Occupational Safety Research Needs in the Field of Robotics and Autonomous Machines in Agriculture

Collection Review

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HIGHLIGHTS

- Comprehensive view of occupational safety research: Prioritizing topics in robotics and autonomous machines.
- Barriers to safety research: Logistical, intellectual property, timeline, and funding challenges.
- Importance of surveillance or tracking system: Documenting fatalities, injuries, and near misses/good catches.
- Priority safety research needs: human-machine interaction, adoption of automation in the work setting, and surveillance/tracking.
- Collaboration with technology developers: Overcoming barriers and exploring emerging technologies and potential safety implications.

ABSTRACT. *In 2022, the SAfety for Emerging Robotics and Autonomous AGriculture (SAFER AG) Workshop was held to discuss and understand emerging challenges related to safety, occupational safety research needs, workforce implications, and other issues associated with robotics and autonomous machines in agriculture. This paper presents the major findings from the occupational safety research track of the workshop. This track identified existing hurdles to conducting occupational safety research including logistical barriers, intellectual property concerns, long timelines, and lack of funding. Considerations for developing a tracking or surveillance system for adverse events as well as*

Submitted for review on 3 October 2024 as manuscript number JASH 16216; approved for publication as a Review Article and as part of the Safety for Emerging Robotics & Autonomous Agriculture Collection by Associate Editor Dr. Aaron Yoder and Community Editor Dr. Michael Pate of the Ergonomics, Safety, & Health Community of ASABE on 28 April 2025.

Citation: Lincoln, J., Gorucu, S., Khorsandi, F., Aby, G. R., Elliott, K., Shutske, J., & Issa, S. F. (2025). Occupational safety research needs in the field of robotics and autonomous machines in agriculture. *J. Agric. Saf. Health, 31*(3), 217-230. https://doi.org/10.13031/jash.16216

exposure related to these technologies were also discussed, emphasizing the need for a comprehensive system. Finally, the priority occupational safety research needs identified during the session were related to human and non-human machine interaction, adoption of automation in the work setting, and event tracking/surveillance. To overcome barriers to research, collaboration between occupational safety researchers and technology developers is crucial. Enhancements to existing surveillance systems can facilitate better understanding of captured events. Additionally, prioritizing research on worker risk from robotics and autonomous machines in agriculture is essential. The integration of robotics and autonomous machines in agriculture has revolutionized the industry but requires evidence-based safety research, outreach, and education to ensure worker safety and health.

Keywords. *Agriculture industry, Autonomous machines, Robotics, Safety research needs, Surveillance.*

The agriculture industry is in an era of digital revolution, with new technologies and robotics transforming land preparation, planting, cultivation, chemical application, yield estimation, harvesting, phenotyping, and post-processing (Oliviera et al., 2021). Advances in harvesting speed, vision systems, and the reduction in damage rates while harvesting plants are leading to the adoption of a variety of robotic and autonomous machines (Howard and Lincoln, 2022). On the other hand, agriculture is among the most dangerous industries in the United States (U.S.) (BLS, 2021). A high number of fatalities and injuries occur in the U.S. agricultural industry (Li et al., 2024). Automation and autonomous machines present the potential to reduce operator exposure to hazards and to transform tasks often characterized as “dirty, dangerous, and demanding” (Quandt et al., 2013), while also potentially helping to alleviate growing concerns about labor shortages (Shutske, 2023).

Examples of the latest machines and robots in agriculture include autonomous machines/vehicles, co-existing robots, collaborative robots, and wearable robots. Autonomous ground vehicles, such as self-driving tractors, sprayers, and harvesters (fig. 1), can perform tasks like tilling, planting, harvesting, and spraying with greater precision than human operators (Rahmadian and Widyartono, 2020).

Co-existing robots operate independently within the same workspace as human workers, performing different tasks without the need for constant human control. Examples of co-

Figure 1. Autonomous tractor (www.monarchtractor.com) (left) and autonomous sprayer (www.gussag.com) (right).

existing robots in agriculture include autonomous mobile platforms for transporting goods, automated irrigation systems, and robotic weeders. Some notable commercial examples of co-existing robots in agriculture are Oz, developed by Naïo, a compact robot with limited need for human control/operation to assist farmers in various tasks, such as weeding, seeding, and planting (NAIO Technologies, 2022). By supporting these essential operations, these co-existing robots streamline agricultural processes, allowing farmers to focus on other important aspects of their work, such as timeliness of operations, farm management, and financial concerns (fig. 2).

