SESSION 2

Process and product innovation in the agricultural mechanisation

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Economic Development, Agriculture and Mechanization

A. Agriculture Economics and Mechanization

1. Among all those who concern them-selves with the problems of agriculture, there are many who still feel that an answer has yet to be found to the question of whether or not farming should be considered an integral part of an economy, to all intents and purposes subject to economic laws, or whether it should be regarded as entirely independent and, therefore, not governed by those laws. The question is an old one that crops up every ti-me problems in the industry call for new methods to solve them or do not come within the logical patterns normally applied.

The answer, with which I personally agree, is that the development of the farming industry cannot be tackled, any more than can that of those areas that pro-vide its inputs, such as mechanization, un-less we bear in mind that *agriculture is in every respect part and parcel of the economic system in all its complexity.* The fact that farming presents certain features that make it different from other industries, largely due to the biological substrate on which it operates and with which in interacts, is not sufficient to divorce it from general economic principles. In other words, it is not an anomalous sector, governed by special standards, but merely one of the many factors that go to make up an economic system.

Once we accept this premise, there follow from it various consequences that will become evident as we attempt to trace the scenario within which, in my opinion, agriculture, and therefore mechanization in that industry, is likely to develop in the near future.

2. Mechanization has been one of the main driving forces behind agricultural progress, and its function has, in the course of time, developed more and more, hand in hand with changes in the industry and in the economy as a whole.

Initially seen as a means of replacing labour with machinery, the introduction of machines in farming is therefore essentially comparable to what happened in other sectors.

Seen as a production factor, *machines may be regarded as a capital asset,* no less than natural resources, the land, labour, or managerial skill; and the pattern that emerges from this is a very simple one, though it makes it possible to pinpoint so-me important features. However, it must be borne in mind that the considerations we shall be putting forward may often pre-sent — in a contrasting, indeed at times contradictory way — two distinct levels, the micro — and the macroeconomic, each generating its own line of argument, and that it will therefore be necessary to make an effort to reconcile the two approaches.

3. An initial aspect is the *replaceability of labour with capital equipment.* To *so*-me degree, and depending on the type of production technology employed, on the aims and on the constraints, labour may be replaced by such equipment, while production remains constant. As regards the production system, this result is achieved through the optimization of production factors, both in individual companies and in the industry as a whole; but it may pose a series of problems externally, due to interaction with the rest of the economy, as previously mentioned. From this it follows, for example, that there are certain behavioural patterns that at times appear to be inexplicable from the point of view of corporate efficiency.

For instance, we have the over-mechanization of many farming companies, which acquire machinery, based not on the average use they make of such equipment, but on peak requirements arising from speci-

fic operations or certain junctures in the production cycle.

Outside the farming industry and within the context of the rest of the economy, we encounter all the complex problems associated with the mobility of labour and its tendency to gravitate towards more remunerative and/or less arduous employment.

Thus, there is an overall shrinkage in the agricultural labour force, both at individual farms and in the industry as a whole, so that plans have to be made to replace manpower by machinery.

4. Another point that emerges from this line of thought is that, *since machines are a capital asset, they are also, for those who use them, an investment.* Thus, the economic situation may be responsible for inducing farming entrepreneurs to bring for-ward or delay replacement of their machinery and equipment in the light of purely financial advisability, rather than for technical reasons or to optimize production. Hence we may find the narrow view of capital expenditure running counter to operating efficiency, and the decisions taken by the farming industry in given situations may also be interpreted as the sum total of individual decisions. For example, during the years when, throughout the European Community, inflation was the dominant economic factor, especially after the second oil crisis at the end of the seventies, the drop in disposable income, on the one hand, and the need to invest any money capital available, on the other, resulted in decisions for which there cannot be any other explanation.

5. Then there are the technological aspects. Capital equipment has, of its very nature, a high technology and innovation content. Moreover, in the area of agricultural mechanization, this fact has, throughout the past and right down to re-cent times, been strikingly evident. Currently, however, it somewhat receded in-to the background because of sensational developments in the so-called biotechnologies, on the one hand, and equally rapid change in information technology, on the other. This innovatory function of technology has a twofold effect, both as an agent of internal change and as a means of adaptation to external developments. Thus, at the same time, it directly affects the need for innovation in other industries — suffice it to remember biological re-search aimed at obtaining produce that will stand up to mechanical harvesting — and stimulates reaction to changes taking place in the biological and chemical fields etc.

We may therefore conclude that the technology content of capital is likely to influence production techniques, and therefore the relationship with other inputs, production structures, and corporate organization at the "micro" level, as well as, in the final analysis, the whole agro-industrial system on the macro-economic scale.

B. Scenarios

6. The ability to adapt and, even more, the degree of response to the interactions that develop with the rest of the agri-cultural system, are a key factor when it comes to analyzing the relationship between the economy and agriculture.

This is even truer and more important at the present stage of development of the industry, in which the speed of change and the economic turmoil, once typical of other sectors, now seem also to have be-come a feature of farming, thus causing a shock reaction in an industry that used, traditionally, to be much slower to deve-lop. It is therefore worth trying, very quickly, to pinpoint the main factors in this present stage of agricultural development, bearing in mind that these will only give us brief summary indications. For a more complete analysis of each individual aspect we shall have to consult the voluminous literature on the subject.

7. Since half-way through the eighties, the farming industry has been having to face up to a problem rarely known in the

history of mankind. For, in the past, the main purpose of agriculture was to pro-duce sufficient food to meet man's growing needs.

That meant having to deal with shortages. *Nowadays*, however, with the exceptions to be mentioned later, *the problem would seem to be just the opposite: in other words, the problem of managing and agricultural system characterized by plenty.* Of course, it has to be remembered that, taking the world as a whole, there are vast areas whose inhabitants are affected by malnutrition or famine, while excess production are a feature of the industrialized, that is the richest countries. Thus there exist, side by side, two totally different situations that nevertheless continuously interact: one of insufficient sup-ply and the other of excess. The prospects for this awkward relationship are uncertain; yet undoubtedly, at least as regards the industrialized countries and that part of the world that is able to pay for its requirements, the problem of a fair part of the nineteen nineties will probably continue to be how to manage surpluses.

Confronted with this problem, which should perhaps more correctly be restated as the flexible management of agricultural production, the customary economic policy measures are entirely ineffective, and reorganization of the system is required — for it is from this situation that most of the farming industry's difficulties stem.

8. The worldwide imbalance as between supply and demand in the area of farm products may be said to be due in part to traditional aspects of agricultural production, which has always been marked by fluctuation and which, for that very rea-son, is a phenomenon that is liable to change. Nevertheless, it is also partly the consequence of overproduction by the system. Indeed, this fact was borne out at the EEC, when production quotas were introduced to reduce milk surpluses, the undesired result of which was to create, first, a beef, and then a grain glut. This explains why it is best to deal with the problem as a whole, rather than by partial re-medial action that only shifts overproduction from one area to another. The short-term effect may well be to enable subsidies to be cut, but nothing will have been done to solve the problem of agricultural surpluses in industrialized countries, which is of a structural rather than episodic nature, or an economic trend.

9. The situation is perhaps more serious than in the past because of the simultaneous occourence of certain phenomena. *Above all, changes are taking place in the demand for agricultural food products.* The phase during which per capita consumption increase has come to an end, while the phase in which demand has depended on precise qualitative aspects such as protein and fat content, appearance, size, etc., is also drawing to a close. At the present time, demand is concentrating on a different kind of quality, such as the naturalness or health-giving properties of food, associated with the concepts of fitness and health, already recognized and well-known on the markets of the USA, Germany, or Great Britain; or, again, the-re is the trend in favour of "ecological" or "biological" foods, with all the ambiguities that such definitions may involve. Because of the halt in population growth and per capita rates of consumption, there is also a tendency for demand to cease to grow in quantitative terms, while a different type of demand is taking shape that will have repercussions on production methods, and therefore on the technologies employed and the quantities required.

10. *A similar trend is followed by another type of demand,* directed at agriculture by the consumer, which no longer calls for *goods or foodstuffs,* but *environmental services, open spaces in which to spend leisure time in other words, "naturalness" in this sense.* The main phenomenon here is therefore growing ecological sensitivity, a fact that cannot simply be dismissed as a passing whim, but must be treated as part of a development that

hinges on two aspects. The first stems from living conditions in large cities, where people have lost touch with an environment whose praises are often sung and which is felt to offer a much better life. The second lies in higher incomes, which bring with them great spending power and ability to diversify in meeting ones need. Thus we have moved from satisfaction of the more basic requirements, associated with lower income levels into the area of luxury commodities, which are, however, felt to be equally necessary, and so must be satisfied. There is thus a call for naturalness, applied both to food and to the environment. Associated with this attitude are regrets for a past that people never knew and rejection of the present, as they flee towards an improbable future.

