Nathan ROSEMBERG

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1. ABOUT THE IMPORTANCE OF THE MACHINE-TOOL INDUSTRY IN THE DEVELOPMENT OF TECHNOLOGY

Historically, the machine-tool played a central role in the industrial revolution of the 19th century and also of th 20th. The point about machine-tools is that they are a capital good. Machine-tools are machine that make machines. And therefore, in order to have a machine using technology, it was necessary to develop a high degree of efficiency in manufacturing the machines themselves. This is exactly what machine-tools have done and they have had an effect that has really been very pervasive throughout all of the industries that have come to adopt machine technologies. There is an interesting pattern of learning that has gone on and continues to go on in machine-tools. That is to say, you device a machine to deal with one particular problem, to produce, let us say, fire-arms, and it turns out that the machine design that is useful to manufacture fire-arms is also extremely useful for producing sawing machines. So you have a transfer of a machine-tool that was developed for on purpose, to produce fire-arms, to producing a new product that is really quite unrelated to fire-arms, sawing machine. Similarly when grinding machines were developed to produce the components of sawing machines would turn out that this same machines would be useful, some years later on, for producing bicycle parts and components. So there has been an interesting process of what I call technological convergence. That is, a technology that was originally developed for one purpose, turned out to have a great many unexpected uses as products came along and they used essentially the same technology. So that historically, machine-tools have played a very seminal role in expanding our machine-making and machine using capabilities and making it possible to produce this machine-tools very cheaply. Something like the same process is going on in parts od electronic industry and computer industry today, that is to say a similar process of technological convergence, where a new capability which is developed for one purpose turns out to have capabilities in a large number of places. What is coming here is the information process and capabilities as opposed to the capability in the 19th century of rapidly remouving metal from a metal cilinder.

2. HAVING THE INDUSTRIAL REVOLUTION DEVELOPED IN ENGLAND, WHY DID THE MACHINE-TOOL INDUSTRY DEVELOP MAINLY IN THE US?

The early machine-tools actually did develop in Great Britain, I think it's fair to say, that historically America came to play an early role of technological leadership with respect to machine-tools. There were a number of conditions in the American market in the 2nd half of the 19th century which were particularly favourable. Machine-tools are particularly important in industries were you are producing a very large volume of a standardize product. The US was already a large economy in the 2nd half of the 19th century by world standards of the time, it was very rich and affluent, at the same time for a number of historical and cultural reasons it was easier to produce highly standardize products in the US than in Great Britain. The social structure of the country was different, the distribution of income in the country was different, America had a population of primarily immigrants, primarily recent immigrants. This were people who started at much lower income levels and they frequently wanted a product that was efficient and reasonably cheap. And American industry, including the machine-tool industry, was very successful at aiming at that particular standardized market. Henry Ford put it in classic terms when he first introduced the model T-Ford, first really cheap car in the 2nd decade of the 20th century. He understood that to get the cost of the product down, it had to be produced in a very highly standardized fashion and the consuming public had to be willing to accept the highly standardized product. Henry Ford said that the buyers of the model T-Ford could buy the car in any colour that they wanted as long as it was black! And that, I think, conveys a significant truth about one of the very favourable conditions for American mass-production technology. In Great Britain, by comparison, although the British played a very important role, in the early development of the automobile, it became an object that was purchased only by the relatively rich and affluent people who imposed their standards on the car quite literally, because many of the first british cars were custom-made and continued to be custom-made for a long period of time. So that these historical and cultural differences made a great deal of difference in conditioning one population in North America to be prepared to accept a highly standardize product were as in the case of Britain it was a matter of appealing to a small elite and to catter to each of their tastes and preferences which were often very peculiar, very idiosyncratic in effect. This differences in the composition of demand played a very important role in explaining the early American success in machine-tools and indeed in the mass-production technologies that were based upon