Collaborative robots conduct work alongside workers. By sharing the workload, collaborative robots allow workers to focus on more complex or delicate tasks that require human expertise (Khosro-Anjom et al., 2014; Tagarakis et al., 2021). In many cases, collaborative robots are equipped with advanced sensing and machine-learning capabilities, enabling them to adapt to the varying conditions of agricultural environments (Emmi et al., 2014). One example of a collaborative robot is "FRAIL-bots" (Fragile cRop hArvest-aIding mobiLe robots) designed to work alongside workers in strawberry harvesting (Peng et al., 2021, 2022). The workers pick strawberries and load them in a tray, then FRAIL-bots transport the full trays to a storage area (fig. 3.). Another commercial example of collaborative robots in agriculture is the Burro 9 (Burro AI, 2023), a four-wheeled robot equipped with computer vision and high-precision GPS technology, enabling it to follow workers

Figure 2. Co-existing robot, Oz, developed by Naïo (NAIO Technologies, 2022).

Figure 3. Examples of collaborative robots developed in academia: (left) "FRAIL-bots," get the full strawberry trays from pickers (Peng et al., 2021, 2022), and (right) a commercial collaborative robot, Burro 9 (www.burro.ai).

and learn routes and function autonomously (fig. 3). Primarily designed to aid pickers, the Burro helps carry heavy loads, reducing physical strain on workers and increasing overall efficiency.

Finally, wearable robots include exoskeletons, which can ease strenuous tasks such as lifting heavy objects (Thamsuwan et al., 2020) or supporting the worker's body in prolonged stooped postures (fig. 4), and monitoring devices, which can empower workers to improve their productivity or monitor vital signs for possible safety and health concerns. For simplicity, we include both active (powered) and passive exoskeletons in this category, although some consider only powered exoskeletons to be robotics.

The development of robotics and automation, including autonomous machines, is not unique to the agriculture industry. Neither is the need to understand the occupational safety and health risks these new technologies either eliminate or create for the worker. To respond, the National Institute for Occupational Safety and Health (NIOSH) established the Center of Occupational Robotics Research (CORR) to provide scientific leadership to guide the development and use of occupational robots that enhance worker safety. The CORR helps to increase the understanding of human and machine interactions to ensure human worker safety by improving the ability to identify and track injuries and fatalities involving automation/robotics and providing guidance on working safely with automation/robotics in all industries (NIOSH, 2024).

In 2022, a diverse group of researchers began discussing the existing applicable standards and existing guidance related to automation and robotics in the agriculture industry. The group quickly recognized the need for a multidisciplinary approach and identified an opportunity to organize a workshop focusing specifically on automation and robotics in agriculture.

A small team of academic and industry partners and NIOSH personnel organized the SAfety for Emerging Robotics and Autonomous AGriculture (SAFER AG) Workshop, held on 9–10 November 2022, at the University of Illinois, Urbana-Champaign (SAFER AG, 2022). The workshop was sponsored by the United States Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA) although the original concept to develop the conference was from the Intelligent Robotics and Autonomous Systems (IRAS) Interagency Working Group (IWG) of the Networking and Information Technology Research and Development (NITRD) Program. SAFER AG's goal was to identify gaps in knowledge and research needs related to risks and regulations/standards,

Figure 4. Wearable robot example: using an exoskeleton to support a worker's body in prolonged stooped posture (Laevo Exoskeletons, 2023).

occupational safety research, and impacts on the workforce and society. The purpose of this paper is to summarize the findings from the occupational safety research track of the SAFER AG workshop.

Materials and Methods

As explained in Shutske et al. (2025), two initial roundtable sessions were held during the workshop to ground all participants and increase familiarity of participants about the trends of agricultural autotomy, examples of robots being applied on farms and ranches, and some of the novel hazards, safety concerns, and other expected and unexpected positive and negative consequences associated with these new types of machines. The initial sessions were followed by facilitated working group sessions.

