Recent Advances in Silage Equipment

XX International Silage Conference

Matthew Digman and Kevin Shinners

Agricultural Engineers
Biological Systems Engineering
University of Wisconsin

Silage-making grand challenges

Climate change impacts on harvest timing and fermentation reliability.

Emission reductions across the entire forage supply chain.

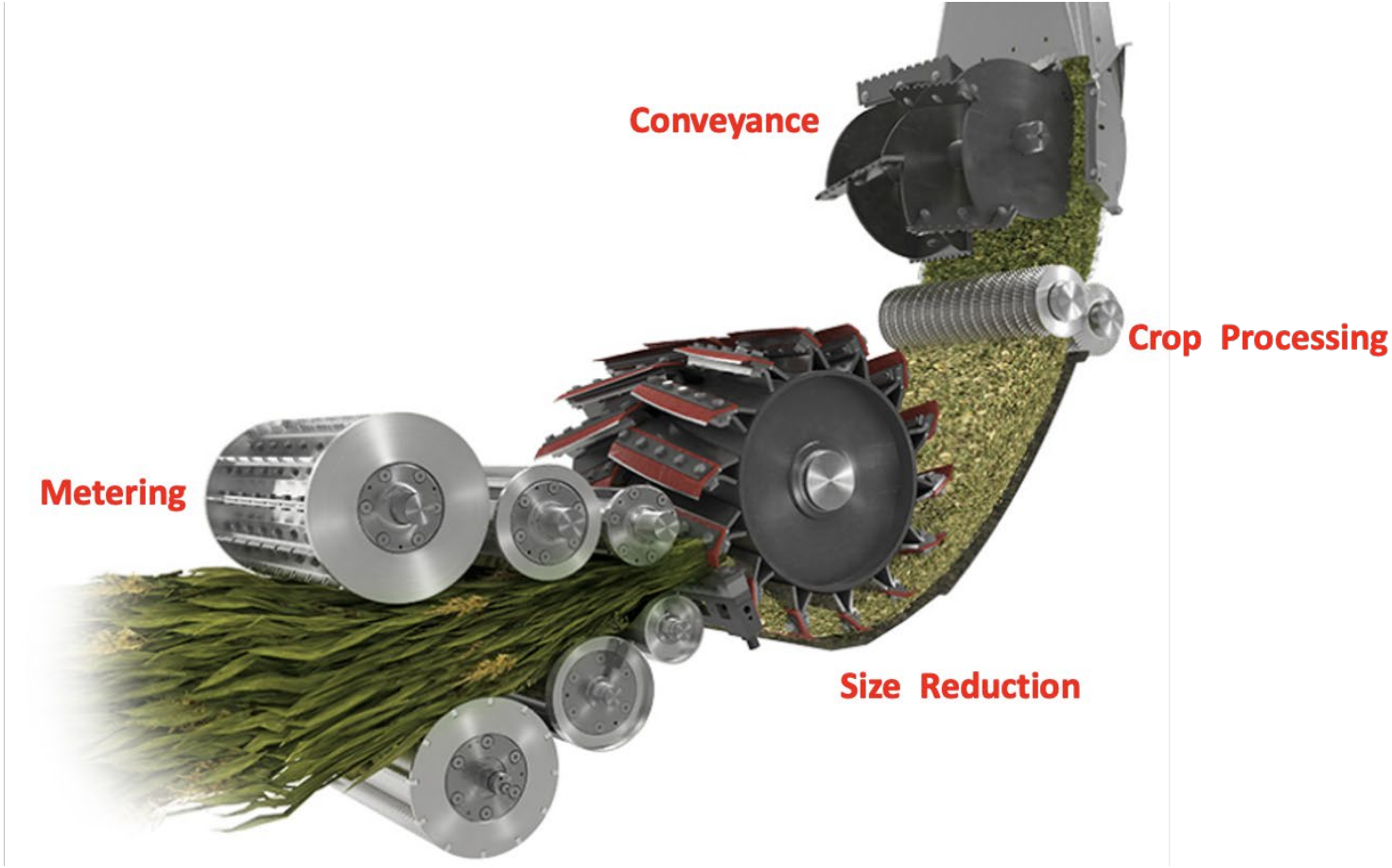
Sustainability in energy, and materials.

Economic viability under market volatility.

Technological adoption for automation and real-time quality control.

Advancements across silage making

What would it take to build an autonomous forage harvester—and how far have we come?


Conveyance
Crop Processing
Metering
Size Reduction


CLAAS
MARTIN KING


ZH JD 9766

What's needed?

1. When to harvest
2. Machine Setup, Maintenance
3. Navigation and Guidance
4. Throughput Management
5. Quality of Job Done
6. Coordination with wagons and trailers
7. Safety and Compliance
8. Connectivity and Data Management

The Demeter System for Automated Cutting, 1997

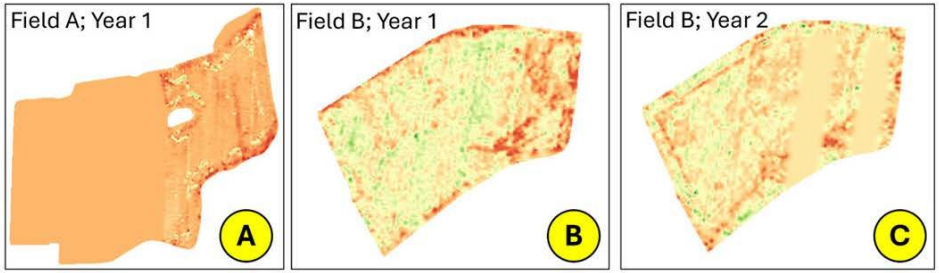
Let’s check our progress!

✅ , S – satisfactory

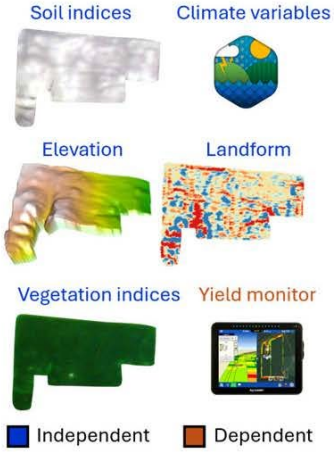
📈 , P – progress

📉 , O – opportunity

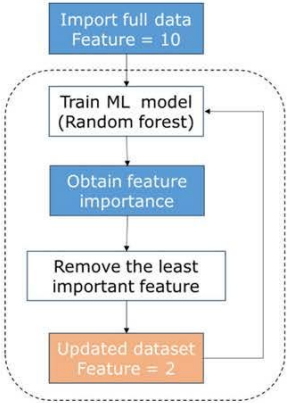
Scenario 1 (A&B): Estimating missing neighboring field yield data (same year).
Scenario 2 (B&C): Estimating missing year field data (same field).