3. WAS THE ROLE PLAYED BY THE AMERICAN GOVERNMENT IN PUSHING THE DEVELOPMENT OF ARMOURIES VERY IMPORTANT

That's an interesting issue: Americans and particularly spokesmen for American business frequently speak publicly in a very ideological fashion. I think, if one looks at American history, one finds that Americans have been much more pragmatic when ti comes to making a very particular set of arrangements. America after all pioneered in a great many ways in the use of public institutions like the Agricultural Extension Service, which I think was one of America's great innovations in exactly 100 years ago, with the passage of the ...Act which provided for a serious of agricultural experiment stations in every state of the country. When it was convenient and when it was sensible for the state to play a role, Americans were not held from doing this by certain ideological committments. The case of the machine-tool industry that happened in the 1st half of the 19th century, we had a system of national armouries, Springfield Massachussetts, Harper's Ferry, Virginia and some other places. These were essentially factories publicly owned and operated that produced fire-arms for the US army. As it happens these national armouries played an absolutely critical role in developing some of the most important new machine-tools and in providing for their rapid diffusion throughout American industry. These national armouries were quite open spaces. They were publicly owned and operated but they were quite public. Private contractors could come in, very often public contractors performed the work for the public sector and much of the learning about new machine-tool technology and the diffusion of that technology took place in this national armouries. This happened in the 1st half of the 19th century and continued in large measure right throughout the 19th century. So the public sector played a very important role in this particular way, in the early industrialization of the US and in particular in the development of those technologies were America became a world leader, that is the machine-tool industry, the technologies that involved highly standardized products that were produced in large quantities.

ABOUT THE ROLE OF THE WEST POINT ACADEMY, RAILROAD ENGINEERS, Westpoint was for many years the only serious institution in the US were one could study engineering. This remained true until the founding of RPI, the Randsom Politecnic Institute in N.Y., up in N.Y. State. That was the 1st place in the US were one could study engineering outside of the places were the officer corps was trained in the Us which is West Point. It is a fact that the first engineers and in particular the engineer who provided the early leadership in the construction of the railroad system were overwhelmingly trained at West Point, if they were trained in the Us, they were certainly trained in West Point until the 1830's when the RPI opened up. That remained the case for a long time. Even when there were other engineering institutes in the US, throughout the 1st half of the 19th century West Point was for a while The most important engineering training center and then after that remained certainly one of the most important.

ROSEMBERG

ABOUT THE RELATIONSHIP TODAY BETWEEN TECHNOLOGY AND WAR

It's a very big and in some ways unpleasant subjects, because a modern technology has provided a continual omnipresent of a kind that the world certainly did not know before the 2nd World War. In the US a very large fraction of technical capabilities has been in the past, since the outbreak of 2nd World War, devoted to military purposes. There have been occasions when there have been what you night call spillovers from the development of military products to the civilian sector and for a while those were rather important., for example, the jet engine, a very important technological innovation. Certainly had its earliest experience in the military sector were the engine was introduced, utilized for a long time, improved and then finally transferred in early 1950's into the commercial sector, to the commercial aircraft industry. It's also true that military demands played an important role in the development of the integrated circuit. I think one has to be careful about defining that role. For ex. if you consider the electronics revolution of the post World War 2 period, the transistor developed in ways that were quite independent of the military. The transistor was basically developed at Bell Laboratories,in private industry. The integrated circuit, much of its most important research in late 50's and around 1960 took place because there was a general understanding with the development of the missile in the late 1950's that there would be a great demand for electronic circuitery that was much smaller, more compact than the circuitery that existed at the time. So I would say that the military demand more precisely, military procurement, for a few years played a very important role in the early introduction of the integrated circuit. The demand for the integrated circuit in the first few years when it came on the market was overwhelmingly a demand from the military sector. At the same time it turns out that the specific research projects that were financed by the military in the 1950's really turned out in retrospect to have been projects that essentially placed their bets on the wrong horses as one would say in english. The technologies that were most successful were the technologies that were largely developed within the private industrial sector. But even there, it's important to emphasize that the great willingness of private firms to commit their own resources to improving electronic technology leading to the integrated circuit, was heavily conditioned by the awareness that there was a large potential military demand if that product would be successfully developed. I believe that that convergence or overlapping of interests that prevailed up to the 1950's between the military and the civilian sectors has been far less important in the US in the last 15 or 20 years for one thing the technologies have . In the last 20 or 15 years there has been a divergence between the military and the civilian sectors, that is the needs of the military sector have become so highly specialized that many of their needs are becoming quite unique, if one considers for example for ex, SDI the starwars, the peculiar demand of that technology are very remote any obvious civilian market. There is a great demand for electronic technologies, but mostly they are concentrating on things such as developing electronics circuits and components that can survive somewhere in outer space at a temperature of 300/400° Fahrenheit while being bathed in radiation. Those needs are very remote from the needs of civilian market were cheapness and simplicity and low cost above all count for so much. Furthermore

