GPS in Agriculture in the Year 2000

PD Dr. Hermann Auernhammer, Weihenstephan (GERMANY)

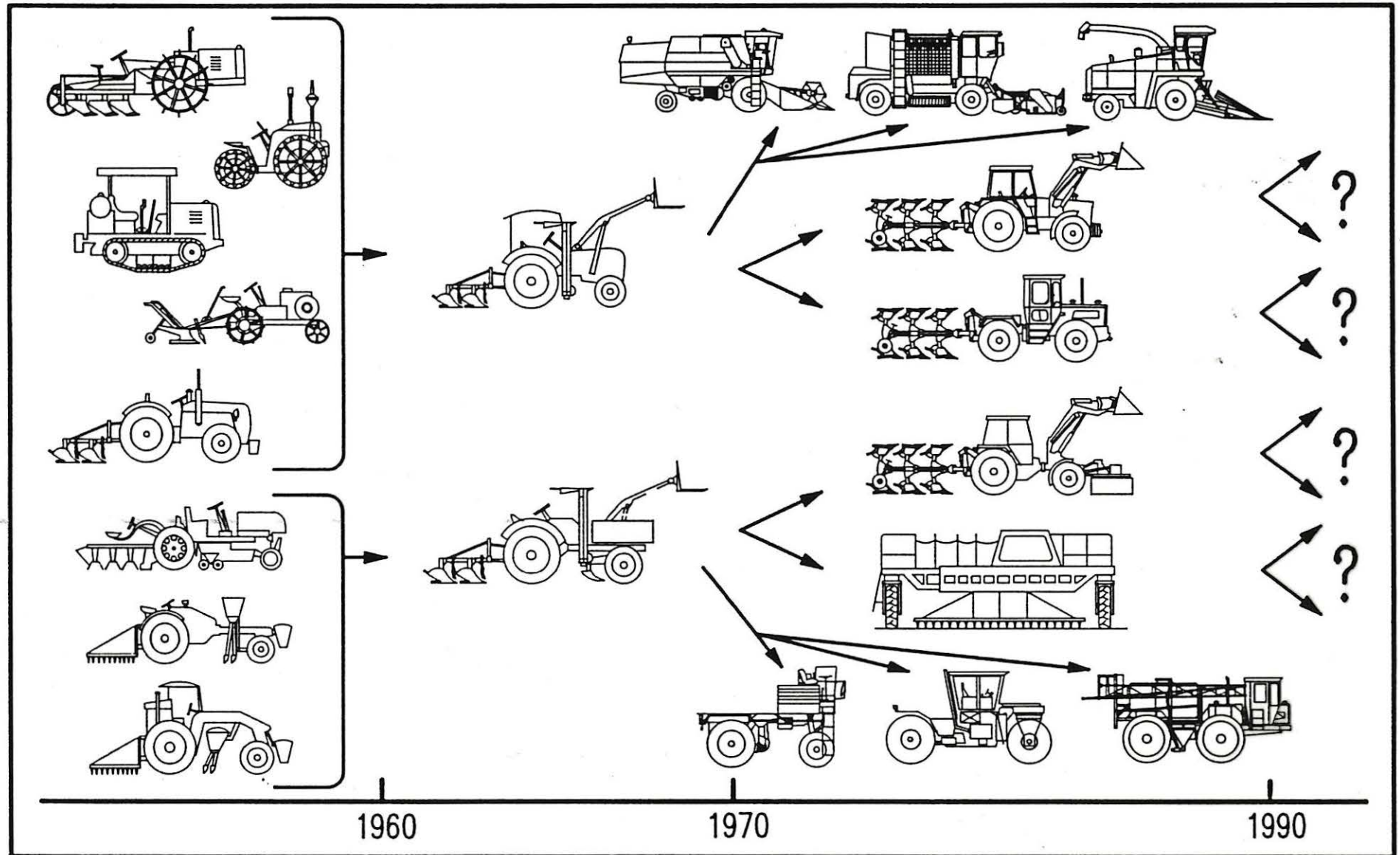
Introduction

Agriculture in the the Year 2000

Location Sensing

Navigation

Conclusions



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Tractor Concepts Through The Years

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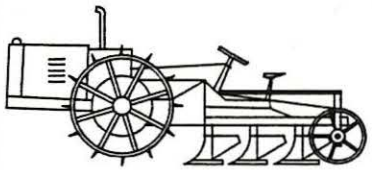
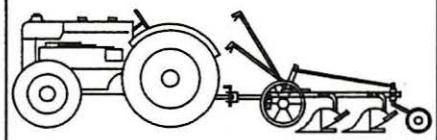
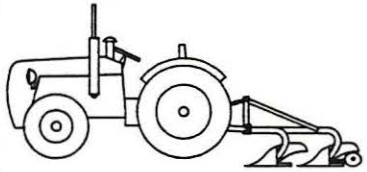
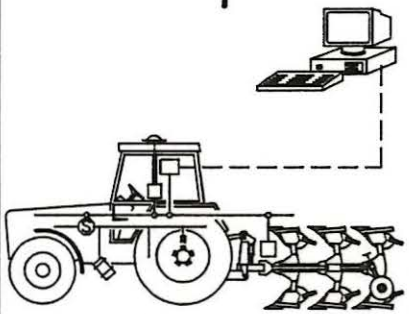
	Milestone			
No.	1	2	3	4
Form				
Characteristic	self propelled working vehicle	universal traction vehicle	tractor implement unit	communicational process link
Innovation	combustion engine	pneumatic tire	hydraulics + three–point–linkage	electronics + communication
Achievement	"biological" independence	mobility	self propelled property	"technical" intelligence
Auernhammer	Milestones of Tractor Usage (Starting point: Animal Draft)			LANDTECHNIK WEIHENSTEPHAN Be 932 389

Agriculture in the Year 2000

1. size of farms is still encreasing

2. more efficient management is needed

3. environment protection will be an integrated part of agriculture production

Farm Profits of Bavarian Farms

Groups of success	Profit in DM / Family worker		
	10 - 25 ha	25 - 50 ha	50 - 150 ha
Top group	49 633	47 851	67 146
Medium group	16 706	22 257	34 168
Low group	- 629	- 2 213	8 147

Source: Bayerische Buchführungsergebnisse (BSTMELF) 1992/93

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Heigl

The Dependency of Farm Profits to Qualification and Farm Size

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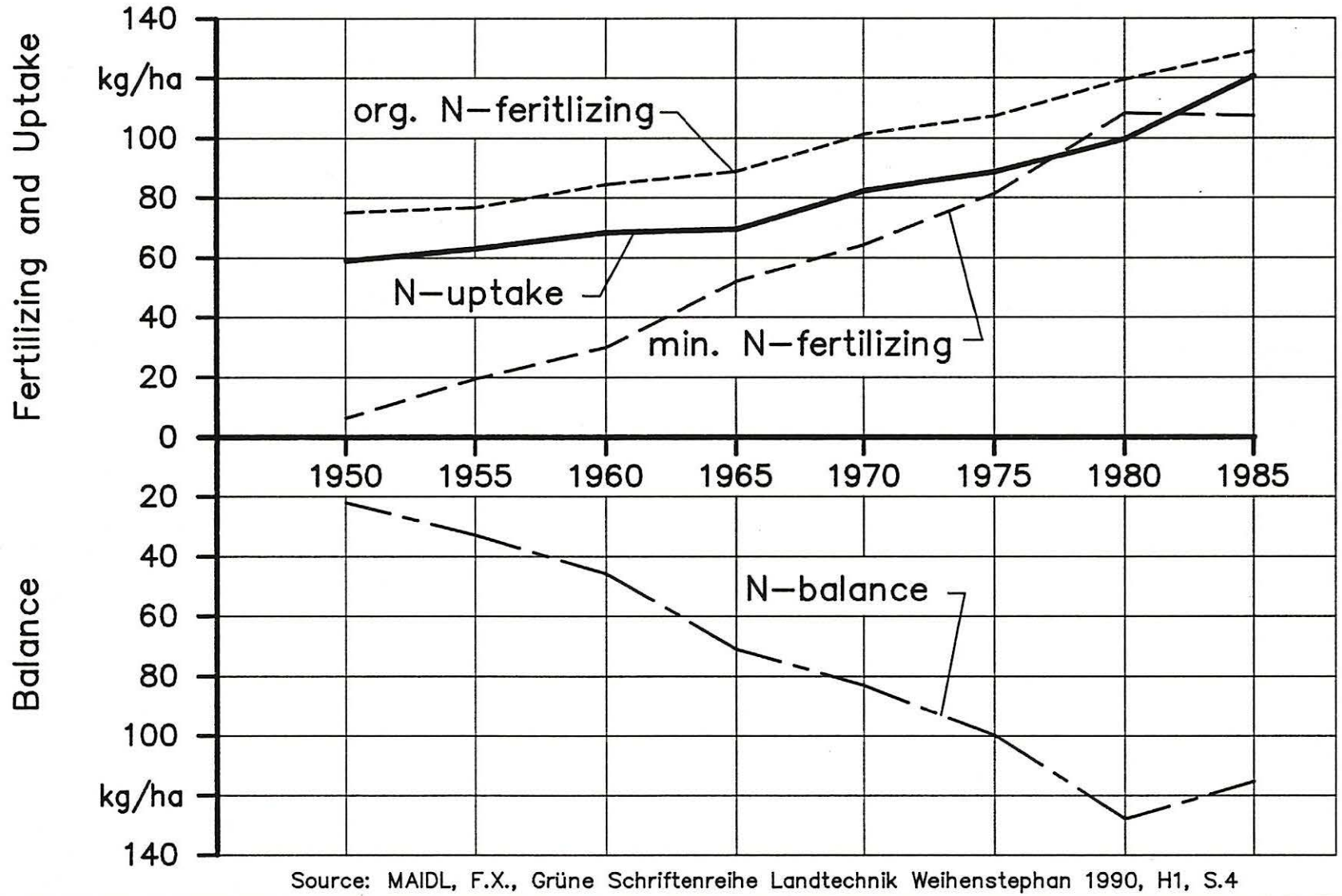
Contamination of Open Waters by Agriculture

38% by phosphate
about 97% caused by erosion

46% by nitrate
mainly caused by overfertilizing

Source: Werner,W.: "Brunnenvergifter Landwirtschaft?",DLG–Mitteilungen 104 (1989), H. 19 S. 979

Auernhammer	Contamination of Open Waters by Agriculture in West–Germany	LANDTECHNIK WEIHENSTEPHAN Be 942 076



Source: MAIDL, F.X., Grüne Schriftenreihe Landtechnik Weihenstephan 1990, H1, S.4

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Development of N–Balance of Farmed Area in Bavaria

(according to MAIDL 1990, Grüne Schriftreihe)

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Farm size Type of farming Extention region	Costs of overfertilizing in DM/ha			
	N	P_2O_5	K_2O	Sum
Farms altogether	98	70	41	209
Farm size 10 ha LF	19	65	59	145
Farm size 10 - 30 ha LF	56	88	50	195
Farm size 30 - 50 ha LF	186	70	51	311
Farm size 50 ha LF	78	60	36	175
Cash-crop-farms altogether	16	43	33	93
Forage-growing-farms altogether	156	80	48	286
Intensive-livestock-farms altogether	155	63	45	299
Mixed-farms altogether	26	71	24	125
Region Hannover	48	54	36	138
Region Weser-Ems	228	82	53	367

Source : Schindler, University Göttingen; empirical examinations 1990

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Maier

"Costs of Overfertilizing" on Farms in Niedersachsen, Depending on Farming-type and Region

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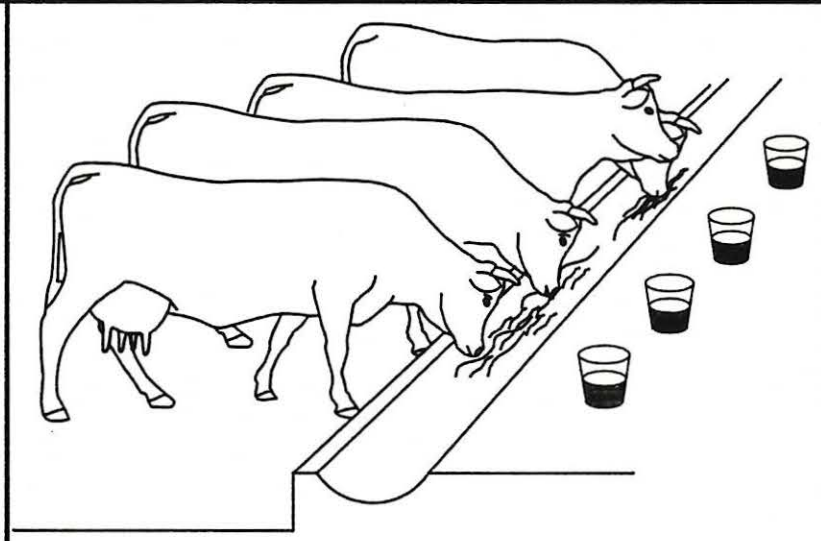
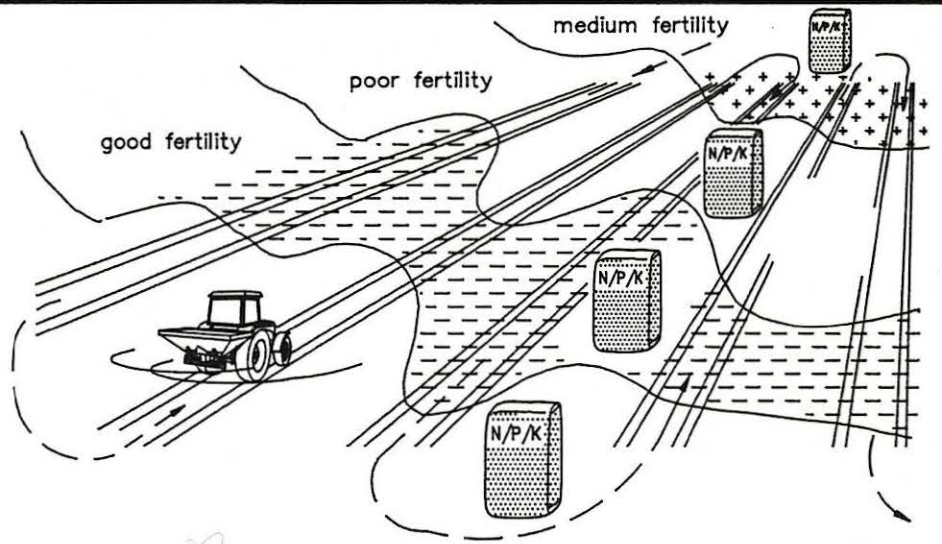
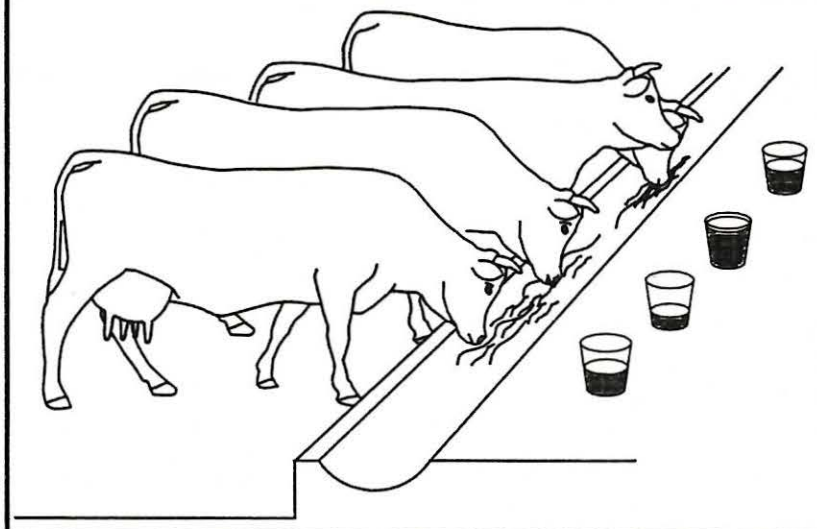
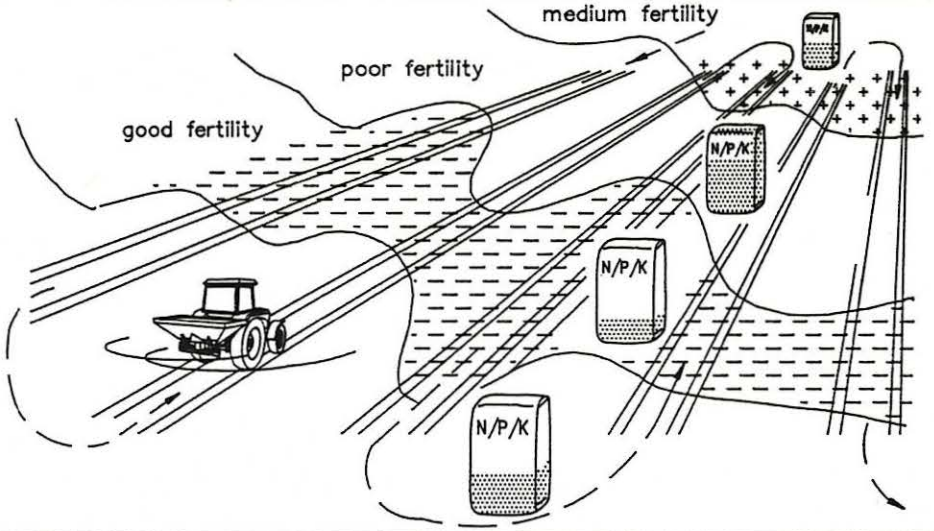
	Indoor Operation	Outdoor Operation
Collective Supply		
Individual Supply		