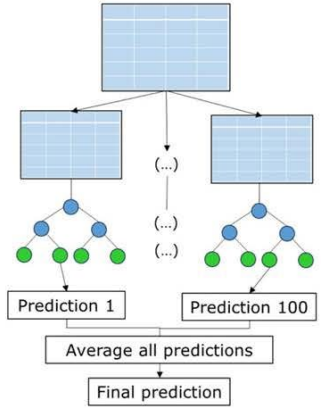
Data



Feature selection
(Boruta)

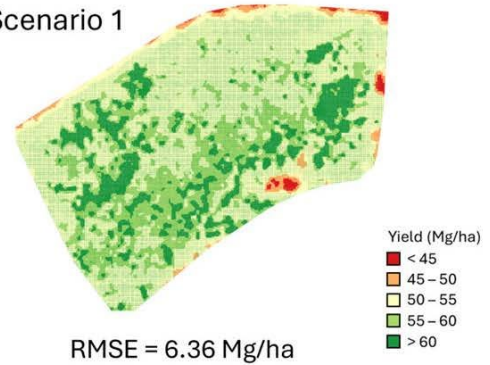


Machine learning
(Extra tree regressor)



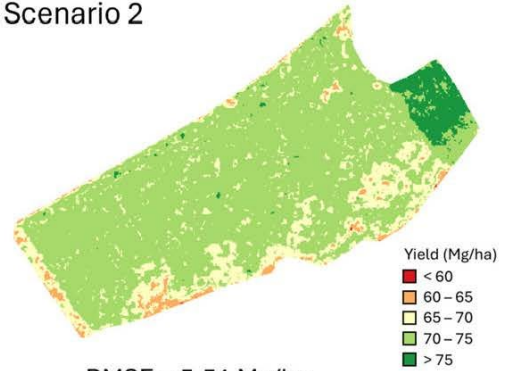
Results

Scenario 1



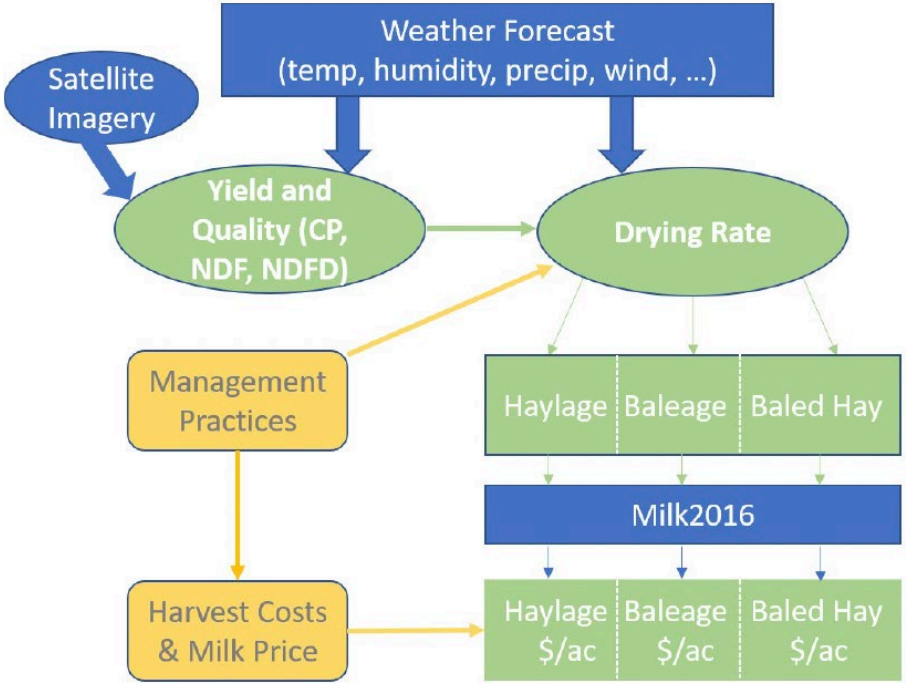
RMSE = 6.36 Mg/ha

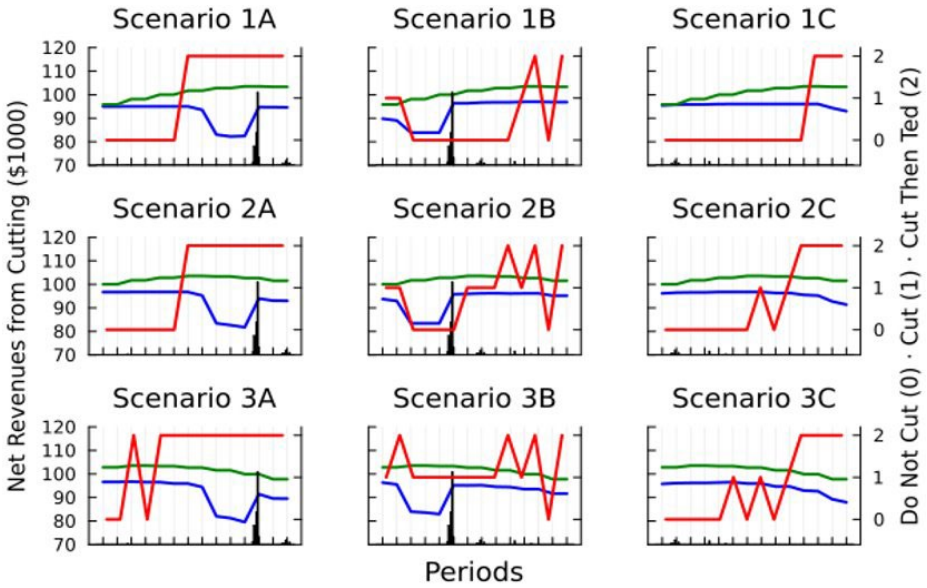
Scenario 2



RMSE = 5.51 Mg/ha

1. When to harvest - Remote Sens. 2024, 16(21), 4081





Alfadvisor

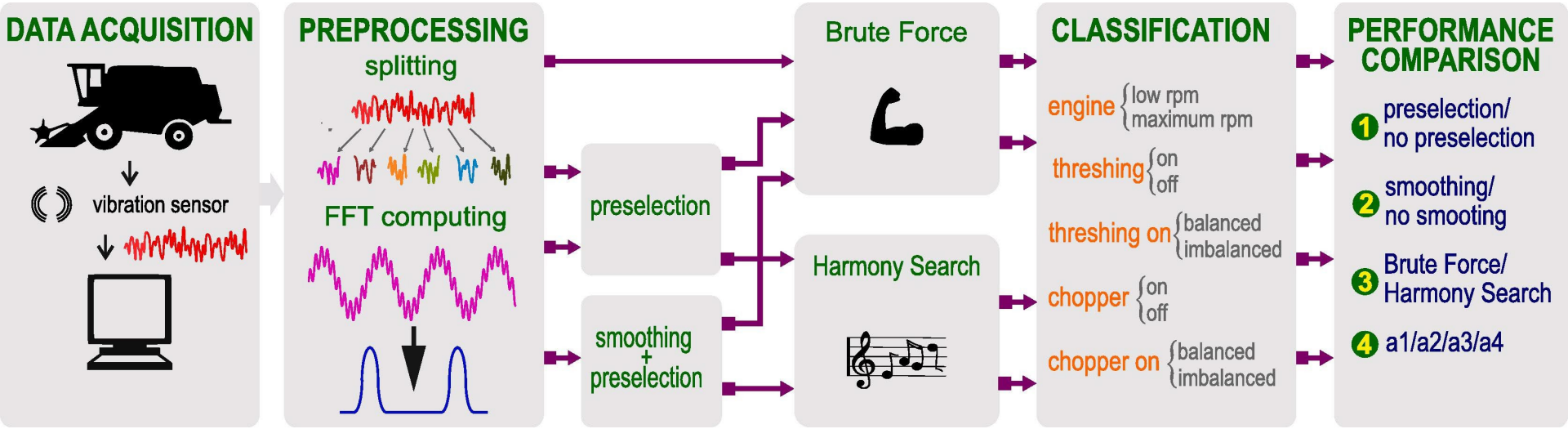
A Web-Based Platform for Decision-Making Support in Alfalfa

📈 P – progress

