Advancing 200mm wafer fabs: The Automation & Autonomy maturity framework

SEMI Smart Manufacturing Group

Innovation Forum for Automation
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Agenda

- Introductions
- Why investing in 200mm fabs
- The industry challenges
- The solution is to increase automation and autonomy
- Proposed Automation and Autonomy framework
- From assessment to implementation/strategy
- Examples and use cases

Introduction

Purpose

⇢ Create a **practical** maturity framework for 200mm fabs to increase production, efficiency, and mitigate business risks considering frequent market cycles

Expected Outcome

⇢ Definitions and terminology, e.g. automation and autonomy
⇢ Automation/Autonomy Maturity Framework
⇢ Fab Assessment, tools, playbooks, use case datasets
⇢ Industry benchmarking and industry standard
⇢ Series of white papers (2026)

Introduction

The Scope

- **Now:** Front-end 200mm fabs, US & Europe
- **Later:** Backend (Assembly, Packaging & Test), 300mm

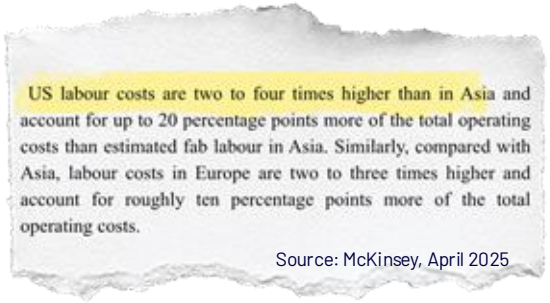
Who's Involved

- SEMI Smart Manufacturing US Chapter
- Automation Group run by Anshu Bahadur and myself
- Active members: AMAT, NXP, PeerGroup, Nexperia, XFAB, Diodes, Stäubli, Flexciton, Polar
- Flexciton - project lead

Why investing in Automation/Autonomy now ?

Cost Pressure

Rising raw material costs, labour cost and price competition from Asia



US labour costs are two to four times higher than in Asia and account for up to 20 percentage points more of the total operating costs than estimated fab labour in Asia. Similarly, compared with Asia, labour costs in Europe are two to three times higher and account for roughly ten percentage points more of the total operating costs.

Source: McKinsey, April 2025

Critical Talent Shortage

An aging workforce and low industry appeal increases the risk of talent gaps

By 2030, the industry will need to add 1 million skilled workers globally, with shortages of over 100,000 engineers in Europe and more than 200,000 engineers in Asia-Pacific.(...)
While universities produce fewer graduates, experienced leaders are retiring. One-third of US semiconductor employees are 55 or older. In Germany, one-third of the workforce will retire within the next decade.

Source: SEMI, June 2025

Why Investing in 200mm Fabs

1. Large ongoing investments

Ministers welcome £115million investment by Seagate Technology

Date published: 11 September 2025

The First Minister and deputy First Minister have welcomed a major investment by Seagate Technology Holdings at its plant in Derry/Londonderry.

MILPITAS, Calif. — January 7, 2025 — The semiconductor industry is expected to start 18 new fab construction projects in 2025*, according to SEMI's latest quarterly World Fab Forecast report. The new projects include three 200mm and fifteen 300mm facilities, the majority of which are expected to begin operations from 2026 to 2027.

2. Key for GaN, SiC, specialty & legacy nodes.

- ST to build high-volume 200 mm SiC campus (Catania)
- onsemi moving Bucheon line to 200 mm SiC in 2025
- Nexperia: $200 M for 200 mm GaN/SiC & silicon at Hamburg

3. Critical for automotive, IoT, power electronics.

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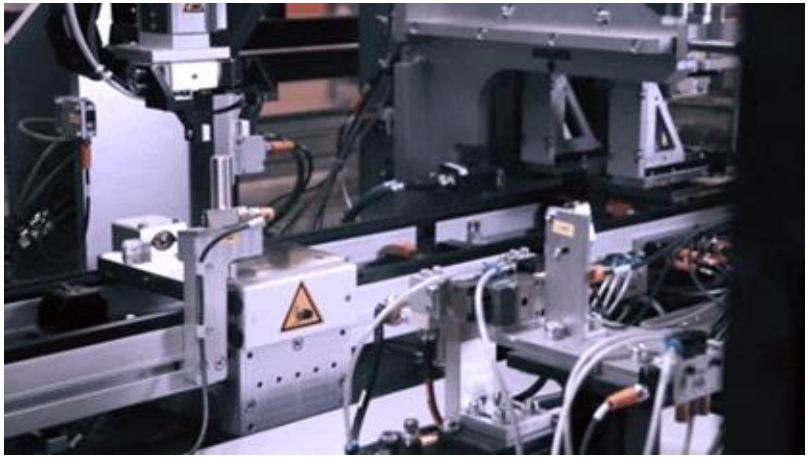
200mm Fabs Face Many Challenges