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Collective and Individual nutrient Supply shown for Indoor and Outdoor Operations

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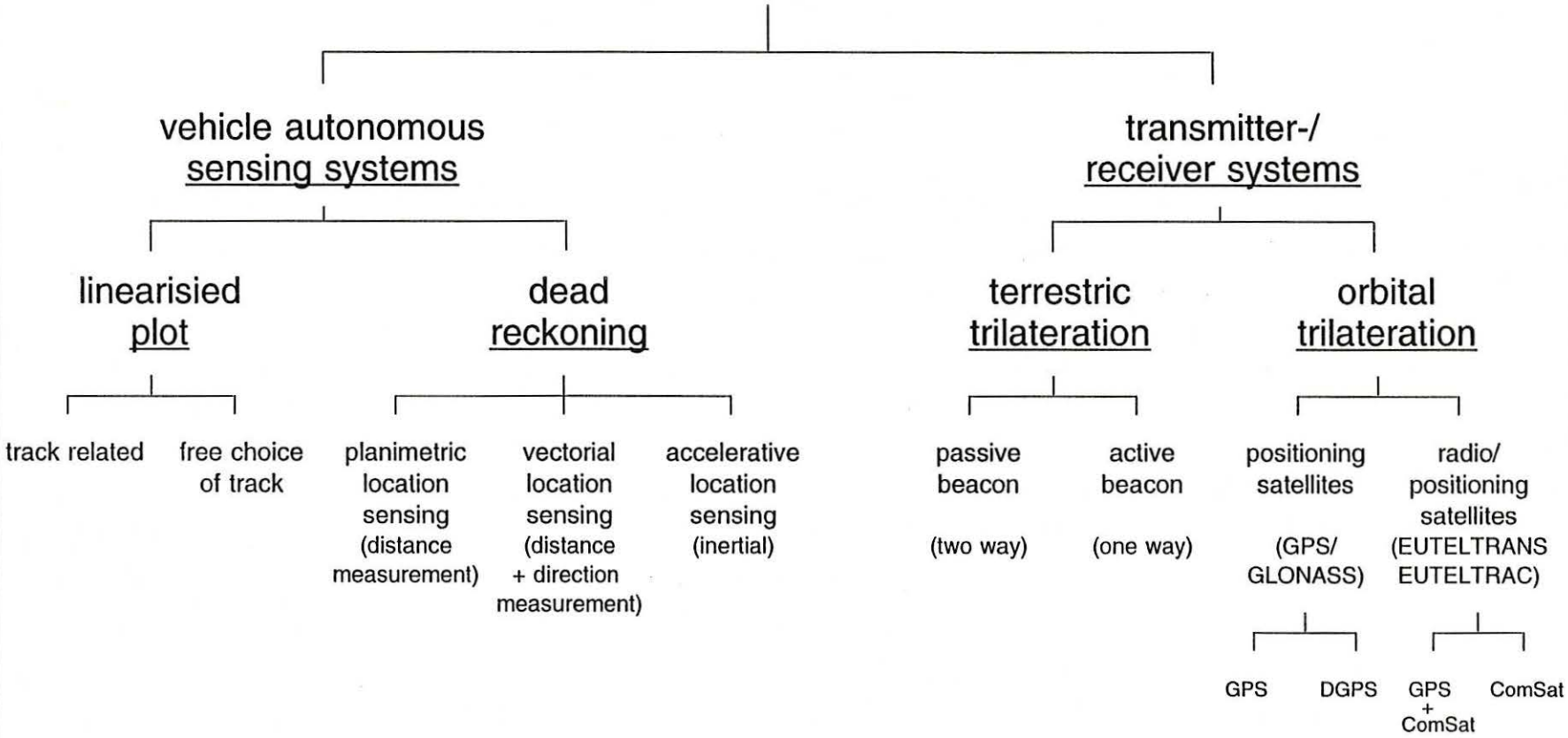
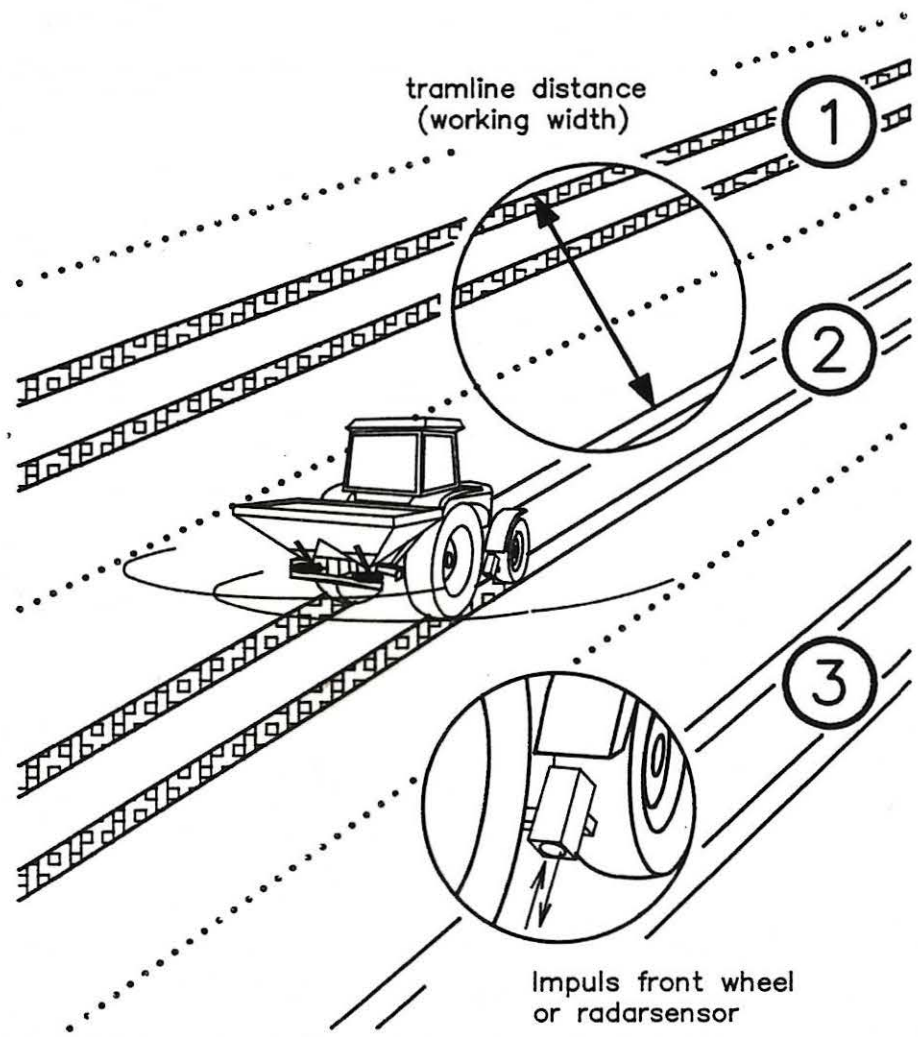
Systems for Location Sensing of Agricultural Vehicles



Auernhammer Maier	Systematic of Location Sensing of Agricultural Vehicles	LANDTECHNIK WEIHENSTEPHAN 94 2AM 013



Function:

Following the added distances of lined working tracks starting at an field dead point

- x is determined using the tram line number and tramline distance
- y is determined by measuring the way starting at the field dead point

Advantage:

* only 1 senor needed
* error–correction possible at every tramline end
* no sensor–infrastructure needed

Disadvantage:

* work only possible if starting at the field dead point
* variing tramline distances cause errors
* after a break it is neccessary to follow the already worked way starting at the field dead point

Error:

working width (x) ± 3 – 12 %
way length (y) ± 1 – 3 % (by error–correction on tramline end)

Assessment:

For carefully working farmers for the on–farm use on fields with row–crops or tramlines suitable.

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Location sensing with the method of "linearized field"

(Function and assessment)

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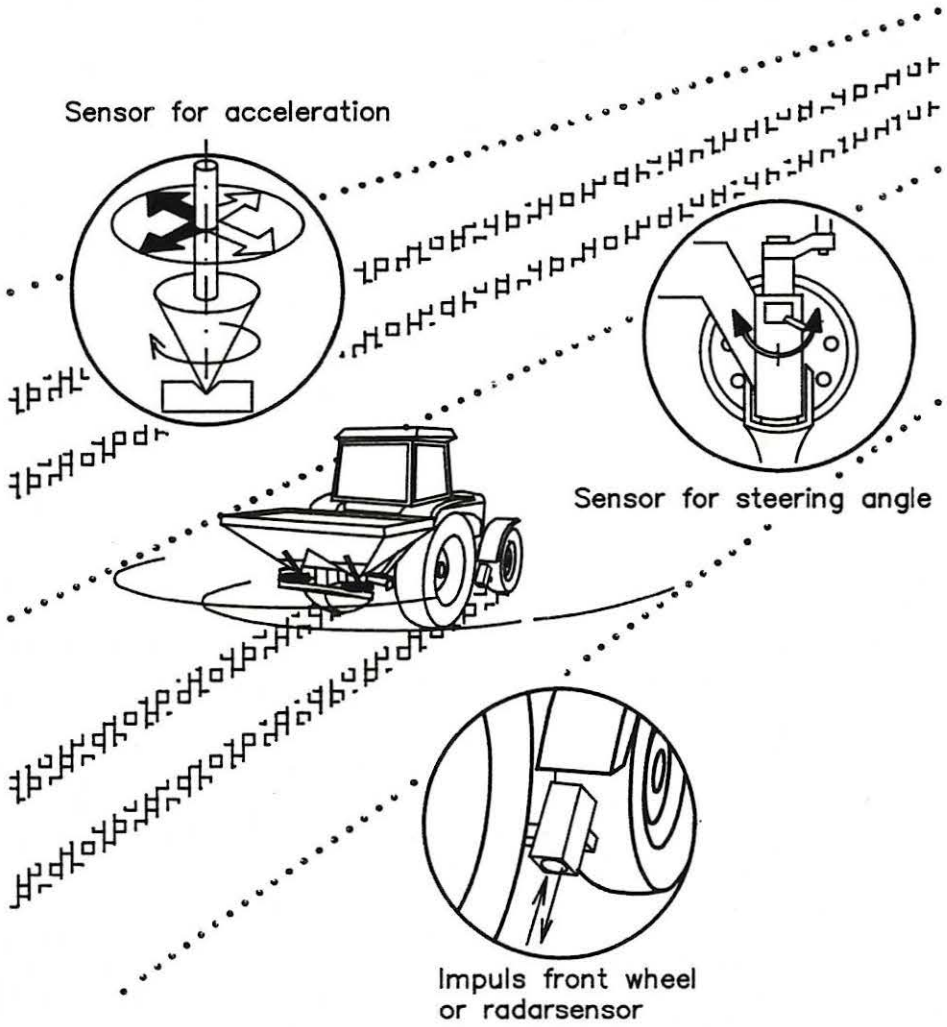

Function:

Calculation of the actuall position by summing up the two dimensional elements of moving by vehicle autonomous sensors .

Advantage:

* no sensor – infrastructure needed

Disadvantage:

* known starting point (dead point) needed
* errors by poor traction (drift of vehicles)
* errors remain in the system and sum up till the system is recalibrated at the starting point

Error:

> ± 1 nautic mile / 8 h (>±6,4 cm/s)
= with 7 km/h > ± 3 %

Assessment:

As a single system not satisfying for agricultural use

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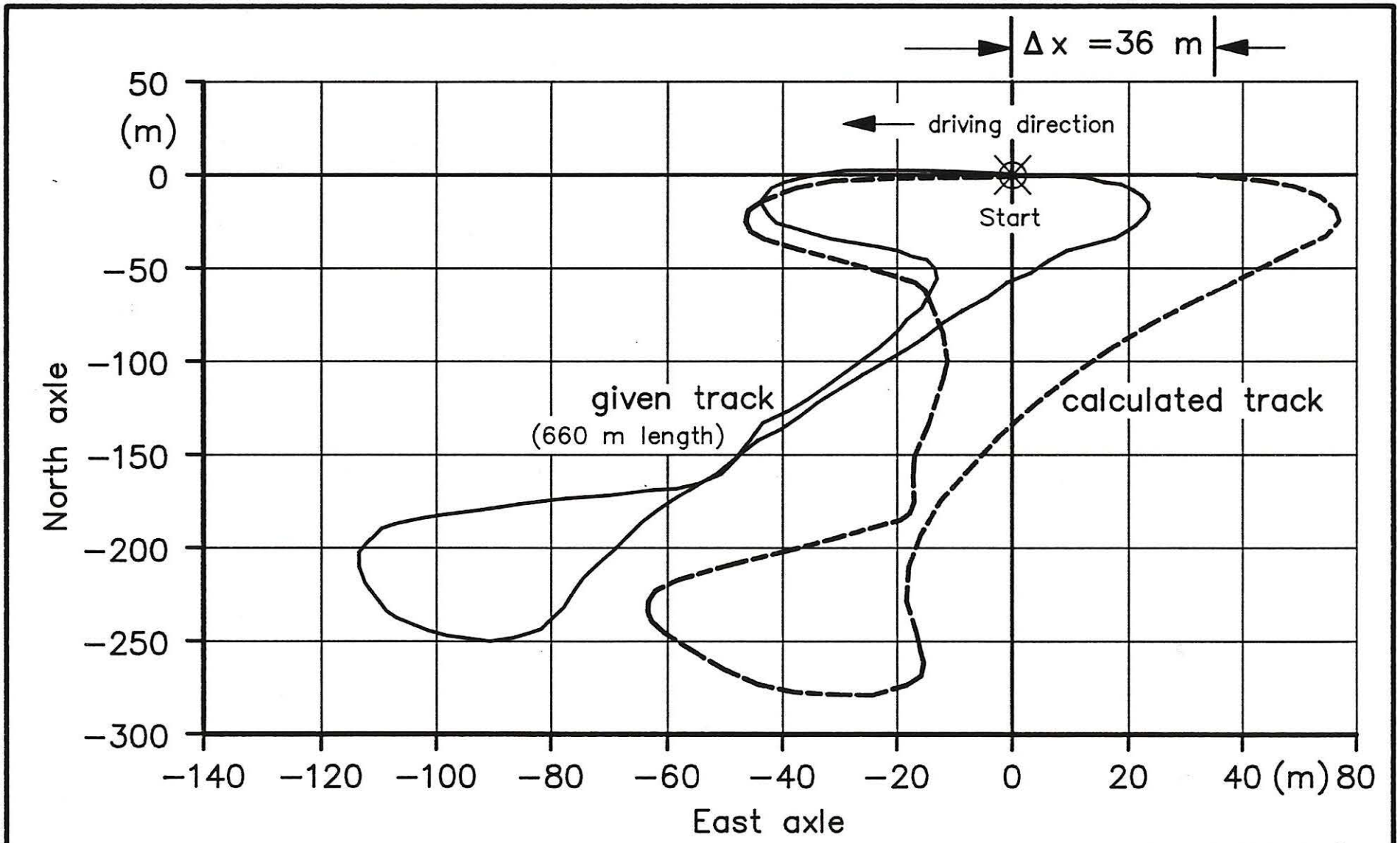

Auernhammer
Muhr, Friedrich

Planimetric dead reckoning with revolution sensors in the front-wheel on a given track

(Unimog U 1400; short cutted gras; flat; 6 km/h; autumn 1991)