However, it would be a mistake to think that the citizen and consumer is prepared to go into reverse and retrace the path of evolution. What in fact he is asking for is a reinterpretation of eating and environmental concepts that, while such things as comfort, hygiene, and modern standards of security are taken for granted, will combine the latter with the requirements of naturalness, for which he is prepared, not only to wage political battles, but on which he is also prepared to spend an in-creasing share of his income.

11. Another highly significant factor, within the framework of current change, is the *internationalization of the world market for agricultural products.* This definition may be taken as meaning at least three different types of phenomena, all of them highly relevant to the subject under discussion. The first is the gradual de facto development of a single, huge world market for agricultural products, especially the commodities. It is a market that at-tracts products from various countries, and a degree of interaction takes place that at once time would never have been thought possible. In fact, this means an accentuation of the effect of structural over-capacity and, at the same time, the need to produce for this large market, rather than for a more limited local a national one.

The second phenomenon is the internationalization of models of consumption, and therefore the development of highly homogenous demand, no longer on a national scale, but for social classes, age-groups, and ways of life that are the sa-me worldwide.

The third is the internationalization of the food industry. For example, as regards mergers and acquisitions, which are so well-known and self-evident that they call for no explanation. For the establishment of large multinational corporations in various countries and of groups operating all over the world are only further incentives to standardize demand, which the farming industry has to get to grips without losing time.

12. Hand in hand with all this there has been a rethinking of agricultural policy — in other words, of that area of economic policy concerned with the farming industry. Policies began to be redefined when it was realized that they were becoming more costly, especially in the more highly industrialized areas of the world, and that, moreover, agricultural subsidies were having a negative effect on the world market. Recent OECD estimates indicated that such subsidies were equal to 25% of the value of agricultural production in Japan, to 19% of such production in the EEC, and to 16% of US farming output. Moreover, this financial aid has often led to trade war, costs the taxpayer money, and is but an inefficient way of achieving the policy objective of bringing incomes in agriculture closer to the levels enjoyed in other sectors. The will to reduce subsidies does, theoretically, exist both in Europe and in the USA, but the obstacles standing in the way of a U-turn are considerable, and no concrete progress has, for example, been made within the frame-work of GATT, with the conclusion of the Uruguay Round expected in a year's time.

13. As regards the EEC, it may be said that, beginning in 1984, policy began to

move along the following lines: a) a general reduction in real prices, obtained by pegging the latter at current levels, b) the imposition of production quotas for the main surplus-prone products, c) a cut in the compensation paid to producers in ex-change for their willingness to withdraw their products from the market, and d) the introduction of stabilizing mechanisms linking prices with the supply/demand ratio.

At the same time, the Community has attempted to give a fresh boost to structural changes by pursuing a policy of "de-coupling": that is, by doing away with the link between the size of subsidies and the amount of production. In this way, it is felt it may be possible to reconcile the objective of improving agricultural incomes with the need to obviate the negative effects of expensive surpluses for which it is difficult to find an outlet on the world market.

The EEC "set-aside" regulation, for example, should be all part of this trend, since it aims to free arable land by taking it out of production and allowing it to lie fallow. Indeed, the significance of this decision is fairly clear, for the Community pays an indemnity to farmers who agree of their own free will not to cultivate a certain area for a given period. Alternatively, farmers may receive a smaller indemnity by undertaking to use the same land to plant forests or for pasture — that is, for less intensive uses. Thus the reversal in policy trends could not be more complete, while nevertheless sticking to the fundamental aim of improving farmers incomes.

14. Lastly, the EEC has decided to include in its more recent structural planning yet another guideline by introducing *incentives to use production techniques with a lower impact on the environment.* Here, too, we have a significant innovation in Community policy. For, in the past, the later was never particularly concerned with this aspect, being content merely to control the finished product. Now, however, the matter of the technologies to be employed in farming is being addressed head-on, which adds up to a significant change, probably due to the more important role now being played by environment, since the latter was enshrined in the 1986 Single European Act, thus becoming a factor in EEC policy on a par with agri-culture, which, of course, has figured ever-since the Treaty of Rome was first signed.

On the other hand, the path of environment-friendly technologies has been pursued by various countries, both within the Community and outside it. In other words, as with the food industry, increasing importance is being given to "softer" production technologies, so that the sa-me trend exists in both stages of food production: first in food-processing and now in farming proper too.

15. *This trend towards softer production technologies has been made possible by technical developments of two kinds.* The first lies in a better understanding of the mechanisms underlying the various stages of production, leading to optimization of the whole process. This has ma-de it possible to improve techniques, thus reducing costs as the final result of action taken on the means to be employed — in other words, by having better tools to do the job in hand.

The second has begun to have a pro-found effect on the biological substrate, on which the agricultural process takes place. This has been the field of the so-called biotechnologies, with specific reference to advanced research in genetics, but also in the area of biological methods for combating parasites and for protecting products against pathogenic agents.

According to the forecasts of experts in the industry, agriculture is still witnessing the maturity phase of innovations introduced in the past, and has therefore been engaged in the optimization of those innovations. In the last years of the next decade, and even greater intensity in the first years of the next one, we shall, however,

be seeing a whole series of highly significant new developments in farming.

16. By way of an example, and to move much closer to the present day, there is now a real and imminent prospect of being able to have substantial supplies of somatothropine, a hormone, obtained by the same process of genetic engineering as that used to produce insulin for human use, that could, it is estimated, increase milk production by anything from 15 to 25^{0}7o. That means we are in the presence of a far-reaching innovation that may ha-ve a significant effect on many aspects of animal husbandry, since the feed requirements of cattle will be different from what they are at the present time, and thus also on the structure of farms, land use, and agricultural machinery. On the other hand, it will be possible to obtain the same quantity of milk with fewer head of cattle: in other words, herds of the same size would produce much more milk, which in turn would mean more problems with surpluses.

C. A New Approach to Production

17. The overall scenario now taking shape indicates that the farming industry will be faced with considerable problems of adaptation in the near future.

Expansion of the market, which, as regards the EEC, is likely to be the result when the Single Market comes into force in 1992, and policy changes under way throughout the world are bound to increase competitivity among producers.

From this we may deduce a number of trends towards adaptation. The first, of a more conventional kind, lies in the continual drive for optimization in the use made of the means of production and, therefore — of particular interest to us — of machines. In the case of the latter, it will become increasingly important to en-sure that size and design are best suited to meet farming needs, with the accent on the mutual adaptability of the machine and the farm using it, and taking into ac-count all the parameters that come into play in striking this complex balance. The first and most obvious factor is the relationship of the machine to the size of the farm. In many cases, the surface area to be managed is, however, much larger than that of the average farm. Joint use and management of machinery thus becomes necessary in order to achieve the optimal operating ratio.

Another problem involved in striking the correct proportions is the ratio between the amount of labour available to a farming company and its machinery. Here, too, we have situations that are theoretically easy to solve, but that, in practice, are far more complicated. In other words, the replacement of labour by capital is in fact far more difficult to effect with than people think, since for one thing, one is dealing here with whole units.

18. It is therefore against this back-ground that we find empirical solutions being adopted in the various countries where problems of this kind are being grappled with. The most obvious one is the pur-chase and management of machines through co-operatives, or at least by companies of the simplified sort. In some coun-tries, however, other models *have* been created to tie in with local situations, such as the "Maschinenringe" in Germany, of forms of "entraide" in France.

A feature of this area of development is the *emergence of agricultural service companies,* in which the entrepreneur, who may or may not be a farmer, supplies service for farmers who need him against payment. In this case, the farm delegates some of its functions to an external organization, being content merely to purchase such services. This phenomenon which is expanding strongly in Italy, allows the farming company greater elasticity and makes for the more effective running of machinery by the service organization.

Naturally, it also means diversifying the types of machines offered by the agricultural machinery manufacturers to meet the

requirements of the dual market thus creat- ed, and so we see the birth of two differ- rent, albeit complementary R&D trends.

19. Factors that need to be assessed wit more care than in the past include the financial aspects of capital expenditure which farms in general, especially family businesses, tend to underestimate.

