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Robots and Capitalism

'The key to innovation is not to be found in chemistry electronics, automatic machinery, aeronautics, atomic physics, or any of the products of these science-technologies, but rather in the transformation of science itself into capital'. Harry Braverman, Labour and Monopoly Capital.

A single image, captured in countless recent press photographs, expresses a central paradox of contemporary capitalism. The picture is one of a worker, typically a highly-skilled spray painter, guiding the arm of a robot through the motions of a precise and complex task. The machine—a continuous path play-back robot—will then be able endlessly to replicate the exact movements of the human being. Almost certainly, the worker who has been selected to 'teach' the robot is the most experienced or the most efficient of this section of the factory's workforce. According to one's point of view, the picture may be seen as representing the ever-progressing triumph of technology, or the ultimate irony of automation—the mechanisation of a dreary and potentially dangerous job, or the moment at which years of carefully acquired skill are transferred to an inanimate object, and the human individual is simultaneously rendered redundant.

Robots and the Limits of Capitalism

But, beyond this, the image also symbolises a crucial issue for our understanding of the present nature and future destiny of the capitalist system. It confronts us with the instant at which living labour ceases to be involved in the productive process, and therefore, according to the labour theory of value, the instant at which this fragment of the productive process ceases to generate surplus value. Envisaging the same event repeated hundreds of times—as it has been in the past few years—we seem inexorably to be propelled towards the conclusions put forward by Ernest Mandel.

In his work *Late Capitalism*, first published in the early 1970s, Mandel argued that the process of automation constituted the critical contradictory force within the development of capitalism: ' . . . we have here arrived at the absolute inner limit of the capitalist mode of production.

This absolute limit . . . lies in the fact that the mass of surplus-value itself necessarily diminishes as a result of the elimination of living labour from the production process in the course of the final stage of mechanisation-automation. Capitalism is incompatible with fully automated production in the whole of industry and agriculture, because this no longer allows the creation of surplus-value or valorisation of capital. It is hence impossible for automation to spread to the entire realm of production in the age of late capitalism'.[1]

The vision of automation as the end of capitalism is not a new one. Mandel's views are clearly rooted in Marx's concept of capitalist development: a process blindly generating, through its own progressive yet self-destructive forces, the seeds of a socialist society where 'labour in which a human being does what a thing could do has ceased'.[2] Indeed the Marxist notion of automation as the harbinger of the end of capitalism has found an echo—albeit in a typically woolly and indistinct echo—in the writings of neo-conservative futurologists such as Daniel Bell. Bell has painted a picture of a post-industrial or information society in which, not only manual labour, but also the centrality of private property and profit maximisation will, it appears, gradually and painlessly wither away: ' . . . the social forms of managerial capitalism—the corporate business enterprises, private decision on investment, the differential privileges based on control of property—are likely to remain for a long time. And yet the functional basis of the system is changing, and the lineaments of a new society are visible . . .
. . . In the new society which is emerging, individual property is losing its social purpose . . . and function stands alone.'[3]

In the past few years, the idea that the full automation of production represents the 'absolute inner limit' of capitalism has acquired particular importance. When Mandel wrote *Late Capitalism*, production systems approaching total automation were almost entirely limited to industries such as oil refining, which work on the continuous flow principle. Assembly line industries still required a substantial (though declining) input of human labour. Since then, the development of robots and their incorporation into data-controlled production systems has created a realistic future prospect of worker-less factories (from the perspective of management no doubt 'worker-free' factories) even in complex assembly processes—including the production of robots themselves. In 1970 there were probably less than a thousand robots in operation around the world: by 1982, according to one estimate, there were more than 30,000.[4]

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[1] Ernest Mandel: *Late Capitalism*, London, Verso Editions, 1978, p. 207. See also Ernest Mandel: *An Introduction to Marxist Economic Theory*, New York 1970, pp. 27–28.

