

TECHNICAL REPORT

Thunderstorm warning systems: detection technologies, standards classification, and measured performance

What the detector “classes” of EN 50536:2011 and IEC 62793:2016 were, why the current edition of the standard deleted them, what physical phenomenon each detection technology measures — with its intrinsic limitations — and what performance the published literature reports.

VERSION 1.1 · 21 AUGUST 2026 · 9 SECTIONS · 27 REFERENCES

96%

of successful warnings in the target area — LLS network, IEC 62793’s own method

≥20 min

of lead time in more than 81% of warnings

40–80%

FAR for EFM-based warnings — KNMI review

Abstract. The standards for thunderstorm warning systems once classified detectors into “classes” (I–IV in EN 50536:2011; A–D in IEC 62793:2016) according to the phase of the thunderstorm life cycle each technology can detect — not according to its performance. The current edition, IEC 62793:2020, expressly deleted those classes and replaced them with a neutral description of three architectures and with measurable metrics: probability of detection (POD), false alarm ratio (FAR), and lead time (LT). This review reconstructs that normative trajectory from the official texts, describes the physical principle and limitations of each technology — electrostatic field meter, single-point sensor, lightning locating system — and compiles the performance reported in the literature, with emphasis on sources free of commercial interest (meteorological institutes and universities). The technologies are not comparable to one another at the sensor level, because they measure different physical phenomena; what is comparable is the warning function they deliver, and that is the level at which the current standard and the literature evaluate them. The document closes with the limits of the evidence and with evaluation criteria applicable to any commercial offering.

Keywords: thunderstorm warning · IEC 62793 · EN 50536 · electric field mill · lightning locating system (LLS) · probability of detection · false alarms · lead time

REFERENCE MATERIAL FOR SAFETY MANAGERS AND OPERATIONS SUPERINTENDENTS · INCORPORATES EXTERNAL TECHNICAL REVIEW (VERSION 1.1)

1

INTRODUCTION

2020

current edition of
IEC 62793 — the one with
the classes was cancelled

0

classes in the current
standard: the 2020 edition
deleted them

Buying a detector is **not**
buying a warning: the
warning is produced by
the system, not by the
standalone instrument.

0 1

Introduction

In tenders and technical datasheets for thunderstorm warning systems it is still common to read that a detector is “Class A per IEC 62793.” The phrase sounds like a top-tier certification. It has a verifiable problem: the current edition of that standard, IEC 62793:2020, contains no classes at all. The standard's own foreword lists the changes with respect to the previous edition, and one of them is, verbatim, “*in Clause 5, classes of TWS have been deleted*”^[1].

Before going further it is worth fixing the vocabulary, because the commercial confusion exploits precisely its blurring. The standard distinguishes two levels. The technologies — the field meter, the single-point sensor, the locating network — **detect**: they are “thunderstorm detectors” (IEC 62793:2020, Clause 5)^[1]. The **warning** is produced by the system: the detection plus an algorithm that turns it into a decision over a defined area. That is a “thunderstorm warning system” (TWS) — it is what the standard's own title names: *Thunderstorm warning systems – Protection against lightning*^[1]. No instrument, by itself, is a warning system; buying a detector is not buying a warning. This document uses “warning” and “alert” as operational synonyms, and reserves “detection” for what the instruments do.

That mismatch between commercial language and normative text is the starting point of this review. Resolving it requires answering three questions in order: what exactly did the classes classify (Section 3), what did the current standard put in their place (Section 4), and what does each technology actually measure — because only from the physical principle can one understand its limitations and why the correct comparison is not between sensors but between warnings (Sections 5 and 6). Section 7 completes the picture with the 2026 landscape of existing networks and their coverage.

0 2

A thunderstorm has four measurable phases, and each emits different signals

The underlying physics is simple, and both editions of IEC 62793 describe it identically^[1,2]. A storm cell electrifies before producing its first lightning flash: collisions between small hail and ice crystals separate charge inside the cloud, and that charge generates an electrostatic field measurable at ground level (phase 1, initial). Minutes later the first discharges appear, almost always inside the cloud (phase 2, growth). The storm then matures and produces cloud-to-ground (CG) and intra-cloud (IC) flashes at its maximum rate (phase 3, mature). Finally the activity decays until it ceases (phase 4, dissipation).

Each phase emits different physical signals: phase 1 produces only a quasi-static field of short range; phases 2 through 4 also produce electromagnetic pulses that travel hundreds or thousands of kilometers. Which signal each technology exploits determines which phases it can see — and that was, precisely, the criterion behind the classes.

3

THE CLASSES

A–D

classes of IEC 2016 (I–IV in EN 50536) — by phase, not by quality

>90%

DE required only of Class C, the only one with a numerical requirement

The class described which **phase** a sensor can see, never its quality or its performance.

03

The classes ranked detectors by the phase they can see — not by their quality

The first European standard for thunderstorm warning systems, EN 50536:2011, introduced a classification of detectors into four classes (I to IV)^[3]. When the IEC turned it into an international standard — IEC 62793:2016 — it renamed the classes with letters, A through D^[2]. The criterion of both was the same: **which phases of the thunderstorm life cycle the equipment can detect**.

CLASS (IEC 2016)	EN 50536	PHASES DETECTED	TYPICAL TECHNOLOGY	PRACTICAL READING
A	I	1–4 (from electrification)	Electrostatic field meter (field mill, EFM)	In theory it warns before the first flash, but only within 5–20 km, without locating the storm or distinguishing a ground flash from a cloud flash.
B	II	2–4 (from the first IC flash)	VHF sensors (~200 km)	Sees the storm from its first in-cloud discharge and maps its extent.
C	III	3–4 (cloud-to-ground flashes)	LF locating networks (LLS)	Locates every ground flash. The standard itself required this class to exceed 90% detection efficiency (DE) with better than 1 km accuracy — requirements the other classes did not have.
D	IV	3 (limited)	Simple LF detectors	Counts nearby flashes with poor discrimination against electromagnetic interference.