The decision taken by a farming com- pany to invest in equipment is strongly conditioned by the financial basis of the farm and of the family, given the fact that most farms are family businesses. A ty- pica] feature of such enterprises lies in the fact that their immediate concern is not so much with maximum profits as wit their own incomes. Consequently, decisions follow different parameters, and this explains the close link between income and the likelihood to purchase machinery. In addition, decisions are influenced by ex- ternal factors, such as inflation, for the reasons already stated.

The problems involved in the correct management of a farm are therefore of- ten dealt with in an apparently contradic- tory manner, which calls for special atten- tion, among other things, from the machinery manufacturers.

20. *But increased competitiveness involves more attention not only to the optimization of processes, but also to the market — that is, to the changes currently taking place in demand.* For the farming industry it is going to be more and more important to meet new kinds of demand in such a way as to command higher prices for its products, or else to maintain higher prices for its products, or else to maintain higher market shares in the face of competition from producers in other countries. Obviously, this competition will, in its turn, attempt to get a foothold in the richer, more profitable market segments. Agriculture, therefore, must succeed in producing what the market wants, if possible adapting itself even quicker, so as to be ready to supply a given product the very moment consumer demand for it materializes.

All this is in line with market trends to-wards quality agricultural products, which offer new features and are more diversified. By this I mean especially the products that appear, to the eyes of the consumer, to be more health-giving, or nourishing, etc., to which reference has already been made, or that are in some way produced more "naturally" in the sense that word is understood by the consumer.

Becoming established in this market segment, which seems to be developing strongly everywhere and serves essentially the upmarket consumer, will call for changes and the ability to adapt production techniques and, consequently, mechanization.

21. This new demand focused on agriculture is, however, also directed at environmental services and non-productive land use, as is the "set-aside" policy. As the result, farming companies will also have to take into account the fact that the production factors, including machines, will have to be used differently from the way they once were. Mechanization has therefore to cater for farming activities of the extensive type, that is for production methods and techniques that involve low environmental impact. To this end, the common link is the biological factor, or at least the tendency to go for products that meet the consumer's "naturalness" requirements. Machines therefore have to be developed that meet these needs: for example, that perform fewer runs over the ground, or that, in the course of the sa-me number of runs, perform several operations. As regards spraying with insecticides, optimal distribution of such pro-ducts could, for instance, reduce the quantities used.

22. *Another interesting and stimulating area of research is concerned with machines suitable for use in conditions of extensive production,* which therefore cost less to operate and are able to take care of large surface areas. This is a new problem, because, up to the present day, the intensity of mechanization was in propor-

tion to the intensity of cultivation, which meant that higher costs could be covered by higher yields. Nowadays, the problem is related to set-aside and to the need to keep large areas of ground out of production without, however, neglecting them: in other words, in a standby situation that calls for new solutions.

Far more advanced, on the other hand, is the development of agricultural machinery for non-productive uses, as in the ca-se of gardening equipment and hobbies in general that, while derived from "professional" equipment, has been adapted to other purposes.

The creation and management of green areas, formally used for agriculture, but that are now given up to environmental purposes, ranging from recreation grounds, golf courses, public parks, etc., right down to natural "bases", call for parallel development in machinery, and thus represent an aspect of demand in its own right.

23. To sum up, it may be said that the overall need for innovation, whether in products or in processes, also involves me-chanization, which has to keep up with such innovation. On the other hand, as we have said, it is in the very nature of capi-tal equipment that it be associated with this requirement.

While, for the time being, there seem to be no substantial novelties in the form of innovative products, the subject of the evolution of production processes is far more stimulating. For, in the course of optimizing the present, more conventional processes, the constant quest for competitiveness ensures continued improvement in the efficiency of machines. Even more promising is the introduction, in agricultural mechanization, of technologies such as electronics, that can contribute towards the achievement of objectives by lowering costs, optimizing the quality of work, and reducing tedious human effort.

24. The capacity for innovation may find a substantial outlet in research on, and the manufacture of new machines based on "softer" technologies, able therefore to reduce, for example, the amount of chemicals used by replacing them with less harmful mechanical methods. Yet another area of interest, from quite a different angle, concerns the current introduction of such methods as biological pest-control, or biotechnological and genetic modifications, which will call for simultaneous adaptation in the field of mechanization. Lastly co-me uses of the environmental or less intensive, agricultural type.

The scenario is thus one in which the farming entrepreneur will be becoming more and more demanding towards the machinery he purchases, because he will apply ever stricter criteria in assessing the value of his investment, and he will be comparing what his machines can give him in exchange for the money he has spent. For, from the moment it is conceived, the machine must be regarded as a product that has to meet the requirements of the market to the maximum extent possible. It must therefore be able to replace human labour, but also other capital, with greater efficiency. It will have, on the one hand, to be in line with technological developments and the progress achieved in machine manufacturing technology and, on the other, with current developments in agriculture.

All in all, a highly stimulating scenario, especially bearing in mind the competitiveness of the industry — a competitiveness that, in the coming years, is destined to become keener.

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The industrial process of implementing innovative ideas to farm machinery

The conversion of innovative ideas in-to practical products is a very complex

process, concerning not only the future of industrial companies, but also the development of the whole national economy. There is no growth without technical progress. The following overview is based on 11 years of my own work in industry, experience from industry consulting and so-me relevant publications.

Figures of the agricultural machinery and tractor industry in the FRG.

The West German agricultural machinery and tractor industry seems to be a good example for innovative product development and therefore I would like to introduce you to some statistics, listed in figure 1. The "Landmaschinen — and Ackerschleppervereinigung (LAV)" associates all big companies. The value of the to-tal production of all LAV-companies is about 7 billion DM (3.5 billion ECU), where both, tractors sold in the domestic market and other agricultural machinery come to 1.4 billion DM each — that is together 40^{0}7o. About 60% of the production value is exported. As a consequence of this high export volume, the FRG. holds the third place in the tractor world market and the first place for other machinery, figure 2.

The production value of all LAV-companies has been achieved in 1988 by 42.400 employees giving a mean turnover of 164.000 DM (about 80.000 ECU) per employee. Due to some companies without membership in the LAV, the real production value of the FRG. is about 10% higher. The non-members are mainly manufacturers of on-farm machinery and implements.

Live-cycle of products and sources for new ideas

The number of totally new developed products is comparatively low. Common practice is mainly to improve present products by innovative development. Figure 3 shows the typical live-cycle of a machine from the industrial point of view. Starting from the introduction of the product, the number of sold units per years has the typical shape of ascending, holding and declining. When reaching the culmination of the A-labeled product, further development towards the A + product must be-gin. Otherwise a decrease in turnover will follow.

Particularly in the beginning of the development of new or enhanced products, many good ideas are required. Figure 4 pointed out, where they might come from and how additional ideas can be produced. In this context the result of an older injury among 139 machinery producing companies is presented in figure 5. About 70^{0}7o of all ideas came in those times from customers, exhibitions, conferences and competitors. Impacts from scientific re-search are included in the remaining 30%. Regarding our branch of industry nowadays, I feel, that research has moved to much more importance.

Contributions from scientific institutes

The collected ideas must be analysed and evaluated by an advanced engineering group prior to the start of product development. An important step in this work is the balance of advantages and disadvantages (pros and cons). This shall be demonstrated by two ideas, generated by re-search work. The first example shown in figure 6 concerns a tire inflation remote control system. The fundamentals of this proposal have been worked out by different research institutes. The first commercially offered system will be shown at this years AGRITECHNICA at Frankfurt.

The second idea is still in the stage of discussion: the change in chassis concepts of utility tractors from rigid block-type to frame-type, figure 7. In order to reduce the strategic risks, we developed at my institute in the years 1984-1988 the "Munich

Research Tractor" with a frame-type chassis (Renius/Kirste). The elastic suspension and shielding primarily of the engine — as well as the transmission if possible — enables a great reduction in noise — e.g. 10dB(A) less stand-by level. Evaluating our practical experience, this is of appreciable benefit for both the user and the environment. Furthermore, increased flexibility to arrange and mount components is achieved. The customer gets bet-ter visibility, lower machine net weight and more convenient space for attachments. The flexible arrangement of components simplifies service and repair work. Finally, the frame can be utilized for cost-efficient integration of front loader and front hitch. These advantages are ballanced by some disadvantages, where the big development step can be seen as the most important one.

