obtained by a sledge on rollers is that when the sledge moves directly over the ground without intermediary rollers. The high sliding friction which then often manifests itself motivated the use of rollers, in the hope bringing the friction coefficient down, as it is known that rolling friction is generally lower. What is troubling in the present context is that in practice often lower values are found than the 0.625 for the rolling friction coefficient obtained by Mohen. Probably the lowest value of the sliding friction coefficient for the normal summer sledge is obtained on

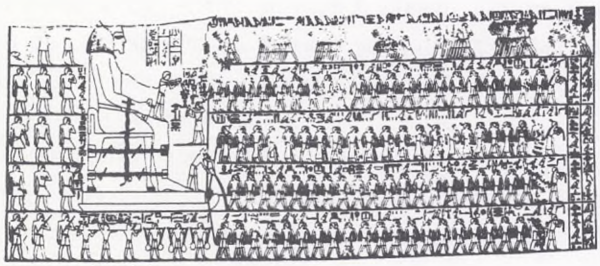


Fig. 3. Transport of a colossus depicted in the tomb of Djehutihoteb in El-Bersheh. (Dibner)

sun-baked Nile loam which has been wetted superficially; Chevrier[12] observed that he could move a sledge with a load of 5 tons with 6 men over such a surface, which would correspond to a friction coefficient of 0.12. Comparison with the scenes of heavy statuary being moved, as depicted in Ancient Egyptian frescoes, shows that the numbers of men pulling invariably exceed the minimum number required on the basis of Chevrier's experiment. Often men pouring water before the runners of the sledge are depicted too in such scenes. Pulling the sledge with the 32-ton monolith would have required a minimum of 39 men according to the result of Chevrier's experiment, less than one fifth of the number required in Mohen's experiment. The most famous Egyptian fresco depicting the transport of a giant statue is the one of the Egyptian nobleman Djehutihoteb[13], which shows 172 men pulling a statue of which the weight may be estimated as having been between 60 and 70 tons (Fig. 3). According to the result of Mohen's experiment, some 400 men would have been required to pull it. Evidently, the Ancient Egyptians would not have used rollers, even if they had known the method, which we do not know.

In other documented instances where loads were moved on sledges, mostly reported by ethnologists working in tropical countries[14], rollers were sometimes used for short stretches, but if they were not, the number of men pulling relative to the load was nearly always less than in Mohen's experiment, indicating a lower friction coefficient. The conclusion is that from the technical point of view the result of that experiment indicates that the method tested by Mohen was *not* used regularly in Antiquity. This in accordance with the little that we know about transport of heavy loads in that period.

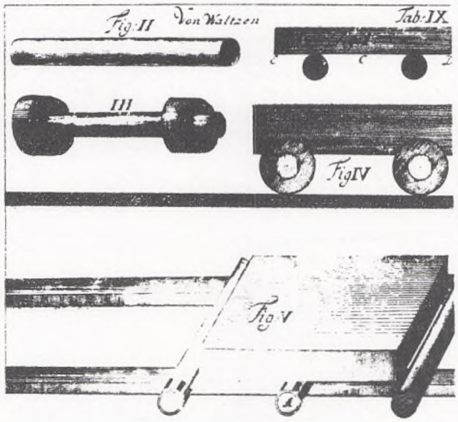


Fig. 4. The use of rollers in German quarries around 1700 AD. (Leupold)

The method in which free rollers are individually rotated by men using handspikes is described in Leupold's "Theatrum Machinarum" of 1725[15]. In Fig. 4 his illustration of the method is reproduced. As stated before, nowadays it is less well-known than the method using passive rollers. Leupold reports that at the time it was used in Germany in quarries, presumably of slate, to transport flat stones over a specially prepared track in the quarry. Although these monoliths weighed more than one hundred hundredweight (approximately 5000 kilograms) they could be shifted by 'a few people', 'without using other *machines* than a number of levers'. The latter refers to the handspikes which were put into the transverse holes at the ends of the rollers which are depicted in Leupold's Fig. V.

The other figures in Leupold's illustration refer to a stratagem which lessened the problem of circulation of these free rollers, in particular the labour of continually transporting them from the backside to the frontside. Of course, the problem can be overcome entirely, as suggested by Mach[16], by making the rollers captive. Mach illustrated his point by a drawing of a primitive load platform with two captive rollers, reproduced in Figure 5. The arrangement is a typical armchair invention. It would not have worked satisfactorily, because the diameter of the roller where the load platform rests on it, is the same as the diameter at which it

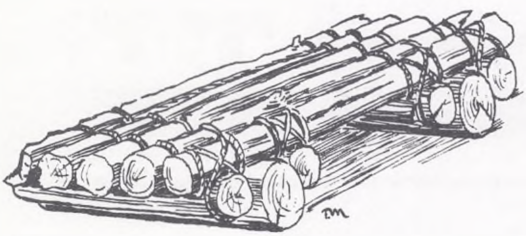


Fig. 5. Captive rollers under a load platform, according to Mach. It is explained in the text that this system would have been unworkable. (Mach)

moves over the ground. If the friction between the platform and the roller is larger than that between the roller and the ground - a pebble caught between roller and platform is sufficient to cause this -, the roller will no longer rotate, but skid over the ground if the load platform is pulled with sufficient force. If the diameter of the roller was made much smaller where it supported the platform, such binding was less likely to occur. The result of this localised reduction in diameter would have been, in fact, equivalent to a pair of interconnected wheels. The problem is, as Mach evidently sensed, that it seems improbable that these captive interconnected wheels could have sprung directly from the roller, but the unworkable cylindrical captive rollers which he proposed do not constitute a credible intermediate stage.

We now return to Leupold, who described what was at least a workable method which may have been an intermediate stage between the roller and a pair of interconnected wheels. It is illustrated in his "Figura III and IV" (Fig. 4), which show free rollers with end discs. According to the accompanying text, "Concerning the point of force these rollers do not offer any advantage, but one goes much further in the same time with the same load, and one does not have to halt as often, and put new [rollers] under. If the discs AB are twice the thickness of the roller, then such go once further than the length of the stone, and so one gains half the time which has otherwise to be spent in putting under [rollers]." In spite of the archaic language, it is clear that a clever stratagem is described, which allows the rollers to be changed far less frequently. Making such rollers with end discs captive would then have been the perfectly logical next step, if we may assume that the stratagem of using end discs was applied in prehistory too.

For captive man-powered rollers the localised reduction in diameter of the rollers was not as essential as it was in Mach's hypothetical cylindrical captive roller, because in that case it is the rotation of the rollers, which is ensured anyway, which causes the progress forward of the load platform, while in the load platform which is drawn or pushed forward it is the other way round. Man-powered rollers and wheels have been used commonly in the transport of heavy loads until the advent of the endless track in the 19th century. Forestier[17] presents a few illustrations of the use of man-powered captive rollers, the earliest from 1485, the latest from 1774, and he mentions the fact that in his day, i.e. around 1900, the system was still employed for moving heavy artillery, with the difference that the rollers were of cast iron. A well-known application of this method was made by the architect Claude Perrault[18] when he had to transport a 17-ton monolith to be used in a wing of the Louvre palace in Paris which he was building in 1665. But it had been used much earlier: in Figure 6 an illustration from 1485 is reproduced, which shows a very large piece of medieval ordnance being moved by this method.

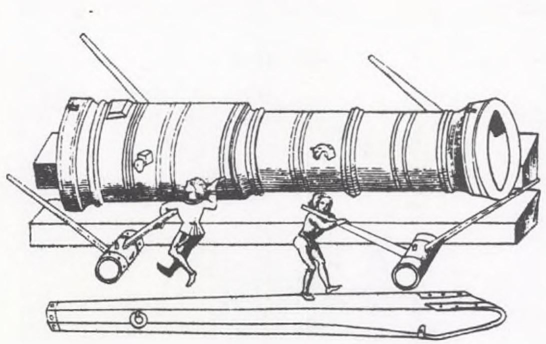


Fig. 6. The use of man-powered captive rollers or moving heavy ordnance, 1485. (Forestier)

Development of the tripartite disc wheel

Leupold did not indicate the direction of the grain of the wood in the end discs on the rollers, but it is probable that the grain ran axially, i.e. that the discs were simply slices of a tree trunk. The drawback of discs or wheels with such a direction of the grain in the wood in the rim of the wheel is that they are prone to fracture. It has been reasoned, wrongly it seems, that for this reason such wheels were never used. In prehistory an additional drawback of such cross-grained discs was, as Stuart Piggott[19] has argued, that it would have required much labour to fashion wheels of this shape before saws of a suitably large dimension had come in general use.

On the other hand, the availability of the cylindrical shape of the tree trunk must have made it attractive to use such slices as wheels, even if they were relatively short-lived. Small, thick wheels of trolleys with axial wood grain have actually been found in the *kurgans* (funerary barrows) of Pazyryk[20], dating from the fifth century BC, and such wheels were still employed early in this century on the trolleys used by Swedish peasants for carting away stones. As an example is presented in Figure 7 a sketch of such a trolley from the province of Småland, which is conserved in the depot of the Nordiska Museum at Stockholm. The wheel diameter of approximately 30 centimetres is typical of trolleys.

Having the grain of the wood around the rim of the wheel running either approximately tangential or in a radial direction results in a much stronger

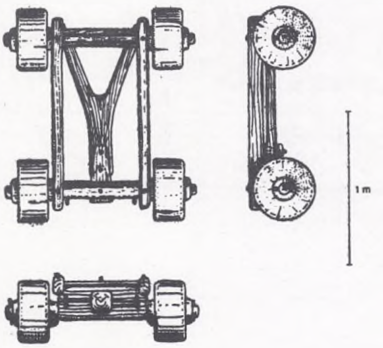


Fig. 7. Trolley from Smaland, Sweden, c. 1900, now in Nordiska Museet, Stockholm. Mus. no. 25121.

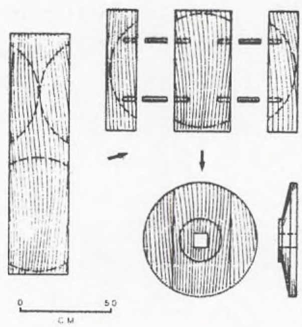


Fig. 8. Tripartite wheel used in the 1920's on a rural cart in Ireland. (After Lucas)

wheel. This fact explains the ubiquitous use of the tripartite disc wheel from prehistory to the recent past. The grain of the wood of the central board is approximately perpendicular to the rim, and that in the side planks approximately tangential. As recent as the 1950's such wheels were still being made in Ireland for use in farmer's carts[21]. The sketch reproduced as Figure 8 illustrates how this tripartite disc was fashioned out of a thick board. It may be observed that the axle rotated with the wheel, hence the square axle hole. Such square axle holes were used in prehistory too. Perhaps the earliest-known example of it is encountered in the third millennium BC tripartite wheel found near the "Pressehaus" in Zürich[22].

Unfortunately, not all axles rotating with the wheels were fitted into square holes. For example, the axle of the well-known copper model of an elementary chariot or "straddle car" from Tell Agrab[23] (north of Baghdad) rotates with the wheels, though the axle holes are round (Fig. 9). The model is dated to the early third millennium BC. Gordon Childe, who could examine it in the Iraq Museum, remarked[24] that the axle rotated in brackets mounted under the draught pole. The driver stands with his feet on two little platforms mounted just above the rotating axle. It may be remarked that the outer surface of the wheel was protected by large hobnails. The three planks of the wheels appear to have been lashed together, presumably with rawhide, which shrinks when it dries. The wheels must have had internal connections, either dowels, as in the modern Irish

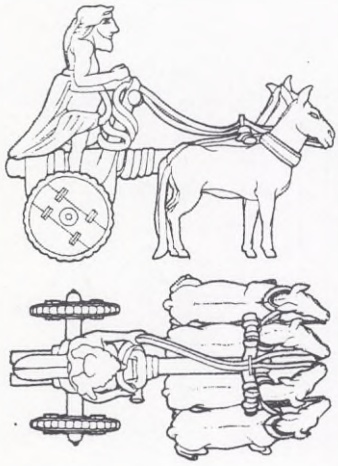


Fig. 9. Bronze model of a straddle cart from Tell Agrab, dated early 3rd millennium BC. (Drawing by J. Morel, from Littauer and Crouwel)

tripartite wheels, or battens. External battens were used in that period too, as we know from the remains of a tripartite wheel from Susa.

A somewhat different model of a tripartite wheel is observed on the earlier wheels of the wagons from the so-called 'standard of Ur' (Fig. 10), and on the straddle car depicted on a stone plaque, also from Ur, probably from Lagash[25] (Fig. 11). Both are roughly dated to about 2500 BC. It seems that here linch pins at the ends of the axles are indicated, implying that the wheels rotated around a fixed axle.

Fig. 10. Four-wheeled wagons depicted on the so-called 'standard' of Ur, c. 2500 BC. They were probably used as munition wagons.

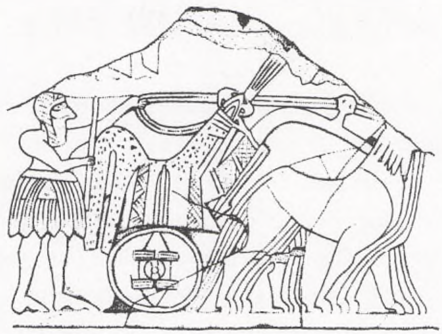


Fig. 11. Relief from Lagash in Ur, depicting a straddle cart. c. 2500 BC.

The semi-lunar shape of the outer planks of these wheels would have caused the 'horns' to be broken off all too easily if the grain of the wood had run straight. Apparently, it did not do that; presumably these planks had been made from naturally grown crooks[26] - 'compass timber' as it is called in shipbuilding (Fig. 12). As in the wheels of the Tell Agrab chariot, these outer planks appear to have been lashed together. A difference between the two depictions is observed in the relative size of the lenticularly shaped middle plank, which in the wheels of the 'standard' are so small that their points are hardly visible beyond the rim of the nave, in contrast to the middle plank of the Lagash wheel, of which the points end on the protection of the outer surface of the wheel (presumably leather, as in

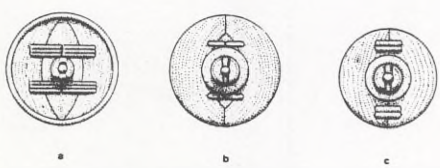


Fig. 12. Indication of the grain of the wood in the wheels depicted in the two previous illustrations, as deduced from their usage.

some remains of wheels of that period). A possible interpretation is that the grain of the wood of the middle plank ran axially. That would have been the right direction for the nave, which otherwise would have been very fragile. Inserted naves are here out of the question, in view of the proximity of the lashings.

A striking illustration of the fragility of naves fashioned out of the main board of the disc wheel was observed by Van der Waals[27] on single-plank wheels found in the Netherlands. These wheels are, as Van der Waals convincingly argued, copies of single-plank wheels from the Pontic plain, about 2000 BC. These, in their turn, are imitations of Mesopotamian tripartite wheels. The tool kit of the neolithic people living in the Pontic plain and the Netherlands at the time was less advanced than that of the Mesopotamians, who had progressed already to the bronze age, so the wheel was made far more laboriously from a single block of wood. These single-piece imitation wheels often exhibited a lighter colouring of the wood surface around the axle hole, and a nave was missing. Van der Waals concluded that originally there had been a nave present, which had been broken off under load, the run of the grain of the wood being unfavourable (Fig. 13). The remedy is simple: an inserted nave in which the grain of the wood runs axially. A small number of single-plank wheels with inserted naves, all dating from the end of the second millennium BC, has in fact been recovered in Northern Germany. Hayen[28] has described these extensively. The best example are the wheels from Glum, near Oldenburg.

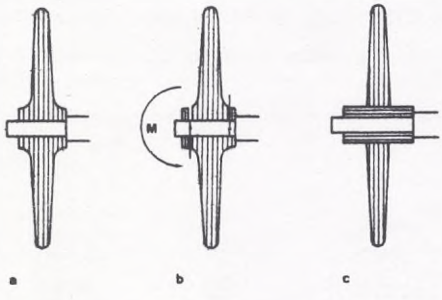


Fig. 13. Fragility of the nave of wheels in which the grain of the wood is perpendicullar to the axial direction. In (b) the application of a mechanical couple causes fracture of the nave, in (c) the remedy is indicated: an inserted nave, in which the grain of the wood runs axially. (After Van der Waals)

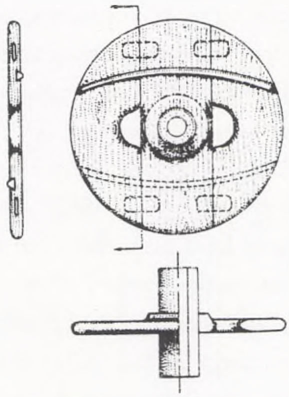


Fig. 14. Schematic diagram of a type of tripartite wheel which was widely distributed during the Bronze- and Iron-Ages in North-Western Europe.

Tripartite wheels with inserted naves dating from the Late Bronze and Early Iron periods in Western Europe have been found over a large area, encompassing Northern Italy, Germany, Denmark, the Netherlands and Scotland. Their uniformity is striking: the position of the three boards is ensured by dowels, and long flexible keys or battens have been driven into curved channels, one on each side of the disc, which have been given an undercut trapezoidal cross section. These wheels were held together by these keys, as bindings were absent. In the outer planks lunate openings were provided[29]. The standard type of wheel is schematically depicted in the accompanying sketch (Fig. 14).

Shaping these undercut curved channels in the boards must have required a tool kit which was in all probability more sophisticated than that available in the neolithic period. The purpose of the lunate openings of these wheels was not readily understood. Similar openings are also characteristic of contemporary wheels of Portuguese oxcarts[30]. It has been suggested that they were cut to lighten the wheel (but in most cases that effect would have been negligible), or to enable the driver to draw the wheel out of deep mud (but the openings in the modern oxcart wheels are often so small that the hand cannot enter them) or to put a stick through the openings of two wheels on the same axle in order to prevent their rotation, for instance when the vehicle was standing on a ferry (but often the openings in opposing wheels on an interconnecting shaft are rotated relative to each other over ninety degrees, which makes this impossible).

The answer must probably be sought in a long-term effect of repeatedly wetting and drying out of the wheel. If there were no openings, after wetting, water would have been retained much longer in the seams between the planks than elsewhere in the disc. During subsequent drying out, the outer planks would have been wet on one side and dry on the other for most of the time, which would have caused them to bend with their ends outwards. Most of that bending would disappear when the whole disc was dry, but some of it would be retained. After many cycles of wetting and drying these outer boards would have acquired a permanent bend outwards. The effect can be observed on the uppermost board of old boarded fences. It seems probable that both the temporary and the long-term bending were undesirable in the tripartite wheel, and that the openings in the outer boards - such an opening is sometimes called "venta", nostril, in Portuguese[31] - were provided to counter these effects.

The crossbar wheel

Although the lunate openings originally were not made to create a lighter wheel, later a slow development took place during which these openings increased in size, then evidently to lighten the wheel. The tripartite wheel with bent keys traversing the diameter severely limits the possibilities of increasing the size of the openings. A tripartite wheel (Fig. 15a) found in 1861 in Mercurago (Northern Italy), probably dating from the end of the second millennium BC[32], illustrates the limit to which this development can go. If it is desired to make the openings larger still, either of two possibilities are open. The first is that the position of the keys is shifted outwards towards the rim. That resulted in a wheel which until recently was widely used on oxcarts in Portugal and Spain. A wheel from Catoira (Portugal) dating from 1400 - 1600 AD is of this type.

The second possibility consists in having the keys traverse the openings. Then there is no longer any reason why they should be bent around the openings, so they can be straight. In addition, there is then no longer any necessity for the keys to be on opposite sides of the central board, so they can now transverse it in the median plane. By chance, a wheel of this type, which is generally known as the crossbar wheel or H-wheel, was also found in Mercurago (Fig. 15b). It may be noted that this wheel still retains the features of the tripartite wheel, with a central board and side boards. In the course of further slow development, the number of

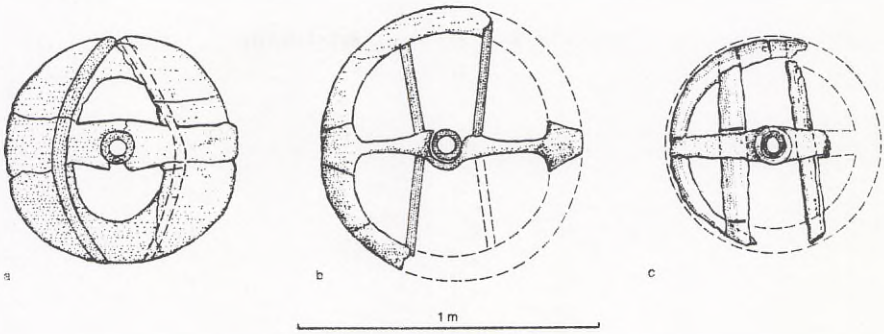


Fig. 15. (a): tripartite wheel from Mercurago (Italy) with large lunate openings, roughly dated at the end of the 2nd millennium BC. (b): crossbar wheel, also from Mercurago, which may have originated from the tripartite wheel. (c): crossbar wheel found in a well in Olympia, from the first half of the 5th c. BC. The number of felloe pieces had increased to 4.

felloe pieces increased. A crossbar wheel recovered from a well in Olympia in 1960 shows four of such pieces, in which the grain of the wood follows the rim. These felloe pieces were presumably grown in that shape; when permanently submerged in water, fire-bent pieces show a tendency to bend back to straight shape in the course of time, which was not observed here. The wheel dates from the first half of the fifth century BC.

In modern times the crossbar wheel is still in use in isolated rural areas. In Fig. 16 an example[33] is presented from the Western Chinese province of Xinjiang. This crudely made wheel has six felloe pieces, as modern crossbar wheels invariably have. These modern wheels are always mounted on rotating axles, while the ancient wheels which have been recovered nearly always have inserted naves, rotating around fixed axles. It may be observed that the inserted nave appears to have weakened the crossbar in the prehistoric wheels. Apparently the availability of spoked wheels with a central nave which do not suffer from this drawback, caused the use of the crossbar wheel with inserted nave to be discontinued. But the strong crossbar wheel on the rotating axle survived. They are still used on carts in central Asia[34] which are used for short-distance haulage over rural tracks.