WHICH PHASE EACH CLASS SEES · IEC 62793:2016 taxonomy, now deleted

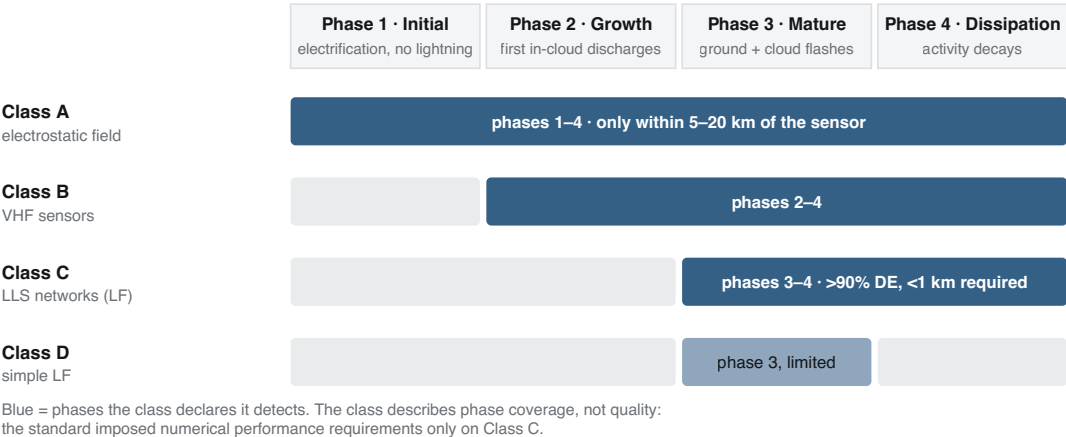


Figure 1. The classes of IEC 62793:2016 (Clause 5 and Annex B, edition cancelled in 2020)^[2]. Own elaboration based on the text of the standard.

Two points of precision matter here. First: **the class was never a performance measure nor a certification**. A “Class A” detector was not a better detector; it was a detector that declares it also sees the electrostatic phase. In fact, the only class to which the 2016 standard demanded concrete performance figures was Class C — the locating networks — with detection efficiency above 90% and accuracy better than 1 km^[2]. Second: the taxonomy aged poorly. Modern LF networks no longer see only ground flashes: after the 2013 modernization of the U.S. National Lightning Detection Network (NLDN), that network also detects between 50 and 60% of intra-cloud flashes^[11] — that is, it sees the phase 2 that Class C assumed was beyond its reach. One possible reading, not made explicit by the committee, is that this mismatch between the taxonomy's boxes and the actual technology contributed to its deletion.

4

CURRENT
STANDARD

3

architectures the 2020
edition describes, with no
hierarchy

POD·FAR·LT

the measurable metrics
that replaced the classes

If an offer invokes a
“class,” it is citing an
edition of the standard
cancelled in 2020.

04

The current edition deleted the classes and put measurable metrics in their place

IEC 62793:2020 (edition 2, published 21 September 2020) cancels and replaces the 2016 edition. It is the edition in force in 2026, and its committee (IEC TC 81, lightning protection) has no third edition in published preparation^[1]. The foreword enumerates the significant technical changes; the first substantive one is the deletion of the classes in Clause 5.

In their place, the standard now describes three architectures, with no hierarchy among them: (a) a local detector — for example an electrostatic field meter —, (b) a network of interconnected local detectors, and (c) a lightning locating system (LLS), referring for the latter to standard IEC 62858^[4]. And it replaces the class table with a matrix of **measurable parameters per technology**: probability of detection (POD), false alarm ratio (FAR), lead time (LT), effective alarms, failures to warn. The standard acknowledges what each architecture contributes: the local detector can warn before the first discharge; the LLS offers uniform wide-area vision, location of every flash, storm tracking, and longer lead time when a storm approaches. It also notes a limitation of the electrostatic sensor: it may not be able to distinguish a ground flash from a cloud flash^[1].

THE STANDARDS, OVER TIME · from classes to measurable metrics

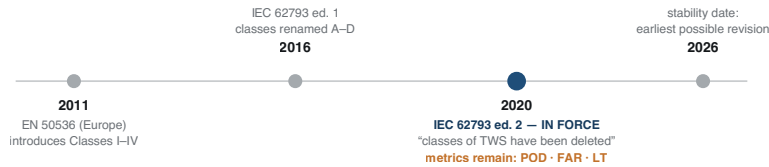


Figure 2. Normative trajectory, verified against the IEC catalogue and official texts (webstore.iec.ch, publication 64935)^[1,2,3]. Any material that invokes a “class” today is citing the 2011 or 2016 editions, both cancelled.

4

CURRENT
STANDARD

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architectures the 2020 edition describes, with no hierarchy

POD·FAR·LT

the measurable metrics that replaced the classes

If an offer invokes a “class,” it is citing an **edition of the standard cancelled** in 2020.