As already shown before, many innovations are based on new ideas coming directly from the customers, e.g. the 40 km/h tractor versions. High speeds however created some new problems mainly vibrations on the road, often intensified by the masses of mounted implements. This problem however has been early investi-gated by research institutes, e.g. by Goehlich et.al. in Berlin, leading not only to a first suspended cab concept, but also to interesting compensation techniques, which will result now in a first commercially available solution on the coming AGRITECHNICA '89.

Another example for such an innovation by cooperation can be seen in the up-coming automatic front wheel drive activation by service brake foot pedal. In this case basic research was done at the TH Darmstadt by Breuer et.al. working very closely together with a tractor manufacturer.

Other basic research work for innovations in tractor hydraulics were carried out by Matthies et.al. in Braunschweig, lea-ding to new concepts of several tractor manufacturers. Many further examples could be mentioned, but reasons of time force me to continue on the topic of de-velopment methods.

The main schedule and the "project foundation matrix"

Referring to figure 8, a first bar schedule shows the main activities of product development versus time. Promising ideas are picked up by product planning, analysed or even refined by the advanced engineering group, discussed with field people in a broader view and afterwards evaluated in terms of economics by use of a relatively high sophisticated process. It is the objective of this work to establish a well-defined product-project using innovative and pre-evaluated ideas. The most important activities are demonstrated in figure 9. This "project foundation matrix" must be seen as the center of a successful development of innovative pro-ducts. It defines particular inputs of the four concerned areas of the company: Re-search and development, sales, factory and finance. These inputs concern not only the detailed description of the proposed project but also production costs and market prospects. Special requirements must be considered for some special market areas. Switzerland for example requires unusual low stand-by noise level, Scan-dinavian countries have a high safety standard, the USA have given outstanding priority to the principle of product liability, other countries e.g. South Africa give only permission to imports, if specific components are supplied by the home industry. In all these questions, development and sales have to cooperate very closely. Further important investigations concern necessary investments and available capacities in the referred areas.

The achieved first economic evaluation of the proposed project usually yields high losses, so that the procedure needs to be repeated with modified inputs until the balance indicates a profitable product. Improvements of the result are often possi-

bile, if functional specifications are leve-led down to a compromise. Sometimes al-so the costs of factory investments can be cut by using the present production machinery with only some modifications. E.g. several tractor companies are running transmission housing production lines for more than 20 years with only some minor changes, although the transmission functions were improved in the same period of time.

In series production, competitive costs can only be achieved, if the individual ma-chine types form a product family package, standardizing a great number of parts to save costs in production and logistics. Figure 10 shows the number of new trac-tors sold in the F.R.G. in 1986 versus rated engine power, covered by three trac-tor families L, M and H.

The main task for the sales department is to determine the future sales profiles and prices for the different market regions. These estimations require outstanding experience and overview and a highly developed communication in sales.

Figure 11 gives an impression of the necessary investments for the development and the factory including characteristic development times. In the first example of a new developed or improved tractor family, about 20-50 mill. ECU and 3 1/2 years of time are required for a major development project. The reason for this im-pressive expenditure and period of time is the very hard competition requiring first-class development and big series production to achieve adequate product costs. In comparison, the example of a fodder-beat harvester-chopper on the right shows considerably less investment costs. For the development of such a harvester, which was recently presented in my country and was based on an existing conventional harvester type, the costs for development and preparation of production are about 1 mill. ECU. A totally new concept is of course much more expensive.

Even if the project seems to be profitable in this stage of the "project founda-tion matrix", it must be checked, whether the necessary capacities for the project are available or can be made available in the concerned areas, sometimes also outside the company. A typical distribution of the main budgets averaged over a longer period of time is presented in figure 12 for development departments in the tractor industry. 40^{0}7o are required for maintenance of the current products. Another 35^{0}7o are used for further development of existing products, 5^{0}70 refer to research and advanced engineering, so that the remaining 20^{0}7o are available to develop new products. There are of course major changes possible from year to year (mainly between the two bars in the centre). The figures will also vary, because of definitions. In the future 5^{0}7o for research and advanced engineering will perhaps not be adequate for competitive innovations.

When the project is settled, different following activities must be established si-multaneously, see again figure 8 and look at the three bottom bars. The first complete product layouts are carried out while product planning is still going on. After release of the development project the layouts are refined, later on, the design is worked out in detail. New components are subjected to lab tests as early as possible. Prototypes are built and tested later. The test results are returned to the design de-partment.

Factory planning starts working at about the same time as the components are tested. Production machinery is modified or completely rebuilt some time later. Possible collisions with still produced "old" products need carefully planning. When production is planned for big series, it is profitable and helpful to test the production machinery early enough by a pilot series. Further changes due to the assembly experiences are introduced to the design documentation. Homologations mostly be-gin coincident with the production release. Starting series production, project management activities are completed. The maintenance department is now taking care

of the product. From the beginning of the project until start of production between two and six years are gone.

Product costs are mainly fixed by development

During product development, the current project stage must be compared continuously with the schedule and the objectives by the project management. Regarding the costs, it is useful to know about the impact of the various departments on the final product costs, Figure 13. The numbers are based on many years of experience. With 70^{0}7o, the impact of research and development on the costs is obviously dominant. The following departments are production preparation by 15^{0}7o, production by 10% and sales with only 5% of the costs. Consequently, if a product is too expensive, the reason is probably a costly design. The overview shows too, that this cannot be compensated by the other departments, particularly not by production.

Figure 14 leads back to the ideas and the finally resulting costs. In the beginning of a development, a lot of ideas are necessary — no problem in the case of a good management. Canceling a non profitable project in an early stage can be a good decision, because development costs are yet low. With progress in time the conversion of ideas becomes more important than the finding of further new product ideas. Due to the increasing number of employees working on the project, development costs rise progressively. To stop the project in an advanced stage would cause an important loss of development costs, sometimes also of investments.

Major changes in objectives only in the case of emergency

Also major changes in the development objectives lead to additional costs, mainly caused by the prolongation of the development time. Therefore, only urgent changes are considered, for example, if the background has changed during the engineering process.

Some urgent development changes might be an answer to innovative products of competitors. For instance, the introduction of a 40 km/h version on standard tractors had an unexpected great success immediately after its presentation by FENDT and SCHLUTER in 1980. Other companies were forced to follow. Even political changes as well as new standards may have some impact on the development of new products. A good example is the relatively fast introduction of noise-isolated cabs in the seventies (whereas nearly no progress can be seen for stand-by noise levels) Techniques for environment protection sometimes are coming up unexpected as the actual increasing use of plant-based hydraulic fluids for agricultural machinery. Tractors often work with the same reservoir for hydraulic and transmission oil. Unfortunately, commonly used wet brakes are not compatible with native fluids. This tendency was not anticipated, neither by research nor by the industry and will probably cause some corrections in current tractor projects, e.g. with the objective to separate the mentioned oil circuits.

Agricultural engineering has future

The industrial process to convert innovative ideas into profitable products is su-rely more complex today than it was in former times. On the other hand, horizons of business in industry have widened continuously. Products, which were developed and produced 100 years ago could of-ten be used only in a specific region, like Bavaria. Nowadays they are developed for application in many countries all over the world. Also the pre-investigating research has achieved high effectiveness today, due to progress in international communica-

tions. In spite of these improvements, I still see possibilities to make further steps forward. Often even language is a barrier being very negative for national economy. Personal contacts worldwide are of particular help to prevent isolation. Good personal relations can also help to balance political instabilities. The history of the 20th century clearly showed, that an ho-nest and free democratic structure is the best basis for innovative products and hence welfare of the people. In all deve-loped countries, innovations in agricultural engineering have been the basis for the development of industrial activities. The present overproduction of food should not let us forget, that long-term nourishment of mankind can only be guaranteed with innovative agricultural machinery. For this reasons, I think, it is worth doing.

THE INDUSTRIAL PROCESS OF IMPLEMENTING INNOVATIVE IDEAS TO FARM MACHINERY

Prof. Dr.-Ing. Karl Th. Renius, Munich / F.R.G.

