SESSION 2

ROLE OF ELECTRONICS AND DECISION SUPPORT SYSTEMS FOR A NEW MECHANISATION

Chairman : Prof. Malcolm MACKAY, AUSTRALIA

The role of electronics and decision support systems in a new mechanization. The point of view of research

by ***Hermann Auernhammer***
Germany

1. Introduction

The advent of electronics in agricultural technology represents a milestone in the long development of tractors and implements (**Fig. 1**). Through electronics, technology becomes intelligent and can communicate. Contrary to use up until now, in which a human acts as a link between the farm management and the mobile units, it is now possible to integrate the technology directly into the management.

Electronics are employed in four basic areas (**Fig. 2**). These are connected through interfaces and require, in free combination of the individual areas, unambiguous, efficient, secure and clearly defined standards. In order to transfer information, the data structure and data contents must be defined.

Intelligent technology requires diverse sensors, adaptive actuators and high performance software. In addition to algorithms for data acquisition, data processing and editing, data conversion, and data storage or data transfer, decision support systems are necessary. These systems must become more and more independent of the operator and be able to work out more complex decisions independently, as the number of sensors increases. Safety aspects and special operational conditions of the technology in the agricultural environment are to be considered.

2. Electronics in mechanization

As with every other development, electronics are introduced and integrated into the existing technology step by step.

2.1 Tractor and internal machine electronics

Electronics in a tractor are comparable to those of self-propelled machines, such as combines, self propelled choppers and sugar beet harvesters. They are much less complex though, due to the lack of equipment control.

Tractor internal monitoring and control: the trend towards networking intelligent controllers is unmistakable in tractor electronics (**Fig. 3**) and the electronics in self-propelled harvesters (**Fig. 4**).

Development worldwide has progressed (**Table 1**), whereby CAN has reached a broad dominance and can be called a quasi-standard. When different numbers of controllers are used, great differences in data transfer (cable type, shielding, transfer performance) result.

With the installation of common rail systems, electronic motor management will become a standard. Together with continous variable transmissions, this will lead to the development of electronically controlled power-train and drive-line systems. Both require connection to the implement electronics.

In addition, as a result of increased working widths and/or higher working speeds, new demands will be made on machines, starting from automatic line guidance systems up to self-propelled vehicles working together with manned guidance vehicle or fully self-sufficient units.

Implement internal monitoring and control: the implement electronics are mainly geared toward distribution techniques. They are currently realized in two ways:

Specialized control systems are set up for optimal operation of specific implements (**Fig. 5**).

They are distinguished by the following advantages and disadvantages:

Advantages

+ optimized for the implement
+ always ready for operation
+ operator interface is optimized for the implement
+ can be built into any tractor

Disadvantages

- short operational period per year

→ high fixed cost burden

- inactive times can cause problems in the electronics
- operator must adapt to every implement change
- requires own sensors for path, slip, and PTO rotation control
- additional effort to transfer data to the main computer

Universal control systems: use a central controller to adapt to individual implements. They communicate through plug connections and activate the required software (**Fig. 6**). These systems require the exclusive use of manufacturer specific parts, thereby strongly limiting true universality.

They are distinguished by the following advantages and disadvantages:

Advantages

+ long operational period per year

→ low fixed cost burden

- no problem in incorporating new implements

+ operator interface always stays the same
+ data transfer is a fixed part of the system

Disadvantages

- implement changes require set up time
- forces to maintain the system set up
- operator interface represents a compromise
- farmer commits himself to one manufacturer
- new technology requires expansion of the central controller

Both systems take control of implement monitoring and regulation to ensure that a fixed quantity is applied to an area. The addition of positioning and navigation components allows for site-specific seeding, fertilizing, application of pesticides and targeted soil testing.

Tractor-Implement-Communication: with the development of the LBS (Agricultural BUS-system) (**Fig. 7**) and the current standardization in the ISO 11783, problem-free integration of implement electronics into the complete tractor-implement system is possible for the first-time.

This opens up entirely new possibilities through:

- problem-free implement expansion;
- manufacturer specific design of the implement computer;
- central control and monitoring of complete tractor-implement electronics;
- inter-implement related control and regulation;
- usage of services by all units;
- central diagnostics;
- problem-free connection to the farm management.

LBS is limited to a 16 unit address space and is therefore conceived for the tractor-implement combination in smaller farms. ISO 11783, with 32 units, is tailored for the needs of larger farms. Both systems function almost identically.

Connection to the farm management: every type of implement electronics is equipped with sensors, and acquires information "quasi free of cost" for the farm management. High-performance bi-directional data transfer between the mobile unit and the farm management is a prerequisite for this. At this time, contactless chip cards and PCMIA- cards are being used widely. The need for cableless transfer already exists today in larger farms and will increase in the future.

2.2 Human interface

Tractors and machines must be monitored and controlled by humans. This means that reliable information must be available and proper intervention possible.

Information display: information technology introduced electronics to tractors and self-propelled harvesters. What started with single displays, has now developed into information displays that can display many different kinds of information simultaneously and allow targeted selection. Electronic units not directly related to the tractor functions have their own information unit that, in general, is inconveniently located in the proximity of the driver's seat.

System interaction: increasing complexity of the tractor-implement combinations has made large numbers of operating elements in the immediate vicinity of the driver's seat necessary. First signs of multifunctional elements can be recognized. Separation of functions is still not discussed (**Fig. 8**), although it is already considered standard for other driver's seats.

Only conventional input devices (switch, potentiometer, mechanical-hydraulic regulator) have been used until now. Voice input is only just starting to be discussed.

Alarm handling: alarm signals are an essential part of driver information. Even with almost limitless possibilities, there are only a few practical and powerful systems offered.

Diagnostics: electronics is communication and electronics has the capability of self diagnosis. In addition to operational diagnosis, with a once-over check at start and a continuous diagnosis during operation, failure diagnosis plays an important part in system analysis. At this time, only systems for tractors and self-propelled harvesters with integrated bus structures are available. Diagnostic tasks and tools are not defined in either the LBS or in ISO 11783.

2.3 Electronics and the Environment

With the increasing size of farms and growing efforts towards "sustainability" in agriculture, electronics is becoming indispensable. The term "precision agriculture" (PA) has been coined and used worldwide for all activities in this direction. Precision agriculture is based on a universally used positioning and navigation system and can be assigned to three job areas (**Fig. 9**).

Positioning: currently the two satellite positioning systems, GPS-NAVSTAR and GPS-GLONASS, can be used free worldwide (**Table 2**), but they are not accurate enough for farming (**Table 3**). This is why the installation and use of a reference system is essential.

Local data acquisition: electronics in tractors and machines, together with GPS, make automatic local data acquisition possible.

The basis for:

- complete field books;
- gap-free operating time records;
- job-related machine data;
- quantitatively correct accounting;

are laid out and the foundation for precision agriculture set.

More exact work: better, and above all environmentally sounder, cultivation is made possible through the use of electronic components. Typical examples of such systems available for tractors today include:

- four-wheel and differential lock control to optimize pulling power conversion;
- electronic wheelslip control for minimal wheelslip.

These systems are preliminary stages for more complex control systems. Their goals are:

- wheelslip reduction with dynamic ballasting;
- exact adherence to pre-set working depths;
- regulation according to plant cultivation optimal crumb sizes;
- depth regulation according to soil type and soil moisture;
- local application.

Local application: current approaches in precision agriculture are geared toward local fertilization according to application maps. They represent a first step towards the "real-time systems" which will be necessary in the future (**Fig. 11**).

This system applies similarly to pesticide application, in which maps, covering or individual plant recognition are used.

2.4 Connecting mobile electronics to the farm management

Economical and ecological conditions support the integration of mobile electronics into farm management. Therefore the farm management must move away from using individual programs, towards a database oriented system.

Data acquisition and data storage: comprehensive management requires a constantly updated data pool to which every system has access. In contrast to the applications up until now, date, time and position are the main classification elements (**Fig. 12**).

Four files are required for interaction between the Management-Information-System (MIS) and the "Mobile Process-System" (MPS):

- instruction file MIS → MPS;
- feedback file MPS → MIS;
- machine fileMIS → MPS;
- field or plot file MIS → MPS.

Standard file formats, according to ISO 11787 (ADIS), allow for universal application and guarantee compatibility independent of the particular transfer medium used.

Larger farms demand "real-time data transfer" from the MPS to the MIS, in order to be constantly informed about the current working situation and about the particular process parameter (yield, moisture, worked area, error values, etc.).

In the not too distant future, the MIS will also be used for remote diagnosis and control of the machines.

Evaluation and interpretation: a very high work load for data processing and editing, representation and interpretation arises from the "precision agriculture" system. Images (earth, air, satellite) and process data must be brought together in the geographical information system (GIS) in order to produce yield and infestation maps.

Planning and prognosis: prognoses and application maps can be derived and produced from the edited information. This is the main purpose for "Decision Support Systems" (DSS) in MIS. However these tasks have more to do with classic farm management and will not be mentioned any further here.

3. Further requirements in research

If one looks at current use of electronics and the developments that will result in the near future, three basic areas in which research will be needed can be recognized. The following examples are not to be considered complete.

3.1 Sensors and actuators

Without any doubt, a continuing and even increasing need for research in the sensor sector will result when "precision agriculture” is realized in "ral-time systems”, and if the current trend in technical development continues to hold on. Above all, the following are required:

3.1.1 Tractor

The three main areas for tractors are:

Row or line guidance: tractor and implement combinations require guidance assistance to ease the burden on the operator caused by increased working widths and working speeds. Possibilities are:

- image processing systems;
- navigational systems (satellite, laser, microwave, radar).

Autonomous guidance: autonomous (unmanned) vehicle guidance will additionally require:

- ideal reckoning systems;
- inertial systems;

with on-line communications equipment in contact with the guiding vehicle or the main control center.

Safety: because of growing farm sizes, more tractors are driven by inexperienced persons with little local knowledge. In addition, driving and working speeds are continually becoming faster. The available engine power is also increasing. This calls for more emphasis on safety matters in the form of:

- identification of dangerous driving conditions;
- identification of signs of instability;
- vehicle positioning with match mapping of site maps.

3.1.2 Machines and implements

Other than in tractors, sensor technology is also needed for various implements:

Cultivation: for a "lasting cultivation", optimal tractor-implement employment requires on-line recording and integration of the most important soil parameters into the technical control system:

- soil moisture content;
- soil resistance (compaction);
- crumb size (crushing effect);
- soil texture.

Contactless sensors should be favored because they minimize stress on materials and because of their high availability.

Crop growth: due to strong weather dependency, necessary measures for crop growth can only be determined by the situation on site, where proper action can be taken immediately. The following sensors are necessary:

- bearing;
- growth level;
- crop activity;
- water stress.

Contactless sensors should also be favored in this area.

Fertilizing: crop growth and crop yield are directly related to the available nutrients. Precision farming opens the door to this area. For the proper supply of fertilizer, high quality sensors are necessary to record:

- soil nutrients (real-time analysis, standing still and on-the-go);
- crop nutrients (especially nitrogen).

Contactless sensors should also be favored in this area.

Crop protection: the second application for precision farming is the local or selective treatment of crops, which greatly reduces the burden on the environment. Suitable sensors for recording and recognition of weeds, pests and plant diseases are a necessary prerequisite. Sensors should make the error-free implementation of these tasks possible. Important starting points are:

- image analysis (soil, air, space);
- spectroscopy;
- reflectometry.

In addition, controllers adapted for the selective application of chemicals or for selective mechanical pest control are necessary.

Harvesting: it is the harvest, in the end, that brings economic success. The most important aspect is minimizing loss through the use of better sensors for:

- quantification of loss;
- detection of incorrect machine settings.

More improvements in yield determination are essential with:

- reduced number of errors;
- simplified or automatic calibration;
- integrated moisture content measuring.

Local weed recognition during the harvesting process would be practical for targeted follow-up treatment and control, including:

- recognition;
- differentiation;
- quantification;
- local assignment.

3.2 Decision support systems

Extensive use of electronics with diverse sensors and controllers make better monitoring and regulation possible if the particular objectives are clearly defined and fixed. This is possible through:

- knowledge and experience of the operator;
- correlations that are scientifically gathered and defined in formulas;
- decision support with powerful databases and decision tools (DSS).

Everywhere were:

- very complex subsystems work together;
- actual correlations are not yet known;
- uncertainty in making a consistent decision exists or;
- more optima are possible;

is where decision tools should be incorporated. They will be used to a greater extent when less qualified operators are employed or when unmanned systems will work in the future. These support systems can be used in three areas:

3.2.1 Tractor

Now that power-shift and/or continuous variable transmissions in combination with electronic engine control systems are going to be standard equipment on tractors, diverse new control strategies have to be developed, for example:

- minimum fuel consumption;
- maximum engine performance;
- constant engine and PTO speeds;
- constant working speed;
- low emissions;

and diverse combinations of these objectives. Decision support systems (**Fig. 13**) can contribute to decision making for the necessary adjustment processes if the model-oriented system for optimization and recommendations is chosen out of the broad range of DSS applications.

Draft optimization: through diverse adjustments in the electronic subsystems (engine, transmission, weight transfer, implement) in combination with diverse local conditions (soil type, moisture content, vegetation) clear correlations are difficult to recognize. Improved and more complex, but at the same time clearer, recommendations would bring about significant improvements in:

- minimizing wheelslip;
- saving fuel;
- reducing costs;
- reducing noise;
- lowering the burden on the equipment.

Recommendations concerning:

- performance reserves;
- temporal foreseeing and spatial adaptation (changes);

could be possible.

Rotation speed optimization: the adaptive abilities of the electronically controlled subsystems (engine, transmission, implement) are oriented to the implement working rate (local yield or effort, properties of goods) and in most cases require constant rotational speeds at changing working speeds and loads. The real-time adaptation to local conditions and the critical timely adaptation to strongly changing demands on performance, present the greatest challenge. Decision support for:

- relative working rate performance;
- reducing noise;
- lowering the burden on components;
- saving fuel and;
- reducing costs;

are important objectives.

Here too, recommendations concerning:

- performance reserves;
- temporal foreseeing and spatial adaptation (changes);

could be important for the experienced operator and would allow a broader range of possible action.

Operation: at this time, this area represents a bottleneck in vehicle guidance because even the newest electronic information equipment can only display one information at a time. The main objective is to obtain comprehensive information about:

- total performance;
- possible performance reserves;
- limiting factors;
- emerging problems and;
- cost assessment.

System diagnostics represents new challenges including:

- alarm handling and pre-information;
- step-by-step diagnosis procedure;
- alternatives available for the remaining work.

3.2.2 Tractor-Implement combination

The network from implement to tractor makes further control possible. Internal implement sensors and demands on the implement for working quality or safety measurements can be incorporated into the system, if the implement allows adjustment by the tractor (not allowed in LBS and ISO 11783 at this time!). Important are:

- goal decisions favoring either the tractor or implement;
- observation of safety-related guidelines (velocity, pulling power or rotation) and;
- consideration of the working environment (farm yard, road, field).

3.2.3 Precision farming in MIS

Lastly, MIS opens a wide range of applications for DSS. According to **Figure 13**, the "data-oriented DSS" should mainly be used for this purpose. Their application is possible (and necessary):

- to complete gaps in data records;
- to interpret recorded situations and;
- to determine necessary measures.

A fringe subject of agricultural technology has been touched on here. The tasks mentioned equally concern farm management (economics), environmental protection and the conversion through MPS. That is why an in-depth explanation will not be gone into at this point. On the contrary, this should be done together with farm planning, cost accounting and legal environmental guidelines.

3.3 Standardization

Subsequently, standardization is to be mentioned. First steps have been taken towards standardization with the introduction of:

- signal connector (ISO 11786; DIN 9684/1);
- ADIS (ISO 11787);
- LBS (DIN 9684/2-5);
- ISO 11783.

Further definitions have to follow. Important are:

- data dictionary for international data description and definition;
- diagnostic systems for ”on-board diagnosis” and remote diagnosis;
- standardized data output for positioning and navigation systems;
- universal interfaces to GIS;
- defined interfaces for tractor components (engine, transmission) in coordination with off-road
- vehicles, municipal equipment and construction vehicles;
- development of high-performance field bus systems, compatible to existing solutions;
- limitation of electro magnetic emissions.

4. Conclusions

Electronics has become an important part of technology today. However, it still only plays a partial role in agricultural technology, although networking and standardization are advancing.

The connection of the MPS to the MIS is essential.

Further developments in the sensor sector, with emphasis on image processing, microwave technology, laser technology and more precise positioning and navigation systems, are necessary.

Decision support systems are necessary for the optimization of:

- the tractor (power train, drive line management, safety requirements);
- operator information and assistance (alarm situation);
- real-time control in soil preparation, fertilizing, weed and pest control;
- MIS for the interpretation of data and for prognosis.

Standardization is a prerequisite for the application of electronics in the light of increasing international emphasis. Further standards are necessary for subsystems, for higher data transmission rates and for the protection of implements through comprehensive diagnostics.

5. References

[1] **Alter S.** - A Taxanomy of Decision Support Systems. Decision Support Systems 1983, New York, Petrocelli Books

[2] **Artmann R., Speckmann H., Robra J.** Datenübertragung zwischen Traktor, Arbeitsgeräten und Bordcomputer. Landtechnik 1989, **44**, 428 - 431

[3] **Auernhammer H.** - The German Standard for Electronical Tractor Implement Data Communication. Proceedings of 2nd International Conference AGROTIQUE 1989, Bordeaux, 395-402

[4] **Auernhammer H.** - Elektronik in Traktoren und Maschinen. München, BLV-Verlag (2nd edition) 1991

[5] **Auernhammer H.** - Landtechnik-Bus-System LBS - die Norm für die Zukunft. Landtechnik 1991, **46** (10), 487

[6] **Auernhammer H.** - Requirements for a Standard for Tractor Implement Communications. ASAE Winter meeting Chicago 1993, Paper n. 93153, St. Joseph, USA

[7] **Auernhammer H., Frisch J. (Hrsg.)** - Landwirtschaftliches BUS-System LBS (Mobile Agricultural BUS-System - LBS). Münster-Hiltrup: KTBL-Schriftenvertrieb im Landwirtschaftsverlag GmbH 1993, Arbeitspapier 196 (ISBN 3-7843-1841-X, 199 S.)