Improvements in model generalizability are needed.

Sensors **2024**, *24*(5), 1397

- ✅ Lubrication
- ✅ Knife sharpening
- 📉 Condition monitoring
- 📉 Maintenance

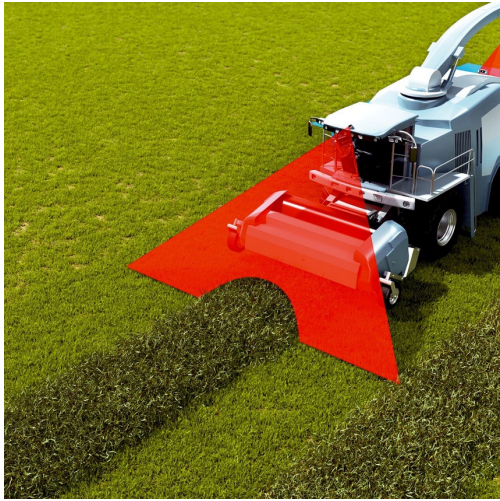


🤫 Not a forage harvester!

O – Opportunities

Machine condition monitoring is a major gap.


Guidance
07:16
W
270°
1 in
1 in
Corn
362
ft
0
Guidance
AutoPath
Set Track
Shift Track
1.0 in
Shift Increment
Location
South 40
Field
SETUP
WORK
SECTION CTL
SECTION CTL
AUTOTRAC
GUIDANCE
SWAP TRACK
AUTO TURN
ISOBUS VT
DISPLAY
FLAGS
BOUNDARY
MENU