[2] Karl Marx: *Grundrisee*, London, Penguin/NLR, 1973, p. 325. This passage is quoted by Mandel in *Late Capitalism*, p. 222.

[3] Daniel Bell: *The Coming of Post-Industrial Society*, London 1974, pp. 372–73.

[4] Consistent sets of statistics on the numbers of robots in use are notoriously difficult to collect, since different authorities use different definitions of the term 'robot'. The first of these figures is an estimate by X.B. Ghali quoted in R. Zermeno, R. Moseley and E. Braun: 'The Robots are Coming—Slowly' in T. Forester (ed): *The Microelectronics Revolution*, Oxford 1980, p. 190. The figure for 1982 is an estimate by the Robot Institute of America (servo-controlled continuous path and point-to-point robots only) quoted in Deizai Koho Centre: *Japan 1983: An International Comparison*, Tokyo, Keizai Koho Centre 1983, p. 19.

The present situation is obviously very far from the state of total automation which Mandel depicts as the limit of capitalism. But if we accept his view that automated enterprises can make profits only parasitically, by absorbing the surplus value created in other parts of the economy, and that the rising level of automation must therefore be accompanied either by increasing exploitation of the remaining labour force or by falling average levels of profit,[5] then it would seem that major capitalist economies are rushing towards their doom like Gadarene swine.

Empirical evidence, though, suggests a more complex relationship between the introduction of robots, the level of labour input and the rate of profit. The most striking instance of recent rapid automation amongst major industrialised economies is probably the case of Japan. In 1978 there were about 3,000 robots in operation in Japan; by 1982 there were over 18,000.[6] In the same year a government survey of corporate enterprises in Tokyo, Nagoya and Osaka estimated that 33.5% of manufacturing corporations were already using robots and that a further 19.5% had plans to introduce them within the next three years.[7] The use of other types of labour-replacing devices such as computers and numerically controlled machinery has also been expanding rapidly in Japan. But between the mid-1970s and 1982 the total employed workforce increased by about 8% and the manufacturing workforce by 3% (though unemployment also rose from 1.9% to 2.4%); average hours worked in manufacturing increased by about 9 hours per month; and the profit rate of incorporated enterprises remained roughly constant, fluctuating between 5% and 6%.[8]

The Japanese case in itself does not disprove Mandel's thesis. It may be argued that the automation of Japanese industry has been too recent or on too small a scale for its effects to begin to be evident, and that rising levels of exploitation, through increased use of contract and part-time workers, are off-setting the decreased rate of surplus value in automated industries. I should, however, like to offer an alternative explanation, and to present the example of automation in Japan as evidence for an interpretation which, although not totally contradictory to Mandel's, suggests a somewhat different outcome to the automation process.

I accept Mandel's statement that total automation of all productive activity (including services) is incompatible with capitalism. We cannot even be certain that it would be compatible with human society of any kind. But I believe that high levels of automation in manufacturing can exist within the framework of an economy which is capitalist in the sense that it is centred on the privately owned corporation and the exploitation of wage labour. A highly automated capitalist economy, however, would have special features which will need careful analysis if

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[5] See Mandel, *Late Capitalism*, pp. 206–14.

[6] R. Zermeno, R. Moseley and E. Brain *op.cit.*, p. 190; Keizai Koho Centre o*p.cit.*, p. 19.

[7] Economic Planning Agency (Japan): *Kigyo no Ishiki to Kodo*, (The Attitudes and Behaviour of Enterprises), Tokyo, Keizai Kikakucho Chosa Kyoku, 1983, p. 64.

[8] Prime Minister's Office, Statistical Bureau (Japan): *Nihon no Tokei*, 1983 (Statistics of Japan 1983), Tokyo, Sorifu Tokei Kyoku, 1983; Research and Statistics Department, Bank of Japan: *Keizai Tokei Nenpo* (Economic Statistics Annual), Tokyo, Bank of Japan, various years.

we are to understand both the dynamics of the system and its potential for transformation. And if, as I believe, such economies are not merely a theoretical possibility but are actually appearing before our eyes, the task of analysis and debate acquires very real importance and urgency.

