International Standard

ISO 18497-2

First edition
2024-07

Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery —

Part 2: Design principles for obstacle protection systems

Tracteurs et matériels agricoles — Sécurité des machines partiellement automatisées, semi-autonomes et autonomes —

Partie 2: Principes de conception pour la protection contre les obstacles

Reference number
ISO 18497-2:2024(en)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 19, *Agricultural electronics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 144, *Tractors and machinery for agriculture and forestry*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition of ISO 18497-2, together with ISO 18497-1, ISO 18497-3 and ISO 18497-4, cancels and replaces ISO 18497:2018, which has been technically revised.

The main changes are as follows:

— obstacle protective systems were made its own part (i.e. ISO 18497-2) and substantially revised to account for the wide range of functionality and use cases within agricultural machines and tractors.

A list of all parts in the ISO 18497 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is a type-B1 standard as stated in ISO 12100:2010.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

— machine manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organisations, market surveillance, etc.).

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

— machine users/employers (small, medium and large enterprises);

— machine users/employees (e.g. trade unions, organizations for people with special needs);

— service providers, e.g. for maintenance (small, medium and large enterprises);

— consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

In addition, this document is intended for standardization bodies elaborating type-C standards. The requirements of this document can be supplemented or modified by a type-C standard.

For machines which are covered by the scope of a type-C standard and which have been designed and built according to the requirements of that standard, the requirements of that type-C standard take precedence.

The structure of safety standards in the field of machinery is as follows:

— Type-A standards (basis standards) give basic concepts, principles for design, and general aspects that can be applied to machinery;

— Type-B standards (generic safety standards) deal with one or more safety aspects or one or more types of safeguards that can be used across a wide range of machinery:

  — Type-B1 standards on particular safety aspects (e.g. safety distances, surface temperature, noise);

  — Type-B2 standards on safeguards (e.g. two-hands controls, interlocking devices, pressure sensitive devices, guards);

— Type-C standards (machinery safety standards) deal with detailed safety requirements for a particular machine or group of machines.

The purpose of the ISO 18497 series is to establish general design principles for partially automated, semi-autonomous and autonomous (see ISO 18497-1:2024, Clause 3) functions of agricultural machinery and tractors.

Manual non-automated functions are addressed in existing agricultural machinery and tractor safety standards. Due to the potential number of different functions of agricultural machinery and tractors and the mixed type and mode to which these functions can exist, it is necessary to establish general design principles. In this way, the combination, operator location, and types of interaction of these functions can be guided so that further type-C safety standards can be developed consistently and explicitly to address the mitigation of risk of injury to operators and bystanders. This is the primary focus of safety standards. Attempting to specify risk mitigation requirements based on combinations of type and mode of functions alone cannot be accomplished accurately for all agricultural machinery and tractors due to the wide variety of the machinery and variety of functionality.

Therefore, the familiar representation of SAE J3016[1] with six levels of automation was deliberately not chosen as a basis for the ISO 18497 series. It is necessary to develop more specific type-C safety standards, using the general design principles of this document, to adequately account for the risks of agricultural machinery and tractors used in a specified way with various types of partially automated, semi-autonomous and autonomous functions.

When the requirements of the ISO 18497 series for partially automated, semi-autonomous and autonomous functions of agricultural machinery and tractors are different from those which are stated in a machine-specific type-C standard dealing with partially automated, semi-autonomous and autonomous functions of agricultural machinery and tractors, the requirements of the machine-specific standard take precedence over the requirements of the ISO 18497 series.

Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery —

Part 2: Design principles for obstacle protection systems

1 Scope

This document specifies principles for the design of obstacle protective systems used in agricultural machinery and tractors that are used in agricultural applications and that have partially automated, semi-autonomous and autonomous functions. Additionally, it provides guidance on the type of information to be provided by the manufacturer on safe working practices (including information about residual risks).

The purpose of this document is to assist in the provision of more specific safety requirements, means of verification and information for use to ensure an appropriate level of safety for agricultural machinery and tractors with partially automated, semi-autonomous and autonomous functions used in a specified way.

This document deals with the significant hazards relevant to agricultural machinery and tractors with partially automated, semi-autonomous and autonomous functions when used as intended and under the conditions of misuse reasonably foreseeable by the manufacturer during normal operation and service.

Applicability of the design principles and any additional detailed requirements for design, verification, validation or information for use are outside the scope of this document. When risk assessment concludes that hazards are not significant hazards, the principles of this document do not apply.

NOTE Safety requirements for specific non-automated functions of agricultural machinery and tractors can be available in machine-specific type-C standards.