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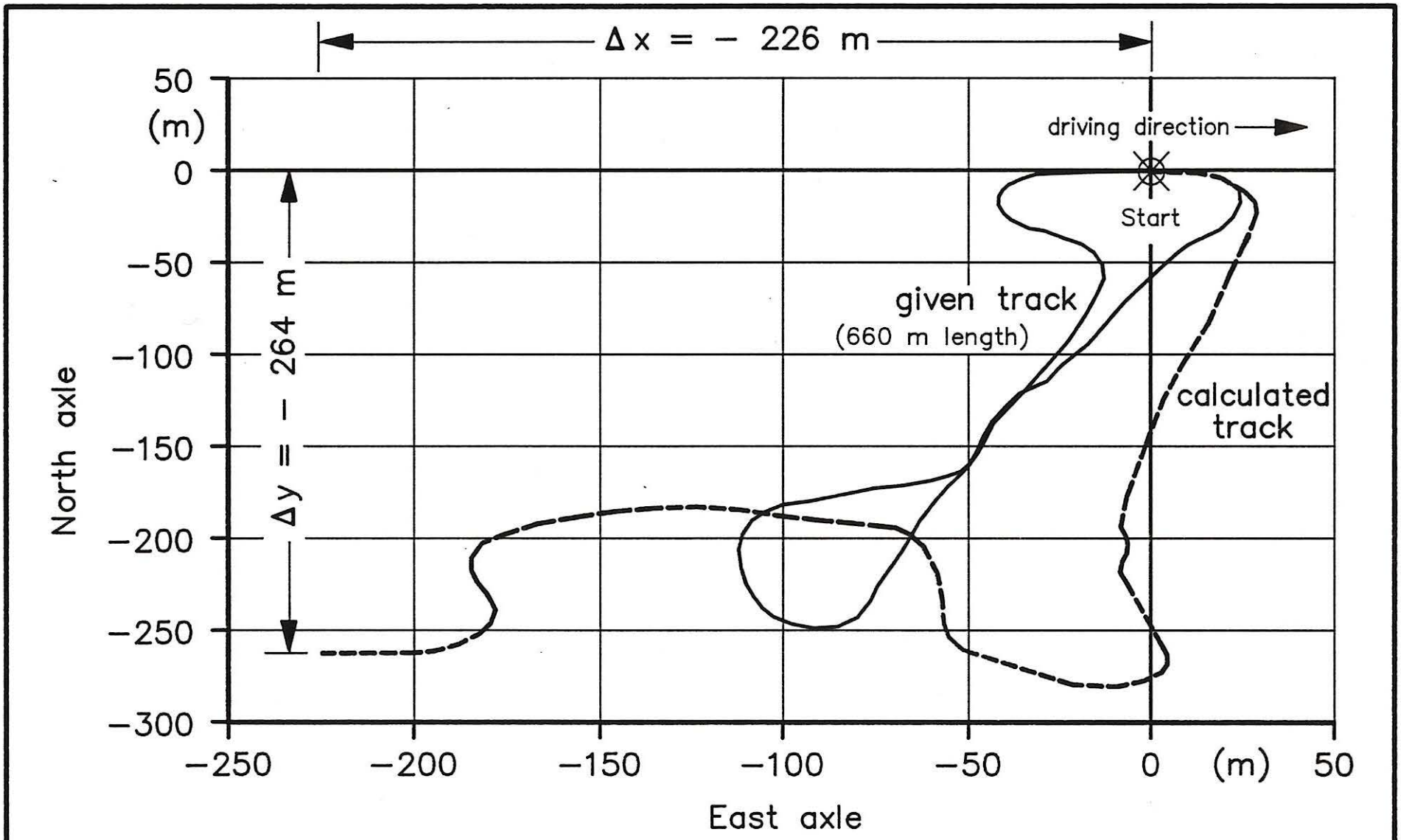
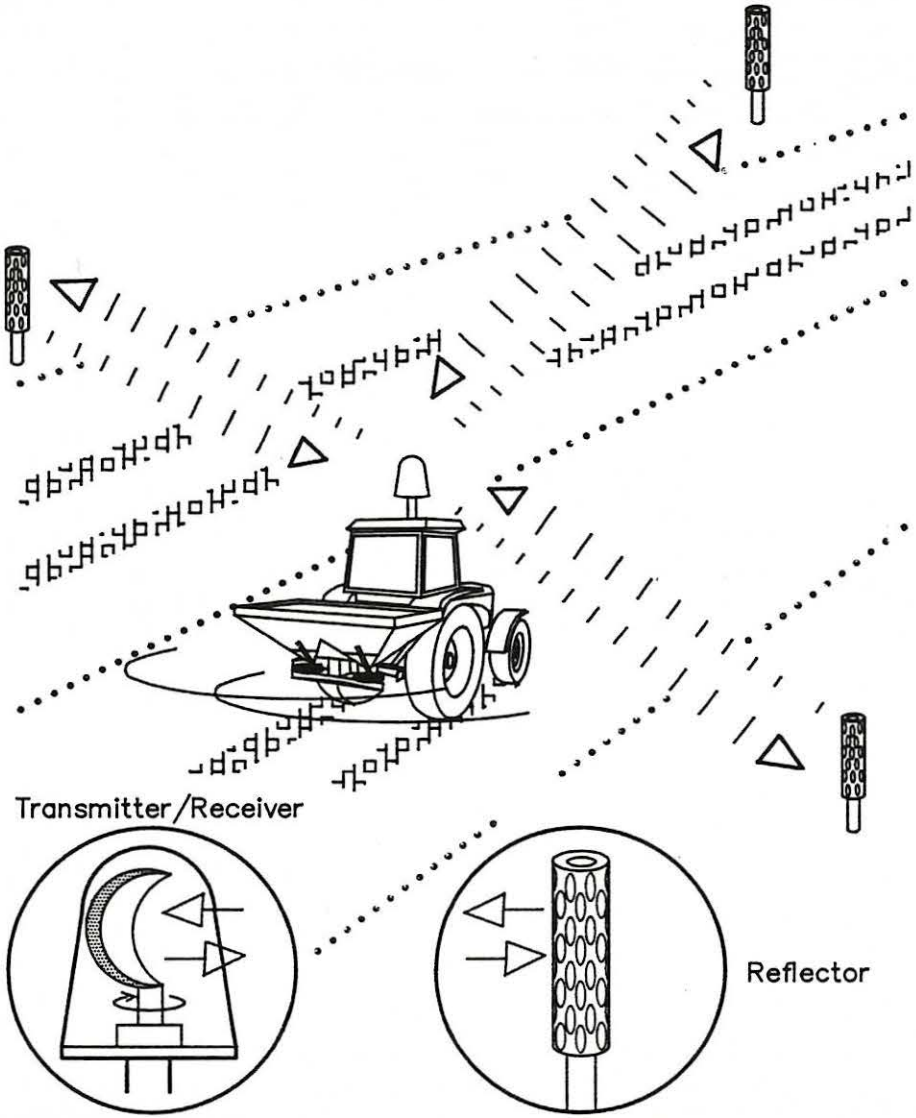


Auernhammer Muhr, Friedrich	Planimetric dead reckoning with mounted ultrasonic sensors on each side of a traktor on a given track (Unimog U 1400; short cutted gras; flat; 6 km/h; autumn 1991)	LANDTECHNIK WEIHENSTEPHAN Be 942 084



Function:

Transmitter/Receiver on the vehicle calculate the distances to the beacon by measuring the traveling time of the microwave signals to the beacon. The position is determined by trilateration.

Advantage:

* high precision
* no farm external actions necessary

Disadvantage:

* cost for installation and maintenance
* flat area needed
* increasing errors close to beacon, may be reduced by 3 or more beacons (higher costs)

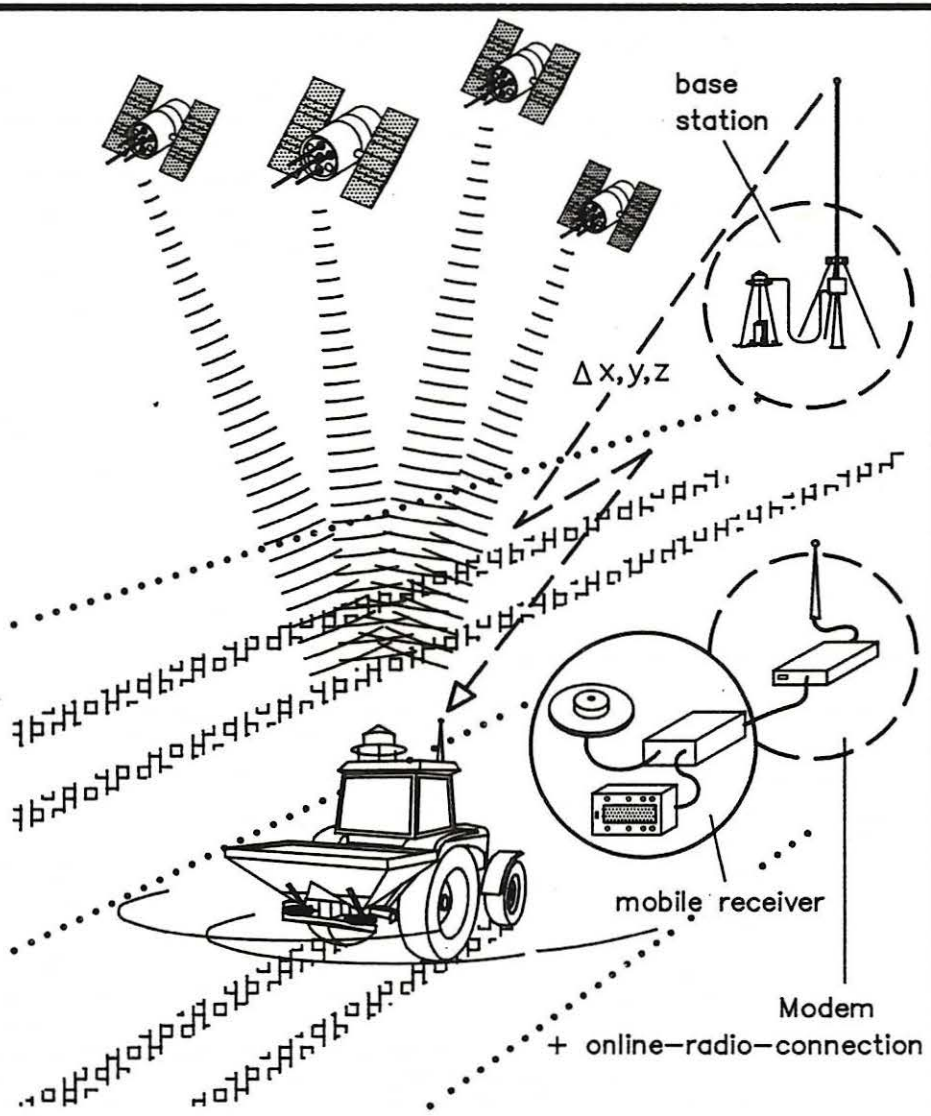
Error:

± 20 cm – ± ∞

Assessment:

As an onfarm system it is well satisfying on large and flat areas.

Auernhammer	Location sensing with the method of "terrestrical trilateration" (Function and assessment)	LANDTECHNIK WEIHENSTEPHAN Ke 942 082



Function:

Satellites on orbits are continuously sending position and time information data. Receivers are calculating the own high precise time. Using the data the traveling time of the satellite signals is determined and the distances to the satellites are calculated. Position detection for 2 D with 3 and for 3 D with 4 satellites (GPS) error reduction by using differential GPS with a base station.

Advantage:

* worldwide high development activity
* universal use for high production numbers and low prices
* position, time and velocity available all the time
* infrastructure build and maintained by the operator

Disadvantage:

* depending on operator
* standardsignals with ± 100 m errors (95 % of all deviations)
* for higher accuracy use of DGPS with base station necessary, requires online–radio–connection, higher costs

Error:

± 100 m with GPS; ± 1 – 2 m with DGPS

Assessment:

Nearly unlimited useability with excellent possibilities for the contractor and machinery–ring use and hilly landscapes (using DGPS)

Auernhammer	Location Sensing with the method of "terrestrical trilateration" (Function and assessement)	LANDTECHNIK WEIHENSTEPHAN Ke 942 085

GPS - NAVSTAR		GLONASS	
NAVigation **S**ystem with **T**ime **A**nd **R**anging		**GLO**bal **NA**vigation **S**atellit **S**ystem	
21 + 3	Satellites (23 available)	24	Satellites (15 available)
6	Orbit levels	3	Orbit levels
20183 km	Altitude	19100 km	Altitude
11h 56min	Orbiting time	11h 16min	Orbiting time
WGS 84	Coordinate systems (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	

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Global Navigation Satellite Systems
Updated in July 1993

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Components			Performance
• Orbit-segment	(21 + 3 stations)		• Global availability
• Control-segment	(master control station monitor stations)		• 24 hours / day useable
• User-segment	(receiver	on land on sea in the air)	• fully meteorological independent
			• highly exact detection of position, speed and time

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System Characteristics Of GPS (Global Positioning System)

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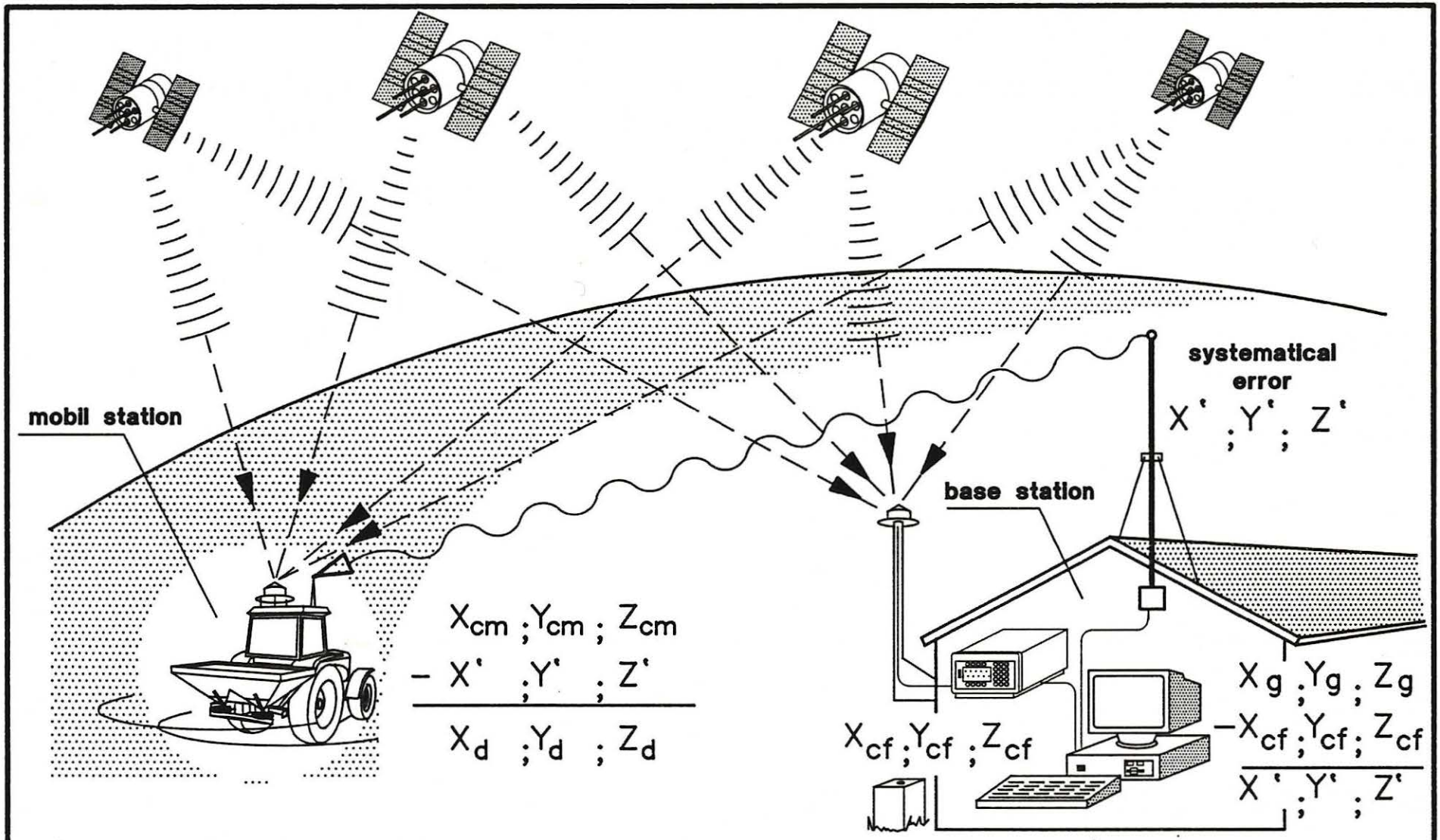
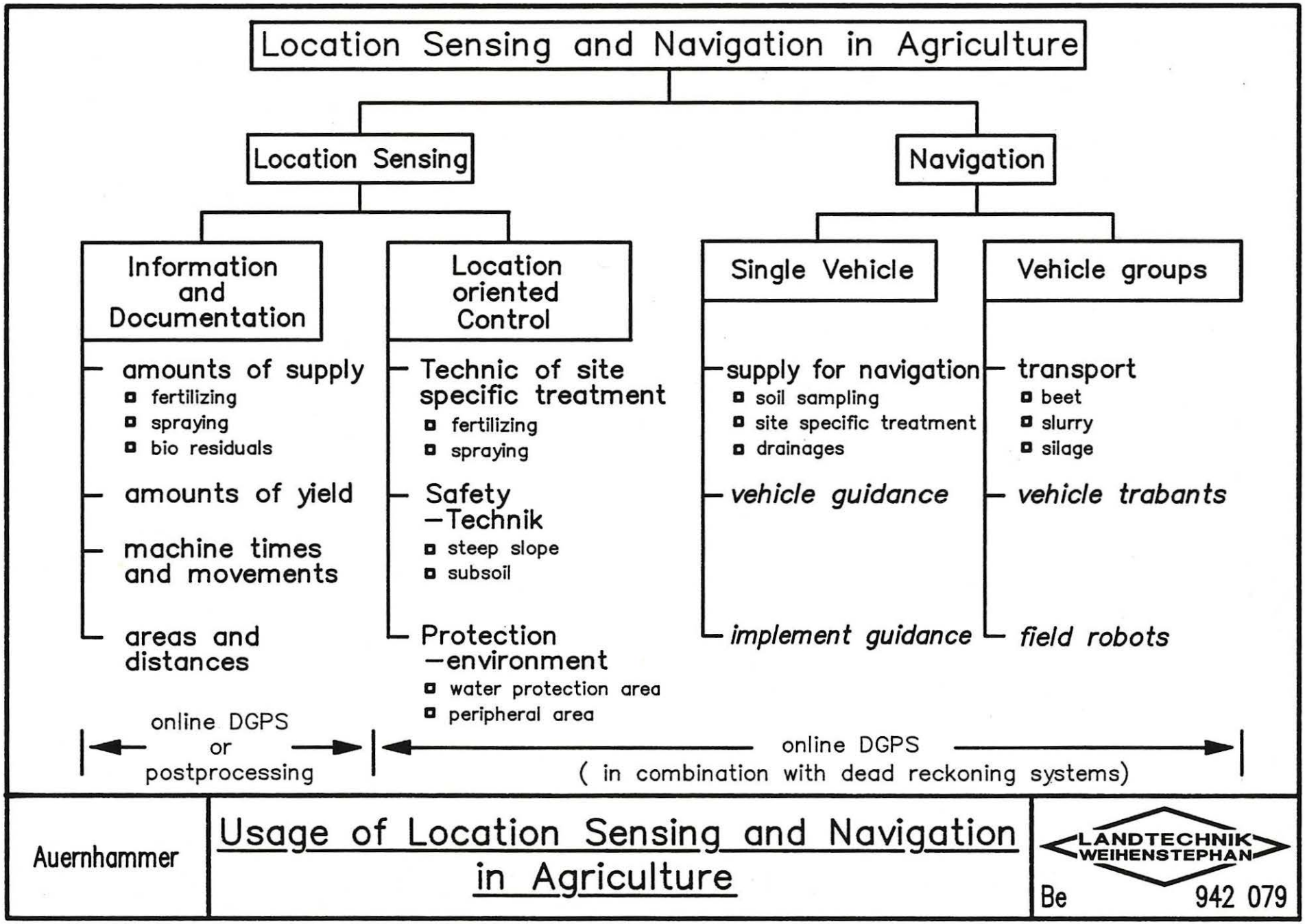


