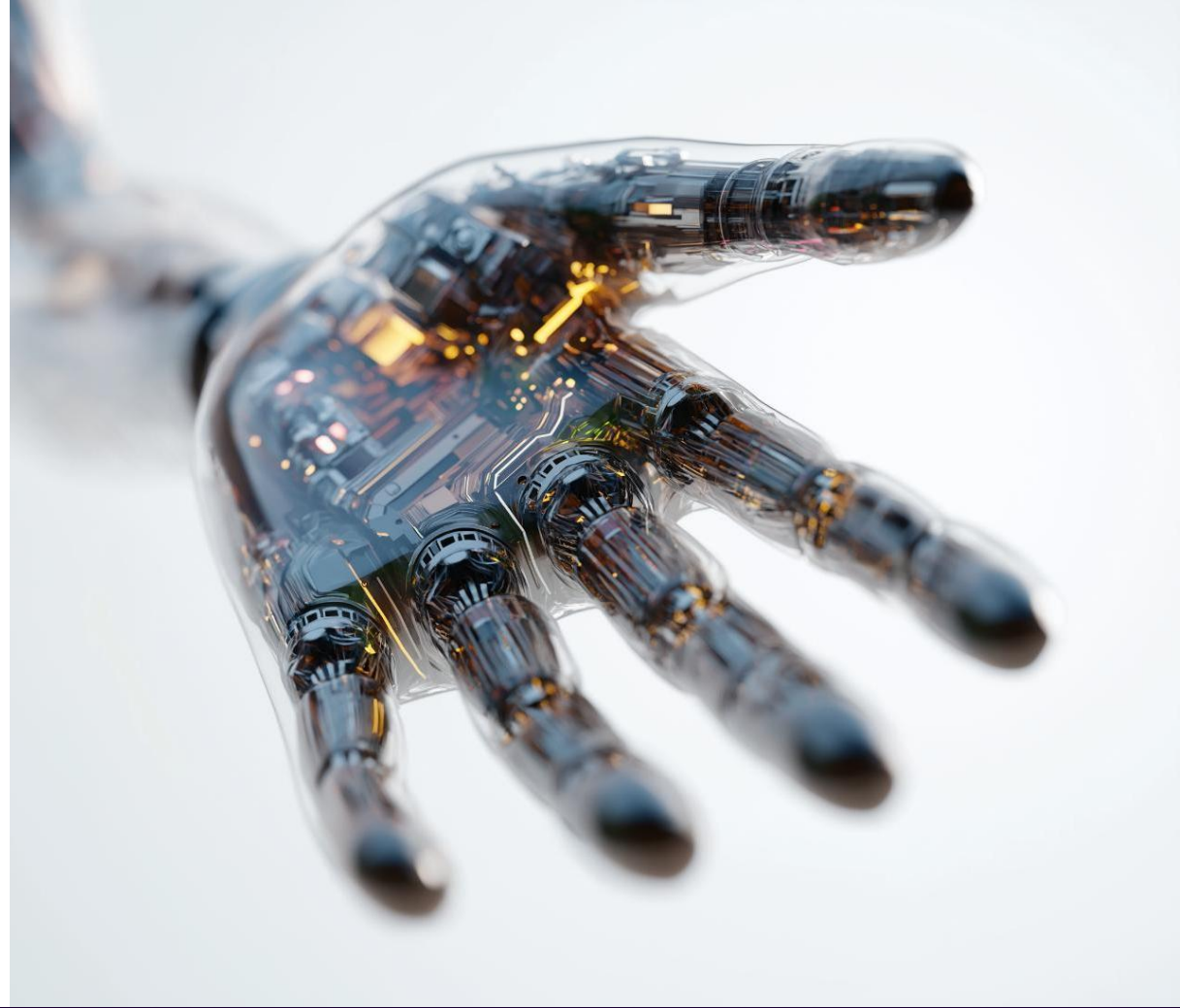


SEMICON WEST 2026 · SMART MANUFACTURING

Automating the Fab that was built for humans

Humanoid robots and dexterous manipulators
in legacy 200mm / 150mm wafer fabs



Thomas Beeg Managing Director · Accenture High Tech / Semiconductor

WHO IS TALKING



Thomas Beeg

Managing Director
Accenture - High Tech /
Semiconductor

30+ years

in semiconductor manufacturing - Infineon, Qimonda,
GlobalFoundries, Wolfspeed, Fabmatics