* the large American military R&D spending, and that counts to a very large percentage of all R&D in the US, those large expenditures inevitably are attracting into military research, some of the most talented scientist and engineers in America who otherwise would be working in civilian markets and designing civilian products. So, at the very least the large military R&D budget has the effect of raising the cost of performing research in the civilian sector. The large military demand raises the price of scientists, perhaps draws some of the most talented ones away from civilian applications.

An important piece of evidence of the damage that the large military R&D budget has upon the civilian market and civilian innovativeness, and civilian competitiveness, is the fact that Japan in the last several decades has had a remarkable growth experience precisely because it has essentially had no military budget. This, I think by the way is an interesting commentary on the marxian argument that was popular at least a couple decades ago, that a mature capitalism could survive and function only so long as it had a large military budget to support it. One doesn't hear this argument very much this days and for, it seems to me, perfectly obvious reasons. It's my judgment, that the large military budgets have a very damaging to the economic viability of the American economy and that whereas a military R&D absorb ,many of the many American scientists and engineers, Japan never accounted that problem at all. Their best talent has gone into the design, the production, the manufacture of civilian products at which they have become extraordinarily successful as the world knows.

* There is an other more subtle effect connected with this and that is that engineers, for ex., who will spend many in a military program, or by the way, in the space program which in many ways has had the same effects, that such engineers learn very quickly that what is wanted is some degree of performance improvement without any particular concern for how much it costs to achieve that performance improvement. So that in the space program it would be a matter of , well don't worry to much about it, just lighten the weight of those engines about 2 or 3% and don't worry about what it costs. That kind of mentality maybe ok in an activity that will have live or dead consequences for a nation, as the space program by the way did not, but when people have worked in an environment of that kind for many years, that is: squeeze whatever little performance improvement you can out of the product and don't pay any attention to what it costs, That is a mentality, an approach, a set of priorities which is deadly if you want to carry it into the civilian sector for the design of civilian products, and many of the engineers who left the space program in the late 1960's or early 70's for ex., encountered exactly that problem, they had been essentially incapacitated for doing civilian product design because they didn't pay attention to cost. Whereas the japanese engineers who were also extremely well trained and extremely clever people, these people were paying attention all the time to getting the cost of the product

down to levels which would make them widely acceptable in civilian market, both domestic and overseas, they were thought to emphasize not slight performance improvements, as in the space program or in the military program in America, but cost production and quality control. And that of course, is precisely what japanese engineers and consumer products have become famous for, quite rightly so, in the last several years. PerHaps I should add that I'm an owner of three cars, they are ll japanese!

ROSEMBERG

The government of the national armouries did devote a great deal of attention to interchangeability, on the other hand they were rather acutely conscious of costs, in fact, there were two very justifications for the achievement of interchangeability of fire-arms. One of them was that if you could, you could reduce the cost of a musket or of a rifle, because you could save all of those tedious steps of filing the separate components to make them fit. Once you could develop that technology as it was eventually developed, there is always a much lower cost of all those products. The second point was that interchangeability was also very important on the battlefield because it economized on the inventory of parts that you would have to maintain in your buying in case on part of the gun suffered some kind of damage, you could very quickly replace it from a relatively small inventory or even, if the inventories happened not to be available it was quite possible to cannibalize parts, that is to take several damaged guns, but to take the parts that were still intactly in one and put them into another. So there were battlefield advantages as well as cost reductions to the achievement of interchangeability in the 19th century, but I would be hesitate to carry this comparisons too far. It seems to me that the entire mentality and scale of operations of the military in the years since 2nd World War is simply, or is their magnitude different from the sort of things that prevailed in the 19th century.

