Tech Stacks in Ag:

The opportunities and challenges of sensor & compute technology stacks for agriculture

2025 ASSBT BIENNIAL MEETING

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Agenda

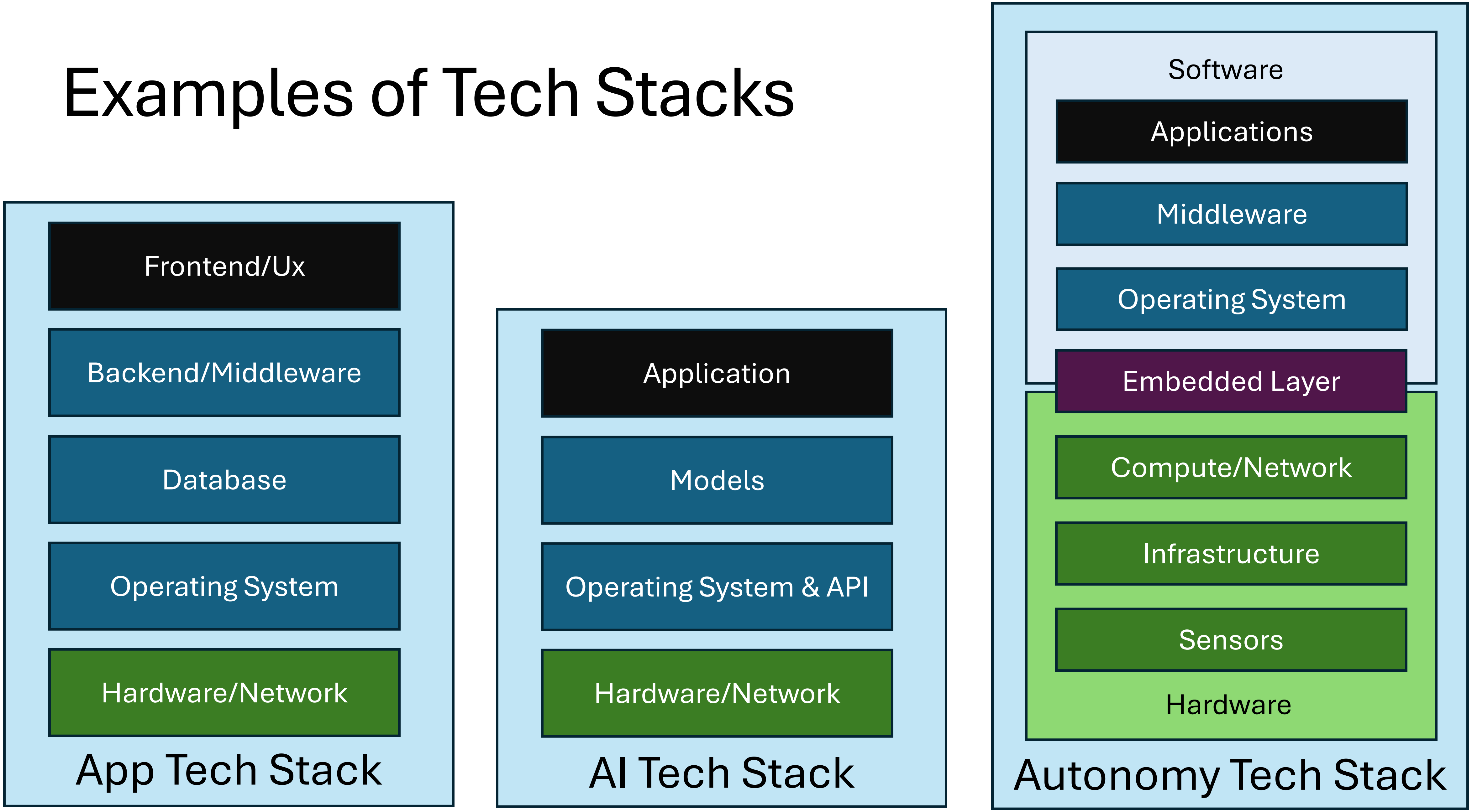
What is a tech stack?	Examples of technology stacks
Sensors	Agriculture Sensor Stacks Sensor Fusion
Compute	Ag and Off-Highway Compute Compute Constraints
Towards Per-Plant Management	Integration for Precision
Towards Autonomy	Integration for Autonomy