30+ cleanrooms

walked in 100mm, 150mm, 200mm and 300mm across the US,
Europe and Taiwan

Operations, IE & Automation

AMHS, MES, WIP flow, equipment engineering, factory simulation

SEMI Smart MFG Initiative

Co-lead Work Group FAB Automation/Autonomy

SEMI FAB AUTOMATION & AUTONOMY WORKING GROUP

Provide a standardized industry matrix

survey that enables fabs to confidentially assess their automation maturity both internally and against peer facilities

Benchmark fab autonomy maturity against results from other fabs

Provide assistance in approaching higher levels of automation and autonomy

Support in calculation ROI to help fab leaders evaluate the impact of implementing automation capabilities

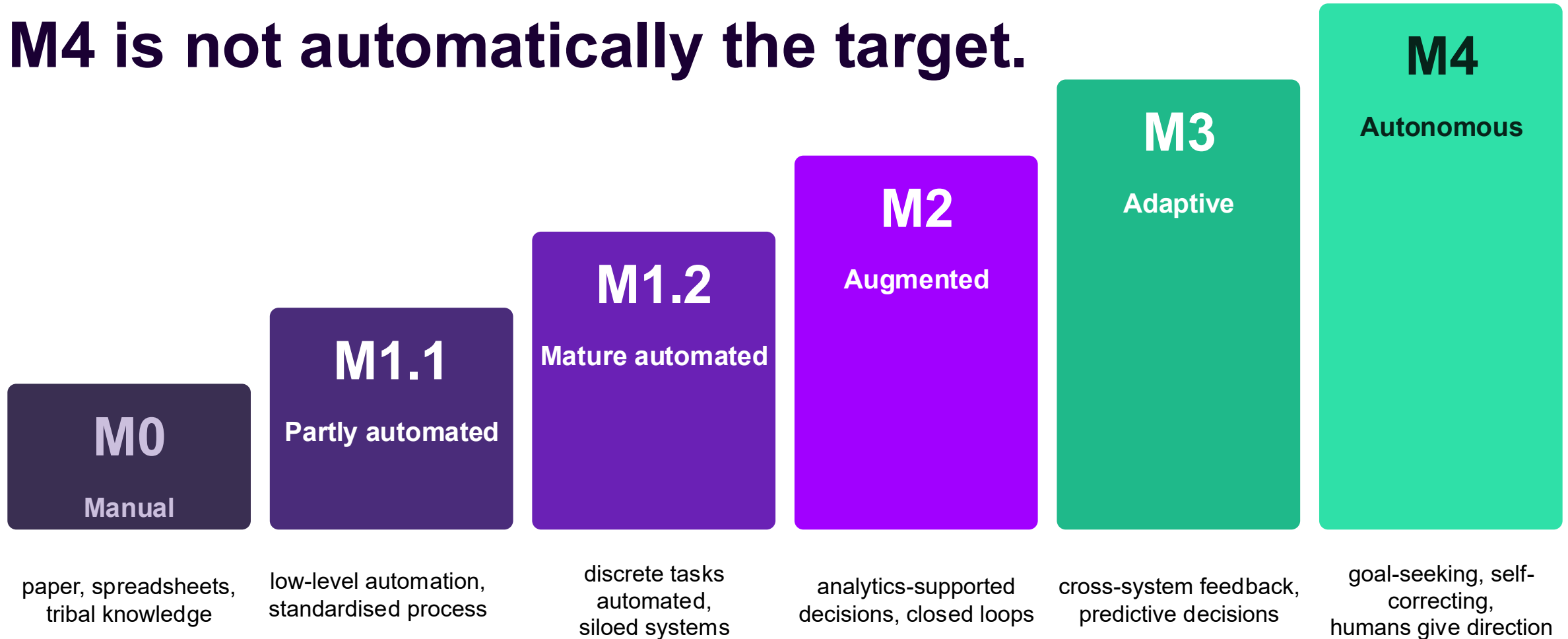


15 Fabs assessed. Eight domains scored.

An industry-wide collaboration under the SEMI Smart Manufacturing Initiative — fabs, equipment makers and suppliers, Accenture among them.