The Fission of the Labour Process

Automation has traditionally been viewed as a linear process by which machines grow larger and larger, and workers fewer and fewer, until all that remains is the single megamachine—monument to the hollow victory of capital—presiding over a factory devoid of human labourers: 'An organised system of machines to which motion is communicated by the transmitting mechanism from an automatic centre is the most developed form of production by machinery. Here we have, in place of the isolated machine, a mechanical monster whose body fills whole factories, and whose demonic power, at first hidden by the slow and measured motions of its gigantic members, finally bursts forth in the fast and feverish whirl of its countless working organs.'[9]

In actual fact, though, the phase of automation which began to gather momentum in the 1970s was not simply the direct continuation of the prolonged historical process of mechanisation, but was based on a principle which marked a radical departure from earlier forms of the development of machinery. This principle is the separation of hardware from software: a separation which may be seen as constituting a revolutionary fission of the labour process itself.[10]

To understand the nature of this fission we need to consider, very briefly, the relationship between knowledge, labour, and machinery. We can begin by observing that all labour involves the purposeful application of human knowledge to the natural world. In its simplest form, this application occurs directly, without the intervention of tools or machinery, as when the women of hunter-gatherer communities picked reeds and grasses and wove them into baskets. Tools, and later machines, contain not only labour but also knowledge: they preserve and diffuse slowly accumulating human understanding of ways by which labour can be made easier and more productive. So knowledge has been a crucial element in production at all times, but for much of history its significance has been obscured by the fact that it could play a part in production only when embodied in the worker or in the machine.

The separation of knowledge from labour and machinery, and its emergence as an independent commodity and element in production has been a gradual process dating back to the very beginnings of capitalism. Essential steps in the process were popularisation of the printed book, and later the creation of patent and copyright systems. These latter measures were crucial because the special properties of

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[9] Karl Marx: *Capital* Volume One, London, Penguin/NLR, 1976, p. 503.

[10] It was a misunderstanding of the nature of this fission which led Herbert Simon to the absurd conclusion that software could be regarded as a form of 'labour'. See H. Simon 'Programs as Factors of Production' in *Models of Bounded Rationality*, Vol. 2, Cambridge, Mass., 1982, pp. 134–45.

knowledge (its lack of material substance; the ease with which it can be copied and transmitted) mean that it can only acquire exchange value where institutional arrangements confer a degree of monopoly power on its owner.

Software represents a special form of the commodification of knowledge. Its origins go back at least to the invention of the Jacquard loom in the nineteenth century, but it was only with the development of computing in the 1950s and 1960s that it began to have real economic importance. Software in essence consists of instructions for performing a particular task, and a major technological key to the growth of computing was the creation of means by which these instructions could readily be stored and fed into a machine. It is this technological key, applied to industrial production, that provides the impetus behind the current wave of automation.

The distinctive characteristic of the robot is its ability to be programmed to perform a number of different tasks, or to vary its action in response to changing external circumstances. For this reason, robots, unlike conventional mass production techniques, are particularly applicable to the production of small batches of varied products. In the earliest robots, movements were controlled by altering electrical connections in a plugboard. More recent versions are programmed by the play-back system (described at the beginning of this article) or by a 'teach box' in which buttons or a joystick are used to define the movements of the machine. But increasingly the trend is towards large automated systems—so-called 'Flexible Manufacturing Systems'—controlled by software written in specialised programming languages. This enables robots to perform complex and coordinated actions, and to mimic more closely the flexibility and responsiveness of the human worker.

