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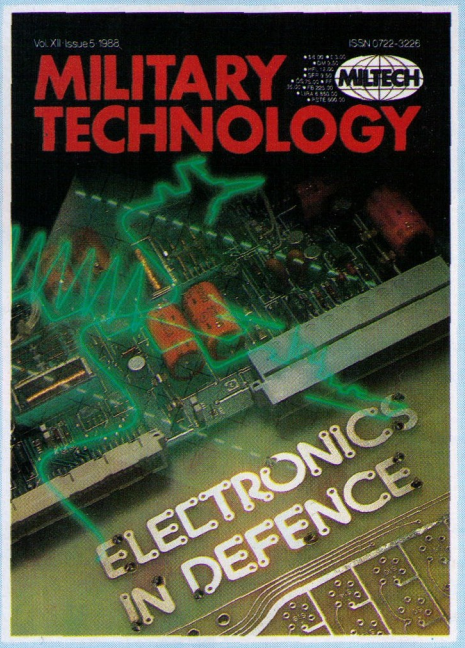

Every day the complexity of electronics increases. Every day the world of defence seems to become more dependent on such emerging complex systems. The cover of this year's Electronics in Defence issue of MILTECH, should suggest to the reader that land, air and sea forces are all similarly dependent, more than ever before, on state-of-the-art military electronics technologies for their smooth running, effectiveness and, ultimately, their survival.

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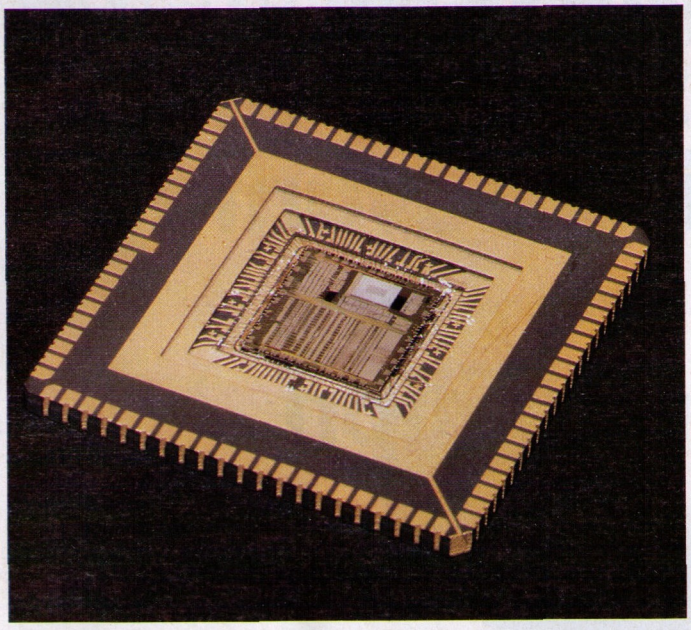


Texas Intrument's single chip epitomises the ever advancing technologies involved in the production of very high speed integrated circuits, the heart of today's computers.

Axel Pavillet

Integrated Circuits for US Defence — and the Defence of US Integrated Circuits

Since the end of WW2, US economic power has been based on industrial production capacity followed by technology, while a marked trend towards service industries is well evident today. These shifts have caused the progressive decay of the US industrial bases (a phenomenon which has given rise to the concept of the "rust belt") and, starting in 1982, a decline in the US trade surplus for high-technology products. In 1986, the US reportedly experienced, for the first time, a trade deficit in this highly-important sector.

This relatively fast decline has been mainly caused by the rapid growth of the Japanese industry, particularly in the electronic sector. This has led to an ever more evident US irritation towards Japan, due not only to highly aggressive Japanese commercial and industrial policies, but also to the fact that the US is starting to realise it is aiming straight towards a situation of technical dependence which could well, in the future, also affect its political and military independence.