HOW A FAB IS SCORED

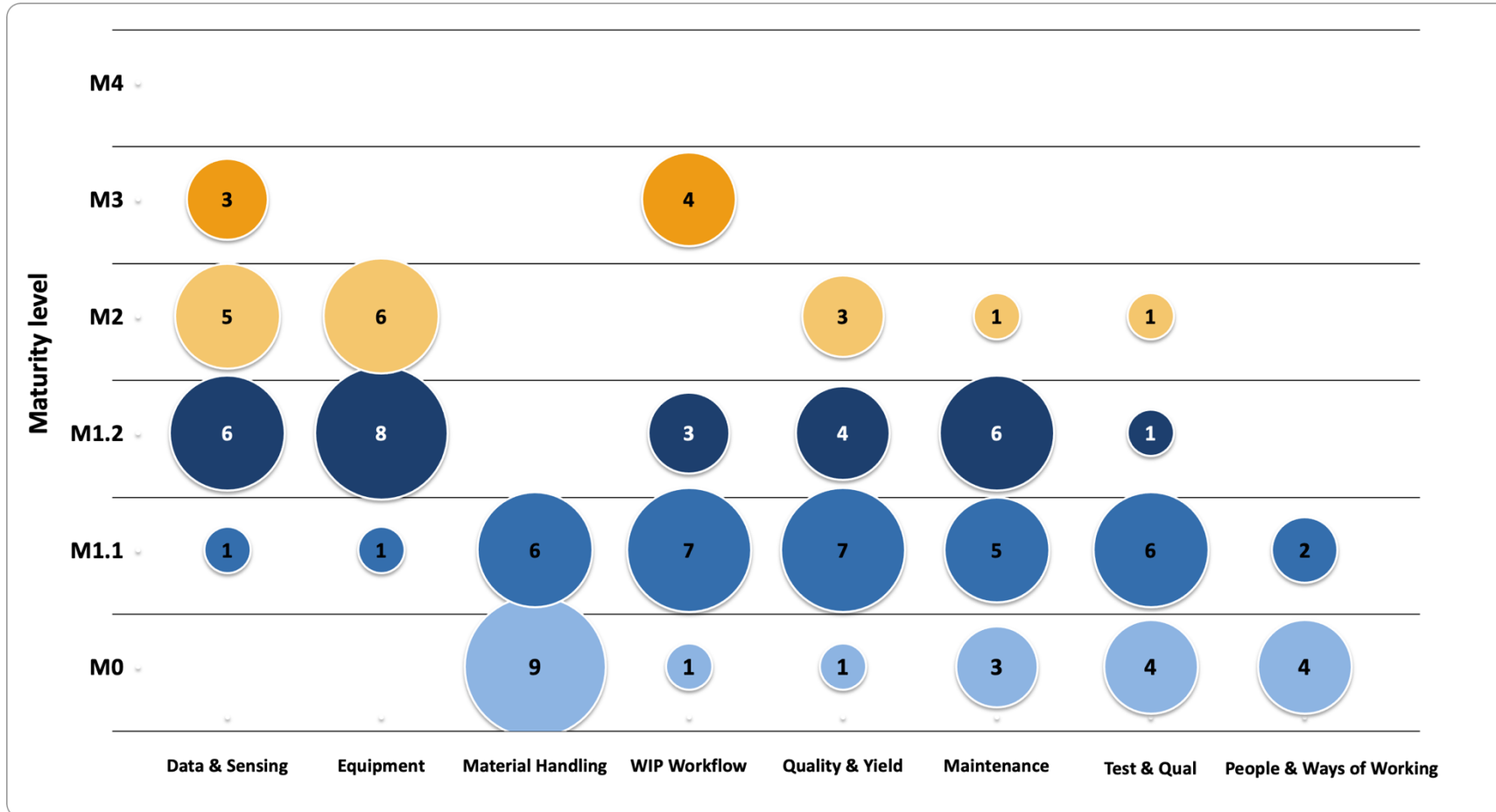
M4 is not automatically the target.



Every level is a stable operating model — the right target depends on the fab's economics.

15 FABs · FABs REACHING M1.2 OR BETTER in most domains

No fab is above M1.1 in material handling



0 of 15

fabs move material at M2 or above.

9 of the 15 are still fully manual.