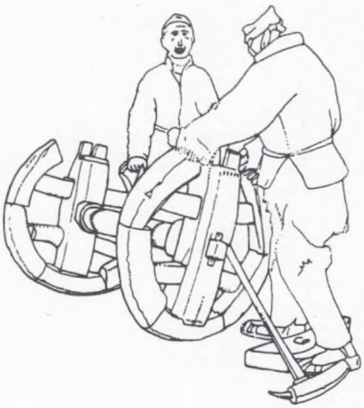


Fig. 16. Crossbar wheel used on a rural cart in Xinjiang (China) in the 1920's. The number of felloe pieces had by then increased to 6. (After a photograph by Hildebrand)

Is the uniformly spoked wheel with the central nave descended from the crossbar wheel? And if so, how? There is no evidence in the archaeological record indicating it, nor does it seem probable that the uniformly spoked wheel could have sprung directly from the cross-bar wheel. The two wheels appear to differ too much for that. In other words, at least one intermediate stage between the two is required in the line of descent - if the uniformly spoked wheel was not an entirely new invention -, but such has not been attested.

Nevertheless, it appears possible that there was an intermediate stage. The few crossbar wheels surviving from prehistory have as a common characteristic that the inserted nave weakened the crossbar considerably. That must be surprising to any craftsman in wood, in view of the fact that nature could have provided a strongly jointed nave and crossbar easily. A crossbar with a 'grown nave' is suggested by the run of the grain in the wood of a tree trunk with a thick side branch. As illustrated in Fig. 17, the branch gives rise to a knot in the wood of the tree trunk, around which the run of the grain forms a thick knob. The grain would run

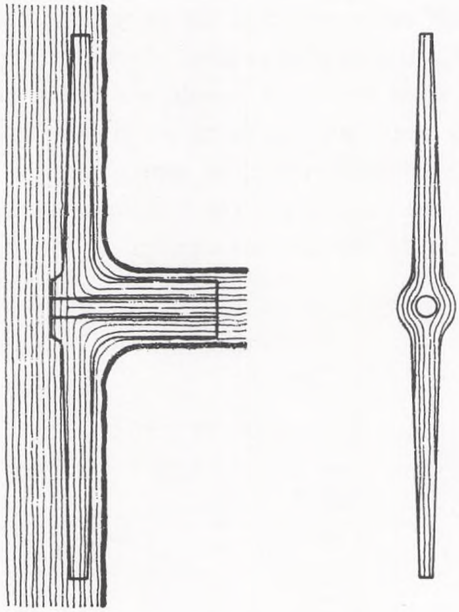


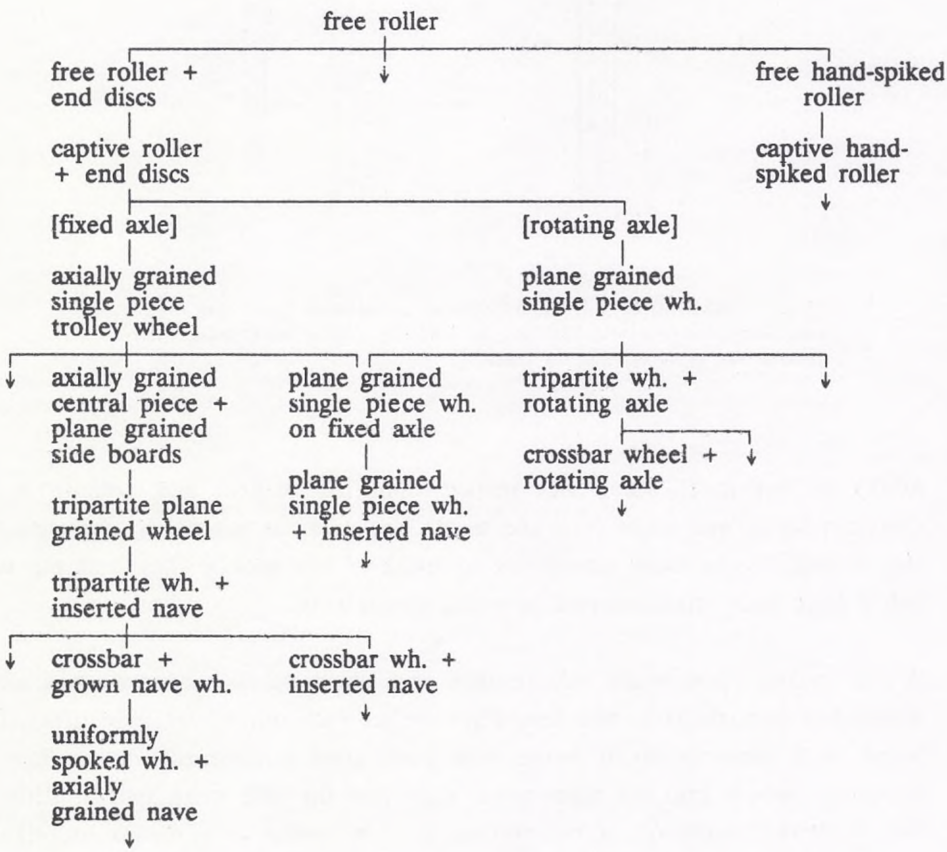
Fig. 17. Hypothetical intermediary between the crossbar wheel and the uniformly spoked wheel. The nave is fashioned from a thick branch of a tree, the crossbar from the trunk.

axially in the nave, which was shaped from the branch, and radially in the crossbar, which was taken from the trunk. The crossbar might have been so thin that it might seem more appropriate to speak of two spokes; they, and the nave, would have been interconnected by strong grown wood.

A four-spoked wheel would have resulted from mounting two such nave and spokes assemblies back to back, and turned relative to each other over 90 degrees. In a wheel with more spokes it would have been good workmanship to mortice the subsidiary spokes into the nave rather than into the thin main spokes. Although this is mere speculation, it nevertheless may be useful as a means to orientate the search for remains throwing light on the development of the wheel.

Conclusions

The foregoing has perhaps made it clear that the multi-faceted considerations and disciplined approach attempted in this paper result in a coherent view of the development of the early wheel. It is not to say that there do not remain stages of development about which one would like to have much more information, or that it is anywhere near a complete description of that development. For instance, disc wheels built up of more than three boards, and the protection of the rim of the wheel, have largely been left out, although in one instance the hobnails were mentioned. It seems, however, that these aspects did not play an essential role in the development of the early wheel. The resulting image of development can be a source of inspiration for further investigation; it certainly does not pretend to being definitive.



The development outlined above can be projected in the form of a 'family tree' type diagram, as presented on the adjoining page. The drawbacks of this type of representation are well-known, especially as regards the simplification which is implied. Some ties between different forms of the wheel are well-established, others are speculative, but the diagram does not allow the distinction to be made. On the other hand, there is nothing fuzzy or vague about it, which seems, on the whole, an advantage.

A few words of explanation: the terms: 'axially grained' and 'plane grained' refer to the grain of the wood running parallel or perpendicular to the axle, respectively. The wheels from Ur are indicated as having an 'axially grained central piece + plane grained side boards'. The lenticular outline of the former, and the bending run of the grain in the latter are not mentioned. Long-time survival, mostly represented by technological fossils, is indicated by arrows. The data on which these are based were taken from authors on the history of transport, Forestier[17], Lucas[21], Galhano[30] and Tarr[34].

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BOEL BERNER

Engineering identity and economic change; Engineers in Swedish Society 1850–1990 *

Introduction: Engineers in a European Periphery

> The engineer stands - because of his scientific training - on the same level as the doctor and the lawyer. His occupation is basically a free occupation, or what the English call a 'profession'. This is undoubtedly a valuable privilege, and one that we should treasure and honour.

These words from a Swedish engineer in 1928 during a debate on engineering ethics and an engineering code of conduct, express the professional ambitions and self-image of many engineers at the time. University educated engineers defined themselves as part of Sweden's educated and industrial elite. They could rely upon a social demand for their advanced technical knowledge, and they were, normally, rewarded with influence and prestige.

But the words do not give the whole picture. Most Swedish engineers were, neither in 1928 nor later, "free" and "independent" professionals. A majority were salaried employees in private firms or state bureaucracies, depending for their welfare on their employers' needs and on labour market fluctuations. The "professional" strategy was one response to this situation. Engineers without a university degree followed a different path. As other salaried employees they formed strong unions based upon their common wage worker situation. Also this strategy has, in the Swedish political and economic context, led to a secure and sometimes influential position. Therefore, there has been no angry "revolt of the engineers" as in the US, no "engineering proletariat" as in early 20th century Germany, and no separate middle class project similar to the British professional one.

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This article will outline the major parameters shaping engineers' identity and work in Sweden.[1] Its focus is on the employment possibilities and self-images of the engineers. Those with an engineering education were a few thousand in the 1880s, or less than 2% of the economically active male population. One hundred years later, their number was about a quarter of a million.[2] Male engineers then formed about 11% of the economically active male population.[3] This growth will be related to changes in Sweden's economic situation, from a backward peripheral country to an advanced industrial society. Engineering ideology must be seen in that context, but will also be discussed in relation to Sweden's unique political and union configuration.

Sweden belongs, with the other Scandinavian countries, to a European periphery. Their economies can be characterized as small, onesided and open (Mjöset (ed) 1986; Alestalo & Kuhnle 1987). Their internal markets are small and companies are more or less forced to export in order to achieve economics of scale, and survive. They also historically rely on one or a few major economic sectors for production and exports: agriculture in Denmark, shipping and aluminium industry in Norway, forest products in Finland and Sweden, iron and steel in Sweden. Industrial development did not start until the late 19th century and then as an effect of a largely British demand for their major products.

These three characteristics - openness, onesidedness, smallness - also characterize many dependent third world economies of today. The Scandinavian periphery, however, managed to evolve into highly developed economies in a relatively short time, or approximately between the 1870s and 1930s. They also succeeded in maintaining a high growth pattern in post-war years. Standard explanations of development and underdevelopment do not fit their case. To explain the rapid economic growth and rising standards of living of, for example, Sweden two types of conditions have been discussed, both of which seem relevant for the understanding also of Swedish engineers. The first condition was the creation of extensive forward and backward linkages from the major exporting sectors to other industries and sectors of the economy. Iron, steel, timber and agricultural products formed the starting point for industrial diversification, technological innovation and multi-facetted economic growth. Swedish engineers - as we shall see - have played a central role in creating the industrial linkages essential for sustained economic growth.

The second condition concerns the relatively peaceful transition to democracy. In the Scandinavian countries (with the exception of Finland), a class compromise pattern was established already in the interwar years - in contrast to the long, painful revolutionary and counter-revolutionary transition to democracy of the southern or eastern European peripheries. A social-democratic ideology based on the welfare state came to coexist with and indeed build upon a pattern of continuous economic and technical growth. Technical and industrial transformation was defined as something which would benefit all social groups. The social image of the engineer has accordingly become a highly positive one.

In the first part of this article I will discuss how the formation of a specialized engineering occupation predated industrial "take-off" but soon became linked to a rapid but peaceful industrialization. The discussion takes us up to the late 1930s. In the second part of the article, Swedish developments are related to post-war international economic integration. The transition to a mass production and consumption economy and a "Swedish model" of institutionalized class compromise brought new tasks and new social roles for the engineers. This discussion takes us up to the late 1980s and the recent restructuring of global, as well as Swedish, capitalism.

Engineers and Industrialization: 1880s to 1930s

The historical background

In the beginning was the state. The absolutist state was the employer of those first called "engineers" - military experts on fortifications and war machines in the early 17th century, often of Dutch or German origin. The role of the military expert must be linked to the rise of the Swedish empire which at its height in the 17th century embraced Finland, parts of Norway, large areas of the Baltic and north German territories. With the rise of other empires, Russia and Preussia, Sweden, in the 18th century, lost its supremacy in the Baltic and Scandinavia. But as late as 1805, the dictionary image of an engineer was still that of "a military man who understands fortification in the field as well as in the fortress"[4]

Mining engineers formed the second important group of state technical experts. The all-important iron and copper production had to be controlled both for quality and quantity. Sweden in the 17th century provided half of the European supply of copper, and in the mid 18th about one third of that of iron. It was "the OPEC of its day" with an almost monopoly of high quality iron, tar and copper.[5] The first engineering exam was a university degree in law and sciences (from

1750) which allowed its bearer to enter the Board of Mines (established in 1637) and exert functions of inspection, control and development in the mining domain.

By this time, technical education had become one of several routes of mobility into a state bureaucracy, otherwise dominated by the nobility.[6] From 1818, military engineers were educated at the Military Academy of Marieberg where soon also a third major group of state engineers got their education. These were the "civil engineers", who were employed in the civil administrations involved in the construction and administration of canals and bridges, later also of railroads and telecommunications. The title **civil engineer** was created in 1844 to distinguish those with military training but civil functions from their military counterparts at Marieberg. In the early 20th century it became the official exam title for **all** engineers with a **university-level** diploma (i e not, as in the English usage, only for those building canals and bridges, etc). It is today translated as a Master of Science degree.

To be an engineer was thus - apart from a few illustrious, highly skilled individuals working as "consultants" to the mining community and the state - from the 17th until the mid 19th century to belong to a hierarchically organized, civil or military **state** corps of military or technical men. Engineers were part of a small educated elite in a largely agrarian and backward society. After the loss of the empire, national ambitions turned to the economic sphere. This elite saw it as its mission to develop Sweden's rich natural resources. Scientists and state officials had extensive contacts with foreign centres of industry and learning. They created academies and learned societies to promote science and technology. But their efforts to modernize the Swedish economy often failed.[7] The country was still too poor, and prevailing customs and social structures did not yet allow for any large scale industrial change.

This situation began to change in the mid 19th century. An industry began to form also outside the traditional mining and ironworks districts. Various schools of technical education were established from the 1820s onwards. In contrast to the situation in, for example, England, many of these technical schools were established by the **state**, as part of a conscious attempt to further the industrial arts. The state already at this time saw it as its mission to create the infrastructural and educational bases for capitalist industry. The Technological Institute in Stockholm was established in 1826 as a state institution. The Chalmer s Institute of Technology in Gothenburg (1829) had a private donation as its financial base, but soon got considerable state support. These two institutes gradually acquired a more scientific orientation at the same time as several middle level engineering schools were created from the 1850s onwards. In 1876, the Stockholm institute got university status, as the Royal Institute of Technology (KTH), something which the Gothenburg school acquired in practice by the turn of the century, but formally not until 1937. These two schools were to dominate the scene until the 1960s, when three more technical universities were established. Both Chalmers and KTH were, as in the German-speaking nations, organized **separately** from the traditional universities. This reflected the prevailing lack of interest in industry and technology in university circles at the time, but would also institutionalize a sharp distinction between the "two cultures" of technology and the humanities for many years to come.

Three aspects are worth stressing in this context. First, what the state created in the mid 19th century was a lasting **hierarchical system** of different levels of technical education, based on the idea of a division of labour with a corresponding demand for various kinds of technical qualifications. The Swedish state guaranteed the quality of the education of **both** middle and higher level engineers (a guarantee given in Britain by professional organizations and in France only to higher level engineers). This meant that middle level and assistant technical tasks could be taken on by engineers with an upper secondary ("gymnasium") school education, whereas leading positions were to be the domain of the "civil engineers". This division of labour also consolidated the title of the "civil engineer" as a high status one. By giving higher technical education university status (in 1876) with corresponding entrance requirements, the state ensured that a civil engineering exam would qualify as a ticket into the educated elite - and thus be socially acceptable to the middle and upper classes of society.[8]

The second aspect to be stressed concerns the **purpose** of the state engineering institutions. They were established with the double goal of serving not only public but also private, **industrial**, needs. In contrast to the situation in, for example, France, a substantial proportion of graduates from the elite schools from the late 19th century went into industry, to practice as designers, draughtsmen or production engineers. This situation reflects the high esteem and cultural centrality of an industrial-technical tradition in Swedish society. But it also points to the emergence by the turn of the century of an industrial career ladder for engineers, linked to the creation of a new type of firms.

Finally, therefore, we should link this development to the type of industrialization taking place in Sweden. Despite the old mining and metallurgy tradition of central Sweden and despite the early existence of some large textile and mechanical engineering firms, industrial "take-off" did not really occur until the 1870s and particularly from the 1890s onwards. An extensive structure of technical education was then already in place. This meant two things. A body of highly educated engineers already existed before large-scale industrial change which was to strongly influence its technical direction. This group of engineers, in addition, had already forged a professional identity for itself, based upon its educational credentials and its importance for the nation's infrastructural and technical modernization. Put together, these factors would make the Swedish engineers look upon themselves as a central force behind industrial transformation and the modernization of society. But they also, as we shall see, made for conflicts and dissent within the emerging engineering community.

Industrialization and structural change

In the period between 1880 and the 1930s Sweden was transformed from a backward, rural and agricultural society to an industrial and increasingly urban one. In the 1930s, finally, more people worked in industry than in agriculture (and forestry) - a transition which had occurred in Great Britain more than one hundred years before. In the 1930s also, the urban population for the first time was larger than the rural one.

This transformation took place in the context of very rapid economic growth. Industry grew fast from the 1890s and by the turn of the century had replaced agriculture as the main contributor to GNP. Early industrialization was in Sweden a predominantly rural phenomenon. It was based on foreign demand for iron, wood and agricultural products, but also on an internal demand for agricultural machinery and simple consumption goods. Small and medium sized companies dominated production. The links were strong to traditional mining and ironworks firms. This pattern would soon branch out into and link up with a new industrial structure. More finished products such as high grade steel, engineering products, paper and pulp were produced and exported abroad. Large scale attempts were made to exploit Sweden's natural resources, notably iron ore and water power, for the benefits of an expanding industry. The taming of the water falls was a major preoccupation of many of the most prominent engineers of the early 20th century - sometimes in bitter conflict with local or public conservation interests (Sundin 1981).

Another central feature was the creation around the turn of the century of several important engineering firms which, until this day, form the backbone of Sweden's industrial and export sector. These industries - SKF in spherical ball bearings, Alfa Laval in cream separators and steam turbines, ASEA in electrical power generation and transmission, Ericson in telecommunications etc, etc - are in the Swedish public image invested with an almost mythical importance. Most of them were based on Swedish innovations, they were established with the help of mainly Swedish capital and they soon created subsidiaries abroad and took up a successful competition on the foreign markets (of which Russia until 1917 was the most important one). They also provided a technical bridge from the old ironworks and mining tradition to an advanced mechanical, electrical and later, electronic engineering industry.

Sweden escaped the destruction of both the first and the second world war, but was hit by the international recessions of the early 1920 and 1930s. The depression years were not as dramatic as elsewhere, but rather provided an occasion for the rationalization of Swedish industry. Standardization and mass production began to replace old-fashioned methods of production and management. Large companies grew stronger, and by the late 1930s all the major companies which were to dominate the country's industrial life until today, were in place.

Political modernization

Sweden's internationally rather short period of intense industrialization and industrial diversification was also a time of political and economic strife. New social groups emerged and tried to mould an identity and a place for themselves in society. Workers organized, as did capitalists. That Sweden's transition to industrial capitalism and democracy was a largely peaceful affair has been explained with reference to the internationally unique political and economic strength of the independent peasantry. According to Francis Castles, there was in Sweden, unlike the situation in either Britain or France, "no need to destroy by revolutionary violence either of the old rural classes /the nobility or the peasantry/ in order to bring about industrialism" (Castles 1973). The independent peasantry was rather a factor **for** industrial change, as it turned to market production of dairy and other agricultural products; its need for farm machinery was important for the early engineering industry. Aristocratic landed interests were weak and the nobility was mostly an urban, bureaucratic class. There was a plutocratic alliance between them and a small class of indigenous, monopoly entrepreneurs, but it was never as strong as in e g Preussia and did not form the basis for an authoritarian type capitalism. Any tendency in that direction was in any event checked by a both politically and economically strong peasant class (Castles 1973).

The rising industrial proletariat could thus evolve in a relatively favourable context. The important metal workers' association was founded in 1888, the social democratic party in 1889 and the national trade union congress, LO, linked to the social-democratic party, in 1898. Union enrolment was rapid; in 1907, a third of all male workers were organized, and 40% of the key group of Metal workers.[9] The central employers' association, SAF, was established in 1902 as a response to the workers' advances. In 1909, the most wide-spread industrial stoppage of the world (before May 1968 in France) occurred, the general strike of 1909. It ended with the defeat of the workers; union membership was cut in half. But it began to rise again after 1912 to reach the figure of 1 million in 1939, or about 75% of all male manual workers.

The right to organize was thus achieved and made us of from an early date by the working class. Alliances with other social forces were, however, a necessary element behind the peaceful transition to democracy. Liberal and socialist groups fought together for universal suffrage, finally obtained in 1919. The alliance between industrial and agrarian popular forces resulted in a historic **political** compromise in 1932 (inaugurating a series of social democratic governments). And capital and labour concluded an historic **economic** class compromise in the "Saltsjöbaden Agreements" of 1938.

These social developments clearly influenced the class position and identity of Swedish engineers. We now need to discuss the two major groups of engineers separately. There is historically and today an important cleavage between the university educated engineers and the rest. Their positions and social identities have followed different trajectories. Their class alliances and loyalties have often diverged, at least until recent years.

The "civil engineers": The contradictions of a professional identity

Academically educated engineers numbered about 2 000 by the turn of the century and 7 000 in the late 1930s, or about 40% of those with an engineering diploma at both dates (Torstendahl 1975; Ahlström 1982). They formed a relatively homogeneous group, united by a common educational background, similar middle or upper class origin, and similar work positions of technical leadership and expertise. They were, since the 1880s, organized in a national professional organization, the **Swedish Association of Technologists (STF)** as well as in many local technical clubs and age-old technical societies bringing together owners, managers and engineers.

In the early 20th century a conflict developed within this body of highly educated technologists.[10] In essence, it set the defenders of a state and nation oriented, scientific, engineering ideal against those who presented themselves as the "modern" engineers. The first group consisted of engineers linked to the traditional areas of engineering expertise, that is, mainly the state and the educational sectors. Their opponents were industrial men of a new, managerial type. The actual number of industrial managers was still very small but they spoke for a growing group of engineers and business leaders in an expanding engineering industry.[11]

These engineers put forward new ideals for society and industry, inspired by American mass-production and attempts at rational production and "scientific management" of both machinery and men. Their aim was to transform both the state administration, higher technical education, and the engineers' own professional organization to serve industrial and capitalist needs. The Association of Technologists should shed its "neutral" and scientific character and the Royal Institute of Technology should become more of a practical, industrial school rather than an academic one.

But the "traditional" engineers who dominated the Association, hit back. They fought for a definition of the engineer as part of an academic and scientific elite and for the Association's image as an impartial and purely technical body. They feared that an reorientation towards industrial and capitalist concerns would stifle technical education and diminish their social own social influence and prestige.

The struggles for the control of the engineering association and of higher technical education lasted well over a decade. They took the form of intense public and internal debates, lobbying, and petitions. The outcome was, in a sense, dictated by historical change. Neither side was defeated. Instead, a new kind of engineering ideal emerged based on **scientific technology**, which would unite the interests of the two contending groups.