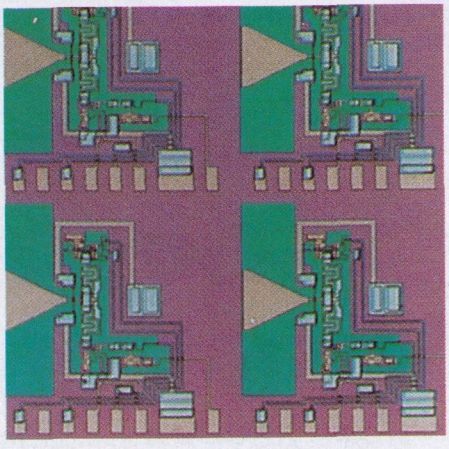
In early 1987, the US DoD published a study on the effects of the current situation in a very critical sector: integrated circuits (1). The study, which was widely distributed and commented on, was prepared, on behalf of the Defence Science Board, by a group of experts headed by Mr Norman Augustine, President of Martin Marietta. The study was commissioned in early 1986, as a direct consequence of the announcement by three of the largest US manufacturers of integrated circuits (Motorola, Intel and Mostek) that they were shutting down their production lines for dynamic memories because of Japanese competition.

The Loss of US Supremacy

The DoD study was based on eight main considerations in logical sequence, as follows:

- ☐ US forces and services rely massively on their technological superiority to achieve victory in war;
- ☐ Electronics is the area of technology offering the greatest performance advantage in defence applications;
- ☐ Integrated circuits are the key for supremacy in electronic devices;
- ☐ Mass production at competitive prices is the key for supremacy in integrated circuits;
- ☐ Mass production of integrated circuits is possible only on the commercial market;
- ☐ The US is losing its supremacy in the commercial market;
- ☐ Technological supremacy for integrated circuits will very soon belong to a foreign country;
- ☐ US forces risk having to depend massively on an *imported* technological superiority.

A dense array of super-conducting circuits typifies the state-of-the-art in electronics. But whether the Japanese will be able to outpace the rest of the world in this field remains to be seen.



Some of these arguments are well known, while others — perhaps less evident at first sight — have been duly highlighted by the study.

1) Military Technological Superiority

It is a well known fact that the US routinely aims for, (and often achieves), absolute technical superiority with its defence materiel, to compensate for the quantitative inferiority *vis-à-vis* the USSR — although no serious effort has ever been made to properly quantify this "compensation". Such an effort would, indeed, be a quite dangerous venture, in that it could compromise the traditional DoD policy of squeezing money out of Congress just by addressing the need to face the overwhelming Soviet quantitative superiority.

2) Electronics: The Key Defence Technology

It is, indeed, quite evident that for a given materiel and a given amount of money, the most important performance gains for this materiel will be obtained by investing in electronics: for instance, given a tank and some money available for retrofit, the best investment is to acquire new optronic sights and fire-control systems. This trend is clearly reflected in the US defence budget, where, on average, electronics absorbs about 35% of equipment funding. This was not true in the past, and could just as easily become untrue again tomorrow, in that software could well dislodge electronics hardware as the single most important defence technology.

3) Integrated Circuits: The Key Electronics Technology

The importance of integrated-circuit technology, particularly in digital electronic devices, cannot be disputed. In addition, the group headed by Norman Augustine had been tasked with analysing DoD dependence on foreign sources for semi-conductors, and they, accordingly, focussed attention on integrated circuits.

4) Mass Production: The Key Industrial Factor

This consideration is a little bit surprising, in that it identifies the industrial "prime mover" with a factor (production) which is not at one of the extremities, but rather in the middle, of a chain starting with R&D activities and ending with the customer (system integrator and/or final user). This situation could be explained with the highly peculiar structure of the integrated circuits industry: very high and virtually fixed costs on the one side (due to investments in R&D and automated production), and very low added value and sharply limited commercial life of the chips (two to three years for dynamic memories) on the other. The situation could change in the future, however, in that some US experts believe that the introduction of custom and (mainly) semi-custom circuits will bring the advantage back to the companies able to design and develop such circuits, as opposed to mass manufacturers.

5) Mass Production is for the Commercial, not Military, Market

Mass production is dominated by a specific type of integrated circuit: the dynamic memories (DRAM), whose technology is taken as a model for other circuits (EPROM, microprocessors, and so on). Hence, he who controls the DRAM market, effectively dominates the electronics industry as a whole.

The author is a principle armament engineer and is currently based at the French Embassy in Washington DC.

Also, the relationship between the electronics industry and defence has undergone a dramatic change. When electronics represented only 2% of the US defence budget, military contracts accounted for more than 50% of the overall turnover of US electronics companies. This situation, which made the electronics industry highly dependent on defence business, continued until the 1960s, when the trend was reversed — and it has continued that way since, with electronics representing more than 35% of the US defence R&D and procurement budget — but defence contracts account for only a mere 8% of the cumulative turnover of US electronics companies.