Disclaimer*: The views and opinions expressed in this presentation are those of the author and do not necessarily represent official policy or position of John Deere.*

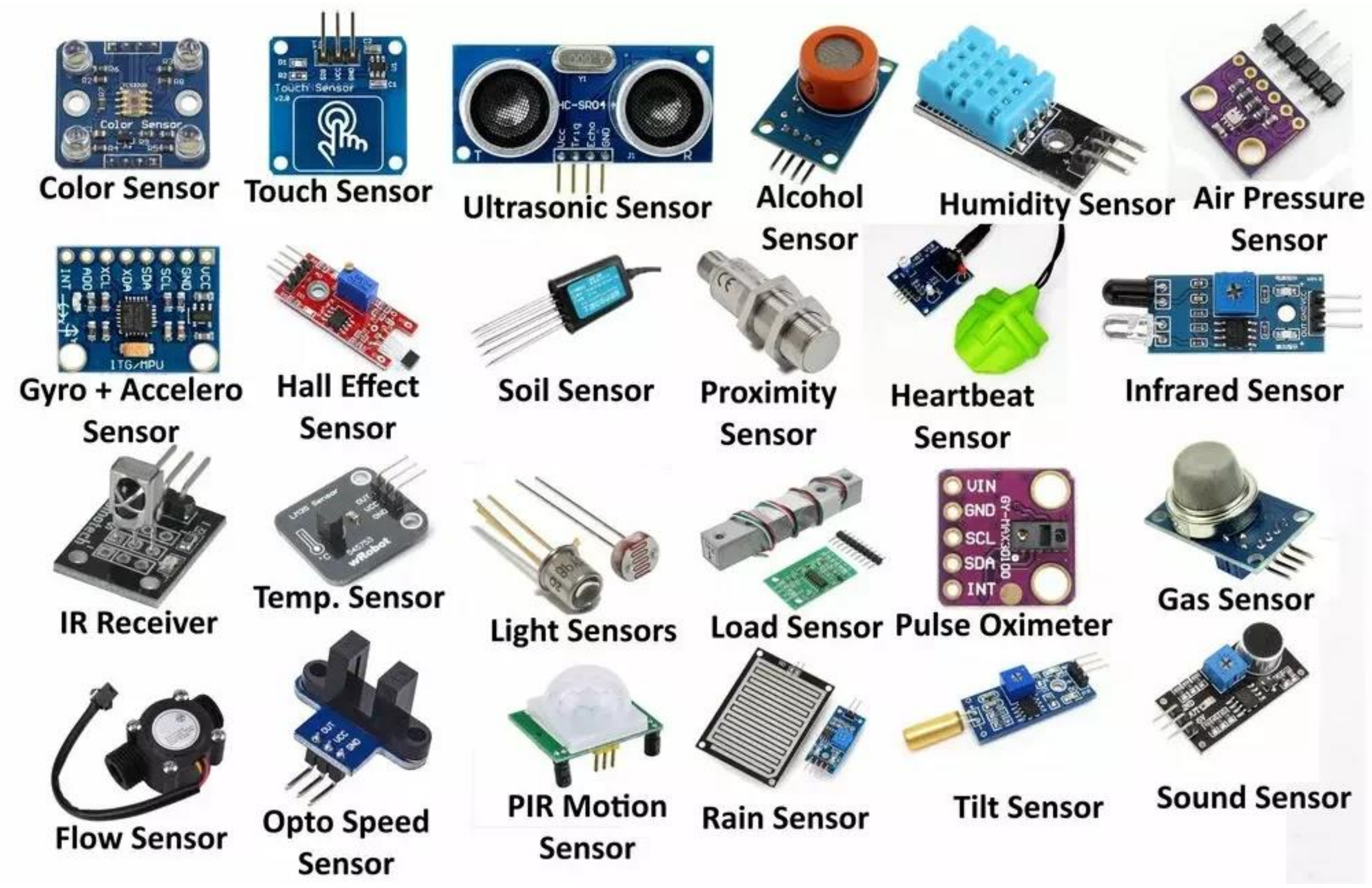
What is a Technology Stack?

