Progress on autonomous vehicles from the machinery manufacturer’s perspective

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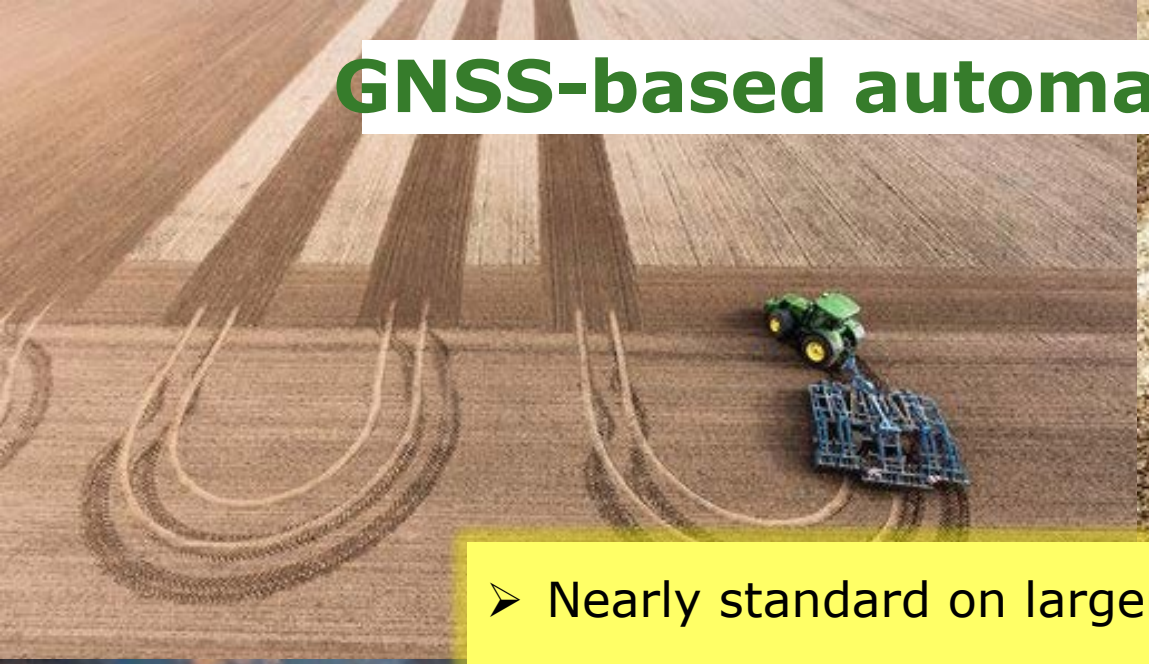
Agenda

- Automatic steering
- Autonomous vehicles
  - Status and latest news
  - Drivers
  - Application examples
  - Challenges
  - Swarm technologies
  - Role of electrification
- Outlook & summary

GNSS-based automatic steering systems



- Nearly standard on larger agricultural machines
- Trend towards higher accuracy (RTK)

Receiver Integration in Cab Roof

University Research Field Robots

Source:
University of Sidney

Source: Robotics Business review

Source: University of Helsinki

Source: Hochschule Osnabrück

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Trend to autonomous (driverless) vehicles?