[8] **Auernhammer H.** - LBS - Einführung in die Praxis. Landtechnik 1994, **49** (2), 104-105

[9] **Auernhammer H., Demmel M., Ostermeier R., Weigel R.** - Bus Configuration and Bus Load in a Tractor Fertilizer Spreader System (LBS by DIN 9684). Proceedings of International Conference on Agricultural Engineering AgEng'96, Madrid, 23-26 September 1996, Vol. 1, 207-208

[10] **BOSCH** - CAN: Controller Area Network. Stuttgart, BOSCH, 1987

[11] **DIN 9684-1** - Schnittstellen zur Signalübertragung. Teil 1, Punkt-zu-Punkt-Verbindung. Berlin, Beuth-Verlag, 1997

[12] **Hirt C.** - Das Landwirtschaftliche Kommunikationssystem (LKS). Landtechnische Schriftenreihe, Österreichisches Kuratorium für Landtechnik und Landentwicklung 1994,

Wien, n. 203

[13] **House W.** - Decision Support Systems. New York, Petrocelli Books, 1983

[14] **ISO 11783** - Tractors, machinery for agriculture and forestry. Serial control and communications data network. Documents under preparation, ISO/TC23/SC19/WG1

[15] **ISO 11786** - Agricultural tractors and machinery. Tractor-mounted sensor interface. Specifications. Geneve, ISO 11786 (E), 1995

[16] **ISO 11783** - Machinery for agriculture and forestry. Data interchange between managegement computer and process computers. Data interchange syntax. Geneve, ISO 11787 (E), 1995

[17] **LAV** - LBS - Das Landwirtschaftliche BUS-System. Frankfurt, LAV, 1997

[18] **Schön H.** - Computer in der Landwirtschaft. Stuttgart, Ulmer Verlag, 1993

[19] **Stone M., Zachos M.** - Straight Talk. Agricultural Engineering 73 1992, St. Joseph, **6**, 13-16

[20] **Terao H.** - Mobile agricultural Bus-System LBS and PA for the large-scale farm mechanization. Proceedings of the International Symposium 1997, Sapporo, Hokkaido Branch of the Japanese Society of Agricultural Machinery

Fig. 1 - Milestonesin tractor development

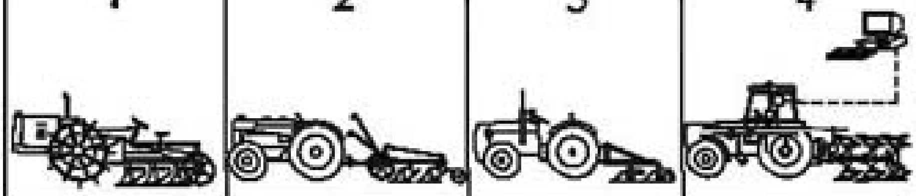
	Milestone			
No.	1	2	3	4
Form				
Innovation	Combustion engine + rotational power	Pneumatic tire	Hydraulics + three-point-linkage	Electronics + communication
Characteristic	Self propelled working vehicle	Universal traction vehicle	Tractor implement unit	Communicational process link
Achievement	"Biological" independence	Mobility	Self propelled property	"Technical" intelligence

Fig. 2 - Areas of employment for electronics in agricoltural technology

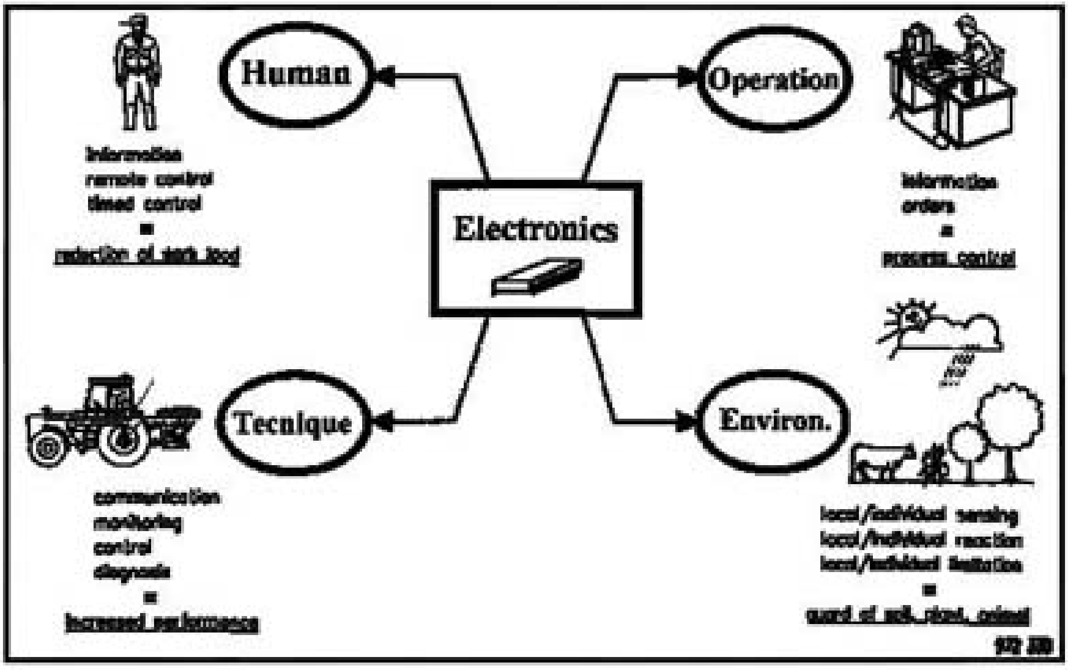


Fig. 3 - CAN in FENDT - tractors

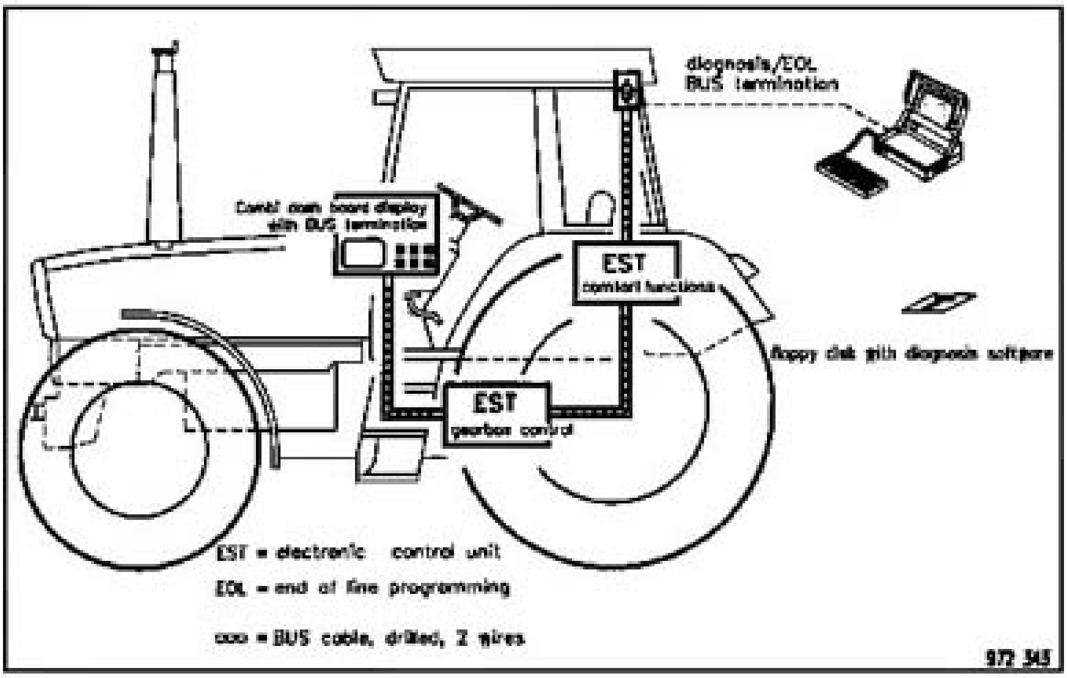


Fig 4 - CAN in CLAAS - combines

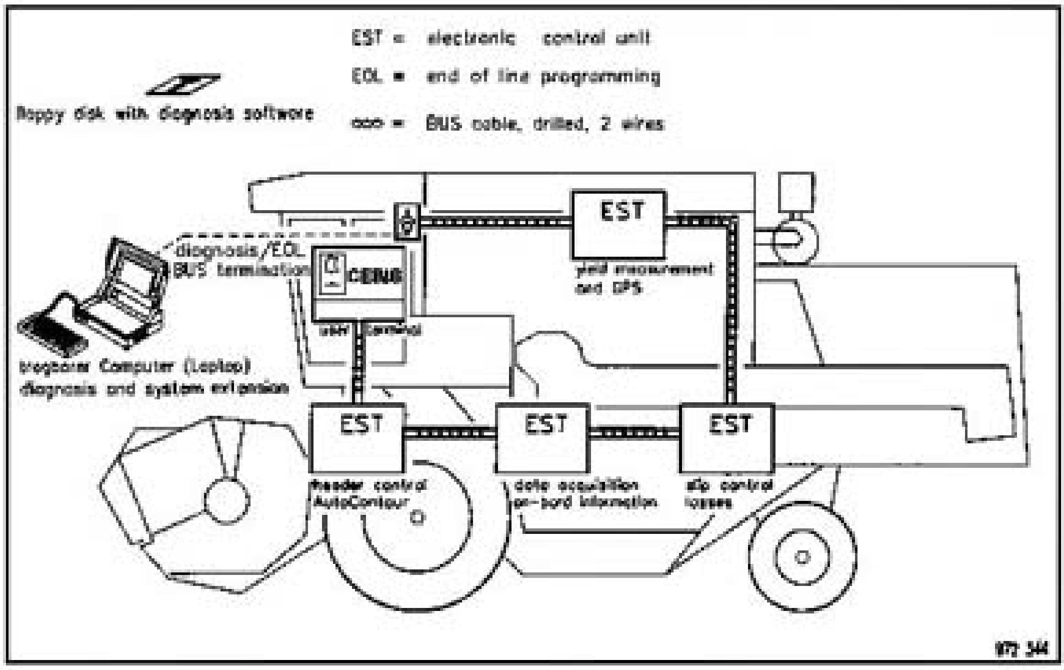


Fig. 5 - Specialized controller in implement control

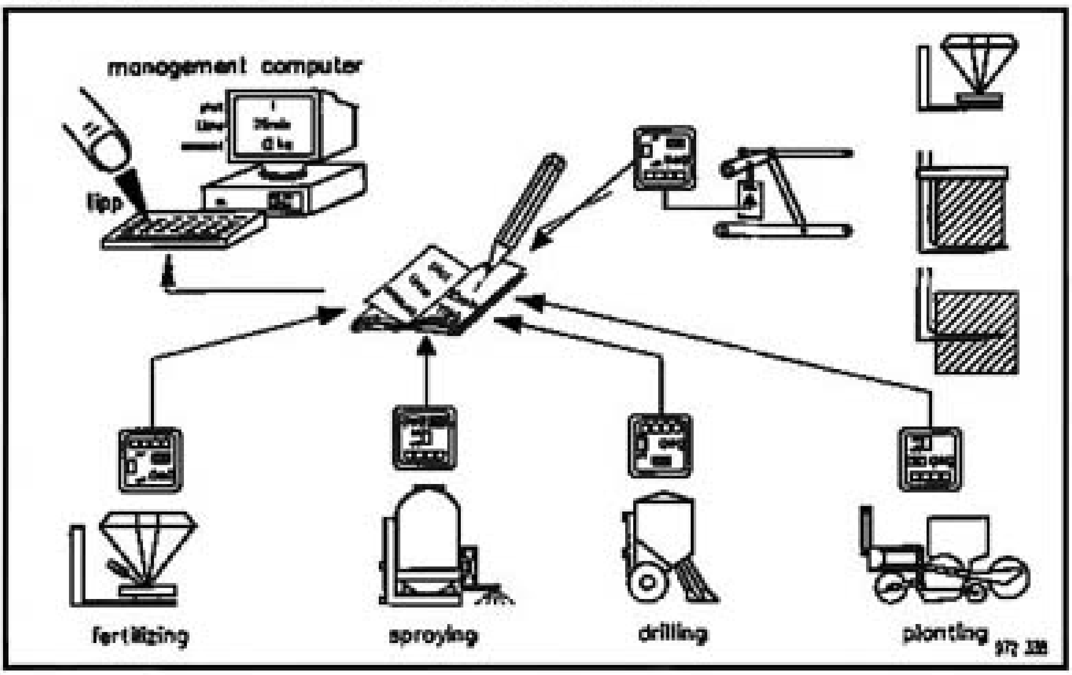


Fig. 6 - Specialized di controller in implement control

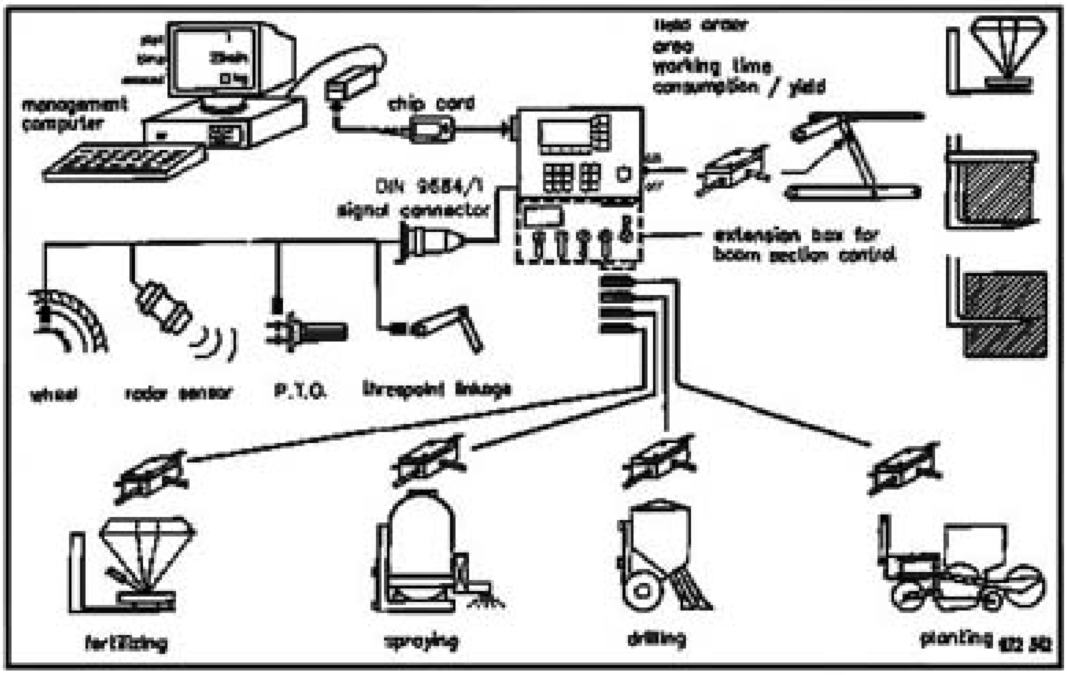


Fig. 7 - Agricultural BUS-System (LBS) according to DIN 9684/2-5

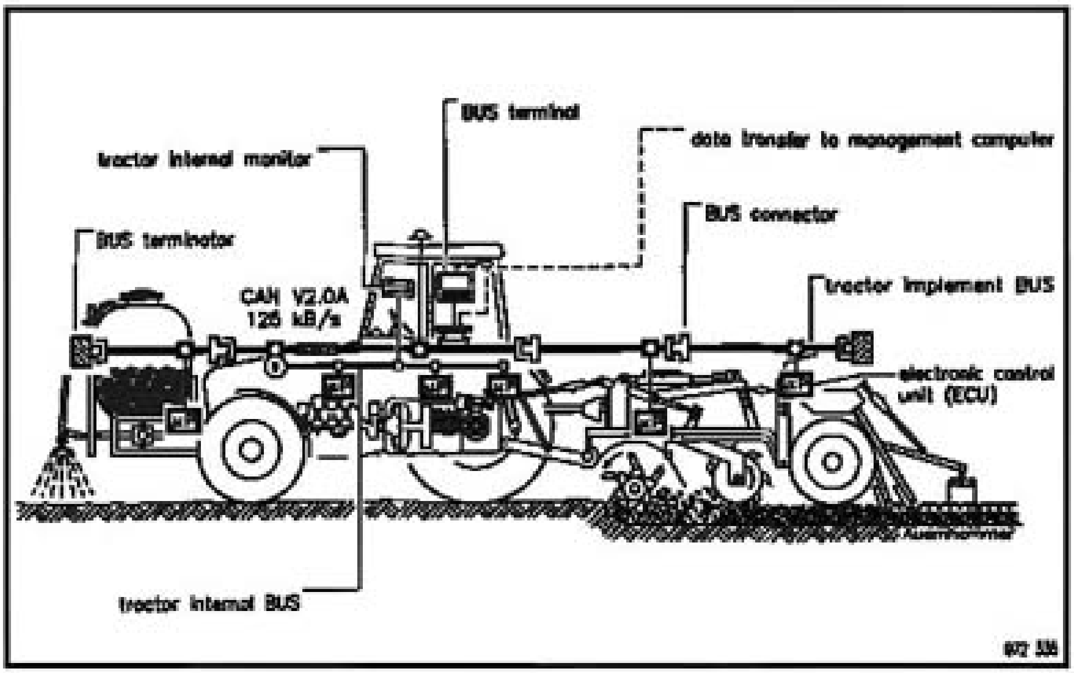


Fig. 8 - Separation of the functional areas "driving" and " implement control"

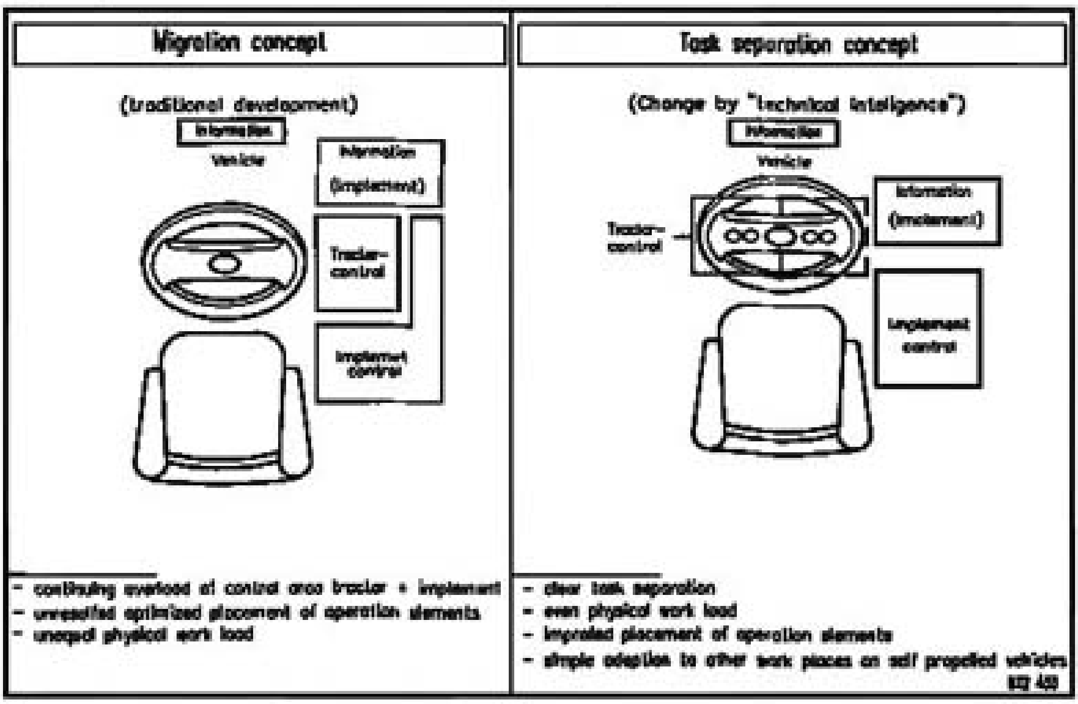


Fig. 9 - Job areas for "Precision Agriculture"