ROSEMBERG

ABOUT THE RELATIONSHIP BETWEEN SCIENCE AND TECHNOLOGY

Science and technology are each very complex fields with individual fields and subjects within each one of them. I would say that we tend to approach the question of those interrelations between science and technology in an overall simplyfied way. I'm speaking here primarily as an American who is familiar with the context of this discussions in America. Science and technology are often discussed as if the relations between them always run in one direction. That is from research, from basic science to applied science, downstream as you might say to technology and engineering, product design, prototype testing and development, etc. In fact, I think it's important to understand that science and technology are much more interactive in nature that is commonly believed. There are all kinds of feedback loops where the causality runs not just from science to technology but from technology back to science. This is so for a number of reasons. In an advanced industrial society such as Italy or the US, there are a great many occasions in industry where certain things happen, certain kinds of problems arise: a particular piece of metal may fracture unexpectedly or may deteriorate under certain circumstances. It's in the nature of an industrial technology that problems are always arising which require the attention of specialists. It's in the nature of an industrial technology that it throngs up unexpected observations or findings of one kind or the other. And finding out why this things happened, very often becomes the source of a mayor discovery. For ex., when radiotelephony was first introduced across the Atlantic Ocean in 1929/1930, there was a great deal of static, a great deal of interference with the transmission od sound by radio crossing the Atlantic Ocean and ITT at Bell Labs, asked one of their engineers to find out what this unpleasant interference was caused by. The man's name was Karl Jensky and he did a study of radiointerference, the purpose of which was the very practical purpose of improving the quality of telephone transmission. And he published a paper a couple of years later recording his findings and briefly he says there are three causes of static and interference. 1st one, he says, is local thunderstorms, and that's obvious, the 2nd one is rather less obvious, he says because it was distant thunderstorms, that could also by bouncing off various layers of the atmosphere, create this interference even when the storms were far away. The 3rd cause, he says, is very strange and I can't explain it, but it's funny, he said, every time, he was using a rotatable antenna, every time I turn my antenna towards the Milky Way or (1w)! Karl Jensky? who was asked to find out how it was possible to reduce the causes of static in telephones, discovered radioastronomy, which was of course the study of the sound that he heard, that he could not get rid off, when he pointed towards the Milky Way, and was actually of course, the radiotransmission of the radiowaves that were coming form there. So here was a very practical problem giving rise to a very fundamental break-throughand this is fare and less common than we believe. If you take the great work of s. Carnot? in establishing the modern discipline of termodynamics, he did this, he discovered the 2nd law of termodynamics because he was interested in improving the working efficiency of the steam-engine and in determining this, he invented or discovered the 2nd law of termodynamics which has become so fundamental to the last 150 years. Here is technology shaping science, not science shaping technology. You didn't have to understand the laws of termodynamics to build the steam-engine, which is a very good thing, because the steam-engine designed 50/60 years before Carnot discovered the 2nd law of termodynamics, so the causality again was precisely the other way around and it seems to me that we drasticly underestimate the frequency with which technology is responsible for mayor improvements in science, that is, the two are much more interactive. If you like the word, the relationship between the two is very dialectical. It is really truly dialectical, it is a system of mutual influence and reinforcement. Technology influences science in some even more obvious and fundamental ways by the development of new techniques of instrumentation, after all, the great Pasteur could not have developed the germ theory of disease, had he not have a microscope through which he could identify these things. I'd like to emphasize that again the relationship is a two way one.Microscopes had been around for a couple of hundred years although they were drastically improved with the ...microscope in the 19th century. But the point is, both require, practical problems are very important and don't forget, Pasteur was working on the problems of the french wine industry , the french brewing industry, he was concerned with the problems of fermentation and putrefaction.