The significance of the application of software to manufacturing, therefore, is firstly that a single machine may be made to vary its movement without alteration to its mechanical structure; but secondly, and most importantly, that the worker's knowledge may be separated from the physical body of the worker and may itself become a commodity. Until now the productive process has always implied the bringing together of machinery and human labour (in whatever proportions). Those who controlled the process extracted more labour from their workforce than they paid for. But it was still correct for Braverman to observe that 'labour, like all life processes and bodily functions, is an inalienable property of the human individual. Muscle and brain cannot be separated from the person possessing them . . . Thus, in the exchange the worker does not surrender to the capitalist his or her capacity for work. The worker retains it, and the capitalist can take advantage of the bargain only by setting the worker to work.'[11]

But with the use of software in production the situation is fundamentally altered. As can be seen in the case of the spray-painter and the play-back robot, the worker does in a very real sense 'surrender to the capitalist his or her capacity for work'. The physical coming together of

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[11] Harry Braverman: *Labour and Monopoly Capital*, New York 1974, p. 54.

worker and machine is sundered, and we are left with, on the one hand, machines which work automatically, endlessly responding to the instructions provided by workers who may be physically far removed from the production site; and, on the other, the increasing channelling of living labour into the process of designing, composing and altering those instructions themselves.

The Perpetual Innovation Economy

If we take an imaginative leap into a future static society where vast, pre-programmed flexible manufacturing systems whir unattended, producing all possible goods and services, then we might indeed conclude that this would be a society where no value could be created and no exchange could occur. But if we look at the continuing uneven diffusion of robotics in the real world of contemporary capitalism we are likely to come to a different conclusion, though one equally compatible with the labour theory of value. This conclusion is that automation causes the centre of gravity of surplus value creation to shift away from the production of goods and towards the production of innovation—that is, of new knowledge for the making of goods. The spread of automated manufacturing, by sundering the labour process and squeezing out surplus value from the production of material objects, forces capitalist enterprises and capitalist economies to become perpetual innovators.

Surplus value is extracted from the labour of workers who prepare software for an automated production system, but this surplus value only acquires meaning and substance when the software is brought together with machinery, and the production of goods begins. Once this happens, however, the value of labour embodied in the software becomes subdivided between a potentially infinite number of products (since software as such can never wear out). Unless the manufacturer is able to maintain total monoply over the technique, spreading automation will rapidly reduce the value of the product, and profits will dwindle to nothing. The only solution to this problem from the point of view of the managers, is to pour increasing amounts of capital and labour into the development of better software, new techniques, different products. The fission of labour inherent in the nature of robots, in other words, creates a situation where it is only in the design of new productive information and the initial bringing together of information and machinery that surplus value can be extracted. Unless this process is continually repeated, surplus value cannot be continuously created, and the total mass of profit must ultimately fall. But over a fairly extended period of time it is possible that high levels of automation may be sustained by the incessant generation of new products and new methods of production.

The idea of a highly automated perpetual innovation economy has implications which are bound to be controversial. The first is that fewer and fewer workers will be engaged in directly productive manual labour, more and more in indirectly productive tasks involving limited physical activity. The second is that information—and not merely any information, but information which contributes to productive processes—will become a commodity churned out by corporate enterprises almost as routinely and monotonously as cars flowing from an assembly line. Both of these points will be considered later, but first let us look at some contemporary evidence for the emergence of highly automated, perpetual innovation systems.

Ever since the beginnings of capitalism competitive pressures have pushed firms in the direction of innovation. But the fact that, with automation, innovation becomes the core of the company's profit-making activity is illustrated in a recent description (by two IBM executives, Mike Kutcher and Eli Gorin) of the enterprise of the near future.[12]

The evolutionary step beyond the automatic factory, according to Kutcher and Gorin, is a creature known as the product enterprise system or PES. The characteristic feature of the PES is that its structure integrally unites the processes of development, manufacturing, sales and distribution, weaving them together in a manner that the authors lyrically liken to a tapestry, or to the music of an orchestra: '. . . because both it [the PES] and the orchestra must combine people, machines (instruments) and programmes (music scores) and make them work together synchronously. Otherwise there will be discord.'[13]