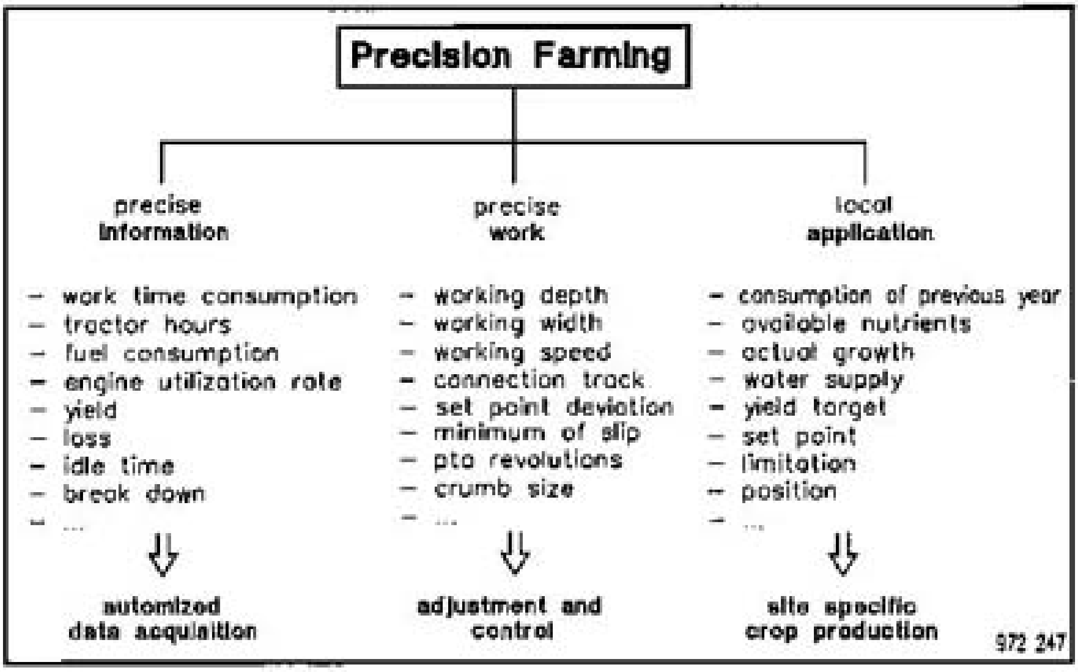


Fig. 10 - Automatic Data Acquisition in sugarbeet harvesting

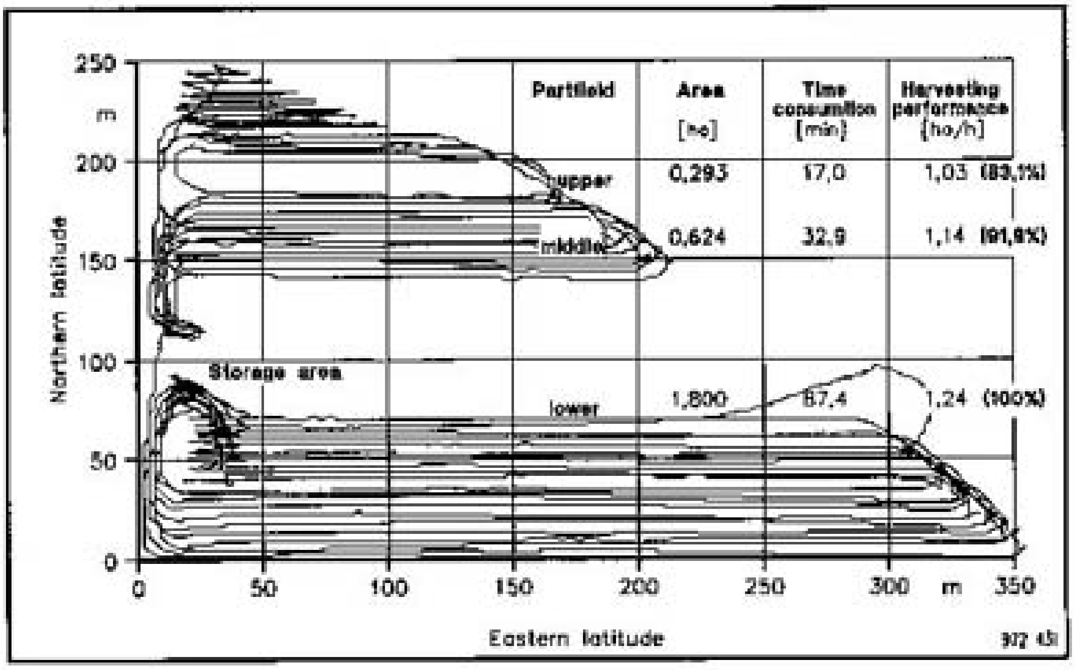


Fig. 11 - Application system for local fertilizzation

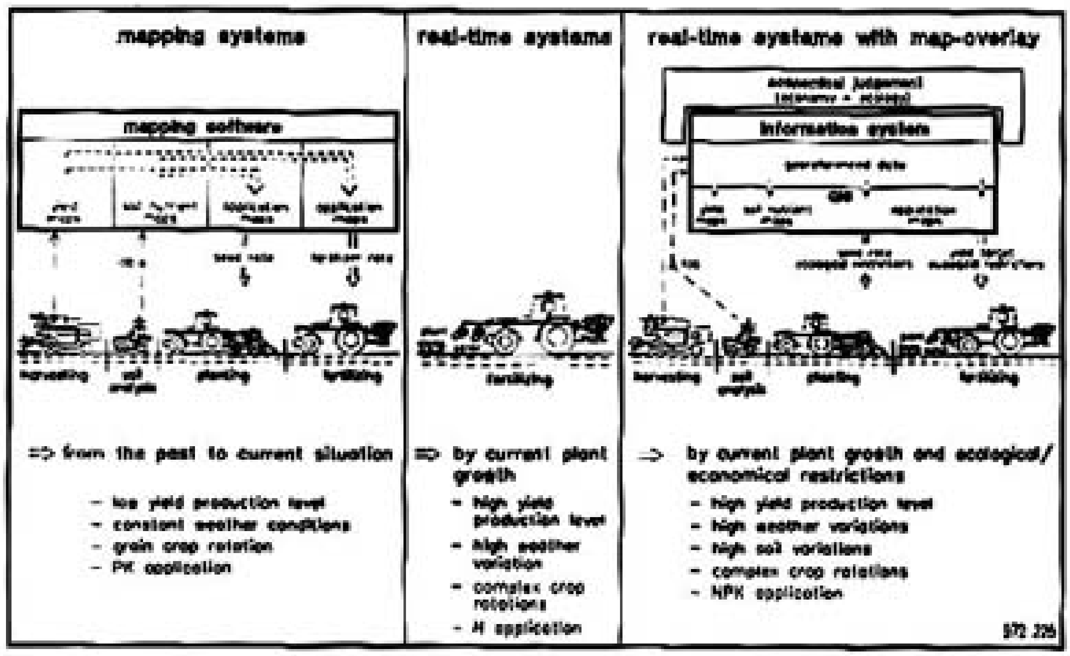


Fig. 12 - Managenent information systm with local data attributes

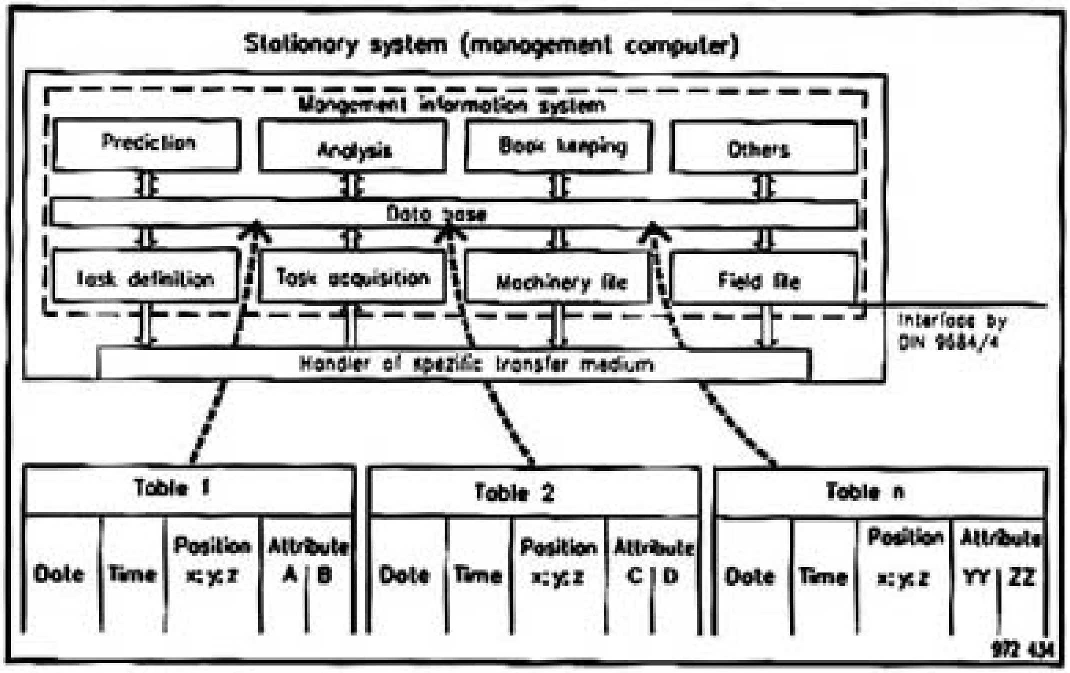


Fig. 13 - Data-Oriented vs. Model-Oriented decision support system types [1]

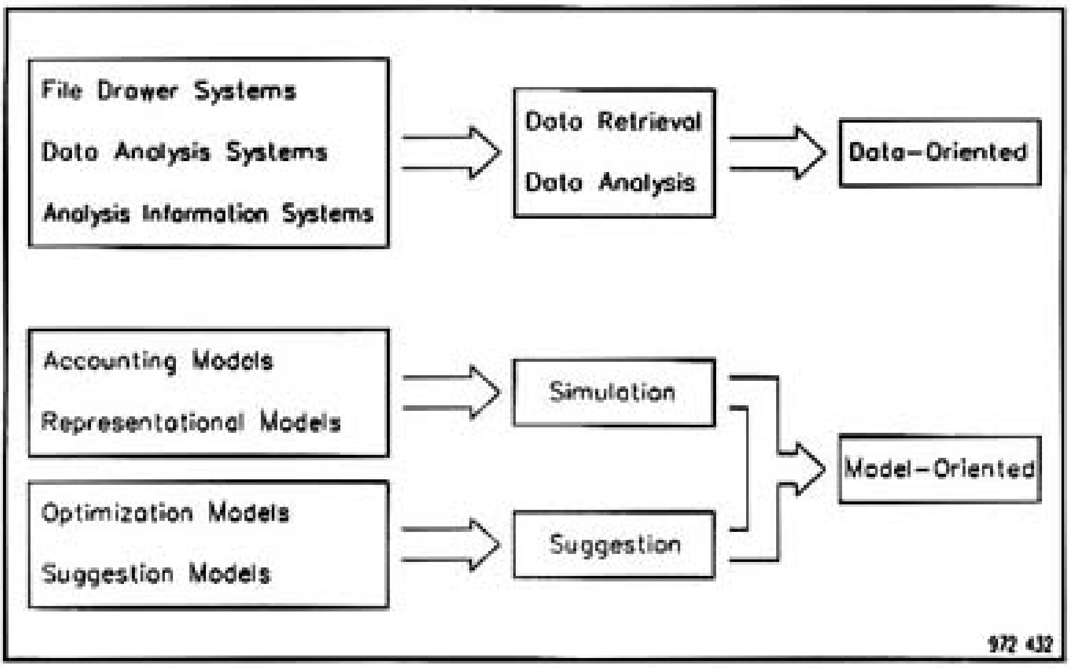


Table 1 - CAN in tractors and self-propelled harvesters

MAKER	PRODUCT	MODELS	NUMBER OF CONTROLLERS	TYPE OF CABLE	TRANSMISSION SPEED	UNITS IN FIELD	SOLD SINCE	CONTROLLERS TOTAL	LBS	SINCE
FENDT	Tractors	500 800 900	2 2 3	Unshielded	100	16000	3/1993	32000	yes	9/1996
FORD	Tractors	8670 8770 8870 8970	4 4 4 4	Shielded	250	10000	3/1994	40000	no	
FIAT	Tractors	G170 G190 G210 G240	4 4 4 4	Shielded	250	12000	3/1994	48000	no	
MF	Tractors	6100 8100	3 3	Unshielded	100	12000	3 /1995	36000	no	
NEW-HOLLAND	SF choppers	FX300 FX375 FX450	5 5 5	Fibre optic	500	700	3/1994	3500		
NEW-HOLLAND	Combines	TF78	5	Fibre optic	500	70	9/1994	350		
CLAAS	Combines	LEXION	up to 8	Unshielded	100	50	6/1995	200		
Total (by 1-Mar-1996; figures from makers)						**50820**		**160050**		

Table 2 - Global Navigation Satellite Systems

GPS - NAVSTAR		GLONASS	
NAVigation **S**ystem with **T**ime **A**nd **R**anging		**GLO**bal=naya **Na**vigatsioannaya **S**putnikovaya **S**istema	
21 + 3	Satellites	24	Satellites
6	Orbit levels	3	Orbit levels
20183 km	Altitude	19100 km	Altitude
11h 56min	Orbiting time	11h 16min	Orbiting time
±100 m (2 drms)	Accuracy	± 25 - 35 m (2 drms)	Accuracy
FOC	17.6.1995	IOC 18.1.1996	
WGS 84	Coordinate system (World Geodetic System 1984)	SGS 85	Coordinate system (Soviet Geodetic System 1985)
Possibility of signal degradation (SA; AS)		**No** signal degradation	
10 years guaranteed useability		15 years guaranteed useability	

Table 3 - Accuracy requirements for positioning in agriculture

REQUIRED ACCURACY	TASK	EXAMPLE
± 10 m	navigation	- targeting of fields (machinery ring, contractor) - targeting of storage area (forestry)
± 1 m	job execution information documentation	- local field operations with • yield monitoring • fertilizing • plant protection • soil sampling • action in protected areas - automated data acquisition
± 10 cm	vehicle guidance	- gap and overlay control (fertilizing, spraying) - grain combining
± *1 cm*	*implement (tool) guidance*	- *mechanical weed control*

Role of electronics and decision support systems for a new mechanization

by ***John K. Schueller***
USA

1. Background

Electronics and computers continue to grow in importance in agricultural mechanization. Their use permeates all aspects: design, control, manufacturing, and management. Evidence of their importance is ubiquitous:

- agricultural equipment companies are acquiring smaller agricultural electronics and software firms;
- agricultural equipment companies are hiring increasing numbers of electrical engineers and computer scientists;
- commercially-produced agricultural equipment contains increasing numbers of sensors, computer controls, and electronic interfaces;
- many educational and technology transfer activities in both the public and private sectors emphasize those areas;
- research and technical efforts, such as the technical journal *Computers and Electronics in Agriculture*, continue to grow in importance and prestige;
- Even many of us Club of Bologna members continue to become more proficient in computers and electronics.

This has not been a recent trend. The trend has been evident since the 1980s and the literature amply documents that trend (Devine, 1983; Searcy, 1991).

Completely documenting the developments in electronics and computers in agriculture would produce too lengthy of a document. So this work will attempt to give a perspective of the current situation through a few examples. More detailed information in the general area can be found in sources such as:

- *Computers and Electronics in Agriculture* (technical journal);
- *Journal of Agricultural Engineering Research* (technical journal);
- *Transactions of the ASAE* (technical journal);
- *AgEng* conferences sponsored by the *European Society of Agricultural Engineers*;
- *Jahrbuch Agrartechnik/Yearbook Agricultural Engineering* (Matthies and Meier, 1997);
- *ASAE* papers.

The area of the greatest crop production interest and activity in the developed, and some of the developing countries, is what is variously known as spatially-variable, site-specific, GPS-based, or precision agriculture. By its nature, this set of technologies is extremely dependent upon electronics and computers. That dependence, and the popularity of precision agriculture, means that a significant fraction of the work involving electronics and computers in agriculture is in precision agriculture, or labelled as such for publicity reasons. Among the sources of information on precision agriculture are:

- *Precision Agriculture* (new technical journal);
- Proceedings of the Precision Agriculture conferences in Minnesota (Robert et al., 1993, 1995, 1996);
- Proceedings of the First European Conference on Precision Agriculture (Stafford, 1997);
- *The State of Site-Specific Management for Agriculture* (Pierce and Sadler, 1997) and the many articles in farmer and farm supplier publications.

2. Developments

The role of electronics and computers is greatly shaped by the technology which is developed and commercialized. It is helpful to review examples of those developments. Many of these developments can be categorized into the groupings which follow.

2.1 Sensors

Anyone who has developed control or management systems for agricultural equipment knows that getting accurate information is crucial. Accurate, fast sensing is almost always critical, and often the dominant problem. Sensing or measuring items has therefore been the focus of many engineering activities.

Yield mapping (Searcy, et al., 1989) is the most important aspect of precision farming. Accordingly, the measurement of the amount of crop being harvested is a prime activity in sensor research, development, and commercialization. The technology for measuring grain flow (Birrell, et al., 1996) on combine harvesters is in its adolescence--functional but needing growth and maturity for optimum performance. The measurement of other crops (sugar cane, sugar beets, forage, cotton, fruits, vegetables, etc.) is in various lesser stages of development. A technical session on the yield mapping of non-grain crops at the 1997 A.S.A.E. Annual Meeting provided an excellent perspective on the state-of-the-art in this area.