It is worth keeping at hand the full vocabulary the standard defines, because it is the language in which any evaluation should be demanded:

PARAMETER (IEC 62793:2020)	WHAT IT IS	PRACTICAL READING
TA / SA	Target area (what is protected) and surrounding area where a flash is already a hazard.	Defining them is the first step: without an agreed TA and SA, no POD or FAR means anything.
MA / CA	Monitoring area used to issue the alarm, and coverage area where the equipment performs adequately.	The MA must fit inside the system's CA — a key question for short-range sensors.
POD (= 1 – FTWR)	Effective alarms over the total number of situations with lightning in the SA.	The safety metric: how much of the real hazard was warned.
POD_x	POD counting only alarms with lead time ≥ x minutes.	The operational metric: a warning without time to act does not protect (e.g. POD ₁₀).
LT (lead time)	Time between the start of the alarm and the first flash in the SA.	Every preventive action must fit within the LT.
FAR	False alarms over the total number of alarms. “False” = no thunderstorm activity in the MA.	A lax definition: an alarm with no flash at the target does not count as false if there was activity in the MA. Demand the method when comparing.
EAR / NEA	Ratio of effective alarms; alarms with no flash in the SA during their duration.	They complement the FAR to see how much alarm was “surplus.”
TAD / TTC	Total alarm duration; time between the last flash and the all-clear.	This is where the production cost lives: shutdown hours per episode.
LA (LLS only)	Median location accuracy.	IEC 62858 requires an LLS to have DE ≥ 80% and LA < 500 m for its lightning densities to be usable in risk assessment ^[20] .
LRC (electrostatic sensor only)	Electric field conditions sufficient to expect a flash in the SA.	The only parameter exclusive to the EFM: risk of a first flash overhead, without location.

Selection from Clause 3 and Table 1 of IEC 62793:2020^[1]. The colloquial “dwell time” corresponds to the standard's TTC.

One additional point for reading datasheets: **IEC 62793 does not certify products**. It defines characteristics, evaluation methods, and laboratory tests (its normative Annex E describes how to test detectors). No IEC certification scheme exists for this standard; market declarations are manufacturers' self-declarations of conformity. Several commercial datasheets for electrostatic detectors still declare “Class A” today, expressly citing the 2016 edition^[14], and the same argument was used earlier with EN 50536 (“Class I”). It is not an error for a vendor to describe its technology with the taxonomy that favored it; it is an evaluation error to read that class as if it were a quality category still in force.

5

PHYSICAL
PRINCIPLES

5–20 km

range of the field meter
(EFM): no direction, no
distance

 $1/d^3$

field falloff with distance
— the origin of the short
range

The electric field **does**
not locate the threat; the
network locates and
tracks every flash, one
by one.

05

Physical principles: what each technology measures, and what that keeps it from seeing

An electrostatic field meter and a lightning locating network do not measure the same thing. One measures a quasi-static field generated by charge separated in the cloud; the other, the electromagnetic pulses of discharges that have already occurred. Comparing them “sensor against sensor” is physically meaningless — they are instruments of different quantities. What is comparable is the **function they deliver**: the warning. Over a defined area, any system can be evaluated with the same three questions: how many episodes did it warn in time (POD), how many alarms were surplus (FAR), and with how much lead time (LT). That is exactly the level at which IEC 62793:2020 and the literature evaluate them^[1,8]. But to interpret those figures one must first understand where each instrument's limitations come from.

5.1 · Electrostatic field meter (field mill, EFM)

Principle. It measures the vertical component of the quasi-static electric field at one point on the ground. In fair weather, that field is 100–200 V/m; when a cloud electrifies overhead, the field reverses polarity and grows beyond 1,000 V/m during the minutes before the first flash^[8]. It is the only instrument that can see phase 1.

Limitations that follow from the principle. The observed field is the superposition of all charges in the atmosphere, weighted by the inverse cube of distance. Four consequences follow, all documented:

- **Short range.** The $1/d^3$ dependence means the sensor sees very little beyond 5–10 km (the 2016 standard attributed ~20 km typical to it)^[2,8]. A storm approaching from 30 km away is invisible until it is nearly overhead.
- **No direction, no distance.** A scalar field measured at one point cannot distinguish “strong charge far away” from “weak charge nearby”: the instrument reports neither where the threat is nor where it is moving^[5].
- **Spurious signals.** Any nearby charge produces the same signature: suspended dust, snow, electrified drizzle, sea spray, exhaust plumes^[8]. IEC 62793:2020 itself gives snow and sand as examples of false alarm^[1]. The environment defines the noise: a dusty open pit is a hostile environment for this measurement principle.
- **The threshold is a dilemma.** The warning triggers when the field crosses a threshold (typically ~2 kV/m). Low threshold: more detection and more false alarms; high threshold: the opposite. The literature reports that with the usual threshold the POD can be high but so is the FAR^[8]. And there is a hard limit: not every flash is preceded by an increase of the field at ground level^[5].

5.2 · Single-point optical + radio-frequency sensor

Principle. It detects discharges that have already occurred by requiring coincidence between the optical pulse and the radio emission, and estimates distance from signal amplitude. **Limitations:** the optical channel is blocked by mountains and buildings; the ranging error is 10 to 40%; it does not see phase 1 and cannot map or track a storm^[8]. Its reasonable role is that of a low-cost local indicator, not the warning system of an operation.

5.3 · Lightning locating system (LLS)

Principle. Several sensors separated by 100–350 km measure the electromagnetic pulse of each discharge (1–500 kHz band, which propagates along the earth's surface). A central processor combines times of arrival (TOA) — and, for sensors that measure it, the angle of arrival (MDF) — to compute the position of each flash with an accuracy of hundreds of meters^[8,10]. Global networks use the same principle in a lower band (<50 kHz, reflected off the ionosphere) and detect at thousands of kilometers with lower accuracy.

Limitations that follow from the principle.