There were 100 attendees of the SAFER AG workshop representing academia (42%), industry (equipment manufacturers) (36%), government, and other organizations (22%). However, details of how these 100 attendees were distributed into the working group sessions in the afternoon are unknown. There were three tracks to choose from: risk assessment and standards, occupational safety research, and societal impacts. The objective of the occupational safety research track was to identify (1) existing hurdles to conducting research in this area, (2) factors to consider when developing a tracking system (surveillance system) for events related to these new technologies, and (3) priority occupational safety research needs. Every workshop attendee (n=100) was asked the following questions:

1. What is the biggest thing holding you back from pursuing partnerships with academic researchers to study occupational safety?
2. When developing a tracking system (surveillance system):
    a. What types of data collection methods and systems are in place to monitor injuries as things become more automated up to and including full autonomous operation?
    b. What additional systems and tools need to be put into place?
    c. What is known about injury and other adverse events from other industries where automation has been more fully adopted?
3. What are the top two occupational safety research topics regarding autonomous machines/robotics that we should focus on over the next 5–10 years?

Then, a subset of attendees (n=25) sorted and organized the responses to identify key themes. The responses were grouped by similarity without any predefined criteria. Themes were identified by grouping the responses with similar meanings through physical sorting. The facilitator then led discussions with the group for 2.5 hours on these themes, took notes, and compiled a summary document of the theme areas. To encourage frank, open, and complete conversations, this session was not recorded or transcribed verbatim. Instead, detailed notes were taken. The details in the notes were purposely not attributed to any specific sector, person, or organization.

Results

What Are the Hurdles to Conducting/Collaborating on Safety Research?

The group reported several logistical barriers that may hinder research partnerships between equipment manufacturers and academicians. These include concerns related to intellectual property and proprietary information, the slow speed of research, and a lack of funding for safety-related research projects. In addition, academicians are sometimes perceived as lagging behind manufacturers in their knowledge of emerging technology such as automation. As a result, equipment manufacturers do not always see collaborating with academicians to conduct meaningful research as effective or beneficial. There are also challenges finding students at universities who have dual interests in occupational safety as well as the technical aspects of automation.

What to Consider When Creating Tracking Systems for Events Associated With Robotics and Autonomous Machines/Vehicles?

Tracking events, or "surveillance," was a significant topic of discussion that included issues related to the type of data needed to be gathered, from whom, with what level of anonymity, who should gather the data, and how it should be assessed. Participants discussed the possibility of utilizing existing injury surveillance systems but emphasized that it is a necessity to develop a separate comprehensive surveillance system to document fatalities, injuries, and near misses related to autonomous/robotic machines (mobile and immobile).

To measure the exposure to potential hazards associated with working alongside robots and autonomous machines as well as to evaluate the risks of injury from these hazards, the group discussed the need for innovation in using robots and autonomous machines for this purpose. For example, the group proposed that machines collect data on the number of interactions with humans as if humans operated the machines within the operational parameters set by the manufacturer. Likewise, sensors could be used to identify when an "event" occurred and what the machine did to respond to it. However, the group identified the importance of developing a process to access these data by authorized parties while protecting privacy. There is also a need to establish a data use agreement for researchers to follow. Onsite evaluations before and after adoption of some automation in the work setting may be used to assess ways to identify adverse outcomes and improve worker safety conditions.

Additional discussion focused on who would collect and house surveillance data. The participants suggested finding a non-governmental entity that could be trusted to collect and oversee the data, with the resources to accommodate adequate storage, use, and data security needs.

The group also expressed a desire to understand near miss events and emphasized the need for accurate nomenclature when defining and documenting events. Terms such as "near miss" may not be the right word if the machine acted as it was designed to do. If the autonomous machine acted in "exactly the way it was supposed to," is "near miss" the correct term to describe it? The incident could have been prevented by activating the safety system correctly and avoiding dangerous situations. Therefore, the group suggested "good catch" and "safety success" as alternative phrases and proposed the following definitions (also see fig. 5):

Incident: an event in which damage to a human or machine was a result.

Near miss: an event where no harm or damage to a human or machine occurred, but with slight alterations in the situation, it could have happened.

