The emergency stop is the hazard

Why a humanoid inverts the safety logic of the factory, and what that costs in operating hours

2026

At a glance

Machine safety has rested for forty years on one assumption: if the power falls away, the hazard stops. With a two-legged machine that assumption inverts, because a humanoid stays upright only as long as its controller runs, and the safe stop is precisely the moment at which it falls. That is why the whole category falls outside ISO 10218, the standard industrial robot safety is built on: that text assumes statically stable machines. The standard that has to close the gap, ISO 25785-1, is a committee draft on 17 July 2026 and not yet a standard. Meanwhile the machines do run, but far less than the attention suggests: the best documented deployment in the world counts 1,250 operating hours after eleven months.

1,250

Operating hours of Figure 02 at BMW Spartanburg over eleven months, according to Figure's report of November 2025

Foreword

About humanoid robots it is difficult to write anything that still holds in two years, and that is precisely why this report exists. It is not about what these machines will one day be able to do. It is about one technical property that is already established today and that governs the rest: a machine that actively balances is a machine for which switching off is not a safe state. That single fact explains why the standards are missing, why deployment stays small and why the figures in press releases and the figures in working hours lie so far apart.

For this report it looked at the project course of ISO 25785-1 at ISO/TC 299, at the pathway report of the IEEE Humanoid Study Group, at the position paper of the International Federation of Robotics, at the text of ISO 10218:2025 and ISO 13482, and at the published deployment figures of the companies themselves. Where a number comes from a manufacturer, that is stated, because in this sector that is the difference between a measurement and a communication.

The content applies on 17 July 2026. ISO 25785-1 sits in a standardisation trajectory that has stages to go, and the deployment figures change every quarter.

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01 The assumption under forty years of machine safety

Machine safety has a founding principle that is so self-evident that it is rarely spoken: the loss of power may not lead to hazard. You find it back in the emergency stop, in the safety circuit at the door of the cell, in the spring brake that clamps shut when the voltage falls away, in the logic of every risk assessment drawn up according to ISO 12100. Switch the machine off and the hazard stops. That is the reason why a red button on a post is a safety device.

ISO/TR 20218-1 formulates it explicitly for robot arms and their tooling: loss of power may not lead to loss of the load, to unexpected movement or to other hazards. For an arm on a fixed

pedestal that is an achievable requirement. The reaction forces are absorbed by the base, the mass stands where it stands, and a braked arm that comes to a halt is an arm that does nothing any more.

> With an arm in a cage the emergency stop is the solution. With a machine that actively balances, the emergency stop is the event.

The pathway report of the IEEE Humanoid Study Group, published in September 2025 with Federico Vicentini, Brandon DeHart and Ben Beiter among its authors, points out drily that humanoids do not keep to that rule: with them, loss of power can lead at any moment to falling over. It is a sentence of fifteen words and it takes the foundation out from under the building.

A two-legged machine is namely not stable. It is kept stable. Hundreds of times a second a controller calculates where the centre of gravity is, where it is going, and which joint angles are needed to prevent it from falling outside the support surface. Standing upright is not a state but an activity. Stop the activity, and the fall follows.

That turns the safety logic around. With an arm in a cell the emergency stop is the solution. With a machine of one and a half metres and seventy kilos that actively balances, the emergency stop is the event that causes the hazard. Whoever presses the button because something is going wrong lets a mass fall in a direction that depends on speed, load and floor slope. The safe state therefore has to be controlled itself, with power, while the standard assumes that safety begins where the power stops.

Source: IEEE Humanoid Study Group, A Pathway Study for Future Humanoid Standards, September 2025 · ISO/TR 20218-1, requirements and hazards for end effectors · ISO 12100, safety of machinery: general principles for design

02 The gap in the series of standards

If you want to know today which safety standard a humanoid in a factory has to meet, the honest answer is that there is none. Not because nobody has thought of it, but because the existing standards do not fit on their own terms. That is not an interpretation from outside; it is in the texts themselves.

ISO 10218, the series for industrial robots that was thoroughly revised in February 2025, assumes statically stable robots. The whole architecture of force limiting, speed monitoring and safe stops presupposes a machine that stays standing where it stands. A walking machine falls outside that, not through an omission but through the scope.

ISO 13482 covers personal care robots and thereby touches some humanoid forms, but that standard was written for another world. In May 2026 IEEE Spectrum published a conversation with standardisation researcher Jae-Seong Lee that puts the problem sharply: the standard names hazards such as unpredictability and incorrect autonomous decisions, but does not turn that knowledge into binding assessment criteria, test methods or enforcement mechanisms for autonomy in an uncontrolled environment.