- Technology is constructed by culture and subject to evolution
  - Competition, selection, replication, mutation
  - Even language is technology
  - Engineering is systematized technology creation & problem solving
- Technology builds on top of (vertically) other technology
  - A **car** needs **wheels** needs **tires** needs **rubber** needs **vulcanization** needs **sulfur** needs **refining** needs **natural gas** needs **pipelines** needs **pumps** needs **fracking** need **wells** need **drilling** needs…
- The term "tech stack" represents the vertical dependencies of sets of technologies needed for a product/service
  - The term is mostly used in the software industry, but gaining in other industries

Examples of Tech Stacks



Sensors



Color Sensor
Touch Sensor
Ultrasonic Sensor
Alcohol Sensor
Humidity Sensor
Air Pressure Sensor
Gyro + Accelero Sensor
Hall Effect Sensor
Soil Sensor
Proximity Sensor
Heartbeat Sensor
Infrared Sensor
IR Receiver
Temp. Sensor
Light Sensors
Load Sensor
Pulse Oximeter
Gas Sensor
Flow Sensor
Opto Speed Sensor
PIR Motion Sensor
Rain Sensor
Tilt Sensor
Sound Sensor

Sensors give info about the environment

Transduction → Translation → Integration

Some sensors have more than one transduction step

Transduction is the conversion of energy forms

Thermocouples:

- Speed of gas molecule → electron movement → voltage difference → translation → temperature

Cameras:

- Photon energy → charge → pixel value → detection

Accelerometers:

- Movement change → deflection → resonance → charge → voltage → acceleration measurement

Sensors in Ag Equipment

Types: Position, temperature, pressure, moisture, humidity, level, geospatial, yield, nutrient, carbon, optical, grain loss, distance, dimension, seed presence, image, chemical, acceleration, speed, oxygen, rate, LIDAR, radar, depth… more.

Environment: -40° to 80-105 ° Celsius (depending on location), vibration and shock, electrical transients, EMC, ESD, chemical exposure…more

Complexity: Simple analog, complex analog, digital, smart

Stacking and Fusing Sensors

Embodiment

- To move in the world needs a model of the world

Unimodal vs multimodal fusion

- Stitching multiple camera feeds
- Building spatial models from multiple sensor modalities
  - e.g., Camera + LIDAR