Source: SEMI Automation & Autonomy Working Group fab assessments, September 2026 · n = 15 fabs ·

M2 = analytics-supported decisions and closed loops

People and Ways of working is a recent domain addition

**The Fabs automated the
decision making.
They did not automate the
material movement itself.**

Dispatching, scheduling and lot selection reach M3 in several fabs — and then a person picks up the box.

The framework is open — and it needs your fab

Domain playbooks

how to move up a level, domain by domain

ROI models

the economics of each maturity step

Model 2.0

refined framework, economics included

A white paper with all the details is coming out later this year

WORKING GROUP CONTACTS

Anshu Bahadur

abahadur@semi.org

Dennis Xenos

dennis.xenos@flexciton.com

Thomas Beeg

thomas.beeg@accenture.com

So why does material handling systematically lag?

Three constraints. None of them is about robots.

WHY — START WITH THE BUILDING

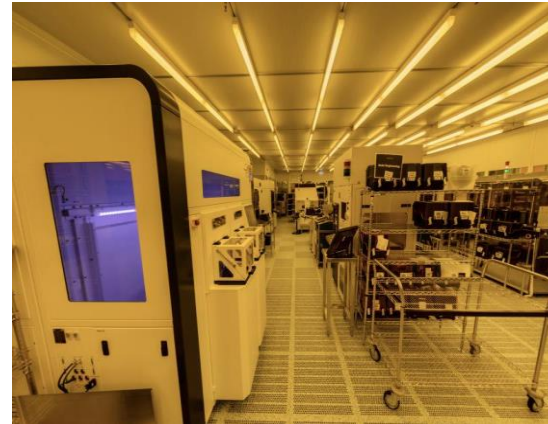
Nothing in a 1990s fab was drawn around material handling automation.



Low ceilings



Aisles under 1 m



Manual LP doors

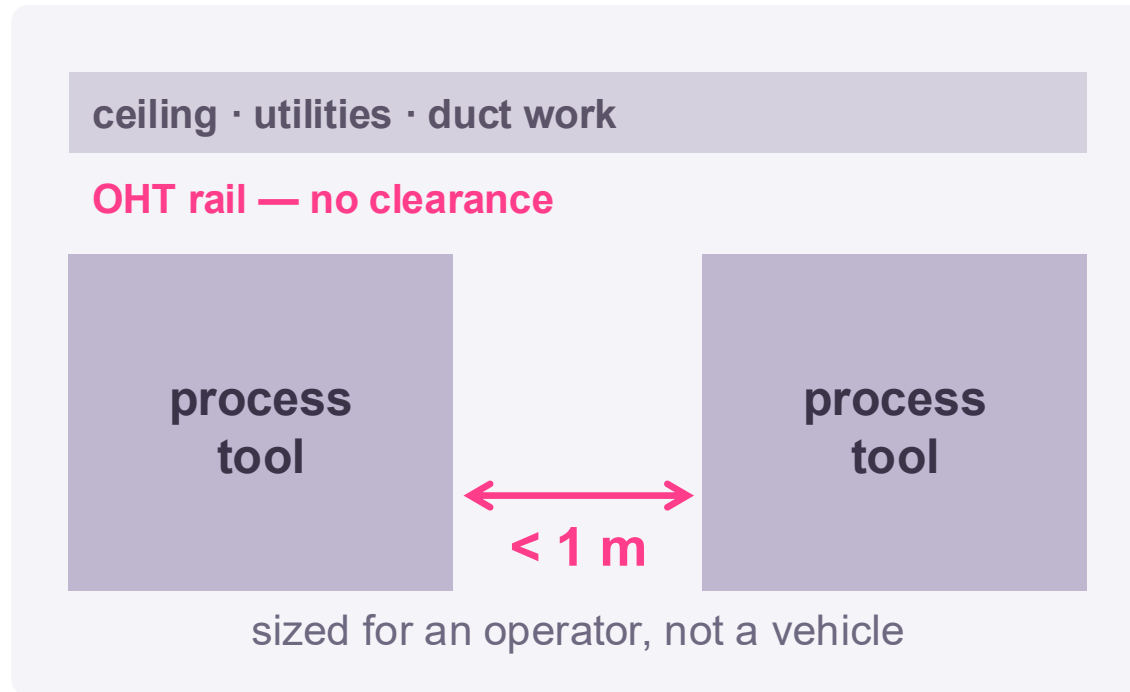


No load ports

Historically grown, tool by tool, for three decades — by people, for people.