Case ACV – Auto

Source: Continental

John Deere Future Technology Zone

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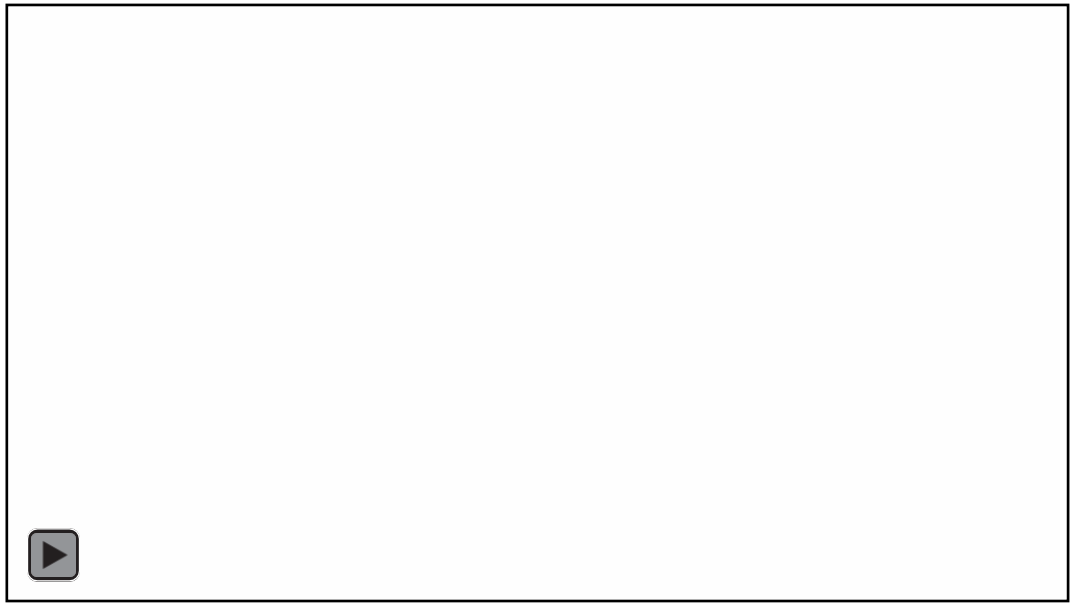
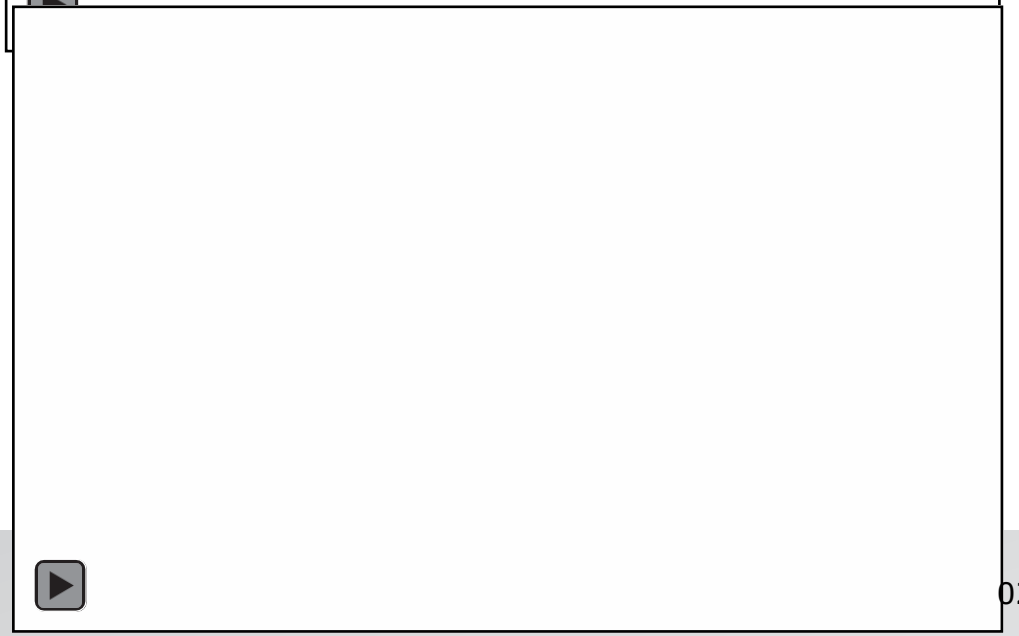
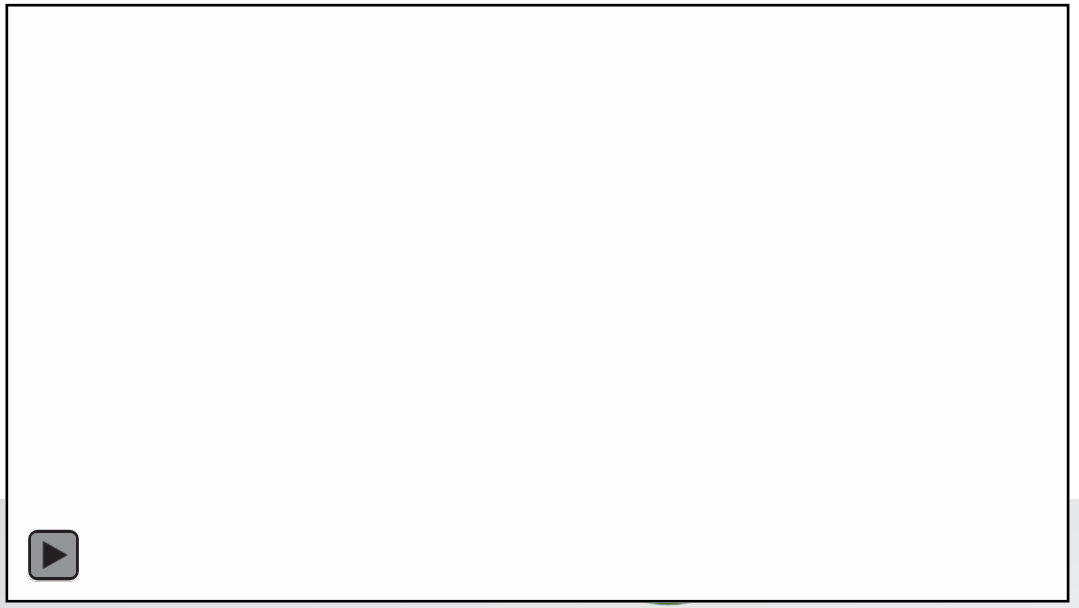
John Deere Prototypes