- **Operational Complexity:** Every fab is different, limited standardization
- **Market Pressures:** Managing volatile demand cycles while maintaining operational efficiency
- **Talent Shortage:** Critical labor shortages in skilled technicians and engineers
- **Business Continuity:** Ensuring resilient operations in an uncertain global environment
- **Technology Gap:** Limited methodology for strategic technology investments

The Result: Ad-hoc projects, reactive firefighting, and missed opportunities for systematic improvement

The Path Forward: Automation and Autonomy

Automation



This system follows a predefined set of if-then rules

Autonomy

This system is free to make its own decisions using AI

The Path Forward: Automation and Autonomy

Automation

Defines HOW to execute task to achieve outcome

Execution of predefined tasks and control logic by machines and software

- **Physical movement:** handlers, OHT/AGV/AMR moves, robot load/unload
- **Tool & workflow automation**: recipe download and selection, step sequencing.
- **Local decision rules:** fixed dispatch rules, control loops at unit operations

Autonomy

Defines WHAT is desired outcome and the system decides HOW

Ability to **formulate and modify plans to achieve high-level goals under constraints**

- Executing plans, adapting to unexpected events, and coordinating with minimal human intervention.
- It layers learning, perception, and goal-seeking optimization on top of automation

What Holds Fabs Back from Greater Automation and Autonomy

- The 200mm fabs were not designed for automation…and full autonomy
  - Lack SECS/GEM or piecemeal implementation (Older legacy tool sets)
  - Classic SECS/GEM not built for data streams → rolling out SEMI EDA difficult
  - AMHS retrofit in legacy bays → Complicate OHS/OHT installs
- High mix speciality flows (power, RF, MEMS) → Need deep tool connectivity
- Brownfield automation needs niche skills → slower, limited upgrades
- ***Lack of ROI clarity → harder to justify, prioritise investments***