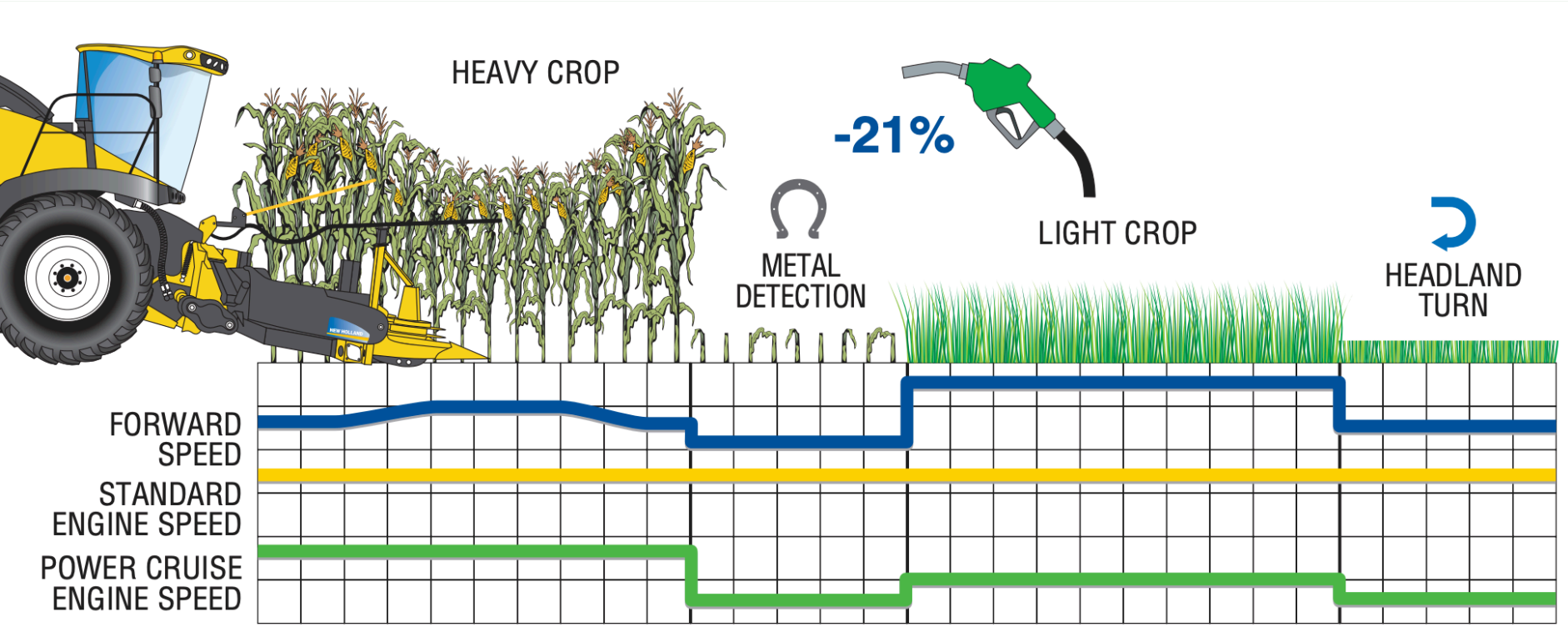


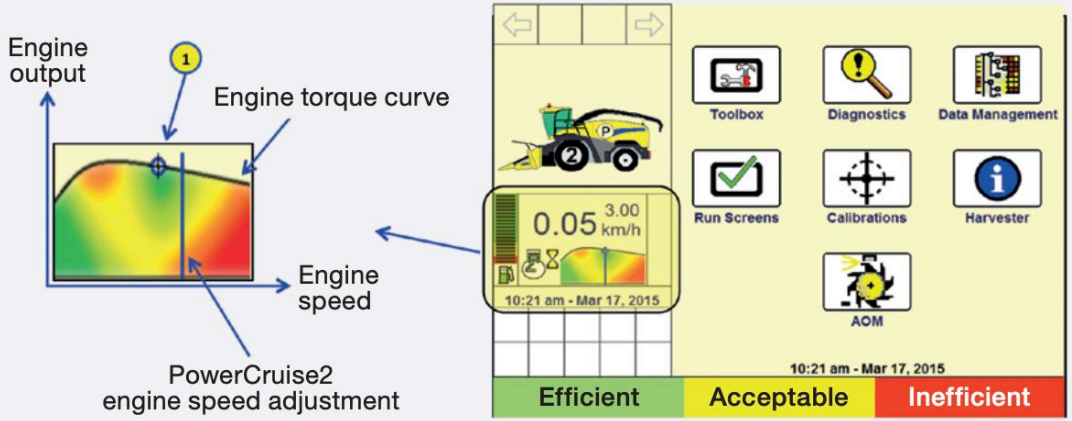

SICK

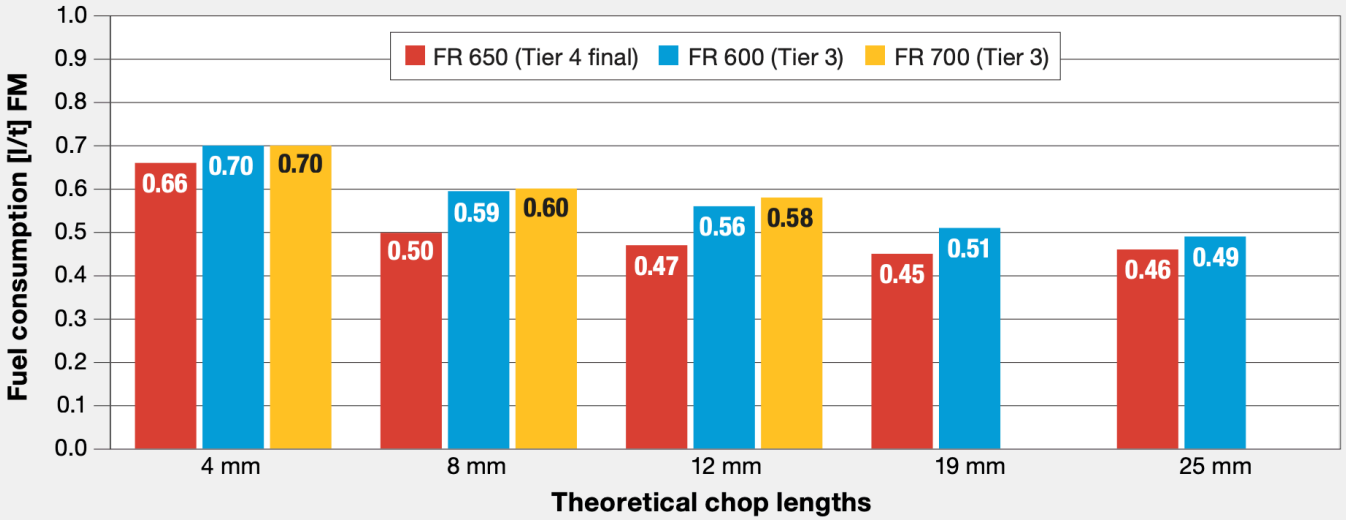

SICK
multiScan

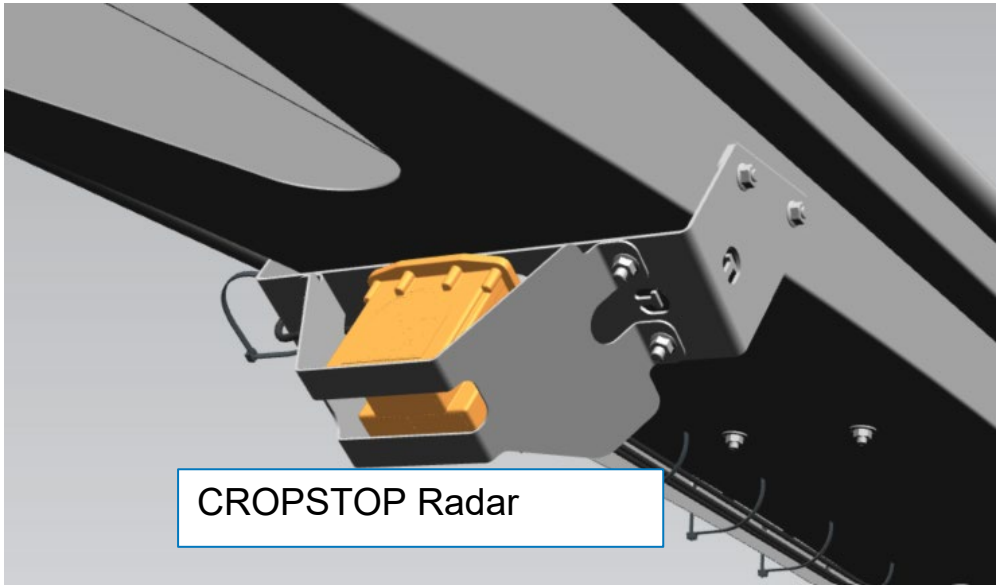
📈 P – progress

There is good progress in this area. Model development and validation in the field environment are ongoing.