This shift is of fundamental importance: defence is no longer indispensable to the electronics industry, whereas electronics has become indispensable to defence.

6) The US is Losing its Supremacy in Commercial Production

The progressive verbal tense used by the report is most probably a stylistic euphemism, because all available evidence indicates that the game — if not the match — has already been lost. In 1975, the world's six leading manufacturers of integrated circuits were all US companies — but only four US companies made it to the list in 1980, and only two in 1986 (when the list included, in descending order of importance, NEC, Hitachi, Fujitsu, Toshiba, Texas Instruments and Motorola). There are only three US companies left to produce dynamic memories — and, of these, only one offers its products on the commercial market, while the other two (IBM and AT&T, which additionally have only marginal business with the DoD) manufacture these chips for their own internal requirements. The result is that within 12 years, the US was down from 60% to 45% of the world market, while Japan increased its percentage from 20% to 46%: accordingly, within five years the US trade balance in the electronics sector collapsed from an $8-billion surplus to a $8- billion deficit.

In order to reverse this negative trend, the US is counting mainly on development of micro-processors and ASIC application-specific integrated circuits, which, by definition, will be manufactured in small numbers only. It remains true, however, that the US fully realises that its industry is losing steam in virtually all sectors and that, in the long run, it risks being strangled by the lack of revenue for investment in R&D activities.

With the battle for the commercial chip as good as lost for the US, one could wonder what is going to happen with the new generation of integrated circuits specifically conceived for military applications, such as the VHSIC (Very High Speed Integrated Circuits): in this sector (which, rather curiously, is not mentioned at all in the DoD study) the US still holds a considerable edge. But given the declining industrial knowledge base, the relatively small financial return (most notably because VHSIC circuits will not be made available for export), and the need for ever larger initial investment when technologies are pushed further forward, it appears likely that the US would be able to maintain its current edge only at exceedingly high — if not eventually unbearable — costs in both human and financial terms.

7) Integrated-circuit Supremacy: Shifting to a "Foreign Country"

This is presented in the DoD study as a direct consequence of the sheer force of industrial mass production, and "foreign country" hence, means Japan. Several explanations have been put forward for this phenomenon, and these can be classified in three categories: the alibis, the contributing factors, and the true reason.

The alibis are most often suggested by the media, but — as openly admitted by the DoD study — a serious analysis shows that they are quite insufficient to explain the magnitude of the phenomenon and the speed at which it took place.

The first alibi is (allegedly) *lower labour costs.* Originally this was undoubtedly one of the reasons for the progressive "migration" of integrated-circuit production towards the Far East, but at present it is made virtually irrelevant by the (at least partial) balancing of such costs and, even more, by the widespread use of automated production.

The second alibi is the *dollar exchange rate.* As the dollar has been steadily declining for the past two years without any appreciable effect on the chip market, this factor, too, can be dismissed as virtually irrelevant. Another study on the US commercial posture in the high-technology sector comes to the same conclusions, i.e. that the de-industrialisation process has far deeper causes.

The third alibi (qualified as "not primarily important", however) is the *dumping of Japanese products* on the US market. Dumping is exceedingly difficult to prove, because the very small added value of a chip permits widely different pricing policies. This notwithstanding, accusations of dumping are the preferred argument of the US mass media, the specialised press and the semi-conductor industry.

As regards **the contributing factors,** social and cultural differences between the two countries do, indeed, contribute to Japanese supremacy. These differences are: the capital cost, in that Japan saves two to three times more than the US; and the "productivity-quality tandem" and all it entails in terms of better relations within a company and low personnel renewal rate. The latter factor is instrumental in allowing Japanese companies to devise long-term personnel training programmes and to maintain their expertise.