Safety Success (instead of near miss): an event in which damage to a human or machine did not result, largely because of human intervention or the safety system of machines.

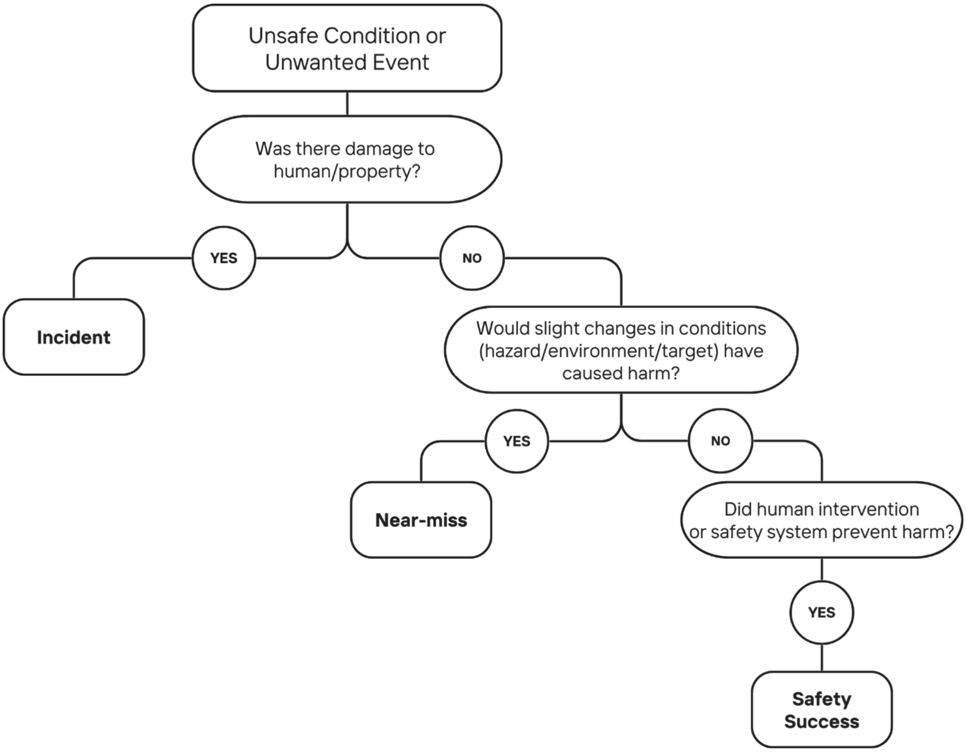

Figure 5. Flow chart illustrating definitions of conditions or events.

The group also discussed potential attribution problems of reporting systems when these structures include coding a single cause, limiting causes to a set of options, masking true drivers of incidents, and others. The problem with identifying a single cause is that they often mask a complex situation in which no single cause was 100% of the reason that the adverse event occurred. The discussion suggested moving away from "causes" and toward "contributors" to highlight the complex nature of each individual event. Moreover, the anonymity of both people and equipment manufacturers involved in an incident was determined to be a key issue and a topic for further exploration. Anonymity will be needed to avoid identifying manufacturers of the machines involved in the event to avoid its use in any litigation.

What Are the Priority Occupational Safety Research Needs?

The final area discussed in the research track was the priority safety research needs. Participants were asked, "What are the top two occupational safety research topics regarding autonomous machines/robotics that we should focus on over the next 5–10 years?" The group aggregated the responses into several categories. Table 1 shows the general research topics followed by a short description.

Research Needs Related to Human Machine Interaction

The priority topic from attendees was research pertaining to human-machine interaction. The group focused the discussion on the importance of developing and evaluating safety

Table 1. Safety research topics collected from SAFER AG Participants by CORR research agenda.