Sweden's late industrialization was here a factor of some importance. Industrial expansion largely coincided with the rise of several important **engineering sciences** which differed from the purely theoretical ones previously taught in higher technical education. New areas of theoretical engineering emerged, such as electrical and chemical engineering. Of great importance for industry were also scientific solutions to problems of an increasingly larger scale of production, of quality control and of new products for an international market. This coming together of science and industry gathered momentum around the first world war, with the creation of industrial research laboratories, joint state-industry research institutes and an Academy of Engineering Sciences gathering an elite of industrial and scientific men (1919). By 1927, it was possible to get a doctorate in engineering at the KTH - and by this time also, the doctrines of "scientific management" and industrial psychology were accepted as essential parts of the engineering curriculum in higher technical education. In this way, the "traditional" and the "modern" engineers joined forces in the creation of a new type of civil engineer, one who would be part of **both** a scientific and an industrial elite. A university engineering degree was established as a normal and desirable background to a career **both** in the technical apparatuses of the state and in industrial management, development and research.

Engineers between labour and capital

Meanwhile, down in the engine room, the workers had organized. The struggles of the "modern" engineers were to an important extent directed against the threat from the organized working class. "Scientific management" was introduced as an ideology and a praxis in order to establish control and solve production problems in the large engineering firms. The engineering community was, however, divided as to the social role of taylorism. Alongside the aggressive, anti-union, anti-social-democratic group of engineers there was a more conciliatory one. Taylorism could, according to its spokesmen, lead both to increased wages and to a more rational production. Engineers, in this perspective, were not the agents of authoritarian capitalism, but independent actors in the class struggle who could serve as a bridge and a moral force binding capital and labour together.

The tension between these two perspectives would run through employer circles at least until the "Saltsjöbaden" agreements in the late 1930s, when the class compromise faction was to prevail.

To identify their **own** position as a wage earning one and to organize collectively with the aim of furthering their own economic situation was, however, a largely foreign thought to the civil engineers, and not only to those in leading positions. Their ambitions were of an professional and individual kind, their positions were well-paid and secure, and their social identification was with a comfortable upper and middle class. This pro-capitalist and elitist orientation they would keep for many years to come.

The rise of the "organization men"

The situation of the other major group of engineers was different. Engineers without a university degree and with only a upper secondary school education or a practical industrial background did not form such a self-conscious community as the "civil engineers". Their social and educational background was more varied, their positions more routine and dependent, even if also their knowledge was in great demand in an industrializing society. Their numbers increased in the interwar years as new tasks of product development, rationalization of production and standardization appeared. In the late 1930s there were about 11 000 engineers with an engineering diploma of some kind, in addition to the unknown number of those in "technical work" but without the education.

The position of these engineers was more precarious than that of the civil engineers. Their work had a more routine and anonymous character, especially in the larger offices and with the disappearance of many traditional ironworks and engineering firms. The depression years of the early 1920s and 1930s meant unemployment for many engineers who hitherto had looked upon themselves as a relatively protected group. As the journal of the Confederation of Industrial Employees put it, bitterly, in 1933,

> /Our members/ still have the duty, come rain come shine, to support their company. They have to obey all orders from their principals without objections, concerning their salaries, employment conditions and behaviour inside and outside the firm... But they have lost their security of employment, they are kicked out on the street without mercy like the casual labourers of olden days. They have lost their social standing when their economic conditions deteriorate... Their awakening is certainly not of the most pleasant kind.

Two important changes took place in the 1920s and 30s. First, many white collar workers began to see themselves as a new and potentially powerful social force.

They had common interests which were separate from those of **both** employers and manual workers. Traditionally, they had set themselves apart from the workers, both in status and political terms. Now they came to realize that their employers did not automatically stand on their side and were even willing to sacrifice them to placate the better organized manual workers.

Secondly, this "revolt of the middle classes" took socially acceptable and, as it turned out, economically effective forms. There was no lasting infatuation with technocratic ideals - despite many articles in the early 1930s depicting the "corruption of parliamentary politics" and the need for those with a technical expertise to unite and take over the crumbling capitalist economy.[12] Neither did a populist right wing political movement take hold of the dissatisfied middle class, as in the great German neighbour to the south. Instead, white collar workers became organized into unions. The **Confederation of Industrial Employees (SIF)** was established in the early 1930s, based on the model of the existing manual workers' unions. This meant several things. First, it organized according to an industrial, rather than a skills principle. That is, it gathered **both** clerical and technical employees, and on **all** levels of employment. Secondly, it established both a strong **central** leadership involved in collective bargaining, and **local** union clubs capable of representing and mobilizing employees in individual firms. Finally, while SIF itself was and is politically neutral (or non-socialist), it could - along with the social-democratic manual unions - benefit at its creation from a pro-union social democratic government and soon also from important legal changes codifying the right to organize and conclude collective agreements (1936) and the "Saltsjöbaden agreements" in 1938 regulating the relationships between labour and capital. These factors together made for an internationally unique strength. Membership of SIF grew rapidly from the late 1930s onwards.

Summary

By the time the two major groups of engineers had defined their respective interests and identities, Sweden had industrialized. It had been transformed from a poor, agrarian society to an urban, industrial one where the standard of living already was among the highest in Europe. The country had gone through the depression with an in many ways modernized and dynamic industrial structure. Modern Swedish politics had begun with the first of many social democratic victories. And the relationship between labour and capital had been institutionalized in a class compromise pattern which would last another fifty years. Swedish engineers were an essential part of this development. Some of them belonged to the technical and managerial elite which was a driving force behind modernization, but which also often was sceptical to the democratic and egalitarian aspects of the new times. Other engineers had a more anonymous role. They were the "office floor" workers of industrial change who had begun to link their fate to that of other large collectives of wage earners in society.

Post-War Tranformations

"Fordism" and the expansion of engineers

The post-war years have seen a substantial increase in the number of engineers. In the late 1930s, there were, as we have seen, about 7 000 engineers with a university degree. Today they are seven times as numerous, or about 50 000. Engineers with lower degrees numbered about 11 000 in the late 1930s. Fifty years later, they were seventeen times as many, or about 185 000, and form about eighty percent of those with an engineering degree.

Behind the expansion in the number of engineers lies a strong demand from both the public and private sectors, and a willingness to spend government resources on technical education and research. The expansion is part of a "fordist" restructuring of Swedish society during the post-war years (Mjöset et al 1986). The heart of fordism is the linkage of rational mass production and mass consumption with a social order that regulates class relations and social welfare in a way that will promote rationality, standardization and growth. The central features of this order were already present in Sweden before the war, but were institutionalized and became part of an international growth economy, dominated by the USA, during the post-war years.

In the Swedish context, three aspects should be stressed. First, there has since the 1950s been an important **industrial expansion and transformation**, involving a widespread diffusion of technical innovations and models of industrial organization from the USA. The need for engineering expertise increased: in military-related production, in the creation of new industries, in product development and, particularly, in the rationalization of existing production lines. Swedish industry is generally highly modern, with an exceptionally high diffusion of new technology, including recent one, such as robots and NC-machines. Perhaps as many as 40% of all engineers and technicians working in industry today are involved in the planning and rationalization of production, a work with more or less pronounced taylorist features.

Secondly, industrial growth and restructuration have taken place within a context of a **mixed economy**, involving first of all an institutionalized class compromise between capital and labour. Salaries have been determined through collective negotiations between strong and centralized organizations, who in a sense have guaranteed that demands will be kept within economically viable limits. This depends for its success on near complete unionization - 85% of both manual and white collar workers in the 1980s - which ensures that all employees will stick to the rules of the game (as long as they all seem to get something out of it). Strike activity which was among the highest in the world before the 1930s, virtually declined to nil after the social-democratic ascendancy to power in 1932 and the agreements of the late 1930s.

Another aspect of the mixed economy has been the widespread incorporation of the branch and interest organizations of capital as well as of the manual and white collar unions into the planning and decision making structure of the state. Together they have formed a kind of "growth pact", uniting an industrial and technical establishment with the social-democratic ruling party, the major trade unions and the state apparatus. The unions until the late 1960s have traded increased wages for an acceptance of management's right to decide on the shop floor, to intensify work and mechanize production at the expense of the "human side" of work. The state simultaneously pursued an educational and labour market policy of geographical mobility, industrial retraining and technical change, in order to serve the needs of an expanding industry - but also as a part of a strong commitment to full employment.[13] The state has also promoted a whole range of advanced technologies, in space technology, computers, nuclear energy and military technology. These efforts have mainly benefited the major Swedish export companies, but also in certain cases provided employment in otherwise declining areas. While some of these effort of a small country to enter the international big technology league, have failed, the high-technology ideal on which they have been based is still a dominant feature in both social democratic, big business and contemporary engineering ideology.

Finally, industrial expansion in the post-war era has rested on the growth of **private mass consumption**, made possible by a constant growth in real wages for large groups in society. The unions have pursued an egalitarian wage policy which has been largely successful until the late 1980s. Private mass consumption has also been favoured by welfare state policies, including e g pension schemes and child allowances, and by massive state programmes in the building and financing of housing. Sweden is today the country with the lowest number of inhabitants per apartment (around 2) in the world. Eighteen percent of all engineers and technicians in technical work are employed in building and architecture. State support and the growth in real wages has benefited other parts of Swedish industry, too, including the "white goods" (refrigerator, washing machines etc) industry, notably the Electrolux company, which is today one of the largest in the world, and the indigenous automobile industry - the only one in Scandinavia - with Volvo as the single largest Swedish company today.

The pattern of fordist transformation is discernible in all the Scandinavian countries. Sweden can, however, be seen as the first and foremost example. Here, the class compromise pattern was established in the late 1930s and consolidated in the 1950s, state intervention to secure technical and industrial growth along a high technology and high productivity pattern was important from the 1940s onwards, and a fordist consumption pattern was firmly established by the 1960s. In this transformation, engineers have again played an important role. Their vision of the world has been favoured by the national "growth pact" between the social-democratic government, labour and big business; their expertise has been crucial to the modernization and rationalization of industry and for the creation of new consumer goods. Many engineers have reached positions of national and industrial importance. Most of them, however, have been part of an ever growing number of socially esteemed but more anonymous designers and administrators of a widely-desired technological change.

Social mobility and engineering education

Modernization means mobility. Many people were, in the 1950s and 60s, forced or induced to move from the declining regions of the north to the expanding industries of southern and central Sweden. Immigration from non-Nordic countries into non-qualified manual positions was strong, particularly in the 1960s. Skilled workers in turn were encouraged to move upwards, to engineering jobs via education or training on the job. In the post-war years of great demand for engineers traditional recruitment patterns could no longer hold (Berner 1988).

Changes at upper secondary, "gymnasium" level have been important. Students with a working class background here form up to 30% of all engineering students. Social mobility into **higher** technical education has been more limited. During the depression years of the 1930s, less than 10% of the students at the most prestigious technical university, KTH, had a working class background. In the 1950s and 60s the figure increased to 18%. There it stayed, despite educational expansion and despite the various reforms of the 1970s to increase working class representation at the university level. Working class students at the KTH still (1984/85) constitute only 19% of an admittedly much larger student body than before.[14] The proportion is higher in the other engineering universities. An advanced technical education, nevertheless, still retains its public image as a "prestige education" (together with e g the schools of medicine and economics), with tough entrance requirements, an advanced and theoretical curriculum, strong **esprit de corps** - and a destination towards positions of industrial and technical influence.

The most important route into technical work for the working and lower middle classes has been through the so-called "technical institutes", which existed between the 1930s and 1970s. These gave a specialized training leading to lower and middle level industrial positions. They recruited large numbers of ambitious young men with little or no education, who at an often considerable personal expense of time and money, here could gain a degree as "institute engineer". They were encouraged in this endeavour by the companies where they worked, and by a strong liberal/social-democratic ideology of "equal opportunity" for all, and especially for the working class "talent reserve". As we shall see below, this generation of "self-made" engineers in many cases reached leading or highly qualified positions in industry. Today, however, this is no longer possible without a university degree.

Women were not considered part of the engineering "talent reserve" until the mid 1970s and, particularly, in the 1980s, when there was again a perceived shortage of highly educated engineers (Berner 1984, 1990). Women had been allowed to enter Chalmer's in 1914 and the KTH in 1921, but their number was insignificant until the 1960s and 70s, and their choice of studies conventional. It confirmed what one leading engineer had declared already in 1901: "Women may be used in technical work but only in certain limited capacities, that is, as draughtsmen or chemists". Women engineers have largely entered the schools of architecture (in Sweden part of higher engineering education) and chemical technology. Today (1988), 43% of the graduates in architecture and 42% of the chemical engineering graduates are women. Previously male dominated fields such as civil engineering (in the Anglo-Saxon sense) now attract more women than before (40% of the new students), perhaps as the result of the introduction of "soft" aspects of environmental and social aspects into the curriculum. But the technical fields linked to Sweden's major industrial and export sectors, are still massively male: Computer technology has 92% male graduates, electro-technical and telecommunications technology 90%, machine technology 88%. All in all, women in the late 1980s formed about 20% of the engineering students at both gymnasium and university level, as compared to 7% at gymnasium level and 11% at university level ten years before. The increase may be the result of a massive information programme since the mid 1970s to get women into technology. The joint efforts of educational authorities, career counsellors, unions, women's organizations and many of the major engineering companies have no doubt had an effect, together with the many legal and practical changes supporting "equal opportunity" at work.

Women engineers at the university level, even less than the men, do not come from the working class. Few have broken the double barriers of class and gender. Most of them have a middle class or academic background, with for example a father engineer as a formative influence and support. Women civil engineers do not make as quick and straightforward a career as their male counterparts, their salaries are also generally lower. Still, the university educated women belong to an elite among the women technicians and engineers in what the census calls "technical work". Two thirds of the approximately 16 000 women in this area have no technical education at all (as compared to 35% of the 230 000 men). More than half of the women (as compared to only 11% of the men) are in low level technician's positions. They work in routine jobs threatened by technical change.[15]

The where and what of engineers' work

Most Swedish engineers work in mechanical engineering (27%), electrical engineering, electronics and telecommunications (19%), and computerer programming and systems analysis (13%). Building engineers are also numerous (18%), while chemical engineers form a smaller group (6%). About eighty percent work in the private sector.[16]

These figures point to the extreme importance of the mechanical and electrical engineering industry for exports, employment and technical change.[17] Production is highly concentrated, more so than in most other capitalist countries. A limited number of companies takes care of a very high proportion of total industrial production, exports, research and development. Ownership and control are also highly concentrated. The major companies are, moreover, multinational firms with important subsidiaries abroad and with a higher rate of investment and employment growth abroad than in Sweden. In several cases they occupy oligopolistic niches in the international division of labour.

What Swedish engineers do is highly related to the position of these large and dominating firms which form the backbone of what Ohlson & Vinell (1987) call the **knowledge-intensive sector** of the economy. This sector is highly dependent upon the technical knowledge of engineers and skilled manual workers for high productivity and product development. Some major companies also belong to the **research-intensive** sector which particularly depends on industrial research for new products and markets. In both cases, technical knowledge is imperative for success.[18] Engineers work in three major areas in these sectors. First, many are employed in the area of durable consumer goods, dominated by a few very large companies, such as Volvo and Saab in automobiles and Electrolux in the "white goods" sector. Secondly, many work in the investment goods sector, producing machines, tools, semi-finished goods, ball bearings etc, which is dominated by some old, very large multinational companies (Asea Brown Boveri, Alfa Laval, Atlas Copco etc), but which also includes a large number of small and medium sized engineering firms. Thirdly, and across this division, a majority of all telecommunications engineers work in the Ericson company of electronics and telecommunications, which - after ABB - is the largest single industrial employer of "civil engineers" in the country.[19]

Not surprisingly, most Swedish engineers and technicians are involved in design (42%) and R&D (18% of all). Investment in industrial R&D has increased considerably during the 1980s. In 1987, about 3% of GNP - an internationally high figure - was devoted to research and development. The government sector's share of R&D is surprisingly low: two thirds of R&D financing is done by private firms. More than half of industrial R&D is carried out by **only four** major companies: Asea Brown Boveri, Volvo, Ericson and Saab-Scania (in aircraft and automobiles), all in the mechanical and/or electrical engineering field.

These four companies have, as we have noted above, dominated Swedish industry for many years.

Most of industrial R&D is actually product development, not basic research, something which in Sweden has been left to the state-financed university sector.[20] The bulk (85%) of private sector R&D is devoted to industrial development. Defense related investments come second, with 12%. The private sector still spends about four times as much on military research as the public one; large parts of these investments are, however, financed by the state or related to military procurements. And, as in the case of the creation of large scale energy and telecommunications structures [21], it is a limited number of large engineering firms which have benefited from this traditional, close collaboration with the state.

To sum up: most university educated engineers and a large number of those with lower education work in sectors dominated by large, multinational, technologically advanced firms.[22] Their work is often innovation oriented and strongly tied to international expansion and competitiveness. What engineers do apparently has been, and will be, central for the survival of Sweden as an industrial nation. Engineers are also geographically centralized to the "growth centres" of advanced capitalism. Most "civil engineers" work in large companies and public agencies in or around Stockholm, the major university towns or the most important industrial towns in central and southern Sweden. Large areas of Sweden and many small and middle sized firms have few or no university educated engineers.

Engineers and the industrial hierarchy

Engineers (of all backgrounds) form a privileged group in society. Their salaries are relatively high, their work security, too, and their work is often of a qualified and independent kind. More than 70% of the jobs in what the census calls "technical work" - and which includes work in both the private and public sectors - are classified as **middle level** positions, and and additional 12% as leading or professional positions. These positions, we should add, are largely filled by **men**. They occupy 97% of the middle level and 94% of the top level jobs.[23]

This pattern is repeated when we look at the private industrial sector only. Most engineers are men, and most of them work in middle level positions. Seven percent of engineers and technicians in industry are in "leading positions", 58 % in "independent and qualified positions", 24% in "qualified positions" and only 11% in "routine work". Technical jobs thus are more independent and qualified than most other types of jobs in society.

There is a strong correlation between level of engineering education and level of work. More than two thirds of those with a higher education are in higher technical positions within industry. Half of those in "leading technical positions", or 7% of the total, are today civil engineers. The rest are promoted engineers with a gymnasium or institute level education dating back to the 1950s or 60s. These people are today near their pension age and companies tend to replace them with civil engineers only. It is today virtually impossible to reach leading **technical** positions in industry without a university degree; new recruits into top and middle level jobs are normally civil engineers.

Until the second world war, civil engineers were also the only university educated group to reach **general** management positions. In fact, they seemed to have a near monopoly, at least in the engineering and steel industry. In 1930, 53% of the employed managers in the 116 largest industrial firms had a higher technical education, a few had a lower technical degree, and only two had an advanced business degree. Today, graduates from the highly selective Business Schools have replaced those with a lower - technical or other - education as employed managers in industrial firms. In 1980, 45% of the 161 largest industrial firms were led by civil engineers and 35% by business economists (Carlson 1986:58).[24]

A third important change is the educational upgrading of **all** engineering positions, not only the top jobs. Engineers with only a lower education (i e the gymnasium level one, since the institute level degree has disappeared since the 1970s) will in the future probably remain in more or less routine, middle and lower level technical jobs. Independent and top level jobs will be occupied by the civil engineers and by the holders of a new middle level university degree.[25] Sweden has in fact, until the late 1980s, differed from many other countries, including other Scandinavian ones, in having no such B.A.level engineering degree - the "civil engineering" degree having evolved into a Master of Science degree. This educational gap may have contributed to the traditional, high status position of the civil engineer. It may also have contributed to the relatively high social mobility of engineers with some formal or in-house education and a lot of practical experience. They were needed in many middle level positions, and even in some top ones. This mobility from the shop or office "floor" may today be a thing of the past.

Today, many gymnasium engineers work in what has traditionally been classified as manual, LO-organized, occupations. The boundaries have become blurred between technical and manual jobs with the introduction of numerically controlled machine tools and other automated processes, but also as a result of work enlargement programmes and other attempts at group organization of production. Programming, computer repair and maintenance, computer aided testing and stock taking are some examples of jobs within a "contested terrain" between the Metal workers union, the industrial white collar union SIF, and the union of supervisory personnel, SALF. Competition between the unions has increased, as each union claims the attractive jobs for its members and tries to increase its membership. A tendency today is to classify such skilled manual work as white collar work and thus as part of the SIF category. But the pattern varies. The central union administrations are more prone to defend traditional barriers than are many local union clubs and representatives. In individual firms, manual workers, engineers, technicians and employers apparently often manage to find flexible patterns of work and union demarcations. Such new, local patterns may, in time, influence also the overall picture of technical jobs and break down the traditional boundaries between manual and mental work (Nilsson 1988).

Organization and identity

One of the major features of the Swedish labour market has been the high degree of self-organization of the major social groups. Interest organizations have evolved into large, centralized bodies, with an important representation inside the state apparatus. No group of employers or employees can afford to stand outside this organizational pattern.

The industrial white collar union, SIF, which is the most important organization within the Confederation of Salaried Employees (TCO), has been very successful (particularly when compared with other countries) in organizing not only rank-and-file office workers but also most middle and even some top level employees in private industry. About 80% of all engineers, technicians and office workers in private industry are organized today, and 71% of those in leading positions (1981)(Kjellberg 1983).

Most of these top level engineers do not belong to SIF, but to the the **Association of Civil Engineers (CF)**, founded in 1954. This is today the largest union within the Confederation of Academically Educated Employees, SACO, created in 1947, and one which organizes civil engineers in both private and public employment. SACO (today SACO/SR) and its member organizations are unique in the Swedish context, in that membership is based on **educational credentials**, not on where you work or what you do.[26] In fact, SACO was established in the 1940s with the explicit aim to maintain salary differentials between university educated and other white collar groups. This policy of defense of an academic elite clearly has set SACO apart from the more egalitarian policies of both LO and TCO.

Nevertheless, most civil engineers were reluctant to join even such an "elite" organization. Many did not accept the principle of a unionization or felt little personal need for its help. Engineering salaries were relatively high and their positions secure. Their loyalty was to their public or private employers, or their professional organization, the STF. They preferred to organize around technical rather than economic interest demands, i e in the STF rather than in CF.

Things began to change in the late 1960s. Large cohorts of M.Sc. (i e civil) engineers entered the labour market after the establishment of several new engineering schools. There was a temporary slump in employment in the late 1960s, and many young civil engineers got routine jobs in large bureaucratic settings. In the early 1970s, the civil engineers' professional organization (STF) merged with their union (CF), in order to strengthen the latter. The thus reinforced CF today organizes 95% of the approximately 50 000 civil engineers.