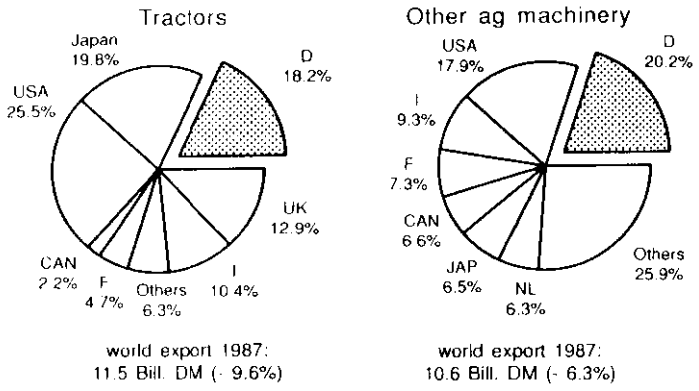
	Mill. DM
Total production value	6950
■ comprising domestic tractor sales	1380
■ ... other Machinery	1430
■ ... export (59,7%)	4150
■ export countries: 1. France 2. United Kingdom 3. USA 4. Netherlands 5. Austria	
Import volume (mainly tractors)	1070

Total number of working people (F.R.G.): 42400

figures courtesy LAV

LD 4730

LANDMASCHINEN TU MÜNCHEN — F.R.G. Ag machinery industry (LAV) 1988 — Fig. 1



courtesy LAV

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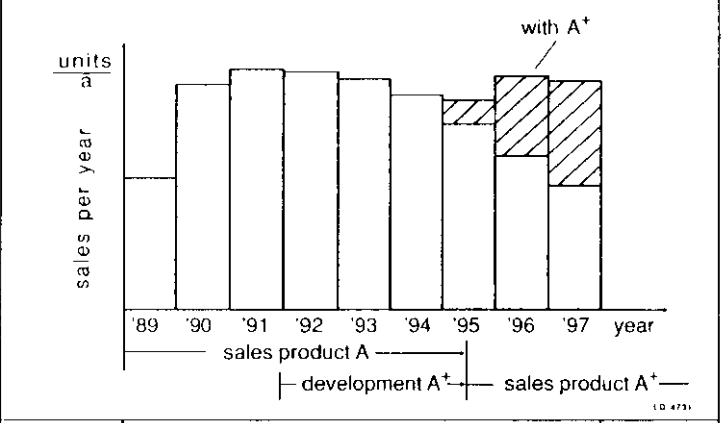
LANDMASCHINEN TU MÜNCHEN — Export of tractors & other ag machinery 1987 — Fig. 2



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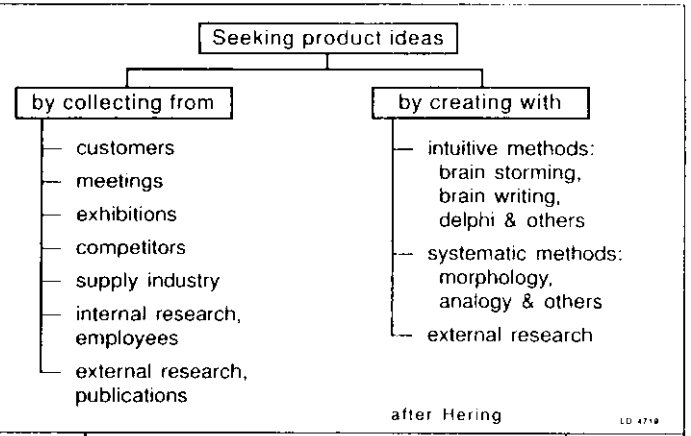
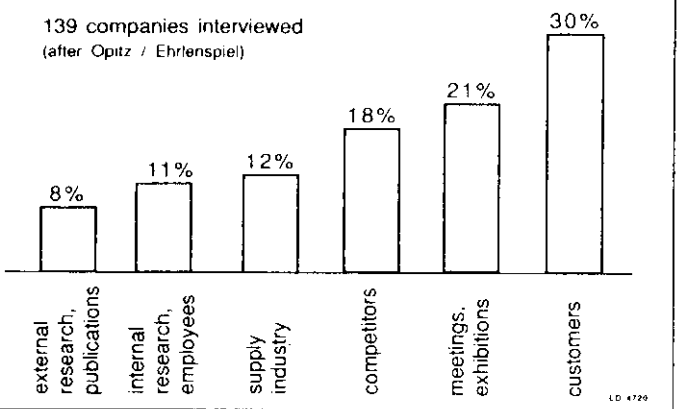
LANDMASCHINEN TU MÜNCHEN — Industrial "lifetime cycle" of ag machinery — Fig. 3



Methods of obtaining product ideas — Fig. 4



Sources for collected product ideas — Fig. 5

Pro	Contra
■ Less soil compaction	■ Extra costs for compressor, tire valves, connecting elements and control
■ Less plant damage	■ Variations necessary in tractor & trailer design
■ Less rolling resistance	■ In the first step: Less operational comfort
■ Less tire wear	
■ Improved dynamic overturn safety	

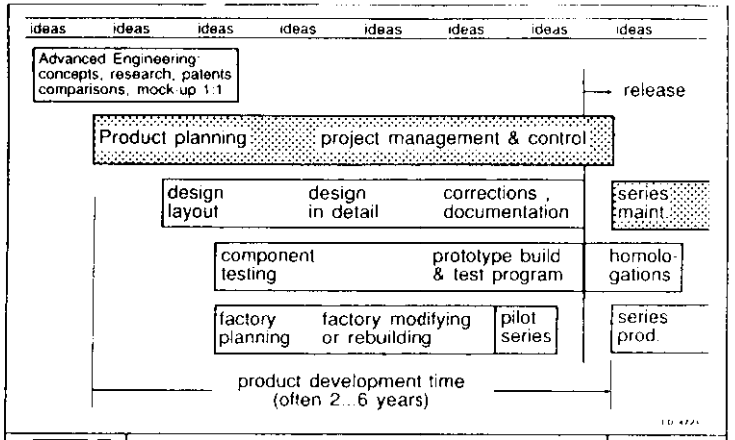
Note: Existing compressors for tractors without accumulator need relatively long period of time for inflating big tires.

Tire inflation remote control — Fig. 6

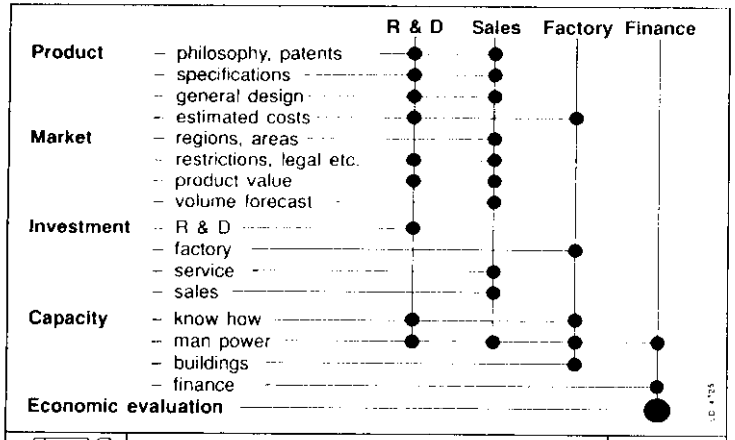
Pro	Contra
■ Reduced noise level by isolated components	■ Tractor with more parts
■ Much more design & component flexibility. Light weight components possible	■ Chassis stiffness must be properly designed
■ Simplified service & repair	■ Profound development step*)
■ Frame used for front end loader & front lift	■ Increased expenses for corrosion protection

*) Note: Temporary concept could perhaps use conventional block transmission with attached front frame.