This document is not applicable to:

— forestry applications;

— operations on public roads including relevant requirements for braking and steering systems.

This document is not applicable to agricultural machinery and tractors which are manufactured before the date of its publication, or to systems applied to agricultural machinery and tractors put into use before the date of its publication.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3767-1:2016, *Tractors, machinery for agriculture and forestry, powered lawn and garden equipment — Symbols for operator controls and other displays — Part 1: Common symbols*

ISO 3767-1:2016/Amd 1:2020, *Tractors, machinery for agriculture and forestry, powered lawn and garden equipment — Symbols for operator controls and other displays — Part 1: Common symbols — Amendment 1*

ISO 3767-2:2016, *Tractors, machinery for agriculture and forestry, powered lawn and garden equipment — Symbols for operator controls and other displays — Part 2: Symbols for agricultural tractors and machinery*

ISO 3767-2:2016/Amd 1:2020, *Tractors, machinery for agriculture and forestry, powered lawn and garden equipment — Symbols for operator controls and other displays — Part 2: Symbols for agricultural tractors and machinery — Amendment 1*

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13849-1:2023, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 13849-2:2012, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation*

ISO 18497-1:2024, *Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery — Part 1: Machine design principles and vocabulary*

ISO 18497-3:2024, *Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery — Part 3: Autonomous operating zones*

ISO 18497-4:2024, *Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery — Part 4: Verification methods and validation principles*

ISO 25119-1:2018, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 1: General principles for design and development*

ISO 25119-1:2018/Amd 1:2020, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 1: General principles for design and development — Amendment 1*

ISO 25119-2:2019, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 2: Concept phase*

ISO 25119-3:2018, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 3: Series development, hardware and software*

ISO 25119-3:2018/Amd 1:2020, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 3: Series development, hardware and software — Amendment 1*

ISO 25119-4:2018, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 4: Production, operation, modification and supporting processes*

ISO 25119-4:2018/Amd 1:2020, *Tractors and machinery for agriculture and forestry — Safety-related parts of control systems — Part 4: Production, operation, modification and supporting processes — Amendment 1*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 18497-1:2024 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Safety requirements and protective or risk reduction measures

4.1 General

Partially automated, semi-autonomous and autonomous functions (see Figure 1) of agricultural machinery and tractors shall be designed according to the principles of 4.2 when obstacle protective systems are used for protective or risk reduction measures of significant hazards, as defined in ISO 12100:2010, 3.8, related to person and/or obstacle contact.

Significant hazards are dependent on the use case of agricultural machinery and tractors with partially automated, semi-autonomous and autonomous functions and shall be determined using a risk assessment in accordance with ISO 12100:2010.

In addition, partially automated, semi-autonomous and autonomous functions of machines shall be designed according to the principles of ISO 12100:2010 for relevant but not significant hazards which are not dealt with by this document. For significant hazards not covered in 4.2, the determination of requirements and corresponding verification procedures shall be done in accordance with ISO 12100:2010.

Specific type-C standards, when available, can give more detailed requirements.

<table>
<tr><th></th><th>Manual non-automated
(see ISO 18497-1:2024, 3.1)</th><th>Partially automated
(see ISO 18497-1:2024, 3.2)</th><th>Semi-autonomous
(see ISO 18497-1:2024, 3.3)</th><th>Autonomous
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<tr><td rowspan="2">Functions
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<tr><td colspan="2"></td><td colspan="2">Autonomous mode (see ISO 18497 - 1:2024, 3.10)</td></tr>
</table>

NOTE See ISO 18497-1:2024.

Figure 1 — Terms used for combinations of functions and modes

Design of machine systems and systems (perception, supervisory or other) to prevent unintended excursions beyond the boundary of the autonomous operating zone shall be designed in accordance with ISO 18497-1:2024 and ISO 18497-3:2024, respectively.

Verification methods of ISO 18497-4:2024 shall be applied to the design principles of 4.2.

There is no sensing technology that works perfectly in all conditions, machine geometries, or applications. It is especially important that the limitations are recognized and known by both the manufacturer of the machine and the operator of the machine. It is also possible to combine the use of complementary technologies in one system to improve the obstacle protective system performance. Examples of sensing technologies include radar, sonar (ultrasonic) sensors, 2D/3D LIDAR, monocular/binocular/omnidirectional vision systems, thermal sensors and pressure sensors (not exhaustive). The advantages and disadvantages of some known technologies are summarized in Annex A.