It could be argued that SACO has not been very successful in defending its members; large parts of its public sector members (such as social workers and teachers) have relatively low salaries. The mainly privately employed engineers are better paid but still constitute a "cheap" labour force when compared with their colleagues in e g Germany and USA (Ohlson & Vinell 1987). The reason for the high unionization of top level engineers must perhaps be sought elsewhere: CF has retained many features of its professional, STF, past. It is strongly oriented towards professional service to individual engineers and to technical education and information to the whole group. And it provides a forum for an elite of educated engineers.

The very few civil engineers who do not belong to CF, belong to SIF, as it seems, for political or ideological reasons. They may not accept the inegalitarian ideology of CF. Or they may work in environments where everybody else belongs to SIF. The latter union is arguably a more central union when it comes to influencing public policy, by virtue of its good contacts with the important Metal workers' union and by its own numerical strength. It is the largest union inside the white collar confederation (TCO) with about 30% of TCO's altogether more than one million members (or about six times as many members as SACO/SR).

Identity and social challenge

As the discussion above indicates, the difference between the M.Sc. engineers and the others is still a salient one, in status, organization and careers. There is a certain overlap in what the different groups do. But civil engineers tend to be more concentrated in top level positions, design and development work, large companies and major growth areas of the economy than are other engineers. They also benefit from higher salaries and better career prospects than engineers in similar positions but with no university degree. Their university background gives them access to a well-established and centrally placed "old boys" network, from which other engineers are excluded, and which serves as a recruitment basis and resource for their personal careers. Differences in work position, social status and background are reflected in political orientations, too. Traditionally, civil engineers, and particularly those working in the private sector, have been a conservative lot. Lower level engineers and technicians to a larger extent have voted also for the socialist bloc.

Swedish engineering identity has, as we have seen, evolved in the context of a swift, peaceful and successful transformation to an advanced industrial society. The social identification of engineers has been with a "fordist" model of growth, based on advanced technology, class compromise, mass production and consumption. But this growth model has recently been challenged in both economic and ideological terms. What we can call the "red, green and blue waves" of discontent (Mjöset ed 1986) have influenced also the positions and identity of Swedish engineers.

The "red wave" started in the late 1960s. It involved large scale protests against taylorist work organization, most notably in the mines and in the automobile plants. The protests were also directed at trade union and socialdemocratic party leaders and their "capitulation" to capitalist demands. Certain important changes ensued. The social democratic party and the unions put forward legal changes aimed at a greater work place democracy and a technical change based on wage earners' demands. Capital reacted with new strategies of rationalization, tied to automation and sociotechnical experiments rather than to direct, taylorist control. Production engineers had to learn new, more "democratic" or group oriented principles of organization, and many time-and-motion studies engineers had to go.

The long-term impacts of the "red" challenge to work organization are less impressive. There has been much talk, but only a few (highly publicized) work places have actually broken radically with the taylorist pattern of work. On the other hand, awareness has increased also among white collar groups of the problematic character of much production technology. Both SIF and CF have had to defend also their **own** members against adverse effects of automation and computerization, and have put forward programmes for greater employee control of technological change.[27]

While the "red wave" challenged the effects of class compromise and of taylorism in production, the "green wave" turned against its **external** preconditions and effects. Important landmarks were the referendum on nuclear power in 1980 and the entrance of a "green party" into parliament in 1988. Engineers and their work was challenged from a new direction, which also included an attack on military technology and various other "moral" issues of technical change. There is today a genuine concern for environmental issues in politics and within the engineering and industrial establishment [28] - but also a profound resistance to fundamental changes in the country's energy, military or industrial policies. The engineering community at large seems divided. Engineers are today much more concerned about the environment than before - but also strongly attached to traditional technical solutions; a much higher proportion of engineers than of the population as a whole for example still supports nuclear power. The central role of the energy, military and car related industries for engineering employment may be a factor at hand. Another may be the continuing predominance of **men** within the engineering community. Women, on the whole, are more critical of technology and more concerned with the moral and "green" issues of politics than are men (Peterson 1987).

The most recent challenge to the "fordist" pattern of growth and class compromise has taken the form of a "blue" or liberal "wave". It involves a critique of the "inefficient" welfare state, negative attitudes towards the unions and the egalitarian wage policies, and a concommittant high regard for individual entrepreneurship, high technology and international capitalist integration. Much of "blue wave" ideology is repeated in the official analyses of the engineering establishment, such as the CF and the Academy of the Engineering Sciences.

In Sweden of the 1990s, the liberal political project has gained a much stronger audience than expected only a few years ago. The social democrats who returned to power in 1982 after a six year "bourgeois" interlude may well lose the elections of 1991. The "red" and the "green" solutions to contemporary problems have, temporarily or not, left the political agenda, as new populist, right wing groups gain popular support. The traditionally very strong class-based voting pattern is breaking up, union membership is in decline, the traditional allegiance to strong interest groups and organizations may be a thing of the past. Social-democracy has become a party among others, no longer **the Party** for almost half the Swedish population and its traditional solutions no longer apply.

In this process, the post-war growth model has broken down. First, the centralized wage setting mechanisms which ensured "reasonable" and equitable wage increases, have partly collapsed. Inequality increased during the "boom years" of the 1980s, which benefited capital and high income groups to a disproportiate degree, while the fiscal crisis of the state made for social inequality and strong pressures towards privatization. Add to this, attacks against the unions, and a lack of solidarity between public sector employees, largely women, who now demand a better deal, and the male industrial workers and employees, who do not want to pay the taxes to achieve it. Swedish society has become more fragmented and individualistic than before.

Secondly, growth itself has become problematic. Swedish companies are good at rationalizing production and introducing new production technology. But most products are of a "mature" kind; there seems to be little dynamics when it comes to the creation of new advanced products and new markets abroad. Sweden's dependency upon a few large companies which dominate the knowledge and research intensive sectors, may prove a real problem in the future - as witnessed by the recent dramatic difficulties of the Volvo and SAAB car companies, with repercussions throughout the economy.

Finally, the scope for independent, "Swedish" (often more radical) solutions to environmental, social or work place problems is rapidly narrowing down. Large areas of economic and technological policy is today completely outside public and even national control. The major Swedish companies are thoroughly internationalized, a pattern which has been reinforced in recent years. Swedish investments in the European Community are ten times as large as community investments here. "Flagships" of Swedish technology are no longer Swedish only, as international mergers increase.[29] The July 1991 application for membership to the EG signals a general acceptance of an international, liberal model of economic growth.

To conclude: There is no longer a stable "Swedish model" of economic and technical growth as in the immediate post-war decades. New economic problems as well as new ideological responses to these problems have made for greater social and ideological divisions, presumably also among Swedish engineers. A major factor behind the increased volatility of Swedish public opinion may be the ascendancy of a variety of middle class groups, many of whom have a technical education or job. Their ambitions and opinions differ from those of the traditional working class.

Today, a new type of society may be emerging. It is based on knowledge and research rather than on labour-intensive industry, on a concern for the environment but also for a "technological fix" to many problems, and on Sweden's integration into an economically and technologically dynamic European Community. In this new society engineers seem to be on the side of the winners. This is indeed also how they see themselves. They are - as the leading Swedish engineering journal proudly proclaims - "the Heroes of the 1990s".

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Notes

1 The discussion is when not otherwise stated based on my own research (see the literature list), as well as on official statistics and census data.

2 Looked at it another way, between 250 000 and 300 000 engineers and technicians today work in what the census calls "technical work" out of a total work force of about 4.3 million. The figures overlap, but only partly. A number of those with an engineering education are not employed in "technical work". The figure for "technical work" also includes a number of people **without** an engineering diploma, especially at lower, technician's level (about 13% of all).

3 Women with a formal engineering degree were non-existent in the 1880s and about 6% of the total in the 1980s.

4 **Ingeniör Lexikon**, Stockholm 1805, quoted in Ahlström 1982:21.

5 Wallerstein, I, **The Modern World System**, 1980, quoted in Alestalo and Kuhnle 1987:6.

6 There was since the 17th century a comparatively high upward inter-generational mobility between peasantry and nobility. The typical pattern was a change over two or more generations from peasant to clergyman to noble. This pattern ties in with the exceptionally strong position of the independent peasantry, both in economic and political terms (Castles 1973, Alestalo and Kuhnle 1987).

7 For one important example, see Lindqvist 1984. Hult et al 1989) give a general picture of Swedish technological developments.

8 The schools mainly attracted those with an industrial or military background. 75-80% of the students between 1881-1910 at KTH and Chalmers had fathers who were either business leaders or white collar employees. The corresponding figure for the gymnasium education was 65% (Torstendahl 1975:254).

9 It should be noted these organizations were based upon the industrial rather than the occupational principle. All manual workers in e g the metal industry, independent of task or skills thus belonged to the same union.

10 See particularly Runeby 1978, Berner 1981, Sundin 1981.

11 About 60% of the university level engineers at the turn of the century worked in the private sector, most of them as salaried employees and to a large extent in leading and/or independent positions. The metal and engineering industry was by far the most important industrial sector. State and municipal employment was important. Civil engineers from KTH in Stockholm were until the mid 20th century virtually the only engineers who could reach leading positions in the civil service (Torstendahl 1975).

12 The university educated engineers were even less interested in the technocratic critique of capitalism. Most of them "believed in capitalism", as one of them said during a debate on the subject in 1933. One exception was the architects, who in many cases linked their social ambitions and ideals of a rationally planned society to the social democratic party. The civil engineers' association also rejected invitations from lower level engineers to form a **common** engineering organisation based on their supposedly shared technical expertise and mission in society.

13 One aspect of this double commitment has been the reorientation of the **whole** educational structure in the post-war years, and especially since the 1960s, in a vocational direction. About 85% of all 17-year olds today remain in upper secondary school. About 70% of them get a vocational education, either in the form of manual training or as a technical and economic education leading to intermediate positions in industry and trade (gymnasium engineers and economists). The strong vocational orientation continues at university level (Berner 1989).

14 Stated another way, this means that only 1-2% of a relevant age cohort of young working class males in the 1960s and 70s entered higher technical education, whereas about 15% of a cohort of boys with academically educated fathers did so. Many of these fathers, of course, were civil engineers themselves.

15 Figures refer to the early 1980s and are based on the census and the discussion in a study made by the Academy of Engineering Sciences (**IVA-meddelande 249**).

16 The percentages refer to the about 275 000 people who in 1985 worked in what the census calls "technical work". Sweden's population was then about 8.3 million and the working population consisted of 2.3 million men and 2.0 million women.

17 To work as a mechanical engineer or technician is actually the single most important male occupation in Swedish society, employing 3.2% of all economically active men.

18 The two other major sectors of the economy are the **labour-intensive** and **capital-intensive sectors.** The first includes forest products, textiles and some food stuff industry, is partly in decline and has very few engineers, and even fewer graduate engineers. The capital-intensive sector includes important continuous process industries in the chemical and petro-chemical industry, the paper and pulp industry and the steel industry. It is often a technologically advanced industry, but it employs relatively few engineers (Ohlson & Vinell 1987).

19 Asea Brown Boveri (formed in 1987 by a fusion between Asea and the Swiss company Brown Boveri) employs about 5 000 university trained engineers (of which an unknown

number abroad), Ericson about 2 500, Volvo about 1 500 and Saab-Scania about 1 000 (**Affärsvärlden** nr 1/1988 :17). About 40% of the today about 50 000 civil engineers work in the manufacturing industry.

20 Three large pharmaceutical companies actually spend a higher proportion of their turnover on research (14-20% in comparison to the engineering companies' 7-12%); in addition they spend about half of that amount on basic research.

21 Two public enterprises are among the 20 largest spenders on R&D in Sweden, the National Board of Telecommunications and the National Energy Board. Both are major employers of engineers and both have evolved in technical symbiosis with the major companies in their field (Ericson and Asea, respectively).

22 In recent years there has been a considerable devolution of computer and commercial activities of many of the large firms to separate service companies. About 20 000 employees have been transferred from industrial companies to the private service sector 1977-82 (or about 60-80% of the growth of the service sector during that period) (Ohlsson & Vinell 1987:99).

23 Engineering unemployment is very low. Immigrant engineers (mainly refugees) from Latin America, Africa and the Middle East form a disproportionate number of those who are unemployed or working in jobs below their capacity. Swedish unemployment was around 3% in mid 1991, but rising and with important regional variations.

24 An indication of the prestige of the title of "civil engineer" is the fact that it was copied by economists aspiring to management positions who, since 1943, call themselves "civil economists".

25 Note that we here discuss engineering jobs with a high technical contents; sales jobs and supervisory positions in production which today employ large numbers of engineers with a lower level education and very few civil engineers will probably continue along the old pattern for some years to come.

26 Another exception is the small organization for industrial supervisory personnel, SALF, with many engineers and technicians.

27 The international labour process debate has been quite important in Sweden, particularly in the work of the Centre for the Study of Working Life, a state research institute with strong union ties. Theoretical debates about the position of engineers have, however, been scarce. Most research efforts have gone into action research and analyses of on-going socio-technical experiments (see Berner 1986 for an overview). The engineering community has shown little interest in other than historical studies of their origin and professionalisation. In the 1980s an interest has emerged in the relationship between women and technology, in the form both of theoretical discussions and of action research (see Berner 1984, 1990).

28 A new code of engineering ethics - the first since 1929 - was adopted by the CF in 1988 as a response to public and internal critique of environmentally unsound technology and of bad business morale.

29 Recent examples include the mergers of Asea with the Swiss company Brown Boveri and of Saab automobiles with General Motors and the extensive collaboration between Volvo and Renault.

R.A. BUCHANAN

Prelude to industrialization: The acquisition of technology by England 1500-1750

Historians of technology have been understandably intrigued by the problems of the transmission of technology - that is, of accounting for the transfer of technological expertise from one society to another. There are macro and micro dimensions to this process. At the macro level, there has been a long-standing controversy between those who take the view that all major advances in technique stem from some common source, be it in Egypt or China or elsewhere, and those who place more emphasis on the spontaneous generation of inventions wherever and whenever conditions are appropriate. It is probably true to say that this issue arouses more interest now amongst archaeologists than historians, because historians have grown cautious about launching upon interpretations involving grandiose generalizations.[1] At the micro level, interest centres on the actual mechanisms of transfer between particular communities, and here there is plenty of scope for historical analysis.

Technological expertise can be passed on in a variety of ways such as by visiting, by teaching, and by acquiring specimens of hardware, but the vital ingredient in all these processes is human contact so that it is useful to focus on the forms which this can take. Some years ago, Warren C. Scoville suggested a typology according to whether a single individual was involved in the process, or a group of individuals, or what he called a "minority migration". It is difficult to draw the line between large groups and significant minorities in what is largely a matter of scale, but there is an important difference between individuals and groups, because whereas the influence of individuals tends to be inspirational and, except in the cases of personal genius, short-lived, that of groups is generally concentrated in working practices which can produce a long-lasting change in techniques.[2] Such groups may set out explicitily to instruct new practitioners in the mysteries of their craft on an apprenticeship or contractual basis, or they may provide an example to be copied as best they can by their hosts, but in either case the end result is a community greatly enriched by the expertise of the newcomers. In this paper we will be concerned with some of the groups of people who made a substantial contribution to the beginnings of industrialization in England between 1500 and 1750.

In speaking of the beginnings of industrialization in England in this period it is not meant to imply simply that a set of techniques was acquired from other more advanced parts of Europe, although something of this nature did occur. Certainly, in early modern centuries, some other parts of Europe possessed more advanced urban communities and industrial activities than any part of Britain. But it would be a mistake to write off the British Isles as a backward territory at this time or earlier. After all, the Vikings had been attracted to Saxon England as a rich land, and as Professor Postan once reminded us in the context of discussing the influence of Italian bankers on fourteenth century England, the Italians were attracted by the wealth of the country, securely founded on agricultural prosperity and English wool.[3] Yet equally certainly, England had much to do in order to catch up with the more advanced industrial communities in Europe, and in the process of developing commercial and industrial enterprises it received great help from groups of foreigners who came to work or settle in the country in this period. Four of these groups were especially significant: the Flemings who came in the mid-sixteenth century; the German miners who came about the same time; the Dutch hydraulic engineers who were active in the first half of the seventeenth century, and the Huguenots who appeared at the end of that century. There were, of course, other immigrant groups during this period, such as various Jewish communities, but they are not associated with specific technological innovations so they will not be considered here.

Attempts had been made in the fourteenth century by King Edward III to persuade Flemish craftsmen to settle in English towns, and there was a continuing interchange between Flanders and south-east England associated first with the export of English wool to continental markets, and later with the processing and finishing of English broadcloth in Flanders. But the first really significant settlements of Flemings in England came in the mid-sixteenth century, and were promoted largely by political and religious upheavals in the Low Countries. The government of Queen Elizabeth I was particularly keen to benefit from these upheavals by encouraging refugees from Flanders to settle in English towns, issuing instructions to towns in the south-east to make the newcomers welcome, and providing facilities for them to acquire property and practise their crafts.[4] It is difficult to quantify the extent of this Flemish immigration, but it was certainly substantial. Samuel Smiles quoted an assessment of 1621 according to which: "there were then 10,000 strangers in the city of London alone... carrying on 121 different trades".[5] According to an estimate of 1571, immigrants from the Low Countries accounted for a third of the population of Norwich, and in Colchester the proportion was probably greater.[6] There were inevitably problems in assimilating such large immigrant communities, but generally they settled in well because their skills were welcomed both by the government and by local people who were suffering from the relative decline in popularity of broadcloth and who were prepared to adopt the "new draperies". For as Smiles observed: "wherever the refugees took up their abode, they acted as so many missionaries of skilled work..."[7]

The "new draperies" were especially significant in the transmission of technology because they gave a new lease of life to the English woollen cloth industry. The skill of the Flemish immigrants in manufacturing high quality fabrics which were lighter and more versatile than the traditional broadcloth were readily acquired by English craftsmen and provided the basis for a revival in the industrial prosperity of East Anglia, and these benefits spread more widely to enrich the English economy. The new cloths, known under a variety of names such as bays, says, perpetuanas, and bombazines, used long-fibred wool as in worsteds rather than the short staples used in broadcloth, and they dispensed with the fulling process to felt the fabric. The success of the new textile processes was an outstanding case of the direct promotion of technological innovation by bringing in skilled workmen from outside.

But the Flemish immigrants into England in the sixteenth century did not only bring skills in textile manufacture. Sandwich, in Kent, which was one of the main receiving ports for immigrants, underwent an urban revival to become a thriving centre of craftsmen, including two potters from Delft who are reputed to have brought the manufacture of their distinctive tin-glaze pottery to England. A somewhat different, although related, migration into the Weald of Kent at this time was responsible for the rapid development of the iron-working industry there, with blast furnaces for the production of cast iron, and many associated processes, all proliferating. It seems that the main source of this immigrant community, probably numbering up to four hundred skilled workers in the 1540s, was Normandy and French Flanders. Brian Awtry has suggested that this accounts for the adoption of many French terms in iron-working processes, and that the immigrants provided "an expanding industrial base" for the development of new techniques.[8]

Moreover, in another crucial industrial process, the manufacture of glass, Dr. Godfrey has recently observed that: "the credit for re-establishing the making of window glass in England and introducing the manufacture of fine tabelware in *cristallo* belongs to an alien, Jean Carré".[9] Carré was a French-speaking Huguenot merchant from Antwerp. He arrived in London in 1567 and obtained a licence to make window glass for twenty-one years. Leasing land at Fernfold Wood in the Weald, he brought over groups of continental glassmakers, and under his enterprise: "this undistinguished forest industry grew into something four or five times its former size".[10] Carré also established a glasshouse in London at Crutched Friars, and brought over Jacob Verzelini to be the master there. Verzelini was a Muranese craftsman from the elite community of fine crystal glass manufacturers on the island of Murano in Venice, although he had worked in Antwerp for twenty years. In 1574 he received a monopoly grant from Elizabeth I to produce Venetian crystal and recruited more workmen from Murano to assist him.[11] Immigrant craftsmen were frequently unwilling to train English workmen in their craft, and some of Carrés recruits returned to the continent rather than agreeing to do so: his partner, Peter Briet, referred to them trying to: "kepe the science out of the Realme".[12] But Dr. Godfrey is in no doubt about the importance of the contribution of the incomers to the glass industry: she says - "The influx of alien glassmakers, whose numbers and skill infused new life into English glassmaking, was unquestionably the greatest single factor contributing to the growth of the industry".[13]

About the same time as the main influx of Flemings into England in the mid-sixteenth century, another group arrived on English shores with a highly valued skill at their disposal. These were the German miners and metal workers recruited to exploit the mineral resources of England and to manufacture brass. The great study of Agricola, *De Re Metallica* , had been published in 1556, establishing the supremacy of German - and especially Saxon - metal workers. To benefit from their techniques, two joint stock companies were incorporated in England in 1568: the Company of Mines Royal, and the Company of Mineral and Battery Works, both depending to a large extent on German expertise and, in the case of the Mines Royal, a substantial amount of German capital. Incorporation followed several years of exploration and negotiation, in the course of which Daniel Hochstetter, the agent for merchant and banking interests in Augsburg, assured himself that mineral resources - especially copper - were worth mining in England, and persuaded German investors to provide a large proportion of the capital. Under the terms of its charter, the Company of Mines Royal was empowered to search for and to smelt ores of gold, silver, copper and quicksilver throughout the counties of Cumberland, Westmorland, Yorkshire, Lancashire, Cornwall, Devon, Gloucestershire and Worcestershire. All the counties of Wales except Monmouthshire were also included.[14]

In practice, most of the mining activity promoted by the Company occurred in Cumberland, although the nature of their monopoly allowed them to exercise control over other operators in the named counties. It was to the Lake District, in particular, that Hochstetter introduced several parties of German craftsmen and settled them in a community near Keswick. There is no certainty about the number involved. Rees refers to a request from Hochstetter and his English counterpart Thurland to introduce 300 to 400 foreign workmen, "skilful and expert Arts men", when copper was discovered near Keswick in 1565,[15] but Rhys Jenkins gives a more conservative estimate of about 170.[16] It seems likely that the discrepancy is due to the reliance of Jenkins on a single source, which was Collingwood's analysis of the Augsburg firm's dealings with the Keswick enterprise in *Elizabethan Keswick*,[17] whereas Rees's account derives from a much more extensive survey of State Papers, which cover several simultaneous operations. There is certainly evidence of other groups of German workmen being recruited about the same time to work as miners in Ireland and as steel craftsmen in South Wales.[18] However, the German community in Keswick is particularly well documented because of the survival of the Augsburg account books from 1564 to 1577 which were transcribed and translated by Collingwood. These depict in vivid detail the comings and goings, mining operations, building work, and domestic expenses of the agents and their staff. They record the arrival of groups of miners from Germany, their search for ores, and their efforts to assay the minerals which they found. The Company erected modern and expensive smelting plant at Brigham, on the east side of Keswick, to help in the processing of the copper produced, but they soon got into difficulties about the distribution and marketing of this product, and it is clear that by 1577 the German financial commitment was being withdrawn and many of the workers had returned home. But a high proportion settled and remained in the district, over fifty marriages being recorded between the incomers and local women. And even though few names of German origin survive in the population of the Lake

District, Collingwood was in no doubt about the tremendous stimulus which the German community gave to the life and economy of the district.[19]

Although lacking in statistical precision, it is certain that the total number of German workers was not very large, amounting to only a few hundred on the most optimistic estimates. Morover, the immediate financial achievement of the Keswich enterprise was not very satisfactory. But the service of these craftsmen in transferring modern techniques of mining and mineral working to England was enormous. A contemporary observer said of them: "High Germans are more intentive and no nation can come near them in the mechanical arts",[20] and they introduced these arts to England. Burchard Cranage, described by Rees as "a German physician and engineer", had introduced water-powered ore-stamping machines to lead-working sites at Duffield and Beauchief in Derbyshire in the 1550s, and they appeared in Cumberland soon after.[21] Other innovations included the double water-wheel for raising ore and water, copper-smelting blast furnaces, roasting furnaces, and many other refinements in the laborious processes involved in the reduction of copper from its ore.[22] German improvements in handtools and equipment also contributed to the subsequent expansion and profitability of the English metal-mining industries.