(g = geodetic; cf = calculated base; cm = calculated mobil; d = differential;)

Auernhammer	Differential "Global Positioning System (DGPS)"	LANDTECHNIK WEIHENSTEPHAN Ke 942 078


Location Sensing and Navigation in Agriculture
Location Sensing
Navigation
Information and Documentation
Location oriented Control
Single Vehicle
Vehicle groups
amounts of supply
fertilizing
spraying
bio residuals
amounts of yield
machine times and movements
areas and distances
Technic of site specific treatment
fertilizing
spraying
Safety -Technik
steep slope
subsoil
Protection -environment
water protection area
peripheral area
supply for navigation
soil sampling
site specific treatment
drainages
vehicle guidance
implement guidance
transport
beet
slurry
silage
vehicle trabants
field robots
online DGPS or postprocessing
online DGPS
(in combination with dead reckoning systems)
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Usage of Location Sensing and Navigation in Agriculture
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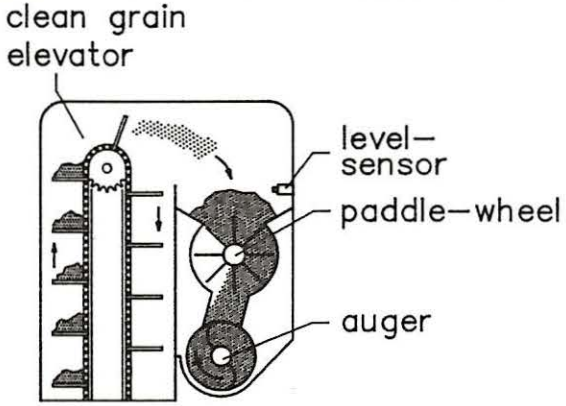
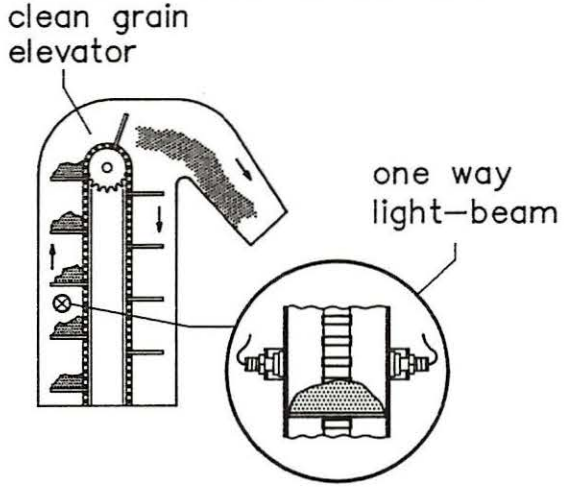
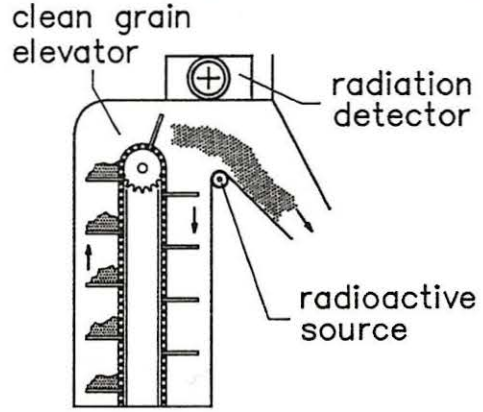
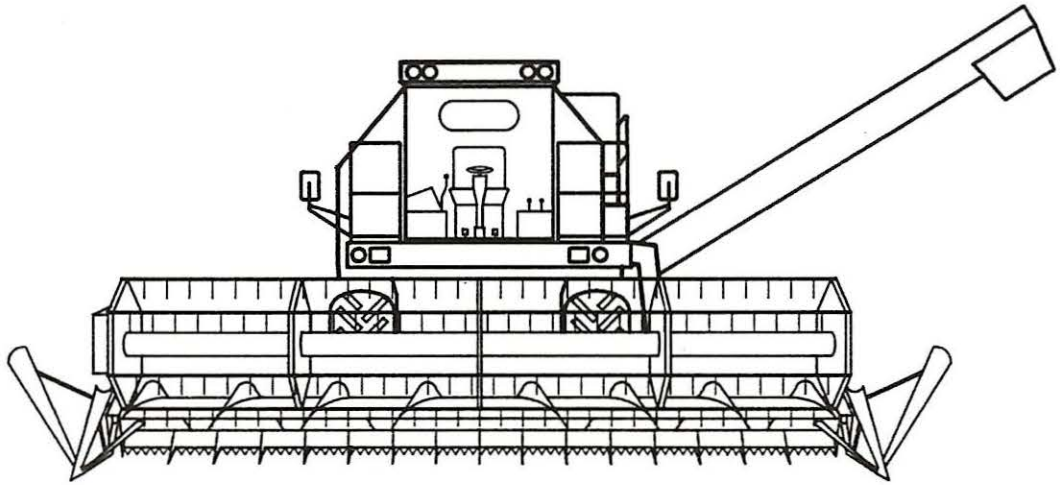


by SÖRLIN



by DIEKHANS





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Available Sensors for Yield–Measurement in Combine–Harvesters

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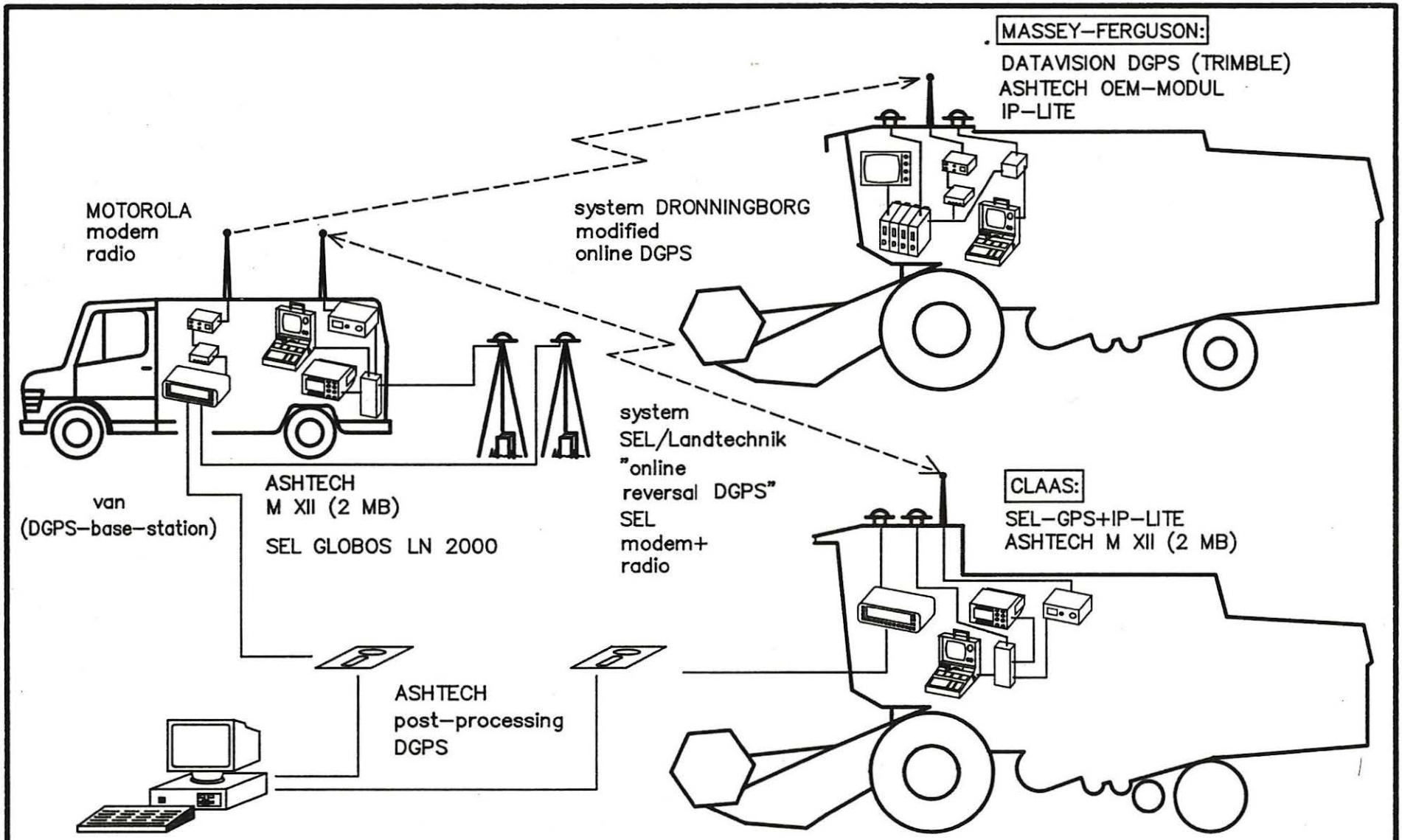

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Demmel, Muhr
Wild, Rottmeier

Positioning and Data–collection for Yield Mapping

(Harvest 1992)

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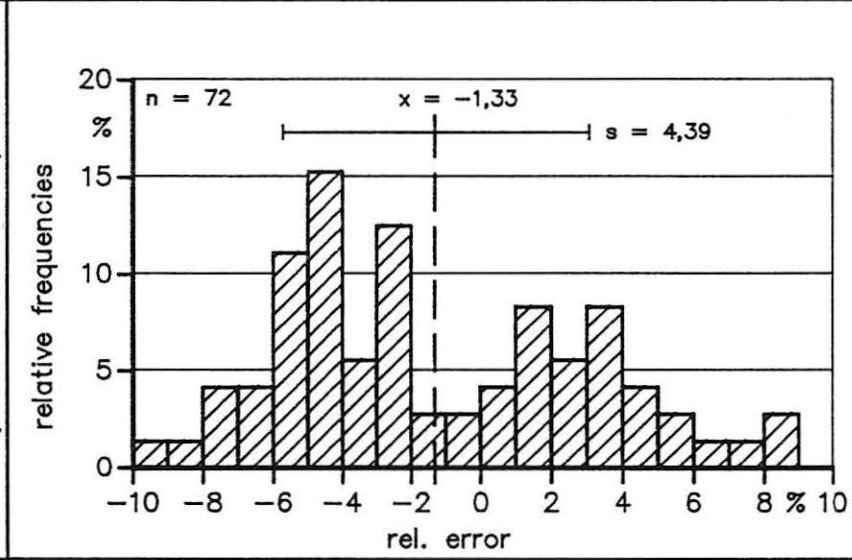
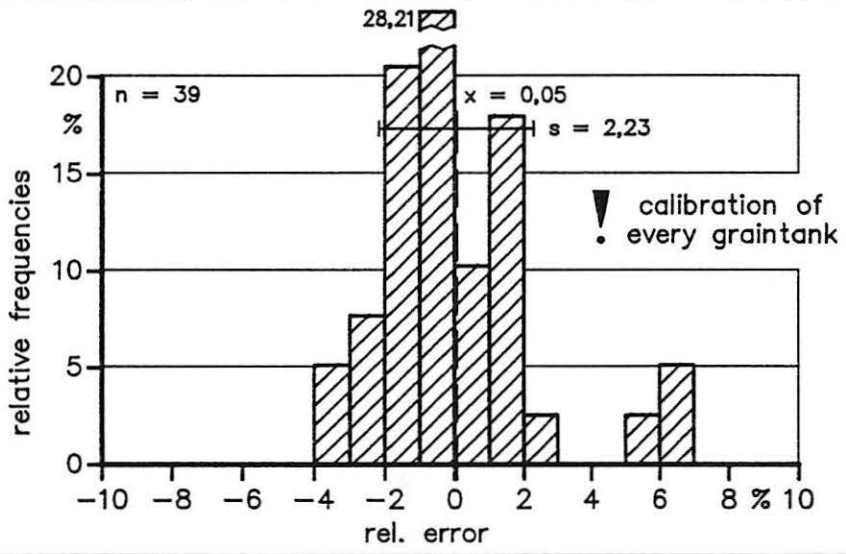
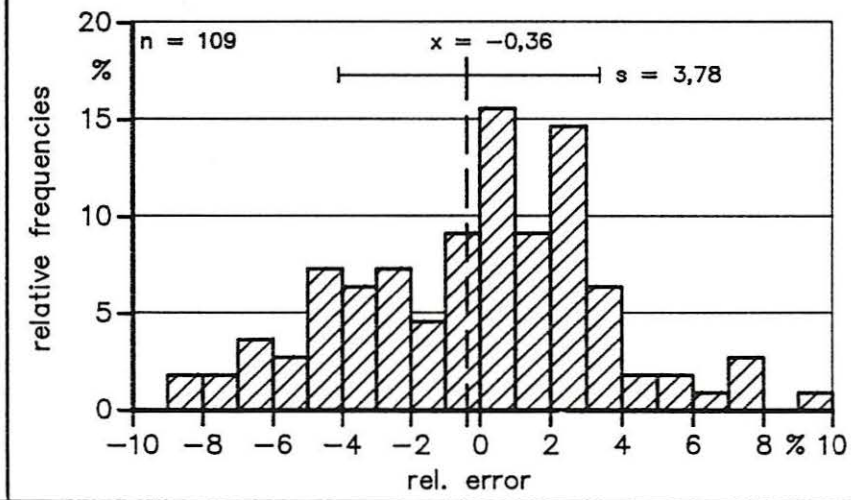
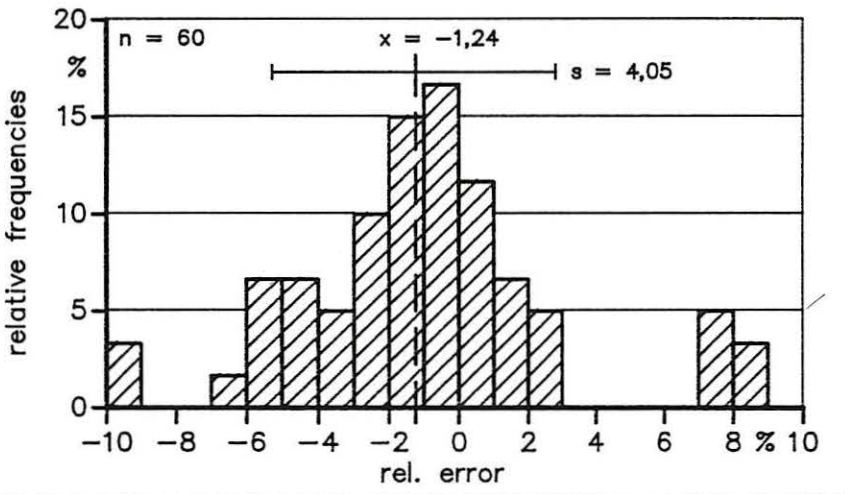
	Harvest 1991; Winter wheat ORESTIS	Harvest 1992; Spring–barley SISSI
Volumeflow measurement system (YIELD–O–METER)		
Massflow measurement system (DATAVISION)		

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Demmel, Muhr
Rottmeier, Wild

Frequencies of relative errors of the yield–measurement (combines) in Scheyern 1991 and 1992 with volume– and massflow measuring systems