Laying the Foundation for an Automation & Autonomy Framework

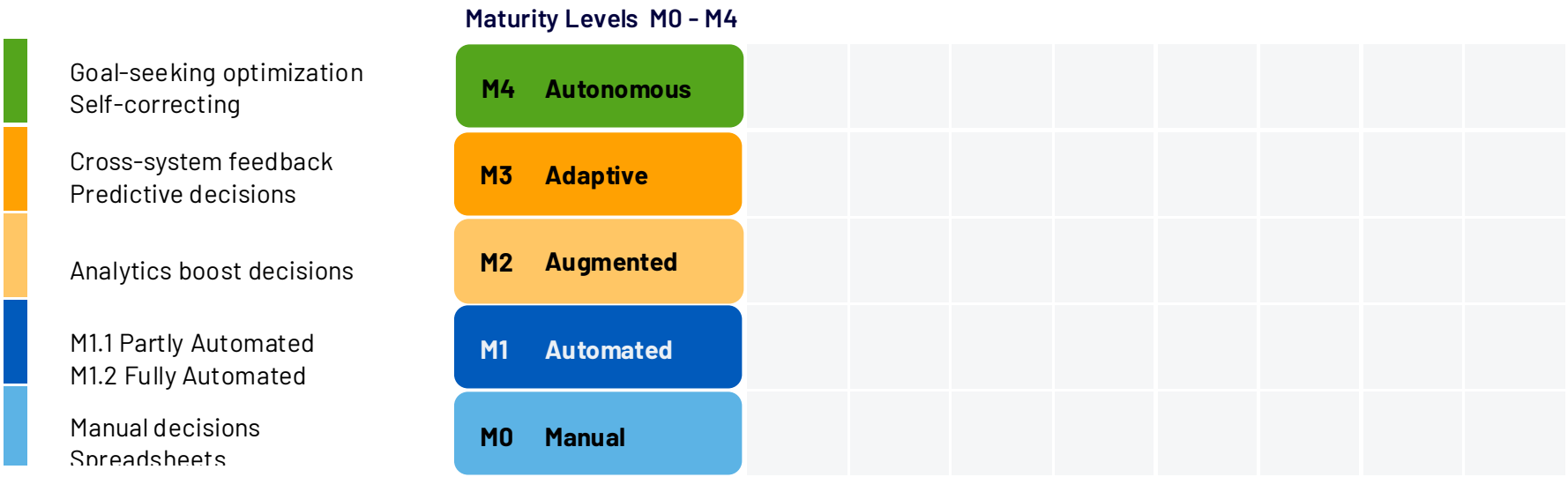
The **Design Principles**

- **Domain-specific** based on the input from fabs
- **Practical** and straightforward to use and actionable
- **Agile**, so it can be modified as technology and markets progressing
- Helps plan next maturity steps with **ROI and investments estimations**
- Driven by **fab KPIs** - that can change over time

The Maturity Framework – The Domains

Data & Sensing	How the fab captures, stores, and structures data for analytics and autonomy
Equipment & Systems Integration	Connectivity and control between tools and fab systems (MES, APC, FDC, AMHS)
Material Handling	Physical movement of lots, wafers, and reticles across the fab
WIP Flow Management	Capacity planning, planning, scheduling, and dispatching from weeks-out to real-time
Quality & Yield	Process stability, SPC/FDC, excursion detection, and yield control
Maintenance & Reliability	Equipment health monitoring, from reactive PMs to predictive maintenance
People & Workflow	How roles, skills, and ways of working evolve with increasing autonomy
Test & Qualification	Lifecycle of test/qual wafers for tool qualification and process monitoring

The Maturity Framework – Maturity Levels



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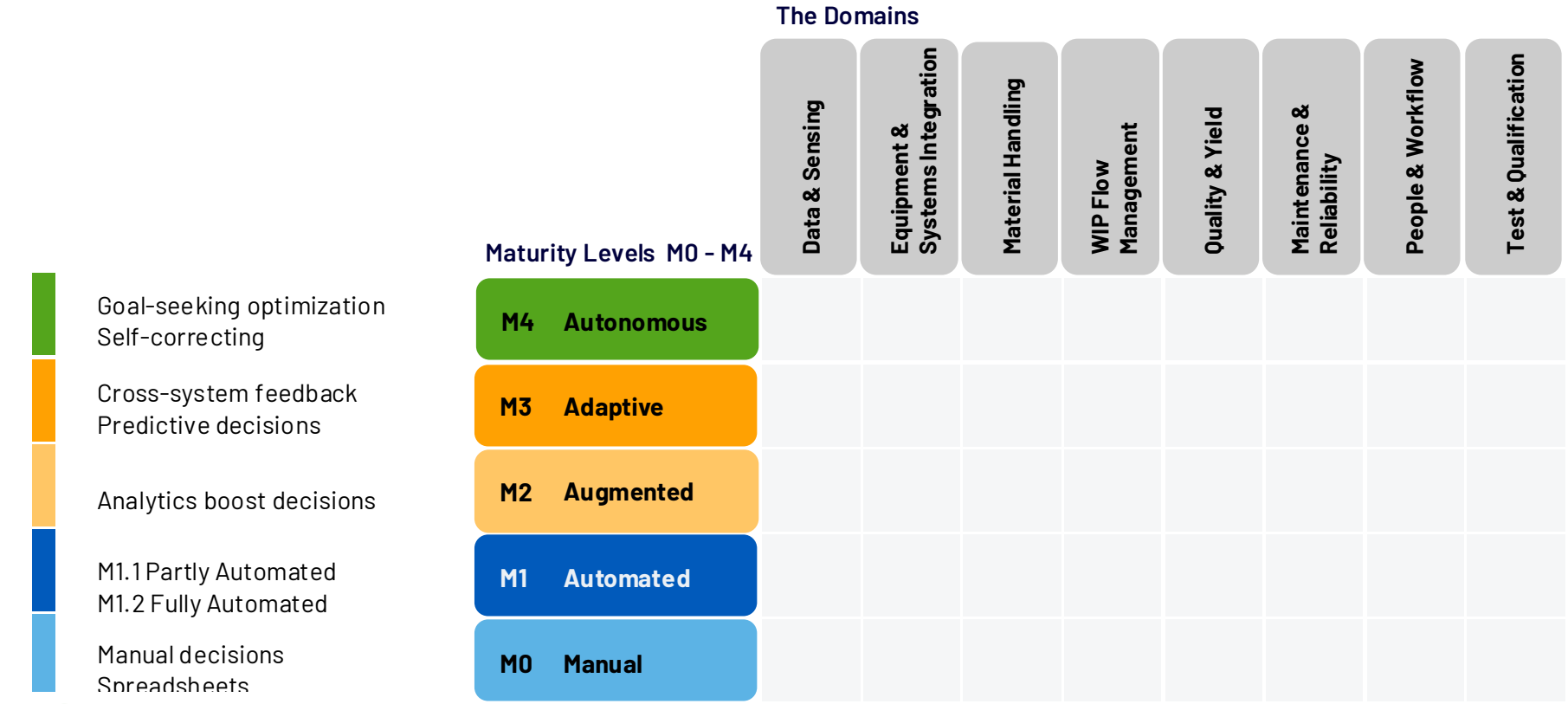
The Maturity Framework