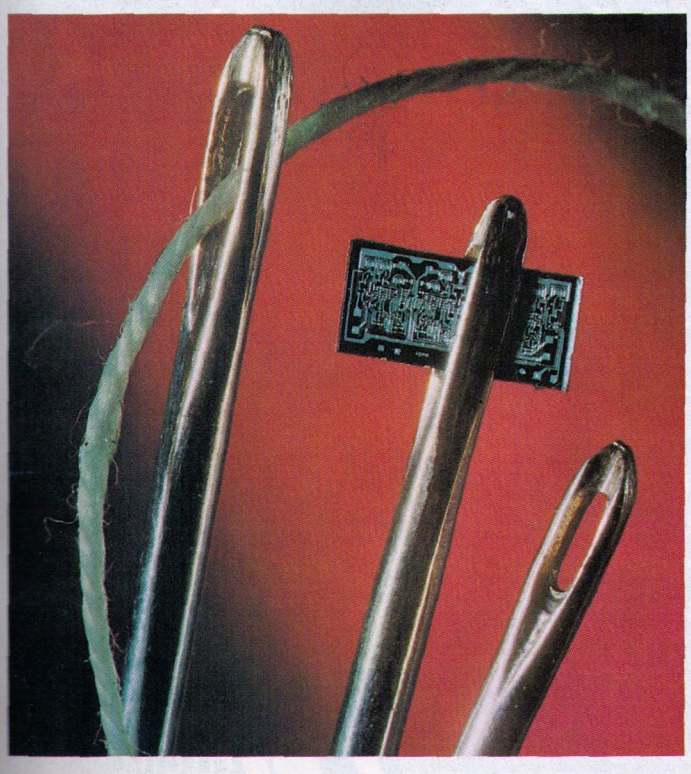
But **the true reason** is that Japan has planned, and is effecting, a long-term strategy aimed at world supremacy in electronics. Before addressing the eighth and last point in the DoD report, it is, hence, necessary to briefly analyse the Japanese long-term strategy and its implications.

Japanese Long-term Strategy

The "discovery" that Japan has formulated a coherent, long-term plan to dominate the world electronics market, and that it is very close to achieving this goal, is presented by the authors of the DoD report as the most disturbing result of their study. Surprisingly, however, this "discovery" is not mentioned again in the conclusions of the report — nor is it mentioned by those who have analysed and discussed the report in the US media. This could be due, either to a belief that the hypothesis was unbelievable or utterly false, or to the ambiguous US attitude towards Japan — which is, at the same time, their competitor, their ally and their historical victim.

The identification of a coherent Japanese strategy is based on the following factors:

- **Protection of the Japanese internal market.** The quest for the world market starts with the absolute control of one's own internal market — and accordingly, Japan has carefully protected its national semiconductor market, with custom duties and other barriers, to shield the birth and then the growth of its industry. To the great annoyance of the US, this protectionist attitude still seems to be in force today.
- **Vertical and horizontal integration.** In sharp contrast with Silicon Valley's "cottage industry", the Japanese semi-conductor industry is controlled by powerful and highly diversified concerns, which guarantee to this industry a natural market for its products and provide a dampening effect in the cyclic crisis periods. Additionally, the Japanese reaction to such crisis periods is not to try to maintain the profits — as is normal within the US industry — but rather to conquer new market shares, which are then kept when the crisis is over.
- **Low investment return.** The above-mentioned policy is practicable only if a low, actually very low, investment return is accepted: ownership by a large and financially powerful concern is, thus, a pre-requisite. US companies cannot afford such an attitude, because their top managers



The miniaturisation of integrated circuits offers an enormous density of operating elements with maximum space conservation. How much further the technology can be developed is hard to say, but the race for supremacy between the US and Japan is far from over.

will immediately be fired. It is so because on the average, most shareholders of US electronics industries keep their shares only for a few months, and then trade them away: shareholding in electronics companies is perceived as a short-term investment which must produce immediate (and substantial) returns. This is a particularly damaging effect of being based on venture capital.

- **Long-term R&D projects.** Again, in sharp contrast with US practices, Japanese R&D activities are focussed on long-term projects, and not on products intended to be offered on the market within a few months. Even more importantly, R&D activities are carefully co-ordinated by organisations such as MITI, to avoid any duplication and any wasted effort.
- **Subsidies to industry.** As a corollary of the co-ordinated R&D effort, the Japanese government directly subsidises its companies — but with a marked preference for those which are growing, and not those which are declining; such direct subsidies appear to be much more effective than the US scheme of indirect subsidies through the defence budget — a scheme which Japan would not be in a position to apply anyway.
- **Personnel training.** Last but not the least, Japan is proportionally training (often in US universities and research labs) twice as many electronics engineers and technicians as the US.

It is left to the reader to decide for himself whether the Silicon Valley scheme has become obsolete for an industry having attained full maturity, and whether the peculiar Japanese tactics and attitudes are simply due to chance, or are rather the elements of an overall grand strategy. But the fact remains that the above analysis entails one of the most poignant criticisms ever of free enterprise and *Grand Capital.*

Military Consequences

The eighth and final point of the DoD report is the direct consequence of the previous point:

8) US forces risk having to entrust their hopes for victory to imported technical superiority.