CONSTRAINT 1

The transport does not fit the bay.



WHAT IT WOULD TAKE TO GET IN THERE

Overhead hoist (OHT)

structural work

Ground AGV / AMR

aisle widening, facility work, tool moves

Fixed arm / platform + cobot

cell build, tool / load port modifications

Human form factor

no building change

Only one needs nothing from the building.

CONSTRAINT 2

The carrier was designed for hands.



Four of the six steps are very hard to execute with a conventional end effector.

Bimanual

One hand holds the box, the other moves the cassette

Force control

Releasing a latch is a force task, not a position task

Particle discipline

Every contact and set-down is a contamination event



CONSTRAINT 3

No E84 or similar protocol - The human is the interface.

300mm was born automated

GEM300 plus E84 made carrier handoff uniform.

Carrier presented

L_REQ / TR_REQ

BUSY → COMPT

Host updated

Interlocked, deterministic, machine to machine.

At 200mm it was optional

Every integration is a one-off. Without E84 there is no interlocked handshake to the tool.

Read tool state OCR / HMI

Place and align compliant placement

Press to confirm physical actuation

Verify and report perception, then a host write

Perception and manipulation - not protocol.

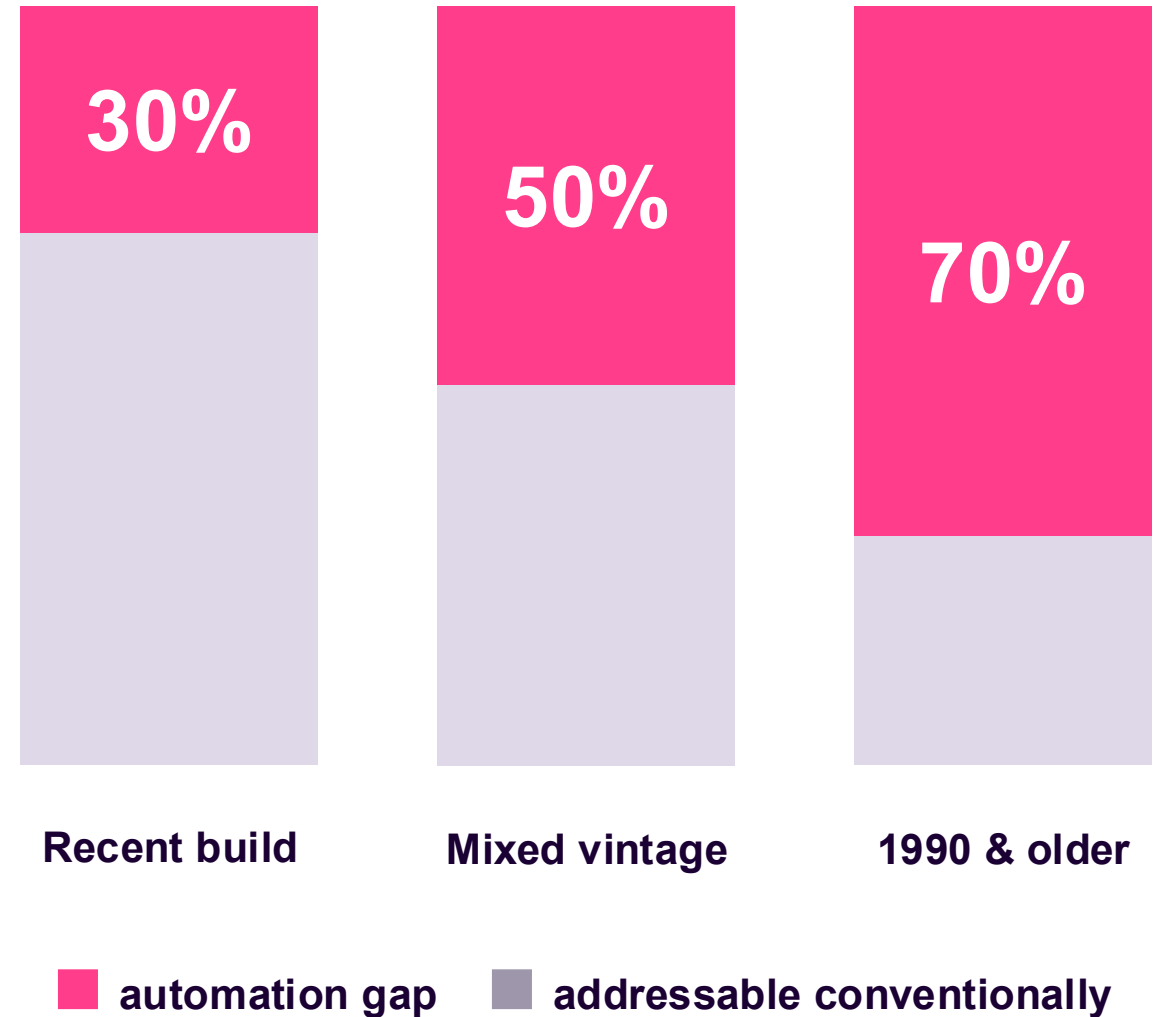
Which is exactly the work a human form factor is built to do.