4.2 Design principles

4.2.1 General

For ensuring an appropriate level of safety of partially automated, semi-autonomous (when automated machine functions operate in autonomous mode) and autonomous functions of agricultural machinery and tractors, the following protective or risk reduction measures shall be provided in the obstacle protective system design to reduce significant hazards related to person and/or obstacle contact. Design recommendations for warning zones and hazard zones in relation to obstacle protective systems are summarized in Annex B.

4.2.2 Obstacle detection — Perception and supervisory systems

a) Prevention of failures to detect, late detection, misclassification and errors in location of a detected person and/or obstacle shall be provided.

NOTE 1 Due to the variety of perception systems, some of the failures above might not be applicable.

EXAMPLE 1 Reasons for typical failure to detect a person and/or obstacle or late detection of a person and/or obstacle:

1) person and/or obstacles are occluded due to crops, dust, fog, snow, rain or other obscurants;

2) perception results become unreliable due to poor or intense lighting conditions (e.g. direct sunlight, reflected sunlight, darkness, shadows);

3) uneven ground causes scanning plane to vary, (e.g. the laser beam might hit the ground or point to the sky when the vehicle is pitching down or up or tilting side to side);

4) vehicle vibration or motion causes misalignment of sensors;

5) person and/or obstacles are moving too fast to be detected;

6) person and/or obstacles are too small, (e.g. the reliability of the radar technology depends on the effective radar cross-section of the person and/or obstacle to identify it);

7) person and/or obstacles do not reflect back in the direction of the receiver, (e.g. laser beam or radar sensor does not detect reflected signal from organic, or transparent; e.g. ultrasonic sensor does not detect acoustic energy from sound-absorbing person and/or obstacles);

8) person and/or obstacles reflect or emit too much energy and saturate the sensor;

9) person and/or obstacles at the same temperature as the environment are not detected by thermal sensor;

10) person and/or obstacle colour is indistinguishable from that of the background (e.g. camouflage);

11) negative obstacles (e.g. holes in the terrain) are not detected;

12) latency can increase due to other applications or computations running on the processor used for the obstacle detection or classification system;

13) dust or other obscurants on the sensors itself can reduce the sensor field of view;

14) difficult terrain condition (e.g. mud, significant slopes) or body of water are not detected;

15) sensor is moved out of alignment or sensor is blocked by a part of or parts of a machine (e.g. cover, shield, tool);

16) sensors interfere with each other (e.g. an array of ultra-sonic sensors positioned to cause interference);

17) electromagnetic interference from internal or external sources;

18) erratic power supply and/or under/over voltage to system components.

EXAMPLE 2 Reasons for typical misclassification of a person and/or obstacle:

1) dust, fog, snow, rain or obscurants blur the edges;

2) inadequate model to sufficiently interpret the ground truth conditions (e.g. due to training or validation);

3) traversable grass or crops classified as non-traversable obstacle;

4) person and/or obstacles are occluded due to crops, dust, fog, snow, rain, or other obscurants.

EXAMPLE 3 Reasons for typical erroneous location of a detected person and/or obstacle:

1) sensor misalignment causing inaccurate position estimate;

2) positioning and orientation system errors (e.g. GNSS error) causing inaccurate machine position or orientation;

3) vibration of the sensor mounting causing sensor motion that is not accounted for by the perception system;

4) dust, fog, snow, rain or obscurants blurring the edges of the person and/or obstacle or environment;

5) inaccurate sensor calibration or registration;

6) wrong estimated location of person and/or obstacle due to multi-path propagation.

b) Restriction of adjustment outside the manufacturer's defined operational limits of the obstacle protective system shall be provided.

NOTE 2 The operational parameter limit of system is defined by the manufacturer (e.g. temperature, speed). The manufacturer does not allow access by operator to adjust parameters, or provides operator access to adjust specific parameters, but the range of allowable parameters is only within the defined manufacturers limit.

c) Adequate person and/or obstacle detection performance for the intended use case shall be provided, which:

— meets the design principles found in ISO 18497-1:2024, 4.2.4.2 g) and 4.2.7;

— fulfils the required risk reduction level of the manufacturer's risk assessment.

NOTE 3 Adequate person and/or obstacle detection performance is a future topic of other standards to provide specific guidance on evaluation criteria and processes. Information on false detection performance is summarized in Annex C.

4.2.3 Operational limits — Perception and supervisory systems

A safe state shall be provided which automatically maintains the defined operational limits in the design of obstacle protective systems that use a perception system, or a supervisory system that uses a perception system, for person and/or obstacle detection.