Remote sensing has seen a recent upsurge in interest which is both technology-driven and market-driven (Horstmeier, 1997). On the technology side, the increasing use of digital cameras and better image processing computers and software has increased the resolution while decreasing costs and delays in information availability. The battle between aerial and space-borne platforms will be accelerated by the upcoming launch of one-meter resolution satellites.

The commercialization of precision agriculture technologies means that farmers are now truly aware of spatial variability, including the actual quantification of the larger-than-expected financial effects. Farmers also now have technologies which allow them to respond to within-field variability, especially through variable rate application of irrigation water, fertilizer, pesticides, and seeds. This all contributes to the market for remote sensing (Shepherd, 1997). Although remote sensing has been around for a long time, its commercial success has been modest. That may change.

The variability seen in yield maps and remote sensing images has led to attempts to understand that variability. Hence, there have been efforts to map, or at least measure, the variabilities in soils (Hummel, et al., 1996), crops, and pests. For example, in soils there is substantial work to measure topography, organic matter, moisture (Stafford, 1988), nitrates, and phosphorous. Locations (Stafford, et al., 1996) and species of weed infestations is another example.

The publicity given precision agriculture has distracted attention away from the ongoing development and commercialization of sensors for use in monitoring and control systems. But progress continues in the directions which have long been evident. Sensors continue to be developed to improve machine performance and to gather information. A recent trend has been the increased emphasis on quality measures. For example, grain protein and moisture content monitors are becoming more popular. Some farmers are manually segregating grain based upon its quality. Such a procedure could be automated.

2.2 Control systems

Automatic control systems continue their moderate pace of adoption on agricultural equipment. There appears to be somewhat of a paradigm shift. Traditionally, the control systems were machinery-centered. The Ferguson system varied implement working depth, not for agronomic reasons, but to maintain an even load on the tractor’s engine. The self-levelling hillside combine harvester acted to kept the combine’s losses at a reasonable level. Now the control systems are becoming more agronomy-centered. The fertilizer and pesticide applicator’s flowrate is now varied, not only to respond to applicator travel speed variations, but also to respond to the varying fertilizer and pesticide needs of the crop and field (Giles and Slaughter, 1997). As another example, a variable-incorporation tillage tool may change its operation in response to localized soil erosion potential. Yet another plants the seed at the proper point in the soil moisture profile (Weatherly and Bowers, 1997).

A definite continuing trend is the networking of control systems. The drive for networking standards for mobile agricultural equipment has been spearheaded by leaders in the field such as Marvin Stone, Herman Auernhammer, John Stafford, and Daan Goense. Whether the networking commonality comes from standardization or eventual marketplace darwinism, the networking of the various systems on agricultural mobile equipment is inevitable.

Agricultural equipment control systems, both open-loop and closed-loop, are becoming increasingly electronic and computer-based. The machine operator is increasingly isolated in his cab from the equipment's subsystems by electronics which do not transmit forces, vibrations, or noise. Hydraulic and clutch systems are increasingly electronically controlled. This also allows actuation to be modulated according to the load and other operating conditions.

2.3 Precision agriculture

As indicated above, precision agriculture is the most popular area in agriculture at this time. The technology (Schueller, 1992) generally involves the following steps when implemented at the farm level:

- the spatial variability of the crop yield is mapped;
- the spatial variability of potential causative factors (topography, fertility nutrients, weed infestations, etc.) is mapped;
- the maps are used to identify probable causes of the variations and to develop potential actions to maximize profitability considering the variabilities;
- the potential actions are evaluated for economic, agronomic, and environmental feasibility;
- the actions are implemented.

It is obvious that electronics and computers are heavily involved in precision agriculture. Electronic sensors and computers to store the data are necessary in the mapping operations. Determination of the optimium actions will usually involve extensive computer work. Computer controllers and electronically-controlled actuators with good control systems are necessary to achieve the desired actions.

The responses to spatial variability can be classified into three categories:

- Homogeneous - If there is insufficient variability to justify a response on economic, agronomic, or environmental grounds, the field should be treated as uniform;
- Strategic - An often-economical method of responding to variability is to make a strategic change. Examples include moving field boundaries or adding localized drainage (Finck, 1997). Such decisions often require the use of decision support systems (DSS) or simulations to determine the potential benefits of a strategic change;
- Tactical - The usual conception of precision agriculture is that the farmer makes tactical decisions. For example, varying the rate of fertilizer or pesticide application according to localized need due to within-field variations in the soil and nutrients. Computers are vital to determine the action algorithm, store the action maps, and implement the control to follow those maps.

The continued commercialization and adoption of precision agriculture will encourage the continued adoption of electronics and computers. Many quantities will need to be sensed so that they can be mapped. Adjustments on various machines will need to be electronically-controlled so that they can be spatially-varied.

2.4 Autonomous systems

Autonomous agricultural equipment, including "driverless tractors", have been discussed for many years. In the middle 1980s there were many technology-driven efforts to utilize advances in machine vision and robotic technologies. However, other than row-followers with mechanical feelers, little widespread commercial acceptance was achieved.

Recent advances in computational capabilities and the general improvement in machine vision technologies (Billingsley and Schoenfisch, 1997) means that autonomous and semi-autonomous vehicles are more feasible. Sensor (Noguchi, et al., 1997), GPS, and map technologies also provide strong tools. The three largest North American farm equipment manufacturers are among those with significant ongoing efforts. There has also been a renewed interest in the universities.

2.5 Databases

The ability to gather and store information, especially with geographical attributes, has led to the generation of databases. The rapidly-decreasing price of computer storage, and networking schemes such as the internet, allow the generation and storage of huge databases of agricultural data. Appropriate software allows the tracking of individual small portions of fields, individual machines, and individual machine operators.

The precision agriculture revolution has resulted in many maps in geographic data bases generated with computer programs called geographic information systems (GIS). These programs present the map layers and perform image algebra. Standardization is still lacking, but there already are many mapped agricultural fields.

Databases of machinery and operator performance are less common. The locator and computer technologies being used for precision agriculture can be easily modified for such tracking and analyzing machine and operator productivity.

2.6 Simulation

Perhaps the greatest use of computers in agricultural universities other than office tasks and data acquisition has been in simulation. Simulation is widely used to study soil and water relations (Azevedo, et al., 1997), plant growth, machinery behavior (Book and Goering, 1997), and machinery operations among its many applications. Advances in computer speed and software allow complicated systems to easily be simulated in detail for many scenarios.

Simulation should be used in precision agriculture to determine the best strategic and tactical actions. Efforts to catch up to the precision agriculture revolution have resulted in some progress in marrying simulation models to precision agriculture. The key is to link the simulation model to the geographic information system.

The dynamic nature of control systems requires that they respond quickly to commands. Due to nonlinear components, classical closed-form analysis of agricultural equipment is often difficult. Dynamic simulations allow the performance to be verified. For example, a poorly performing piece of tactical precision agriculture equipment may be worse than homogeneous operation despite all the initial cost (Schueller and Wang, 1994).

2.7 Decision support systems

Simulations are just one type, or one component, of decision support systems. The farm operator has to manage a broad spectrum of activities requiring a great breadth of detailed knowledge. It has long been a goal to use computers to provide expert help in making decisions. Much research and development has concentrated on attempting to provide such help, often through state-of-the-art technologies such as expert systems and neural networks. Donnelly, et al., (1997) and Smith et al., (1997) are just examples of such a systems. Progress has generally been slow. But some systems are now starting to see commercial usage. The GOSSYM-COMAX package is seeing commercial usage in USA cotton to schedule irrigation and fertilization (Dale, 1997).

3. Mechanization in a computer and

electronic age

The continuing expansion of the capabilities of computers and electronics will have implications for agricultural equipment and agriculture in general.

3.1 Machine design

Even though most agricultural equipment companies are in the midst of generally profitable times, their expansion of staffs has been modest. This is due to there finally being some evidence of productivity gains from computerization of engineering functions. Just as computerized data acquisition systems have sped up testing, the design process now requires less staff due to the more user-friendly and powerful computer-aided design (CAD), finite element method (FEM), simulation, and computational fluid dynamics (CFD) software packages. The more accurate designs generated with these tools lead to less design and test iterations.

The use of electronic and computer controls will continue to create a more comfortable, and hopefully more productive, operator environment. Less vibration, actuating forces, and noise were mentioned above. But electronic and computerized displays and controls can be designed to provide information in a more useful manner and to allow easy control. Recent iterations of equipment design show more signs of attention to ergonomic detail, essentially making the cab more operator-centered, rather than machine-centered.

The use of electronics and computers may allow the requirements of mechanical components to be relaxed. For example, electronics can compensate for some degradation (such as nonlinearities) in mechanical characteristics in hydraulic valves. Control lever requirements are similarly relaxed.

The local conditions can also be accommodated. For example, the effective cost of fuel varies widely. The engine control algorithm can be changed for different local tradeoffs of productivity and fuel economy. Quality requirements and optimum loss variations based upon location of harvesting may be reflected in controller algorithm or parameter changes.

The implications of progress may be greater in specialized machinery, such as harvesters for fruit, vegetables, and specialty crops. Computer-aided design techniques can be used to create custom machines and then the sensors and controls can be programmed according to the machine's specialized tasks. Even larger volume products, such as tillage tools, can be custom designed for local conditions.

3.2 Manufacturing

The computer and electronics proliferation in manufacturing factories has introduced greater flexibility. Rather than being dependent upon sales projections and maintaining large inventories, the modern flexible production line can produce equipment in mixed batches as needed. This technique is somewhat limited in the agricultural equipment industry due to the nonuniform sales pattern during the year.

Recent advances in programmability, controls, and dynamic compensation have increased the speed and flexibility of metal removal and deformation machines. This increases the flexibility of component production analogously to the increased flexibility of assembly operations.

3.3 Precision agriculture

The theme of flexibility due to electronics and computers also extends to the crop production operations themselves. Precision agriculture is the utilization of the electronic and computer systems on agricultural equipment to manage small nearly-homogeneous areas within larger, heterogeneous agricultural fields. It also provides the means to gather data for databases of crops, machines, and operators. In the near future data will be frequently gathered automatically and transfered by wireless means to management computers.

3.4 Control systems

The traditional role of electronics and computers in agricultural equipment is to improve the performance of the equipment in doing its assigned task. Control systems utilizing those components respond to variations in the crops, soils, and environments to optimize performance. They also improve operator comfort and performance by either performing tasks for the operator or by aiding his performance. On the agricultural equipment itself, computers and electronics detect performance errors or problems and attempt to correct them.

3.5 Concepts Affecting the Role of Electronics and Computers

The above discussion points out the concepts which affect the role of electronics and computers in contemporary agricultural equipment:

- crops, soils, and pests are variable within agricultural fields and the equipment must respond accordingly;
- agricultural equipment must be adjusted or adjust itself to local conditions;
- computers and electronics can improve the performance of components and subsystems on agricultural equipment;
- computers and electronics can improve operator comfort and performance;
- agricultural equipment is a useful platform for the acquisition of farm management data. This data will be automatically gathered and transferred;
- autonomous or semi-autonomous vehicles may result from near-term application of further electronics and computers to agricultural equipment;
- computers and electronics in the design and manufacturing of agricultural equipment allow greater flexibility in design and construction and facilitate custom equipment.

4. Implications for developing countries

Although every country's situation is unique, the above implications of the increase in electronics and computers in agricultural equipment appear to be widely applicable. An initial impression might be that computers and electronics might be less appropriate in developing countries, that maybe this discussion is irrelevant to them. However, there are some reasons why computers and electronics in agricultural mechanization are relevant:

- the variability in fields in many developing countries is as great as in the developed countries ;
- the gathering of information is also important in developing countries, especially considering less historical data availability;
- machinery sharing in developing countries increases the potential value of automatic proper attribution of yields or input consumption;
- electronic sensing and control may relax the requirements on mechanical components for agricultural equipment, allowing the mechanical components to be manufactured locally with importation concentrated on small, sophisticated components;
- electronics and computers allows the embedding of diagnostics to aid agricultural equipment maintenance and repair.

The use of electronics on agricultural equipment in developing countries should consider these issues as well as the traditional concerns about introducing advanced technology.

The continuing decrease in the cost of personal computers while their capabilities increase enhances the potential for decision support systems, expert systems, and simulations in developing countries. The internet makes information available near instantaneously worldwide (Manguena, 1997). Sophisticated programs can be run on inexpensive computers to aid management decisions. For example, Gebresenbet, et al., (1997) used a battery-powered data logger and power spectral density analysis to optimize an animal-drawn plow. A network similar to the Virginia system which provides weather, pest and frost advisories, and cultural and pesticide recommendations (Deck and Phipps, 1997) could be set up in developing countries for local crops.

References

[1] **Azevdo A., Singh P., Kanwar R., Ahiya L.** - Simulating nitrogen management effects on subsurface drainage water quality. Agricultural Systems 1997, **55**(4), 481-501

[2] **Billingsley J., Schoenfisch** - The successful development of a vision guidance system for agriculture. Computers and Electronics in Agriculture 1997, **16**(2), 147-163

[3] **Birrell S., Sudduth K., Borgelt S.** - Comparison of sensors and techniques for crop yield mapping. Computers and Electronics in Agriculture 1996, **14**(2/3), 215-234

[4] **Book R., Goering C.** - Load sensing hydraulic system simulation. Applied Engineering in Agriculture 1997, **13**(3), 415-419.

[5] **Dale D.** - How to map mid-season profits. Farm Journal 1997, **120**(9), 21.

[6] **Deck S., Phipps P.** - Development and implementation of a bulletin board system for information transfer to the Virgina peanut and cotton industry. Applied Engineering in Agriculture 1997, **13**(3), 415-419.

[7] **Devine T.** - Proceedings, Agricultural Electronics--1983 and Beyond, December 11-13 1983, Chicago, Illinois.

[8] **Donnelly J., Moore A., Freer M.** - GRAZPLAN: decision support systems for Australian grazing enterprises. I. Overview of GRAZPLAN project and a description of the MetAccess and LambAlive DSS. Agricultural Systems 1997, **54**(1), 57-76.

[9] **Finck C.** - Drainage boom: Wet springs, high dollar corn and yield monitors fuel the upsurge. Farm Journal 1997, **120**(9), 14-16

[10] **Gebresenbet G., Zerbini E., Astatke A., Kaumbutho P.** - Optimization of animal drawn tillage implement system: Part 2, development of a reversible plough and a ridger. Journal of Agricultural Engineering Research 1997, **67**, 299-310

[11] **Giles D., Slaughter D.** - Precision band spraying with machine-vision guidance and adjustable yaw nozzles. Transactions of the ASAE 1997, **40**(1), 29-36

[12] **Horstmeier G.** - High-tech eyes: Remote sensing continues to show promise. Farm Journal 1997, **121**(6), 24-25

[13] **Hummel J., Gaultney L., Sudduth K.** - Soil property sensing for site-specific crop management. Computers and Electronics in Agriculture 1996, **14**(2/3), 121-134

[14] **Manguena H.** - Internet-based decision support systems. Resource 1997, **4**(4), 11-12.

[15] **Matthies H., Meier F. (eds.)** - Jahrbuch Agrartechnik / Yearbook Agricultural Engineering 1997, Vol. 9. KTBL, LAV-VDMA, VDI-MEG

[16] **Noguchi N., Ishii K., Terao H.** - Development of an agricultural mobile robot using a geomagnetic direction sensor and image sensors. Journal of Agricultural Engineering Research 1997, **67**, 1-15.

[17] **Pierce F., Sadler F. (eds.)** - The State of Site-Specific Management for Agriculture 1997, ASA/CSSA/SSSA.

[18] **Robert P., Rust R., Larson W.** - Proceedings of soil specific crop management: a workshop on research and development issues 1993, Minneapolis. April 14-16, 1992

[19] **Robert P., Rust R., Larson W. (eds)** - Proceedings of the second international conference on site-specific management for agricultural systems 1995, Minneapolis. March 27-30, 1994

[20] **Robert P., Rust R. Larson W. (eds)** - Proceedings of the third international conference on precision agriculture 1996, Minneapolis. June 23-26

[21] **Schueller J.** - A review and integrating analysis of spatially-variable control of crop production. Fertilizer Research 1992, **33**, 1-34

[22] **Schueller J., Wang M.** - Spatially-variable fertilizer and pesticide application with GPS and DGPS. Computers and Electronics in Agriculture 1992, **11**(1), 69-84

[23] **Searcy S. (ed)** - Proceedings, Automated Agriculture for the 21st Century 1991, Chicago, Illinois. December 16-17.

[24] **Searcy S., Schueller J., Bae Y., Borgelt S., Stout B.** - Mapping of spatially-variable yield during grain combining. Transactions of the ASAE 1989, **32**(3), 826-829

[25] **Shepherd M.** - Digital Aerial Photography for site-specific operations. Implement & Tractor 1997, **112**(1), 10,43

[26] **Smith E., Lindwall C., Green M., Pavlik C.** - PARMS: A decision support system for planting and residue management. Computers and Electronics in Agriculture 1997, **16**(3), 219-229.

[27] **Stafford J.** - Remote, non-contact, and in-situ measurement of soil moisture content: a review. Journal of Agricultural Engineering Research 1988, **41**, 151-172

[28] **Stafford J. (ed)** - Precision Agriculture ‘97. Proceedings of the First European Conference on Precision Agriculture 1997, Warwick, U.K. September 7-10.

[29] **Stafford J., Lebars J., Ambler B.** - A hand-held data logger with integral GPS for producing weed maps by field walking. Computers and Electronics in Agriculture 1996, **14**(2/3), 234-247

[30] **Weatherly E., Bowers C.** - Automatic depth control of a seed planter based on soil drying front sensing. Transactions of the ASAE 1997, **40**(2), 295-305.

Role of electronics and decision support systems for a new mechanization

by ***Allen R. Rider***
USA

1. Introduction ... call for a new mechanization

Today’s manufacturers of agricultural equipment are charged with inventing and developing the products which will help feed the world in the next century.

Bold innovations in mechanization are needed to increase the food output from the world’s existing farmlands. Changes of the past thirty years concentrated on making bigger, faster and more fuel-efficient machines that are also safer, more comfortable and friendlier to the environment.

We have progressed about as far as we can with hydraulic controls and mechanical power.

Now, tremendous technological advances in electronics, communications systems and information gathering and storage are being adapted to achieve new levels of performance, capacity and precision thought impossible only a few years ago.

I will address two areas key to the new mechanization: the role of electronics and the role of decision support systems in the agricultural equipment of today and the future.

The role of electronics is an amazing and almost limitless one . . . as agricultural engineers and designers use their creativity to adapt the latest electronics technology to the unique needs of tillage, harvesting and processing equipment of all kinds.