- **Blind to phase 1.** A network only sees discharges: if the storm forms exactly over the point to be protected, the first flash comes with no prior warning. This is the scenario historically used to justify adding a field mill; Section 8 examines why that path is no longer practicable and what covers it today.
- **Performance is a property of the network, not of the sensor.** Detection efficiency depends on the number of sensors, their separation, and the location method. Diendorfer's classic model quantifies it (Figure 3): the same 6-sensor network detects 96.5% of flashes if its sensors measure time and angle, and 76.6% if they measure time only (which requires 4 sensors per flash); when one sensor goes out of service, the former drops to 94.5% and the latter falls to 60.3%^[10]. Two “network” offerings can therefore perform very differently depending on their design — that is a procurement question, not a detail.
- **Weak discharges and classification.** Low-current flashes may not reach the threshold of enough sensors, and the separation between ground and cloud discharges is not perfect. The most recent independent verification of the U.S. network measured 92% detection of ground strokes with 92% classification accuracy (98% for negative first strokes)^[12]; with rocket-triggered lightning, 100% at flash level and a median accuracy of 173 m were measured^[13]. These numbers exist because the technology has been audited for decades with ground-truth data — instrumented towers, rockets, high-speed cameras^[10,12,13].
- **Partial intra-cloud coverage in the LF band.** A modern LF network detects on the order of half of intra-cloud discharges (50–60% in the U.S. network)^[11]; full mapping of in-cloud activity requires VHF sensors, of much shorter range.

5

PHYSICAL PRINCIPLES

5–20 km

range of the field meter (EFM): no direction, no distance

1/d³

field falloff with distance — the origin of the short range

The electric field **does not locate** the threat; the network locates and tracks every flash, one by one.

Two architecture notes complete the picture. First: a regional network can be combined with a global VLF network in a single location algorithm, so that the global network backs up the local one if a sensor fails and observes storms long before they enter the local area — the documented implementation of this fusion is Vaisala's, which combines in one processor the measurements of local LS7002 sensors and of the global GLD360 sensors^[15]. Second: that long-distance vision has warning value for the hardest problem of all — the first flash of the day. If an isolated storm has already produced its first flash over a neighboring mountain range, the same meteorological conditions are usually present over the site of interest, and that distant datum allows the local alert state to be escalated before the hazard is one's own^[16]. The argument comes from a technical memo by a lightning meteorology specialist (unpublished); it is recorded with that provenance.

PERFORMANCE IS A PROPERTY OF NETWORK DESIGN · 6-sensor model · blue = time+angle · amber = time-only

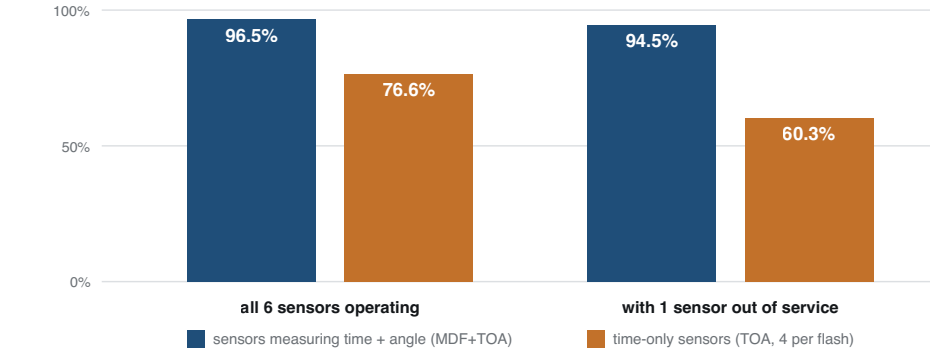


Figure 3. Cloud-to-ground flash detection efficiency in a 6-sensor model network with a 200 km baseline (Diendorfer, IX SIPDA, 2007, Table 1)^[10]. The figure does not compare the EFM against the network: it compares two network designs against each other, and illustrates that in locating systems performance — and its resilience to a sensor outage — is a design property that must be asked about and verified, not assumed.

HOW FAR EACH TECHNOLOGY SEES · logarithmic scale

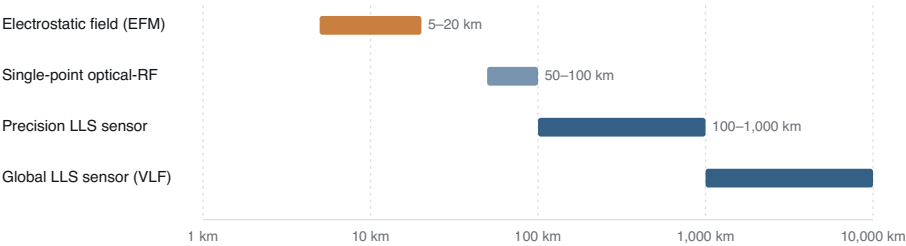


Figure 4. Typical range per technology^[2,8]. The scale is logarithmic: between the EFM and a global network there are three orders of magnitude. A network's lead time does not come from predicting phase 1, but from seeing the storm approach from afar and tracking it; the EFM's comes from phase 1, but only for storms that form overhead.

6

MEASURED
PERFORMANCE

96%

successful warnings from
an LLS network —
IEC 62793's own method

≥20 min

of lead time in more than
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40–80%

FAR of electric-field warn-
ings (EFM) — KNMI reviewThe field meter **warns
often and warns poorly**;
the network turns every
storm into a tracked
object.

o 6

Measured as a warning, this is how each technology performs

With the principles clear, the published figures read without surprise. The studies with real-storm data are cited here; among them, priority is given to those from institutions with no product to sell.