Kutcher and Gorin provide a rather detailed imaginary example of the operation of the PES. The product designer becomes aware of a market demand for a new transport mechanism. The project engineer provides the basic concepts for the design. Through a series of twenty-five steps, other designers and engineers fill in the details—selecting suitable materials and tools for production and creating the programme for the automatic manufacturing of the product. Lastly the authors show how faults in the manufacturing programme are detected and solved, and the efficiency of production continuously improved. A point which is not explicitly discussed, but which is of enormous importance, is that this description is not concerned with the way in which the enterprise *produces* products, but with the way in which it introduces *new products.* Its whole structure, indeed, is centred on the development, alteration and refinement of productive processes. Without these activities, the PES would lose its *raison d'être*. It is, in fact, the quintessential perpetual innovation enterprise.

The accelerating drift of surplus value creation from production to innovation can be observed, not only at the level of the individual enterprise but also at the level of the total economy. Here a particularly clear example is again provided by the case of Japan. The rush to automation since the early 1970s—propelled in the first instance by a nexus of contradictions in Japanese capitalism including shortages of cheap labour, pollution and energy problems—has been accompanied by an increasingly vigorous campaign by government and big business to popularise the concept of a so-called 'information society': that is, of a society in which the production and sale of new productive informa-

[12] Mike Kutcher and Eli Gorin: 'Moving Data, Not Paper, Enhances Productivity', *I.E.E.E. Spectrum*, Vol. 20, No. 5, May 1983, pp. 84–88.
[13] *Ibid.*, p. 84.

tion rather than goods will become increasingly central to economic life. A mass of reports on the subject have been compiled by governmental and quasi-governmental research bodies.[14] Many of these explicitly recognise that there is a logical sequence of development from the automated manufacturing of goods to the creation of an economy in which the production of technological knowledge is the main source of profit: 'Corporate automation such as OA [Office Automation] and FA [Factory Automation] can be considered the first stage (substitution) within the information technology revolution, and by the constitution of the information communications infrastructure, this will eventually advance to the second stage (amplification) where intellectual labour will be amplified. We can assume that this will lead to the third stage (societal transformation) where the economic social system of industrial society will be transformed into one appropriate to the information society.'[15]

The motive force behind this sequence, however, is obscured by a rosy mist of sanctimonious verbiage, full of references to the disappearance of 'present materialistic value thinking' and its replacement by 'time-value thinking, in which life-time self-fulfilment will assume major importance'.[16] In fact, the shift in emphasis from goods production to information production has nothing whatever to do with declining 'materialism' or life-time self-fulfilment, and everything to do with the exigencies of surplus value extraction in the highly automated economy.

That automation leads to perpetual innovation is reflected in the real world by the declining share of Japan's corporate capital expended on material inputs such as machinery and raw materials, and the growing share expended on non-material inputs such as software, data services, planning, and research and development. This is part of a trend—sometimes described as the 'softening of the economy'—which has attracted much attention amongst students of the Japanese economy.[17] Unfortunately, the research published on the subject so far uses extremely broad categories: development planning, management and marketing activities all being lumped together as 'soft inputs'. Its findings, therefore, give only the crudest indications of the emergence of the perpetual innovation economy in Japan. However, it may be of some significance that more than half of Japan's industries in 1970 could be classified as 'very hard industries' [that is, industries where material goods made up 80% or more of the total value of inputs], but that by 1980 only 27.3% could be included in the 'very hard' category.[18] Figures derived from a Japanese Labour Ministry survey of machinery

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14 For example, Economic Deliberation Council, Information Research Committee: *Nihon no Joho Shakai—Sono Bijion to Kadai* (Japan's Information Society—Vision and Tasks), Tokyo, Keizai Shingikai 1969; Japan Management Information Development Council: *Joho Shakai Deikaku* (Information Society Plan), Tokyo, Nihon Keiei Joho Kaihatsu Kyokai 1972; Economic Planning Agency, Social Policy Bureau: *The Information Society and Human Life*, Tokyo, Economic Planning Agency, 1983.