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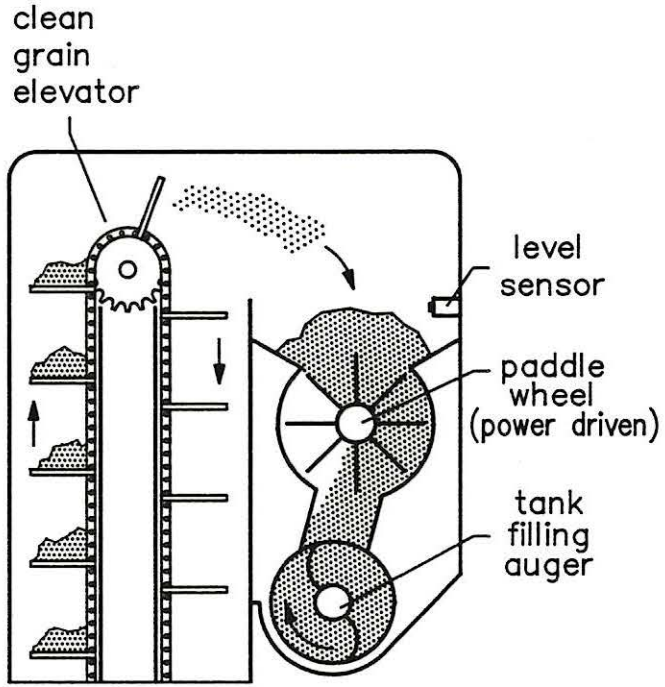
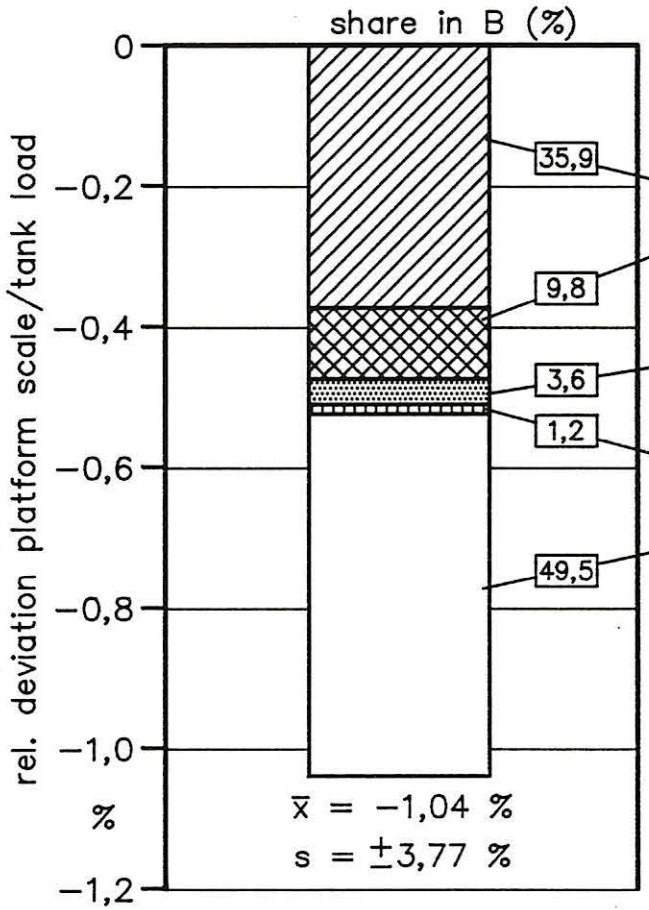
1991 winter–wheat 7.5 t/ha, 40 grain tank loads
1992 summer–barley 5.5 t/ha, 39 grain tank loads
(1992 calibration after unloading every grain tank)





	x̄	s
grain density	67,4	4,21 kg
calibration eyery grain tank	0,5	0,5 j/n
grain moisture	14,2	1,57 %
tank load	4,04	1,313 t
random		

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Closed Volume Measurement System for Combines

(Measuring Prinziple and Errors from Field Tests in 1991/92)

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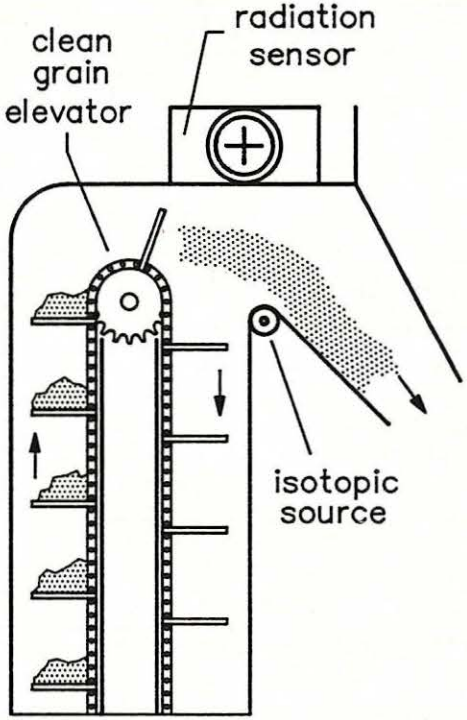
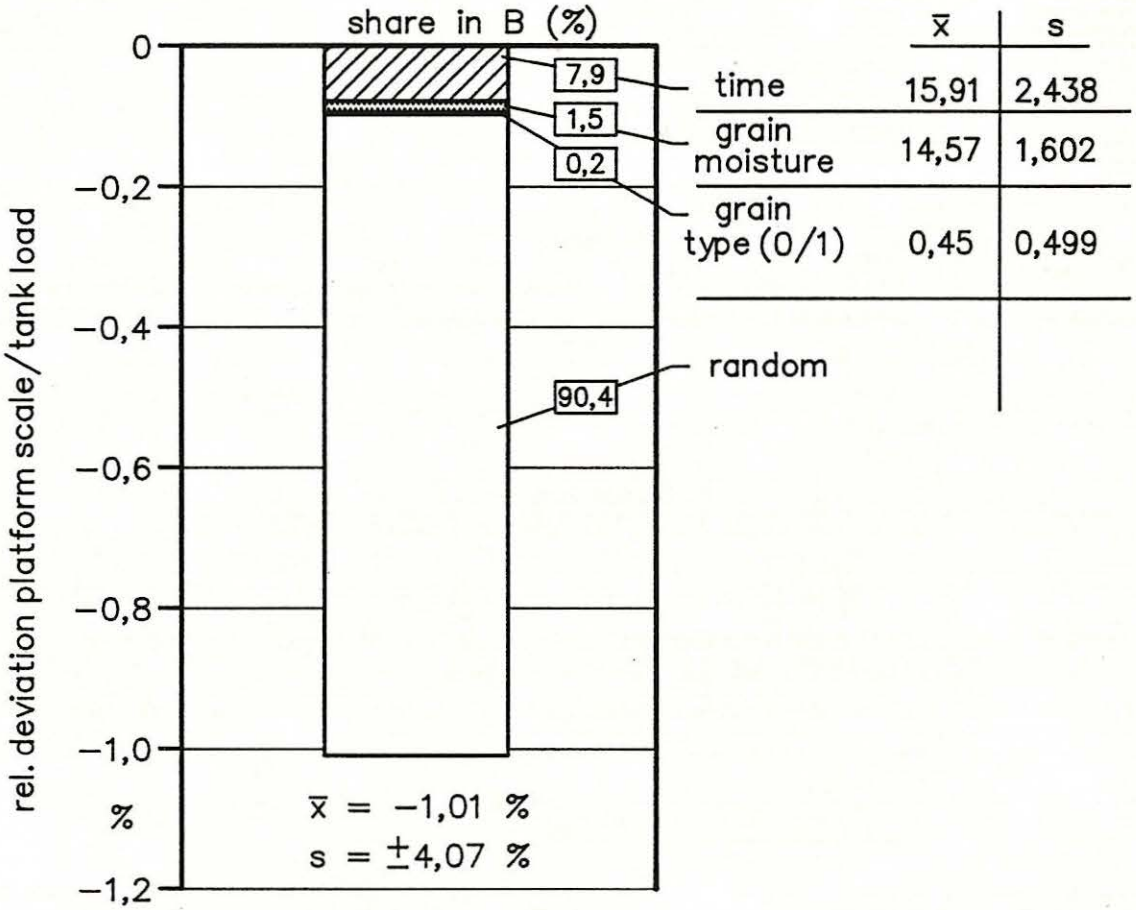
1991 winter–wheat 7.5 t/ha, 72 grain tank loads

1992 summer–barley 5.5 t/ha, 60 grain tank loads





	x̄	s
time	15,91	2,438
grain moisture	14,57	1,602
grain type (0/1)	0,45	0,499
random		

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Mass Flow Measuring System for Combines

(Measuring Prinziple and Errors from Field Tests in 1991/92)

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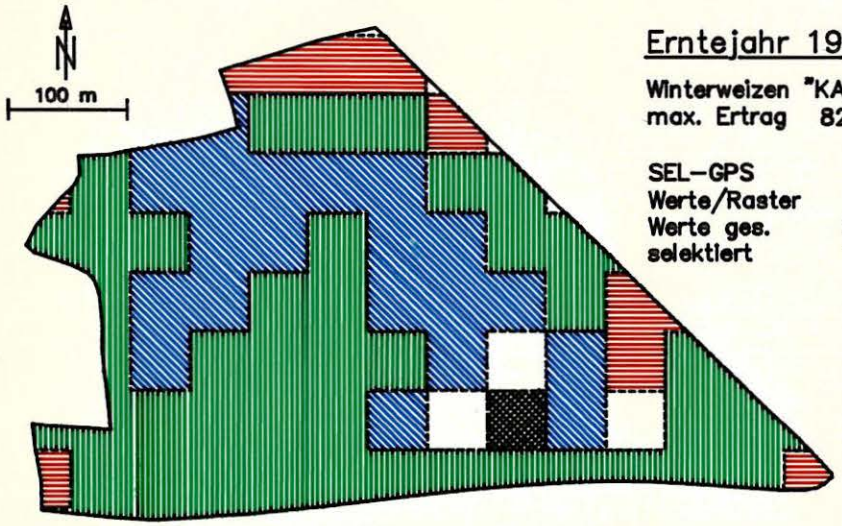
ohne Ortung | Ertrag bis 40 dt/ha | 40 bis 60 dt/ha | 60 bis 80 dt/ha | ab 80 dt/ha

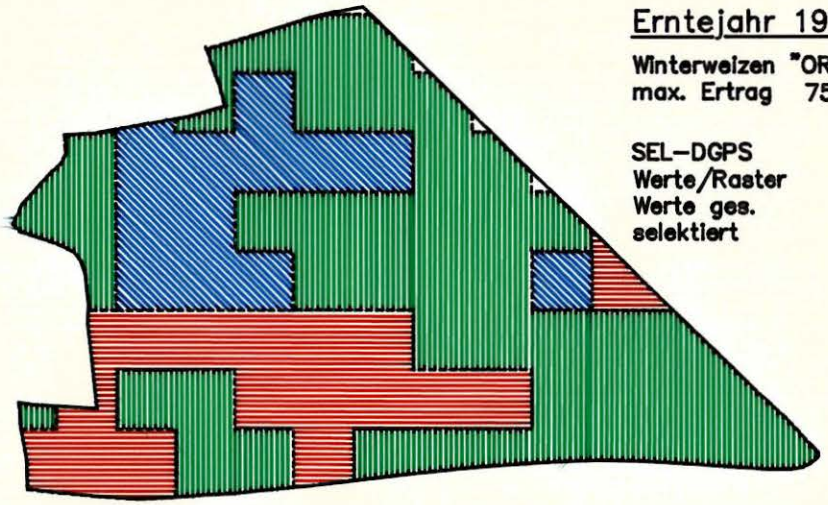


Erntejahr 1990

Winterweizen "KANZLER"
max. Ertrag 82 dt/ha

SEL–GPS

Werte/Raster	141
Werte ges.	45 597
selektiert	13 419



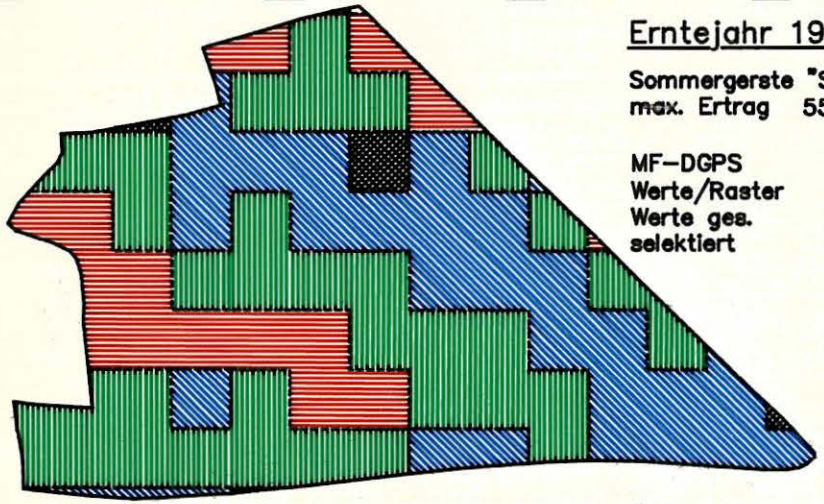
Erntejahr 1991

Winterweizen "ORESTIS"
max. Ertrag 75 dt/ha

SEL–DGPS

Werte/Raster	25
Werte ges.	2 302
selektiert	2 285

Ertrag < 30 dt/ha | 30 – 40 dt/ha | 40 – 50 dt/ha | > 50 dt/ha



Erntejahr 1992

Sommergerste "Sissi"
max. Ertrag 55 dt/ha

MF–DGPS

Werte/Raster	44
Werte ges.	4222
selektiert	4163

Vegetationsbedingungen, Düngung, Ernte und Ortung

1990 normale Witterung; 180 kg N/ha einheitlich;
Vorfruchteffekte; Stroh gehäckselt;
CASE Jumbo 8900 + DANIAVISION + GPS (SEL LN 2000)

1991 normale Witterung; 160 kg N/ha einheitlich;
Stroh gehäckselt;
MF 34 RS + DATAVISION + DGPS online (SEL LN 2000)

1992 extreme Trockenheit; 40 kg N/ha einheitlich;
Stroh–Rundballen JOHN DEERE 550 + DGPS online
(ASHTECH RANGER XII)
MF 40 RS + DATAVISION + DGPS online

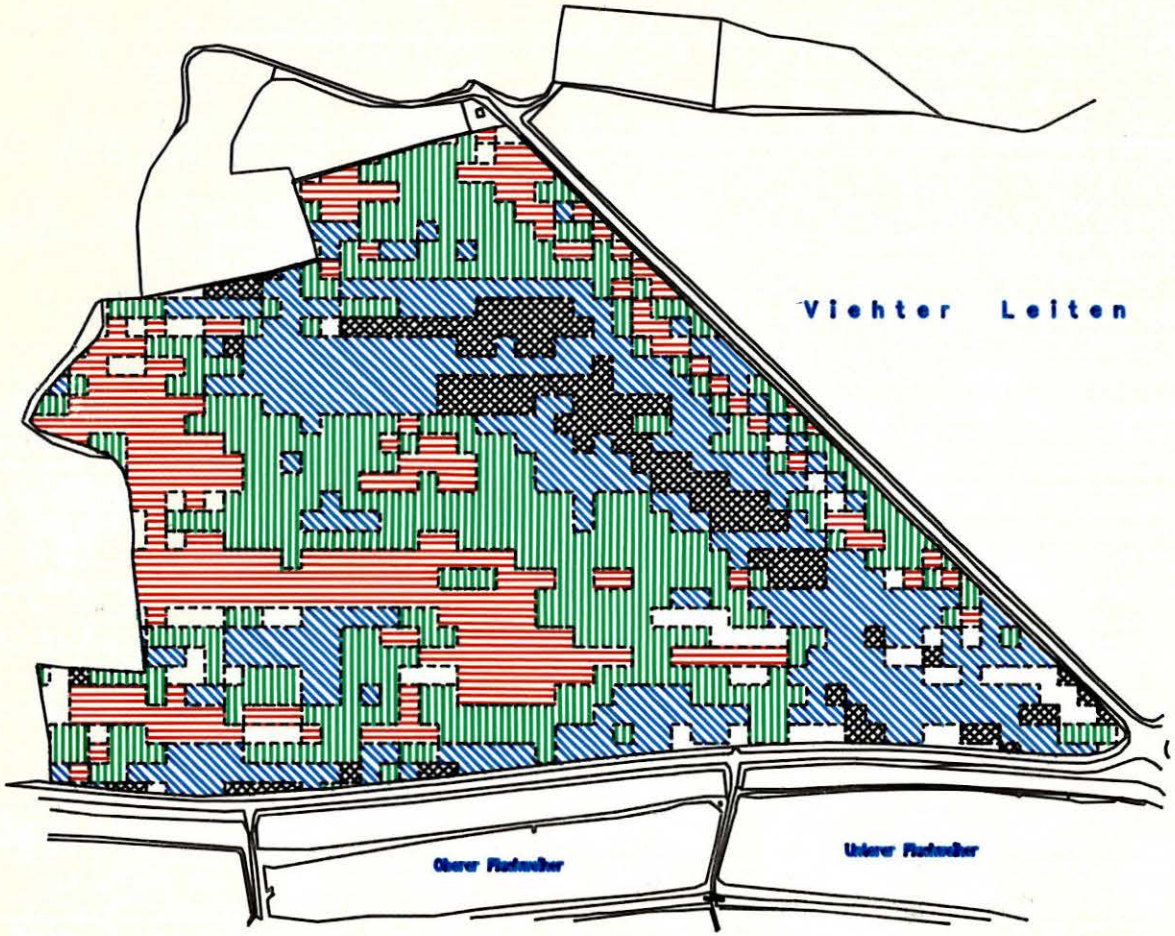
Auernhammer
Perger

Ertragskarten Scheyern "Flachfeld"

(16,6 ha; Erntejahre 1990 – 1992; Rastergröße 50 x 50 m)

LANDTECHNIK WEIHENSTEPHAN

Be 922 369



ohne Ortung

Ertrag bis 30 dt/ha

30 bis 40 dt/ha

40 bis 50 dt/ha

ab 50 dt/ha

Max. Ertrag	61 dt/ha
Raster	12 m
Werte pro Rast.	3
Werteanzahl	4222
davon selekt.	4163