HEAVY CROP
-21%
LIGHT CROP
METAL DETECTION
HEADLAND TURN
FORWARD SPEED
STANDARD ENGINE SPEED
POWER CRUISE ENGINE SPEED


Engine output
1
Engine torque curve
Engine speed
PowerCruise2 engine speed adjustment
0.05
3.00 km/h
10:21 am - Mar 17, 2015
Toolbox
Diagnostics
Data Management
Run Screens
Calibrations
Harvester
AOM
10:21 am - Mar 17, 2015
Efficient
Acceptable
Inefficient

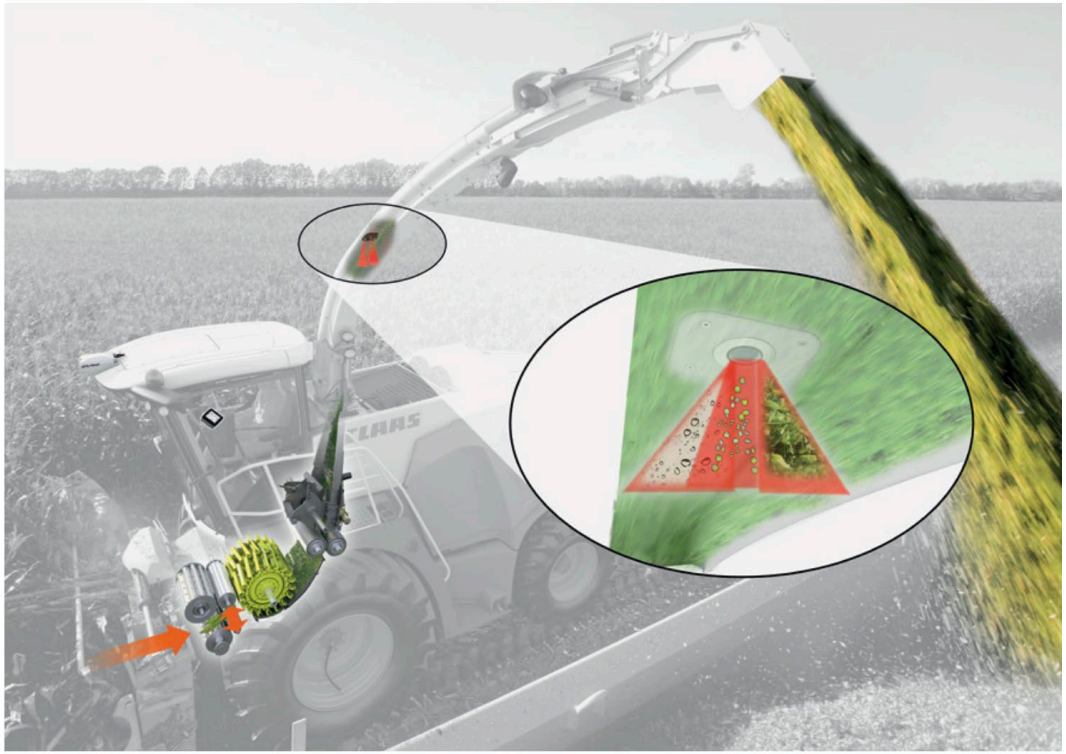

FR 650 (Tier 4 final)
FR 600 (Tier 3)
FR 700 (Tier 3)
Fuel consumption [l/t] FM
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.66
0.70
0.70
0.50
0.59
0.60
0.47
0.56
0.58
0.45
0.51
0.46
0.49
4 mm
8 mm
12 mm
19 mm
25 mm
Theoretical chop lengths

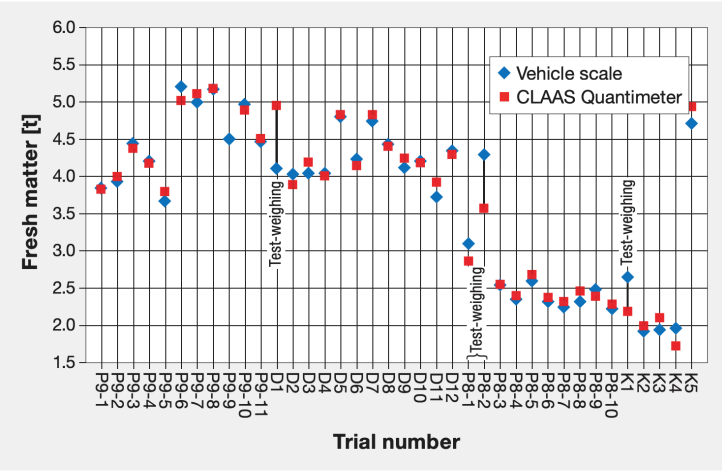


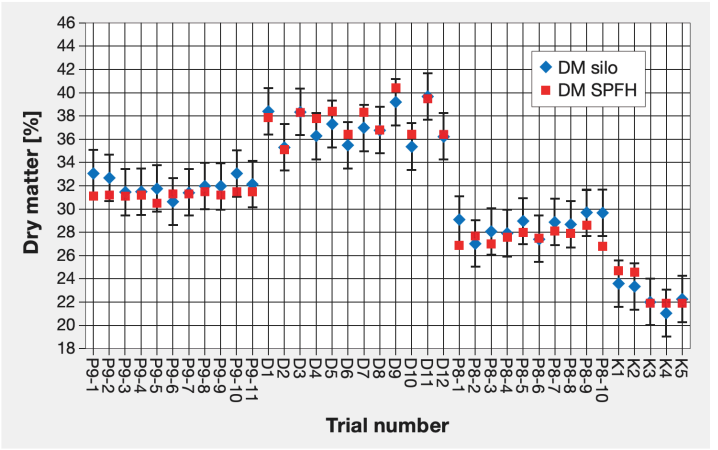
- Rock detection
- Metal detection
- Blockage detection

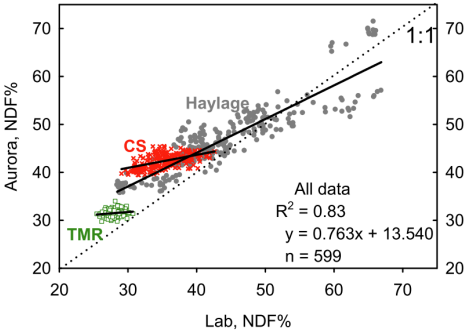
📈 P – progress

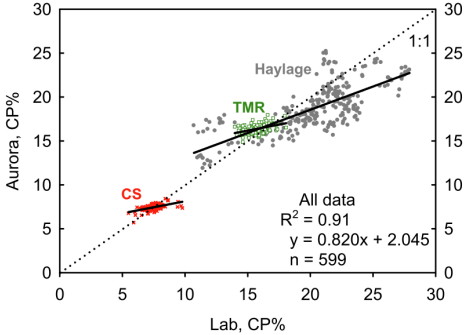
These autopilot features will add value to current systems and will also serve as key enablers for autonomy.