In that same piece Lee explains why that gap cannot be closed by defining the environment of use more tightly, which is the usual way out in machine safety. The value of a domestic humanoid depends on working in uncontrolled conditions. A robot that is only safe in

standardised rooms, with healthy adults, under well defined conditions, is no longer a domestic humanoid.

So a situation arises that is unusual in the industrial safety world. There are machines on floors, there are customers, there are contracts, and there is no type C standard that says what is good enough. Manufacturers fall back on ISO 10218 and ISO 13482 where those fit, on ISO 12100 for the risk assessment, and further on their own technical judgement, which a regulator may assess afterwards.

Source: ISO 10218-1:2025 and ISO 10218-2:2025, scope, ISO/TC 299, February 2025 · ISO 13482:2014, safety requirements for personal care robots · IEEE Spectrum, Domestic Humanoid Robot Safety Standards Are Shifting, interview with Jae-Seong Lee, 19 May 2026

03 The standard that is being written

ISO/TC 299 has started on the gap. The project is called ISO 25785-1 and the title says what it is about: safety requirements for dynamically stable industrial mobile robots, with legs, wheels or other forms of locomotion, part 1 about the robots themselves. The notion that delimits the category is actively controlled stability, and that is a more precise delimitation than the word humanoid, because a two-wheeled machine can also have to balance actively.

The project registration of ISO reads as a timeline and it is the most sober source about the state of affairs. The new project was approved on 22 May 2025 and registered the same day, after which the working draft started. The comment period closed on 21 June 2025. The committee draft was registered on 8 May 2026 and the consultation on it started on 12 May 2026. On 17 July 2026 the project stands at stage 30.20.

What still comes after 30.20 is not trivial: the closing of the comment period, possible referral back to the working group, approval as a draft international standard, the public enquiry on that, a final draft, formal approval and only then publication. Those are four stages that each cost months and that each know a way back.

The leadership of the American delegation consists of Federico Vicentini of Boston Dynamics, project leader Kevin Reese of Agility Robotics and Carole Franklin of the Association for Advancing Automation. That has an advantage and a price. The advantage is that the requirements will be technically achievable, because they are written by people who build the machines. The price is that the pace of the standard depends on the diary of companies that also have to deliver in the meantime.

The substantive direction is known from the work of the group. The standard becomes a type C standard, which is to say that it gives specific requirements for this machine category and not only general principles. It tackles the fall as a hazard in its own right: performance thresholds for the recovery of balance under nominal load, and the formalising of fall zones. That last is a notion that does not exist in classic robot safety, because an arm in a cell falls nowhere.

Source: ISO/CD 25785-1, Robotics: Safety requirements for dynamically stable industrial mobile robots, ISO/TC 299, project stages consulted on 17 July 2026 · Tech Briefs, Safety in Motion: Setting the Standard for Humanoid Robots, 13 May 2025 · IEEE Humanoid Study Group, A Pathway Study for Future Humanoid Standards, September 2025

04 What the machines really do

Next to the standards question stands a measurement question, and it is equally uncomfortable. Of humanoids there are very many images and very few numbers. The numbers that exist come almost all from the companies themselves, and that is no reproach but it is a property a reader has to take into account.

The best documented case is the deployment of Figure 02 at BMW Group Plant Spartanburg. According to the report Figure published in November 2025, that deployment ran eleven months, in shifts of ten hours from Monday to Friday. The machine loaded more than 90,000 sheet metal parts, took roughly 1.2 million steps and contributed to the production of more than 30,000 examples of the BMW X3. The total of operating hours amounted to roughly 1,250. Figure took the F.02 machines out of service afterwards.

> The best documented deployment in the world reached fewer hours in eleven months than one employee in the same period.

Put that number next to an ordinary employee. A full-time worker does roughly 1,500 to 1,700 hours in eleven months. The most documented humanoid deployment in the world, in shifts of ten hours, over five days a week, eleven months long, came out below what one person makes in hours in the same period. That is not little for a prototype on a real line. It is something else than the images suggest.

The second well documented deployment is that of Agility Robotics. The company reported on 20 November 2025 that its machine Digit had moved more than 100,000 totes at the site of GXO in Flowery Branch, under a multi-year agreement in which GXO pays for the work instead of buying the machines. A deployment database that follows the sector counts in addition more than 65,000 operating hours across nine customer sites and names GXO, Schaeffler, Toyota Motor Manufacturing Canada and Mercado Libre as commercial customers.

They are honest figures, and precisely for that reason it is useful to say what they are not. They contain no intervention rate: how often did someone have to step in. They contain no fault data. They are not broken down per customer. And they are not transferable: the figures of Figure 02 say nothing about Figure 03, because that is a different machine.