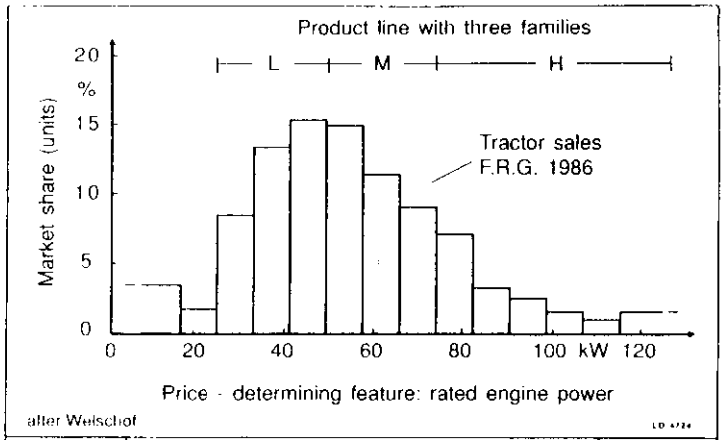
Frame - chassis tractor versus block concept — Fig. 7



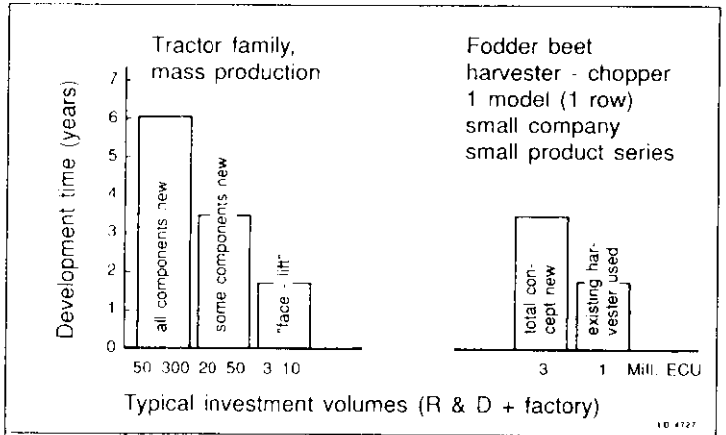
Schedule of managing new products (example) — Fig. 8



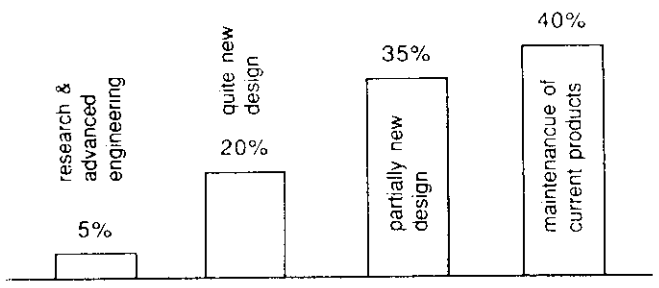
Evaluation process of proposed products — Fig. 9



Classification of tractor power ranges — Fig. 10



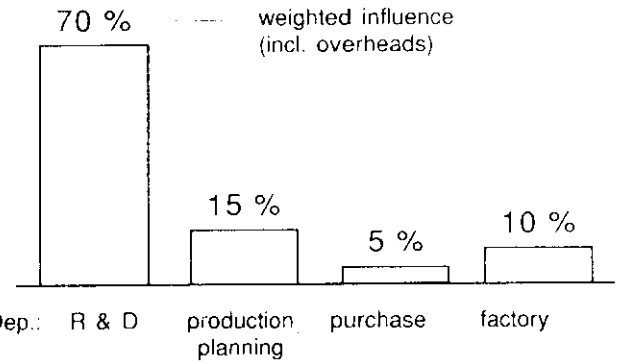
Expenses for new products (examples) — Fig. 11



Partial budgets include engineering services and other engineering overheads

LD 4729

Typical tractor engineering budget (average over a longer period) — Fig. 12



after industriemagazin

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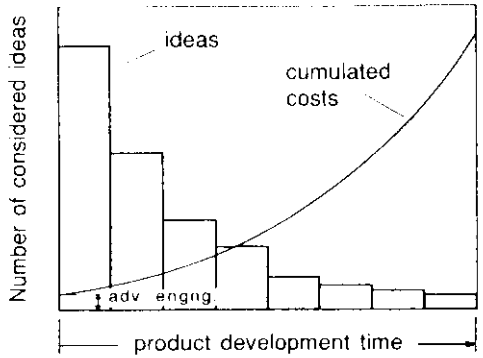
Determination of product costs — Fig. 13



LD 4728

Product development: Ideas & costs — Fig. 14

J. Lucas

The only good reason there can be to utilize new technologies is the extent of their efficiency and their productivity. Thus it is particularly interesting to be able to foresee the future and confront the efficiency and productivity of various technologies.

Mechanical technologies with their constant perfection permit earnings of 20, 30, 40% on the price of a product.

This is an irrefutable fact.

Electronic technologies, however, pre-sent another type of improvement. To demonstrate this I will mention figures which seem to me to be most significant.

A man working out calculations does approximately ten operations per second for five hours a day. A present day calculator can do some ten thousand operations per second for twenty hours a day. This is indeed incredible.

Until now, on the other hand, we have not given adequate attention to this fact since the eventual potential of a calculator had been concealed from us by the procedures and techniques for its maxi-mum use.

I believe almost all of us use the procedures for preparing a text; such an instruments appears to be very powerful be-cause it means that a secretary does not have to retype the same letter four times and provides a perfect final printed copy. But, in reality, electronics at the present, scale of its use provides us with only a minimal part of its possibilities.

In astrology, electronics has shown, for many years, greater potential, but it is of-ten the case that we are not well informed and do not fully understand this sector.

In the near future we will be able to witness the progress for use of electronics which has already been foreseen. We ha-ve passed the first threshold, that of the Personal Computer, made possible today by the reduction in cost of its components. Now we are approaching the second threshold: that of personal artificial intelligence.

Progress in this direction, which has already been developed with micro-electronics, will permit us to make this step forward rapidly.

Calculators which are specialized in artificial intelligence and are still today not used on a wide scale, have already, in only a few years, made enormous advances. Five years ago it was possible to buy in artificial intelligence 0.7 mips of calculation potential for 600.000 French Francs (= 150.000.000 Lit.) Today, we have 22 mips for 160.000 FF (= 40.000.000 Lit.). This represents a coefficient of 1200, over a very short period of time. Thus, this ex-traordinary phenomenon of progress in electronics for calculation will mean that those who know how to use it will be working on an optimum efficiency level. Then the coefficients for efficiency will no longer be in terms of 1.2-1.4, but much higher.

For these reasons I am convinced that we must consider very carefully the who-le body of innovations which electronics now, and in the future, will offer for mechanized agriculture. They are already considerable. We will examine them so that you can see that already, only in the CEMAGREF laboratories (who provided me with the slides I will show), their application is of utmost importance. I will take the opportunity furnished by this exa-mination to point out even further possibilities but I remind you that the CEMAGREF laboratories are not the only ones existing in this sector.

The slides which Prof. Matthews showed us earlier demonstrated several of the applications and progress in Great Britain. At the University of Milan, the laboratory of Prof. Pellizzi utilizes to a great ex-tend electronics and data processing. Several projects for agricultural robotics are carried out in collaboration with the Universities of Seville and Madrid in Spain. These are only a few of the examples I will show you. The bulk will be in French, but you must remember that agricultural robotics is being studied in all European

countries as well as in the USA, Japan, Australia and others.

The MAGALI robot picks delicate fruit. There is the slide. The biggest problem for robotized fruit picking is the treatment of the image which indicates the position of the fruit. When the treatment or processing is summary, you obtain an image where it is difficult to distinguish the lo-cation of the fruit. On a more detailed processing treatment, using several wide band filters, it is possible to obtain a computerized image with improved contrast and finally, using interferential filters, rapid calculation; and gradient operations, it is possible to locate the fruit by means of computer. The MAGALI robot, even if it has just been released from the laboratory, is already quite well known, with its three eyes and three video cameras with interferential filters.

The robot has been used with apples; a type for oranges has already been deve-loped in collaboration with the Spanish university with which we work. It appears that oranges are easier to work with than apples but in practice, this is not true. This is what is emerging in the field of fruit harvesting and the prospects are most encouraging. If today we have achieved results with calculators at a reasonable prince of investment, in the future, we should have even better results with much faster calculators which will not be expensive. The-se new calculators will permit us to robotize, at reasonable cost, innumerable processes involved in agricultural production, such as fruit harvesting. It is essential to realize and understand that the development of the first robot, which was probematical and difficult, will lead to opera-tions which will cover a wider scope be-cause the initial development problems have been overcome.

The positioned robot for milking cups is another device which is well known to-day.

This is a spectacular example of progress of epic dimensions. This feat began more than ten years ago when micro-processors were not commonplace on the market. We presented the first electronic management of milking herds using a specific calculator target for this purpose. The device, well known today, were perfected several years later; A medallion instrument developed by CEMAGREF sets in motion a hybrid circuit. These medallions have been utilized in present day systems developed by industry for automatic rationed feeding systems. But, it is not enough to resolve the feeding problem as the next step is milking and, above all, the milking cups. First the Japanese and then the Dutch seriously worked on this problem of automatically positioning the mil-king cups. The problems are that a cow moves in its stall, even if the stall is custom built to its dimension. The udders also move. We considered making a processing scheme of the natural position image of the nipple. This is not an easy task and the image cannot be obtained rapidly. Once we knew of the obstacles en-countered by the Japanese (who eventually abandoned the project) and the Dutch, we turned to another method which involves the laser scanning of the nipple area which turned out to be very efficient, as well as the signal to be processed. It can be processed in just a few milliseconds with a normal micro-processor and this makes it possible to locate the four udder nipples each tenth of a second.