Field meters. The review by the meteorological institute of the Netherlands (KNMI) of the literature and the operational experience of airports concluded: POD from 20 to 60% and FAR from 40 to 80% for EFM-based warnings^[5]. In Spain, measurements over real storms gave, depending on the method, POD of 37 to 47% and FAR of 78 to 88%, with mean lead times of 6.5 to 8 minutes^[6]. And the Florida study by Murphy, Holle and Demetriades found something more uncomfortable: adding field mills to a lightning detection network **worsened** the joint performance of the warning system compared with using the network alone (POD of 16–38% combined, against 67% for the network alone), because in their sample 89% of the storms arrived already mature from outside the mills' range^[7]. The conceptual experiment was repeated in the Colombian Andes with local data: in Medellín (1,600 m, complex orography), the locating network alone with cell-tracking criteria gave a POD of 51% and a FAR of 41%; adding the full set of electric-field criteria raised the FAR to 85% (204 alarms, 164 false), and the best combined adjustment settled at POD 68% and FAR 46%^[24]. The mountains did not rescue the electrostatic principle.

Two recent additions complete the picture without changing it. The state of the art in signal processing — a micro-electromechanical field sensor on Canton Tower, with adaptive filtering, time-frequency analysis and ground truth from a validated network — achieved its best 2023 result at POD 77%, FAR 40% and a mean lead time of 22 minutes^[25]; the authors themselves acknowledge that the FAR remains high and that the sensor reports no position, and a re-reading of their figures — depending on how the no-lightning days flagged by the method are counted — raises the effective FAR toward 70% (M. J. Murphy, technical review of this document, August 2026). At the other extreme, the literature contains extraordinary claims for the EFM — POD 91% and FAR 8% in Kolkata^[26] — whose method illustrates the underlying problem: a warning area of 17.5 km (beyond the sensor's physical range), a monsoon climate with near-daily thunderstorms, and ground truth taken from a consumer-grade single-point detector. It is exactly the kind of figure that does not survive the question about method and areas (Section 8).

Locating networks. Evaluated with the methodology of IEC 62793 itself over 105 sites during five years, a European LLS achieved more than 96% successful warnings in the target area, and more than 81% of warnings with a lead time of at least 20 minutes^[9]. The same reference reports the operational experience with field sensors: false alarms from dust and sand storms, and failures to warn from deficient maintenance^[9].

The three technologies, side by side. There is a single simultaneous comparison of the three technologies known to this review, and it comes from a network manufacturer's internal technical report — it is included for documentary transparency, with that provenance declared. During 14 weeks of 2015, at a test field in Colorado, a field mill, a single-point optical-RF sensor and the U.S. national network operated at the same time, with the same area of concern (10 km radius) and the same lead-time criterion (≥2 minutes). Result: the network achieved a probability of detection about 30 percentage points higher than the mill, with a false alarm ratio 5 points lower; the single-point sensor produced mostly false alarms^[15]. The detail that gives the result weight is that conditions favored the mill: a clear site, no nearby power lines, and no snow during the period. Its limit is the obvious one: it is neither published nor peer-reviewed, and its author has a product in the comparison.

For the single-point sensor, however, independent evaluation now exists: a commercial "lightning prediction system" — whose manufacturer claims more than 4,000 units in operation, in use by professional sports teams and public institutions — was evaluated over five years (2020–2024) at a Florida sports facility against the U.S. locating network: more than 700 warnings analyzed within a 4 km radius, with a high probability of detection but also a high false alarm rate, and a correspondingly low critical success index, varying year to year^[27]. The pattern matches the Colorado experiment: the single-point sensor warns often, and for that very reason it warns poorly.

MEASURED PERFORMANCE, STUDY BY STUDY · blue = probability of detection (POD) · amber = false alarm ratio (FAR) · light tone = reported range

EFM — range in the literature

KNMI review, 2013 [5]

EFM — threshold method

Aranguren 2009 [6] · mean lead 6.5 min

EFM — polarity reversal

Aranguren 2009 [6] · mean lead 8 min

EFM + lightning network, combined

Florida, Murphy et al. 2008 [7]

Lightning network alone (same study)

Florida, Murphy et al. 2008 [7]

EFM + network — Andean mountains

Medellín 1,600 m · López et al. 2012 [24]

LLS network, IEC 62793 method

105 sites, 5 years · Schmitt & Rousseau 2016 [9]

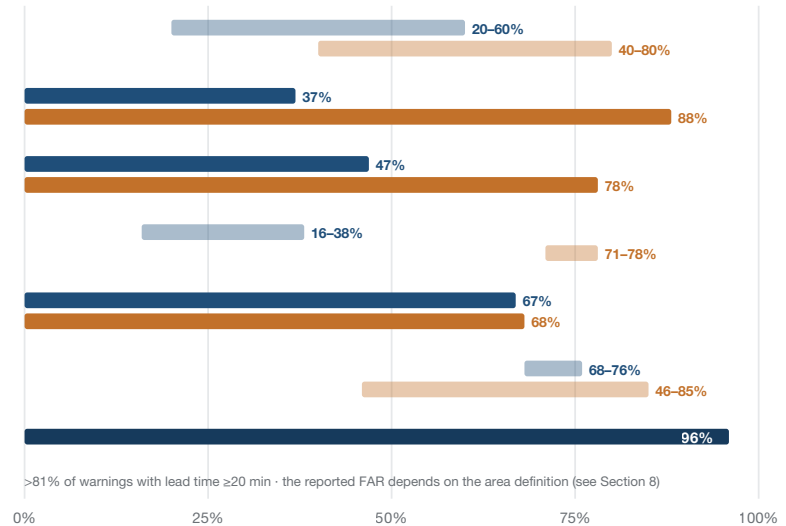


Figure 5. POD and FAR reported by study. The figures are **not directly comparable between studies** — each uses different warning areas, lead-time criteria and climates — but the direction is consistent across all of them. Light bars = reported ranges.