Is this the future?

Drivers for autonomous vehicles

- Shortage and cost of educated labor
  - Large arable farming vs. specialty crops
- Cost reduction of driverless machine
  - No cab needed
- Soil compaction reduction
  - Controlled traffic farming vs. light weight robots
- Reduction of input costs (seed, fertilizer, pesticides) through precise placement up to single plant treatment
- Autonomous cars & trucks
  - Strong cost reduction of safeguarding sensors
  - Facilitates legal approval discussion
- Strong focus of venture capital and startup companies on agricultural robotics

Seeding/Planting

Source: Small Robot Company

Source: DOT

Source: AgroIntelli

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Weed Control

Source: Saga Robotics

Source: Carré

Source: EcoRobotix

Source: Naio Technologies

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Spraying

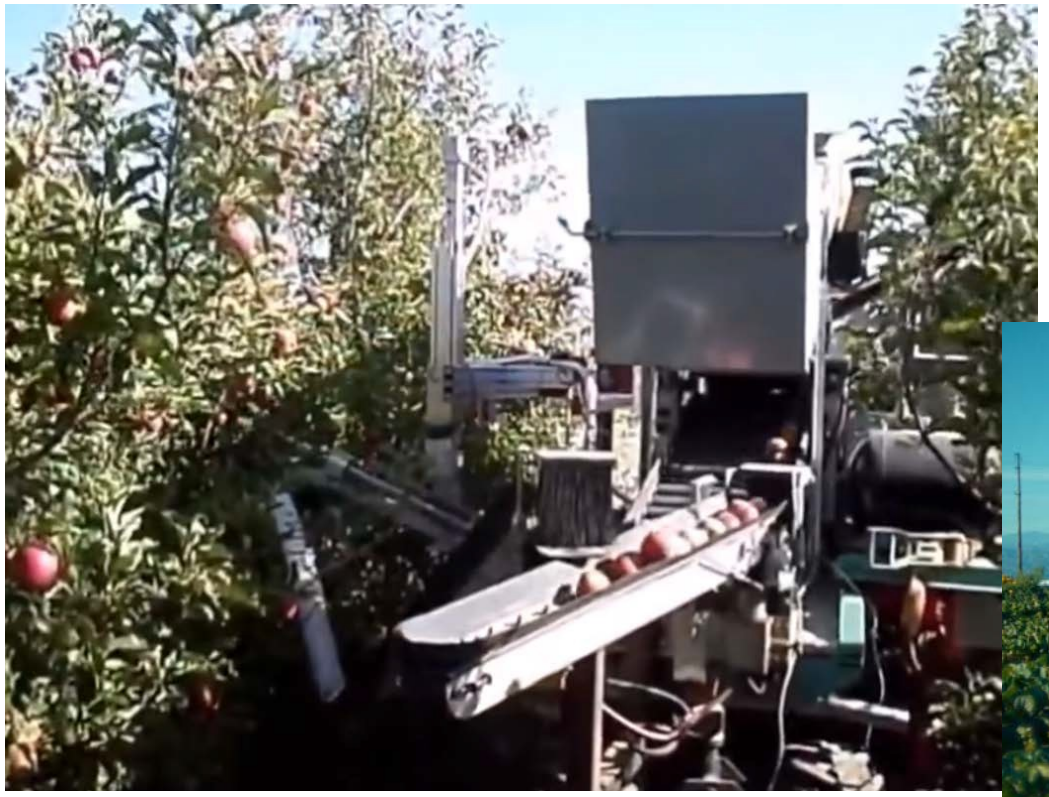
Source: GUSS

Source: Jacto

Source: SwarmFarm Robotics

Harvesting

Source: Harvest CROO Robotics



Source: FFRobotics

Source: AGROBOT

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Challenges for autonomous vehicles

- Product liability
- Legal situation
  - Driving on public roads
- Safeguarding sensors
  - Challenging environment (dust, dirt, fog, vibrations)
- Monitoring of other machine functionality
- Logistics
  - Handling of harvested material or inputs (seed, fertilizer)