This dependence can take two very different forms, namely dependence during the *development* of a given military system, or during its *service use.*

Dependence during the development phase is mainly caused by lack of technological capabilities. In this context, US manufacturers are beginning to face a dilemma which their European colleagues have known only too well for quite a time, particularly regarding integrated circuits, to buy abroad, or to buy second choice. This is quite a serious problem for companies that want to become involved in highly ambitious projects such as SDI, or must develop very sophisticated C³I systems which are feasible only with correspondingly sophisticated microchips. The problem is further exacerbated the US procurement policy: being kept under close scrutiny by the mass media and Congress (both highly suspicious of military expenditure), the DoD must obtain the lowest possible prices for a given item from manufacturers. The negative final result is that the prime contractor will routinely select the cheapest components able to offer the requested performance — no matter whether they are manufactured abroad or not. The likelihood of finding foreign-manufactured semiconductors — not only mass-production items such as memories, but also highly advanced devices such as GaAs transistors — in US weapons systems, which was virtually zero in the past, is hence increasing.

The progressive internationalisation of the electronics components industry makes it difficult to properly define what a "foreign component" should be, or rather what the foreign content of a given component is — at production, assembly, or test level. The DoD report seems to suggest that the US does not have a reliable screening system to identify the origin of these electronics components: a separate enquiry was needed to identify those weapons systems using semi-conductors available only from foreign sources. The result of this enquiry was a rather worrying list of some 20 major systems, including, most notably, the F-16 fighter and the M-1 ABRAMS MBT.

While dependence during the development phase poses political and economical problems, dependence during the materiel service use has completely different effects, and this for two reasons: to start with, development of major weapon systems takes such a long time that, when the system enters service, its electronics components are already hopelessly obsolete; in addition, a given generation of electronics components has a far shorter "life expectancy" than a generation of defence materiel (two years as opposed to 20 years).

The problems, hence, are mainly linked to procurement. Would it be more advisable to organise a national production line, or rather to buy abroad? The first solution would be costly and restrictive — but the second could become highly dangerous in the event of a long conflict which would imperil procurement from overseas. It would be necessary to stockpile sufficient strategic reserves for use while a national production line — for which tooling and expertise will no longer be available — is again organised.

These considerations tend to justify the US penchant for procuring at home rather than from abroad, rejecting offers even from their closest allies. This is no longer the rule, however. Due to the progressive disappearance of national production, US defence manufacturers are increasingly becoming dependent on supplies from abroad (not only Japan, but Europe as well) for "obsolete" circuits originally developed and manufactured in the US. Is the US dependence going to become omnidirectional?

For the time being, it is Japan that really matters. The Japanese hegemony in industrial electronics is placing the US in the same position *vis-à-vis* Japan, as Europe has always been *vis-à-vis* the US. In turn, European countries are increasingly relying on Japan to the detriment of the US — which, as long as Japan's political weight remains far lower than its industrial and economical weight, is, indeed, in the European interest. What really worries the US, though, in addition to its dependence on Japan, is the risk of losing control over technology transfer to the East: the US reaction to the "Toshiba affair" is highly indicative in this respect.

The Study Group Recommendations

The DoD report sharply criticised the adverse consequences of free enterprise, and is hence anti-liberal in nature: no surprise, then, that in its conclusions it recommends a classical State intervention policy. As openly admitted by a Pentagon official, such a conclusion was easily foreseeable, in that most members of Norman Augustine's group were, or had been, DoD civil servants.

The proposals by the study group range from establishment of a State-supported industrial consortium to the creation of a management council for the whole of the US semiconductor industry and to financial support for universities. The two most interesting suggestions are the proposed Sematech consortium and the concept of State financing of R&D activities to lower production costs.

The Sematech Consortium

This proposal calls for the establishment of a consortium, organised by industry and financed by the DoD, tasked with the development and production of a new generation of dynamic memories (identified as "technological prime movers"). In practice, however, things are a little bit different. The participating companies (all members of the Semiconductor Industry Association) have so far agreed only on a joint study of manufacturing techniques — ruling out from the very start the truly innovative aspect of the original proposal, i.e. joint development, production and marketing of a new circuit in an effort sharing all the resources of the different companies. Additionally, there is no certainty that DoD financial support will be maintained at the required levels, and — as was already the case for other similar ventures — complex formulae had to be found to circumvent anti-trust regulations.

