Robots Ecosystems
InfoAg 2018
St. Louis, MO
Tuesday, August 17

S.A. Shearer
Food, Agricultural and Biological Engineering
Ag robot proliferation...
Weight (ballasted): 60,000 lb_f
Engine (max.): 620 hp
Weight/Power: 96.8 lb_f/hp
Increasing Equipment Size
Compaction Yield Loss
Visualizing Yield Loss

Visible V12

Yield Map

Adjusted Map

Yield (bu/ac)
- 10 to 90
- 90 to 125
- 125 to 150
- 150 to 175
- 175 to 200
- 200 to 226

Equalizer - 104,800 lbs
Wheeled - 96,000 lbs
Planter Reliability

<table>
<thead>
<tr>
<th>Failure Rate</th>
<th>Width (Rows)</th>
<th>4</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01%</td>
<td>99.7%</td>
<td>96.2%</td>
<td></td>
</tr>
<tr>
<td>0.10%</td>
<td>96.8%</td>
<td>61.6%</td>
<td></td>
</tr>
</tbody>
</table>


http://www.bauerbuiltmfg.com/db-series-planters.html
High speed field operations…
High speed field operations…
Sensor Densification of Field Machinery
Emerging cultivation practices...

In-Season Application (High Clearance)

Biologicals (Multi-Product Application)

Targeted Application (Vision Systems and AI)

Narrow Row Corn (Wheel/Track Size and Spacing)
Strip Intercropping
# Emissions – Nonroad EU Stage V

## EU Emission Directive

<table>
<thead>
<tr>
<th>Performance class</th>
<th>2013</th>
<th>2019</th>
<th>EPA Emission Directive</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0 &lt; P &lt; 8$ kW</td>
<td>-</td>
<td>Stage V (PM 0.4/0.6 / NOx+HC 7.5)</td>
<td>Tier 4 final (PM 0.4/0.6 / NOx+HC 7.5)</td>
</tr>
<tr>
<td>$8 \leq P &lt; 19$ kW</td>
<td>-</td>
<td>Stage V (PM 0.4 / NOx+HC 7.5)</td>
<td>Tier 4 final (PM 0.4 / NOx+HC 7.5)</td>
</tr>
<tr>
<td>$18 \leq P &lt; 37$ kW</td>
<td>Stage III A (PM 0.3 / NOx+HC 7.5)</td>
<td>Stage V (PM 0.015 / NOx+HC 4.7 / PN 1x10^9)</td>
<td>Tier 4 final (PM 0.03 / NOx+HC 4.7)</td>
</tr>
<tr>
<td>$37 \leq P &lt; 56$ kW</td>
<td>Constant: Stage III A (PM 0.3 / NOx+HC 4.7)</td>
<td>Stage V (PM 0.015 / NOx+HC 4.7 / PN 1x10^9)</td>
<td>Tier 4 final (PM 0.03 / NOx+HC 4.7)</td>
</tr>
</tbody>
</table>

- **EPA** refers to the Environmental Protection Agency.
Mechanical Life and Technical Obsolescence

\[ v_u = 0.01 \cdot p_c \cdot t_p \cdot (1 - 0.01d_r)^{tp_g} \cdot (1 + 0.01i_r)^{t_b_g} \cdot i_f \]

where,
- \( v_u \) - technology upgrade cost at given age ($)
- \( p_c \) - purchase cost ($)
- \( t_p \) - technology portion of purchase cost (%)
- \( d_r \) - technology depreciation rate (%)
- \( tp_g \) - time since previous generation (yr)
- \( t_b_g \) - time between current generation and initial generation (yr)
- \( i_r \) - inflation rate (%)
- \( i_f \) - inflation compound factor: 12 – monthly, 1 - yearly
Modern Agricultural Tractor
• An 8R coming out of Waterloo should have a mechanical life of 20,000 h.
• In the Midwest this tractor will likely be used 500 h/yr.
• Mechanical life of the tractor might exceed 40 yrs.