Another range of skills was associated with the working of metals into consumer commodities, and here again the crafts of Continental immigrants, mainly from Germany, were invaluable. The Company of Mineral and Battery Works was incorporated at the same time as the Mines Royal in 1568. It was a smaller enterprise than the Mines Royal, involving only a tenth as much capital, and none of this was raised abroad.[23] All the same, foreign craftsmen were essential for its success. A Saxon craftsman called Christopher Schutz, described by Lord Cecil as "a battery man of great skill under whose influence the wire and battery work would prosper",[24] had been brought over in 1566, and the discovery about that time of deposits of calamine in Somerset by a team of German mineral prospectors provided another necessary item in the establishment of the first successful brass-working industry in England. Several groups of German workers were recruited to expand the brass manufacturing processes in the Bristol region. They were often referred to as "Dutchmen", but Joan Day has demonstrated that most of them were German, coming from the area of Aachen.[25] They established water-powerd brass-battery hammers and annealing ovens, and English workers acquired their expertise in brass-making by serving with these skilled teams. As with the miners of Keswick, the role of the English workers was initially subservient to that of the skilled foreigners, but the example was one which could be followed, given sufficient incentive and persistence, so that these technological skills were very successfully transmitted to an English environment.[26]

The general influence of Dutch initiatives on English technology occurred over a wide range of processes between the mid-sixteenth century and the end of the seventeenth century, and has been discussed elsewhere.[27] Useful acquisitions included many improvments in agriculture, ship-building, and mercantile practices which were assimilated by visitors to Holland or other people having cause to observe Dutch methods closely. Here we are concerned only with those techniques which were transmitted directly by immigrant groups, and that means in particular the work of the hydraulic engineers. The numbers involved were not large, consisting for the most part of a few small teams of Dutch workers operating under a handful of distinguished engineers, amongst whom the best known is Cornelius Vermuyden. Born at St.Maurtensdijk, Zeeland, in 1590, Vermuyden was not the first Dutch hydraulic engineer to take an interest in the drainage of low-lying fenland in England, and it seems that he came to the country in 1621 at the instigation of some of these compatriots who had been employed by English land owners to advise them on the improvement of their property. Most prominent amongst these landowners were the Russells, Earls and later Dukes of Bedford, who had managed to win the support of King James I for largescale land-reclamation works around the Wash. These plans, however, were slow to materialize, and meanwhile Vermuyden received other drainage commissions, notably at Hatfield Chase in south Yorkshire. His success in this venture, although only partial, led to him receiving a knighthood at the hands of King Charles I in 1629.[28]

Francis, the fourth Earl of Bedford, at last managed to assemble a group of proprietors to raise the capital for the drainage of the Fens in 1630, and he engaged Vermuyden as engineer of the project. Despite difficulties with the proprietors and local residents, perennial shortage of capital, and the many problems caused by the political disruption of the Civil Wars, he completed this task by 1655. Vermuyden's Great Level constitutes only a third of the total area of the Fens, but his methods of controlling the flow of the Great Ouse dominated all subsequent land drainage schemes in the area. These methods did not go without challenge. Westerdyke, a rival Dutch engineer, advocated deepening and embanking existing river courses, whereas Vermuyden favoured the cutting of new straight courses to carry off excess water, with banks built well back from the edges of the waterways to allow for "washes" or artificial flood-plains. Both methods were used in the Fens, but Vermuyden's solution made the more spectacular contribution to the landscape, with its twin "Bedford Rivers" in particular running in parallel lines for 21 miles across the flat expanse of the Great Level, and it was features such as this which most impressed posterity and guaranteed that Vermuyden received the major credit for the achievment.

Vermuyden's interests were not confined to land-drainage. He came to own property in several parts of the kingdom, including King's Sedgemoor in Somerset - although he does not appear to have undertaken any hydraulic engineering in that area of fenland - and he held a share in lead-mining partnership at Wirksworth in Derbyshire. Despite his honours received from the early Stuart kings, he appears to have established good relationships with Oliver Cromwell - himself a Fenland landowner - who used his services in delicate negotiations for treaty with the Dutch at the end of the First Dutch War in 1653, and with the collapse of the Protectorate Vermuyden's career seems effectively to have been terminated. He died in comparative obscurity in Westminster in 1677. He appears to have been a disputatious and obstinate man, but his skill as an hydraulic engineer was generally recognized so that for as long as he lived he was regarded as the outstanding authority on river control and drainage works. It is not clear to what extent he relied upon teams of workers recruited in Holland, after his early years in England when, as we have seen, he arrived as a member of a group of Dutch experts. Harris refers to "an army of Netherlanders" descending on Hatfield Chase to work on Vermuyden's scheme there, but it seems likely that the numbers generally involved were fairly modest. The important event for the history of technology, however, was that this handful of skilled workers, operating under an engineer of genius, was able to mediate a craft to English engineers who were subsequently able to undertake river control and drainage works without help from abroad. It was, indeed, a very substantial transfer of techniques, even though so few people were involved.[29]

The fourth group of immigrant craftsmen who brought new techniques to England in the two centuries immediately before the Industrial Revolution resembled in scale the sixteenth century Flemish artisans rather than the German miners or Dutch hydraulic engineers. Whereas the latter two groups came, as we have seen, in small numbers, not exceeding a few hundred at most, the Huguenots who arrived in the second half of the seventeenth century came, like the Flemings, in thousands. Like the Flemings, also, they came as refugees from religious and political persecution. The Huguenots were French Protestants, who had achieved religious toleration under the terms of Henri IV's Edict of Nantes at the end of the sixteenth century, but for whom life had gradually become more difficult under the reluctant tolerance of Louis XIV and became unbearable when that monarch revoked the Edict in 1685. The revocation led to a sustained exodus, as something like 200,000 French subjects sought to leave the country, which they had to do secretly and against the express orders of the King, and to seek refuge in those European countries which would recive them - Switzerland, which was anxious not to incur the wrath of Louis XIV, so that it did not encourage the refugees to settle - Prussia, Holland, and England. It has been estimated that 50,000 took refuge in England, and although many moved on or returned to France, a high proportion of these established permanent settlements.[30] A further 5,000 went to Ireland, where they played a major part in establishing the linen industry.[31]

The Huguenots who settled in England represented a broad cross-section of bourgeois and artisan society, so that they brought capital and enterprise as well as industrial skills and applied themselves diligently to replicating manufacturing processes which they had practised in France, and which were now applied to promoting the interests of the nation which had emerged as the chief rival of France. The element of novelty about these processes is debatable, and it seems likely that the Huguenots did not achieve many outstanding industrial innovations. But they gave a profound stimulus to industries such as silk manufacture, linen manufacture, and paper-making, promoting them as powerful instruments of industrialization in a society which was beginning to grasp opportunities to profit from trade and industry. The contribution of families like the de Portals to paper-making was typical of this sort of stimulus. As Smiles concluded in his work dealing with the Huguenots, to which reference has already been made: "In short, there was scarcely a branch of trade in Great Britain, but at once felt the beneficial effects of a large influx of experienced workmen from France".[32] Scoville speaks of the Huguenots having "fortified" branches of the textile industry, and the image is a happy one because it conveys the correct impression of reinforcing an existing situation rather than creating a brand new one.[33] He also quotes a contemporary, Sir Francis Brewster, as saying in 1702 that "the English have now so great esteem for the workmanship of the French refugees, that hardly anything vends without a Gallic name".[34] There can be no doubt that the influence of the Huguenots was strongly felt over a wide field of English industry and trade.

Apart from their direct contribution to technical improvment, the Huguenots made an impact on the transmission of technology in two less obvious ways. The first was in their military prowess. Schomberg, who became the leading general of William of Orange and who master-minded the operation whereby the Prince became William III of England in the "Glorious Revolution" of 1688, had been one of the outstanding generals of Louis XIV before his Protestant loyalties obliged him to transfer his allegiance, and many thousands of Huguenot soldiers of less eminent ranks adopted a similar course and reinforced the armies of the rivals of France. It is not mere coincidence that the Revocation of the Edict of Nantes marked the high-water mark of Louis XIV's military domination of Europe, because thereafter some of the most able French military minds were aligned against him, and with the change in political balance of Europe the way was open also for the exploitation of the economic advantages of England in relation to its historical rival.

The second point springs directly from this. However difficult it is to quantify the technical transmission of know-how brought about by the immigration of Huguenots into England, it is apparent that the shift of this expertise from France to England had a decisive part in altering the balance of economic advantages between the two countries. What was an enrichment to the English economy had to be an impoverishment of the French economy, and so the transfer of Huguenot skills played a crucial role in determining the *locus* of the Industrial Revolution. Thus England had good cause to be grateful to the Huguenots. The fact that many of them found it difficult to become assimilated into English life, and preserved their French language and culture in tightly self-conscious clannish groups within the towns where they settled, and continued to think of France as their homeland even after the first generation of immigrants had died out, does not qualify the cause for gratitude to the "gentle and profitable strangers"[35] who tipped the balance of industrial prosperity in favour of England and against France.

The immigrant community in Bristol is well-documented in the Register of the French Church, which records the names of 324 families as arriving between 1687 and 1705.[36] They were mainly artisans, merchants and seamen, and obtained employment as "tailors, corsetiers, hatters and wig-makers, shoemakers, cabinet-makers, goldsmiths and engravers... smallholders, bakers, confectioners, butchers, coopers and distillers, iron-founders, brass-founders and glass-makers... hauliers of goods on land and transporters of merchandise by sea..."[37] Despite the resistance of Pastor Gautier and other members of his flock who remained French-speaking, the community gradually became assimilated into Bristol life, and David Peloquin became mayor in 1751, while other families such as the Casamajors and Laroches acquired large fortunes as Bristol merchants. The Huguenot community was thus a most benign influence on Bristol life, of which it became an influential and respected part.

This survey of the four main immigrant groups who brought their skills to England in the period 1500-1750 has inevitably been superficial, but it has nevertheless served to indicate some important processes of technological transmission, of both a particular and a general nature. The particular cases include the introduction of specific techniques, such as the new draperies, skills in mining and metal-working, hydraulic engineering, and glass-making. These innovations were introduced by the immigrants and subsequently acquired by English craftsmen, to the great enrichment of economic activity in the country. The general cases are represented by the marked stimulus to the English economy provided by the influx of capable and hard-working craftsmen and merchants, giving a new vitality to traditional processes and inspiring futher innovation. In these cases, it was the enterprise and diligence of the incomers which was significant, rather than any particular technique.

Although the groups which we have considered in this paper differed in size, composition and motivation, they all demonstrate the value to a recipient community of an influx of personnel with skills and aptitudes in which it is itself deficient. The fact that England was prepared to accommodate and assimilate these groups in the period under review shows a readiness to recognize its deficiencies and to seek ways of remedying them. This was particularly significant because virtually all the processes which were introduced by the incomers were crucial to the success of English industries - in textiles, in mining and metal-working, in hydraulic engineering, and in vital new industries such as glass-making, paper-making, and pottery manufacture. English workmen had thus a powerful incentive to pick up new skills from those foreigners who, for whatever reason, came to work amongst them. Probably more than any other factor, this comparative openness to new influences was responsible for England being able to take advantage of the possibilities of rapid industrialization after 1750. It meant that the successful inward transmission of technology through immigrant groups became a most effective prelude to industrialization.

NOTES

[1] It is worth observing that a stimulating debate continues amongst archaemetallurgists about the origin of such crucial processes as the reduction of metals from their ores: see Robert Maddin (ed.) *The Beginning of the Use of Metals and Alloys*, MIT Press, 1988.

[2] Warren C. Scoville: "Minority Migrations and the Diffusion of Technology" in *Journal of Economic History,* 11, 1951, 347-360.

[3] M. M. Postan: "Italy and the Economic Development of England in the Middle Ages" in *Journal of Economic History,* 11, 1951, 339-346. Postan's article immediately precedes that by Scoville, under the general heading of: "Spread of Techniques".

[4] Joan Thirsk: *Economic Policy and Projects: The Development of a Consumer Society in Early Modern England,* Oxford, 1978. See also D. Coleman: "An innovation and its diffusion; the 'new draperies'", *Economic History Review,* 2nd series, 22, 3, 1969.

[5] Samuel Smiles: *The Huguenots - Their settlements, churches, and industries, in England and Ireland,* London, 2nd.ed.1876, 103.

[6] Charles Wilson: *Holland and Britain,* London, 1945, 22. For Norwich and Colchester population statistics, see also Nigel Goose: "The 'Dutch' in Colchester: The Economic Influence of an Immigrant Community in the Sixteenth and Seventeenth Century" in *Immigrants and Minorities*, 1, 1982, 261-280.

[7] Smiles, *op.cit.,* 115.

[8] Ibid., 97. For the Wealden iron industry, see Brian G. Awtry: "The Continental Origins of Wealden Ironworkers, 1451-1544", *Economic History Review,* 2nd series, 34, 4, November 1981, 524-539.

[9] Eleanor S. Godfrey: *The Development of English Glassmaking,* Oxford, 1976, 16-17.

[10] G. H. Kenyon: *The Glass Industry of the Weald,* Leicester, 1967, 13-14.

[11] Godfrey, *op.cit.,* 28-29.

[12] Ibid., 24.

[13] Ibid., 251.

[14] W. Rees: *Industry before the Industrial Revolution,* Cardiff, 2 vols. 1968, vol. 1, 374. See also M. B. Donald: *Elizabethan Monopolies - The History of the Company of Mineral and Battery Works from 1565 to 1604,* Edinburgh and London, 1961. Hochstetter was the agent for David Haug, Hans Langnauer & Co. of Augsburg.

[15] Rees, *op.cit.,* 376.

[16] Rhys Jenkins: "The Society for the Mines Royal and German Colony in the Lake District" in *Transactions of the Newcomen Society,* 18, 1937-38, 225-234, especially 226.

[17] W. G. Collingwood: *Elizabethan Keswick,* Kendal, 1912.

[18] Rees, *op.cit.,* 139 and 249.

[19] Jenkins, *op.cit.,* 226-7; Collingwood, *op.cit.,* 168-9. See also Roy Millward and Adrian Robinson: *The Lake District,* London, 1970.

[20] Maurice Wynne, quoted Rees, *op.cit.,* 25.

[21] Rees, *op.cit.,* 138.

[22] Jenkins, *op.cit.,* 230-1.

[23] Donald, *op.cit.,* 2.

[24] Rees, *op.cit.,* 389.

[25] Joan Day: "The Continental Origins of Bristol Brass" in *Industrial Archaeology Review,* 7, 1, Autumn 1984, 32-56. See also J. W. Gough: *Mines of Mendip;* 2nd ed. 1967, who describes Schutz's search for calamine in the Mendips, 206-210.

[26] Rees, *op.cit.*, 379 and elsewhere.

[27] See my paper, as yet unpublished: "The Dutch Connection - Technological Influences on Britain in the 17th and 18th Centuries.

[28] For details of Vermuyden's career, see L. E. Harris: *Vermuyden and the Fens: A study of Sir Cornelius Vermuyden and the Great Level,* London, 1953; and Dorothy Summers: *The Great Level - A History of Drainage and Land Reclamation in the Fens,* Newton Abbot, 1976.

[29] See Harris, *op.cit.*, p. 49 and elsewhere. Although the Dutch established the modern techniques of land drainage in England, their work was not immediately pursued. The next period of substantial land drainage came with the development of civil engineering profession in Britain, in the second half of the eighteenth century: see R. A. Buchanan: *The Engineers - A History of the Engineering Profession in Britain, 1750-1914,* London, 1989.

[30] Warren C. Scoville: "The Huguenots and the Diffusion of Technology" in *Journal of Political Economy,* 60, 1952, 294-311 (Pt. 1) and 392-411 (Pt. 2), see particularly 297 and 298. See also Smiles, *op.cit.*, 242, whose estimates were some three times higher than those of Scoville.

[31] Scoville, "Huguenots", 307-8.

[32] Smiles, *op.cit.*, 277.

[33] Scoville, "Huguenots", 302.

[34] Ibid., 304.

[35] Smiles, *op.cit.*, 318.

[36] Ronald Mayo: *The Huguenots in Bristol,* Bristol, 1985. See the almost identical article by Mayo, "The Bristol Huguenots 1681-1791" in *Proc. Huguenot Soc.London,* 21, 1970, 437-454.

[37] Mayo, 1985, 20.

NANCY FJÄLLBRANT

The Development of the Textile Industry in Western Sweden: The Importance of British Capital, Technology, and Skills

1. Introduction

The development of the cotton textile industry in western Sweden during the period 1800 to 1870 shows a fascinating interplay between local factors and actors and imported foreign influences. During this time there was a gradual transition from hand-loom weaving in cottages, farms and small factories to power-weaving in larger industrial mills - from a home-industry to capitalist production. In this article an attempt will be made to trace some of the effects of British influence in this early industrial development. The Swedish west-coast region will be briefly presented. This will be followed by a description of factors which influence industrial development - both local and foreign. Examples of the support of British capital and the transfer of knowledge to the early west Swedish textile industry will then be given.

2. The development of western Sweden after 1600

Western Sweden consists of the coastal provinces of Bohuslän and Halland together with the adjacent interior province of Västergötland. Göteborg (Gothenburg), is a major port on the Göta river and Sweden's second largest city. Other ports on the west coast are Uddevalla and Marstrand in Bohuslän and Varberg and Halmstad in Halland (see Fig.1). The northern part of the Swedish west-coast region - the provinces of Bohuslän and Västergötland - is in many parts a rugged countryside with a hard granite core covered with meagre moranic soil. This can be contrasted with the southern part of the west coast region - the provinces of Halland and Skåne - which is much more fertile and where agriculture played a dominant role right up to the middle of the twentieth century.

2.1 The proto-industrial west Sweden

During the eighteenth and the greater part of the nineteenth century, people in Sweden lived in a predominantely agricultural society, and products were made by hand. The living conditions of the people were affected very little by technical inventions during this proto-industrial period. Agriculture was the dominant occupation for 80% of the population. (Lindqvist 1989).

Fig.1. Map of western Sweden

Most farms in Bohuslän and Västergötland were relatively small, and from an early period agriculture was supplemented by fishing or the production and sale of handicrafts. People were poor but self-sufficient. A diversity of products were made, such as woollen and linen textiles, metal-work, wooden products. The development of these handicrafts was based on locally available (or easily obtained) material, and played an important part in individual economies. A suitable motto for the region could well be: "Man tager vad man haver." (Kajsa Warg) [You make the best of what you've got.].

Swedish proto-industrial work and society has been described by Hecksher (1942) and Utterström (1957). The early development of the Swedish textile handicraft industries has been examined by Schön (1979), in a thesis "Från hantverk till fabriksindustri. Svensk textiltillverkning 1820-1870" (From handicraft to mechanized industry. Swedish textile manufacture 1820-1870). The proto-industrial society until the 1860s, in the district (härad) of Mark (about 50 kms south-east of Göteborg), has been described in considerable detail by Ahlberger (1988) in his thesis "Vävarfolket" (The Weaver People).

Water transport has played an important role in the historic development of the region. Communication with the west - Denmark, Germany, the Netherlands and Britain - was well established during the late Middle Ages. Transport within the region was by coastal shipping or up the rivers, such as the Göta river, Viskan, Ätran and Nissan. These and the large lakes such as Lygnern provided means of transport into the interior, particularly in the winter when frozen. Forests and rocky hills formed a barrier between the eastern provinces of Götaland and the western Svealand.

Bohuslän was part of Norway and Halland part of Denmark until the Peace of Roskilde in 1656. The port of Göteborg formed the only *Swedish* outlet to the west and to the North Sea during the period 1621-1656. Western Sweden right up to the eighteenth century was largely a rural country. The town of Borås was founded in 1618, Göteborg in 1621. The towns and cities were small as can be seen from Table 1.

Table 1. The populations of a number of Western Swedish towns during the period 1800 - 1860

	1800	1810	1820	1830	1840	1850	1860
Alingsås	851	862	950	1210	1267	1388	1616
Borås	1774	1750	2053	2194	2378	2733	2988
Falkenberg	668	636	663	792	862	953	1131
Göteborg	12804	14346	16519	21036	21558	26084	37043
Halmstad	1317	1134	1611	1887	2257	2761	3945
Kungsbacka	342	347	439	456	473	577	539
Kungälv	774	864	756	820	749	867	947
Marstrand	1327	1259	1087	987	943	1014	1078
Uddevalla	4081	3100	3655	3624	3576	3832	4629
Ulricehamn	633	750	1240	1253	1328	1455	1424
Varberg	1402	1331	1494	1787	1660	2123	2503

Source: Historisk statistik för Sverige. Historical statistics of Sweden. Table 12. Population in cities and boroughs.

3. Factors affecting industrial development of the cotton textile industry in western Sweden.

3.1 General factors

The development of any industry is based on a closely interwoven combination of factors/and actors. Knowledge, capital, raw materials, workers, distributors and markets all form part of a delicate interactive network and provide a framework for industrial development. Fig. 2 shows a general model of factors affecting industrial development. The development of the cotton textile industry in western Sweden shows an intricate interplay between local and international factors and actors. In Section 3.2 the influence of specific western Swedish local factors will be presented and in Section 3.3 international influences affecting the development of the west Swedish textile industry will be introduced.

