AEM
Association of Equipment Manufacturers

Levels of Autonomy for Non-Road Equipment

This document serves to provide a common language for the Association of Equipment Manufacturers (AEM) and its members to discuss autonomy in non-road equipment, educating and informing both internal and external stakeholders. **It is not intended to be all-inclusive or all-encompassing, but instead serves to offer a glimpse into the implementation of autonomy in the non-road industry.**

Non-road equipment is designed to execute specific functions relative to its intended applications and tasks in non-road environments in agriculture and construction. Construction worksites, farm fields, dairies and feedlots, areas of animal husbandry, etc., are dynamic environments defined by fences or other boundaries with some level of restriction for access or entry. **These do not apply to on-road operation of non-road equipment.**

It is important to note that autonomous operation is based on pre-determined conditions for operation and pre-defined boundaries for work. This is one of many unique distinctions between the non-road and on-road industries.

For the purposes of this document, a machine can be a single machine or a combination of machines, products, and systems (components working in coordination, acting with self-awareness within a system). **It should be noted that an operator can take control of a machine at all times, in any of the levels highlighted in this document**.

About AEM

The Association of Equipment Manufacturers (AEM) is the North American-based international trade group representing non-road equipment manufacturers and suppliers, with more than 1,100 member companies and over 200 product types across five diverse industry sectors, including agriculture, construction, forestry, mining, and utility.

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	LEVEL 0 MANUAL OPERATION	LEVEL 1 ASSISTED OPERATION	LEVEL 2 PARTIAL AUTOMATION	LEVEL 3 CONDITIONAL AUTOMATION	LEVEL 4 SUPERVISED AUTONOMY	LEVEL 5 UNSUPERVISED AUTONOMY
DEFINITION	Manual operation with no automated functions.	Single or multiple automated functions, with on-board, active human operation.	Multiple automated functions, with on-board, active human machine operation and supervision of automated functions.	Automated functions within pre-determined conditions, with active on- or off-board operator supervision.	Autonomous operation within pre-determined conditions and a pre-defined boundary, with passive on- or off-board operator supervision.	Autonomous operation within pre-determined conditions and a pre-defined boundary, with no operator supervision required to complete a task.
INDUSTRY USE CASES	Machine has no automated functions and requires an operator to complete all functions and tasks.	Machine may have multiple automated functions to assist with task completion, but each operates independently from one another with an operator operating the machine.	Machine has multiple automated functions operating as a singular system to make real-time adjustments to complete a task with an operator operating the machine.	Machine is completing tasks independently, with an operator (physically or remotely) monitoring the environment and providing oversight of machine's decision-making.	Machine is monitoring environment and defaults or escalates to operator (physically or remotely) for decision-making when encountering obstacles or outside of its capabilities (obstacle detection).	Machine is capable of completing the assigned task, with no operator input, with confidence it will do the job due to a redundancy of systems.
ROLE OF OPERATOR	Operator is solely responsible for situational awareness and safeguarding the machine and is managing all (100%) functions.	Operator is solely responsible for situational awareness and safeguarding the machine and is managing the majority (>50%) of functions.	Operator is solely responsible for situational awareness and safeguarding the machine and is managing some (<50%) functions with oversight of all functions on the machine.	Operator is responsible for situational awareness and safeguarding the machine, is actively supervising all functions, and is required for initiation and completion of a task.	Operator is passively supervising the machine for situational awareness and acting as necessary for completion of a task or troubleshooting.	Operator supervision is not necessary for completion of a task.
ROLE OF MACHINE	Machine serves as a mechanical device for completing a task.	Machine is managing some (<50%) functions.	Machine is managing the majority (>50%) of functions.	Machine is managing specific functions to complete a task and supports situational awareness through obstacle detection and alerting the operator.	Machine is managing all (<100%) functions to complete a task, with partial situational awareness, and can safeguard (or stop) itself through obstacle detection alerting the operator to manage various environmental conditions or situations.	Machine is managing all (100%) functions to complete a task, with full situational awareness and safeguards itself through obstacle detection and can manage various environmental conditions or situations.
CONSUMER EXAMPLES	• Hand duster	• Vacuum	• Air fryer	• Smart thermostat	• Robotic vacuum	• Robotic lawnmower with adaptive capabilities
CONSTRUCTION EXAMPLES	• Base excavator	• 2- or 3-D machine guidance	• Grade control with auto steer	• Remote excavator operation	• Autonomous soil compaction	• Autonomous haul truck
AGRICULTURE EXAMPLES	• Base sprayer	• Section control	• Multiple product variable rate application (VRA)	• Targeted spray application with auto steer	• Autonomous spraying	• Autonomous spraying with auto reloading

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