Modern Combine Technology
reducing losses, increasing actual yields

Prof. Thomas Herlitzius
Chair Agricultural Systems and Technology
• current technology drivers in agricultural production
• trends and markets in agriculture
• combine technology
• limits of technology and future demands
• technology trends
• visions
Today high performance agricultural machines establish productivity by
- growing working width,
- higher operational speed,
- larger storage volumes,
which expands engine power, weight & size.

weight and dimension now are becoming a major limitation (NA, EU)

Machines become smarter by
- Process Automation
  - Internal System-and Process Control
  - Machine Fleet Management
  - Process Chain Control
  - Autonomous Machine Control

yet immature

Source: Claas
Source: Horsch

April 2016
DLG Conference: Current and future trends in global and Iranian agriculture
(Agrotech - Agropars, Shiraz)
Rule #1: Productivity growth = power & dimensional growth
Growth of Engine Power for the Global Harvester Market

- **Forage Harvester**
- **Axial Combine**
- **Conv. Combine**
- **Tractors**

**Picture Sources:**
Manufacturer Product Brochures

**Engine Power [kW]**
- Conv. Combine: 11,7 kW/a
- Axial Combine: 8,4 kW/a
- Conv. Combine: 5,0 kW/a
- Tractors: 1,8 kW/a
Average European Combine for 2030 probably will be:

- **500 kW** diesel engine,
- **14 m³** grain tank,
- **35 ft** platform,
- **21 t** machine weight,
- **36 t** in operation with header and full tank
Combine weight distribution

Comprehensive undercarriages to control soil compaction

Wide single tires

- Even load distribution in the contact area
- Combine width stays within 3.5 m
- Supports high axle loads
- Active suspension systems are required & Cost

Tracks

- Combine width exceeds legal limitations for road transport
- Uneven pressure distribution in the soil
- High inflation pressure is required to sustain axle load while transporting

Even load distribution in the contact area
Combine width exceeds legal limitations for road transport
Uneven pressure distribution in the soil
High inflation pressure is required to sustain axle load while transporting

Track width

Length of track [cm]

Length of the contact area [cm]
Productivity always increases
Peak performance and efficiency of the machine itself and its interfaces to other processes keep increasing

Automation of machines and processes gets to much higher levels
Process knowledge and sensing is extensively developed, M2M, utilization of installed capacity is improved

Automation of process chain
area specific harvesting process by utilization of spatial and historic information, logistics optimization and machines assistance in logistics planning

Precision Farming / Smart Farming
Precision Agriculture
Undercarriage gets more complex
Tire performance keeps (contact area) getting better, additional axles are a cost conscious alternative to tracks (half cost, less wear, less rolling resistance)

Reliability and Uptime becomes more value
Systems for remote diagnostics and predictive maintenance based on actual load mapping and accumulation will amortize

Light Weight Design
Medium and long term solutions will be required that decrease weight per installed engine performance, fibre composites are expected to be used also in structural an functional components

CO₂ – Reduction
Limitations and regulation of CO₂ emission will come
Productivity Growth and Combine Evolution

Growing cost for value

Preferable cost to price relationship

extensive solutions: grain tank, shoe size, separator area, tracks, additional axles

smart controls solutions: feedrate control, coordinated machines, operator assist
After a steady increase in machinery parameters in the past, agricultural machinery is becoming smarter and more connected.

Evolution of agricultural machinery, past and future (Europe)

Source: Roland Berger Consultants
- Historically every major stage in grain harvesting technology had a peak period around 50 years before new concepts were starting to compete.

- **Dimensional and weight limitations for road transportation are reached and for large combines exceeded. Axle loads in many cases have negative impact to soil compaction.**

- **Machine guidance and Smart Farming are only two examples of enabling technology for semi and fully autonomous vehicles that is emerging as a future trend.**
Combine Technology Principles

conventional market is shrinking

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(Agrotech - Agropars, Shiraz) Slide 14
Effect of Conditions

- Threshing quality
- Grain damage
- Straw quality
- Loss

Target of quality parameter

MOG feedrate
MOG moisture

Axial Threshing
Tangential Threshing (axial separation)
Tangential Threshing (walker separation)
Effect of Adjustments

- Threshing quality
- Grain damage
- Straw quality
- Loss

Target of quality parameter:

- Concave clearance
- Cylinder speed

Adjustments:

- Axial Threshing
- Tangential Threshing (axial separation)
- Tangential Threshing (walker separation)
Trends for Mobile Machines in technology driven markets

Future Mobile Machines

Process Productivity

Autonomous Systems

• Open and closed loop process control of
  • components
  • machines
  • process chains

• Alternative (hybrid) drives

• Reliability and durability, machine diagnosis (self- / remote- diagnosis)

• Services along the process chain
Why optimizing combine processes?