The role of decision support systems is huge as well with the advent of site-specific crop management . . . the demand is great for a new set of management tools that link computers, on-the-go sensors, global positioning systems and other highly technical devices.

We at New Holland, along with our research cooperators around the world, are proud of our innovations in these areas, and are honored to share the highlights of many of them with you.

As most of you know, New Holland is a global manufacturer and marketer of equipment formed from the merger in 1991 of the agricultural and construction divisions of Fiat, based in Italy ... and Ford, based in the United States. The success of New Holland is built on some of the best-known and trusted names in ag and industrial machinery: Agrifull, Benati, Braud, Fiatagri, Fiat-Hitachi, Fiat Allis, Ford, Laverda, New Holland, and Versatile.

These names have been pioneers in mankind's transition from animal power to the tractors of today and to the radar, laser, satellite communications and other forms of electronic intelligence.

2. Innovations through electronics

In today's economic environment, farmers worldwide ask for help in maximizing the potential of their land.

More timely ground preparation, precision seeding and the precise application of chemicals are all absolutely critical for higher yields and the economic success or failure of farmers today.

Optimization of the harvest - making the most of the crop that is grown by improving grain handling and enabling faster harvesting - is also critical.

Electronic advancements are a major part of what makes these improvements possible; New Holland has a strong heritage in electronics innovations.

For example, we were the first to pioneer the crucial ability to detect metal debris coming into the feedroll of forage harvesters. Before our electronic metal detectors were introduced in the mid-1970s, there was no way to detect and therefore prevent metal objects from causing cutterhead damage or from becoming an unwanted part of the forage that could lead to hardware disease in cattle.

Similarly, New Holland was the first to provide rock protection for rotary combine harvesters with an electronic stone detector invented in the mid-1980s. First used on New Holland TR combines, the system detects rocks electronically by distinguishing the acoustic signatures of rocks striking a sensor. A mechanical trap door then automatically ejects the stones before they can be taken in by the rotors.

A third important innovation made possible by electronics was the first automated, self-propelled bale wagon developed by New Holland in the early 1980s. This machine gave operators the unique capability to program various bale stack patterns to fit their storage and transportation needs, giving them much higher productivity.

2.1 Field preparation

A more recent example of an advancement in productivity for field preparation and planting is the use of the microprocessor to control tractor transmissions. This replaces traditional mechanical linkage to the clutch pedal or shuttle control and provides pre-programmed shifting patterns.

The New Holland M/60 Series tractors, in the 100 to 160 engine horsepower range, feature semi-powershift transmissions that replace shift levers with push-button controls, thereby simplifying operation and reducing fatigue for the operator.

The powershifts are accomplished with 5 hydraulic clutches controlled by solenoid-operated pressure control valves, which in turn are controlled by a microprocessor-based electronic control module. This module controls current through the solenoids via a pulse width modulated proportional control. Shifting between the ranges is synchronized, and the synchronizers are also shifted by hydraulics, controlled by solenoid-operated valves, which are controlled again by the control module.

Productivity in the field is maximized in several ways.

The electronic control system makes about 4 million calculations per second and adjusts the performance of the transmission 100 times per second. Such monitoring also keeps maintenance downtime to a minimum.

Speed matching automatically matches forward ground speed to engine speed by selecting a suitable gear.

Because there are six power shift speeds in each range, only one range change is necessary between 1.3 and 8 mph**,** and the transmission is protected from damage caused by high-speed shuttling by the microprocessor.

The need to stop the tractor to change range during field work is minimized . . . so this increases work output and decreases operator fatigue.

The overall result is that by replacing many operator decisions and manual, mechanical shifting movements with electronic controls and programming for shifting on-the-go, field work can progress much faster for timely soil preparation and planting.

2.2 Harvesting

Another area where the role of electronics is crucial to the achievement of maximum productivity is the area of harvesting grain efficiently, thoroughly and on schedule.

Combine and forage harvesters have become very complex machinery, designed to process a large variety of crops. And, more grain-producing countries will be moving toward the high standards for grain loss that are already common in Europe today.

In order to optimize these processes and therefore productivity, many sub-systems and parameters must be monitored and controlled as never before.

For these reasons, conventional mechanical or hydraulic controls are no longer capable of meeting the demands of the crop complexities and larger and larger harvesting units.

That is why New Holland engineers chose to go into a new direction - using fiber optics and CAN (Controller Area Network) protocol - in the design of New Holland TF combine harvesters. By doing this, we produced a new monitoring and operational system that improves operation, maintenance and safety in a machine that is much less complex to operate than its predecessors. These improvements, coupled with the increased physical capacity of the harvesters themselves, provide greater efficiency in the field.

The CAN protocol allows the harvesters to be run with sensors, actuators, monitors and CPUs (Central Processing Units) that are decentralized elements or nodes in a communication network. The communication between nodes is based on fibre optics to assure trouble-free data communication protected from electromagnetic radiation disturbances. Control signals are energized primarily through the fibre optics, which transmit messages more than four times faster than traditional copper. All functions are described in software, and the use of flash memories allows a continuous reprogramming to improve the system or introduce new features.

Today, a modem on the farm allows us to reprogram a combine or forage harvester from the central engineering office. Based on this technology, three trouble-shooting systems have been developed for FX forage harvesters.

For the operator, safety warnings and diagnostic feedback appear on the InfoView monitor in the cab, providing trouble-free and maintenance-free operation.

InfoView provides constant performance feedback to the operator, including information on the area and time harvested, ground speed, cutterhead and engine rpm, metal detection and crop processing.

The second part of the trouble-shooting system is the “CAN-Spy,” a built-in system with which the user can look at the system.

The third trouble-shooting component is a personal-computer-based tool called “FlexiCOS”™, an interface that allows non-specialists to check and correct functions based on looking at all system inputs or outputs and their performance on a PC.

These advanced diagnostics, combined with such automated systems as the Adjust-O-Matic™ system that fully automates knife sharpening and shearbar setting from the cab, allow the operator to cut more crop more efficiently, again adding to the productivity from an acre of land.

2.3 Integrated controls

Looking ahead to even more advanced technology, New Holland is working with the Silsoe Research Institute in England and Dowdeswell and Lucas Advanced Engineering. We are investigating the potential to improve tractor and implement productivity by improving control systems communication and coordination.

The integrated system is being developed to increase tractor and implement performance, improve quality of work, reduce operator workload and fatigue and reduce implement set-up times.

The microprocessor has opened the way to completely integrated control which can be supervised or overridden by the operator if necessary, but which otherwise will manage engine, transmission, hydraulics and implements completely automatically according to a predetermined strategy.

Productivity improvements of 10 percent or greater are achievable with such integrated control systems based on advanced electronics.

3. Role of decision support systems in the new mechanization

There is no question that the innovations of site-specific crop management . . . precision farming . . . are becoming an important factor in the future of crop production.

Precision farming involves gathering information dealing with the yield, location and time variation in a field, then using that information to manage inputs and practices on sections of that field versus treating the entire field in the same manner.

The goal is to be more productive, efficient and environmentally sensitive to natural resources.

To accomplish this, precision farming relies heavily on application of the Global Positioning System of navigation and many new measuring and decision support systems. Using satellite-based information to map fields by matching input applications and yields with specific points is one way space technology has come to earth.

The space age has come to agriculture in another exciting way I'd like to address before I continue on the topic of today's precision farming.

3.1 Unmanned and automated equipment

Let me introduce you to the not-too-distant future of agricultural robotics using NASA and New Holland technology.

Two-and-a-half months ago, a New Holland Model 2550 SpeedRower self-propelled windrower cut 100 acres of alfalfa in a California field ... with no operator on board (**Fig.1**).

This robotic harvester ran continuously all night, guided only by GPS information programmed into its on-board controls and only stopping at all so the engineers observing its labor could eat supper. The windrower knew exactly where it was at all times as it cut the big rectangular field, divided up by flood irrigation borders.

The machine's programming calculated the distances between borders and then calculated the cut width needed to make six even cuts . . . starting at one end and working its way all the way across in a regular pattern. When the sun came up, the field was well cut . . . the cut rows straight as an arrow.

Earlier in the day, the automated SpeedRower cut fifteen acres of six-foot-tall Sudan grass by itself using only its vision system - video cameras and sensors (**Fig.2**) that kept it going along the proper cut line without any help from GPS data.

Again, there was no operator on board, and no operator in a base unit feeding it instructions.

This is where we are with Demeter, an exciting joint research project between NASA, New Holland and the National Robotics Engineering Consortium at Carnegie Mellon University in Pittsburgh, Pennsylvania.

The goal is to bring NASA-developed planetary rover technology down to earth to run unmanned, automatic windrowers.

Such automation will help reach the goal of higher productivity with more predictable performance, maximum use of manpower and optimization of the harvest window. Most importantly, it will permit efficient harvesting at a higher operating speed than is possible with current equipment that depends heavily on the alertness and stamina of human operators.

Demeter is the prototype, not just for many types of agricultural harvesters, but also for other large, mobile machines operating outdoors in heavy and sometimes dangerous applications, such as excavating, mining and timbering.

Demeter has been born from more than a decade of research, funded by planetary rover and road navigation research programs. New Holland is supporting the Demeter research in the form of a prototype self-propelled windrower unit and technical support from our research and development and design groups.

We are also excited to be exploring the incorporation of this automated technology into the engineering development process for our next-generation haytools, such as the New Holland Swather Model HW340 with disc header.

The background knowledge and software control architectures for wheeled on- and off-road vehicles has come from work with military land vehicles.

The space agency's projects with rovers used on the moon and elsewhere provided multiple iterations of physical robot controllers, open-field navigation and vision-based perception.

From this base, the Demeter team defined and implemented two core technologies for mobile agricultural equipment - FieldNav and FieldHand.

Combined, these technologies represent Demeter, a system with the knowledge and capability to harvest without a human operator on board. It uses onboard and remote sensing to accurately locate itself to the task; executes and monitors its physical actions in real-time with multiple levels of safety; and accepts high-level directives, generates and executes plans and interacts with its operators.

The essential functions are software-controlled, with manual operation supported through simple safety-circuit electronics and firmware.

FieldNav is the hardware and software that transforms a self-propelled agricultural harvester into a machine controlled by computers. It includes the electromechanical adaptation of the equipment for drive-by-wire control (no mechanical linkage) and provides the physical control over the various motions of the machine.

FieldNav also monitors operation to ensure safety (including emergency stop features) and possesses a core navigational capability through combined dead-reckoning, inertial and GPS data.

The other core technology, FieldHand, either assists or replaces the operator in the cab. FieldHand consists of a number of behaviors normally performed by the operator, including “seeing” and tracking the crop cut-line and monitoring the cut row. It also detects the end of the row, executes turns, and detects and avoids obstacles in the field.

Combining FieldNav and FieldHand provides the capability of unattended operation in the field.

The vision system of FieldHand detects and tracks the crop cut-line using intensity segmentation and color segmentation and sends steering and velocity commands to FieldNav. FieldNav takes the steering and velocity commands and converts them to electric signals which operate the hydrostatic transmission.

The primary benefit of the Demeter system will be increased productivity derived from its ability to operate continuously at very high speeds.

The computer system does not feel stress or tire, as does a human operator. It is both productive and predictable.

Demeter has been tested with the SpeedRower cutting up to six and one-half miles per hour while using its vision system.

When coupled with our higher capacity machines, refined versions of Demeter will increase the top operating speed far beyond the capacity of a human operator for any extended length of time, even in the best ergonomic seat and operator environment.

In turn, Demeter will allow agricultural equipment manufacturers to design even faster cutting implements, which will directly translate into significantly increased productivity.

FieldNav and FieldHand will first be evolved commercially to become CutCruise, a revolutionary cruise control that will unburden the operator and increase productivity.

The operator will only need to open the field and then engage CutCruise, which will then cut the rest of the field at near maximum speed, confirming its actions periodically with the operator.

The advantages of this parallel those of the integrated control system discussed earlier for tractors and implements.

Future commercial versions will be the full Demeter system as its being tested now, an automated harvester capable of unattended operation in the field.

Initially, the unmanned Demeter is expected to be the second machine used in a field as a “drone” behind a “master” machine equipped with CutCruise and a human operator on board who will operate both machines. This drone would be guided by its vision system backed up with GPS guidance to confirm and enforce the boundaries of the field.

3.2 Precision farming

As I mentioned earlier, there is a growing demand for equipment with highly specialized

decision support systems for use in site-specific or precision farming.

I'm pleased to give you a preview of some of the work New Holland is doing in this area, internally and with university researchers.

In the forage segment, we have provided a Model 650 Roll-Belt round baler being used in Dr. Leonard Bashford's work at the University of Nebraska to design a yield monitor for use on round balers. Dr. Bashford has taken the lead in this area by developing a yield mapping strategy for forages using a round baler.

He believes that it is important that yield be obtained for all crops grown on a field, including forages, if one is to achieve a complete site-specific crop management scheme.

His system for on-the-go yield monitoring with round balers uses differential GPS receivers, transducers and an instrumentation system using load cells in the baler axles and drawbar to calculate weight of the baler every 3 to 4 seconds.

The weight readings and GPS field coordinates are displayed and recorded on a laptop computer and can be downloaded to an office computer to create yield maps of hay fields. Measuring yields is only one part of precision; measuring inputs is important as well.

An important need for proper nutrient management, including meeting increasingly strict environmental standards, is the ability to distribute livestock manure accurately onto the land and have proper documentation when needed.

New Holland and the University of Delaware are at work on this task.

A new manure spreader in the research-and-development stage at New Holland uses spinner disc distribution to control precisely the amount of material applied as well as the spread pattern and distribution. In our work with the university, GPS readings give a time and location stamp that helps us log and record the spread rate information used for mapping and documentation of how much manure went where.

As you and I know, there's no question the majority of the work on precision farming is associated with yield monitors installed on combines for grain crops.

New Holland does not yet offer a yield monitoring system on our combines, and we're not really concerned about that. I say that because this is still a very young technology . . . we still have a lot to learn about it . . . and we're going to take the time that is necessary to achieve our objective.

That objective, of course, is to offer a system that is improved over what is currently available in the market place. So, we are in the midst of testing an exciting new type of non-contact sensor that we hope and believe will be capable of measuring three major field parameters from a single sensor.

Using our new task controller now in development and this new sensor, an operator would know the grain flow, moisture and test weight for any point and time in the field as he harvests.

He will be able to monitor all the precision-farming functions, including the GPS system and the status of all the sensors. He also will be able to experience the convenience of minimal and accurate calibration, overcoming one of the major complaints about the existing systems in the field.

This will help ensure that the data being collected is valuable and accurate data. But, don't hold me to the specifics on this regarding capabilities or any timing.

What I can say is this R&D project is unbelievably exciting right now and progressing extremely well, and we hope it continues to do so.

4. Making innovations available

It is one thing to invent improved equipment that makes use of the latest technology. It is another thing to make these innovations available to farmers on a broad basis.

New Holland is not only committed to the development and manufacturing of the equipment our customers want and need, making use of our thirteen Centers of Excellence strategically located around the world.

We are also committed to doing whatever it takes to deliver and service of that equipment to our customers around the world. New Holland is uniquely positioned to make this possible, with our global network of dealers and joint venture partners.

One of our most recent moves to extend the reach of new technology was our agreement in principle to acquire a substantial equity interest in the world leader in air seeder systems and technology, Flexi-Coil of Saskatoon, Saskatchewan, Canada.

We look forward to bringing a wide range of seeding, tillage and chemical application equipment to our customers around the world, including Europe, to help speed the transition to cropping systems that use less tillage and fewer trips across the field.

5. Conclusions

So, in a world faced with an ever-growing demand for grain but with limited resources on which to grow it, these are but a few examples of the developments in electronics and other engineering innovations that will help make possible the further intensification of agriculture.

How far can we go to save labor, increase precision, reduce yield loss and the time it takes to plant and harvest, while increasing the hours that machines can operate in the field with less demand on the operator?

That is our challenge over the next thirty years and beyond.

Advanced electronics and decision support systems will be some of the most important components of farm equipment now and in the future.

New Holland and our friends in the industry are inventing many more ways to increase productivity.

Let us persevere in using them in our mission to feed the world.

Fig. 1 - Robotic harvester by New Holland

Fig. 2 - Video camera and sensors on no operator harvester

Multifunctional application of the DEUTZ-FAHR TCS-SAT System in precision farming

by ***Wilhelm von Allwörden***
Germany

1. Foreword

The use of agricultural machinery which is not the exclusive property of the farm on which it is used, the wish for higher yields and the observance of strict environmental conditions are heightening the demand for the application of equipment which will manage agricultural land in a way which targets specific areas. The systems offered by SAME-DEUTZ-FAHR for such sitespecific farming are introduced below.

2. Why is precision farming necessary

Sitespecific farming may be desired for a variety of reasons. The type of soil, availability of nutrients and the water supply of most agricultural land has a heterogeneous structure, resulting in varying yields. Managing land with reference to specific areas now offers the possibility of supplying nutrients more effectively to areas which give lower yields, matching the precise requirements of the soil. It is also possible to carry out alternative cultivation methods on the soil, so that a good yield can also be obtained from these areas. This can generate considerable savings, since a reduction of about 30-35% of the variable production costs for fertilisation is possible. Reduced levels of fertiliser, corresponding to the actual need, can be applied at points where the supply of nutrients is already high.

Particularly on large farms, and when leased or shared machinery is being used, this can only be done with appropriate equipment for precise area management. This contrasts with the husbandry methods of the past, in which the farmer himself worked on all parts of his own land. He had therefore a better insight into the conditions and the productivity of his lands, and could take steps to increase yields in the light of his own experience.

A further reason for the application of precision farming is the demand for more ecologically oriented arable cultivation, in pursuit of which the legislature is increasingly prescribing a variety of regulations. A rising nitrate concentration in ground water, which has already reached critical levels in some parts of Europe, can be reduced by precision farming. Since the nutrients are applied according to the actual need, and are then absorbed by the crops, the wash-out of excess applied nutrients in is greatly reduced.

3. The application of precision farming

A number of different requirements must be met if precision farming is to be effective. The determination of position, performed with the aid of GPS or DGPS, plays a key role here. It is needed in all the procedures involved in the work.

Generally, precision farming begins with the recording of field boundaries. This is necessary both for a precise determination of what the areas involved are and for the subsequent processes.

A second step is the sampling of the soil with reference to position - that is, to specific, small areas - in order to obtain an overview of the nutrients present in the particular field and the capacity of the soil. The farm manager is involved in the application of appropriate software to generate fertiliser application maps. These are intended to ensure an even availability of nutrients across the entire field. The fertiliser application maps are used to control GPS-guided fertiliser spreaders, according to their current position in the field. This means that the fertiliser can be applied in the quantity and with the composition determined as corresponding to the requirement at that location. It is moreover possible at sowing time to alter the sowing density, and to some extent also the mixture of varieties, in relation to position. An optimal exploitation of the ground is thus possible.