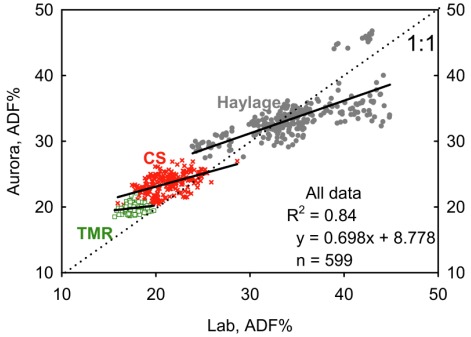


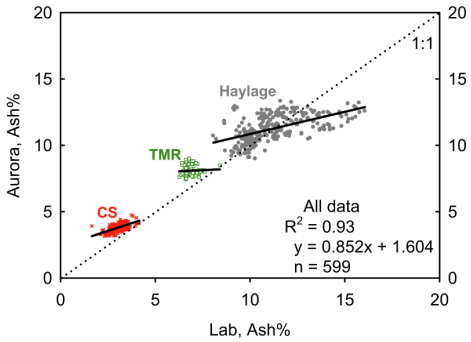

Fresh matter [t]
Vehicle scale
CLAAS Quantimeter
Test-weighing
Test-weighing
Test-weighing
Trial number


Dry matter [%]
DM silo
DM SPFH
Trial number


Aurora, NDF%
Lab, NDF%
1:1
Haylage
CS
TMR
All data
R^2 = 0.83
y = 0.763x + 13.540
n = 599


Aurora, CP%
Lab, CP%
1:1
Haylage
TMR
CS
All data
R^2 = 0.91
y = 0.820x + 2.045
n = 599


Aurora, ADF%
Lab, ADF%
1:1
Haylage
CS
TMR
All data
R^2 = 0.84
y = 0.698x + 8.778
n = 599


Aurora, Ash%
Lab, Ash%
1:1
Haylage
TMR
CS
All data
R^2 = 0.93
y = 0.852x + 1.604
n = 599

(a) Original image.

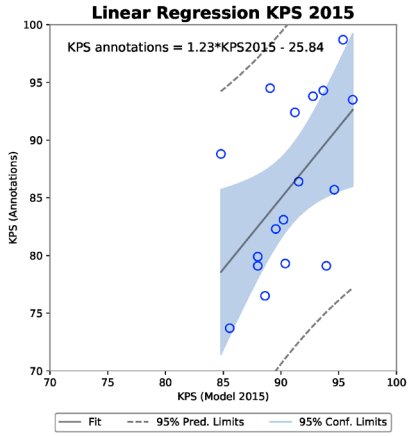
(b) 2015 model.

(c) 2016 model.

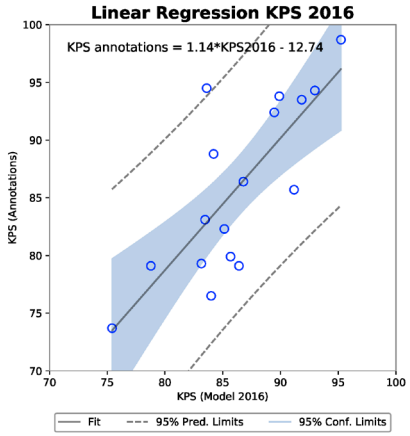
(d) 2017 model.

(e) 151617 model.

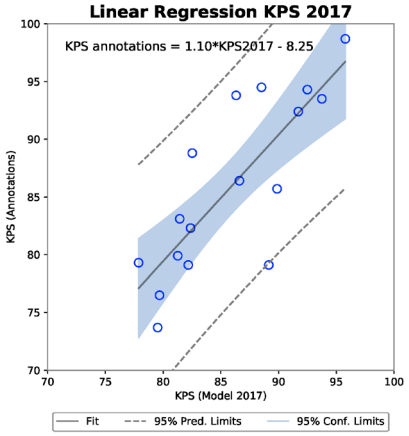
- Unsorted kernels, RGB images
- Strong correlation (r^2= 0.78) between R-FCN predictions and CSPS



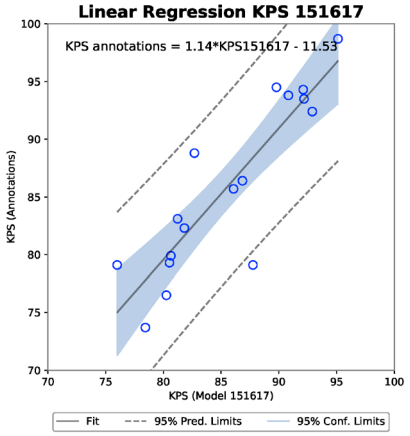
(a) 2015 model.



(b) 2016 model.