ROSEMBERG

IS IT EASIER TO DO RESEARCH IN SCIENCE OR IN TECHNOLOGY

I'd like to put it differently. Within the academic world in

particular, there is a tendency to think of science as being a

really fundamental aspect of the human enterprise in discovering

things and there was a tendency, certainly strong in America, to

treat technology or engineering as being somehow of less importance or significance or in some sense not quite so difficult as science, as the kind of activities for which one wins a Nobel prizes. But the fact of the matter is that there is an enormous gap between doing scientific research, finding something that is fundamentally new and doing something that is economically useful with that knowledge. Let me point out first, that in the Us, when you talk about research and development, R&D, most R&D is not basic science at all. Most R&D is D, that is development activity, product design, building and testing of prototypes, pilot plants, developing, improving manufacturing processes and so on. In fact, the recent figures are in America roughly, that development, this activities, is about 68 % of all R&D, applied science is slightly under a quarter and basic science, which is what people think when they think of R&D, basic science constitutes in America today one 12th of all R&D expenditures. When new scientific breakthroughs occur, and one should not draw the inference that all technological developments depend upon science, nothing could be further from the case, one of the most important improvements in the transportation sector, in the post World War II years, has been what we call in english "containerisation". Containerisation believe me, did not depend upon science, it is essentially the idea that you can save a lot on labour cost, particularly on trans, shipment costs if you put the things that you are shipping in a larger box. That's an acceptable oversimplification. You don't need to be a scientist to develop the idea of putting things in a larger box. You certainly could not patent the idea of containerisation, you would be laughed at at any patent office in the world if you went in to patent this idea, what's the idea, it's a box! That essentially is what containerisation was. First of all, much technological change continues to take place at that level with little if any, reliance upon basic scientific knowledge, however, even when as it's often the case, scientific knowledge is fundamental, it's very easy to underestimate the degree of difficulty involved in taking that new scientific knowledge and incapsulating it in a useful marketable commercial product. This days, there was a great deal of attention all over the world about the recent breakthroughs in superconductivity, the discovery of higher temperature and superconductivity, scientist from many nations have reporting extremely exiting results. From the scientific point of view this is truly a remarkable breakthrough, but I expect maybe decades before we have incorporated that new purely scientific piece of knowledge into things of commercial value. Well, here is a great deal of talk about magnetically levitated trains, we might no be so far form that one actually, but when it comes to things like the ability to store electricity, because there is no resistance, when you have achieved superconductivity, you can in effect store electricity, which is in effect a mind (1w) concept. Developments of that kind are probably decades down the road. The degree of difficulty in moving from that breakthrough to the design of complex products that will work, that will be safe, reliable, that will serve a particular consumer need, and then developing a separate technology to facture all of this things, that's the kind of work that takes very probably decades. I would compare the recent breakthroughs applied to conductivity to Faraday's discovery of electromagnetic induction, back in 1831. It was several decades before it became possible to translate that discovery that profound discovery into new products. Actually, there was one important new product that came out fairly quickly, that was the electric telegraph, which did come fairly quickly. But it was more than 40 years later, only after much deeper understanding of electromagnetic phenomena, that was achieved by Maxwell in the 1970's, that we had a rigorous mathematical formulation that pointed in some specific direction within what, ten years or so, Hertz confirmed the existence that Maxwell had predicted of electromagnetic waves and in not many years after that Marconi was the first to exploit this new knowledge for the transmission of sound over radiowaves, what the wireless transmission of sound is. It's interesting because the british still use the word wireless, which rather graphically portrays what it is whereas in America we say radio. So, we tend to underestimate the importance of those later stages of the development process, the prototype building, the pilot plant test, the product design. Those are very time consuming activities, they are very expensive activities, and I would like to insist that they are very creative activities. In the academic world there tends to be a status ranking where we think of the more fundamental levels of knowledge achieved by the basic scientists as being what is important and what comes later on is mere engineering or mere technology. Well, that I think is remarkable unfair, because the creativity of what engineers and technologists do at that level is quite simply of fundamental importance and I think there is a great underappreciation of the degree of difficulty of what goes on at those levels and their extreme importance to technological improvement. In qualitative terms again, it's clear, let me repeat, 68% in America of R&D is these kinds of activities, the development.