The robot which uses this system is al-ready in use in commercial dairy farms. At this point, all sectors are very interested in the application of automation and the use of robots.

Electric shears are an instrument which appears to be quite simple on superficial examination. They have now been perfected through the use of electronics by the company of PELLENC & MOTTE, and provide working conditions which are more comfortable and give much more efficient results. Many attempts to robotize vine cutting have been under study in re-cent years but it remains a very difficult operation.

Rational feeding of pigs is a very useful operation. Electronics is not present in the installations proposed by ACEMO and yet it is capable of filling an entire box and permits a constant control of the quantity fed to animals and of the coefficient of transformation of feed into meat.

Several stabilization systems for insecticide treatment device adopt an electronic system. A rapid calculation process and special receivers provide perfect stabilization.

Forestry equipment is already using important electronics. The cabin is already outfitted with a significant number of small calculators, but there is room for improvement and we have built a prototype; a mechanism which is completely automatized for cutting trees. A driver is still present because there are still problems which the robot cannot take care of on its own: such as a fallen tree in its path, then it is necessary to input instructions, it can-not encompass this alone. This prototype, whose general movements and those of its arms are driven by a computer, has already cut hundreds of trees automatically. It cuts, prunes and loads automatically.

Let us now turn from these machines to the sector of tractors. The tractor ca-bin today is normally furnished with a large number of electronic devices and the command panel of a large number of trac-tors adopts electronic systems. Electronics is quite satisfactory for use in electrohydraulic surveys which require numerous regulations. It is less so when a television screen is installed in a tractor. It is true that the work load of the driver is much reduced when using this screen, for example during plowing. The screens with co-loured liquid crystals will permit us, in the very near future, to install, on a regular basis, such screens. They provide an ef· fortless survey of the work which must be controlled and also furnish a real time configuration of the situation picture b} means of an artificial intelligence system located on the tractor, the coloured cry-sta.] screen and the software installed in the calculator on board will become the principal components of the command panel.

A large selection of sensors will make it possible for us to make a new step for-ward in the direction of robotized equipment: high frequency location signals will indicate the position of the tractors within a radius of one or two decimeters in a field a kilometer wide. The electronic command box of this apparatus is not large in size.

Electronics will also help farmers in their choices and, more particularly in the choice of the materials they are required to buy. A Videotel service put into operation by CEMAGREF, already allows farmers to know the characteristics of materials which are available in the market. This is today a widely used service, considering that it has been in operation for not even a year. The Videotel service makes choices easier and will require a very important support effort from the point of view of software. This effort, in my opinion, will represent an excellent opportunity for international collaboration.

So, Ladies and Gentlemen, this has been a rapid overall view of what we can expect from advanced technology and more precisely, from electronics and data processing from now into the future.

Electronics has penetrated every field and the examples are innumerable. It transforms the entire scope of society and it is also transforming agriculture. Within five or six years we will most probably be confronted with robots which plow fields and take the place of human labour and at the same time preserve and protect the environment.

J. Matthews

Interaction between engineering and biology

I don't have slides for this particular talk which is largely informal but which I hope will provide some "food for

thought" today and for the future. I apologise if it is a rather preliminary and tentative presentation. It is an area where none of us has done quite enough thinking and I believe that much more thought is necessary.

I would first define engineering in this context as engineering science and applied physics. To some extent these two over-lap. We are all working in a biological area and are in this way supporting biological industries, be they agriculture, horticulture, forestry, aquaculture or food processing. The latter is still largely biological in two aspects. The product has a bio-logical background and the consumer is totally biological.

I believe that biology is moving to be-came more interactive with us through advances in molecular biology and consequent biotechnology. Computing and greater analysis is enabling biological models with some quantification to be produced, and hence biologists are able to converse with us in increasingly quantifiable mathematical terms. Because of this they are increasingly looking upon nature's activities, the activities in a plant, in an animal etc., as a process. So process engineering is another of the bridges between us. I will next say a word or two about where we are not moving today but will perhaps do so in the more distant future, and then I will come back to describe what I see as a strategy for more immediate activity which is described on the matrix diagram handed round. What is still relatively unsure and a year or two ahead in my view, is a proper definition of the engineers' role in relation to molecular biology and genetic engineering in particular. There has already been some engineering contribution and many of you will know DNA genetic material has been injected into cells ballastically — effectively by firing the material into the cell. In the future we shall need to think about whether this is viable only as a research technique or whether this and other techniques currently employed at the research bench will have an application in industry. In particular, micro-engineering needs to be further contemplated and perhaps employed for manipulation at the cellular. In the same way we can enhance our vision of microscopic systems and hence identify them. Through mycrobotics we should be able to manipulate at this micron level.

Biotechnology includes as one of its principal activities the multiplication of either plant or animal tissues and this is clearly an area where process engineers ha-ve much to do in view of the need for very precise fermentation and growth conditions, separation and transport techniques which are not harmful to the cells, and the monitoring and assurance of both thermal and mechanical conditions throughout the process which do not inhibit its activity. It will be recognised that although in biotechnological terms this all seems terribly new, the brewer has functioned in this role for centuries. I would be interested to hear whether in other countries the engineers are finding important roles in this topic area. One can recognises the need for studies of fluid mechanics of tran-sport, mixing, stirring and separation, and perhaps some study of energy conservation.

A title less certain, and perhaps even an area that might be regarded as psuedoscience, is developments in the communication between plants and animals and man. We can obviously communicate with an animal by a voice so there is nothing new in that. Animals can communicate with us through their electrophysiological signals such as ECGs, EEGs, and EMGs. I wonder whether one day we will be monitoring such signals and learning to interact with an animal through electromagnetic messages. A plant also incorporates inter-cell signals which are based on electrical as well as chemical changes. The-re is a great deal of folk lore about com-municating with plants, including singing or talking to them, and perhaps some evidence that human interaction is just signi-

ficant. It is, however, an area of very varying opinion. I venture to suggest that one day in the relatively long-term future we shall learn to interact with the electrophysiological signalling in both animals and plants but am not in a position to say any more today.

I therefore come back to the matrix chart handed out which presents some structure for thought about today's engineering. On the vertical axis I have taken seven of the topic areas which I believe either to be fast-moving at present or to be highly relevant to current needs. I am su-re that individuals will complain that I ha-ve left out topics, and indeed one could have added others, but I need to make the point by being sufficiently brief. I think from other papers and discussions one can see that there is a unity among our experts and so some of the topic areas have been mentioned a great deal today. These include image analysis, robotic, sensor science, and information engineering.

We have just heard about many applications in these areas but I want to make the point very strongly here that at the re-search level we need to think in generic terms and to advance the sciences or technologies across the whole application area. My table shows the main subdivisions of this application area in the horizontal level as being crops, animals, food and then a generic column. I think some of our efforts have to go into individual projects and indeed most of the people who are active in the field would probably tell me, and I accept this, that we cannot advance without using specific examples for the advance. We must have examples and you clearly cannot advance on a purely generic front with no point in view. I think, however, we do need to recognise that the-re is a generic aspect to any work under-taken and that certain biologically related needs which will be common across animals, plants and food, will come about purely because we are dealing with biological materials in each case.

As an example I take the case of image analysis. This may be related to robot control, to sensing, monitoring all sorts of processes, or machine guidance. We are unlikely to be able to take systems from use in the factory industry since there everything can be arranged to suit the instrumentation or the robot, and views can be clear and designed. In our case we are going to get incomplete images with hid-den components as other animals or other plants interfere with part of the view. For example, an apple may hang half in front of another apple and we have to target the one behind for various reasons. So it is not surprising here that the generic area I have given as an example is the working with incomplete images. It will be possible because, for example, everyone knows what a cow looks like and we do not really need to see 100% of the cow to know that it is a cow. If we can see 70% we can draw in the rest. This will apply similarly to an apple or a cauliflower or a fish.

Looking more broadly at my matrix, shaded in are four boxes which, as a physical scientist (!) I have arranged symmetrically. These are all examples where working on the specific proposal one can look at the same time to advance the technology by broadening more general under-standing so that other people coming beyond can make further advances.