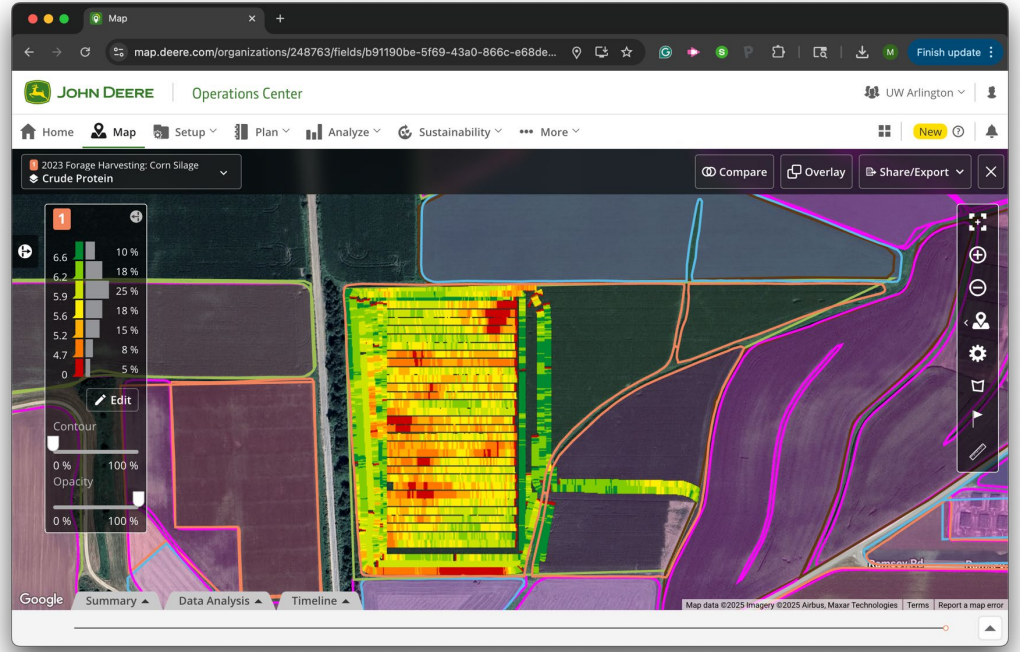
(c) 2017 model.



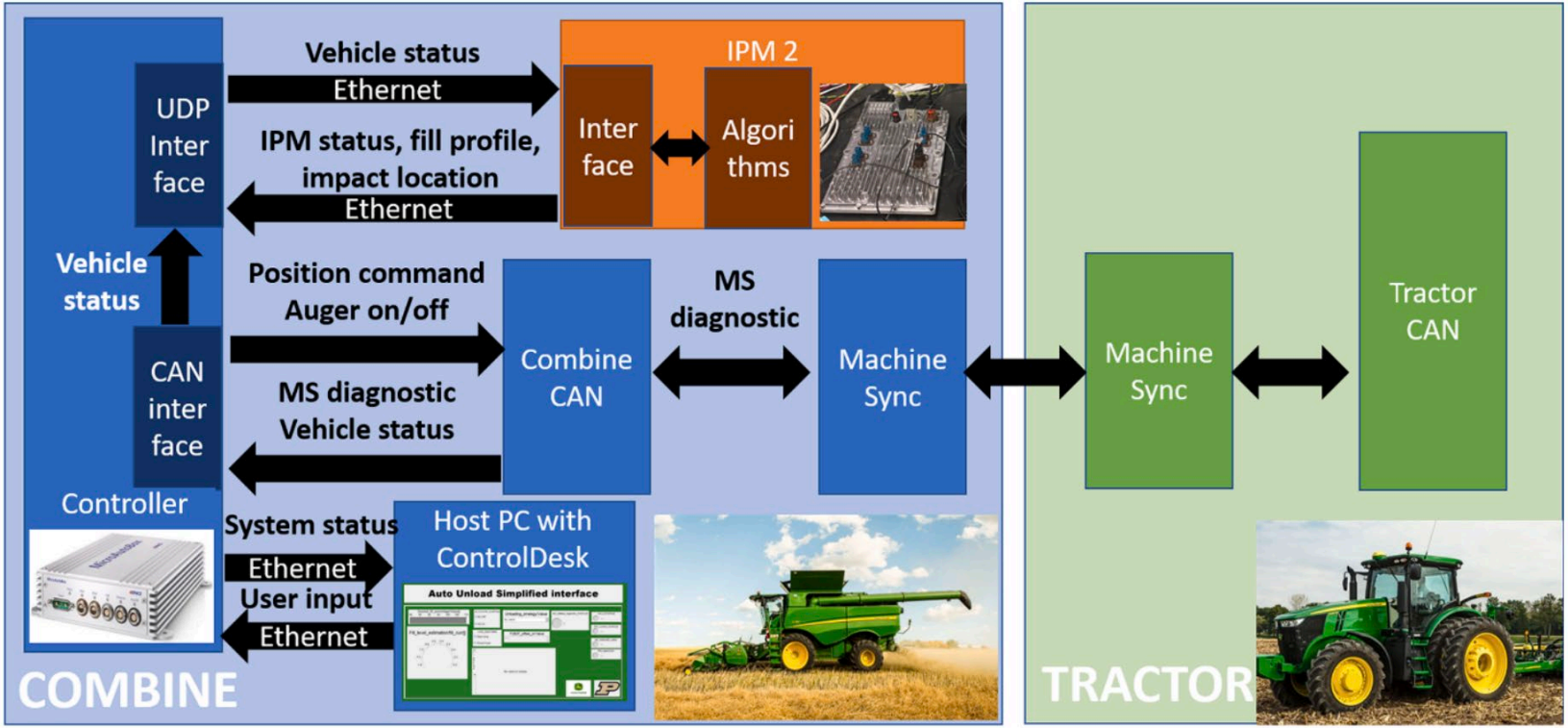
(d) 151617 model.

P – progress

There is a gap in performance for forage nutritive value, CSPS, and actual length-of-cut.