ROSEMBERG

ABOUT TECHNOLOGY AND THIRD WORLD

First of all, I think technology has given a great to the less developed countries of the world, in a variety of ways. This is most apparent in agriculture. South and Southeastasia has gone through an amazing technological transformation in the last 25 years. Let me remind you that 20, 25 years ago India experienced a mayor famine, a famine that probably would have resulted in death by by starvation of 10/15/20 million people, had it not been for massive transfer of grain mostly from the US to India. Nobody ever thought that India would achieve anything like a decent selfsufficiency in the basic food products. Today India is not only selsufficient in the basic cereal grains, but India is now on small scale, an exporter of grain. India is now an exporter of grain to the URSS. China, a country which also suffered perennially of food shortages and lived on the edge of starvation, China is an exporter of grain, primeraly corn, to the URSS. This would have been inconceivable 20, 30 years ago. So that technology has in fact brought about a massive improvement in human well being at least in respect to the food supply. In the parts of Asia that historically where most subject to starvation.

ROSEMBERG

CHINA'S IMPROVEMENT

I would say that there have been two basic factors that have brought about the improvement in chinese agriculture and I'm not sure about figures for back in the 1930's but chinese agriculture, the food supply has been extremely precarious in the last 50/60 years. China benefited immensely from the introduction of the new highly fertilized responsive improvements in grain that came out of the International Rice Research Institute in the Philippines and the later modifications of wheat and other cereal grains. So yes, the agricultural improvements were heavily dependent upon very recent technology improvements which were responsible for raising agricultural productivity, but equally fundamental in the last several years, of course, is essentially the closing down of the chinese collective farms, which have now been accepted as having been ..., a national disaster. China has gone through a drastic series of social changes, specially in the agricultural sector within the last ten years essentially as I say closing down the huge collectives, a great deal more of individual decision making, a great deal more of marketing incentives, a much greater degree of freedom on the part of the original farmer to select his cropt, to be sure there are still minimal compulsive deliveries of grain to the state at predetermined prizes. Nevertheless chinese agriculture has gone through a drammatic change which has been dictated largely by an increasing reliance upon prices and individual incentives at the level of the individual farm. There is not yet large scale private ownership of land or freedom to develop an employment relationship, which is still very problematical for ideological reasons but chinese society, and don't forget chinese society is still overwhelmingly rural, has moved heavily in the direction of greater reliance upon marketplace, not complete, but greater reliance than existed 10 or 15 years ago upon ordinary market incentives, while individual farmers do not own their own land, they are getting longer and longer leases, the longer a lease gets, the more it begins to look like something like private ownership, the more you begin to reproduce something like an incentive system, 15 years is a pretty good lease after all.Chinese agriculture has been, as near as I can find out, I visited China about a year and a half ago, and at that time, I was simply astonished at the differences that I could observe in the countryside in comparison to the early visit, three or four years before that. To answer your question why all this is in a way an elaborated answer to the issue of why technology has not brought greater benefits to the third world, first part of my answer would ne: I think it has in some parts of the wold, and 2nd part of the answer is that technology is not and never will be a kind of a magic wonder that you can wave technology. It's a set of human capabilities, it envolves knowledge, about certain realms of human activities, but how well it works for the achievement of social purposes depends very much upon the social context in which it is located. If you ask why technology did not prevent the massive starvation that we observed in Africa south of the Sahara, part of the problem has to do I guess with droughts but I can assure you that there have been droughts in southsaharan Africa as far back as there is a history of that region, certainly one of the factors that was fundamentally at fault here was a set of social arrangements which essentially weakened and in some cases destroyed the incentive of the small peasant farmer in subsaharan Africa to produce and to bring to market a surplus of agricultural products. In subsaharan Africa you have had a miserable experience of

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early leadership in the construction of the railroad system were overwhelmingly tra