THE THREE CONSTRAINTS COMPOUND

30–70%

of legacy fab floor space is not economic to automate with conventional transport.

- The spread tracks building vintage, carrier mix and E84 coverage - not fab size
- Automating the busiest routes leaves the remainder manual



**The building was designed
around the human body.**

**That is already
the specification.**

WHY A HUMANOID — AND NOT ANOTHER ROBOT

**One platform, in the envelope
the fab already allows.**

	AMR / AGV	Fixed arm	Platform + cobot	Humanoid
Navigate legacy aisles	needs ≥ 1 m	no mobility	1 m+, no stairs	human envelope
Open / close a carrier	no manipulator	single arm	single arm	bimanual
Inspect en route	add sensors	cell view only	partial	head + hand cameras
Facility change	aisles, marking	cell, tool rework	aisle work	none assumed

Not a replacement for AMHS — it reaches the areas AMHS cannot serve economically.

WHAT YOU ACTUALLY GET FOR IT

Three things, and they are all about what you don't rebuild.

1

No facility change

It works in spaces already designed for people. No rail, no aisle widening, no structural review.

2

Equipment reuse

Hands operate the HMIs and load ports already installed. No fixture per tool, no retrofit per tool.

3

Reusable task data

Human demonstration trains the next workflow. Every task added makes the next one cheaper.

One generic platform · many use cases · no infrastructure change

EXPECTED IMPACT — IN ADDRESSED AREAS

Take the human variability out of the move.

20–40%

cycle time reduction

10–20%

increase in fab output

3–4 → 5–6

WIP turns, manual to automated

Move latency transport and load / unload on demand, not on operator availability

Shift coverage 24/7, 365 — without added headcount

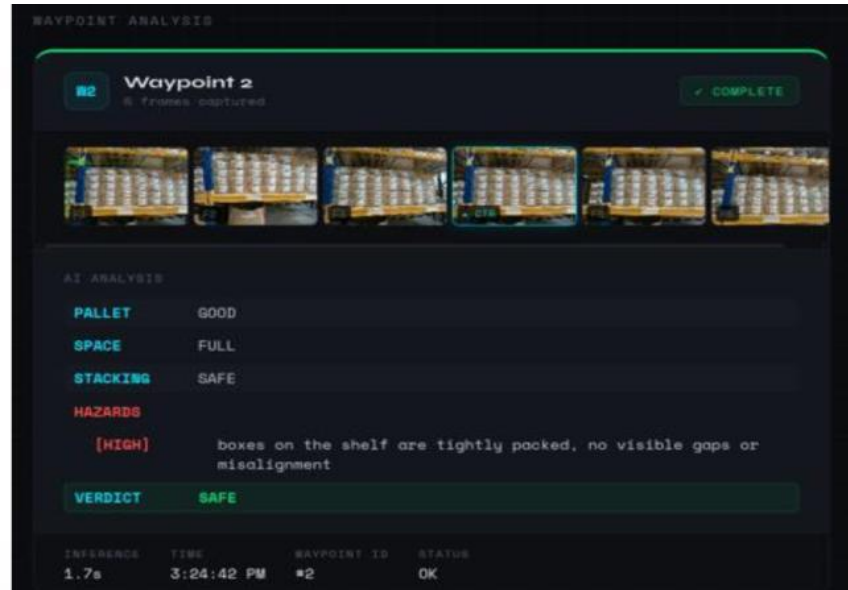
Wait & hold fewer lots waiting on a person

Flow variability consistent execution reduces queueing

What is not ready (yet).