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Customer sites where Agility Robotics reports deployment of Digit, together accounting for more than 65,000 operating hours (position July 2026)

Source: Figure, report of the deployment of Figure 02 at BMW Group Plant Spartanburg, November 2025 · Agility Robotics, Digit Moves Over 100,000 Totes in Commercial Deployment, 20 November 2025 · Humanoid factory deployment database, status classification of published deployment cases, July 2026

05 Why the hours stay low

The usual explanation for those low figures is that the intelligence does not stand far enough yet. That is partly true and it is not the binding constraint. In its position paper Humanoid Robots: Vision and Reality of July 2025, published on 14 August 2025, the International Federation of Robotics set out the trade-offs, and the bottlenecks it names are more banal than a reasoning model: limited battery life, high costs and task-specific limitations.

The battery is the clearest. A machine that has to correct hundreds of times a second in order not to fall consumes power also when it does nothing useful. Standing still costs energy. With an arm on a pedestal standing still is free. That difference translates directly into operating hours per charge and therefore into hours per day, and it is the reason why part of the sector puts wheels under the torso and drops the walking.

> With a machine that actively balances, standing still costs energy. With an arm on a pedestal, standing still is free.

The IFR points out in addition that classic industrial robots are simply better for fast and precise repetitive work: simpler, faster and more reliable. That is a statement from the trade association of that same industry and it is therefore often waved away, but it follows from the physics. A machine that has to watch over its own balance spends control bandwidth and margin on a problem a pedestal solves for free.

And then there is the safety margin. As long as there is no type C standard, a company lawyer or an insurer is looking at the same question as the engineer: how do you prove that this is safe enough. The answer in practice is fencing, low speeds, separate aisles and supervision. Precisely the measures that undermine the promise of the humanoid, because that promise was that the machine would fit into the existing environment without rebuilding.

So you get a chain that stands on its own. No standard, so fencing. Fencing, so less shared space. Less shared space, so fewer tasks. Fewer tasks, so fewer hours. The IFR estimates that broader application can take five to ten years if economies of scale bring the production costs down. That is an estimate from a trade association and not a fact, but it explains the figures better than the images do.

Source: International Federation of Robotics, position paper Humanoid Robots: Vision and Reality, July 2025, published 14 August 2025 · IFR, press release accompanying the position paper, Frankfurt, 14 August 2025

06 Two continents, two speeds

The regional differences are not cosmetic. In its position paper the IFR describes four positions that each arise from a different consideration. China has put humanoids at the centre of its national strategy and formulated concrete targets for mass production. In the United States tech companies and private capital drive the development, with a strong orientation towards logistics and production and with the machine as a means of production, not as a companion.

Japan has the longest history. Honda showed Asimo in October 2000 and the Japanese line has always been that robots must be able to live together with people and be accepted as part of society. Europe puts the accent, according to the same paper, on the ethical side and on robots that work next to people in industry, with the emphasis on safety and on what the paper calls a human-in-command approach: the robot assists the human, not the other way around.

That European position is not sentiment but an expectation about regulation, and it arrives precisely at the subject of this report. The IFR establishes it itself: humanoids that use forms of AI fall in the EU under the regime of the AI Act, and like every machine they have to be safe. Both sentences stand next to each other in the paper without the paper concealing that the instrument to prove that second one is not finished.

For European companies that means a double burden and a single advantage. The burden: two regimes, one of which has no standard yet and the other no complete set of harmonised standards. The advantage: whoever builds in Europe builds from the start for the strictest environment, and that is historically the cheapest order. Sliding safety into an architecture afterwards is more expensive than designing it in.

What the paper does not do, and that does it credit, is name a year in which the machines are there. It says that broad application as a universal household help is not on the table in the short and medium term. For a trade association that has an interest in enthusiasm, that is a strikingly reticent sentence.

Source: International Federation of Robotics, position paper Humanoid Robots: Vision and Reality, July 2025 · IFR, press release Humanoid Robots: Vision and Reality, 14 August 2025

07 What it changes

For whoever builds, the centre of gravity of the difficulty shifts. The attention lies on perception and control, and that is where the research and the capital go. The permission to put the machine next to a human, however, hangs on another question: the demonstrable control of the fall. Performance thresholds for balance recovery under load, fall zones, behaviour on loss of power. Whoever measures and documents that already now has later the evidence the standard will ask for. Whoever waits until the standard is there measures only then.