The first one is entitled "Computerised Husbandry Monitoring". It is the use of image analysis, and I would not necessarily restrict it to visual images — it could be acoustic or infra red — to tell us all that can be learned about an animal by this technique. The intelligent husbandry man — even the champion husbandry man — learns all that he needs to know about the animal by looking at it. He watches it not only as it stands but how and as it moves, he looks at its posture, he looks at its behaviour in relation to the rest of the herd; if it is as large as the rest of the herd or is smaller and therefore perhaps has something wrong with it. If he sees the ani-mal and its colleagues within the herd clu-

stered together, this suggests that they will be cold, but if they are lying well apart if could be suggested that they are too hot. All this information is taken in by the husbandry man and although I believe it may take us two or three years to copy the capture and understanding of these various images, I do believe that ultimately it can be as effective as manual observation and furthermore, with the bringing together of expert systems employing a number of skilled men to make decisions or identifications, then I believe it can be more skilled. More general advances in artificial intelligence and the use of faster computers such as transputers make it not only practicable but economic.

The identification and learning systems can be self-teaching these days. For example, I will quote where we have been working on training an image system attached to a robot to decide where to cut a callus type microplant. Using neural network techniques to employ a trainable program-me, we have, I think, within some 200 practice runs in which the human operator informed and corrected the robot, enabled it to achieve a decision accuracy within the machine and its artificial intelligence of better than $80^0$7o. It is not there-fore necessary to contemplate long periods of detailed programming to make these advances but to employ more specialised and intelligent programs to make their own advance. In the ultimate practicable embodiment it will not be one camera loo-king at one pen of pigs together with one computer analysis equipment, but rather the employment of mobile cameras to cover large numbers of pigs or other animals, probably being able to look at each group every hour, but sharing the capital cost against a large number of animals.

My second example, in the robotics column, deals with the cutting of meat. It is an area where I am aware of three or four teams working and I suspect because of commercial confidentiality in some instances, there may well be more than that. Again we see that, although the process is essentially a factory process, the robotics already developed for factory activities cannot be employed for meat cutting because of the variability from one animal to the next, the biological susceptibility of the carcass to handling, and a number of other aspects related to the accuracy of cutting against the bone etc. which make the challenge greater than has normally been met routinely in other factory industries.

This paper so far has dealt substantially with guidance but has said relatively little about end effectors or manupulators attached to the robot. These end effectors have to deal in many agricultural cases with fragile materials, with resilient materials and with materials which are often alive. An example, of course, is robotic milking where the cows are undoubtedly alive, or the slaughter of fish or other animals that are alive at the beginning of the process. They must have adequate welfare at that point so we need to consider mechanical engineering technology related to robotic manipulators and processing elements. This indeed is one area where mechanical engineering, which is perhaps relatively mature in many parts of our agricultural engineering, has its own advances and developments to make. In addition to handling we have to look at mechanical end effectors for inverting, for picking or cutting, for slicing, trimming, for arranging (within the food industry) and for many other processes.

Again the more generic aspects of this work must involve multidisciplinary teams. In handling an apple it is necessary to involve plant physiologists who will understand the requirements for pressure limitation, for impact limitation, and can interpret contact and interactive needs in a way that the mechanical engineer can design to engineering standards. In closing this section it is perhaps worth mentioning that our nearest partners in this type of activity are in the field of surgery where robotic surgery and robotic patient handling are both being worked on.

My next example is perhaps a surprising one since it is a much more mature area, and that is the area concerned with the physical characteristics of soil. Soil mechanics has been fundamental to agricultural engineering for all time, and a number of good principles have been uncovered. However, I have to say that I do feel that the real contribution to the design of machines has been somewhat less than has been our continual expectations of the topic. The principles are good and well understood, and can in a qualitative way be taken into account in machine design, but I wonder just how much we have had quantitative design coming from the knowledge of soil mechanics. I say this with some embarrassment but I do think that internationally we have not achieved quite as much as we should have done. However, soil physics is back as a "fashionable" topic because of environmental considerations. The core consideration is the transport characteristics of fluids within the soil.

This arises from the increased use of protective chemicals and of fertilisers, and the situation where surplus chemicals are being transported through the soil into water supplies. In many areas of Europe it is now accepted that nitrate levels in drinking water are uncomfortably high.

I think this challenges us to look again at the soil and see if we can tailor its characteristics rather better than we do at the moment. Now we look upon creating a seed bed as creating a rather homogeneous arrangement of soil in the top several centimetres. Could we start thinking of our seed bed where the transport characteristics of the soil to and within the rooting zone are very good, but where the tran-sport away from the rooting zone is in fact deliberately bad? I think that this is a challenge which should be looked at more deeply and we could make some contribution to reduce the ill-effects of chemicals in the soil. We also need to look at the gaseous exchange between the soil and the atmosphere because within processes such as denitrification in the soil we are releasing chemicals which are potentially at a level of creating significant atmosphere pollution. Another way in which we might look at this area is to consider the use of small quantities of plant growth substrates. We do not need to stick to soils when we can obviously contemplate composts and materials such as vermiculite. Foaming polymers are also a possibility and might well serve in the immediate region of the germinating seed to improve that germination and enable nutrients to be placed in a more captive fashion.

My final example concerns ergonomics and my example is within the generic column. I believe that we really do need so-me further concentration on applying ergonomics to management practices in agriculture. We have done a lot of ergonomics research in the workplace and quite a lot concerned with the worker's environment. We have heard a lot at the conference about information technology and its management role. The farm, however, has particular management needs. The farmer or manager has particular attributes which must be taken into account if a combination of human and computer based management is to be really effective. We therefore need to look at the mancomputer interface.

Some of the questions that we need to answer are;

(a) How much information will the manager need?

(b) Will he need the intermediate information from which the computer is ma-king recommendations?

(c) Will he need information on second best solutions and so on, but still be able to exercise some decision?

(d) How much will decisions and recom-mendations need to be quantified in financial terms.

My expectation would be that the man will require a great deal of information to study before taking decisions in using the computer as a decision support system or before allowing it to make automatic de-

cision. If I were a farmer I would not be interested in simply being told to go out and put on so much spray chemical to a certain crop today. I would want to know the intermediate information as what happened if I didn't do it and left it until to-morrow, or what would happen if different quantities were used. I think I would wish to interact with the computer a lot more than I think a man in another industry might wish to do. Perhaps more importantly I would point out that there is another element and this is the element of risk and probability in agriculture. In contrast with other industries our actions do not have certain effects; they relate to a level of probability and risk which is connected with weather, with biological variability and with a number of still un-quantified factors. Added to this, one needs to realise that farmers cannot opti-mise their profits over a long period without considering intermediate years. Cash flow is bound to be important since we are talking of small businesses with very limited financial resources. This needs to be known, studied better in quantitative terms, and will certainly be a contrast to many other industries.

Therefore, Chairman, I think that al-though it may not be an exhaustive commentary on the relationship between bio-logy and engineering, this sums up how I see it. Central to our efforts must be multidisciplinary collaboration. In advancing technology we must not go just for specific developments but rather look to broaden the enabling technologies, if necessary, by choosing examples, so that we can advance on a generic front.

Examples of challenge and application in principal engineering topic areas

Topic	Animals	Food	Plants	Generic
Image Analysis	Computerised "husbandry" monitoring	Microbial detection and identification	Localised targetting of protective chemicals	Three-dimensional image reconstruction
Sensor Science	Oestrus detection in dairy cattle	Constituent Analysis	Characterisation of soil states	Intelligent knowledge based systems (IKBS) for interpretation from sensor arrays
Robotic Systems	Milking on demand through automatic cluster attachment	Cutting of meat from the carcass	Micropropagation pruning and grafting	End effectors for handling live and fragile organisms
Information Engineering	Health assessment, diagnosis and treatment	Expert system development in process management	Plant growth optimisation through IT network	Decision making in areas of uncertainty and high economic risk
Analysis and Modelling	Interactive milking	Heat and mass transfer in complex, multiphase systems	Transport characteristics of non-homogeneous porous media (soils)	Simulation of complex three-dimensional non-homogeneous system
Process Control	Environment control using livestock parameters	Self-learning control to ensure safety in processing	Combined heat, RH and CO_2 control in protected cropping	Multi-variable control
Ergonomics	Dust in livestock housing	Quality inspection and grading of fruit and vegetables	Telechir micro-manipulation in tissue culture	Man-machine interface design optimisation in management systems