6. Coordination with wagons and trailers

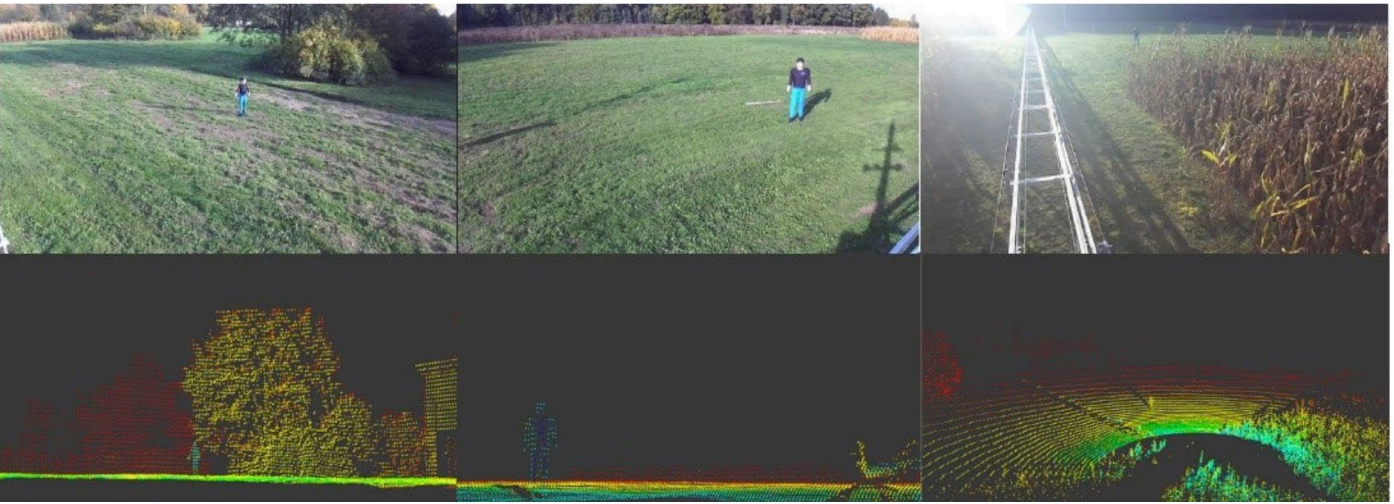


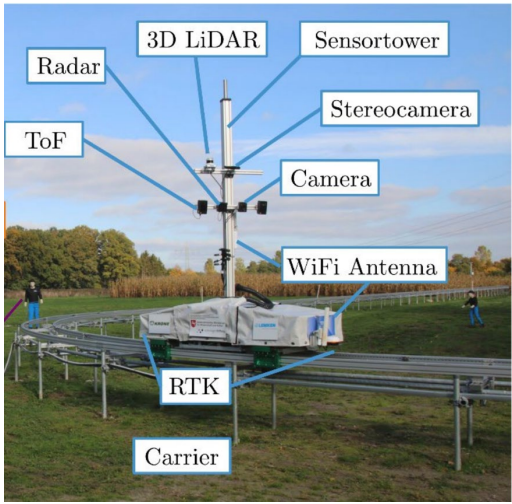
🤔 Not a forage harvester!

6. Coordination with wagons and trailers – Mixed fleet challenge.

📉 O – Opportunities!

Coordination with over-the-road vehicles will pose a significant challenge.

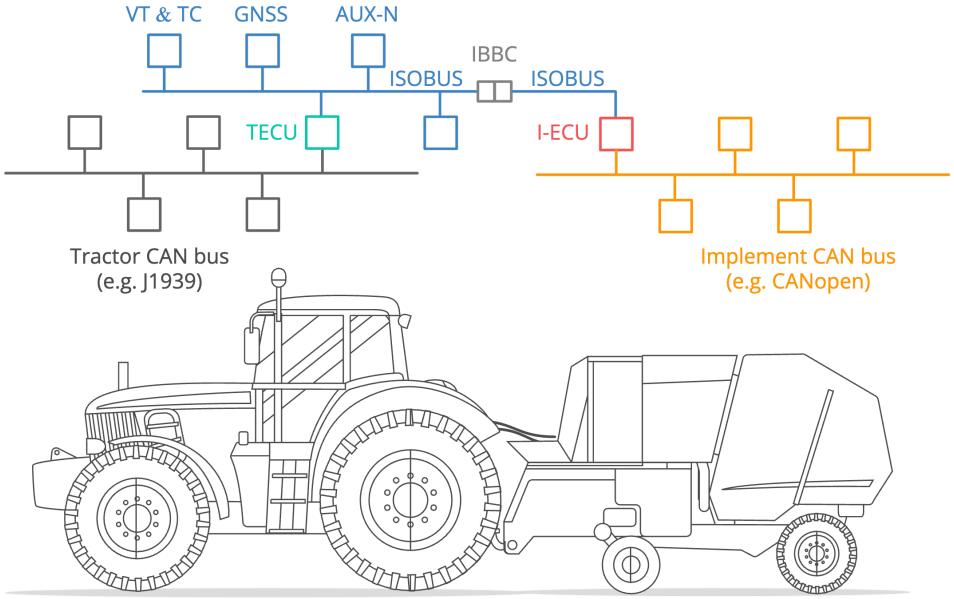



3D LiDAR
Sensortower
Radar
Stereocamera
ToF
Camera
WiFi Antenna
RTK
Carrier

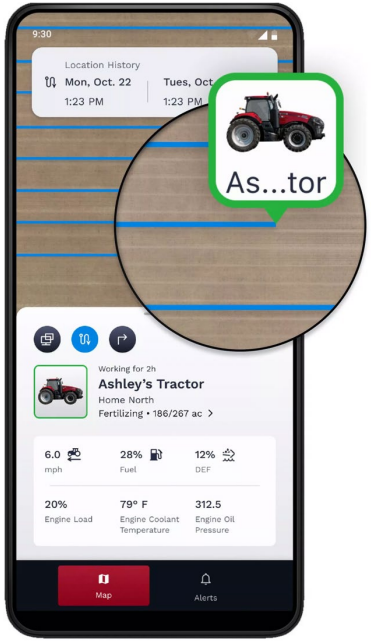
O – Opportunities!

More needs to be done to understand how vehicle safety systems will perform in the field environment.

Sensors **2017**, *17*(11), 2579


VT & TC
GNSS
AUX-N
IBBC
ISOBUS
ISOBUS
TECU
I-ECU
Tractor CAN bus
(e.g. J1939)
Implement CAN bus
(e.g. CANopen)


Map


9:30
Location History
Mon, Oct. 22
1:23 PM
Tues, Oct
1:23 PM
As...tor
Working for 2h
Ashley's Tractor
Home North
Fertilizing • 186/267 ac
6.0
mph
28%
Fuel
12%
DEF
20%
Engine Load
79° F
Engine Coolant Temperature
312.5
Engine Oil Pressure
Map
Alerts

Olathe, January 13, 2025

Basildon, May 15, 2025

STARLINK

P – progress

Industry has made significant investments, but there remains a gap in interoperability.

Report Card	
1. When to harvest	
2. Machine setup, maintenance	
3. Navigation and guidance	
4. Throughput management	
5. Quality of job done	
6. Coordination with wagons	
7. Safety and compliance	
8. Connectivity	

Overall:

Significant progress toward autonomy over the last decade

Near-term investments will reduce specialized training and operators while improving safety and quality of life.

Illustration generated using OpenAI's DALL·E via ChatGPT, customized for conceptual visualization.

Thank you for your curiosity and attendance!