EXAMPLE 1 Typical operational limits:

1) Environmental-related parameters (e.g. sun radiation, darkness, fog, temperature, all kinds of atmospheric precipitation and conditions, terrain irregularities, crop irregularities);

2) Person and/or obstacle identification-related parameters (e.g. small size of obstacles, fast speed of person and/or obstacles, poor reflective properties of person and/or obstacles);

3) Machine-related parameters (e.g. operating speed, sensor alignment, sensor field of view, vibrations, computation demands for processors);

4) Component-related parameters (e.g. dirt on the sensor, sensor temperature too high/too low).

NOTE Due to the variety of perception systems, some of the operational limits above might not be applicable.

EXAMPLE 2 Speed of machine exceeds operational limit (cannot maintain operational limit) of obstacle protective system therefore the machine reduces speed to a controlled stop and changes out of the active state to a different safe state.

4.2.4 Visual indication — Partially automated and semi-autonomous (manual mode)

A visual indicator shall be provided to the operator which shows the current state of the obstacle protective system where automated machine functions operate in manual mode.

NOTE Visual indicators differ from visual alarms which are specified in ISO 18497-1:2024, 4.3.

4.2.5 Audible indication — Partially automated and semi-autonomous (manual mode)

An audible indicator shall be provided to the operator which sounds when the obstacle protective system enters or leaves the active state where automated machine functions operate in manual mode.

NOTE Audible indicators differ from audible alarms which are specified in ISO 18497-1:2024, 4.3.

4.2.6 Monitoring

4.2.6.1 Partially automated and semi-autonomous (manual mode)

See 4.2.4 and 4.2.5 for monitoring aspects.

4.2.6.2 Semi-autonomous and autonomous

Notification shall be provided through the notification system to the operator for the current state of the obstacle protective system.

4.2.7 Faults and failures

4.2.7.1 General

The machine design utilizing an obstacle protective system for partially automated, semi-autonomous and autonomous hazardous functions shall comply with ISO 25119-1:2018, ISO 25119-1:2018/Amd 1:2020, ISO 25119-2:2019, ISO 25119-3:2018, ISO 25119-3:2018/Amd 1:2020, ISO 25119-4:2018 and ISO 25119-4:2018/Amd 1:2020, or ISO 13849-1:2023 and ISO 13849-2:2012.

Use of a supervisory system can be a means to detect and take action from faults and failures.

For software and data that are critical for safety, measures and methods shall be provided to minimize accidental or intentional corruptions from external sources (e.g. cyber-attacks or perturbations).

NOTE See Reference [2] and [3] for more information regarding cybersecurity.

Protection from faults and failures of the power supply for partially automated, semi-autonomous and autonomous functions shall be provided.

4.2.7.2 Communication failures

Systems shall be provided with means to allow only intentional and safe communications. Functional safety standards (see 4.2.7.1) shall be applied for communication failures.

If communication failures prevent the required communication between system elements of obstacle protective systems (e.g. sensor signals and the supervisory system), the system shall enter a safe state.

The acceptable time duration for communication failures shall be dependent on the application and the use of the information. When this time is exceeded, the obstacle protective system shall enter a safe state. The time between a communication failure and entering a safe state shall be consistent with maintaining a safe condition in relation to, for example, the maximum permitted travel speed, the extent of the warning and hazard zones, the response time of the obstacle protective system, effectiveness of the guarding and stopping performance.

NOTE The following are examples of sources of communication failure: issues affecting network performance in general, network physical or configuration changes, machines added to or taken from the network, noise issues (e.g. unintentional jamming, EMC), hardware failures, systemic failures, software defects, network configuration changes, bandwidth limitations, weather-related issues, changes in topography, system power issues, intentional hacking, spoofing, or jamming.

4.2.7.3 Partially automated, semi-autonomous and autonomous

If faults due to failures cause an impaired condition for the obstacle protective system, automatically entering a safe state shall be provided in the design of obstacle protective systems for partially automated, semi-autonomous and autonomous hazardous functions.

4.3 Labelling and identification

Symbols shall comply with ISO 3767-1:2016, ISO 3767-1:2016/Amd 1:2020 and ISO 3767-2:2016, ISO 3767-2:2016/Amd 1:2020.

4.4 Information for use

In addition to information cited in ISO 18497-1:2024 and required by machine-specific standards, the operator's manual shall provide information specific to obstacle protective systems for partially automated, semi-autonomous and autonomous functions including the following:

a) information detailing the operational limits of the obstacle protective system (e.g. environment, person and/or obstacle and machine/implement parameters);

b) operating condition limits and procedures for all modes of operation;

c) supplementary to b), prohibited conditions for all modes of operation (e.g. ground conditions, weather conditions, crop types);

d) information on the visual and audible indicators, the meanings of indications and any action to be taken;

e) information on the machine marking and identification;

f) information on carrying out service and maintenance operations, inspections and calibrations;

g) information on the location and use of controls for enabling, activating and overriding;

h) information on the safe state descriptions covered under the risk analysis of the machine manufacturer;

i) information on the symbols and signs used.

