Evidence of Safety in Autonomous and Highly-Automated Agricultural Machines

- John Shutske, Professor & Extension Agricultural Safety Specialist
- University of Wisconsin—Madison
- Department of Biological Systems Engineering
- School of Medicine & Public Health Affiliate Professor

Some Background

- My background – Tech applications in ag safety (human presence sensors, control systems, automated fire control); human factors; safety education, policy, culture.
- Development of NEW risk assessment methods in the absence of historical data.
- One of the leaders of SAFER Ag 1.0 (late 2022) and 2.0 (late 2024).
- Familiar with California situation (FIRA events, CAL-OSHA activities).
- Shout-out to my colleagues in this space (academia, federal agencies, private companies).

My Opinion – Layered Approach to Achieve Higher Levels of Safety

- Detailed data on safety system and component performance
- Exposure data – over multiple seasons, what is this system “seeing?”
- Integrating consensus-based engineering design standards
- Compliance with “Functional Safety” standards for systems that have a safety function
- Risk assessment with engaged designers, dealers, service/deployment people, and end users
- Learning from other industries – Mining, Construction, Manufacturing, Motor Vehicles

Data – Possible Approaches, Limitations, Directions to Improve

- “Chicken & egg” situation – in risk assessment, we often rely on historical data (injuries, deaths, outcomes)
- With NEW tech, these data do not exist
- Our data collection systems have only recently been modified to pick up ag robot and autonomous machine incident
- Note on recent changes to Occupational Injury and Illness Classification System (OIICS)
- What about the approach of saying: “We’ve operated for XXX hours without an injury or death?”

We* Suggest a Different Data Approach

- Knowing that a machine has seen XXXX hours of operation is a START
- Need to know “What did machine see over those operating hours?” – What situations did it encounter? During encounters, how did safety functions perform?
- Were there close calls? Safety successes?
- What were the conditions when the safety successes and close calls happened?
- Were operational “edge conditions” reflective of the real world?
- Idea (from paper) to aggregate exposure/performance data anonymized by use case and sensor type (e.g., LiDAR sensors on tractors doing tillage).

Shutske, J.M., Issa, S.F., Johnson, T., Khorsandi, F., Pate, M.L., Gorucu, S., Walsh, J., Yoder, A.M., Dukes, E., Aby, G.R. and Versweyveld, J., 2025. SAFER AG–Risk Assessment, Data, Design Standards, and Regulation: Needs and Recommendations. *Journal of Agricultural Safety and Health*, *31*(1), pp.1-13.

Engineering Design and Safety Standards – “Compliance” and/or Evidence of Full Consideration

- **Quick Primer:**
- Engineering design standards = bedrock for safe design
- Consensus development
- Research-informed
- Ideally include ALL stakeholders in development
- While voluntary, they are often a first line pursued (by plaintiffs or defendants) in litigation.

Engineering Design and Safety Standards – Autonomy and Highly Automated Machine Efforts

- MUCH effort in the last 10 years to make ag autonomy standards applicable, usable, and clear
- Reference 2024 version of ISO 18497
- Title: Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery.

More on Standards

- ISO 18497 reference in previous slide – there are MANY others – see papers below.
- Standards compliance is complex.
- Large companies often have full teams and units that focus MUCH of their effort on standards development and compliance.
- A bigger challenge with smaller companies, start-ups, inventors.
- There are multiple “types” of standards – Types A, B, C (ranging from GENERAL to more specific details).
- SaferAg 1.0 recognized the need for more standards-related outreach, and SaferAg 2.0 included more professional development for the industry.

Shutske, J. M., Sandner, K. J., & Jamieson, Z. (2023). Risk assessment methods for autonomous agricultural machines: A review of current practices and future needs. *Applied Engineering in Agriculture*, *39*(1), 109-120.

Functional Safety – Compliance and Analysis

- Functional safety = evaluation and design of components and systems that have a safety-related function.
- Strong connection to motor vehicles – In your car, multiple safety components built into braking, steering, vision sensors, radar.
- Includes analyses of component and system performance under a wide range of conditions; design to specified “performance” levels; multiple means to document safety performance.
- Starting point for understanding: ISO 25119.
- Several firms provide consultation, support, and training for Functional Safety.

Risk Assessment with Multi-Disciplinary Input and Engagement

- We lack data for traditional methods that require estimates of the “probability” of incidents.
- We can work in a team setting (engineers, dealers, service personnel, operators, etc.) to brainstorm likely/foreseeable issues and events.
- Interactions between the PERSON, MACHINE, and surrounding ENVIRONMENT is complex.
- Methods like Fault Tree Analysis, FMEA, and HARA (Hazard Analysis and Risk Assessment) can provide structure.
- Failure to “anticipate” what COULD occur is a failure of imagination.

What Else is Needed?

- All in this sector need to think “safety first” – not just big OEMs.
- If a company says, “safety is less important” (based on size, mass, speed, high energy hazards) it must still be able to SHOW that safety was carefully examined and documented via standard compliance.
- If (as an example), contact with a 100-pound robot is not a “concern” – this will show up as we evaluate “severity” in the risk assessment.
- A single significant incident will have profound impacts based on public perception.
- Learn from other industries:
  - Construction and mining are closest analogs – similar concerns, slow and controlled trials, tethered machines, highly defined operating spaces
  - Manufacturing has been doing this for several decades – Initial uses in highly protected zones (often inaccessible to humans) – but now more mobile (enabled by tech improvements and functional safety requirements)
  - ALL of these industries lean HEAVILY into engineering standards and functional safety

Final Thoughts

- Engagement – getting ALL stakeholders to the table.
- Hernan Hernandez, Executive Director of CA Farmworker Foundation (10/18/2022) in Fresno:
    - “One thing that I do want to emphasize is the workforce that we have today knows the fields. They lived in the fields. They worked in the fields for 10, 20, 30, 40, 50 years. They know exactly what the terrain looks like. They know exactly how to do the work. And one thing that we would want to see is more farm workers being included in the discussions so that therefore we can produce better technology that's not only safe, but also has the input of a worker. And then how do we train that employee so that therefore they can develop the new skill sets that they need to operate, to maintain, and to service that machine.”

Questions, Comments, Final Thoughts?

- John Shutske, University of Wisconsin—Madison, Department of Biological Systems Engineering
- shutske \at wisc.edu
- Check out additional articles at: https://asabe.org/jash
- Thanks to colleagues around the U.S. for great thinking, collaboration, and concern for this important work!!