Yield maps are generated at harvest time as a third step. A GPS-supported determination of position is again needed to generate a yield map. A system for measuring the throughput is additionally required, so that the yield can be related to specific locations. Suitable software generates the yield maps from the data on position and yield. These yield maps can then again be used to recognise areas of lower productivity. This, together with a soil analysis, enables appropriate action for the next growing period to be decided. The position-specific nutrient uptake must also be calculated with the help of the yield map, and this in turn is used in the generation of the next fertiliser application maps.

4. The SAME-DEUTZ-FAHR TCS-SAT system

The Terminal Control System Sat (TCS-SAT) is the basis of SAME-DEUTZ-FAHR's approach to precision farming. It deals, apart from the general machine-specific tasks, with the processing of positional data in association with the throughput data, the yield recording and the data bank processing.

Figure 1 shows the system's monitor with the standard operating screen. All the information of importance to the harvesting operation is shown, on-line, in this operating screen. This includes the grain throughput in t/h or t/ha, and the current grain moisture content. An IBM compatible PC with a Pentium processor forms the heart of this system. The proven AG LEADER system from America is used as the yield sensor. An advantage of this deflection plate system as against volumetric measurement procedures is that the sensor signal is proportional to the mass flow, meaning that changing volumetric weights do not have to be taken into account. After proper calibration, this system can achieve measurement errors of less than 1%.

In addition to this operating screen, there are other screens which are used to deal with the job and the customer. The job and/or customer data can be directly loaded into the computer from a PCMCIA card, or entered using an external PC keyboard. Positional and yield data are stored on PCMCIA chip-cards, which can be obtained with capacities of between 2 and 12 MB. Experience indicates that a storage capacity of 2 MB is sufficient to record the yield and position data of a 25 ha field.

An important component of the TCS-SAT system is the “LMID-DeutzFahrGIS” graphical information system, which processes all the recorded job and yield data and which, in addition to a wide range of other functions, also prepares the yield maps and the fertiliser application maps.

4.1 Field perimeter recording

To record the field perimeter, either the combine is taken around the boundaries of the field, or the GPS receiver and the computer terminal are simply removed and fitted to a tractor or cross-country vehicle. The field boundary data are stored on the PCMCIA card. Since the terminal computer is based on an IBM compatible design, it is also possible to connect the GPS receiver through the serial interface to a standard notebook on which the TCS software is installed and running.

4.2 GPS-supported soil sampling

The GPS receiver and the terminal computer or a notebook are also used for the position-related soil sampling. After the perimeter of the field has been recorded, the GIS software generates a grid for the field in accordance with which the soil samples are to be taken. The resolution of the recommended sampling grid can be selected. It can also be adjusted to particular local conditions. A moving map is displayed on the TCS screen as the samples are taken, which makes it possible to drive to the sample points. When the analysis has been done the laboratory data from the samples are read into the GIS system together with the GPS data, which makes them available for the generation of the fertiliser application maps.

4.3 Yield mapping with throughput measurement and positional determination

The deflection plate system from AgLeader is used (**Fig. 2**) by SAME-DEUTZ-FAHR for the yield measurement. In this system the stream of material coming from the elevator belt is routed to a deflection plate. The material stream thus exerts a force on the deflection plate. The force, which is proportional to the mass rate of flow, is recorded by a force measurement cell taking the rotation speed into account. In contrast to volumetric throughput measurement procedures, a continuous measurement of the volumetric weight (density) is not required.

The TCS system calculates the appropriate mass rate of flow from the signal magnitude. Since the flow of harvested material needs a certain time to pass from the cutter bar to the top of the elevator, the throughput figures that have been measured are allocated to the appropriate position with a negative time displacement, and are stored every three seconds. In addition to the throughput measurement, the moisture level of the stream of material is continually measured at the graintank auger and displayed on the TCS monitor.

Figure 3 shows the TCS monitor with the yield screen, displaying the total yield data and the average grain moisture of a job, together with the yield and grain moisture data of individual loads.

When a job has been ended the data can be printed on an optionally installed printer directly in the field as a confirmation.

Figure 4 shows the information screen. This displays the job and area information, and, in the bottom row, the current positional data which is saved together with the associated yield data every three seconds for the purposes of the yield mapping.

Depending on the customer's wish, a mobile reference station with a range of about 15 kilometres or reference signals from geo-stationary satellites, which, for a fee, are available in all parts of the world, may be used for the DGPS reference signal which is needed in addition to the GPS signal. The RDS, long wave and marine reference signals are not currently being used by SAME-DEUTZ-FAHR because of their limited availability.

4.4 Software for site specific farming.

The principal piece of software used is the “LMID-Deutz-FahrGIS” geographical information system. It consists of a number of modules and can be further expanded. The program is provided with the following features and functions:

- interface with all necessary functions to TCS-SAT;
- reading all the GPS data from the SAME-DEUTZ-FAHR agricultural machines, and their display in appropriate maps;
- reading out all job data from the SAME-DEUTZ-FAHR agricultural machines - including when no GPS is connected;
- the input and background display of all kinds of maps (e.g. topographical maps, tax maps maps, from other agricultural services);
- input and backround display of aerial or satellite photographs;
- use of customer data files;
- generation of customer jobs and the transfer of the necessary information to the SAME-DEUTZ-FAHR agricultural machines selectively for jobs with or without GPS connection;
- reading in of soil tests (GPS co-ordinates as well as values obtained from the laboratory);
- generation of nutrient maps corresponding to the laboratory data read in;
- generation of yield maps based on the TCS-SAT data read in;
- generation of fertiliser application maps corresponding to the data being managed;
- print out of all maps to scale;

- transfer of the fertiliser application maps to SAME-DEUTZ-FAHR tractors with the corresponding cultivation machinery.

The LMID-SATGIS program module is additionally needed for taking the soil samples. It has the following additional functions:

- creation of the soil sample grid adapted to the field outline;
- navigation across the ground to the sampling points.

4.5 Site specific fertilisation

In order to apply fertiliser precisely adjusted to specific areas, the TCS-SAT computer together with the GPS/DGPS module is mounted to the tractor to be used. A universal job computer mounted on the tractor is controlled by the TCS and takes over the control of the fertiliser spreaders involved. The necessary commands for the control of the fertiliser spreaders are taken over by the software from the TCS computer. The software is in each case programmed for the corresponding fertiliser spreaders, and is loaded from the TCS computer. The fertiliser application maps generated by LMID-Deutz-FahrGIS are also read in from the PCMCIA storage cards.

If the fertiliser spreader now moves across the field, the application densities depending on the current position are passed from the TCS via the job computer to the fertiliser spreader, which opens and closes the control vanes appropriately.

5. Conclusions

With TCS-SAT and the LMID-Deutz-FahrGIS software, SAME-DEUTZ-FAHR offers a complete system for sitespecific farming. In addition to the proven yield measurement, the user now has the opportunity of carrying out soil samples and fertiliser application precisely targeted to specific areas. The system is fully expandable.

Considerable quantities of materials can be saved through the use of this system. It benefits the environment to the same measure, since nutrients are applied just as they are needed. The yields furthermore can be raised to the ground’s maximum capacity.

Fig. 1 -Monitor of the TCS-SAT

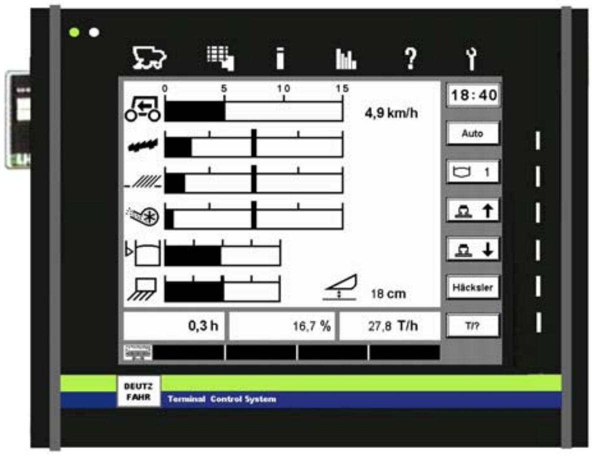


Fig. 2 - AgLeader Flowmeter

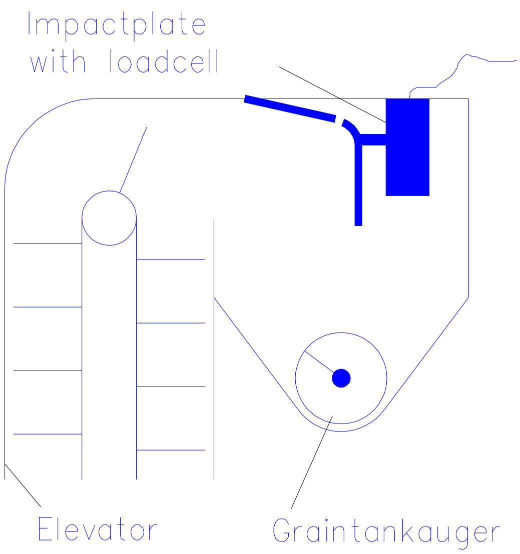


Fig. 3 - Yield screen

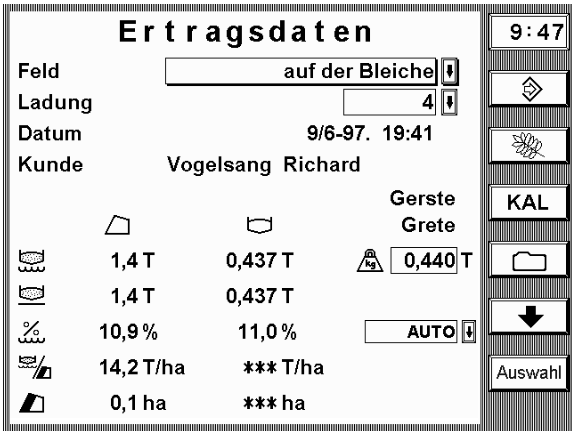
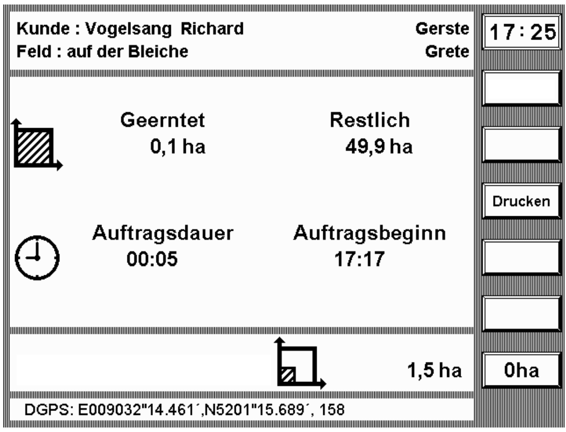


Fig. 4 - Information screen



DISCUSSION

A.M. El HOSSARY

I think we have been overly-fascinated by the role of electronics and decision support systems for mechanisation. Prof. Schueller declared that such innovation can be easily applied in developing countries. But I wonder, at what cost? What is the impact of applying precision farming on productivity? What is the rate of loss reduction? It seems to me that at the next Club meeting we need comparative studies indicating the merits of such innovations against the traditional methods, discussing the economics of such operations.

J. HELLEBRAND

Allwörden gave us an introduction on soil sampling and how to produce application maps. But, you know, soil sampling is cost intensive - that means it causes high costs. Then, there's another question: the dynamics of nitrogen in the soil. The nitrogen content of today is not the nitrogen content of a few weeks later. So we need to know the actual nitrogen content - especially the nitrate content - to solve fertilisation. And it is not very useful information if we have the nitrogen contents of three months ago. Another question, which has not been discussed up to now in precision farming, is that water is essential for the growing of plants and for the yield. Especially in relation to the type of soil and soil variability. Up to now it is not known what is the influence of rain intensity and rain distribution in the course of the year on the yield. My next question is for Allen Rider. I was surprised to know that we already have automated tractors, and do you think that there is really a future for these automated machines on the field? In Europe, where we have small farm enterprises, and especially in developing countries, this is perhaps a view of what will be in 100 years. I am not sure. You showed us a menu screen by GPS - you could recognise that it's really spread. Now we know that we have losses of nitrogen, especially of ammonia, if it is spread; it can be as high as 90%. So you cannot take this as a basis for application of ammonia, except immediately after spreading, working into the soil. You have to combine it. It depends a little bit on the weather and other conditions, but the contact with air is essential for the losses of ammonia. So, going back to my first point, the main question is really: what will be the future for developing countries? Another question I would raise is:
what is the use of GPS technologies in farms in South Africa, Africa, Asia or South America? It's an open question today, but maybe we can see what will be the developments in the future in terms - let's say - of improving the output, of increasing the result. And this might be decisive.

H. AUERNHAMMER

The question of what are we doing with precision farming in developing countries is quite an interesting one. As you may already know, I am an economist and not an engineer, so in all my publications you will find that the first step in using electronics is to get more and better information. This is important world-wide, whatever you do. Sometimes I do not understand why GPS is only used for location sensing, because GPS is also the best system for time measurement, and it's really accurate. So I think the first step in developing countries is to get more information, targeted to specific needs. I also believe that you have to go through the same steps we did with electronics: first you have to look to the most important task. I don't know what it is, and I'm sure it is different in different countries. But still, information is the most important thing. Another point you raised was reducing the workload, or looking more to the economic success. Again, this depends on your standpoint. If we have conditions where the driver is only driving a tractor for, let's say, 200 hours a year, there is not very much point in reducing the workload even further. On the other hand, if you look at the very large farms where the driver is sitting on the tractor for 800 hours or more, and working with very complex tractor-implement combinations, then it's absolutely necessary. Another question is the distinction between economic and ecological success, which differs from country to country. I'm afraid that most evaluations of precision farming focus mainly on the economic success. If we look at it from the ecological standpoint, precision farming is something we must to have. Even if there is no economic benefit, we still have to have it, otherwise we will not be able to reduce the pollution of our environment. Those are only some ideas on your question.

A.R. RIDER

Let me give you our view concerning where we're headed with automation. To believe that operatorless vehicles are a medium for all operations is not practical. What we are trying to do is - number one - provide a type of cruise control for the operator, so that he is free to concentrate on the actual field operation which is taking place. I can visualise this type of thing installed on a combine, primarily as a guidance type system, while the farmer monitors all of the other operations. A combine has many functions going on simultaneously, and so that would make it practical. In connection with operatorless machines, I would reiterate that we don't visualise the first step as being three or four machines operating in a field by themselves. Instead, we envisage a situation more along the lines I described earlier: probably somebody in a field with one or two or three drones following on large operations. Certainly this is not going to be a solution that is suitable for the smaller operators. But contractors may conceivably decide they want to do that - have one operator with two machines. So it's an evolutionary type thing. We believe that the work we're doing is addressing the issue of obtaining more output from a machine with less operator input than it currently requires. You'll be able to get longer hours without the stress and the fatigue, and eventually get to the complete operatorless machine.

H. D. KUTZBACH

In my opinion GPS is a major challenge, and I think we will get it. And I also think we will also get autonomous vehicles such as those you described, and perhaps not 100 years down the line, but in just 10 or 5 years' time. But you showed it only for a type of machine where it's very easy to do it. It's only going ahead and knows the heading in it, so it will be a big task for us in setting the machines. I want to explain that we can also use these yield maps for setting the machines - this has not been mentioned. If we can predict the yield, for example from the last machine pass, we can calculate the yield for the next pass, and the machine can be set in advance by the electronics. So the driver doesn't necessarily have to slow down or speed up: that can be done automatically by the electronic controller. And that's not only for grain harvesting, it might be possible for other mobile operations too. For example we could control the draught force of the tractor, not only with a spring measurement but also in advance - knowing that in the previous pass there was a rut or compacted plot in the field, we can slow down the tractor or do whatever is necessary. So I think we should look at that too. I also have a question for Mr. Rider about the new system which he is working on. He didn't mention, and nobody mentioned, the measurement of the cutting widths for determining yield maps. I think it's very important to measure the actual cutting widths, because that defines the yield. And nobody has measured the time delay between cutting and measuring the yield. So that is another critical point: establishing yield mapping. Finally, a critical remark about electronics: we as engineers tend to get carried away with electronics and offering a lot of on-screen possibilities. For example, in my lecture room I am now forced to use a screen which has three menu levels. My previous screen had just three switches - light on, off, darker and lighter - whereas now I have to navigate through three menu levels on this screen... so I cannot operate it during the lecture. And that's a problem for all electronics - make it as easy as possible and make it as reliable as possible, and look for mechanical control: everything that can be controlled mechanically should be done mechanically rather than electronically. For example, you mentioned the control of the nozzles: this can be easily done with a flowmeter - a transparent plastic tube in the nozzle, which lets you see whether it is operating or not without any electronics. And, for example, you can meter fertiliser proportionally to the speed by using a speed-driven pump rather than electronics. So there might be an easy and cheap mechanical alternative to using electronics.