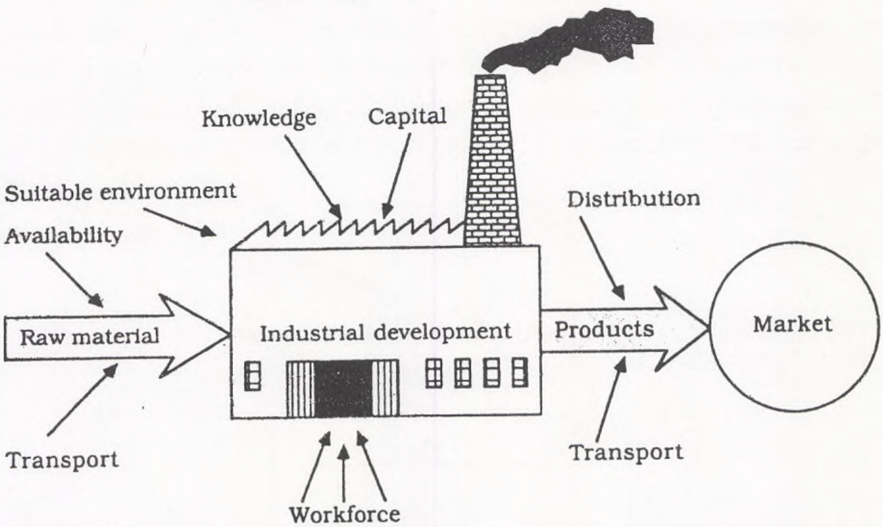

Fig.2. Ceneral factors affecting industrial development.

3.2 Local factors

How were the independent, self-sufficient people of western Sweden able to move from their proto-industrial society to full industrialisation? Textile handicrafts played an important role in the household economies with spinning and weaving of flax and wool. This gave many people in both farms and cottages *knowledge* and *skills,* built up over many centuries, of material and design. *Raw material* - flax and wool - was produced locally or obtained from near at hand. *Capital* was supplied by a number of richer farmers (förläggare = putter outers), who bought the woven products and organized the finishing and dyeing of these and their subsequent *distribution* and sale by the wandering pedlars who ranged far and wide throughout Sweden and even to Finland, Norway, and Denmark. The spinning and weaving were done by hand, that is driven by human *muscle-power*. When cheap cotton yarn became available as a result of the development of the cotton textile industry in Lancashire, the putter-outers provided the capital for buying the imported yarn. Spinners trudged to fetch their raw-materials and delivered the woven pieces for payment (the price of the raw yarn being deducted). There was a well-established textile industry in western Sweden, at the beginning of the nineteenth century, based on the use of local materials. For a description of this proto-industrial society see Ahlberger (1988). Another local factor which was important for the development of the textile industry was the *damp climate* of western Sweden and the relatively *soft water*. Both of these are advantageous for the spinning and weaving of cotton. The factors/actors which influenced the development of the cotton textile industry are shown in Fig. 3.

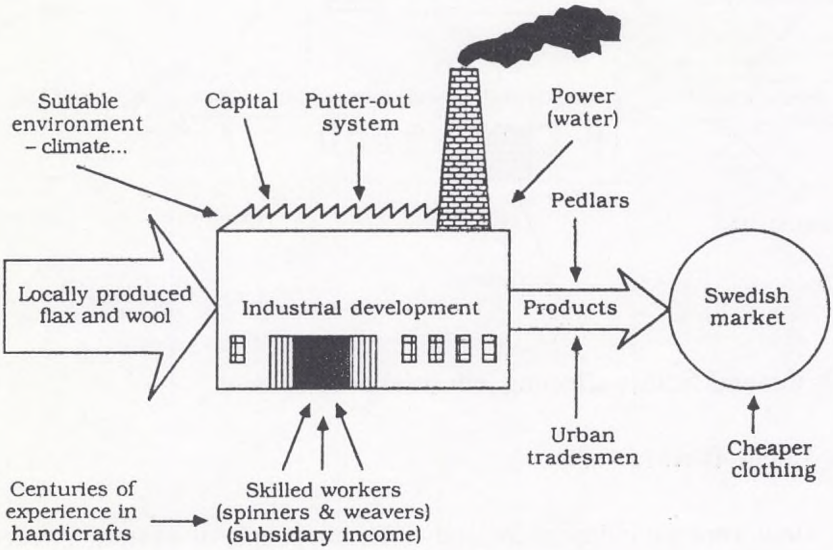

Fig.3. Local factors/actors affecting the development of the cotton textile industry in western Sweden.

3.3 International factors/actors affecting the development of the cotton textile industry in western Sweden

The latter part of the eighteenth century had seen the dramatic growth and development of the first industrialised city in the world - Manchester - and the industrialised cotton textile industry in Lancashire. This resulted in the production of large quantities of cheap cotton yarn. The new material available from England was very attractive. Swedish import regulations forbade the import of cheap woven cotton cloth, in order to protect the home-industries, but the import of cotton yarn was permitted. This yarn was imported via Göteborg, and financed by capitalists and the local putter-outers, and a start was made in the industrialisation of the textile industry in western Sweden. Not only the *raw materials* were imported from abroad, but *knowledge and skills,* in the form of textile machinery and skilled textile workers, also came from outside Sweden. These external factors and actors will be examined in greater detail in Section 5. A diagrammatic overview is given in Fig. 4.

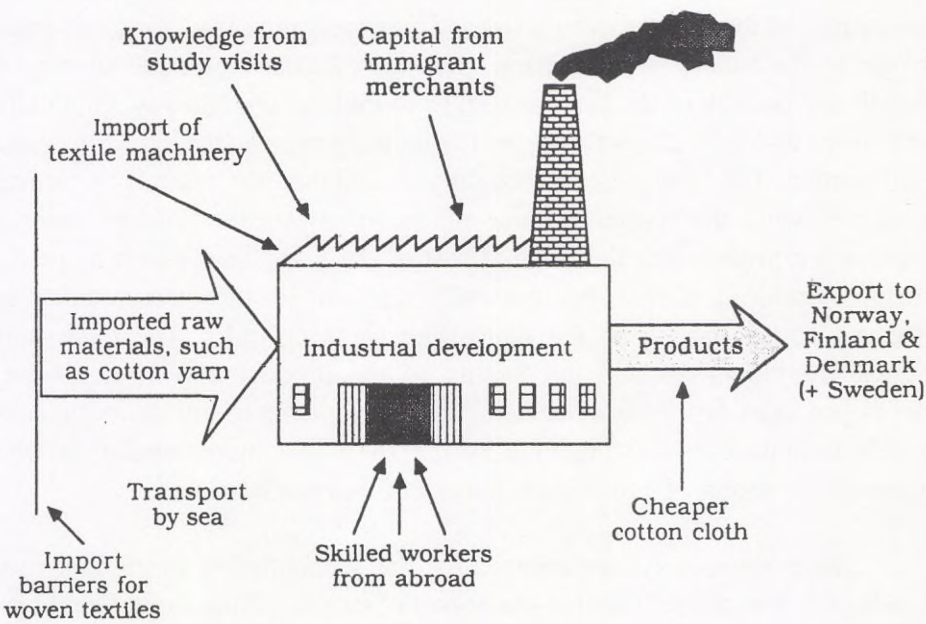

Fig.4. International factors/actors affecting the development of the cotton textile industry in western Sweden.

4. The importance of local capital, organization, skills and distribution channels

4.1 The organization of the handicraft textile industry and the finding of Swedish capital for the new industrial mills.

During the proto-industrial period from 1750 to about 1830, the textile manufacture was largely a domestic industry or cottage craft. Spinning and weaving had from time immemorial been carried out in the homes. The organization of this domestic textile industry in the district of Mark in Västergötland has been described in considerable detail by Ahlberger (1988), pp. 13-58, see also Utterström (1957). Towards the end of the eighteenth century a number of local small-scale financiers began to appear. These were to be found among the more well-to-do farming class. They bought up a larger part of the home woven textiles. These were then sold, or given against credit, to the locally based pedlars, who then sold these products through the length and breadth of the land, as well as to Finland and Norway. Gradually a new form of organization for the textile industry was developed - the "putter-out" system. The "putter-outer" bought yarn and this was fetched by weavers, who then wove the textiles at home and returned with the finished materials, receiving a price minus the original cost of the yarn. The latter was perhaps locally produced at first, but gradually replaced by the better quality and cheaper cotton yarn from the Lancashire spinning mills. The putter-outer controlled the prices and the quality of the product and used his well-developed sales distribution network. The development of this domestic cotton textile organization was favoured by the 1816 customs deregulation which allowed the import of cotton yarn, but not of woven material.

The putter-out system allowed for the accumulation of capital, in the hands of a few richer "farming-putter-outer" families. This capital could then be used for the establishment of the early mechanized textile mills. A particularly good example is to be seen in the case of Sven Erikson who founded the Rydboholm weaving mill in 1834. The initial investment was not very high for the first mills, but Rydboholm was financed during its first years by the extremely profitable domestic textile distribution system. In other cases, Swedish landowners, such as the Berg family of Nääs - Peter Wilhelm Berg and his son Johan Theodor - found the necessary capital to start industrial textile manufacture. An important consideration would be the availability of water-power for driving the machinery. This was one of the most important factors in establishing the Nääs mills.

4.2 Spinning and weaving skills - a local tradition

There was little tradition of textile manufacture in Sweden. There was, however, the example of Jonas Alströmer, who, in 1723, managed to smuggle in three knitting machines from Holland and establish a textile manufacturing works at Alingsås, during the 1730s. Alströmer employed an Englishman - Stephen Bennet - from Leicestershire as foreman and manager of the Alingsås Manufakturverk. The business ran into financial difficulties during the second half of the eighteenth century and in 1818 was finally closed (Strâle 1884, Hult 1987).

There was a long tradition of domestic production of textiles, but very little mechanization in Sweden at the beginning of the nineteenth century. Weaving of all but coarse textiles required good lighting conditions. A certain amount of collaboration had developed in that a number of weavers (usually men) worked together in small "factories." Weaving was carried out here on hand-looms. It has generally been supposed that the skill of the home-weavers was one of the factors influencing the founding of a weaving-mill at Rydboholm (see Heckscher). This can be questioned, as Schön points out, since the number of people employed in factories at the beginning of the 1830s was very small. In contrast to the early spinning-mills which required relatively unskilled workers (children were often employed), the weaving mills needed experienced adult workers. Women were commonly employed as weavers. Schön suggests that many of the weavers at Rydboholm came from Göteborg, where three "handicraft factories" had recently been closed down. This is similar to the situation at Nääs, during its expansion in the mid 1840s. When the Kullen mills burnt down in 1846, many of the workers took employment at the nearby Nääs.

This Swedish lack of experience in working in mechanized textile factories was later commented on unfavourably by the English foreman at the Rydal spinning mill, to an American visitor (Brace 1857):

The women, sir, that's where we have difficulties. They arn't used to such uninterrupted work. At home they have always been used to talk and gossip with each other during their work, I have great difficulty in teaching them to be observant and careful. And they are so unreliable. Why can't two Swedish women meet without breaking into a little dance together?... But they will learn eventually. This is a young nation, very young... This will take a long time...

Many of the independent cotton weavers in Sjuhäraden did not adapt easily to the hard discipline of a factory life with the long hours of work and rules and regulations. The working day at Rydal in 1855 was twelve and a half hours netto stretching from 5.30 a.m. to 7 p.m. - 75 hours per week - (Winberg 1989). There were fines for coming late, and physical punishment was not uncommon. People stayed away from work if they felt like it, preferring the freedom of their cottage industry.

4.3 Local trade distribution channels

After incorporation of Halland and Bohuslän with Sweden in 1658, an attempt was made to regulate trade through the towns. This favoured the levying of taxes on imports/exports etc. Certain towns such as Göteborg had trading privileges, whereas these were not granted to other towns such as Uddevalla, Marstrand or Kungsbacka. This conflicted with the strong local traditions of peasant-farmer distributors. West coast farmers sailed and traded from Kungsbacka and Onsala in Halland as well as from the coast of Bohuslän. The pedlars of the interior drove their oxen from the Sjuhärad region of Västergötland up to the mines of Bergslagen. Oxen provided leather for the driving thongs of the mine pumps, as well as meat. The pedlars took with them and sold the local handicraft products, thereby providing an excellent distribution and marketing channel. Indeed the region of Västergötland known as the "Seven Districts"-Sjuhäradsbygden - Gäsene. Äs, Veden, Bollebygd, Mark, Kind and Redväg districts - were granted trading privileges in 1712. This was very unusual for an area without a township. In the eighteenth and early nineteenth centuries, there were constant struggles for trading rights between the pedlars of Sjuhärad and the burghers of Borås and Ulricehamn.

5. International influences in the development of the west Swedish cotton textile industry

5.1 The development of the textile industry in western Sweden

Many of the earliest cotton textile mills were situated in western Sweden, in an area relatively near to Göteborg. This was perhaps to a large part due to the ease of importing by sea the raw-material in the form of raw cotton and cotton yarn. The latter was being produced in Lancashire, in the early nineteenth century, in large quantities - due to the mechanization and industrialization of cotton spinning. These raw-materials were principally imported through Göteborg where there was a considerable number of British merchants (Sahlin 1964, Townshend & Adams 1946). Until 1842 there was an embargo on the import of the cheap cotton woven material, produced in England, in order to protect the Swedish home-industry, but it was possible to import cotton yarn

5.2 Early industrial development of the west Swedish cotton textil industry

Examples of early west Swedish textile factories are Gamlebokullen (often called Kullen) Sweden´s first cotton mill founded in 1795 at Lerum in the county of Älvsborg; the Sjuntorp spinning mill at Sjuntorp, near Trollhättan in the county of Älvsborg, in 1813; the Mariedal spinnery founded in 1826 and the Rosendal spinnery founded in 1831 both in Mölndal in the county of Göteborg and Bohus; the Anderstorp spinnery founded in 1829 in Lindome in the county of Halland; the Nääs factories, founded in 1833 in Skallsjö parish in the county of Älvsborg; the Rydboholm mill for the weaving of fine cotton fabric, founded in 1834, at Viskafors in the county of Älvsborg; the Jonsered mills for the weaving of cotton, flax. hemp and jute, founded in 1835 in the county of Göteborg and Bohus; and the Almedahl mills for linen spinning and cotton and linen weaving, founded in 1840, in Almedahl, near Göteborg. These were followed by the Mölnlycke weaving mills, founded 1852, in the parish of Råda, in the county of Göteborg and Bohus; the Gamlestaden spinning and weaving mills and dye works, in Göteborg, in 1853; the spinning mills at Rydahl, founded in 1853, at Kinna in the county of Älvsborg; the Ahlafors spinning mills founded in 1854 in Nol in the county of Älvsborg; the Carlsberg spinning mills, founded in 1855, at Carlsberg in the county of Göteborg and Bohus; Kampenhofs cotton spinning and weaving mills and dye-works, founded in 1856, in Uddevalla in the county of Göteborg and Bohus; the Wiskaholm mills founded in 1857 by a group of Englishmen - Edward Davies, Charles Hill, and William Robertson - in Borås, in the county of Älvsborg; L.J.Winquist, Fritsla Mechanical Weaving Mill (Mekaniska Väfveri) founded in 1860, at Fritsla in the county of Älvsborg and the Alingsås Cotton Weaving Mills (Alingsås Bomullsväfveri) founded in 1862, by Charles Hill, in the town of Alingsås, in the county of Älvsborg. Many of these mechanized textile mills were established with the direct or indirect help of British actors, either in the form of capital, or through the import of technical knowledge in the form of textile machinery or through the help of skilled textile workers.

The relative amounts of cotton yarn produced in the home-industries and the mechanized factories, as well as the amount of yarn imported is shown in Fig.5 (taken from Schön, p.101). This diagram shows that until about 1835 the home industries could compete with factories in spinning cotton. At about the same time the locally produced yarn equalled the amount imported, though qualities may well have differed. The Swedish spinneries produced a thicker yarn, by means of trostle spinning machines - a version of Arkwright´s machine- whilst the finer yarns were imported. There was a sharp drop in both imported and Swedish produced cotton yarn in the 1860s - corresponding to the difficulties in obtaining raw cotton during the period of the American civil war.

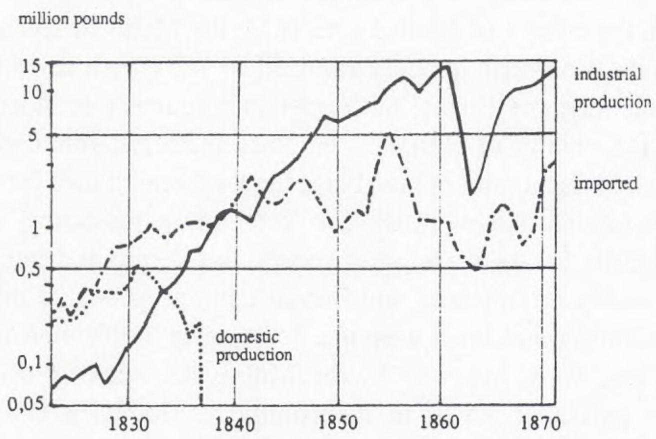

Fig.5. The production of cotton yarn from Swedish home-industries and factories and the amount of cotton yarn imported during the period 1823-1871 (after Schön).

5.3 British capital for development

Many of the early mills were strongly influenced by a number of British actors - either in the provision of *capital,* or *management,* or through the immigration of *skilled workers.* For example the initiative to build the first Swedish cotton spinning mill was taken by William Chalmers and Henry Greig. They obtained a licence to erect a cotton spinnery and weaving-mill in 1795. William Chalmers was born in Göteborg in 1748. His father, who had the same name, was a Scottish businessman. William Chalmers, the son, was for many years a representative of the Swedish East India Company, living in Canton from 1783-93, after which he returned to Göteborg, becoming director of the East India Company. He amassed a considerable fortune and pioneered many industrial and social developments. A description of the life of William Chalmers can be found in Bodman (1929), see also Dubb (1829) and Cormack (1958). After six months Chalmers assigned his licence for the spinnery to Fredrik Hummel, who employed C.Hindrick Strimberg to build the Gamlebokullen mill at Lerum, in the county of Älvsborg in 1795. Strimberg had previously worked at a mechanized "Manchester-type" cotton-spinnery in Copenhagen. The Kullen mills ran into financial difficulties and were taken over by creditors in 1818. The principal creditor was Alexander Barclay, a British merchant from Göteborg. Kullen was destroyed by fire in 1846 and not rebuilt. Barclay started another textile mill in Göteborg in 1847. Hindrick Strimberg moved from Kullen to be manager of the new spinnery at Sjuntorp, in 1813. He played an extremely important role in the design and construction of practically all of the machines used at Sjuntorp. The actual construction was carried out by workpeople at Sjuntorp - carpenters and smiths (Hollman 1948).

Lancefield and May were granted a charter in 1829 for the Anderstorp cotton spinnery at Lindome in the county of Halland. Another example of the provision of capital for the new west Swedish textile industry was the founding of the Jonsered industrial complex, which included both textile mills for the weaving of cotton, flax, hemp and jute, and wood-making machinery, by William Gibson and Alexander Keiller, in 1835. The site of Jonsered, a few miles inland from Göteborg, was chosen because it was possible to obtain water power from the river Säve. William Gibson was born at Arbroath in Scotland, in 1783. He was sent to Göteborg at the age of fourteen, where he worked as an ironmonger's assistant. He started a brewery in 1805 and became a burgher of the city at the age of twenty three, later becoming a prominent Göteborg industrialist. Alexander Keiller, who was born in Dundee in1805, came to Göteborg in 1825, where he established a hemp and flax spinning mill in the Majorna district. William Gibson and Alexander Keiller established a mechanical spinning mill in Göteborg near Drottningtorget in 1828. The site was very cramped for space and the mill was transferred to Jonsered in1835. The partnership between Keiller and Gibson was dissolved some years later and Keiller founded Keiller´s Engineering Works (later Götaverken). Gibson had a strong interest in social welfare. He built a church and an almshouse and established an institution for poor children.

A later example is that of R.W. Bley who was granted a charter in 1856 for the Kampenhof textile works in Uddevalla, in the county of Bohus. These included a cotton spinnery, weaving mill, bleaching and dye works. In 1857, Edward Davies established the Wiskaholm weaving mills at Borås in - this was the forerunner of Borås Wäfveri (the Borås Weaving Mills).

6. Information and technology transfer from abroad

6.1 The import of textile machinery

One of the greatest problems to be faced in the establishment of the early textile mills was how to obtain textile machinery. England jealously guarded, as far as possible, its technical advantage in the industrialisation of the cotton textile industry. The export of textile plant was prohibited until 1842. Those wishing to set up textile factories in Sweden had to either smuggle in British machinery or to buy what they needed from the continent. In connection with the latter an Englishman, William Cockerill, played an important role. He was born in England in 1759, emigrated to Belgium as a mechanic and constructed, at Verviers, in 1799, the first wool-carding and wool-spinning machines on the European continent. In 1807 he founded a machine workshop at Liege. This became a focal point for orders for textile machinery from all over Europe. Cockerill had another textile machinery establishment at Seraing - the Société Cockerill de Seraing. It can be noted that the export of tools and material used to make textile machinery was not forbidden. In Sweden, the Malcolm brothers: Andrew, Alexander, John and James, started a textile machinery workshop in Norrköping, in 1836 (Malcolm, 1869).

A vivid account of how textile machinery was obtained is given in the diaries of Johan Theodor Berg, son of Peter Wilhelm Berg, founder of the

Nääs textile mills. Johan Theodor Berg, had a military background as a cavalry officer, when he was asked by his father to assist in the planning of the new factories. He studied in detail a number of local factories such as Gamlebokullen i Lerum, but was not allowed in the linen-spinning mills of Gibson and Keiller. In 1833 Johan Theodor Berg set off on his first "foreign study journey" He travelled via Aachen to Liege, where he met among others, John Cockerill and saw the packing cases marked P.W.B. containing the machines for Nääs. The quotation for these machines is still in existence. He also visited a Mr Alexander´s cotton spinning and weaving mill whilst in Liege. Then he travelled via Rouen, Dièppe and Brighton to London, where they had ordered two trostles, a spinning mule, a roaving frame, a doubling frame and carding machines.This secret transaction was arranged by Isaac Vallentin of Göteborg and a German merchant in London, one I.L. Steinhaeuser. The goods were shipped via Hamburg to Göteborg. Johan Theodor Berg stayed for three weeks in London, where he met the Swedish inventor John Ericsson, before leaving for Manchester in December 1833. Accompanied by Steinhaeuser, he visited Crighton and Widdop Carding and Finishing Machine Makers, Gores who had made the spinning machines for Nääs, and Bowler Machine Makers (specialists in the production pf spindles and flyers). Steinhaeuser then introduced Berg at Walker and Smith´s Foundry and Machine Workshop, at Bury, where fly frames and drawing engines were produced. Berg was also taken to Sharp and Roberts.