  - Transport to/from field
- Complete re-design of machines
  - Optimal machine size depends on application
  - New cropping systems?
- Availability of robotics/AI engineers

Trend towards swarm technologies?

Source: AGCO/Fendt

Source: SwarmFarm Robotics

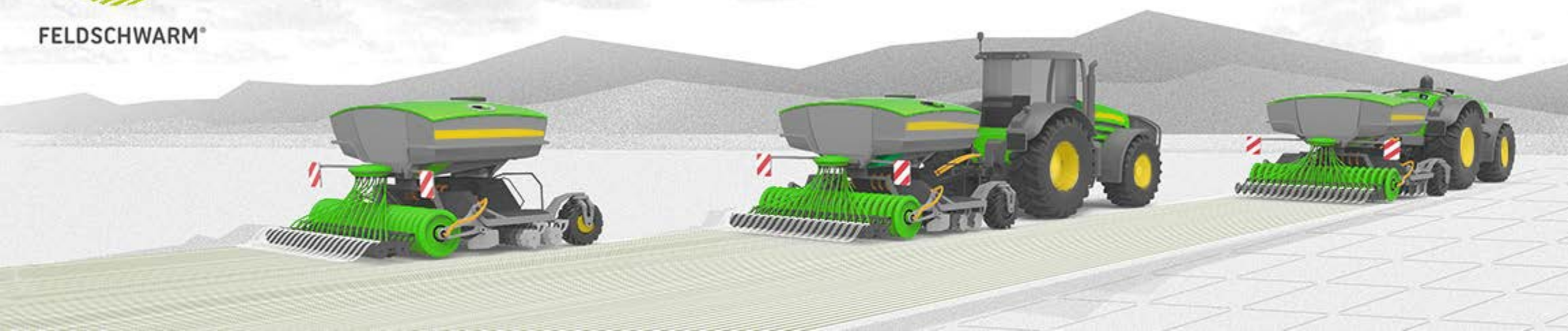
Autonomous field swarms

Bundesministerium für Bildung und Forschung

Goals:

- Swarm of autonomous and semi-autonomous operating implements
- Electrically driven units
- Higher automation level with lower specific power requirements

FELDSCHWARM®



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Role of Electrification

- Too low power density of batteries
  - Applications with short durations
  - Not usable for 24h operations on large farms

- Potential Solutions
  - Fast exchange of battery packs
  - Solar panels for low power applications
  - Fuel cells (Hydrogen)
  - Connecting to the grid

Connecting to the grid

Outlook and Summary

- GNSS-based automatic steering solutions are mainstream.
- Growing research and venture capital investment in fully autonomous vehicles.
- There are a lot of drivers towards autonomous vehicles, but a lot of challenges are still ahead of us.
- Field robots will be introduced first in specialty crops due to labor cost and labor shortage.
- Swarm technologies and alternative energy concepts seem to be necessary for introduction in large arable farming.