Congress has two main worries about Sematech: on the one hand, it is suspected that the participating companies could "appropriate", for themselves, the technologies developed by Sematech with taxpayer's money, and would not share them with other US companies; on the other hand, it is feared that such technologies — once applied in production machinery and integrated circuits — will be quickly transferred to foreign competitors through export. From this point of view, the success (or otherwise) of the venture appears to be highly dependent on the speed at which technologies will spread — a speed which should be, neither too slow, nor too fast. This promises to make the industrial aspects of Sematech a very sensitive affair.

But to convince US manufacturers to actually join forces remains a rather difficult proposition, and the first Congress fear is, hence, perhaps unfounded: the Microelectronics & Computer Technology Association, established five years ago along nearly the same lines, appears to be heading towards collapse because of the progressive withdrawal of the participants fearful of future competition from their own joint subsidiary.

This fear — i.e. the prospect that Sematech could well become a competitor to all its individual members — is only one of several factors which have delayed the creation of the joint consortium. In fact, asking the DoD to support the *civilian* semi-conductor industry is a contradiction in terms: some observers fear that industry, strengthened by government financial help, would eventually twist Sematech out of its original purpose — which would lead to a defence electronics industry totally dependent on military contracts, as is already the case with the aerospace and naval shipbuilding industries. The proposal to have the Pentagon involved in industrial policy is a direct result of the absence of an Industry Ministry in the US governmental organisation.

DoD Financing for R&D Activities

The study also suggests that the DoD should finance research aimed at developing better manufacturing methods, in order to both lower costs and improve the quality of integrated circuits for military applications. Rather paradoxically, there is also the suggestion — although this suggestion is not included in the conclusion — to use commercial components (cost and quality being the very points in which commercial production currently has the edge). But to increase the use of commercial components would mean becoming even more dependent on Japan (at least in the short

term), while at the same time further damaging the position of the US industry. Another study (the Perry Report) maintains, however, that this would be a sound policy, producing substantial savings ($800 million in 1990).

In fact, when a given integrated circuit is available in both civil and military versions, the differences between them are linked more to the casing and the quality control testing than to production characteristics as such — this being the result of rules established in the 1960s, when quality of mass production was not yet perfectly mastered. Accordingly, the cost ratio between a highest-quality commercial component and its military versions can vary between 1:1 and 1:15.

A compromise will have to be found between these two approaches, which are in conflict with each other in the short term — but not necessarily so in the long term: the financial advantages stemming from an increased use of commercial components could be invested to finance research in military components. Also, the defence establishment — which can no longer control the semi-conductor industry — has, in the long term, a logical, keen interest in exploiting to the maximum the available semiconductors made by industry.

Further Results of the Study

The Fairchild Affair and Sanctions against Japan

The Fairchild affair and the sanctions against Japan, appear to be more, or less, direct consequences of both the study itself and the way it was received and extensively reported on by the US mass media.

Fairchild — the world's Number Two semiconductor company in 1975 — was subsequently acquired by the French company Schlumberger, without an eyebrow being raised (in the DoD's view, France is not "a major factor in the hi-technology field"). The announcement, in early March, 1987, of an agreement for the sale of Fairchild to Fujitsu was highly inopportune, in that it came at the very moment the US media were echoing and debating the government study, released in late February. Official fears and reservations were, in any case, focussed more on the financial gains Fujitsu could expect from selling main-frame super-computers on the US market, rather than on the Pentagon's further increased dependence on Japan. The legal instruments available to the US Administration to block the deal were rather weak and disputable, and Fujitsu would most probably have won the case in US courts should it have elected to resist: but the Japanese, faced with government and widespread media pressure, preferred to bow down and withdrew their offer. Fairchild was eventually acquired by National Semi-conductors — at a far lower price than originally offered by Fujitsu.

One of the most important legal consequences of the affair is that the US Congress is now debating a law which will give the administration full legal authority to block similar deals when "they are not in line with the economic interests of the US, or its national security". Under the double pressure of the mounting US deficit and the rising yen, one could guess that quite a number of "Fairchild affairs" are around the corner.