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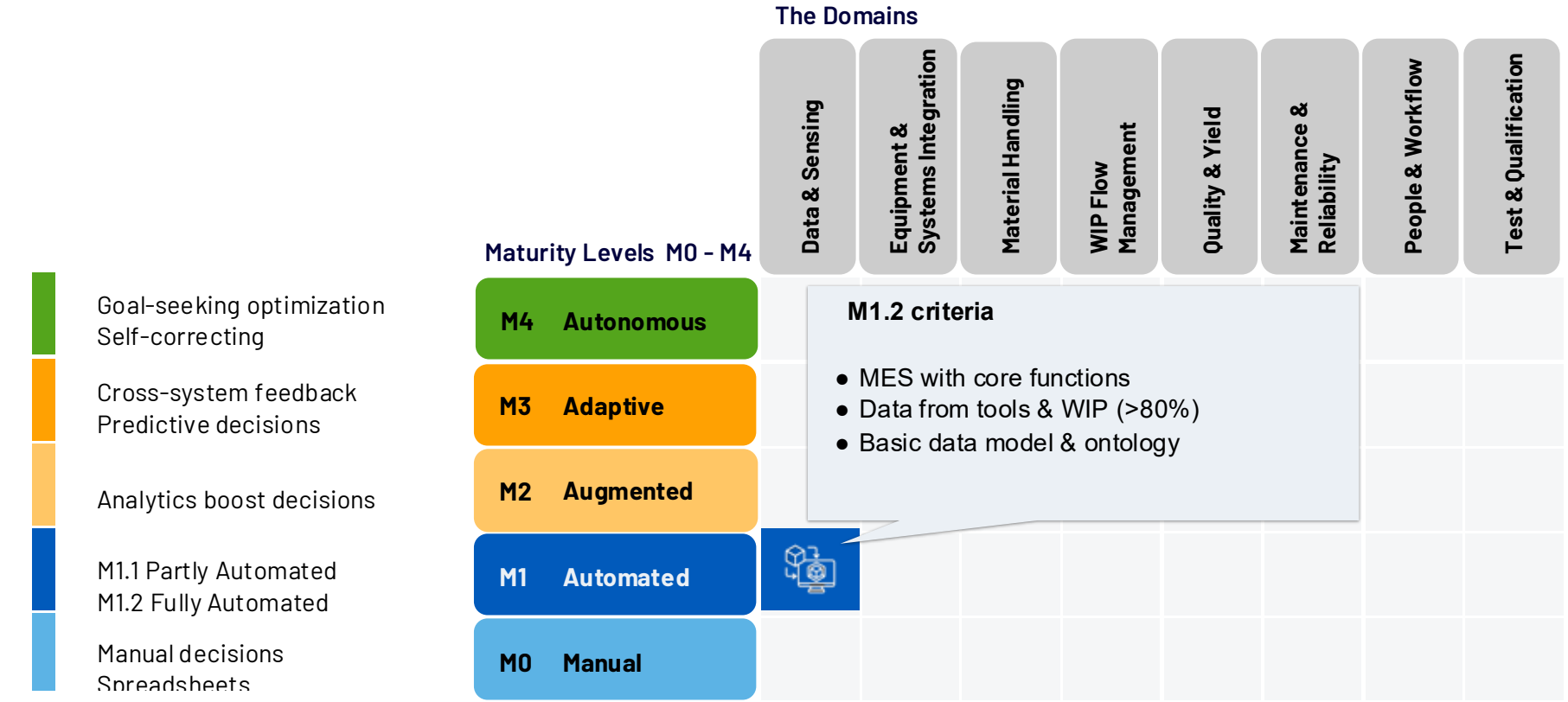