N

200 m

Erstellt mit ARC/INFO am 19.10.1992

Perger

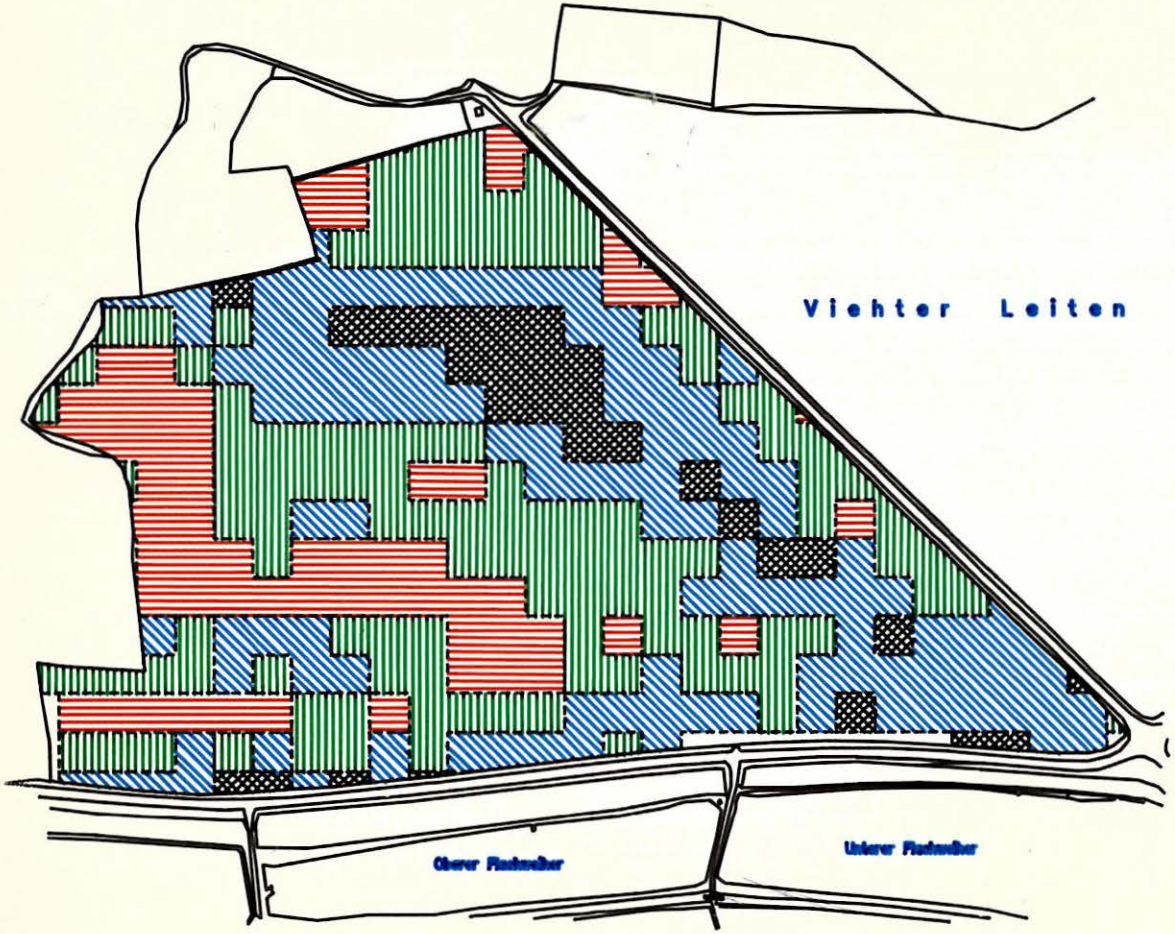
Auernhammer

Ertragskarte Scheyern 'Flachfeld' (16.6 ha)

(Sommergerste,MF-DGPS,Ertragsermittlung 'DATAVISION-FLOWCONTROL',30.7+3.8.92)

LANDTECHNIK WEIHENSTEPHAN

92 2AP 154



Yield [t/ha]	Area [ha]	%
- 3.0	3.2	19
3.0 - 4.0	6.2	37
4.0 - 5.0	5.7	34
5.0 -	1.4	8
No position	0.2	0

Area [ha]	: 16.6
Size of grid [m]	: 24
Mean yield [t/ha]	: 3.8
Max. yield [t/ha]	: 6.0
Data per grid	: 13

N

200 m

Created with ARC/INFO on 30.06.1993

Perger

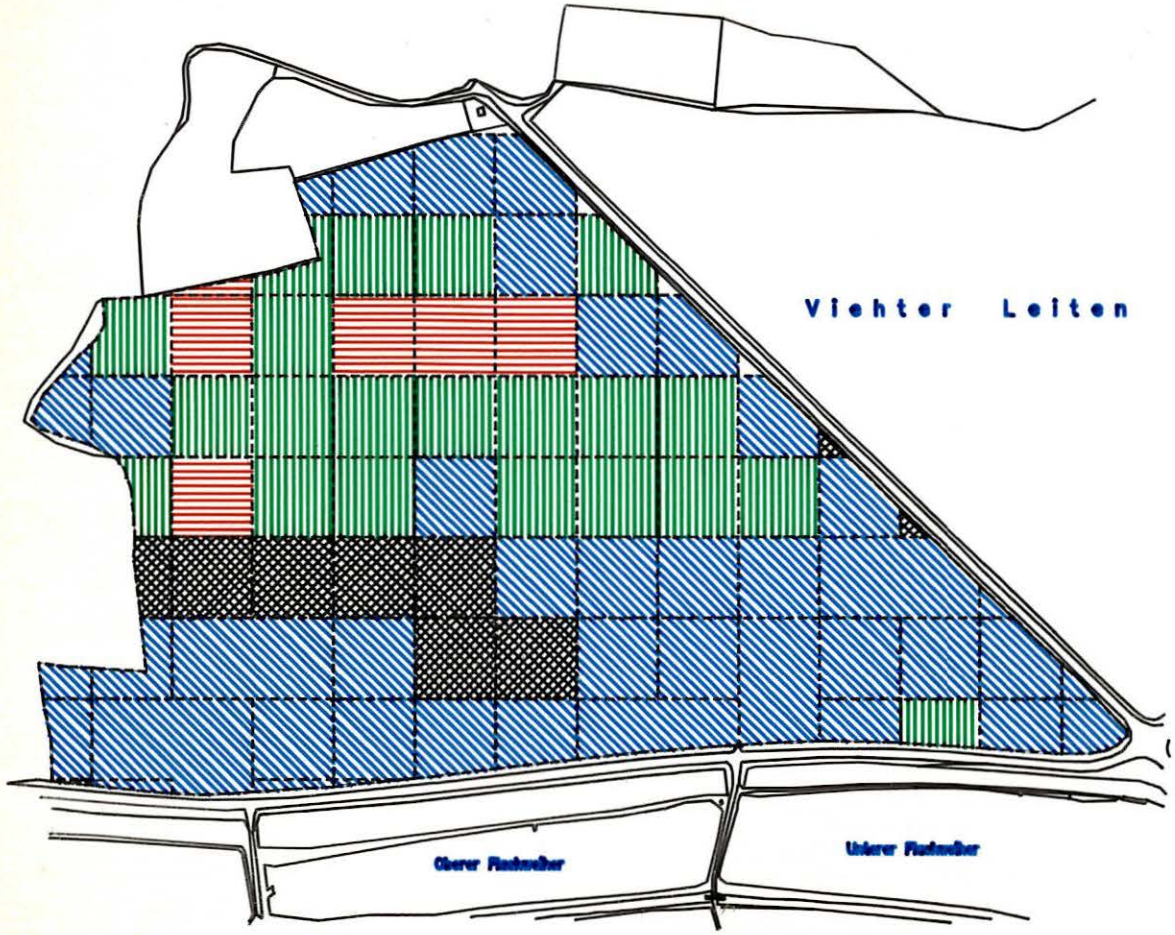
Auernhammer

YIELD - MAP Scheyern 'Flachfeld' 1992

(summer-barley,MF-DGPS,yield-detection'DATAVISION-FLOWCONTROL', 7/30+8/3/92)

LANDTECHNIK WEIHENSTEPHAN

93 2AP 100



Ohne Ortung

unter 20 kg/ha

20 bis 40 kg/ha

40 bis 60 kg/ha

ueber 60 kg/ha

Maximum	71 kg/ha
Raster	50 m
Werte pro Rast.	25
Werteanzahl	2302
davon selekt.	2285

N

200 m

Erstellt mit ARC/INFO am 19.10.1992

Perger

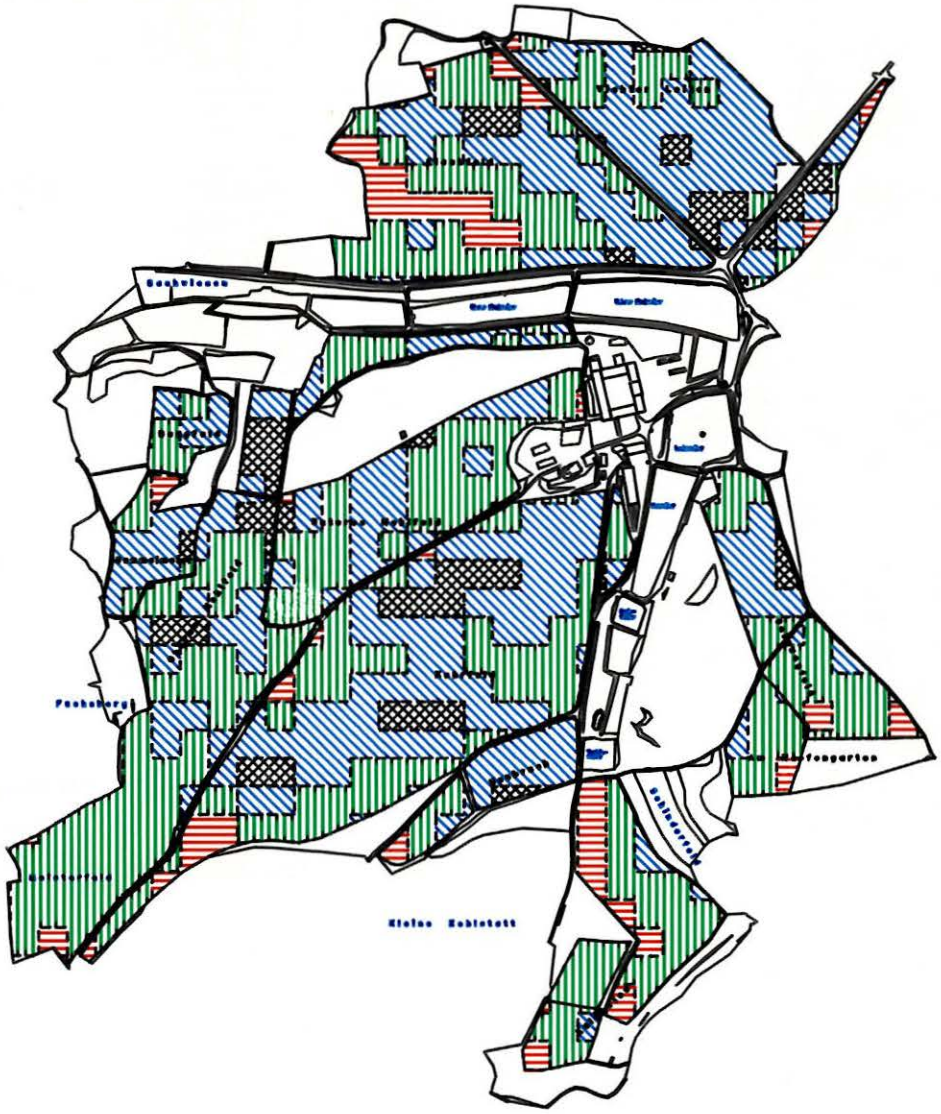
Auernhammer

N- Bilanz Scheyern 'Flachfeld' (16.6 ha)

(W-Weizen 'ORESTIS', Vorfrucht Getreide, Duengung 160kg/ha einheitl., 1991)

LANDTECHNIK WEIHENSTEPHAN

92 2AP 163



Yield [t/ha]	Area [ha]	%
- 3.0	7.7	7
3.0 - 4.0	50.1	46
4.0 - 5.0	41.9	39
5.0 -	7.8	7
No position	0.6	1

Area [ha]	: 108.2
Size of grid [m]	: 50
Mean yield [t/ha]	: 4.0
Max. yield [t/ha]	: 7.2
Data per grid	: 82

N

500 m

Created with ARC/INFO on 14.07.1993

Perger

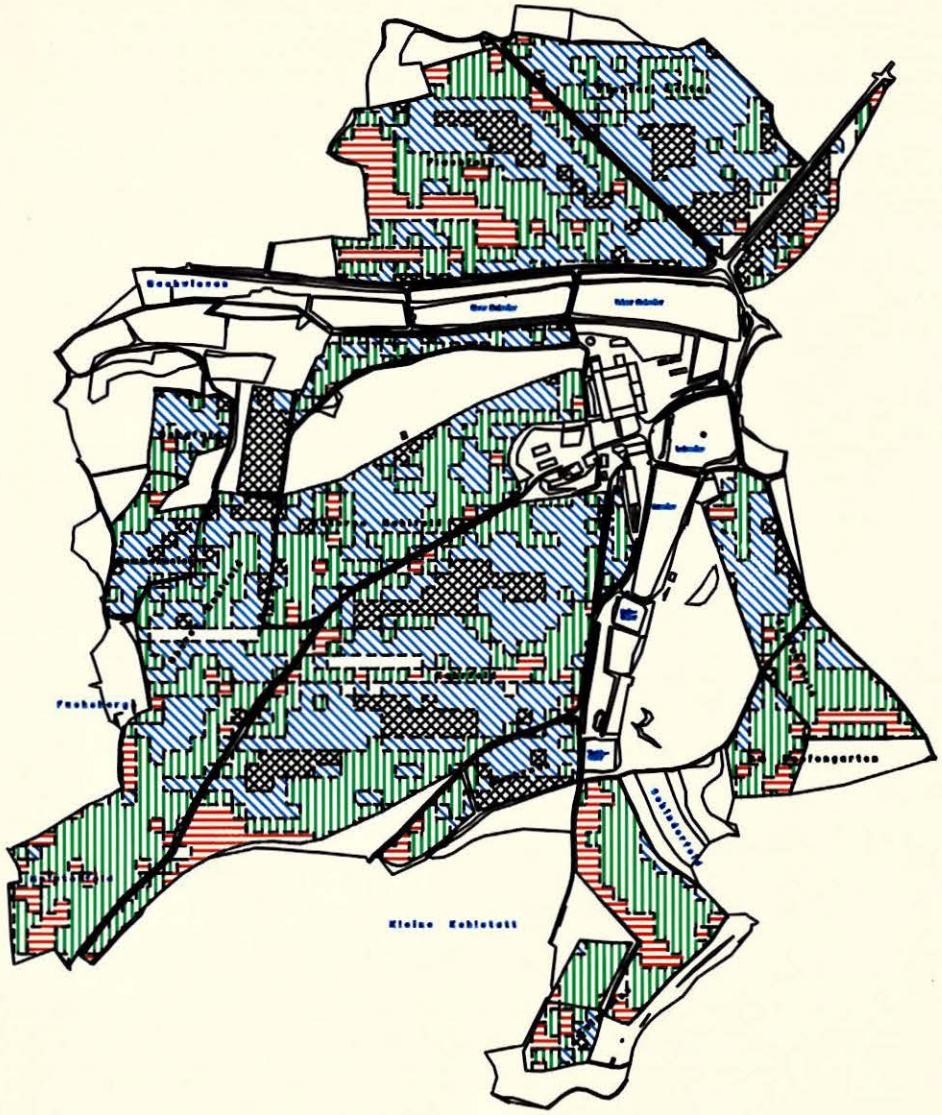
Auernhammer

YIELD - MAP Scheyern * total * 1992

(summer-barley, MF-DGPS + Ashtech-DGPS, 7/30 - 8/7/1992)

LANDTECHNIK WEIHENSTEPHAN

93 2AP 157



Yield [t/ha]	Area [ha]	%
- 3.0	11.6	11
3.0 - 4.0	43.6	40
4.0 - 5.0	38.5	36
5.0 -	11.4	11
No position	3.1	3

Area [ha]	: 108.2
Size of grid [m]	: 24
Mean yield [t/ha]	: 4.0
Max. yield [t/ha]	: 7.6
Data per grid	: 28