The practical reading: the field meter buys a few minutes of theoretical lead time at the cost of operating most of the time between the false alarm and the late warning; the network turns every storm into a located, tracked object, and its lead time comes from seeing the storm approach from tens or hundreds of kilometers away. **False alarms are not an academic figure:** the safety literature documents that repeated, unnecessary evacuations erode people's willingness to obey the next alarm^[8].

6

MEASURED PERFORMANCE

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FAR of electric-field warnings (EFM) — KNMI review

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07

The 2026 landscape: which precision networks exist and what territory they cover

The natural next question is where precision coverage actually exists. The census below reflects the state as of August 2026, based on operators' sites and the validation literature; it should be read with two caveats. First: figures “declared” by operators are consistently more optimistic than independent validations — the South African network, for example, declares 90% detection and 500 m accuracy, and the 2022 academic evaluation measured 84.9% and 59–124 m over Johannesburg^[18] — which is why the table distinguishes both. Second: the operator map has moved a great deal in recent years (Earth Networks became part of AEM; Siemens' BLIDS network passed to OVE/ALDIS in 2023; TOA Systems' network was acquired by AccuWeather in 2025), so the operator's current status is itself a datum to verify when contracting^[22].

PRECISION NETWORK	COVERAGE (2026)	OPERATOR	SENSORS · TECHNOLOGY	PUBLISHED PERFORMANCE
NLDN	Continental U.S. (+200–300 km off-shore)	Vaisala (private)	>100 · LF, MDF+TOA	Declared: CG flash DE >95%, LA ~84 m ^[21] . Continuous peer-reviewed validation since the 1990s ^[12,13] .
CLDN (with NLDN forms NALDN)	Canada	ECCC (government)	~80 · Vaisala LF, MDF+TOA	Academic validation with 20 years of data ^[22] .
EUCLID	Europe, ~31 countries	Consortium of national networks (ALDIS, Météorage, BLIDS, AEMET, NORD-LIS...)	~168 · LF, MDF+TOA	Validated: CG flash DE ~96–98%, LA ~100 m at the network core ^[17] .
LINET	Europe, 17 countries	nowcast GmbH (data provider to the German weather service)	~90 · VLF/LF, TOA	Validated 2009: DE ≥95%, LA ~150 m; the operator declares ~75 m today ^[22] .
ENTLN	~100 countries, highly variable density	Earth Networks / AEM (private)	>1,600 · broadband, TOA	Declared: DE up to 95% and LA <100 m where the network is dense. Validated in Florida with triggered lightning: CG flash DE 94–97% ^[19] .
JLDN	Japan	Franklin Japan (private)	31 · LF, MDF+TOA	Declared: mean position error <300 m; IEC 62858 conformity self-declared ^[22] .
KLDN	South Korea	KMA (government)	~21 · LF + VHF	Validated: CG DE ~90%, LA 150–250 m ^[22] .
ADTD / CNLDN	Mainland China	CMA (government)	>400 · TOA+MDF (domestic development)	Literature: flash DE ~90%, LA 300–500 m ^[22] .
ILLN	India	IITM / MoES (government)	83–112 · ENTLN technology	Declared: LA <500 m; academic validations 2021 and 2025 ^[22] .
GPATS · WZTLN	Australia	GPATS (private) · DTN APAC	Own TOA · integrated with ENTLN	Data providers to the Bureau of Meteorology; scarce public performance data ^[22] .
SALDN	South Africa	SAWS (government)	~24 · Vaisala LF, MDF+TOA	Declared: DE 90%, LA 500 m. Validated 2022: flash DE 84.9%, LA 59–124 m (Johannesburg) ^[18] .
RINDAT	Southern, south-eastern and central-western Brazil	CEMIG + FURNAS + INPE + SIMEPAR	~34 · Vaisala LF, MDF+TOA	Operational since the 1990s; limited public performance documentation ^[22] .
Keraunos	Colombia (partial: Venezuela, Panama, Caribbean)	Keraunos SAS (private)	~20 · LINET, TOA	The only Andean precision network; academic validations 2016 and 2021 ^[22] .

Long-range global networks are a distinct category — kilometer-scale accuracy, planetary coverage — and complete the picture where no precision network exists:

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precision networks in the central Andes (August 2026)