The part of the talk that decides whether you believe the rest of it.

This is running today - in an operating warehouse.



VLM output written back to the enterprise system: condition, hazard, verdict.

Accenture with Vodafone Procure & Connect and SAP · Duisburg, Germany ·
announced April 2026, shown at Hannover Messe

Navigation

routes an occupied, unmodified facility

Perception

structured output at working speed

Integration

SAP EWM sources and records missions

Operations

multi-day running, alongside people

A cleanroom is not a warehouse.

CARRIES OVER

Autonomous navigation

aisle traverse, obstacle avoidance

Visual inspection

VLM condition and anomaly

Barcode / ID reading

carrier and lot ID with read-back

Enterprise integration

mission in, result out — MES and MCS

Fleet operations

dispatch and exceptions

DOES NOT CARRY OVER

Cleanroom compliance

class 10/100 particle, ESD, materials

Dexterous carrier handling

latches, lids, loaded cassettes

Precision placement

millimeter seating in a recessed nest

Tool-side handshake

an E84 equivalent that does not exist

Qualification & EHS

fab safety case, gowning, protocol

The right-hand column is what the fab work is aimed at.

Two limits decide what is possible this year.

50–200 ms

per token of vision-language-action inference
- against roughly ≤ 10 ms for safe contact control.

30–60 %

of manipulation precision lost to the sim-to-real gap. Balance risk beyond 1.5 m reach or 5 kg carried; bimanual work needs full-body torque optimisation.

Fully autonomous carrier handling in a cleanroom is not reachable with today's platforms.

PLATFORM READINESS

No platform on the market is cleanroom-rated for a wafer fab.

0

cleanroom-rated humanoid platforms available today

2-3

credible candidates for early co-development

2027+

earliest realistic cleanroom pilot

WHAT THE FAB HAS TO SPECIFY

Particle generation

sealed joints, bellows, class 10/100 counts

Materials

low-outgassing, no exposed lubricants

ESD

dissipative surfaces, wafer-safe limits

Actuation

electric only — hydraulics are out

End effectors

hands qualified for latches and lids

Safety case

interlocks, gowned staff, fall containment

Market signal: STMicroelectronics has publicly stated plans to deploy more than 100 humanoids in its older plants in the coming years (Reuters). Readiness view is our own OEM review; no vendor is characterised individually.

A **specification** problem before it is a **procurement** problem.

Write the requirement set from the fab's constraints — aisle, carrier, load port, particle class — not from a platform datasheet.

HOW WE PLAN IT

An AMHS upgrade and a humanoid program are different projects.

AMHS / AMR upgrade

Primary constraint

building and layout

Capital profile

front-loaded, infrastructure heavy

Lead time driver

construction windows, tool downtime

Unit behaviour

deterministic, programmed paths

Reversibility

low - the building has changed

Humanoid programme

robot capability and qualification

staged per robot and per skill

skill training, cleanroom qualification

learned policies, bounded autonomy

high - redeploy or return it

Gating follows technology readiness, not a construction schedule.

TWO PARALLEL TRACKS

Hardware proof now. Cleanroom platform in parallel.