N

500 m

Created with ARC/INFO on 14.07.1993

Perger

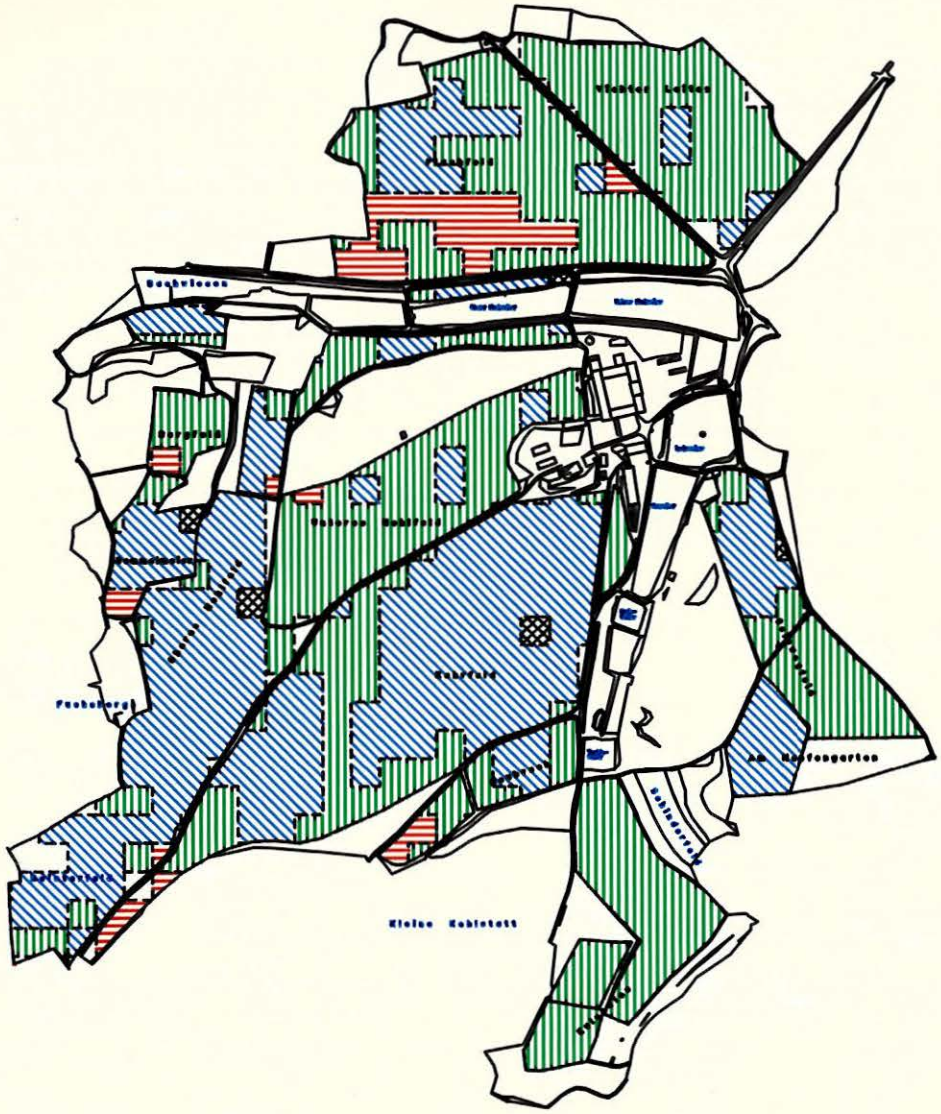
Auernhammer

YIELD - MAP Scheyern * total * 1992

(summer-barley, MF-DGPS + Ashtech-DGPS, 7/30 - 8/7/1992)

LANDTECHNIK WEIHENSTEPHAN

93 2AP 159



Yield [t/ha]	Area [ha]	%
- 4.0	5.7	5
4.0 - 6.0	54.1	50
6.0 - 8.0	44.8	42
8.0 -	0.8	1
No position	2.0	2

Area [ha]	: 107.4
Size of grid [m]	: 50
Mean yield [t/ha]	: 5.9
Max. yield [t/ha]	: 8.6
Data per grid	: 118

N

500 m

Created with ARC/INFO on 31.07.1993

Perger

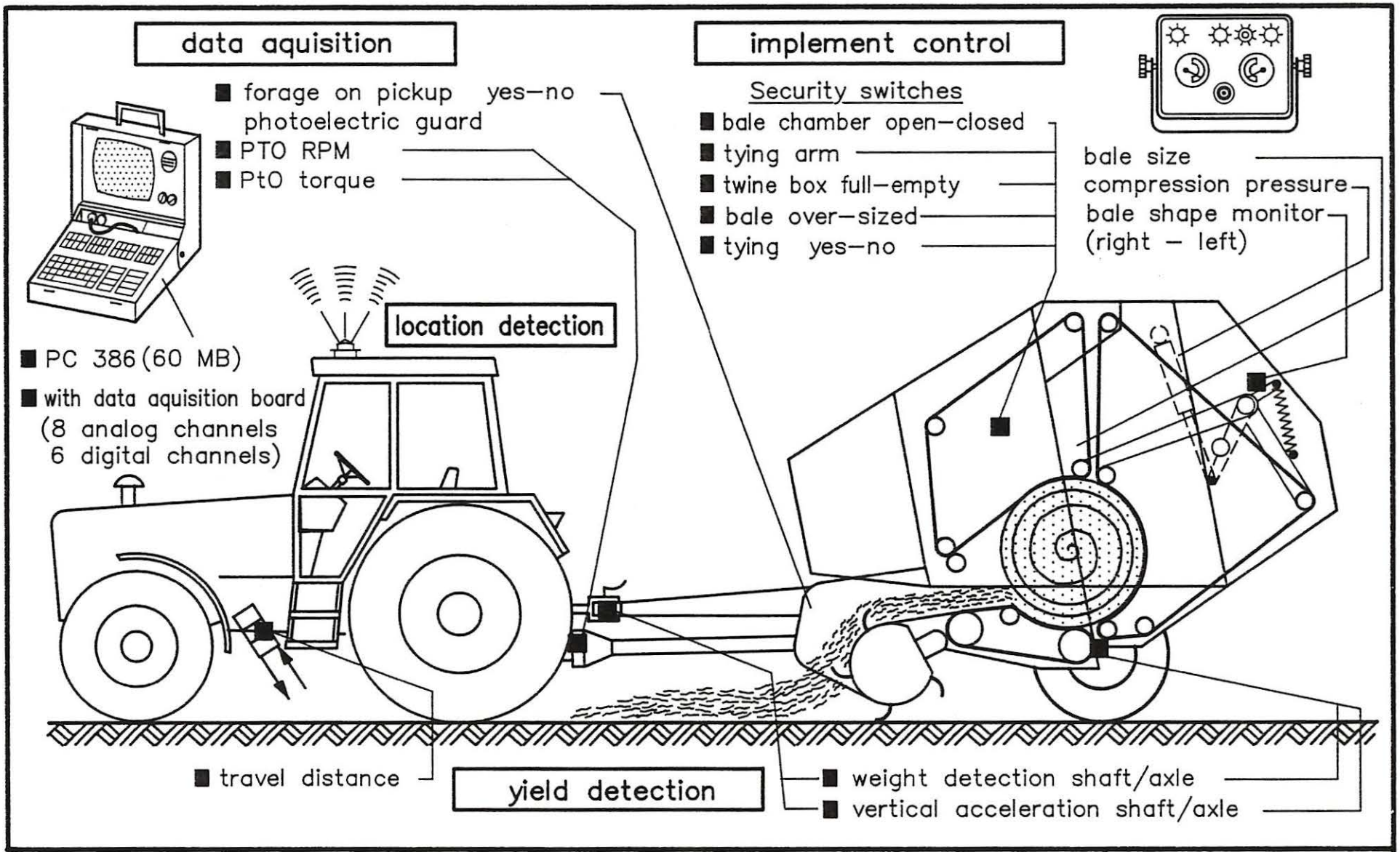
Auernhammer

YIELD - MAP Scheyern * total * 1991

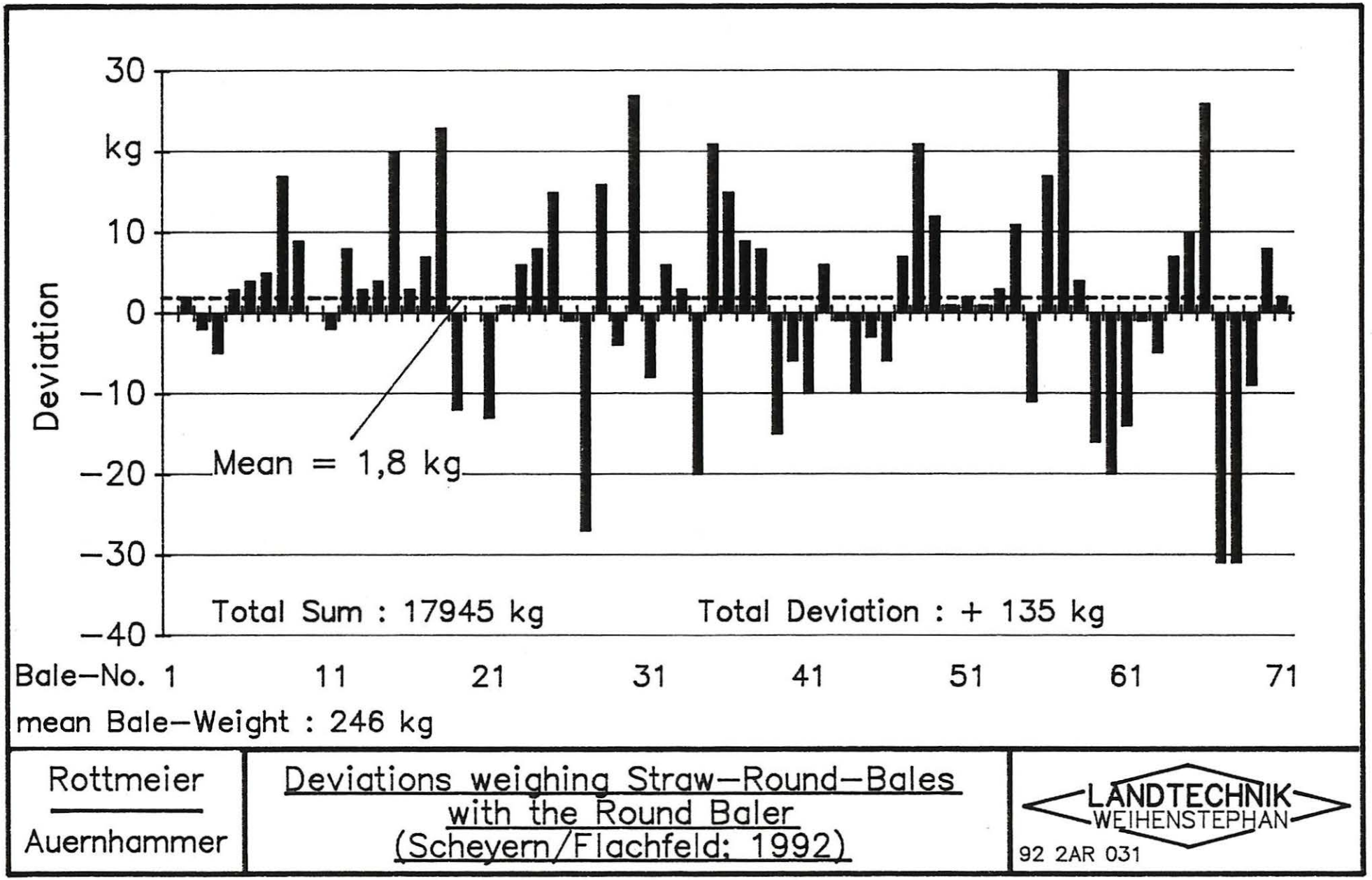
(winter-wheat, SEL-DGPS + GPS, 8/12 - 8/19/91)

LANDTECHNIK WEIHENSTEPHAN

93 2AP 172



Rottmeier Auernhammer	Data Aquisition for Yield Mapping and Electronical Implement Control at the Round Baler	LANDTECHNIK WEIHENSTEPHAN Ke 932 206



Rottmeier Auernhammer	Deviations weighing Straw−Round−Bales with the Round Baler (Scheyern/Flachfeld; 1992)	LANDTECHNIK WEIHENSTEPHAN 92 2AR 031

Plot	Area	Total time	Rel. part of total time			
	ha	hour:min	threshing	bin emtying	idle drive	stand still time
Kehrfeld	25.5	9:56	63.05	6.33	13.00	17.30
Flachfeld	16.6	6:54	72.69	6.10	13.71	7.49
Unteres Hohlfeld	9.9	3:20	62.44	7.58	22.07	7.83
Eulenwies	5.3	2:14	67.37	6.62	19.37	6.58
Unteres Geiswegfeld	3.4	1:25	70.51	7.27	16.66	5.57
Oberes Geiswegfeld	3.3	1:33	68.76	7.58	21.60	2.05
Heubruch	3.1	1:30	71.08	6.09	16.84	5.70
Hopfengarten	2.1	1:02	65.96	4.70	25.04	4.29
Mean (without Kehrfeld and Unteres Hohlfeld)			**69.40**	**6.37**	**18.87**	**5.28**

Auernhammer
Heigl

Automatic Work Time Aquisition with DGPS and Additional Sensors

LANDTECHNIK WEIHENSTEPHAN
94 2AH 007

Plot	Plot size	Threshing distance	calculated parameters from the threshing distance	
			working width	rel. deviation from the real working width
	(ha)	(km/ha)	(m)	(work.width = 5,5m = 100%)
Flachfeld	16,6	2,37	4,22	76,73
Eulenwies	5,3	2,25	4,44	80,73
Unt. Geiswegfeld	3,4	2,27	4,41	80,18
Ob. Geiswegfeld	3,3	2,11	4,75	86,36
Heubruch	3,1	2,58	3,87	68,73
Hopfengarten	2,1	1,97	5,07	92,18
Mean		**2,26**	**4,46**	**80,82**

Spieß

Auernhammer, Wild

Calculated Threshing Distances Using GPS For Positioning Detection Harvest Scheyern1992