SAFER AG Safety Research Topics Prioritized	Short Description
Human-Machine Interaction (Including Use/Misuse of Autonomous Machinery)	Participants described this as the study of interaction between humans and machines. This includes the need to test and develop safety engineering and warning systems, calibrating trust and confidence, cognitive research, behavioral research, and user interfaces.
Non-human machine interactions	Autonomous machines will interact with non-humans (e.g., animals, other vehicles, irrigation system) as well. Research is needed to understand indicators that could lead to a safety incident.
Adoption of Automation in the work setting	This includes understanding the drivers for adoption of technology and how much a desire to reduce safety risks is included. This reflects a need for encouragement of automation, safety-specific adoption, and understanding what role AI should play, if any.
Surveillance	The need for a comprehensive surveillance system to centralize documenting fatality, injury, and near miss events.

engineering and warning systems to protect workers from hazards when interacting with machines. Related to this is the concern associated with the maintenance and repair activities or any other condition or operational state in which a machine is not acting as expected. Workers may face risks while performing these tasks in close proximity to automated systems. The group discussed the need to implement robust obstacle detection and response systems that can adjust the robot's operation or enforce safety stops when a human enters a specified high-risk zone. A high-risk zone is the opposite of safe envelopes for the robots and workers. A high-risk zone could be 1 foot, 2 feet, 3 feet, etc. around the robot, depending on its size, speed of operation, and body materials.

Attendees also discussed the need to understand behavioral research, such as exploring how robots and automation can influence human behavior. Understanding these influences is crucial for designing systems that promote safe and efficient collaboration between humans and machines. Detection of the presence of a human should be prioritized to understand how humans can be made aware that the machine has acknowledged their presence in its vicinity. In particular, detecting the presence of a human being should be a priority, not only in terms of sensing technology but also in terms of communication, to ensure that workers are aware that a machine has recognized their presence and adjusted its behavior accordingly. Visual signals and auditory alerts could be used to improve this mutual awareness.

Lastly, worker trust and confidence were identified as key factors when working with or near machines. Establishing trust between humans and machines is essential for fostering a positive work environment where individuals feel comfortable and secure in their interactions with automated systems. Inconsistent or imprecise robotic movements can significantly erode worker confidence, leading to hesitation or errors in human-machine interaction.

The group also discussed the use and misuse of autonomous machinery, and attendees identified three different types of usage: intended usage, alternative usage, and misuse. The group was concerned about the operator having the ability to override machine controls. They highlighted the importance of turning off the machine when necessary and wanted to enforce safe operating procedures to minimize the risk of incidents due to outside interference. They discussed the implementation of temporal, spatial, and functional controls over an autonomous system.

Additionally, the attendees acknowledged an alternative uses category to recognize that machines may be used for purposes other than those originally intended by the manufacturer. This does not fall under either intended use or misuse since it does not imply purposeful hindrance of machines or engagement in activities prohibited by instructions. Finally, the workshop participants also addressed possible misuses and related research areas. These included deactivations or disabling of safety features, intentional sabotage, and operator error.

Research Needs Related to Non-human Machine Interactions

Autonomous machines will interact with non-humans (e.g., animals, other vehicles, irrigation systems). Research is needed to understand indicators that could lead to a safety incident not involving a human. Animals, power poles, trees, holes, ditches, ponds, houses, other vehicles, and unexpected items like an abandoned wheel, cart, or piece of steel or wood are all present in agricultural settings. In order to complete their assigned tasks, agricultural autonomous machines must interact with all of these non-human objects. The techniques agricultural autonomous machines employ to detect and avoid those items while still completing their tasks are implied by interacting with/sensing these objects.

Research Needs Related to Adoption of Automation in Work Settings

The group discussed how the adoption of automation in agriculture is influenced by a variety of factors. The first includes the willingness of agricultural workers to conform to more prescribed operations when using autonomous machines. To understand this willingness, it will be important to gather perspectives from diverse groups such as farmworkers, youth, women, individuals who speak a language other than English as a first language, those over 60 years old, workers with disabilities, and marginalized communities, as well as owners/employers. Understanding user acceptance is crucial in understanding barriers to the adoption of automation. Successful adoption of technology can also be studied considering similar factors.

Research Related to Surveillance

Building on the discussion about tracking (surveillance), the workgroup included surveillance as a research need. The development of a comprehensive surveillance system to centralize documenting fatality, injury, and near miss events is a research priority. The group discussed the possibility of utilizing existing surveillance systems, documenting near misses, and collecting data through the autonomous machines themselves. Finally, logistical barriers and opportunities for manufacturers to share their data were identified.