- **efficiency**
- **productivity**
- **ROI**

Solutions on the market

**Interactive Combine Adjustment**
Source: deere.com

**IntelliView**
Source: CNH

**CEMOS/ CEMOS AUTOMATIC**
Source: www.wnif.co.uk
What does “optimizing combine processes” mean?

- react to a large number of influencing parameters that show high variation
- find an acceptable compromise for the competing harvesting goals
- permanently adjust machine settings

The goal “optimizing combine processes” is a complex optimization problem.
Example Combine Concept Study

Swarm of Small Combines

- field work
- road transport

Functional Modules

- field work
- road transport

Autonomous Units under Supervision

On Trailer

Cutting and Gathering Unit

Stationary Threshing Unit

On Trailer

Swarm of Small Combines

Autonomous Units under Supervision

On Trailer

Cutting and Gathering Unit

Stationary Threshing Unit

On Trailer

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<th>Functional Modules</th>
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</thead>
<tbody>
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<td>Autonomous Units under Supervision</td>
<td>Stationary Threshing Unit</td>
</tr>
</tbody>
</table>
Robotic (Auernhammer 2005)

Robotics in Agricultural Farms

Nano – Robots (2030)
Are working within the plant to improve health. Future vision

Micro – Robots (2020)
Are working at the plant to improve health and growth. First ideas and applications known.

Are working at plants from seed to harvest. Singular solutions exist. Handling of large masses in short time limited.

Medium & Large – Robots (2015)
Are working as half or fully autonomous machine systems at scalable productivity. Technology available, first applications as master-slave systems in research.
Challenges of Robotics

Challenges are:

- Cost and safety of autonomous machines.
- Process automation is not at a level, where machines could fully operate independent from the operator.
- Transport and field setup needs to be addressed without loading the autonomous concepts with major cost.
- New system configurations always provides
  - development risk
  - acceptance risk
- Self-propelled platform needs a propulsion system that is robust and functional under all terrain conditions while doubling weight if storage is filled
- Field traffic and fleet management – smaller units → interactions and communication is inflates
Venum I Foldable header

- 17.6 m wide foldable header
- Integrated header trailer leading to only 9.2 m transport length
- Separate height adjustable chassis overcompensate the extra weight

50-650 mm
Venum I Ground contouring system

- Suitable for rough grounds
- Closer to intended cutting height
- Contour system leads to reduced crop loss

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(Agrotech - Agropars, Shiraz)
• Moving the cabin instead of moving the header
• Many possible options were sketched and proofed
• The result: two separate cabins instead of one moving cabin
Conceptual Evolution of Machines

1820, 1850, 1900, 1950, 2000

- Scythe and flail
- Stationary thresher
- Binder and stationary thresher
- Tractor pulled combine
- Self-propelled combine

"Giants" or "dwarfs"

Quelle: AGCO
Swarm Technologies

14 kW, 2,3l, 1,6t  
253 kW, 9l, 12,5t

1950  
Heute

Systemkosten

Robotik Einheiten
kleine installierte Leistung, hoch automatisiert

Feldschwarm
Leistung skaliert durch Anzahl der Einheiten

zukünftiger Punkt des Break-Even erwartet

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Future agricultural development needs to consider to re-organize the total system, because of

Limitations of arable land
- increased risks of soil degradation,
- competing uses of soil,

Globalization of markets and production
- movement to commercialization,
- existence of global markets,

Climate change and resource limitations
- focus on ecosystem services,
- application of genetic engineering,

Social Changes
- increase in farm size, however slower than machine growth
- changes in social structure
Modern Combine Growth

50 years ago: 45 to 55 kg/kW
20 years ago: 35 to 45 kg/kW
Today: 40 to 45 kg/kW
Future: 35 kg/kW?
Feedrate Example – Non Conventional