15 Economic Planning Agency: *Information Society and Human Life*, p. 49.

16 *Ibid.*, p. 50.

17 See for example, Y. Nagatomi: 'The Softening of the Economy', *Japan Quarterly*, Vol. 30, No. 3, July–Sept, 1983, pp. 256–60; K. Sheridan: 'Softnomization—The Growth of the Service Sector in Japan', Paper presented to the national conference of the Asian Studies Association of Australia, Adelaide, May 1984.

18 Nagatomi, *op.cit.*, p. 259.

manufacturers emphasise the growing centrality of the perpetual generation of new products and techniques in a rapidly automating industry. Between 1977 and 1980 the only sections of this industry to increase their workforce were those involved in planning, research and development [Table 1]. Figures for the economy as a whole suggest that this is not an isolated example. Technical and professional workers constitute the most rapidly growing section of the Japanese workforce, increasing by 29.4% from 1975 to 1982, while the number of office and clerical workers increased by 18.7%, and of production process workers by 4.3%. In 1960 the ratio of technical and professional workers to production process workers in Japan was 1 to 5.8; by 1982 it was 1 to 3.4.[19]

EMPLOYMENT TRENDS IN GENERAL MACHINERY AND EQUIPMENT MANUFACTURING—JAPAN—1977–83 (% change)

	1977–80 (actual)	1980–83 (projected)
Total employees	−3.2	4.6
Production employees	−4.8	5.3
Management employees	−3.1	−0.4
Planning, R. & D. employees	2.6	7.2
Marketing & sales	−0.2	6.0

Source K. Ikehata *et al: Industrial Robots: Their Increasing Use and Impact*, Tokyo, Foreign Press Centre, 1982, p. 43.

Workers and Scientists

Mandel, after setting out his views on the economic impossibility of fully automated capitalism, went on to state: 'It may be objected that automation eliminates living labour only in the production plant; it increases it in all those spheres which precede direct output (laboratories, research and experimental departments) where labour is employed that unquestionably forms an integral part of the "collective productive labourer" in the Marxist sense of the term.'[20] His principal answer to this objection is that 'a transformation of this kind would imply a radical suppression of the social division between manual and intellectual labour. Such a radical modification of the whole social formation and culture of the proletariat would undermine the entire hierachical structure of factory and economy, without which the extortion of surplus-value from productive labour would be impossible. Capitalist relations of production, in other words, would collapse . . . For reasons of its own self-preservation capital could never afford to transform all workers into scientists, just as it could never afford to transform all material production into full automation.'[21]

Here it seems to me that there are two key concepts which may at first appear to resemble one another, but which need in fact to be examined separately. The first is the 'radical suppression of the social division between manual and intellectual labour' and the second is the transformation of 'all workers into scientists'.

The first process, it could be argued, has been occurring within

[19] Prime Minister's Office: *Nihon no Tokei*, 1983, p. 32.

[20] Mandel: *Late Capitalism*, p. 208.

[21] *Ibid*, p. 208.

capitalist economies for many decades. Braverman, for example, described it when he observed the historical transformation of office work from an integrated middle-class profession to a routine low-paid occupation more 'manual', in a real sense, than the jobs of many factory workers.[22]

The second concept, that in the automated economy workers would become scientists, depends crucially upon the multitude of images conjured up by the word 'scientist'. A scientist is not merely someone engaged in the production of scientific knowledge. A scientist, at least in the majority of 19th and 20th-century societies, has been someone highly educated; belonging to a privileged social stratum; possessing rare and valuable knowledge which gives her or him a considerable measure of economic power; performing coherent, meaningful and at least partly self-directed work. A society consisting entirely of such people would not be a capitalist society as we understand it. But, I would argue that the perpetual innovation economy is more likely to result in the disappearance of the scientist (in this sense of the word) than to cause the transformation of all workers into scientists.