Annex A
(informative)

Perception system technologies

A.1 Visual perception system (camera)

A.1.1 Description

A visual perception system using cameras, that can record and send visual images, can detect objects based on visual images and classify them as persons and/or obstacles.

A.1.2 Typical ranges

Practical range of 127° horizontal and 115° vertical. Distance: not limited.

A.1.3 Typical advantages

— Scratch, dirt and water resistant;

— works in low-light conditions;

— more than one moving object can be distinguished;

— can measure velocity and direction of moving object.

A.1.4 Typical disadvantages

— Distances hard to judge;

— difficult to detect stationary objects;

— direct light or sunlight into the camera causes detection problems;

— mud, dust and raindrops on camera lens can distort the image;

— flying debris, rain, snow can cause false detection;

— objects in shadow area difficult to distinguish;

— does not discriminate between persons and other moving objects (*).

(*) systems exist with morphological recognition where analysis algorithms can classify persons and/or obstacles according to their appearance.

A.2 Passive infrared

A.2.1 Description

A device that uses wide-angle lens camera, using the temperature gradient of the objects to build the images and to classify objects.

A.2.2 Typical range

Not limited.

A.2.3 Typical advantages

— Detects a person versus its background;

— independent from light intensity, works also in darkness;

— detects also static persons;

— not affected by dust.

A.2.4 Typical disadvantages

— Fragile lens;

— affected by humidity;

— cannot measure distance;

— cannot detect persons that have the same temperature as the environment (e.g. 37 °C).

A.3 Electromagnetic signal or ultrasonic transponder

A.3.1 Description

System that uses electromagnetic or ultrasonic signals emitted by an electronic tag worn by persons or animals.

A.3.2 Typical range

Adjustable 20 m in every direction.

A.3.3 Typical advantages

— Works in all directions;

— robust and reliable.

A.3.4 Typical disadvantages

— Does not monitor anything without a tag.

A.4 Ultrasonic

A.4.1 Description

System that uses reflecting sound waves to detect the presence and measure the distance of an object.

A.4.2 Typical range

Horizontal: 6 m

A.4.3 Typical advantages

— Accurate indication of distance;

— detecting a wide range of persons and/or obstacles.

A.4.4 Typical disadvantages

— Time delay limits application to operating speeds;

- performance can be affected by adverse weather;
- multiple sensors required to construct a detection zone;
- cannot discriminate between persons and other objects.

A.5 Doppler radar

A.5.1 Description

System that uses emitted and reflected microwaves from a moving object. A frequency difference indicates motion.

A.5.2 Typical range

Angle 160°, unlimited range.

A.5.3 Typical advantages

- Not affected by dust, snow, rain, dirt, darkness, temperature, sunlight;
- reflecting well on most objects;
- can detect speed and direction of an object.

A.5.4 Typical disadvantages

- Difficult sensing of stationary objects, can only detect moving objects;
- cannot discriminate between persons and other objects;
- false detections: can sense objects outside a detection zone.

A.6 Laser

A.6.1 Description

System that uses a pulsed laser and a revolving mirror.

A.6.2 Typical range

Practical range of 8 m and scan angle of 180°. Beam thickness of 5 mm.

A.6.3 Typical advantages

- Detection zone can be precisely configured.

A.6.4 Typical disadvantages

- Can suffer from interference from direct sunlight;
- smoke and dense fog could act as a barrier;
- interference with other laser operating on the same wavelength;
- lens requires frequent cleaning.

A.7 Light Detection and Ranging (LIDAR)

A.7.1 Description

System that can measure distance to, or other properties of, a target by illuminating the object with pulsed light. A scanning laser rangefinder generates a 3D cloud of the environment. Similar to a radar, but using laser light instead of radio waves.

A.7.2 Typical range

From 1,5 m to 120 m, Horizontal 250°, Vertical 20°.

A.7.3 Typical advantages

— Good field of detection;

— no electromagnetic interference;

— resolution much better than RADAR;

— accurate distance and speed measurement;

— short wavelength penetrates not dense objects (e.g. grass, weeds, leaves);

— can discriminate between traversable (grass) and not traversable objects.

A.7.4 Typical disadvantages

— Can suffer from interference from direct sunlight;

— smoke and dense fog could act as a barrier;

— interference with other laser operating on the same wavelength;

— lens requires frequent cleaning.