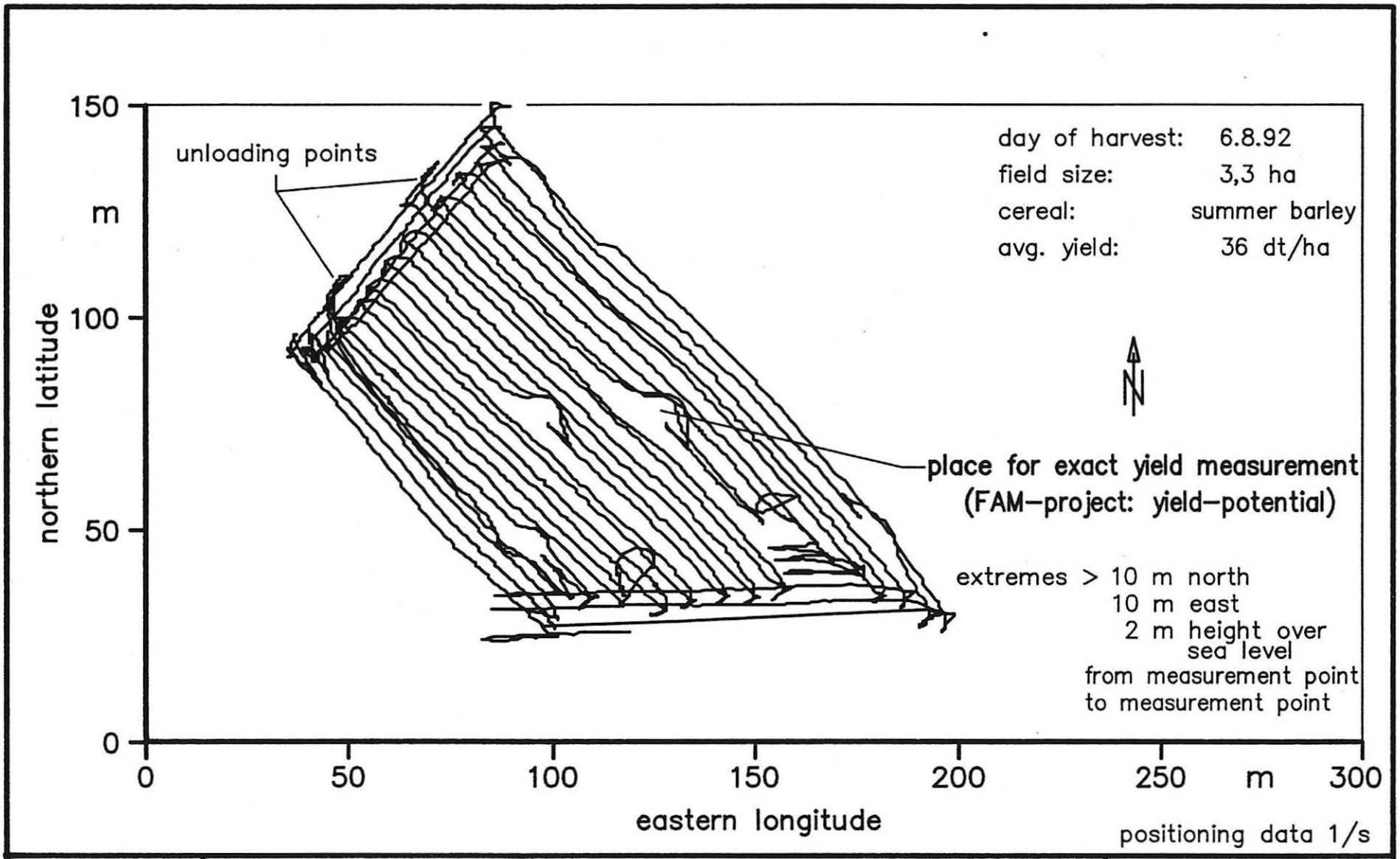
LANDTECHNIK WEIHENSTEPHAN

94 2AS 001

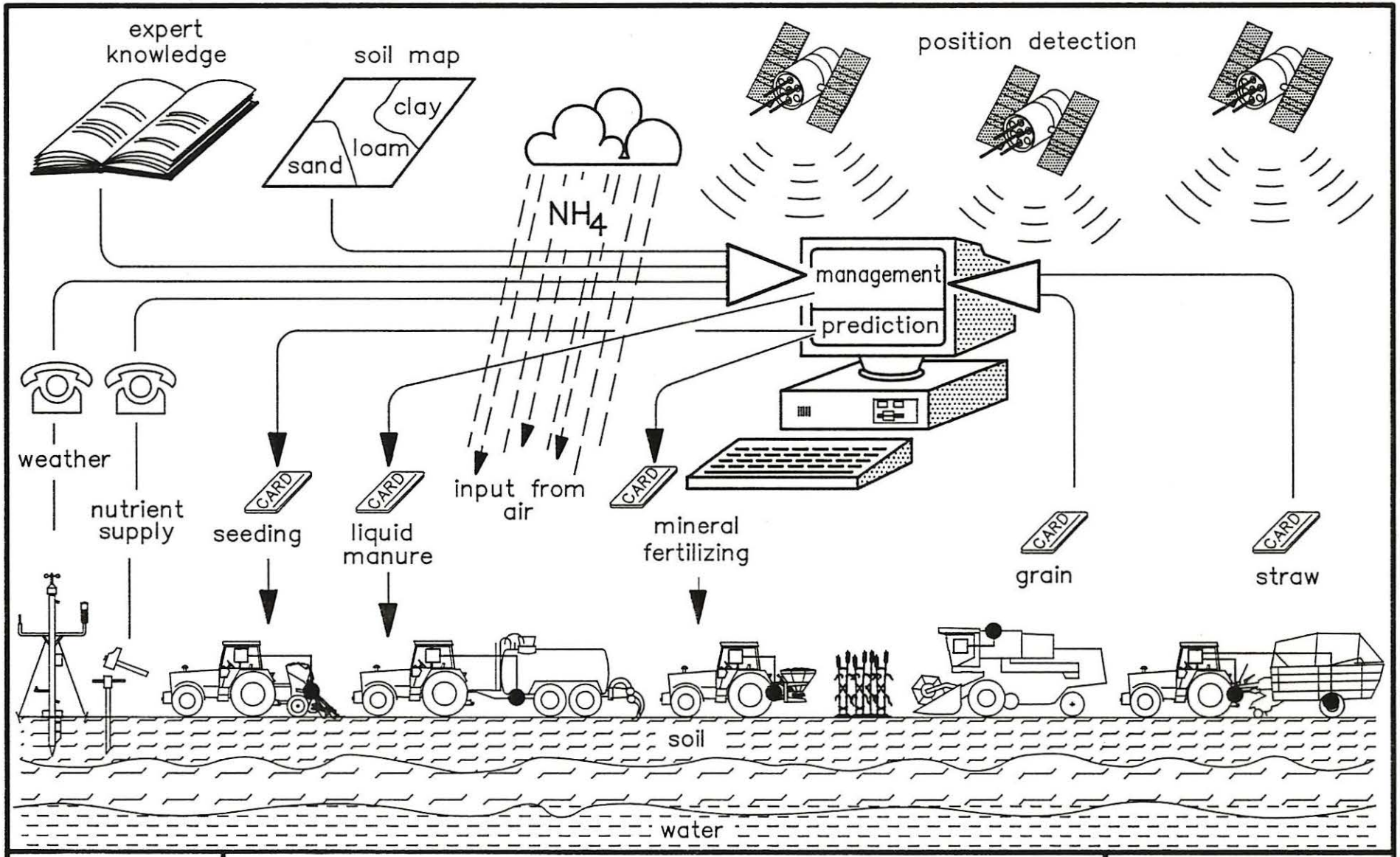
Plot	Geodetic measured ha	Deviation from area measurement	
		DANIAVISION %	Plot coordinates %
Kehrfeld *	25.5	- 7.06	- 2.65
Flachfeld	16.6	+ 6.71	- 3.87
U. Hohlfeld *	9.9	- 7.78	- 2.54
Eulenwies	5.3	+ 4.91	- 6.11
Heubruch	3.1	+ 8.71	+ 2.07

*** DANIAVISION does not include the whole area!**

Auernhammer / **Heigl**	**Area Measurement with On-bord Computers and GPS - Plot Coordinates**	LANDTECHNIK WEIHENSTEPHAN 94 2AH 006



Auernhammer	Combine Harvester Traces "oberes Geiswegfeld" in Scheyern 1992 (online DGPS: ASHTECH MXII–Basestation + ASHTECH OEM–Sensor; MF40RS 18", DATAVISION; sliding middle from 3 data, extremes deleted)	LANDTECHNIK WEIHENSTEPHAN Be 932 260



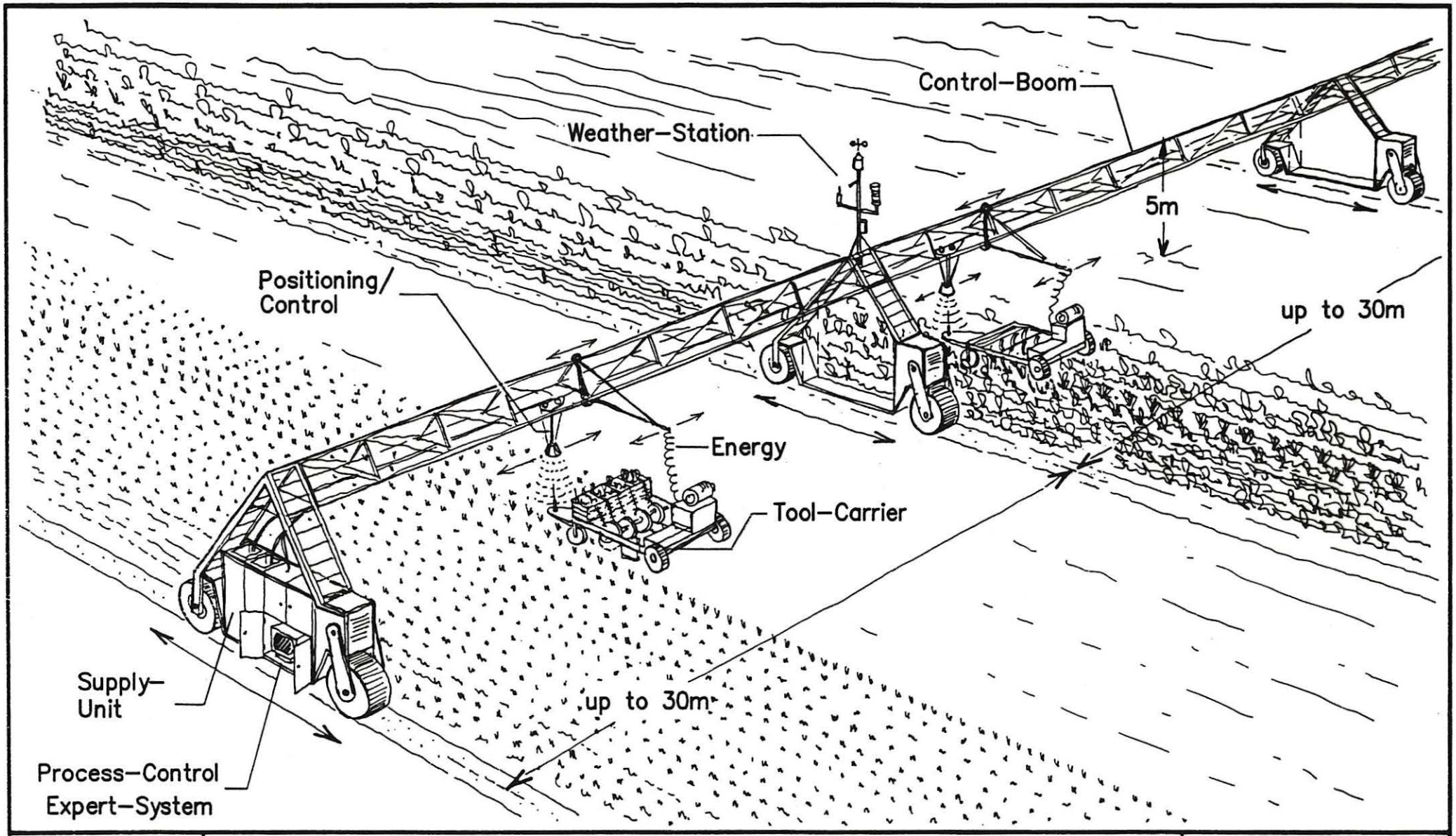
Auernhammer

Electronics in a closed loop system

"Technology for environmental–oriented fertilizing"

LANDTECHNIK WEIHENSTEPHAN

Ke 912 223



Meyer

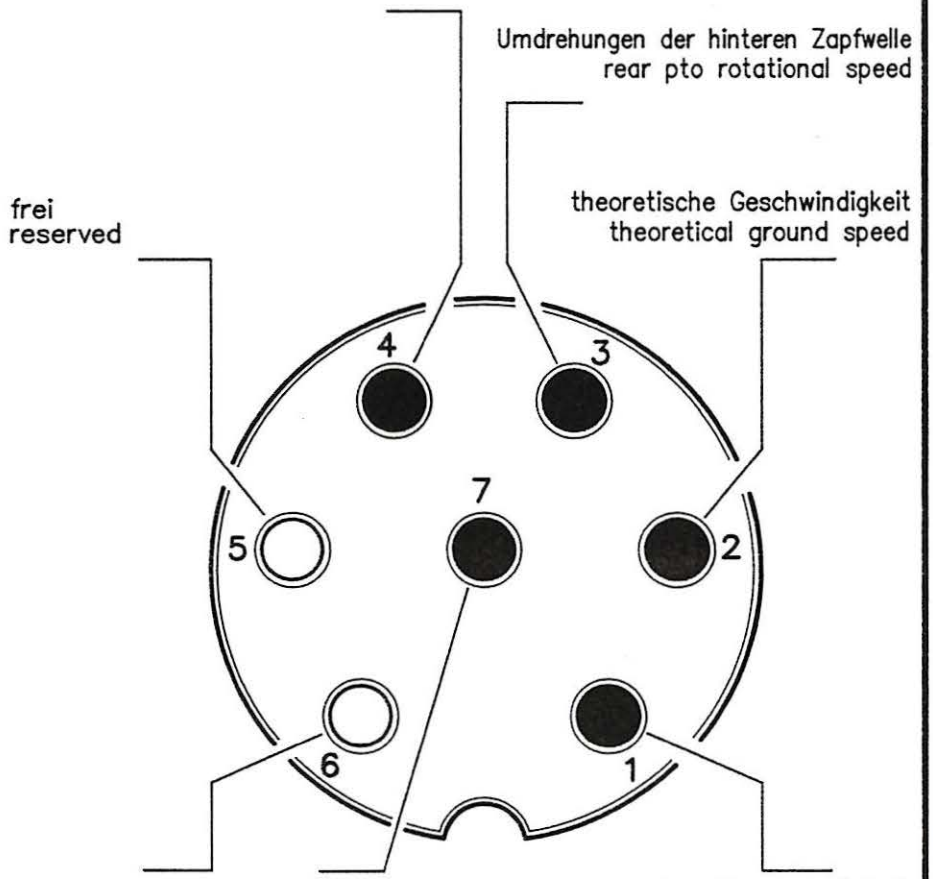
Computer Controlled, Single–Plant Orientated Plantproduction

–ecologically beneficial, labor saving, soil protecting–

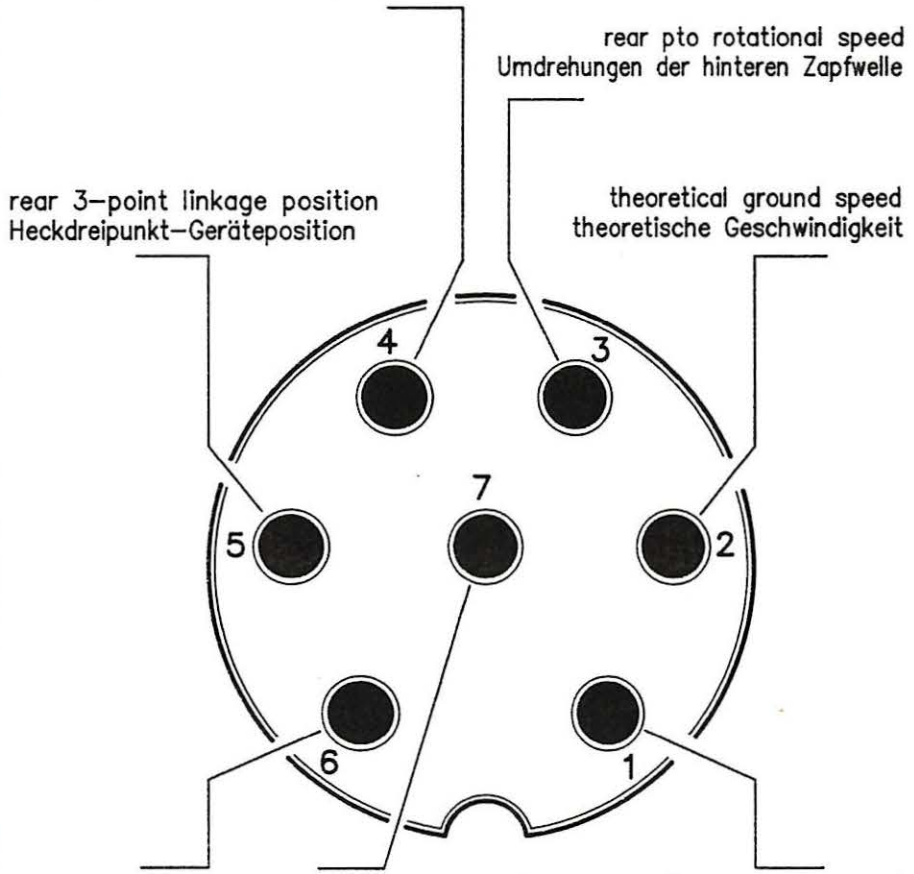
LANDTECHNIK WEIHENSTEPHAN

Ke 922 126

DIN 9684, Teil 1



ISO/DIS 11786 (Vorschlag, draft)



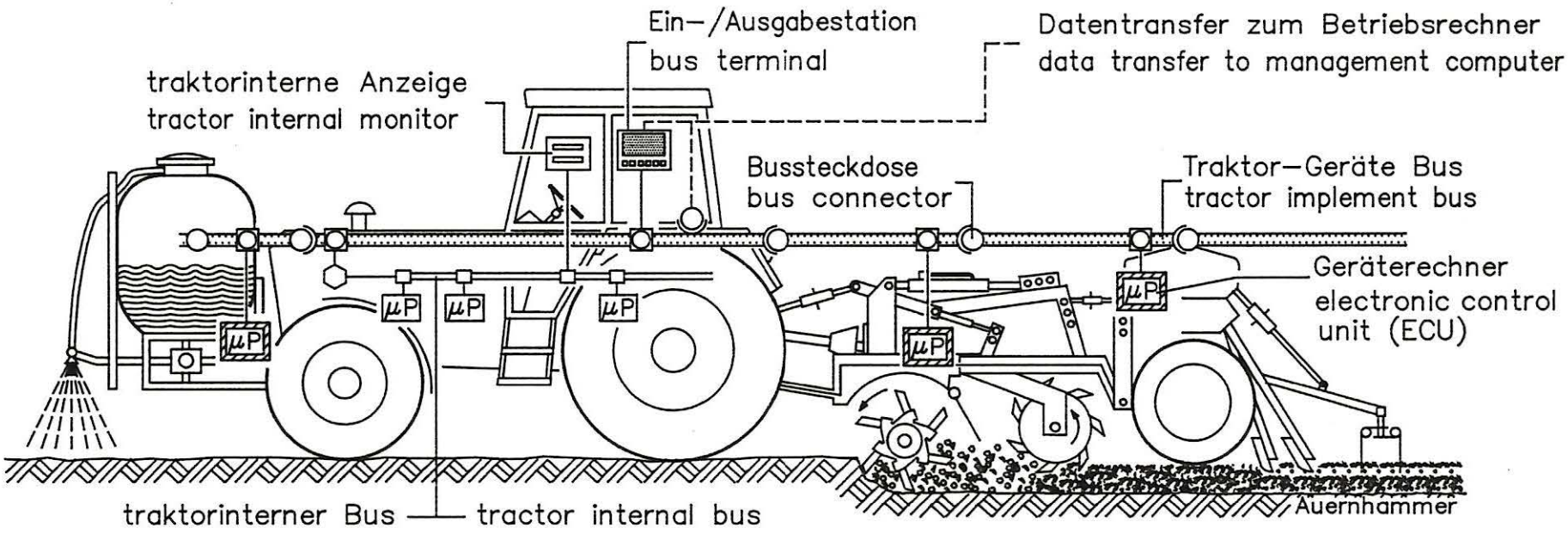
Auernhammer

DIN 9684, Teil 1 und ISO/DIS 11786

(Draufsicht Steckdose schlepperseitig; entspricht AMPHEMOL C16–1)

LANDTECHNIK WEIHENSTEPHAN

Be/Ke 932 255



Auernhammer	**Landwirtschaftliches BUS – System (LBS)** (DIN 9684)	LANDTECHNIK WEIHENSTEPHAN Be 932 248

Conclusions

1. Increasing farms need more efficient management. They must do their job always in an environment friendly way. Therefore site spezific information is the key for this type of agriculture. Location sensing becomes to the challenge of the agriculture of mornings.

2. From the multitude of possible location sensing systems for agriculture GPS offers the best possibilities. It requires no additional infrastructure and guarantees largely easily the cover all agricultural managed areas.

3. The location sensing finds their main application area within information and documentation (yield detection, monitoring of fertilizer supply and so on). Location sensing is thus not only a part of the crop technology. Rather it is an element of the tractor as the universal vehicle in the agricultural operating at all.

4. Simultaneously location sensing opens the local treatment during fertilizing and pest control. It makes in a first time environment friendly agriculture possible.

5. Ultimately location sensing leads to navigation. It opens new aspects for single vehicle as well as for vehicle groups. For the first time driverless vehicle can emerge. They can be used as trabants together with manually guided vehicles. Still further in the future unmanned vehicle sets like a "herd of robots" can do even each labor on schedule with least soil and environment load.