After these initial visits, Steinhaeuser returned to London, leaving Johan Theodor to continue his studies in Manchester. Mr Henry Gore took good care of the young Swede, not only did Johan Theodor visit the Gore Workshop daily, but he was also invited home to the Gores. The trostle machines for spinning warp yarn had some 320 spindles, through a patented tube construction 1831. One young spinner could handle at least 288 spindles - a remarkable increase in capacity as compared to hand spinning. Berg studied the ingenious "tube-frames," patented by Joseph Cheeseborough Dyer, at Crighton and Widdops, as well as carding and spinning machines. He was particularly impressed by Sharp and Robert's "superb workshops" where he saw the latest looms and the self-acting mule, where not only the stretching was mechanized, but also the return and self-winding of the yarn, so that the mule operator had simply to watch over the working of the machine. There was even a bell which warned that the bobbins were full. Johan Theodor did not, however, buy this new machine, as he feared that he would have to employ expensive specially skilled workers to maintain it. Gore gave him letters of recommendation to a number of machine makers and introductions to workshops, spinning and weaving mills, bleaching and dye works. He visited not only Manchester, but also Rochdale, Leeds, Halifax aand Bolton, pursuing his practical and theoretical studies. He even travelled on the first railway in the world - the Liverpool and Manchester Railway - which was opened in 1833. He then returned via London and Harwich on the sailing ship Liberty, which arrived in Sweden on February 7th 1834. Well at Känsö, the quarentine station in the Göteborg archipelago, Johan Theodor had to remain there for some time, due to a cholera epidemic. Then at last he was able to put the knowledge and skills acquired during his foreign tour into practice - in the building and development of the Nääs textile concern.

Johan Theodor Berg kept in contact with the English manufacturers that he met during his first foreign study tour. He visited England again, in connection with the expansion of the Nääs mills, in 1846. He sailed directly from Göteborg to Hull, and then travelled to Leeds and Manchester, where he visited his old friends the Gores, and ordered three throstle machines. Later he travelled to Liverpool and Glasgow, before returning to Manchester where he placed an order for 2,352 spindles with Higgins and Sons of Salford, three carding machines from Crightons and two selfacting mules from Parr Curtis & Madeley. In 1854, Johan Theodor Berg paid yet another visit to England, this time accompanied by his family.

The first Swedish mill for the weaving of fine cotton fabric was founded at Rydboholm in 1834, at Viskafors in the county of Älvsborg, by Sven Erikson and his partners Johan Christian Bäfvermann and Johan Francke. How were the machines obtained for Rydboholm? The machines required to operate the factory, together with twenty-five mechanized looms were ordered from an Englishman J. Barker who lived in Stockholm. Possibly Barker, in his turn, ordered the machinery - a winding machine, a warp machine and a dressing machine - from Åkers gun-factory and the looms from Munktells in Eskilstuna. Francke had been active in corresponding with a Mr Alan Wilson of Stockport in Lancashire. Francke travelled to England and with Mr Wilson´s help ordered machinery from John Butler of Bolton. The machines were shipped via Hamburg to Göteborg and thence to Rydboholm.

The Malcom works at Norrköping were not large and the machines produced could neither compete in quality or price with similar machines produced in England. Demand was limited and the works were closed down in 1855.

6.2 Skilled workers from abroad

It was necessary to have skilled workers in order to run the machinery in these new factories. Many of the "masters" or "overseeers" were recruited from Lancashire. In this section a number of cases of Englishmen who came to the developing west Swedish textile industry will be presented.

One particularly well documented recruitment of skilled English textile workers is that connected with the establishment of the Rydboholm fine-art weaving mill in 1834. Thanks to Francke´s correspondence with a Mr Adam Wilson of Stockport, James Harth, born in 1798 was engaged as master weaver, Thomas Curran, born 1804, as warp master, Joseph Wilding, born 1806 as weaver and Richard Wood, born in 1792 as master dyer. These four Englishmen set sail in May 1835 for Sweden. They first travelled to Hull, where they embarked on the schooner *Peter & Jan*, and arrived in Göteborg on the 25th May (Mannerfelt & Danielson 1924). On the 28th of May they travelled, together with a foreman named Hans, on the rough roads passing through the dark forests to Rydboholm, in Mark.They had been promised that their wives and children would follow as soon as possible. Three wives and eleven children followed the same route at the end of July and Mrs Wood with three children came later in the year. There were many difficulties to be faced during the first period, but at the beginning of 1836 the factory was in operation with some twenty looms. In December 1836 the resident registered personell with the Rydbohom factory were:
1 master weaver and mechanic -James Harth
3 dressers and 1 assistant (Thomas Curran)
2 overseers or weaving overseers (William Lee and Joseph Wilding)
1 bookkeeper - N.A.Lange
2 master dyers (Richard Wood and J.E.Hagberg)
9 workers - 1 stoker, 1 smith, 2 lathe operators, 1 carpenter, 1 labourer
17 children for winding
3 warpers
4 grown children for heddling and fastening
72 weavers (16 residents at Ryboholm)
1 maker of weaver's reeds
2 passers up

1 housekeeper
2 maids

The master dyer Richard Wood, died in the December of 1837 and was replaced by a Swede - J.E. Hagberg. According to Mannerfelt, the Englishmen did not really feel at home in Rydboholm. An unmarried warp master - William Lee - and another bachelor Abraham Higson were reprimanded, and Lee had to be forcibly removed and sent home to England during the summer of 1838. Richard Wood´s widow and children returned to England in the same year. Mr. James Harth and Mr. Joseph Wilding returned, with their families, to England in 1840. Abraham Higson became overlooker. He had worked at Rydboholm for about three years but was only 26 years old. After two years he was fired, as he had failed to fulfill his contract to teach another replacement. Thomas Curran, employed as warp master in 1835, received a contract in 1840 to oversee and be responsible for all the machinery, including some 144 looms. For this he was paid a salary of 1,638 Swedish *daler* per year, plus free accomodation of two rooms and a kitchen.

Mannerfelt (1920) notes p.73 that it was not easy to attract workers, and that those employed in the factory were often absent without leave. Indeed, it would hardly seem tempting to leave the freedom of home spinning and weaving for the stringent conditions of factory life. During the winter it was difficult to keep the factory adequately warm and there was also the not inconsiderable risk of fire. Schön suggests that many of the weavers at Rydboholm came from Göteborg where three "handicraft factories" had recently been closed down.

In the early 1840s Rydboholm had many difficulties, partly due to the bankruptcy and death of Francke, whose share was bought up by Sven Erikson. There was a period of economic stagnation and there was growing Swedish competition as other weaving mills were started. Rydboholm received many complaints about the quality of work delivered and Sven Erikson decided to look for a competent manager. Through the offices of the merchants J.G.Grönwall & Co. he was put in contact with Charles Hill, who had been born in Bolton, in Lancashire, in 1816. Hill´s father, who was well-to-do, died young, and a trustee squandered his fortune, leaving Charles penniless. He was apprenticed at a cotton weaving mill and acquired both knowledge of weaving and machinery (Berg 1965). Hill had married Margeret Howarth and had two children - a son Edmund Howarth and a daughter Betsy.

He signed an agreement with Sven Erikson about his employment at Rydboholm and travelled from Hull to Göteborg, arriving 16th June 1843. Charles Hill worked at Rydboholm for some ten years, after which he moved to Norrköping, in eastern Sweden, where he became one of the founders of Norrköpings Bommullsväfveri - "Tuppen" (the Norrköping Cotton Weaving Mills). He also became one of the partners in the Wiskaholm Mill at Borås in 1857 (see below). In 1860, Hill purchased land in Alingsås and founded in 1962, Alingsås Bomullsväveri, located on the very site of Jonas Alströmer's first Swedish textile factories (Stråhle 1884 and Hult 1987. Hill successfully managed the mills and was succeeded by his son Edmund (the history and development of the Alingsås Cotton Weaving Company is given by Berg, 1965).

Two other young Englishmen who worked at Rydboholm were Edward Davies (sometimes spelled Dawies) and James Boyd, who came to Sweden in 1952. James Boyd,who was born in England in 1826, replaced Charles Hill as weaving master. Davies and Boyd and their families are described by Mannerfelt of being of "superior social standing" to the first English employees. Davies became the first master of the Rydal spinning mills. In 1857 he bought land in Borås and together with Charles Hill of Norrköping and William Robertson of Göteborg founded the Wiskaholm mill.On the first of October 1859 this was converted into a limited company, in which Davies, Hill and both William and his brother John Robertson had shares. Textile production had started in 1858, but the new factory had to face considerable difficulties, not least of which was the shortage of cotton as a result of the American civil war. Davies left hastily for England in 1863, leaving his company to its fate, and bankruptcy was declared in 1864.

James Boyd left Rydboholm in 1853 and set up as a calico printer with J.P. Broberg in Borås. Boyd moved to Borås in 1857, where he was accepted as a burgher. He returned, however, to Manchester in 1858.

6.3 Study tours by Swedish industrialists

One of the ways to acquire information and knowledge about the textile industry - its machines and methods - was to travel abroad and study the newest developments. Sometimes these were not shown to foreign entrepeneurs, but a suprising amount of information could be obtained in this way. The various study tours of Johan Theodor Berg, the owner of the Nääs textile mills have been described in some detail (see Section 6.1 above and Nääs Fabrikers Minnesskrift, 1933).

The master of Rydboholm Sven Erikson also went on a foreign tour in 1844.Sven Erikson was now 43 years old, and on this his first foreign journey, he had as cicerone William Gibson, son of William Gibson founder of the Jonsered industrial complex. William Gibson the second was at that time 28 years old. They left Sweden on the 28th April, travelling probably via Copenhagen, Kiel, Hamburg and Antwerp to England. Unfortunately Erikson did not keep a detailed diary of the journey. Results can, however, be seen in the machinery that was purchased - 12 broad power looms from Liège, an order for a "modellstol" from Wolff, Hasche & Co. of the Sharp, Roberts & Co. system (this order was, however, not fulfilled). Sven Erikson studied the production of the strong moleskin type of material, and probably realized the necessity of starting a dye-works at Rydboholm and became interested in the possible import of Scottish cattle. Many of his new ideas were put into practice in the following years.

7. Discussion

This short account is a case-study of information and technology transfer. It shows the close inter-relationship between local and external factors in the creation and implementation of industrial development. Illustrations of this technology transfer are well illustrated in the case of the Nääs Textile Works. When it had been decided to start cotton textile mills, the eldest son Johan Theodor Berg set off on a long study tour to learn as much as possible about the busines and to order some of the necessary machinery. The results of this work were in the most part transferable, but not so in all cases - the organization of the heating of the factory was underdimensioned for Swedish winter conditions.

The early textile mills were usually situated near to a source of water power. A certain amount of capital was required in order to get started. Many of the early mill owners were merchants who had acquired capital through trade. A number of these merchants had come from Britain and were, therefore, likely to be aware of the industrial developments in Lancashire. There were, however, Swedish early mill owners, such as Sven Erikson of Rydboholm. He had acquired capital through his extensive "putter out" operations in connection with the home-weaving of cotton textiles. For many years these operations subsidised the fine-art weaving mill that he started in 1834. Sven Erikson gradually built up experience of the textile weaving through the recruitment of skilled operatives and managers. He had access to an extremely efficient distribution network of pedlars and later began to deal directly with foreign exporters and importers.

Wiskaholm is an example of a mill which foundered. Here we have a group of relatively young Englishmen setting up in business. They certainly had knowledge of the textile manufacturing processes, but probably lacked capital and business skills to tide them over the difficult period at the beginning of the 1860s. Knowledge and skill without capital and business acumen did not succeed.

In the development of the cotton textile industry in western Sweden, there are many links to the west, to Britain. These built upon the tradition of water-borne travel and connections that had been built up through the previous centuries. Many British merchants were already well established in Göteborg and they played an important role in the technology transfer necessary for setting up a new industry. Less has been written of the equally important role played by skilled textile operatives, who left the mills of Lancashire for the wilds of Mark. One can only imagine how strange and fearsome the journey must have seemed - first the sailing voyage from Hull to Göteborg, then the jolting journey over the abyssmally poor roads through seemingly endless forests to "darkest Mark." Most of them returned home after a number of years. What a tale their children would have to tell about their stay in wildest Sweden.

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SVANTE LINDQVIST

Of Love and War and Money: The Historical Role of Communications Technology

Introduction

A well-known observation from the early days of the transistor was the following: "If the development of the car had parallelled that of electronics, it would today have been the size of a sugar cube and cost a dime".[1] Leaving aside the fact that this observation ought by now to have been amended to "... the size of a grain of sugar and cost a cent", I mention it only in order to say that this is just what this paper is not about. When tracing the development of communications technology it is all too easy to depict it in terms of heavier flow of information, shorter transmission times and ever increasing distances. From a technical point of view this development is of course indisputable, but what is questionable is whether we gain much insight into the *historical* significance of communications technology by studying the subject from a quantitative perspective. Technology in general in the Western world – at least since the Industrial Revolution – shows a pattern of more or less exponential growth in

[1] An earlier version of this paper was first presented at the seminar "Telecommunications and Society – A Mutual Exchange", arranged by the Royal Swedish Academy of Engineering Sciences, Stockholm, May 30, 1990. This version was presented at a seminar at the Program Technology and Social Change at the University of Linköping, January 18, 1991.

terms of performance and efficiency. Since a characteristic of exponential growth is that the growth keeps growing, every epoch has been able to proclaim with the same self-assurance (and the same veracity): "We live in the Century of Technology! An age when technological progress is faster than ever."

This is an idea that is given visible expression, and indeed reinforced, by many museums of technology. There are few museums of technology today which do not have a permanent exhibition on the theme of telecommunications. Normally these exhibitions, too, endorse the general conviction that our own time is unique, and the artifacts in their glass cases help to confirm the visitor in this opinion. The nostalgia of old telephones and the quaint charm of printing telegraphs of polished brass serve the purpose of exemplifying obsolete technology, and, by implication, define what is outside the glass cases as modernity. But of course these objects themselves were once the acme of modernity, and in their day they presented a stark contrast with old-time mail coaches and optical telegraph systems. And surely we all realize, somewhere deep in our hearts, that the old telephones and the ancient telegraphs will one day have to make way in the glass case for the computerized telecommunications systems of today, i.e. that what is seen today as the cutting edge of technology will one day appear just as antiquated to the museum visitors of the future, who will relate these objects to *their* technological world outside the glass case.

Accounts of quantitative development thus serve only to confirm us in the comfortable certainty that we live in a time of unique technological progress, a time of technological change of a kind never seen before. "We", in this case, means all of us living our earthly lives on the same little segment of the abscissa of time – whether that happens to be the 1790s, the 1890s, or the 1990s. My intention is not, therefore, to depict the history of communications technology in quantitative terms from the relatively arbitrary vantage point of the 1990s.

Having thus stressed the relativistic character of technological development, we will proceed to search for *qualitative* changes in the history of communications. In particular, we will ask how the introduction of telecommunication has changed the reciprocal relationship between communication and society during the last hundred years.

The Dichotomies of Communication Technology

There is a fundamental dichotomy of communication technology, well-known to its practitioners, but rarely stressed in historical studies. Communication is often regarded as an entity, a collective denominator of what are in fact two distinctly different activities. An analysis of the historical role of communications must begin by distinguishing between point-to-point communication and mass communication as two fundamentally different social activities, i.e.:

(1) Point-to-point communication
Communication between two social units, e.g. by letter or telephone;

(2) Mass communication
Communication from one social unit to a large number of social units, e.g. by printing press or radio.

This division, however self-evident, becomes useful if we specify the different characteristics of the message and its diffusion. The message transmitted in an act of point-to-point communication is unique, intended for a particular recipient whom the sender wishes it to reach. This often implies that the sender does not want the message to reach others, i.e. it is secret. Mass communication, on the other hand, is a matter of sending an identical message to as many recipients as possible within the target group. The requirements here are a uniform message and maximum possible diffusion, i.e. it is public. These dichotomies (*Fig. 1*) will provide the framework for our discussion. In this perspective, the history of communication may be seen as a story of the various attempts to devise technological means of achieving these differing social objectives. To assist us in focussing on the role of telecommunication, we will also make a simple chronological division into two periods: before and after the mid-nineteenth century, i.e. we will compare the technological solutions before and after the introduction of telecommunication.

	Point-to-point communication	Mass communication
Message	Unique	Uniform
Diffusion	Secret	Public

Fig. 1 The dichotomies of communications

Point-to-point communication

The title of this paper comes from a poem by the Swedish-American poet Carl Sandburg. "Under a Telephone Pole" was one of his collection of *Chicago Poems,* published in 1916. By that time, several decades had passed since the telephone had replaced the telegraph as the most important communication technology in the American cities. The local telephone networks of the various cities had been linked in a network of interurban telephone lines – stretching the length and width of the American continent. The theme of Sandburg's poem is telecommunications, seen from an important, yet often neglected, angle:

"I am a copper wire slung in the air,
Slim against the sun I make not even a clear line shadow.
Night and day I keep singing – humming and thrumming:
It is love and war and money; it is the fighting and the tears, the work and want,
Death and laughter of men and women passing through me, carrier of your speech,
In the rain and the wet dripping, in the dawn and the shine drying,
A copper wire."[2]

Sandburg's poem makes us focus on the qualitative aspects of "information" – a concept generally used in general and non-descriptive terms as if it were some kind of bulk cargo. The neglect of what might be called the emotional dimension of megabytes, the qualitative content of "information", may lead us to forget that the point-to-point messages are in effect ones of "love and war and money", i.e. messages which are in some sense secret. They are meant to reach a specific recipient – and this recipient alone. The technological solution to this social need before the age of telecommunication was the addressed and sealed envelope. This is also a highly symbolic technology, since the addressed and sealed envelope can be used as a metaphor for all technological solutions to the problems of providing point-to-point communication, e.g. messages sent by electronic mail today. The entire history of point-to-point communication technology actually boils down to nothing more than the story of the efforts to provide the envelope with an address to reach the right recipient and to seal it to prevent others from learning the contents, e.g. the scrambled messages on the hotline between Moscow and Washington. For discussion of love, war and money we all want the greatest possible secrecy.

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[2] Carl Sandburg, *The Complete Poems of Carl Sandburg* (New York, 1970), pp. 70-71.

In Alexandre Dumas' novel *The Count of Monte Cristo*, published in 1845, (the very year in which the first French electric telegraph was installed), the question of the secrecy of point-to-point communication plays a major role in the plot. The hero, Edmond Dantés, is able to ruin one of his enemies by bribing a postal official on an optical telegraph line to Paris. By sending false information about the stock market, Dantés leads his enemy to speculate until he is ruined and driven to suicide. The problem of secrecy remained with the introduction of the electric telegraph. During the late nineteenth century, many comprehensive systems of trade codes, consisting of combinations of letters to denote standard phrases in commercial correspondence, were published, e.g. *Ager's Standard Telegram Code* of 100,000 words. One reason for doing this was the wish to reduce the number of signs used in telegraph communications and thereby to lower the cost, but many companies also used their own secret code books. One way of writing the history of point-to-point communication would be to write it, as it were, as the reverse image of the conventional history, i.e. as the history of code-breaking.[3] The efforts to protect the messages (whether seals, trade codes, military ciphers or measures to combat the problem of telephone bugging or the unauthorized hacking into the electronic mail), like the attempts to gain illicit access to these messages, are, I would like to argue, an integral part of the history of communications. A case in point is the work of Claude E. Shannon. In 1948 he published his classic paper, "A Mathematical Theory of Communication", which laid the foundation of modern information science. Less known, but equally important in the field of cryptanalysis, is his other paper, "Communication Theory of Secrecy Systems", published the following year in the same journal,

[3] There is a large literature on the history of codebreaking, for a general overview, see: David Kahn, *The Codebreakers: The Story of Secret Writing* (London, 1966).

Bell System Technical Journal. Shannon has described his work at Bell Labs during the war, which eventually led to the publication of his two papers when the war was over:

> "I'd worked on communication systems and I was appointed to some of the committees studying cryptanalytic techniques. The work on both the mathematical theory of communications and the cryptology went forward concurrently from about 1941. I worked on both of them together and I had some of the ideas while working on the other. I wouldn't say one came before the other – they were so close together you couldn't separate them."[4]

The history of point-to-point communication in general, I would suggest, is similarly related to the development of cryptanalysis. Figuratively speaking, the sealed envelope had no sooner been devised than methods of removing and invisibly replacing the seal had also been developed, methods which enabled the envelope to be steamed open and the letter to be read. Consider the fact that the U.S. code-breaking National Security Agency is reportedly larger than the CIA. Many major political crises, as in the case of the Watergate tapes, have occurred when what was supposed to be a secret point-to-point communication has been revealed, when the seal of the addressed envelope has been broken. The Zimmermann telegram, the breaking of the Enigma code and the capture of USN Pueblo are all important political events in twentieth-century history. The seal of the envelope may also be broken quite deliberately by the sender, as in the case of the students' revolt in China in May 1989, when the students were able to maintain contacts outside China by sending messages to random numbers on all the fax machines to which they could gain access – i.e. they used large-scale point-to-point communication to achieve mass communication.

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[4] Kahn 1966, p. 744.

Another way of describing the history of point-to-point communication would be to treat the subject as military history. This would underline the point that military development in general has always constituted the cutting edge of technology. Point-to-point communication could perhaps be seen simply as the civilian application of technology already developed and used by the military. The Chinese telephone network, for example, dates back to the beginning of the century. The Western troops marching to Beijing during the Boxer Rebellion in 1900 strung telephone wire behind them and that wire was left in place after the suppression of the rebellion, providing civilian use for the new technology in China.[5]

The question of secrecy and the importance of military development are thus two major aspects of the history of point-to-point communication that I would like to emphasize. The bandwidth of the telephone turned out to be wide enough to transmit not only the information content of human speech, the megabytes of vowels and consonants, but also the emotions expressed by the shifting frequencies of the human voice. Who has not argued violently on the telephone with members of his or her family? Or whispered into the mouthpiece words of endearment to a loved one? This has had one significant and unexpected consequence. Even if the metaphor of the addressed and sealed envelope may still be applied to modern telecommunications, the social impact of the telephone has resulted in one major qualitative change. Before the advent of the telephone, social networks – such as those that exist within a family of several generations – were generally limited to the distances of everyday mobility, since they were maintained by personal face-to-face contact. The telephone permitted

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[5] Ithiel de Sola Pool, *Forecasting the Telephone: A Retrospective Technology Assessment* (Norwood, 1983), p. 90.

the development of new social networks that were not limited by physical distance. It has created a new, invisible infrastructure of society, new social networks that are unknown and invisible subsets of the electronic networks. How did *you* last speak to your parents, children, or best friend – was it face to face or on the phone?