Smart Phone
• Which model do most people carry today?
• What is “expected life” of an iPhone?
Supervised Autonomy

ASI Mobius Solution
Common Telematics Solutions
Internet Access (FCC 2018)

200 kbps

10 Mbps
Future field production system?
Multiple Machine Control Architecture
Communications and Control

• Arduino Mega 2560/Raspberry Pi with Ethernet shell for control and communications interface
• Ubiquiti Networks Rocket M radios, AirMAX Sector antennas and UniFi video cameras
• Dell T7810 Precision Workstation (Dual Intel Xeon Processor E5-2687W)
Autonomous Tractor Development
SwarmFarm - Australia
## Alternative Ownership Models

### Table 1. Summary of Alternative Methods of Acquiring Farm Machinery Services.

<table>
<thead>
<tr>
<th>Method</th>
<th>Capital outlay required for investment</th>
<th>Cash flow requirements</th>
<th>Repairs and maintenance costs</th>
<th>Income tax deductions</th>
<th>Operating labor</th>
<th>Control over use and timeliness of operation</th>
<th>Risk of obsolescence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ownership:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash purchase</td>
<td>Full cash cost</td>
<td>Operating costs</td>
<td>Depreciation, operating costs</td>
<td>Supplied by farm operator</td>
<td>Full control</td>
<td>Full risk</td>
<td></td>
</tr>
<tr>
<td>Credit purchase</td>
<td>Down payment or trade-in</td>
<td>Operating costs plus loan payments</td>
<td>Depreciation, operating costs, interest</td>
<td>Supplied by farm operator</td>
<td>Limited control over timeliness and use</td>
<td>No risk</td>
<td></td>
</tr>
<tr>
<td>Custom hire</td>
<td>No investment capital required</td>
<td>Custom hire cost</td>
<td>No cost</td>
<td>Custom charges</td>
<td>Supplied by custom operator</td>
<td>Limited control over timeliness and use</td>
<td>No risk</td>
</tr>
<tr>
<td>Short-term rental</td>
<td>No investment capital required</td>
<td>Operating costs plus rental fees</td>
<td>Limited cost depending on agreement</td>
<td>Rental fees</td>
<td>Supplied by farm operator</td>
<td>Limited control over timeliness and use</td>
<td>No risk</td>
</tr>
<tr>
<td>Lease:</td>
<td>No investment capital required</td>
<td>Operating costs plus lease payments</td>
<td>Full cost</td>
<td>Supplied by farm operator</td>
<td>Full control</td>
<td></td>
<td>Low risk</td>
</tr>
<tr>
<td>Operating lease</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finance lease</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Full risk</td>
</tr>
</tbody>
</table>

Source: https://www.extension.iastate.edu/agdm/crops/html/a3-21.html
“How Smart, Connected Products Are Transforming Competition”
by M.E. Porter and J.E. Heppelmann
Venture capital seeking a home...
Gartner Hype Curve
Summary Thoughts

- Low-power autonomous tractors will minimize liability (< 100 hp).
- Mitigation of soil compaction likely to drive the adoption of autonomous ag equipment (< 10,000 lb GVW and < 3.0 psi ground contact pressure).
- Removal of human operator reduces base machine cost (i.e., cab enclosure, HID lighting, air conditioning, air suspension seat, tractor styling, visibility, etc.) from >$1,000/hp to < $750/hp.
- Obsolescence and mechanical life should coincide (5,000 h life, or 5 to 7 cropping seasons).
- Expect a resurgence in spark ignition engines -- emissions and mechanical life will drive adoption.
- Extended operating hours (24x7), increased field efficiency and ability to move equipment between regions will amortize technology costs over more acres.
- Parts and service will be provided via dispatched trucks, significantly altering traditional dealership model.
- Preferred approach will be supervised autonomy -- machine intelligence, edge/fog computing and broadband internet access will enable adoption.
- Alternative machine forms will support alternative cropping systems – strip intercropping, inter-seeding of cover crops, etc.
- New business and ownership models will challenge status quo leading to the dominance of contract farming and ag logistics services!
Questions?