A.R. RIDER

I'll comment on a couple of things. I must admit that when we went into the project with NASA we had exactly the same observations you did: this would be very straightforward, very simple, very few things that we needed to monitor, and then we could make it operate. In practice, this turned out not to be true. We found there were many things that had to be programmed in to identify potential problems. For example: cutterbar plugging, conditioner plugging, windrow formation, engine failures. Also safety-related items: for example, if an animal were to run out in front of you, would it shut down. So there were lots of elements which made it quite a challenge to incorporate them all. I will give you an example. We were operating on cut line, and we had the machine follow it perfectly down the field going in one direction. But when it turned around and came back, it would wander off. So we took it down to the other end of the field and tried again, and it went perfectly down one way, but when it turned around and came back it wandered off. At first we could not understand what was going on, but then we finally determined that it was following its own shadow. When it was cutting into the sun it was a non-event. But when it was cutting away from the sun it had the shadow on the cutterbar in front of it, and it started following that shadow as the differentiation in the colour. So there turned out to be some really interesting challenges to make it work. I agree totally, it's not the most complex machine, but it is a machine that fits our business, and one that offers us opportunity. One of the exciting features about it for us is that there are many large commercial hay operations in the western US that do not have good reliable labour available. And we know that there are some customers that are very interested in that. So we think we've picked a practical product as opposed to one that's just necessarily simple. Two others I will comment on: one is the width of cutting capability. We have improved the capability of controlling cutting width by reducing the unused cutterbar portion by about 33%. According to our past measurements, with a pull-type cutting implement where you're sitting on the tractor and looking behind you, most people will leave an average of almost a foot of unused cutterbar as a safety. On a self-propelled unit, where you're looking directly forward, we found that the unused portion is probably in the neighbourhood of about 6-9 inches. With the electronic capability, we're seeing that down to the order of 3-6 inches. So clearly there are some advantages that have been derived there. Also, coming back to the field we talked about that we cut - that was a large field divided up into borders. What it really did is it calculated what does it take to make six even rows. As it turns out, the headers are not always exactly the right width to take full utilisation of it when you're in commercial fields like that. So it works very well on that, also. One other point I'd like to address, and which you asked about, is electronic complexity. We absolutely agree that complexity is a big issue, not just for the future but even with today's products. I can remember some examples in my career when we thought - we being the engineers doing the development - that we had a very simple machine. However, when we got it to the customer during our test program, he considered it to be very complex. I have to say that this problem with electronics and complexity is almost directly correlated to age and to background. When you have older farmers, in the fifties age range, trying to use electronics for the first time, they find it very difficult. On the other hand, a young college graduate *coming onto the farm - he loves electronics and he will tinker with it, and actually make it operate. So there is a real challenge for us in developing appropriate technologies which are easy to operate. The other point is reliability: particularly in situations where there are safety implications, reliability is of the utmost importance, and we'll have to do a lot of work on that. We currently have a program which, in the event of an animal running in front of the unit, first of all automatically ask itself, through the positioning system: am I still in the field? i.e. there's something out here I don't recognise. And if it decides yes, I'm still in the field, then it asks itself: is it still in my field of vision? If the animal is still there, the unit will shut down. If it's moved out of its field of vision then it'll go on. So, again, we totally agree.*

A. MUNACK

First, I would like to congratulate today's speakers. I think the presentations on electronics were very exciting and interesting to listen to. However, they also left me, at least, with some additional questions. The first one for me, and which also ties in with yesterday's presentations, is: what about standardisation? Yesterday Prof. Kutzbach told us about Claas AgroLog and AgroCom for instance, and today we heard something about electronics and yield mapping from New Holland and Deutz-Fahr, and that leaves me with the question: how compatible are all these systems? Are they stand-alones, or are there some industrial efforts to make them compatible? Because I think the world-wide success will also depend on the standardisation of these products. Secondly, I'd like to return to a question which was raised yesterday by Mr. Guidotti: he said that in his experience as a contractor, he has found that electronics has some problems in terms of reliability, and he proposed the use military-specification electronic components. Today we heard quite a lot about electronics from the manufacturers, but there was no mention of this reliability issue. So I think there is a difference between how the sellers and the buyers are viewing the product, and this should also be addressed in the discussion. My third comment is that we saw many ways in which electronics can help increase productivity. But, aside from Mr. Auernhammer I think no-one addressed the problem of sustainability. The industrial presentations showed us productivity but no sustainability. To quote my neighbour to the right - Dr. Peiper - who said: "look, there's a truck on the field!" In fact, in one of the New Holland slides there was a truck on the field. So what about the effects and consequences in terms of sustainability for all these industrial developments which are going on at the moment?

W. VON ALLWÖRDEN

First there's standardisation. In Germany at least, we have an organisation where we talk to each other in order to get a standard for all these connections. We already have some standards in place - these were also mentioned this morning - for the bus systems of the connecting parts, and the like. I think this will not be a problem in the future - I think we will be able to overcome this and reach a common standard, especially because the main source for all these components is a single supplier. As for reliability, our concept is that the combine must continue working even in the event of a computer failure. In other words, you have to be able to use the combine even if its complex on-board electronics are not working. It should also be stressed that, in our experience, it is not the electronics that is the problem - the main problem is the cables and sensors, rather than the processor, screen or computer which we have on board. So from that point of view I think we will have to put a lot of quality control into the assembly of cables, the assembling and guarding of the sensors. As for the question of weight, of course when you take a large combine like our top-liner with 9-metre cutting head and a weight of about 15 tons, or a comparable 15-ton combine from New Holland, and then you add 12 tons in the bin, you have a total of 25 tons on the field. OK, we have wide tyres, we have double tyres, but that is still a high weight. If on the other hand you put three or four small combines on the field, each of which weighs 10 tons with a full bin, and use the same wide tyres, you can overcome the compaction problem. So we are also thinking in this direction. But in answer to the question of what we from industry are doing in the short term, I believe the farmers want large combines to reduce manpower, and so we supply large combines. And when, in ten years' time, they'll want smaller combines, we will produce small combines and sell small combines. So we supply what the farmer wants.

Dr. Bernard CHÈZE
France

I'm very enthusiastic about what has been said this morning - technological progress seems to be really spinning forward. All this is particularly interesting to me because, when I was in Cemagref, we sometimes wondered whether our ideas were a little far-fetched. So we are pleased to see that some of these concepts have been taken up, and that major manufacturers are integrating these ideas into products. I'd like to comment on some problems we have had with different aspects; one is the link between the tractor and the machines. In certain countries there are a small number of big, powerful tractor manufacturers, who are facing a great many small-scale machinery manufacturers. So when you talk about the link between the tractor and machine, and all your schemes are based on that, it's clear that you need standardisation - that has been already said. Although it's true that the speed of standardisation within a single country is low, you can still achieve something; but when it comes to the European or international level, it's much more complicated, and it's difficult to achieve it in a good way. For example, we had something on an emergency stop that we wanted to put on a round baler. The problem was how to link it to the tractor. Well, there was a very cheap solution, which was to stop through the clutch of the tractor, but this meant that clutch of the tractor needed to be hydraulic, electromagnetic, or something like that. This was the more economical *solution. But if the tractor manufacturer didn't want to do that, the manufacturer of the round baler had to fit an electromagnetic clutch, which represents a high cost for the machine. Imagine each machinery manufacturer having to fit this sort of thing to implement a safety feature. So that's one of the problems - the link between the tractor and the machine. Another link which is missing - and this has been pointed out by some speakers - is the lack of biological sensors in general. We certainly need a lot of research in this field; it seems that the technological research as such is going faster than the biological research. Unfortunately, if you want to have a complete system, you will still have some missing elements which prevent you from achieving the full result. That's a pity, but I think that we have to convince biological people to address this issue. My last comment concerns the role of the operator. It's true that there is less and less physical difficulty in the machine operator's job, which really has become easier. But what about the operator's mental workload? Of course, you can prepare a lot of pre-set decisions, but the final responsibility is ultimately taken by the operator. So you can imagine how these sorts of workers will increasingly have to be persons with some kind of technical or systems-type training, capable of making a synthesis of all the inputs and finally deciding what to do. There are also some dangerous or tedious jobs which the operator still has to do. For example the coupling of the machine to the tractor: research is being done on this aspect, but for the moment there is still the need for the worker to physically do something, and there is still the aspect of safety. Mr. Rider said that this is a major part of their research, because you increasingly get this sort of situations. I'm thinking also of the maintenance tasks which the worker has to perform: it is becoming increasingly important to integrate safety into the design of machines. So I think industry research and development needs to add something more on security. And of course, there is also the problem of vibrations. Clearly, from this point of view the ideal solution is not to have an operator at all, but this however has many other drawbacks. But you can an operator sitting on a tractor, being subjected to a great many vibrations, and at the same time trying to use these very sensitive electronic controls. So it's not such an easy job.*

A.R. RIDER

I think I've covered the safety aspects. I think it's absolutely critical and imperative that we spend a lot of time on that, and truly understand all of the perceived opportunities for an accident to occur. That's very very difficult. It's an issue that from a US standpoint is particularly critical for us because of our product liability. To be able to put on the market a product in which every potential safety hazard has been dealt with represents a big challenge for us, so we're spending a lot of time and a lot of effort in that area. We recognise that it is a show-stopper unless you can figure out how to develop maximum safety and security.

D. SUTTON

Just a couple of anecdotes to add perhaps a tempering influence to the discussion. What we've heard is wonderful, and it's exciting and - as Prof. Munack said - it's fireworks. Because we have a technology or scientific drive here showing what is possible. And that's superb. We've also heard one or two contributions that have reminded us that technology is very time and location specific. What is appropriate here and now is not necessarily appropriate over there, now; but it might be later on. So one needs to keep going and keep investigating, and that's why it's wonderful to hear about the work of this morning's speakers. I'd just like to make a couple of points to highlight reaction of the operator, the human - the "consumer" if you like - to these sort of things. Some twenty or more years ago the London Underground system built a new line called the Victoria line, which had fully-automated systems that did not require a driver. So the trains would come in, and they'd stop, and everything was all automated. It was considered totally unacceptable at the public level for safety reasons, and that's why I mention this now - because it follows on the important point about safety. The public would simply not be able to accept such a device - they would never get on it. And so to this day, the Victoria still operates with automatic trains but with a driver sitting in there, pretending to hold the handle. And yet in the same city we have fully automated train systems: some of you who have travelled through Gatwick airport will know that there is an automatic train that takes you from one terminal to another, and in East London there is the Docklands Light Railway which is fully computer-controlled with no operators. So you have these extremes of public reaction, or concerns about the safety and other factors. And, just to finish on a lighter note, one other related anecdote: in the UK, like in a lot of countries, livestock production is partly carried out in hill areas where grazing is open, and you need to control the animals some way, and we use sheepdogs. Silsoe research institute is in fact developing a fully robotic sheepdog. And now we have a lot of very worried sheepdogs, who fear they're going to be put out of business in the UK. So resistance to change is not only human, it's also animal!

J. SCHUELLER

I'd like to expand on the developing country aspects in a little bit more detail. The situation of course varies greatly from country to country. In Brazil, there is a high level of interest in these systems, and also - I think - a high level of applicability. For example we are currently working in São Paulo state. But of course this may not be the case in other countries, such as in the small landholding areas of Africa. And even within a single country there are significant differences. For example in India, which I am more familiar with, the situation in Punjab is very much different from the situation in Behar. So we need to look at the individual situation. I'd also like to respond to a couple of other comments that have *been made. Bernard was absolutely correct in his statement that the key to all this is the sensors. Sure, in the field of GPS systems we still have to decide which one to use, but that technology is going ahead by itself. The sensors for agriculture are the critical component for any control system, and it seems to me that that is the area where our colleagues need to be focusing their efforts. One thing that wasn't mentioned in too much detail, but which should perhaps be mentioned here, is that in addition to the actual control and the mapping, these systems also make it possible to collect a great deal of information. Prof. Auernhammer stressed the importance of information earlier on. Farmers in the US are worried that Cargill and Continental Grain will use wireless yield monitors to get real-time reports from throughout the world as to exactly how much grain is being harvested, and use that data to play the commodity futures market. Farmers are already using the yield monitors, the moisture content and in some cases people are using infrared grain protein analysis to segregate the grain as they harvest it. This essentially enables them to mix a special optimum quality grain that only just meets the requirements, thereby maximising their profit. The same thing is being done for sustainability. People who apply pesticides and fertiliser are using the maps for legal protection, to prove that they have not applied any fertiliser - for example - near a particular stream. One of the first uses of yield maps was in a case where a neighbouring farmer had sprayed on a windy day. The farmer who got damaged took the yield map to the neighbour and said, you have to pay me for this many bushels of grain, because all along the side of the field I lost this grain. You can be assured that this technology caused the farmer next door to be more careful in subsequent years.*

H. AUERNHAMMER

First of all, I'd like to comment on Prof. Kutzbach's statement that two parameters had not been mentioned this morning: the working width and the time delay. I would respond by asking: do we really need them at the present time? If the accuracy of the location systems increases down to 10 centimetres, we can perform both calculations during a post-processing phase: it's cheap, reliable and can be influenced by practical experience. That's one thing. It does become necessary if you go to a cruise control system, but until we have it, we should think about whether we need it or not. My next comment concerns the issue of yield maps. We were shown some examples this morning which - in my opinion - were too complex to be useful. Why do we need 10, 15 or even 20 classes of yield. What is the reason? The farmer only needs the information of the deviation from the average yield, divided into no more than 3 or 5 classes. The farmer is willing to adjust his fertiliser rate in a range of 10 or 15% below average to 10 or 15% above the average. So that's what we need in yield mapping. And still, I believe we have to do a lot of work on yield mapping, on post-processing. We can install software, which is cheap, and we can install highly sophisticated tools. Another point is standardisation. At the moment we are in a situation where standardisation is needed and avoided at the same time. Because full-line manufacturers are not necessarily interested in a standard. And now, in an increasingly globalised situation, national standardisation activities will become less important. Instead, we will have to go to ISO standards, which take a long long time and cost a great deal of money. I think we have to work on ISO standards, but ISO should be able to delegate the standardisation work to a country or to a group of countries. Otherwise we will have no good standards in the future in the right time. We also need some additional standards, for example for interfaces to information systems, interfaces to location systems, and so on. But I am afraid we'll have to wait, and wait, and wait.

Dr. Rainer RAMHARTER
Austria

I just wanted to make a short comment on Prof. Auernhammer's statement about the use of electronics in developing countries. I am sorry but I cannot follow your opinion. Taking into consideration the fact that two thirds of the world's land is still cultivated by animal drawn and hand tools - manual work - I cannot see any sense in using this. And I am afraid this situation is not likely to improve in the next few years. It may even become worse. Take for example the case of our Eastern European countries: if you travel there today, you'll see how many horses are once again being used there. Horses have become very important for the population's food supply, because the previous agricultural system has broken down. So I think we should watch it a bit more, and take a more realistic view

Prof. J. ORTIZ-CAVAÑATE
Spain

I was going to make a comment similar to Dr. Sutton's, in that I was very impressed by the example which Mr. Rider showed us - the New Holland automatic unmanned windrower. However, in my opinion this is not a realistic approach. What I consider to be very important, for the future, is that all this electronic equipment and sensors and so on should be used to help the driver: to facilitate his operations, to achieve a better quality of work, but not to eliminate the driver altogether, because I don't think that this is a realistic approach for agriculture. In my opinion, these unmanned machines are possible because the technology is available, but their future could be similar to that of the aeroplane - you all know that aeroplanes continue to become more automatic, but the pilots are still there.

L. J. CLARKE

I'd just like to continue where Mr. Ramharter left off, and again add something to the developing country perspective. As an engineer I was very excited and interested in the presentations. But then I must think back to my job responsibilities at FAO, which is mainly to developing countries and developing-country agriculture.

So just to put things into perspective, in sub-Saharan Africa 80% of all field operations are done manually, 15% by animal draught, and 5% by the use of tractors. And the main aspiration of the 80% of the people who are using manual labour is to move up to animal draught and also to tractors. And they have three main concerns: the primary one is cost, the next one is quality, and the third one is the functional capability of what's on offer at the next stage of technology. And what we've heard this morning is an overriding, not a total, but an overriding emphasis upon increases in the operator's productivity: how we can develop man-machine systems which will improve quality and productivity? Whereas for developing countries I think this is of far lesser importance. And my concern is that the top level of technology which is being developed and manufactured in Europe and in North America is moving rapidly out of the reach of developing countries. And there will just not be anything suitable available in the future. So I think we should give a thought to how electronics can assist developing country agriculture. And I would say that the main area would actually be at the point of manufacture, through a system for lowering manufacturing costs in order to make lower-cost items available. We're talking about the difference between 30 dollars for a draught animal plough and 50 dollars. And also, the use of electronics for design, to produce lighter and better quality implements. i.e. the use of electronics to improve and lower the costs of already existing technology.

Dr. El Hassan BOURARACH
Morocco

I agree with what has been said about the electronics. In developing countries, we can say that theoretical role of electronics is to help the operator to use and adjust the machines. But the reality is that electronics is more problematic than helpful to the operator. In many cases the operators disconnect the sensors, which causes damage to the machines. However I do see a role for electronics in the research area in our countries, because it enables us to collect a lot of information such as parts-breakdown statistics and data about the conditions in use of machines. And that can help in the design of machines. The question is economical: will the developing countries be able to find simple machines without electronics in the future? I think the answer is no, and so they'll have to follow this trend. And then the solution will lie in training: we will have to give more training to our operators, our farmers, and we scientists and manufacturers will have to pay more attention to ergonomic behaviour of our operators in developing countries. Because until now, all the attention has been focused on operators in developed countries, whereas we don't really know how the machines are used in developing countries. There are a lot of innovations in our countries, and that can be incorporated into the basic design of machines.

J. SCHUELLER

I think we need to keep a couple of things in mind, and that is that the variance within the developing countries is greater than the variance within the developed countries; that the situation varies from country to country as well as within countries. We also need to keep aware of the realities: in 1985 I did a paper on the tractor industry in India. At that time they were producing 70,000 tractors. The tractors were out there, in the field, certainly only in a minority of the country, but it was in a significant portion of the country. Yet in my opinion the research establishment was not supporting that at all. I believe, though, that it is possible to apply these new technologies. We're using them in hand-harvesting of oranges in Florida. We have a little box that, every time we come to pick up a bin, the operator of the truck that picks up the bin pushes a button: in this way the device records where each bin of citrus has been picked up. This is being commercially sold in Florida, and it's a cheap little box with just a GPS receiver. It records where each bin has been picked up, and then you can download that data to obtain a map of your citrus yield. That's cheap, inexpensive, would certainly be of use in plantation-type crops. There's a lot of interest right now in these technologies in Malaysia, for oil palms and for other crops. So there are applications in developing countries. But your point is very well taken, that these technologies cannot be adopted unless there is proper training of the people who are using them, and that the technologies must be sufficiently developed to be robust. With reference to Mr. Rider's comment, yield mapping - even in grain - is in its adolescence, and it still is not perfect. The technology needs to mature a little more before it works properly. But it is of some use. And with these technologies the question to ask is maybe not "is it perfect yet?" but rather "is the net contribution positive?". And does it take us in the right direction?

S. G. ABBAS

It seems that most of us agree that the usefulness of electronics and decision-support systems is essential to agriculture these days. However, from the manufacturer's point of view we must realise that small or medium-sized machines are in greater demand in developing agricultures. Therefore I echo the points raised by Prof. El Hossary and Dr. Sutton about the economical and social considerations on the subject. In the meantime I urge to look into the cost and the social implications of such developments for agricultural equipment which is specifically marketed to the developing agricultures.

Dr. Bernard BONICELLI
France

I'd like to comment, first of all, about the fact that electronics and decision systems must be very simple to use. We think that the best to achieve this is to design systems in which electronics and computers disappear. Systems in which you have only a few simple functions to use, without any screens or the like. My second comment is that manufacturers currently seem to be using these new technologies from the marketing point of view and for commercial advantage. But in future, the *standardisation of systems will simplify the question and really demonstrate the advantages of these technologies. I believe it really is easier to control and manage complex machines, such as those we find in agriculture, with the help of electronics and computers. In conclusion, I would say that our research is not yet complete. I think that nowadays it is still difficult for farmers to make good, informed choices. We must help people with these choices, and continually validate the universality of the principles to ensure correct choices for the future.*

P. ABEELS
It has been shown how sensors, actuators and other devices have been introduced on existing machines, and we must be proud of what has been developed step by step as the technologies have become available. However, I would put this question to the manufacturers: is it or should it be possible to work "backwards", and develop a machine taking the various sensors and actuators as a starting point. Perhaps with other processing systems. Because nowadays these systems are mainly applied on big machines, and I believe we need some machines that are more adapted to biological requirements.