The illusion that work which does not involve direct manual production is necessarily intellectual and creative is one eagerly propagated by the ideologues of the information society. But in fact, recent experience reveals a quite different reality. As the commodity production of knowledge has become more central to corporate profit-making, so the urge to improve the efficiency of workers in this field has led to an increasingly fine division of labour, and to the growing fragmentation and routinisation of tasks. Here the complex information network and database systems play a role in some ways comparable to the role of the conveyor belt in factory production. They make possible the breaking down of previously complex integrated tasks into a series of small, isolated components which can be performed by less skilled workers.

The deskilling of intellectual work has been most obvious and extreme in the development of software production over the past couple of decades,[23] but other areas such as planning, engineering and to some extent scientific research have also been affected. While robots have driven workers from the assembly line, computers have turned many areas of highly technical work into relatively simple routine operations. Computer aided design [CAD] for example, creates a situation where engineers working on a design team 'will not talk to one another, because all the information they need about a project is in the computer.'[24] Simultaneously, it is suggested that 'with CAD, engineers

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[22] Braverman: *Labour and Monopoly Capital*, pp. 315–26.

[23] I have examined this process in more detail in 'Sources of Conflict in the "Information Society": Some Social Consequences of Technological Change in Japan since 1973', paper presented to the national conference of the Asian Studies Association of Australia, Adelaide, May 1984; see also Mike Duncan: 'Microelectronics: Five Areas of Subordination' in Les Levidow and Bob Young (eds.): *Science, Technology and the Labour Process*, London, CSE Books, 1981, pp. 172–207.

[24] Fred Guterl: 'An Unanswered Question: Automation's Effect on Society', *I.E.E.E. Spectrum*, Vol. 20, No. 5, May 1983, p. 91.

tend to rely too heavily on design rules instead of considering different—and possibly better—ways to do things.[25]

The work of architects, too, is gradually being transformed by computer technology: 'For them there has been specifically produced software package known (appropriately) as HARNESS. The concept behind this system is that the design of buildings can be systematised to such an extent that each building is regarded as a communication route. Stored within the computer system are a number of predetermined architectural elements which can be disposed around the communication route on a Visual Display Unit to produce different building configurations. Only these predetermined elements may be used and architects are reduced to operating a sophisticated "lego" set.'[26]

Even within the sanctum of scientific research and development, the pressures of the perpetual innovation economy erode the remaining vestigates of intellectual independence. Scientists who, to a large extent, operated according to their own rules, and who possessed some sense of proprietorial pride in the product of their labour, are replaced by intellectual workers whose relationship to the fruits of their research is not fundamentally different to the relationship between the Ford assembly-line worker and the mass-produced car.

Consider, for example, a recent Japanese government publication which advises companies on the setting up of their own computerised information systems. The model system outlined in this document aims to increase the productivity of research and prevent duplication. To achieve these aims, both the results of the company's own research projects and information on research published elsewhere are fed continuously into a central computer from where they are made available to all sections of the enterprise. This means that the company's scientific workers must be coerced into producing all research results within a strictly regulated mould. Mass produced knowledge becomes a reality: 'The most fundamental point is that, when information is collected, this should be done in a standardised way. As well as determining the size and format of blank forms [for research reports], it is desirable that even the presentation of summaries and the use of terminology should be uniform . . . Some people have the idea that the reporting of research results should be a voluntary act by the employee. This might be so in a situation where an academic atmosphere is jealously guarded. However, it is necessary to foster an ethos in which the production report becomes the employee's duty, and a spirit of complete mutual "give and take" amongst employees is established.'[27]

The mass production of knowledge does not result in the equal de-skilling of all jobs. Some, in spite of intensive computerisation, continue to require individual judgment and initiative. What emerges, therefore, is a hierarchy of knowledge-producing occupations ranging from the

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[25] *Ibid*, p. 91.
[26] Mike Cooley: 'Contradictions of Science and Technology in the Productive Process' in Hilary Rose and Steven Rose (eds.): *The Political Economy of Science*, London 1976, p. 80.
[27] Science and Technology Agency (Japan): *Kigyo to Joho Katsudo* (Enterprises and Information Activity), Tokyo, Kagaku Gijutsucho, 1983, pp. 80–81.

highly trained scientific researcher or the long-term planner, who retains some independence of action (and identifies in part with the goals of management), to the data compiler or computer programmer whose work is as routine, as alienating and as poorly paid as that of most skilled manual workers.