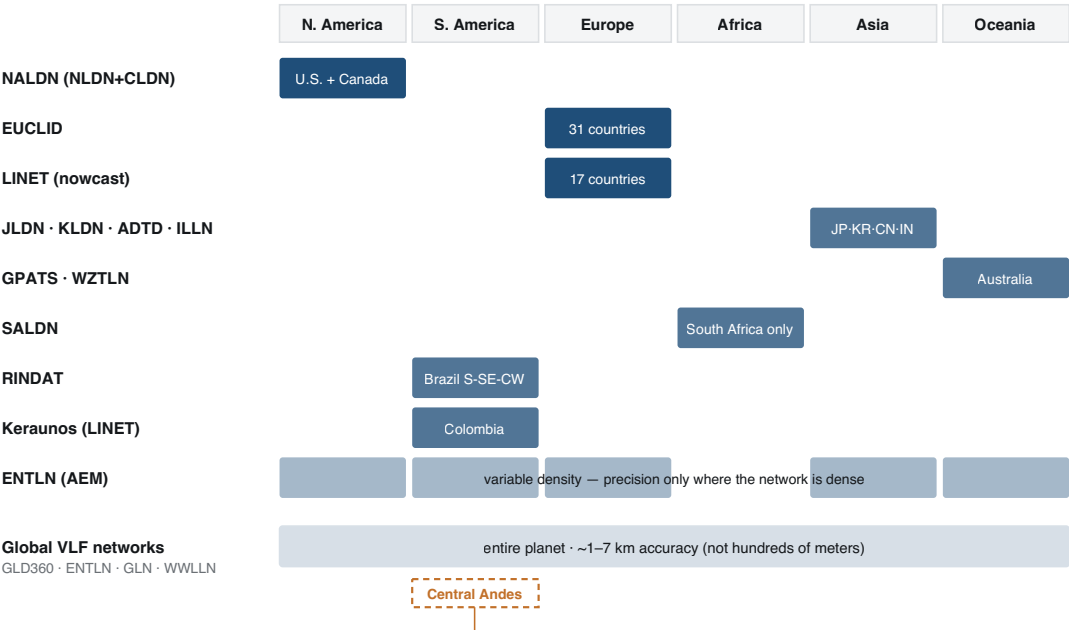
31

countries covered by EU-CLID, Europe's largest validated network

In the central Andes **there is no precision network**: coverage is built at site scale.

GLOBAL NETWORK (VLF)	OPERATOR	PUBLISHED PERFORMANCE
GLD360	Vaisala (private)	CG flash DE 86–92% (measured over the U.S.); median LA ~1 km since version 4.0 (Feb 2025); previously 1.5–2 km ^[21] .
ENTLN global	Earth Networks / AEM	Outside its dense zones it operates with lower DE and kilometer-scale accuracy ^[19,22] .
ATDnet	Met Office (United Kingdom)	Europe and Atlantic; LA 1–5 km; flash DE ~90% near the core ^[22] .
GLN (former TOA Systems)	AccuWeather (acquired in 2025)	>500 global sensors; sub-km accuracy only in the U.S. ^[22] .
WWLLN	Academic (U. Washington + ~70 institutions)	DE 11–35% (up to ~60% for intense flashes); LA 2–7 km. Valuable for research, not for operational warning ^[22] .

WHERE PRECISION COVERAGE EXISTS · August 2026



Peru, Chile, Bolivia and Argentina have no precision lightning locating network (August 2026): the coverage available over those territories comes from the global VLF networks (kilometer-scale accuracy), complemented — where they exist — by site-level warning systems (TWS under IEC 62793) installed by each operation.

Figure 6. Coverage matrix by region, August 2026. Solid blue = national or continental precision coverage; medium blue = coverage limited to the indicated subregion; light blue = multi-country network with highly variable density (and therefore accuracy); pale blue band with border = long-range global coverage, a distinct category (kilometer-scale accuracy), not an inferior one. Own elaboration from operator sources and literature^[17–22]; coverages evolve and must be verified when contracting.

For the Andean reader, the conclusion of the census is direct: in the central Andes the only available “network” is the global one, and its kilometer-scale accuracy is sufficient to track storms and anticipate their approach, but it does not substitute for a precision network or a well-designed site-level warning system. In that geography, warning performance depends almost entirely on how the local TWS is designed — the choice of technologies, the target, surrounding and monitoring areas (TA/SA/MA), and the criteria of Section 4 — and not on a national infrastructure that does not exist today.

That gap has, however, a route to closure that the census above does not capture, because it does not appear on maps of national coverage: **site-scale precision deployments**. The three dominant technology ecosystems install networks on demand, at any scale, with distinct and documented architectures. nowcast deploys turnkey national or private LINET networks — Colombia’s Keraunos network was born that way. Earth Networks (AEM) densifies its ENTLN by installing local sensors that integrate into its global network — the Indian network is, in fact, a country-scale deployment of that technology. And Vaisala offers a hybrid architecture in which a local cluster of LS7002 sensors is fused with its global GLD360 network in a single central processor, in one location algorithm^[15]; since those sensors measure time and angle, two or three are enough to deliver accuracy of hundreds of meters over the operation and its surroundings (Section 5.3), with the global network contributing the long-range vision and the redundancy against a sensor outage. For an operation in the Andes, that is today the only practical route to precision coverage: building it at site scale — with any of the three architectures — and evaluating it with the same metrics of Section 4, which do not distinguish between a national network and one’s own.

8

EVIDENCE

27

references; the weight falls on sources with no commercial interest

20–25%

of cells open with a ground flash: no one warns first

A field mill, today, enters **only as a subordinated system**: its signal never stops the mine on its own.