W. VON ALLWÖRDEN
If you consider the development of the slashing process - how long has it taken for the machine which just slashes the corn? When you see a machine that is a hundred years old - we have it in a museum - and you compare it to a modern combine, such as those we saw today, what's the difference?

P. ABEELS
I agree totally, but if we look at some fundamental books about technology and compare technologies of different materials, we find that there are a lot of other alternatives to the traditional one. So we should not necessarily be tied to the traditional structures which we see in the museum.

K. Th. RENIUS
I would like to come back to the question of the developing countries, and first to give the figure for the current production in India: it is between 200-220 thousand this year, and is still increasing. I believe the market volume will be even higher in years to come. Now I agree with Mr. Clarke and John Schueller that we cannot in general say whether developing countries will or will not accept, will or will not make use of electronics. I think the gap between the most highly-developed and the least developed countries is increasing all the time - in terms of both technology level and power. But there are of course some countries between these extremes, which may become very important: for example India and Brazil, and China if it chooses privatisation. In China I believe they are taking the first steps towards shareholder companies. I was there some months ago and talked to some government representatives and, if it continues in this direction, China will be another country that falls between these extremes. And I think some electronic applications may also be of interest to them. Their problem, from what I have gathered during my many visits, is that this mid-level technology is not available in books, in publications or from companies: there is almost nobody who can provide information about this mid-level technology. That is one big deficiency, at present. Another problem is education. And so my question to CIGR, who I believe are in the process of preparing a wonderful handbook on machinery, is: does this booklet include something about basic knowledge on information technology and electronics applications?

O. KITANI
What we have been discussing is not just the small portion of agricultural technology related to machinery. For example decision-making is also processed with this kind of system. It is also related to the wider area of trends - what we have been discussing is also the future direction of information technology. And as we accumulate and obtain more and more information from these kind of systems, it becomes increasingly important to select the proper information in terms of its quality, the efficiency of gathering it, and in terms of utilising this kind of information. And for these purposes I think it is very important to cooperate with other fields, other disciplines, which is why I am very pleased to have here someone like professor Auernhammer, who is originally from agronomy. I think we need more interdisciplinary cooperation to develop more practical and better systems in the future.

J. PAWLAK
New electronic developments will permit the application of innovative agricultural production systems. One example is precision agriculture. Practical use of these systems will be possible on condition that they are economically feasible. But in calculating the costs and profits, we should take into consideration not only the economy of chemicals and their effects on the quality of products, but also the effect on environmental conservation. Taking into account the environmental effects is important as a basis for state policies which promote environment-friendly solutions. We should consider that the effects of improving the environment affect the whole of society, so it is justifiable for society to contribute to the cost of implementing the systems. Perhaps in the form of subsidies for farms which use the new environment-friendly but more costly agricultural production systems. The problem is that we don't have the basic input data to evaluate the effects on the environment. Therefore, interdisciplinary research and studies are necessary to supply this data. This is very important for agricultural engineers, but agricultural engineers will not be able to solve all the problems, because the effects are on different fields of human life, including health protection, landscape, etc. I would just like to point out the need for such studies.

D. WHITE

I wanted to make a fairly brief comment on this problem of yield mapping, which has been highlighted by a number of speakers around the table. In fact it was Prof. Kutzbach who first raised the question earlier this morning, when he asked about cutting width. But I think the other problem that he highlighted was the fact that, by the time you have actually measured your yield, your machine has rather inconveniently moved on a bit. This is a very interesting problem; it is a function of the particular machine, it is a function of the forward speed, and it is a function of the throughput. The problem has been addressed by two people at Silsoe research institute, Lark and Stafford, and I wanted to draw your attention to the fact that they have a paper published earlier this year in the Journal of Agricultural Engineering Research, which is very well worthwhile reading to anyone who is interested. They have actually used a statistical function - which does need calibration in the field - but they have then shown a way in which they can beat this problem. If, having read the Lark and Stafford article, anyone thinks that they have something better, I would be delighted to receive a paper on the subject.

Y. KISHIDA

I want to make some comments in connection with the problem of developing countries. In the next century, surely our biggest problem will be food, because of the population is still increasing and agricultural land is very limited. And the resources we can use to produce food are now decreasing, per capita. That means that in the 21st century the key technologies will be those that increase land productivity. Therefore we need to develop more sophisticated technology aimed at increasing land productivity, such as precision farming. But in today's discussion we have heard many people who come from different countries and have diverse agricultural backgrounds: for example people who come from developing countries say : how can we introduce these technologies in developing countries? It has been mentioned that in some countries, two thirds of the land is still cultivated by animals and manual labour. Nonetheless, I think that the current trend of mechanisation is from "muscle" mechanisation to "brain" mechanisation. This is a very strong trend. It has also been said that the technology gap is just expanding, but this diversity in technology levels can also be viewed in a positive light: to solve the world food problem we will need many different varieties of technology, appropriate for the different areas. And I want to ask you to consider one thing: how can we introduce this kind of new electronic technology to improve the situation of agricultural mechanisation in developing countries? I think we have a great opportunity to extend the applications of the new electronic technologies for the simple mechanisation, also for the small-scale mechanisation. One example is the case of Japan: our agriculture is very peculiar because our average farm size is still very small, 1.2 hectares, and there are many small, scattered plots. To overcome this we are now discussing the promotion of mechanisation using electronics, and the development of small-sized highly automated machines. In this way we can overcome our handicaps. So I think electronic technology should be adapted in many ways for the many different agricultural conditions. I think the technology gap is expanding, but at the same time there a lot of opportunities to improve world-wide agriculture.

H. AUERNHAMMER

I have the feeling that the discussion about developing countries has mainly been focused on the use of mobile equipment. I would say that in developing countries we first of all have to gather more input information. That means we must also focus our thoughts on some kinds of image processing - from satellites, from the air - to see what happens on the ground. Yesterday we talked about cooperatives and contractors. I think that in developing countries maybe the key to the use of electronics is more centralised: it might first be introduced by the government or union-type organisations, and then brought down to the level of cooperatives or contractors.

C. CHAKKAPHAK

I appreciated and was fascinated by the current technology developments on actual machinery. In Thailand the situation is that about 50% of 90 HP tractors being purchased in the country are second-hand tractors. This is about altogether 2500 units a year. Similarly about 80% of smaller-sized 30 HP 4-wheel tractors are imported from Japan, are second-hand tractors. This is simply because of the need for lower-priced machines. This is just an example - I have discussed a little with my Japanese friend on the need for simple tractors for Asia, and the fact that because - even today - the tractors currently manufactured in Japan are too sophisticated and expensive for our farmers. This is just the example of the current situation.

H. CETRANGOLO

To take a realistic approach, I think that the electronics is one of the ways to improve agricultural production. Especially to produce more, at lower cost, and in a more environment-friendly manner. And another point, concerning the discussion between developed and developing countries: I think that another distinction which can be made is between open-market and closed-market economies. And I believe that, with globalisation, the countries with open market economies are going to have similar strategies for agricultural production, and also their labour costs will be similar. For that reason I think that it is possible to have good electronics developments in each case.

A. R. RIDER

I just want to clear up a couple of things, to make sure that we all understand one another. The first point I'd like to address is standards: someone made the comment that the large companies really don't care for standards. Quite the contrary: we would much prefer that there be *standards. The problem is that a large company grows impatient with the standard-development process. If there's an economic opportunity out there to sell a product, the objective for the industry is to make some money for their shareholders, and so as a consequence you go ahead without the standards being fully developed. I recognise this leads to problems, because if two or three companies go ahead and do their own thing, how do you ever get them to concur and agree later on? And I think all of us agree that did not occur on hydraulics - in fact there are still differences in hydraulic standards. So it's not an issue of whether we want it or not, we would much prefer to have standards, and it's absolutely critical in this electronics area that we do that. The second thing is associated with developing agriculture. I think that sometimes we in the large companies are perceived as not being interested in it, and as not having any plans to support that. Again, I would suggest that quite the opposite is true. Clearly there must be an economic opportunity and there must be viability associated with it for us to participate, but - to give you an example - I can tell you that, today, the only new plant that New Holland is building happens to be in India. And it's being built with the express intent of manufacturing what we would call a low-specification tractor, to meet the needs of that marketplace, and so we are continuing to look at that. We have a group in our corporate office whose only task is to identify opportunities in new markets, and we certainly understand that it's not in the sophisticated markets, with all the electronics and the automation we've been talking about. We recognise that the opportunity is for the lower-spec related products. I would contend that we spend more money on developing that market and that opportunity than any other single market. We probably spend more development on the economically viable areas, such as those in Western Europe and North America, where we're looking for high-spec products, because that's where the opportunity is. We believe we already have the product capability to supply the lower specialized markets. So I though that from an industry perspective we should share that, so that you recognise a slightly different viewpoint from what you may have interpreted on the whole.*

J. HELLEBRAND

I would like to follow up on your remarks concerning standards, I think this is a point which needs to be stressed once again. Bus systems have been mentioned three times in the discussion, but it takes a lot of time to prepare a proposal for an international ISO standard and come to an agreement on all sides. Therefore, there should be efforts both from industry and from the research community to implement this in the future. Once again I would like to stress the fact that precision farming depends on information we use for agricultural applications. And therefore more research is necessary to develop sensors and other systems to get the right inputs for the control of precision farming instruments.

SESSION 3

EUTRAC: POSTGRADUATE CERTIFICATE/MSC IN EUROPEAN AGRICULTURAL ENGINEERING

EUTRAC: Postgraduate Diploma/MSc in European Agricultural Engineering

by ***Nigel Warner and Rainer Ramharter***
UK, Austria

1. Introduction

This is a multinational co-operation programme validated by the Royal Agricultural College, Cirencester UK with the aim of producing agricultural engineers with a knowledge of the industry in at least two EU countries and with the necessary technical language capabilities and cultural knowledge for a career in an ever changing and broadening market place.

Current partners in the programme are :

- the Institut fur Agrartechnik, Universitat Hohenheim,
- the Istituto di Ingegneria Agraria, Università degli Studi di Milano
- the Institut fur Land, Umwelt und Energietechnik, Universitat fur Bodenkultur
- the Royal Agricultural College, Cirencester.

The course was developed to combine the strengths and expertise of the partner universities in the areas of agricultural engineering and machinery management, to reflect the current multinational developments within the agricultural engineering industry itself, and produce a multi-national, multi-lingual programme which would be attractive to both students and potential industry employers.

2. Course Structure

The course requires students to undertake a part of their studies in another EU country, in a language which is not their natural tongue and is structured into the following basic elements :

a) *a preliminary qualification* - Students must have a suitable preliminary qualification in agricultural engineering or related subject, plus the necessary language skills to undertake a period of study in another country. This period of study may or may not be a part of the normal academic provision of the partner university. ie students already possessing a suitable qualification in agricultural engineering and having the language skills necessary for study abroad may enter directly onto the final year of the programme.

b) *a European semester* - Students study at a partner university centre and in a second European language. This gives the students the chance to benefit from the individual areas of expertise of the partner university. The costs associated with travelling between the home university and partner university may be eligible for Socrates support. Students may elect to leave the programme at the end of this semester. Providing all elements have been successfully completed and they have achieved the necessary credits, they will be awarded a Postgraduate Certificate by the Royal Agricultural College.

c) *a Postgraduate semester* - All students wishing to continue with the programme will study at Cirencester. Successful completion of both this and the European semester will lead to the award of Postgraduate Diploma in European Agricultural Engineering from the Royal Agricultural College for those who wish to leave the programme at this stage.

d) *an MSc dissertation* - Students who achieve sufficiently high marks in the Postgraduate Diploma will be eligible to register for and complete an MSc dissertation. This dissertation can be completed at any of the partner universities, but must be submitted in English to the Royal Agricultural College. Successful candidates will be awarded the Royal Agricultural College MSc in European Agricultural Engineering.

3. Future Developments

It is hoped by all the current partners that an expansion of the programme with new partners from other EU countries could take place as soon as possible. This would widen the opportunities for student mobility and study, and enable different areas of expertise to be brought into the programme from the new partnerships. There may also be opportunities for students to complete their studies for elements (a) and (b) in their natural tongue, providing they undertake language classes at the same time.

Possibilities also exist for an expansion of the programme outside the current EU boundaries for students wishing to take advantage of similar agreements between partner universities not currently within the Eutrac framework.

The Royal Agricultural College would welcome such new opportunities for expansion of the programme, and looks forward to exciting future discussions in this area.

The final area to develop is that of industry collaboration. It is hoped that in the future, greater industry support will greatly enhance the course's appeal. Such support could be in terms of direct financial aid to individual students or to one or more of the partner universities, or indirect support in terms of use of equipment, facilities, information etc within the teaching programmes of the individual universities concerned. Discussions between any of the partner universities and industry representatives would be warmly received.

4. Conclusions

The Eutrac programme is a new venture in education and deserves to succeed. The agricultural engineering industry which it will serve is ever changing and is itself becoming more multinational. Students graduating with a qualification in European Agricultural Engineering from the Royal Agricultural College, Cirencester will have unique skills which could be a valuable asset to the industry and I for one hope to see the industry embrace the principles of this course and give it the support it deserves.

DISCUSSION

B.A. STOUT

I want to enthusiastically endorse what the speakers have just said. This fits in exactly with a speech that I gave last week in Mexico and will give next week in Greece, called "the globalisation of agricultural engineering". And while there may be administrative obstacles to expanding this programme across the ocean, I would like to talk with you about the possibilities, and I just urge all of us to get behind this because globalisation of the industries that we serve is a reality, it's not a future dream. And it's something that our young people need to pay more attention to because their career development is going to depend, to a large extent, on getting the kind of training that you're talking about.

Prof. P.L. FEBO
Italy

I speak as chairman of CIGR Working Group 1, and the Special Interest Group of EurAgEng No. 12 on the harmonisation of agricultural engineering curricula. First of all, I would like to congratulate the speakers on their presentation, and put a question about a point which I didn't quite understand - this program at present works for students who come from Austria, Germany and Italy, as well as the UK. But I didn't understand how it would work for UK students, because it should be the other way round. Another thing: with the permission of our chairman Prof. Pellizzi, I would like to publicise my working group: I suppose some of you know that, under the auspices of CIGR, we have produced a report on agricultural engineering curricula which includes universities from 25 countries, and we are very busy in updating and improving this report by including other countries and other universities. I know that here I will have the opportunity to contact many of you, which I will do tomorrow, this evening, anytime during the course of the meeting. But please, if you are interested in joining this with your university or your country, do contact me. In any case you will receive a letter from the secretary of the working group, Dr. Da-Wen Sun from Dublin University.

N. WARNER

To answer your question, all students from all the universities are on the same structure of program: they all have to spend one semester taught in a separate country in a second language. So regardless of where they initially register as their home university, one semester has to be taught abroad. And then it's only at the final postgraduate diploma level that they all come back to Cirencester.

R. RAMHARTER

Perhaps I should mention that the main difference between the Continental and UK systems is that Continental students do it in addition to their regular studies, while for UK students it is a standalone course. Let me just take this opportunity to inform that, if anybody is interested, I have here a flyer and a course guide.

D. SUTTON

I just wanted to ask - why EUTRAC? I presume Royal Agricultural College comes in it somewhere as an acronym, or not?

R. RAMHARTER

No, EUTRAC means European Transformation of Agricultural Curricula. This is the curriculum development name from Brussels, and we think it sounds rather nice.

S. G. ABBAS

As I understand it, I think students from New Zealand can come to Germany and can pay the same fees as a German resident, and vice versa in New Zealand. And I wondered if in future this could be extended to other countries- I am sure it could on the New Zealand side.

LIST OF PARTICIPANTS

Hugo A. CETRANGOLO - Full Member	Argentina
Malcolm MCKAY - Full Member	Australia
Rainer RAMHARTER - Keynote Speaker	Austria
Pierre F.J. ABEELS - Full Member	Belgium
Henry JIMÉNEZ - Full Member	Colombia
Pavel KIC - Full Member	Czech. Republic
Ali M. EL HOSSARY - Full Member	Egypt
Bernard CHÈZE - Full Member	France
Bernard BONICELLI (standing in for Gérard JACQUIN)	France
Hermann AUERNHAMMER - Key-note Speaker	Germany
Wilhelm VON ALLWÖRDEN - Key-note Speaker	Germany
Juergen HELLEBRAND (standing in for Jürgen ZASKE)	Germany
H.D. KUTZBACH - Full Member	Germany
Axel MUNACK - Full Member	Germany
Karl Th. RENIUS - Full Member	Germany
Uri M. PEIPER - Full Member	Israel
Giuseppe PELLIZZI - President	Italy
LJ. CLARKE - Full Member	Italy
Roberto GUIDOTTI - Key-note Speaker	Italy
Paolo CELLI - Full Member	Italy
Pietro PICCAROLO - Full Member	Italy
Eugenio TODESCHINI - Full Member	Italy
Gennaro GIAMETTA - Associate Member	Italy
Franco SANGIORGI - Associate Member	Italy
Marco FIALA - Technical Secretary	Italy
Yoshisuke KISHIDA - Full Member	Japan
Toshiyuki YOTSUMOTO	Japan
Osamu KITANI - Full Member	Japan
KOBAYASHI (standing in for Yasuo TAKIZAWA)	Japan
Bassam A. SNOBAR - Full Member	Jordan
Arturo LARA LÓPEZ - Full Member	Mexico
El Hassan BOURARACH - Full Member	Morocco
Bert SPEELMAN - Full Member	Netherlands
Syed Ghazanfar ABBAS - Associate Member	New Zealand
Jan PAWLAK - Full Member	Poland
Oleg S. MARCHENKO - Full Member	Russia
Leonid KORMANOVSKY - Full Member	Russia

V.M. KRYAZKOV - Full Member	Russia
J. ORTIZ-CAÑAVATE - Full Member	Spain
Chak CHAKKAPHAK - Full Member	Thailand
Nigel WARNER - Key-note Speaker (standing in for John ALLISTON)	UK
David WHITE - Full Member	UK
Derek SUTTON - Full Member	UK
Richard O. HEGG - Full Member	USA
Allen R. RIDER - Full Member	USA
John SCHUELLER - Full Member	USA
Bill A. STOUT - Full Member	USA

TABLE OF CONTENTS

8TH MEMBERS' MEETING
BOLOGNA, October/November 1997