Beyond that, it is clear that, even in the highly automated system, the diffusion of labour-replacing techniques is very uneven. Many jobs—particularly jobs involving personal services—continue to be relatively un-mechanised. At the same time, because the perpetual innovation economy involves continual alteration of productive techniques and stimulation of demand for new products, it requires a workforce which is highly flexible—easily taken up and easily discarded. It is therefore likely to be characterised by growing insecurity of employment and increased reliance by companies on a large pool of part-time, temporary and contract labour.

The Limits of Innovation

The perpetual innovation systems implicit in the concept of an 'information society' do not solve the problems posed by the emergence of robotics. Even as the making of knowledge becomes a mass production industry—and a vital source of corporate profits—so it too becomes subject to the forces of automation, little by little fracturing and pushing out the human element of the innovative process itself. Mandel's 'inner limit' of capitalism recedes, but does not disappear.

At the same time, the outlines of other possible limits to the development of the system become apparent. The long-term survival of highly automated capitalist economies will in part depend upon the possibility of new knowledge being produced with the speed and consistency necessary to maintain corporate profits. In the past, innovative activity has tended to occur in uneven patterns, as clusters of major inventions triggered subsidiary chains of minor innovation. The extent to which the commodification of knowledge can turn the irregular surge and ebb of innovation into a steady flow remains to be seen. Even more crucially, it remains to be seen how long demand for the products of innovation can be sustained in a society characterised by highly unstable employment patterns.

In the more immediate future, however, for as long as automated capitalist production maintains its viability through innovation, it creates new structures which expand the boundaries both of human potential and of human misery. These structures must be studied if we are to understand the futures into which the system is leading us, and the means by which we may control and alter those futures.

Two preliminary comments on the emergence of highly automated capitalism can be made with some confidence. Firstly, highly automated systems are appearing within a world economy marked by grotesque international inequalities of wealth, and are likely to amplify these inequalities. Perpetual innovation economies of the type outlined here depend upon the existence of sophisticated social structures—high general levels of education, complex corporate networks, strong state systems. Those developed nations whose economies are being transformed into highly automated 'information societies' will use their existing advantages in these areas to strengthen the ties of dominance and dependence between themselves and less developed areas. Both the products of their automated factories and the commodified knowledge of their innovation-producing corporations will help them to increase their unequal share in the benefits of world trade—a situation which will of course be blessed by neo-classical economists with the euphemism 'comparative advantage'.

Secondly, the diffusion of robotics and the emergence of perpetual innovation economies accentuates the central paradox of capitalism—that is, the gap between technology's increasing potential to liberate people from suffering, isolation and boredom and the reality of continuing human bondage to dehumanising social and economic systems.

Having in part disagreed with Mandel's views on automation, I should like to conclude by quoting a passage from *Late Capitalism* which is wholly applicable to the highly automated economy: 'The worst form of waste, inherent in late capitalism, lies in the *misuse* of existing material and human forces of production; instead of being used for the development of free men and women, they are increasingly employed in the production of useless and harmful things.'[28]

I would argue, however, that it is only if we take seriously the implications of emerging automated capitalist economies—if we recognise concepts like the 'information society' as representing something more than the mere fantasies of the ruling classes—that we may be able to comprehend and criticise these economies' misuse of technological possibilities, and to explore ways in which their productive forces can be redirected towards the 'development of free men and women'.

[28] Mandel: *Late Capitalism*, p. 216.