Compute

SAE/Ryan Gehm

Ag & Off-Highway Compute

What kind of compute: CPU, GPU, TPU, FPGA, ASIC

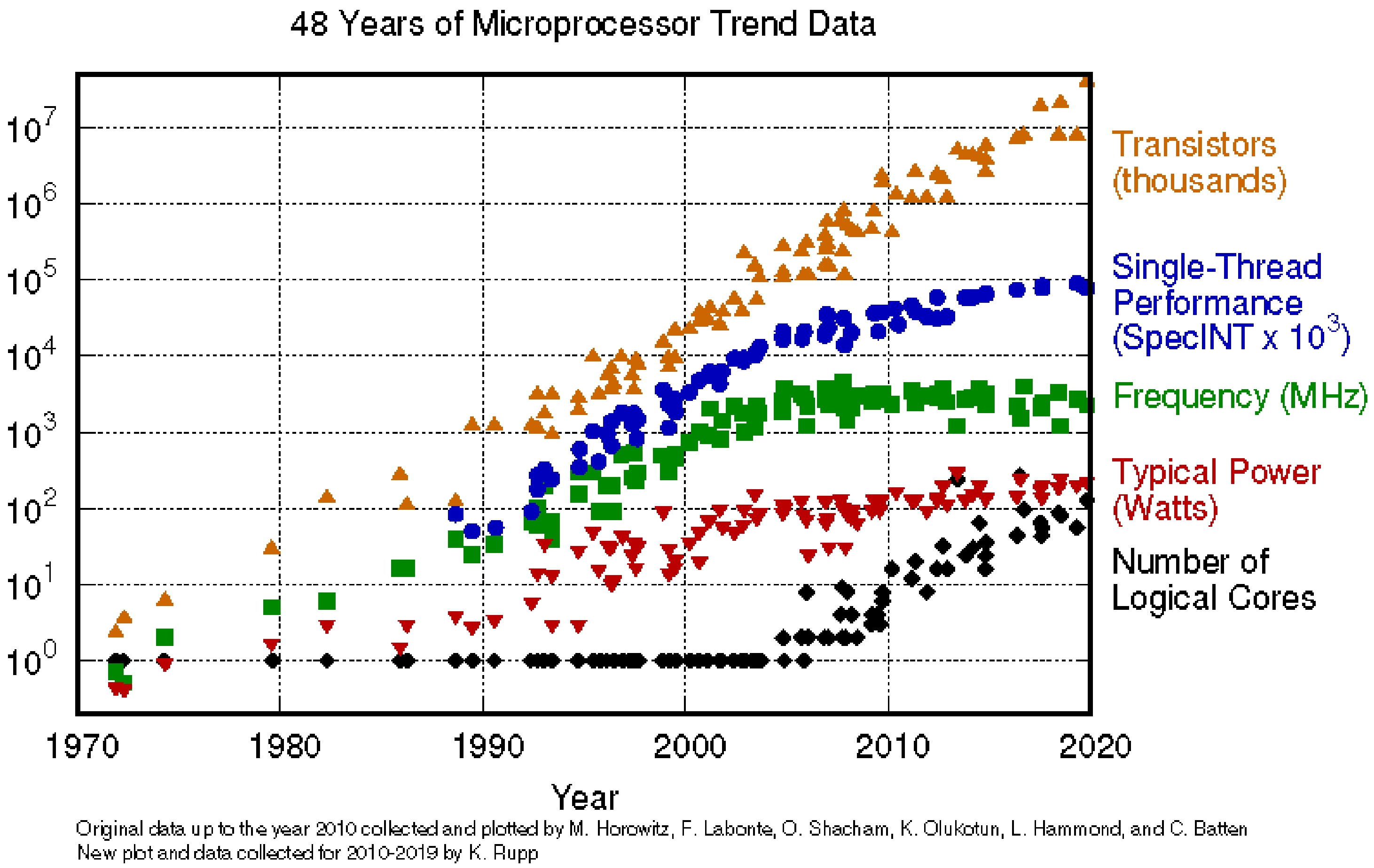
- Flexibility versus efficiency

Where is the compute: edge, node/hub/module, or cloud

How much compute is needed: simple analytic, simple algo, complex algo, high bandwidth, inference, bi-directional

Compute Constraints

- Scale/supply/cost
- Transistor size
- Thermal management
  - Modeling
  - Material science
- Architecture
- Software
- Ruggedness



The Journey to Per-Plant Management

Seed singulation

Per-plant application

Precision guidance

Per-plant yield

Agronomics data

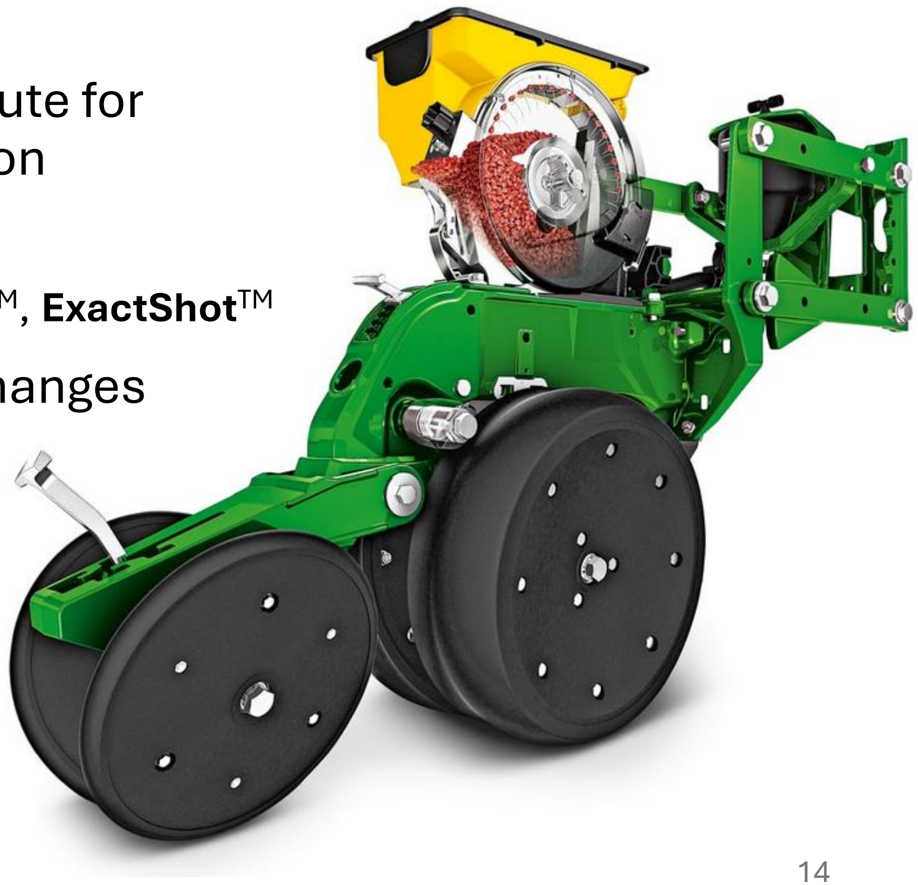
Sensors & Compute Integration for Precision