For whoever buys, the most important sentence in a quotation is not what the machine can do but against which standard the risk assessment is drawn up and with which residual risks. As long as ISO 25785-1 is not published, formal conformity with that standard does not exist and nobody can claim it. A supplier who says that their machine meets ISO 25785-1 is describing a text that can still change.

For the insurer and the company lawyer the question is sharper than for the engineer. With an arm in a cell the liability chain has crystallised after thirty years of practice. With a walking machine without a type C standard, every incident is a case of first instance about the question of what the state of the art was at the moment of putting it into service. Documentation is in that situation not administration but the evidence itself.

For the staff organisation something applies that is in no standard. The machines that run today do so in fenced zones with supervision. That means that the business comparison does not run between a robot and an employee, but between a robot with guidance and an employee. Whoever sets up a trial and forgets that cost measures the wrong thing.

And for everyone the timeline applies. The committee draft is from May 2026. There are four stages to go and every stage knows a way back. Whoever plans for a published standard and an accepted application in the same year plans a coincidence that the history of standardisation rarely delivers.

Source: ISO/CD 25785-1, ISO/TC 299, stage 30.20 on 17 July 2026 · IEEE Humanoid Study Group, A Pathway Study for Future Humanoid Standards, September 2025

08 What does not add up yet

The first objection against this report is that it lives off company figures. The 1,250 hours come from Figure's report. The 100,000 totes come from a message by Agility. Neither is verified by a third party, neither contains intervention data, and both are published by parties with an interest in how they are read. That does not make them untrue. It does make them communications, and the sector has no independent measurement to set against them.

The second is that the comparison with a human employee is skewed and that the most refutable sentence of this report is in the previous paragraphs. A prototype on a real production line is not deployed to make hours but to learn, and the hours are therefore not the aim. Someone can rightly say that 1,250 hours on a running BMW line is worth more than 5,000 hours in a test hall. That argument is valid. It only changes nothing about what can be said about the scale of the deployment.

The third is that the inversion of the safety logic does not hold universally. It holds for machines with actively controlled stability, and that is precisely why ISO 25785-1 chooses that formulation and not the word humanoid. A humanoid upper body on a stable wheeled base does not fall over when the power falls away and sits closer to the existing standards. Part of the sector has made that choice deliberately, and it is a defensible choice that rarely counts in the discussion.

The fourth is that nobody knows which thresholds the standard will set. The substantive direction is known from the work of the committee, but thresholds for balance recovery under nominal load are no physical constant; they are agreements. They are written by a group in which the builders of the machines hold the pen. That is the rule in standardisation and not the exception, and it is also the reason why outside parties ought to get involved in the national mirror committees while it is still possible.

The fifth is that the absence of a standard is neither a free pass nor a ban. There are machines on floors next to people who have not chosen their own risk. The responsibility for that lies today with the builder and the user, with ISO 12100 as the only handhold and with the judge as the backstop. That is an uncomfortable place to let a sector wait until stage 60.00.

Source: Figure, report on the deployment of Figure 02 at BMW Group Plant Spartanburg, November 2025 · Agility Robotics, Digit Moves Over 100,000 Totes in Commercial Deployment, 20 November 2025 · ISO/CD 25785-1, title and scope: dynamically stable industrial mobile robots, ISO/TC 299 · ISO 12100, safety of machinery: risk assessment and risk reduction

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Venture Campus BV | Schaarbeekstraat 20E bus 11 | 9120 Beveren, Belgium | +32 333 11 333 | venturecampus.com

SOURCES

ISO/CD 25785-1, Robotics: Safety requirements for dynamically stable industrial mobile robots (legged, wheeled, or other forms of locomotion), Part 1: Robots, ISO/TC 299, stages consulted 17 July 2026 · IEEE Humanoid Study Group, A Pathway Study for Future Humanoid Standards, September 2025 · ISO 10218-1:2025 and ISO 10218-2:2025, ISO/TC 299, February 2025 · ISO 13482:2014, safety requirements for personal care robots · ISO 12100, safety of machinery: general principles for design, risk assessment and risk reduction · ISO/TR 20218-1, end effectors · IEEE Spectrum, Domestic Humanoid Robot Safety Standards Are Shifting, 19 May 2026 · Tech Briefs, Safety in Motion: Setting the Standard for Humanoid Robots, 13 May 2025 · International Federation of Robotics, position paper Humanoid Robots: Vision and Reality, July 2025, published 14 August 2025 · Figure, report of the deployment of Figure 02 at BMW Group Plant Spartanburg, November 2025 · Agility Robotics, Digit Moves Over 100,000 Totes in Commercial Deployment, 20 November 2025 · Humanoid factory deployment database, status classification of published deployment cases, July 2026