Discussion

The research track discussion revealed a variety of barriers to conducting research, challenges to surveillance or tracking events, and priority research needs.

To overcome barriers to research, occupational safety and health researchers need to engage and collaborate with developers of technology to learn about what emerging technologies are available, what is being developed, and what may be possible with time (Howard and Lincoln, 2022). It is also increasingly important for occupational safety and health researchers and practitioners to not only become familiar with existing manufacturing safety standards and gaps within those standards but also the lengthy standards development process, if only to better understand how manufacturers are implementing standards. Better still, joining consensus standards groups to help shape new standards for emerging technologies may help to mitigate adverse worker impacts. Similarly, equipment manufacturers are encouraged to collaborate with each other. This collaboration can help ensure safety in automated and autonomous agriculture across all equipment manufacturers (Reid, 2024).

Both manufacturers and researchers need to work together to overcome the challenges of tracking events and conducting surveillance. The need to monitor adverse events to better understand the occupational safety impact of automation and robotics in agriculture remains. The main source of data for occupational fatal and nonfatal workplace injuries is the Bureau of Labor Statistics (Murphy et al., 2019). BLS's Injuries, Illnesses, and Fatalities (IIF) program collects data and reports through the Survey of Occupational Injuries and Illnesses (SOII) and the Census of Fatal Occupational Injuries (CFOI). A list of possible agricultural injury surveillance data sources with their capabilities to capture "robot" or "autonomous machine or vehicle" related incidents is given in table 2.

The Occupational Injury and Illness Classification System (OIICS) coding scheme is used by BLS, Occupational Safety and Health Administration (OSHA)'s severe injury reports, AgInjuryNews, and workers' compensation data in some states. Some improvements have been made recently to better identify events related to robotics and automation in agriculture.

In 2022, OIICS went through major revisions, and OIICS Version 3.0 is effective starting in 2023 (BLS, 2023). The new version of the OIICS has revised agricultural equipment under the Source/Machinery category to better accommodate the agricultural industry. The new version reserves the terminating digit, '8,' for autonomous and robotic equipment.

OIICS Version 3.0, Source/Division 9 (safety and environmental factors and conditions) includes code "966: Autonomous or robotic system failure" to be used to indicate the failure or malfunction of computer systems designed to replace human operators on all types of vehicles and machinery and code "9224: Human exoskeleton equipment" for a wearable mobile machine that allows for limb movement with increased strength and endurance. With these enhancements, it should be easier to identify and therefore to understand events captured by existing systems.

Shutske et al. (2025) also discussed data needs from SAFER AG. The participants in the Risk Assessment Track also spent considerable time discussing the need for data related to injuries, fatalities, and other adverse events. This group discussed the limitations of current systems since few of these machines are actually in service it will take years to have enough data to use in risk assessments. Since members of this working group were primarily equipment manufacturers, there was an extensive discussion about the importance of any system being voluntary, reporting, and liability issues for engineers and manufacturers. The workgroup discussed at length who would collect and report into such a system, who

Table 2. Agricultural injury surveillance data sources and their capabilities.

Data Source	Injury Severity	Classification Scheme	Narrative Search
BLS, CFOI	Fatal	OIICS	Restricted access
BLS, SOII	Non-fatal	OIICS	Restricted access
OSHA	Fatal, non-fatal	OIICS + keywords	Yes
State Workers' Compensation Data	Fatal, non-fatal	Varies	Varies
AgInjuryNews.org	Fatal, non-fatal	OIICS	Yes
Consumer Product Safety Coalition – National Electronic Injury Surveillance System (NEISS)	Non-fatal	Own classification	Yes
Electronic Health Records	Fatal, non-fatal	ICD	Varies

would have access to the data, and what incentives would be needed to participate. (Shutske et al., 2025) The group made two recommendations that aligned with the discussion from the Occupational Safety group, including that an exposure-based database and associated risk assessment methods should be a high-priority topic and a priority area for future research.