Systems need high fidelity and accuracy

- High resolution imaging and fast high-density compute for weed/crop detection/recognition and yield estimation
- e.g., Deere ecosystem
    - **See & Spray**™, **ExactEmerge**™, **ExactApply**™, **ExactRate**™, **ExactShot**™

Sensing systems must account for environmentally changes

Systems must be field upgradable



The Journey to Autonomous Systems

Autonomy need automation of functions (sometime the order of automating matters)

- e.g., Deere ecosystem
  - **AutoTrac**™ – auto-steer with precision GPS
  - **AutoTrac**™ **Row Sense** – extends AutoTrac™ in post emerge (stays off crop rows)
  - **AutoPath**™ – automatically determines full-field guidance lines
  - **AutoTrac**™ **Turn Automation** – automatically turns and lines up for the next rows
  - **Section Control** – sections a field for rate variable application and minimizing overlap
  - **Machine Sync** – control speed and position of unloading wagons
  - **In Field Data Sharing** – machines can see the same as-applied coverage maps
  - **TruSet**™ **Tillage Technology** – adjusts tillage depth dynamically
  - Generation I and II **Autonomy Kit**

Autonomy needs connectivity (e.g., Starlink)

- Remotely monitor, interact and see performance data

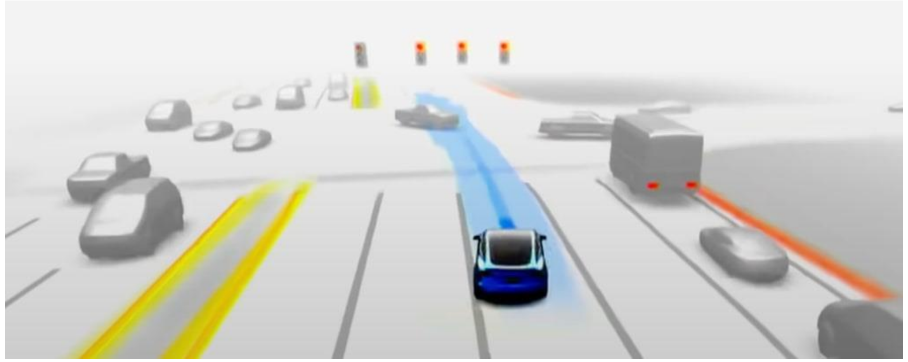
Autonomy needs sensor fusion for trainable models for inference

Systems must be field upgradable

Sensors & Compute Integration for Autonomy

- Sensors must feed trained models
  - Training must include LOOOOOONG tail of corner conditions
  - Farmsite autonomy is on- AND off-highway autonomy
    - Off-highway models need unique training data
- Dynamic model creation must account for sensor variability
  - What happens when a camera lens gets dusty?
  - What happens when a sensor mounting shifts?
- System must be “functionally safe”
  - Redundant, reliable and secure

ISO 26262



Summary

- The **maturity of technology stacks** advance by incremental de-constraining and innovation at each layer in the stack
  - Each iterative improvement is driven by economics
  - AI might accelerate things
- **Per-plant management is hard**, but will continue as long as value continues to be unlocked
  - Likely to be increasingly compute intensive
  - Not clear how much total value is unlockable with optimizing from data
    - But a lot of value is likely to be unlocked
- **Autonomy appears to be inevitable** and achievable
  - Long tail of corner conditions paces autonomy

Questions?