The sanctions against Japan have been officially declared because of an alleged Japanese failure to comply with the terms of a previous agreement, which engaged Japan not to sell integrated circuits on the US market below a certain minimum ceiling price. The US have played plaintiff, prosecutor and judge in this affair — and it is, hence, rather difficult to ascertain whether, or not, the Japanese had, indeed broken their engagements. In fact, it would appear that the Japanese had formally respected the agreement — although they were, perhaps, a little bit too willing to tolerate the negative consequences of the price crash on the internal Japanese market (which, in turn, had been caused by reduced sales on the US market).

The nature of the sanctions — additional import duties on complete products, but not on the "chips" as such, in order not to affect US companies using Japanese-manufactured semi-conductors — confirms that US dependence on Japan is not confined to defence, but involves the US industry as a whole (there is no export of Japanese defence products towards the US, and thus, as regards defence, the additional import duties are meaningless). This largely explains the centralised planning attitude the US Administration is increasingly taking towards the national semi-conductor industry, although the existing structures are still inadequate for the task. But change is taking place.

Any Lessons?

We are, thus, forced to conclude that integrated circuits for defence can well play a role in the defence of integrated circuits: this "double-edged" policy is, indeed, very "US-style", with the emphasis being placed on the goal of military independence (rather than on economic protectionism) in that the former is much less controversial.

Given the extremely high degree of inter-dependence between the Western economies, however, one wonders whether independence at the design level is not an illusory aim, even in the military sector. Such independence is rapidly becoming unaffordable even for the US, in that it demands larger and larger R&D investment. Additionally, better co-operation between the Allies implies both an equitable sharing of R&D tasks and cross purchases of materiel and components — indeed, such cross purchases are an important factor in the stability of an alliance, because they make that alliance's members increasingly dependent on each other.

As regards defence of industry, one could also wonder whether the approach, apparently selected by the US Administration — which, in practice, amounts to copying foreign economic planning — is, indeed, a realistic solution. Centrally controlled economy and planning are concepts directly at odds with the US mentality and with the independent spirit displayed by the most dynamic part of the US industry, which regards subsidies as an adictive drug and State patronage as a vicious challenge to the shareholders' sacred rights.

In reality, one of the main causes for the current, unsatisfactory situation in the US electronics industry is that production has not been given the level of priority it deserves — in both capital investment and mental attitude. The progressive decline of production capability has triggered a parallel decline in the corresponding expertise and, eventually, at least a part of the ability to innovate will be lost as well. Additionally, when waging a commercial war, production should be regarded as the economy's army: the navy and the air force — technology and services — can win battles, but only the army can take and hold enemy territory. This is a lesson all countries entering the post-industrial era should ponder with great attention.

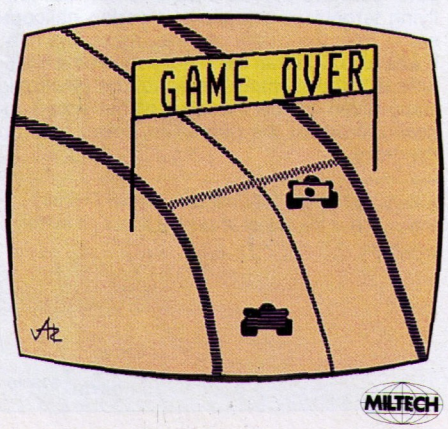
Finally, the publication of several US studies on the decline of the United States and the solutions to be adopted seems to indicate that this decline is a generally acknowledged fact — which does not necessarily mean that solutions to reverse the trend can, indeed, be found.

The Coming Battle: Data Processing

Electronic chips are sometimes referred to as "industrial rice", because of their main area of origin. Actually, however, it would be more accurate to refer to them as strategic minerals — the more so because these "minerals" can be put to work only after being "treated" by software, whose importance in relation to hardware is continually increasing.

Factors such as the Japanese programme for a fifth-generation computer, the Fairchild affair, or the remarks by Makoto Kuroda, MITI's number two man (he declared to a US audience that US attempts to sell super-computers, no matter how good in quality and/or price, were a pure waste of time), all indicate that Japan is trying to apply, to the data processing market, the same highly-successful strategy it perfected for the hardware market. In this sector, however, nothing can be taken for granted yet: Japan's relative weakness in software being well known, even Europe could have a chance (although controlling the chip market is a very good starting point).

Thus, the US and Japan are engaged in a race for new technologies which are already completely transforming our world. Japan may already have won the first part of the race, and US fears for the future might be depicted as:



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