o 8

What the evidence supports — and what it does not

- **The field meter's scenario is real; the instrument is no longer the answer.** When the storm forms exactly over the site, no lightning-based system warns before the first flash, and in some regions up to 20–25% of cells open with a ground flash^[8]. That scenario historically justified adding a field mill as a complement, and IEC 62793:2020 still acknowledges the local detector^[11]. But the evidence and the market now point in the opposite direction, for four converging reasons. First, the measured result: when the mill was combined with a network, the joint system **got worse** — the instrument contributed more noise than warning^[7]. Second, the physics of integration: a location processor fuses measurements of discharges (times and angles of electromagnetic pulses), and the mill does not measure discharges — it delivers nothing a processor can fuse. The only thing combinable is its *alarm*, at the decision layer, and that is precisely what was tried in Florida. A field mill next to a modern network does not form an integrated system: it forms two parallel alarm systems. Third, the market: the manufacturers that operate validated networks discontinued their mills — Vaisala's EFM550 is out of the catalogue and Campbell Scientific's CS110 is listed as “retired” on its own manufacturer's website^[23] — and the current supply comes from specialized manufacturers without a validated locating network, the same ones that sustain the “Class A” claim^[14]. Fourth, the environment: suspended dust, the normal condition of an open pit, is its classic source of false alarms^[1,8,9].
- **What covers that scenario today.** Three routes, all inside a modern system: **total lightning detection** (in most storms the first discharges are intra-cloud, minutes before the first ground flash^[8]); **meteorological precursors** — radar criteria over the cloud's charging zone achieve a probability of detection (POD) of 84 to 100% with lead times of 7.5 to 17 minutes^[8, Table 19.7]; and **quantifying the scenario** with the network's own data: one year of operation tells what fraction of the site's episodes formed overhead. If that fraction proved material and a mill were still evaluated, it would have to enter as a second, subordinated system — its signal never as the sole trigger of a shutdown — and with its long-term support resolved in writing.
- **Geography modulates the result.** The authors of the Florida study caution that at high-altitude sites the surface electric field may grow more before the first flash, and the EFM may perform better than in their data^[7] — a relevant nuance for mountain operations. As a counterweight, suspended dust, abundant in open-pit mining, is one of the classic false-alarm sources of the electrostatic principle^[1,8,9].
- **Part of the literature has commercial interest, and this review declares it instead of hiding it.** Several of the studies cited were written by scientists of manufacturers or network operators^[7,9,11], and two documents are unpublished material: a manufacturer's internal report^[15] and a specialist's technical memo^[16]. They are included because they contribute evidence that exists nowhere else — the only simultaneous comparison of the three technologies, and an architecture argument about the first flash — always with their provenance in sight. The core figures of this review, however, rest on the sources without that interest — a state meteorological institute^[5], universities^[6,12,13], an Austrian research institute^[10] — and the directions coincide.
- **Declared false alarm ratios (FAR) are not comparable between vendors.** The 2020 definition of false alarm is lax: an alarm with no flash at the target does not count as false if there was activity in the monitoring area^[1]. Two datasheets can declare very different FARs measuring the same thing. Without the method and the areas defined, the isolated number says nothing.
- **No figure in this review replaces an on-site evaluation.** The numbers come from Florida, Spain, the Netherlands, France and Austria. The direction is consistent across climates, but the exact performance at a specific site is verified with the methodology of Clause 9 and Annex D of the standard itself, on site data^[1].

9

EIGHT QUESTIONS

8

questions that evaluate any offer with the standard's tools

94.5%

detection a good network keeps when a sensor fails (question 6)

Eight questions with the standard's tools are enough to evaluate any commercial offer.

09

The eight questions an operations manager should ask

This entire document fits into eight questions. They are written as the person responsible for an operation's safety and production would ask them — and next to each one, how to demand the answer with the tools of the standard.

THE QUESTION, IN PLAIN TERMS	HOW TO DEMAND THE ANSWER
1 · Does it see every lightning flash that threatens my operation?	Ask for the POD (probability of detection) measured on data from your own site, with the standard's method. Reference points: networks exceed 90%; field mills fall between 20 and 60% (Sections 4 and 6).
2 · Does it know where each flash struck — and how does it achieve that precision here, where there is no national network?	Ask for the median location accuracy and what sustains it. In the Andes, accuracy of hundreds of meters is only achieved by adding local sensors to a global network — ask how many local sensors the offer includes and how they fuse with the global network (Sections 5.3 and 7).
3 · How much warning do I get before the storm arrives?	Ask for the POD with minimum lead time (for example POD _{10'} : warnings with 10 minutes or more). A network that sees the storm at 100 km gives tens of minutes; an isolated local sensor, minutes (Sections 4 and 6).
4 · How often will it shut me down for nothing?	Ask for the false alarm ratio (FAR) and how it was measured — the standard's definition is lax and two offers can declare incomparable figures. Every needless shutdown costs production and, worse, the alarm's credibility (Sections 4, 6 and 8).
5 · What about the storm that forms right over the mine?	Ask how the system covers it: intra-cloud detection (the first discharges of nearly every storm) and meteorological precursors. If you are offered a field mill, three questions suffice: who manufactures it and will support it in five years?, how does it integrate — or not — with the network's processor?, and can its signal, by itself, shut down the mine? (Sections 5 and 8).
6 · Does it keep protecting when a sensor fails?	Ask for the efficiency with one sensor out of service. With time-and-angle sensors the network keeps 94.5%; with time only it falls to 60.3% (Figure 3). A sensor failure is routine, not an exception.
7 · When can I safely get back to work?	Ask how the end of the alarm and the total duration per episode are defined (TTC, time to the all-clear, and TAD, total alarm duration, in the standard): that is where the shutdown hours live — and the risk of resuming too early (Sections 4 and 6).
8 · Who has verified all this, besides the one selling it to me?	Ask for validations by universities or meteorological institutes with real data. What operators declare systematically exceeds what third parties measure, and the IEC does not certify products: without a third party, everything is self-declaration. And if the offer invokes a "class," it is citing a cancelled standard (Sections 3, 4 and 7).

This document is a technical reference review: it describes what the standards and the published literature say, with their limits. It does not constitute a purchase recommendation or an engineering specification for a particular site.

Acknowledgements and references

Acknowledgements. Drafts of this document were technically reviewed by Martin J. Murphy (Vaisala Inc.) and Ronald L. Holle (Holle Meteorology & Photography); their corrections and the additional references they contributed are incorporated in this version. The judgments — and any remaining errors — are the authors' responsibility.

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external technical reviewers: Martin J. Murphy and Ronald L. Holle

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references verified against the official IEC and CENELEC texts

The normative citations were **verified** against the official IEC and CENELEC texts and previews.

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