TRACK 1 — Accenture-led

PoC & ROI digital twin

Manipulator hardware build

Hardware PoC at fab

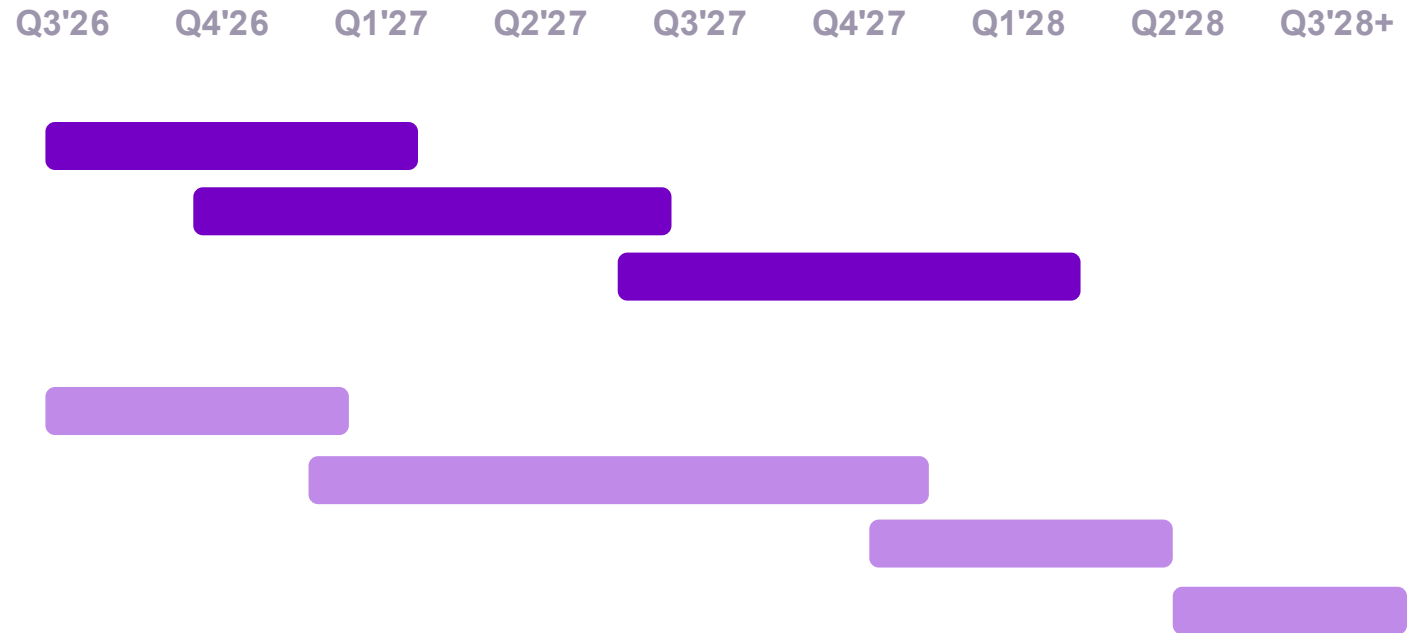
TRACK 2 — humanoid OEM

Identify OEM partner

Co-develop cleanroom platform

Hardware PoC pilot

Deployment at scale



Track 1 does not wait for a platform. Track 2 does not start from a blank sheet.

One aisle. One workflow. Eight to twelve weeks.

1

Aisle &
use case

2

Site &
process data

3

3D
scanning

4

Digital twin
build

5

Manipulation
training

6

Findings &
go / no-go

WHAT IT SETTLES BEFORE ANY CAPITAL IS COMMITTED

Does it fit?

clearance at the narrowest point, doorways, thresholds

Where does it fail?

failure modes enumerated in simulation, not in the fab

Can it reach?

load port height, recess depth, box table vs. the envelope

How many robots?

fleet sizing against measured move volume by route

Simulation retires unknowns. It does not qualify anything.

No physical deployment

no procurement, install or operation in the fab

No cleanroom qualification

no particle, ESD or contamination testing

No production integration

no MES, AMHS or equipment control build

No safety certification

no hazard analysis, no machinery certification

What it does produce: the minimum capability requirements for a viable solution, the adaptations that would raise task success, and the evidence to decide whether a physical pilot is worth building.

STATUS

Both tracks are running now.

TRACK 1 — TWO US 200MM FABS

Aisle selection

representative bay, one target workflow

Scan and twin

physics-ready model of the aisle

Manipulation training

carrier handling against measured criteria

Manipulator hardware

developed in parallel to the twin work

TRACK 2 — OEM ENGAGEMENT

Requirement set

particle, ESD, materials, end effector, safety

Candidate platforms

assessed on force control and hand capability

Co-development scope

cleanroom-ready platform for scale

Input from Track 1

measured constraints, not assumptions

Written from fab constraints — not from platform datasheets.

What was science fiction is
shipping now - and the curve is steepening.



12
months



First humanoid half-marathon -
only 6 of 21 robots finish

Same race - a humanoid beats
the human world record

**If you run a legacy Fab or
build humanoid robots**

**wait until everyone is doing it
or start today ?**

Thank you.

Thomas Beeg · Accenture - High Tech / Semiconductor
thomas.beeg@accenture.com · factoryphysicsandautomation.com



Scan to join the journey