The top research areas identified in the research track were related to human-machine interactions, non-human machine interactions, and barriers to the adoption of automation and surveillance. Conducting research to understand the risk to workers from robots and autonomous machines in agriculture should be a priority. It is estimated 80% of agricultural technologies are still in the research and development phase (Oliveira et al., 2021). Therefore, there is an opportunity to investigate the safety and health implications of emerging technologies when still in the development phase, potentially reducing risk before product release. However, the literature primarily focuses on developing the technology itself and exploring potential productivity gains, with limited research discussing the potential impacts on worker safety if the technology were adopted. A systematic literature review on the safety of automated/autonomous agricultural machinery conducted by Aby and Issa (2023) found that only 62 peer-reviewed research articles in the last ten years focused on safety, and the majority (~80%) of these papers focused only on the technology development (perception sensors) and production efficiency. An additional literature review by Hayden et al. (2022) aimed to assess the impacts of technology in livestock farming on occupational safety in agriculture. Among the 3,248 articles screened between 2015 and 2020, 624 focused on crop and harvesting automation, and 80 were about livestock farming, particularly dairy farms, where 56% used robotics regularly (Hayden et al., 2022). While these technologies offer potential safety benefits, the review highlighted gaps in evaluating how the technology impacts the safety and well-being of livestock owners, operators, and workers.

Previous research efforts have focused exclusively on non-human objects and human detection while overlooking the reaction of the agricultural autonomous machine afterward. The primary task of agricultural autonomous machines is related to activities such as weeding, planting, and spraying rather than to detect non-human items and/or humans that present risk, such as human injury. Therefore, future research should expand on how agricultural autonomous machines should robustly avoid human and non-human objects upon detection and continue performing their tasks without downtime. Additional research efforts are also needed to examine the exposures and risks associated with adjusting, maintaining, and repairing various automated and autonomous machinery types. Work by Gerberich et al. (1998) found that 37.1% of the farm machinery injuries documented in a multistate study occurred while the operator was repairing or adjusting the machine. The potential for "intimate contact" and hazard exposure during routine maintenance is also described by Narasimhan et al. (2010).

This idea of an exposure-based database was also discussed in the *risk assessment and standards group* (Shutske et al., 2025). Participants in this track discussed *innovative solutions, including creating an exposure-based database and exposure definitions that could serve as a foundation for future risk assessment processes.*

The occupational safety research track of the SAFER AG Workshop allowed for productive discussions on various safety issues related to robotics and automation in agriculture. However, there are several other critical safety considerations that must be addressed to ensure the safety of workers and bystanders, and these topics were discussed in the Risk

Assessment and Standards track. Each application of these technologies requires its own risk assessment. For instance, the size, horsepower, and speed of the robotic and autonomous machines present different safety risks, necessitating specific or tailored solutions for each scenario. Additionally, the work setting results in varied safety risks. For example, equipment used for a specific task in a barn poses different hazards compared to those used in a field. Furthermore, we cannot always consider the risk of using just one piece of robotic/autonomous machine at a time. It is not uncommon to have a combination such as a robotic arm with an autonomous ground vehicle. Lastly, the operation of autonomous equipment in co-working environments presents unique hazards that need careful management to protect workers, particularly when maintenance is being performed. One topic SAFER AG chose not to include in discussions is the increasing use of unmanned aerial vehicles (UAVs) in agriculture. UAVs are used in agriculture in various ways and introduce additional safety considerations.

Conclusions

This paper summarized the results of the SAFER AG Workshop on Occupational Safety Research track. Removing barriers to research, pursuing tracking/surveillance systems, and developing research projects for priority topics were discussed. The integration of robotics and autonomous technologies in agriculture is revolutionizing the industry, but important safety and health concerns need to be understood and controlled. The areas of needed research align with the NIOSH Center for Occupational Robotics Research. The need for evidence-based research, outreach, and education is critical to ensure that these technologies are well-researched in a responsible and sustainable manner for the safety and health risks of workers. To address these challenges effectively and foster innovation, it is crucial to reduce barriers between manufacturers, employers, and researchers. By focusing on common goals, collaborative efforts will lead to more effective solutions and safer working conditions for everyone involved.

Acknowledgments and Disclaimers

The workshop was funded by the USDA National Institute of Food and Agriculture: Project FLA-ILLN-741-677; proposal # 2022-07106; accession no. 1029426. We thank the University of Illinois for hosting the workshop.

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

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