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Feeder house Concave Rotor

<table>
<thead>
<tr>
<th>Feedrate [t/h]</th>
<th>Mean of ratio kernel/straw</th>
<th>Weight of 1000 kernels [g]</th>
<th>Length in direction of flow [m]</th>
<th>Width across direction of flow [m]</th>
<th>Height of material flow [m]</th>
<th>Lower speed of material flow [m/s]</th>
<th>Upper speed of material flow [m/s]</th>
<th>Density (kg/m³)</th>
<th>Running time [s]</th>
<th>Flow of kernels (Amount of kernels per cm²)</th>
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<tbody>
<tr>
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<td>27,8</td>
<td>27,8</td>
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<td>1,39</td>
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<td>1,39</td>
<td>0,70</td>
<td>0,04</td>
<td>3,4 ... 5,1</td>
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<td>45</td>
<td>45</td>
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<td>0,4</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>0,75</td>
<td>3,12</td>
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<td>0,01</td>
<td>0,4 ... 2,3</td>
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<td>2,00</td>
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<td>3,00</td>
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<td>56,1 ... 84,1</td>
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<td>1,04 ... 1,56</td>
<td>1,04 ... 1,56</td>
<td>1,04 ... 1,56</td>
</tr>
</tbody>
</table>

Wheat – good conditions
### Feedrate Example – Conventional

- **Plate sensor separator**
- **Wheat – good conditions**

<table>
<thead>
<tr>
<th>Feeder house</th>
<th>Concave</th>
<th>Beater</th>
<th>Separator</th>
<th>Feedrate [t/h]</th>
<th>Total (50% kernels, 50% straw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>40</td>
<td>29</td>
<td>28</td>
<td></td>
<td></td>
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<tr>
<td>13.9</td>
<td>11.1</td>
<td>8.1</td>
<td>7.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.4</td>
<td>0.4</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.00</td>
<td>0.75</td>
<td>0.50</td>
<td>4.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.39</td>
<td>1.39</td>
<td>1.39</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0.05</td>
<td>0.01</td>
<td>0.12</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.80</td>
<td>5.00</td>
<td>5.00</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.50</td>
<td>28.00</td>
<td>17.00</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>57.1 ... 71.4</td>
<td>28.5 ... 159.9</td>
<td>2.8 ... 9.7</td>
<td>14.0 ... 28.0</td>
<td>Density (kg/m³)</td>
<td></td>
</tr>
<tr>
<td>0.57 ... 0.71</td>
<td>0.03 ... 0.15</td>
<td>0.03 ... 0.10</td>
<td>5.75 ... 11.50</td>
<td>Running time [s]</td>
<td></td>
</tr>
<tr>
<td>3.2 ... 4.0</td>
<td>0.2 ... 1.0</td>
<td>0.2 ... 0.7</td>
<td>2.6 ... 5.2</td>
<td>Flow of kernels (Amount of kernels per cm²)</td>
<td></td>
</tr>
</tbody>
</table>
Electrification of Mobile Machines

- Diesel & combustion engine stays power source
- Safety and standards solvable
  - Hybridization limited ↔ Storage cost & size,
  - Recuperation potential very limited
  - Tractor – implement interface is going to come
Faculty of Mechanical Engineering

Faculty of Mechanical Science and Engineering - Institute of Processing Machines and Mobile Machinery

6152 students
of them 1217 freshmen

1137 staff

632 research fellows externally funded
170 budgetary research fellows
146 administrative budgetary staff members
138 administrative externally funded staff
52 professors

staff-student ratio (2012):
118,3 students/professor
32,2 students/member of academic staff

doctoral studies & post-doctoral studies (2012):
67 doctoral studies
1 post-doctoral studies

income from external funding (2011): ~ 51 Mio. €
~ 1 Mio. € per professor

patent applications: 84 (2012)
papers (2012):
764 F professional journals,
698 conference papers (2.226 total)

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The faculty continues to offer **Diploma programs**!

- mechanical engineering
- materials science
- process engineering and natural materials technology
- mechatronics*
- regenerative energy systems*

* cross-faculty degree programme
INSTITUTE OF PROCESSING MACHINES AND MOBILE MACHINERY
Director Prof. Herlitzius

CHAIR CONSTRUCTION MACHINES AND CONVEYING TECHNOLOGY
Prof. Kunze

CHAIR AGRICULTURAL SYSTEMS AND TECHNOLOGY
Prof. Herlitzius

CHAIR OF PROCESSING MACHINERY AND PROCESSING TECHNOLOGY
Prof. Majschak

LEITUNG
Prof. Herlitzius
Dr. Müller
Dr. Hübner

SEKRETARIAT

SOIL & TILLAGE / RENEWABLE ENERGY
8 Engineers

ALTERNATIVE DRIVES / AUTOMATION
8 Engineers

HARVESTING TECHNOLOGY
10 Engineers

MEASUREMENT & DATA ACQUISITION
2 Engineers

EXPERIMENTAL WORKSHOP
8 Technicians Agricultural Systems and Technology
3 Processing Machinery and Processing Technology