We cannot yet assess the consequences of this important but invisible structural change in society. However historians, used to written source material as they are, will soon discover to their dismay that it is no longer possible to trace the arguments and deliberations behind decisions. Social interaction is today to a large extent maintained by telecommunications, and especially, I would like to suggest, such interaction as is rich in human drama – conversations of love and war and money. This leaves no archival material for future historians, only a ripple in the electromagnetic field of the earth. We will have to learn that society is no longer what we see around us, but what we hear in our earphones or what we see on the screens of our networks. The modern image of total human isolation is the well-known close-up in the movies of the cutting of the telephone wires to a house.

Mass Communication

Mass communication – communication from one social unit to a large number of social units, often individuals – involves giving a uniform message the maximum possible diffusion among the group which one is seeking to reach. What, before the age of telecommunications, were the technological means of making the message uniform and making it public?

The problem was particularly acute in the new nation states that emerged in the Europe of the fifteenth and sixteenth century. The central government always had a vital need to be able to communicate. In order to keep the nation together as a political, economic, military and religious unit, it was essential to be able to reach as many of the population as possible, as quickly as possible, with identical messages – preferably without offering any opportunity for argument. These messages might be new laws, taxes, religious and political doctrines, military call-ups, etc. The development of mass communications is to a considerable extent the history of the struggle for closer control of growing areas of human activity and thought. The cause of this struggle is reflected in purely technical factor such as increasingly extensive communications systems, more rapid dissemination and, above all, greater centralization.

For a long time the Church served the interests of the state in this respect, as pastors read out proclamations from the pulpit. This was particularly important in the days when literacy was limited and when the clergy provided the link in communication between the literate bureaucracy and the general population. One particularly efficient instrument of the system was the law prescribing compulsory church attendance: an ordinance which guaranteed that the central authorities could reach virtually the whole population once a week.

Another technology for mass dissemination of uniform messages was the printing press, which emerged at about the same time as the nation states. Its appearance was, quite simply, a consequence of the diffusion of the art of paper-making to Europe from China. To copy a Bible on parchment had required the skins of some fifty sheep. This cost was now almost eliminated, and the cause of bottlenecks in the production line now became the cost and inefficiency of manual copying. After the invention of the printing press in response to this situation, the new technology of mass communication spread rapidly over Europe. During the late fifteenth century the number of printing offices grew swiftly in the major European cities. The printing press was not as efficient as the pulpit when it came to reaching the lower and broader strata of society, because of the low rate of literacy. But for the diffusion of large amounts of uniform information – i.e. a book – to a large number of literate people, the printing press was far superior to the spoken word.

There was, however, one aspect of the printing press which was crucial. Printing is a technology which is difficult to control. The press could be used to print political lampoons and even sedition just as easily as laws and ordinances, unorthodox tracts and even blasphemies as easily as Bibles and sermons. The printing press was in this sense a democratic invention and its history is to a large extent the story of attempts by the State and the Church to impose central control. In very much the same way as the history of point-to-point communication can be told negatively in terms of cryptanalysis, so can the history of mass communication be told in terms of attempts to stop others from putting uniform messages across to large numbers of people. The history of political and religious censorship, a major factor in intellectual culture since the emergence of the printing press, is thus also a part of the history of communication technology. Not only nationally but also internationally, for example the battle between Soviet jammers and "Voice of America".

In her study *The Printing Press as an Agent of Change*, published in 1979, the American historian Elizabeth Eisenstein shows how the invention and diffusion of the printing press shaped the Reformation in early sixteenth-century Europe.[6]

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[6] Elizabeth L. Eisenstein, *The Printing Press as an Agent of Change: Communications and Cultural Transformations in Early-Modern Europe*, 2 Vols. (Cambridge, 1979). Cf. idem, *The Printing Revolution in Early Modern Europe* (Cambridge, 1983).

Luther and other reformers used the new technology quite deliberately to spread their messages further afield, beyond the area they could cover by travelling around and preaching themselves. A page of print travelled more easily and in greater secrecy than a man. Between 1517 and 1520, Luther's pamphlets sold well over 300,000 copies, which is truly remarkable considering the total population in the German-speaking parts of Europe and the literacy at the time. The spread of religious pamphlets outside the control of the established church created a forum for discourse that was not bound by the walls of churches. Not that the printing press was the cause of the religious upheaval that divided the Church in the West, but it influenced the impact and spread of the process. Luther himself described printing as "God's highest and extremest act of grace".[7]

All that is really needed for mass communication is a combination of the two elements used by the church:

(1) Compulsory attendance, i.e. a method of guaranteeing the attention of the population;

(2) The pastor in the pulpit.

Compulsory church attendance made it possible to bring the target group, in other words the adult population, into the confined space of the church building, and to count on their silent attention for a couple of hours every Sunday. The State and the Church could then say what they wanted to the population from the pulpit. But how is it possible, figuratively speaking, to get the population into church and to ensure their attention in the age of electronics? Dictators such as Mussolini and Hitler used the new technology of radio in the 1930s just as deliberately as Luther had used the printing press. There was a connection

[7] Eisenstein 1979, Vol. 1, p. 304.

between the spread of fascism and the introduction of the radio in the 1930s analogous to the connection between the Reformation and the invention of the printing press. This development was foreseen by Lewis Mumford in 1932 in his classic *Technics and Civilization*:

> "Perhaps the greatest social effect of radio-communication, so far, has been a political one: the restoration of direct contact between the leader and the group. Plato defined the limits of the size of a city as the number of people who could hear the voice of a single orator: today those limits do not define a city but a civilization [---] there are now the elements of almost as close a political unity as that which once was possible in the tiniest cities of Africa. The possibilities for good and evil here are immense."[8]

And in our mind's eye we can all see Hitler in front of a huge microphone, and we can almost hear his voice. Hitler and the radio form such a powerful image in twentieth-century history that we tend to forget that a microphone alone is not enough if you want to reach a large audience, no matter how powerful the radio transmitter. It is equally vital for people to have means of receiving your message. The microphone and the radio transmitter may be the equivalent of the pastor in the pulpit, but they are not sufficient. It is also essential to bring the people within earshot in an enclosed space below the pulpit. The obvious strength of broadcasting is that it is not subject to the same spatial constraints as older methods of mass communication, but for a central authority – indeed for anyone who wishes to get his message over – this is also a problem.

Hitler solved the problem with the state-subsidized development of the *Volksempfänger*, a simple but reliable swastika-decorated wireless set that was mass-produced in the 1930s in such numbers that the price was within the means

[8] Lewis Mumford, *Technics and Civilization* (New York, 1962), p. 241.

of the working class as well, long before the *Volkswagen*. But it was also necessary to get the population to listen on the right wavelength at the right times. Established wavelengths, regular broadcasting times and a range of programmes dominated by musical entertainment during the evenings and at weekends ensured that the population became used to listening to the radio in their non-working hours. The radio, as Torsten Hägerstrand has pointed out, binds the listener to a timetable designed by others.[9]

In this way, the citizens of the Western nations were tricked in the 1930s into entering what I would like to call the "electronic church". In a sense we have, of course, remained there ever since. The only difference is that today the means of arresting our attention are so much more subtle and carefully planned. The "electronic church" is similar to the church, not in terms of the contents of its message, but as a technology that ensures mass communication to the desired target group under controlled conditions. Television uses different kinds of programme to encourage the various desired groups to enter the "electronic church" before preaching its commercials, all carefully monitored through the viewing figures.

Broadcasting may appear a far more efficient form of mass communication than the outpourings of the priest in the pulpit: it is not restricted by time and space because the transmission time is not limited to Sunday's service and the broadcasts cover the whole country. But is broadcasting more effective in solving the fundamental problems of a uniform message and public diffusion? Uniformity, yes, but there is no way in which a modern central authority can

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[9] Torsten Hägerstrand, "Decentralization and Radio Broadcasting: on the 'Possibility Space' of a Communication Technology", *European Journal of Communication* 1 (1986), p. 20.

guarantee that it really does have the undivided attention of the whole population at least once a week. And with the combination of satellite television and individual parabolic antennas, broadcasting will no longer be a centralized and easily controlled technology. The metaphor of the "electronic church" will lose its meaning when our living rooms contain dozens and dozens of superimposed "electronic churches". No one will be able to control our choice of channel, and broadcasting may change into a democratic technology not unlike the printing press of the sixteenth century. Radio and TV stations may perhaps have lost the fundamental importance they have had in warfare and *coups d'état* since the Second World War. Even the voice of Hitler will drown in the "signal-noise ratio" of future propaganda, but will the voice of Luther still be heard?

The Theological Importance of Modern Electronics

When block printing, the simple predecessor of book printing, reached Europe, it immediately found two uses: for playing cards and for images of the saints.[10] We can see the same early use for both profane and sacred purposes in the infancy of radio in the 1920s. Not only did radio transmitters broadcast dance music from the roaring twenties, they also enabled many older people – either physically too enfeebled or residing too far away to go to church – to listen to the Sunday morning service in the headphones of the crystal set. Radio and its successor, television, have retained this religious significance throughout the twentieth century. Services, sermons, devotional programmes and sacred music have obtained a far wider distribution throughout the community than in the period of nearly two thousand years for which they were physically restricted to the church. In our century telecommunication has expanded, or rather exploded, the

[10] T. F. Carter & C. L. Goodrich, *The Invention of Printing in China and Its Spread Westward* (New York, 1955), p. 191. Cf. Eisenstein 1979, Vol. 1, p. 376.

church. The church building retains its ceremonial importance, but the spatial limitations of religious preaching have been removed.

In states with powerful central control, the State quickly acquired a monopoly of the new technology. The Swedish Broadcasting Corporation, for example, has been a state-owned monopoly since 1924 and has always had close links with the Lutheran State Church of Sweden. The religious portion of the total broadcasting output is today only a small fraction. In the 1930s the percentage was a good deal higher, but the decrease in percentage can to a considerable extent be ascribed to the longer hours of broadcasting and to the introduction of two music channels. Although there has undoubtedly been some reduction in the offering of religious programmes, which reflect the general secularization of the West, this should not lead us to neglect the theological importance of modern electronics. On the contrary, it may be asked whether the technological development of the twentieth century has not strengthened both the propagation of religion and its content? I would like to suggest that the development of telecommunications has indeed strengthened rather than weakened the content of Christianity and its persuasive ability. That human speech can be transmitted by electromagnetic radiation has given greater plausibility to the Christian message of an omnipotent deity who can reach us all. Prayer, rising from the individual human heart to an infinitely sublime God who hears everything must have seemed a rather abstract concept to people before the age of radio. We, however, need only open our heart to the message, only to "tune in on His wavelength". His is, of course, the ultimate communications system: world wide and immediate point-to-point communication with total secrecy; a switching technology yet to be achieved by human engineering.

Recension

Gisela Buchheim & Rolf Sonnemann (red), **Geschichte der Technikwissenschaften**. Birkhäuser Verlag, Basel 1990. 520 pages.

Why is it that outstanding scientists such as Johan A. Brinell, Carlo Alberto Castigliano, Richard Mollier, Wilhelm Nußelt, Harry Nyquist, Aurel Stodola or Karl Terzaghi are almost never mentioned in history of science books? They all made important contributions to different fields of science. In addition, their names are household words, all over the world, among engineers using Brinell hardness tests, Castigliano methods, Mollier diagrams or Nußelt numbers, or studying Nyquist's works on control theory, Stodola's on the theory of gas turbines or Terzaghi's on the stability of soils.

Conventional answer: These people were engineering scientists, and so belong to the history of technology. Counter question: why, then, are they almost never mentioned in history of technology books? Answer: they were rather more scientists than engineers . . . .

This existence of a non man's land between the two disciplines - history of science and history of technology - was noted by Rolf Sonnemann at the Technical University in Dresden. As editor of the comprehensive work *Geschichte der Technik* (Edition Leipzig 1978, 502 pages) he had placed main emphasis on the technological development of tools for production and its interaction with the development of society. The companion volume *Geschichte der Naturwissenschaften*, edited by Hans Wußing (Edition Leipzig 1983, 564 pages), likewise presented its topic in a mainly social political perspective. To fill the gap between these two areas of history, Sonnemann in 1980 started a research project at TU Dresden aiming at mapping the rise and development of engineering sciences.

Ten years later he and his research group had completed the present *Geschichte der Technikwissenschaften*, a comprehensive, unified account which ties together the two other fields. Like the two Edition Leipzig volumes it addresses a general readership. It is well illustrated (386 black and white and 103 colour pictures), and well indexed. It also presents a rich selection of relevant literature, including many east European works, until now little known in other parts of the world. West European and American literature is not that well represented.

Claude Louis Marie Navier (1785-1836) is another pioneer in engineering science, whose name is conspicuously absent from the pages of most of history of science books. In 1821 he stated the fundamental equations of the theory of elasticity, the scientific basis for the calculation of the carrying capacity of structures. His textbook *Résumé des Leçons données à l'école des ponts et chaussées sur l'application de la Mécanique à l'établissement des constructions et des machines* (first edition 1826), became a classic and was reprinted several times. This and other works by Navier placed much subsequent construction work a scientific basis. A process of "scientification" started, which eventually led to a separation between the professions of designer and master builder. The importance of Navier, both engineer and scientist, one of the great engineering scientists of all time, is made fully clear in the book. He is an archetype of an engineering scientist.

The advent of railways placed new demands on bridge engineers. Bridges now had to carry much heavier loads than before, and here Navier's theory for the stiffness and strength of slender beams found immediate use. The tubular *Britannia* railway bridge across the Menai straits in Wales, built in 1850, is an early example of successful application of Navier's theory.

It was, however, found to be inadequate already in the construction in 1844 of a wooden bridge carrying the St. Petersburg - Moscow railway across the river Werebia. The young railway engineer D.J. Jourawski (1821-1891), a graduate of the Institute of Ways and Communications in St. Petersburg, then further developed the beam theory to make it applicable also to less slender beams. Jourawski's achievement, important even efter 150 years, and still taught in engineering schools all over the world, is however not mentioned here. The Jourawski theory may be seen as a characteristic example of a scientific development coming out of a specific technical problem, one which had to be solved then and there.

More is, on the other hand, said about Franz Dischinger (1887-1953), pioneer in the use of prestressed concrete. In 1938 a large highway bridge was built over the Teufelstal near Jena in Germany. With its 138 meter span it was then the world's largest bridge of its kind. Dischinger made a series of careful measurements to study the behaviour of the concrete, both during the erection of this bridge and after it had been taken into use. Measurement cells, moulded into the concrete, recorded a slowly developing deformation, known as creep. The Teufelstal bridge, in fact, served as a full scale laboratory in a basic research project to study the time behaviour of concrete under load.

The design and construction of artefacts, such as iron, steel, or concrete bridges, is but one ultimate object of engineering science. Another is to develop industrial processes, such as used for mass production of automobiles or computers. Yet another is to analyse the properties of technological systems, such as an electric power grid or a city traffic system. All these aspects of engineering science are given due attention in this survey, which extends from the middle ages until our time.

The Introduction poses the question: "Under what specific historical conditions did the engineering sciences arise, what made them possible and, finally, necessary?" The answer is stated very bluntly: "It was the new dynamics of the capitalist system of production, which created new room for the productive forces. The bourgeoisie cannot exist without continuous revolutionizing." The authors' perspective is entirely European: "Coming from Europe, the industrial revolution and the engineering sciences changed the world". These somewhat uncompromising statements, should hopefully not scare the reader away from the book. It is a competent and comprehensive account of the development in this borderland between science and engineering. It does not refrain from describing various complicated engineering relations, and it succeeds remarkably well in these efforts. The book, the first of its kind, is to be welcomed by scholars in both the adjacent fields of history. It shows, very clearly, that bridges, steam engines, and airplanes were not just built. They also created new branches of science.

Jan Hult

Excerpts from Nouvelles ICOHTEC Newsletter, No. 11, May 1992

Vienna 1991

The 19th International Symposium of ICOHTEC was held in Vienna on 1st-6th September 1991. Resident members were accomodated in a student hostel, Hotel Hans Dobling, which provided good communal facilities and was conveniently placed for the Alte Wirtschafts-Universität, where the main business of the meeting was conducted. The symposium was organized by Hellmut Janetschek, of the Technisches Museum Wien, with a strong Scientific Committee and a team of supporters. Over a hundred members of ICOHTEC attended, and they were very grateful to this team for their excellent arrangements. The main theme was "The Development of Technology in Traffic and Transport Systems", but as on other ICOHTEC occasions there was plenty of opportunity to introduce different subjects. Following a trend begun in Paris the previous year, there was some doubling up of sessions in order to give everybody who wished to do so the opportunity to present a paper. Over sixty papers were read, in ten separate scientific sessions. The Symposium was fortunate to receive strong backing from the City, the Technical Museum, the Österreichisches Industriellen-Vereinigung, and other bodies, so that with this help the organizers were able to arrange some first class receptions and social events, including a trip to Sopron in Hungary to visit the Technical Museum there, and excursions to Semmering (for a train journey over the Pass) and to the industrial area of Lower Austria. Members were able to discuss current issues in the development of the History of Technology, such as the need to provide regular and convenient meetings for European members, and the Executive Committee at the close of the Symposium was able to indicate ways in which ICOHTEC might proceed with this matter. The Symposium was a very convivial event, further enlivened by some considerable unplanned excitements, in addition to being a most instructive occasion.

Uppsala 1992

Plans are now complete for the ICOHTEC Symposium to be held in Uppsala, Sweden, on Wednesday 19th August 1992, in conjunction with the Annual Meeting of SHOT, which will be meeting for the first time outside North America. Professor Jan Hult has organized a selection of twelve papers around the theme: "The Steam Engine as a Greek Temple: Art and Technology throughout History". These will be presented in the course of one day in the SHOT meeting, running concurrently with the other themes and activities in what promises to be an exceptionally lively and rewarding conference. All arrangements for attendance and accomodation are being made through: Uppsala Turist & Kongress 'SHOT', Fyristorg 8, S-573 10 Uppsala, Sweden. For enquiries about the ICOHTEC Symposium, contact Professor Hult at the Center for the History of Technology, Chalmers University, S-412 96 Gothenburg, Sweden.

Tel: (46) 31 772 15 01. Fax: (46) 31 772 38 27.

Zaragoza 1993

The First Circular has recently been distributed for the 19th International Congress of the History of Science, which will be held in Zaragoza, Spain, on 22-29 August 1993. A variety of themes in the History of Technology appear under the heading of "Scientific Sessions" for which papers are invited, in addition to the projected ICOHTEC Symposium. After consultation amongst members of the Bureau, it is proposed that this should be on: "The Place of Theory in the History of Technology". It is hoped to secure a framework of invited papers on Econometrics, Systems Theory, and Social Constructionism, exploring the contribution which they can make to our understanding of the History of Technology, and the relationship which they need to maintain with more traditional narrative history. This is an important field of current debate amongst historians of technology, so it should provide an illuminating discussion in the context of the International Congress. Enquiries, and suggestions for speakers, should be addressed to the Secretary General. For the congress itself, contact: XIX International Congress of the History of Science, Facultad de Ciencias (Matematicas), Ciudad Universitaria, 50009 Zaragoza, Spain. Our President, Sr. José A. Garcia-Diego, is a member of the Organizing Committee.

Constitutional changes

The Zaragoza Congress will be the next occasion for the convening of the General Assembly of ICOHTEC. It is at this meeting that we will need to consider the constitutional changes recommended by the Bureau and Executive Committee in order to fulfil the requirements of enabling ICOHTEC to perform more effectively the functions of a "EUROSHOT". These involve (i) enlarging the role of individual membership; (ii) modifying the procedure for electing the Executive Committee and Officers; and (iii) ensuring continuity of planning for ICOHTEC activities.

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An ICOHTEC Journal

The Executive Committee in Vienna instructed the Secretary General to "explore the possibility of a closer liaison with *History of Technology*, the Mansell annual publication." The Secretary General duly consulted the Editor of the journal, who has provided us with the following statement: "Dr. Graham Hollister-Short, History of Science and Technology Group, Imperial College, London, has been editor since 1989 (with F. James) of *History of Technology*. He is an active member of ICOHTEC and has participated in most meetings since Smolnice in 1982. He is anxious to maintain the complexion of *History of Technology* as an international journal and to ensure, as far as possible, that it reflects the most important research being done in the discipline in all parts of the world. He would welcome papers for consideration for publication in the journal. It appears once a year, and normally comprises about eight papers. Volume 13 (for 1991) broke new ground in being devoted to a single theme, namely the history of electrical engineering. This is a format which might well be repeated in the future, more especially if it would serve to encourage the evolution of ICOHTEC along the lines many members favour. In any event a greater degree of liaison might well be thought to serve the larger interests of both ICOHTEC and *History of Technology*." Dr. Hollister-Short's address for correspondence is: History of Science and Technology Group, Sherfield Building, Imperial College of Science and Technology, London SW7 2AZ.

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Oxford 1993

Professor Robert Fox, of the University of Oxford, is organizing an international conference on 8-11 September 1993, on the theme of "Technological Change" - - "The conference will provide an opportunity for a fundamental re-examination of the state of the discipline of the history of technology in its widest sense. The emphasis will be on problems of broad interest, in particular on methodology and the interdisciplinary and comparative perspectives that are increasingly of concern to historians of technology". Offers of papers should be made to Professor Fox, Modern History Faculty, Broad Street, Oxford O1 3BD, UK, by 30 July 1992.

Georgius Agricola 1994

We have received notice of the formation of a committee to organize the commemoration of the 500th anniversary of the birth ofGeorgius Agricola in 1994. The events envisaged include ceremonies, exhibitions, conferences and excursions. Members of ICOHTEC interested in participating should contact Stadtverwaltung Chemnitz, Agricola-Ehrungen 1994, Sekretariat des Vorbereitungskomitees, Postfach 847, O-9010 Chemnitz, Germany. Queries relating to mining, metallurgy and excursions should be sent to: Bergakademie Freiberg, Agricola-Ehrungen 1994, Komitee Montanwesen, Postfach 47, O-9200 Freiberg, Germany.

The address of the Secretary General, Professor R.A. Buchanan, is

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Notiser

Nyutkommen litteratur

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Sangwan, Satpal, **Science, Technology and Colonization: An Indian Experience 1757-1857**. Anamika Prakashan, Delhi 1991. 196 pages.

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