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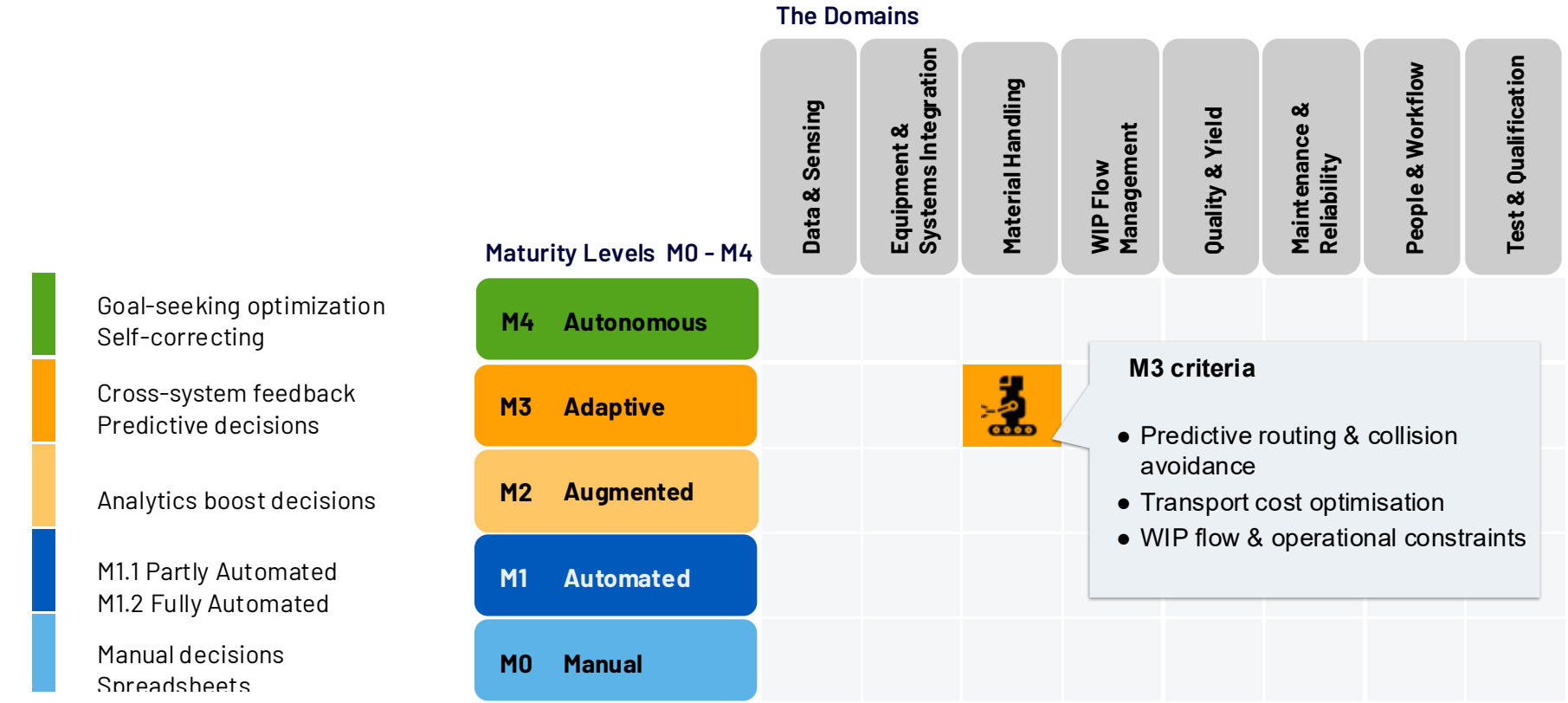

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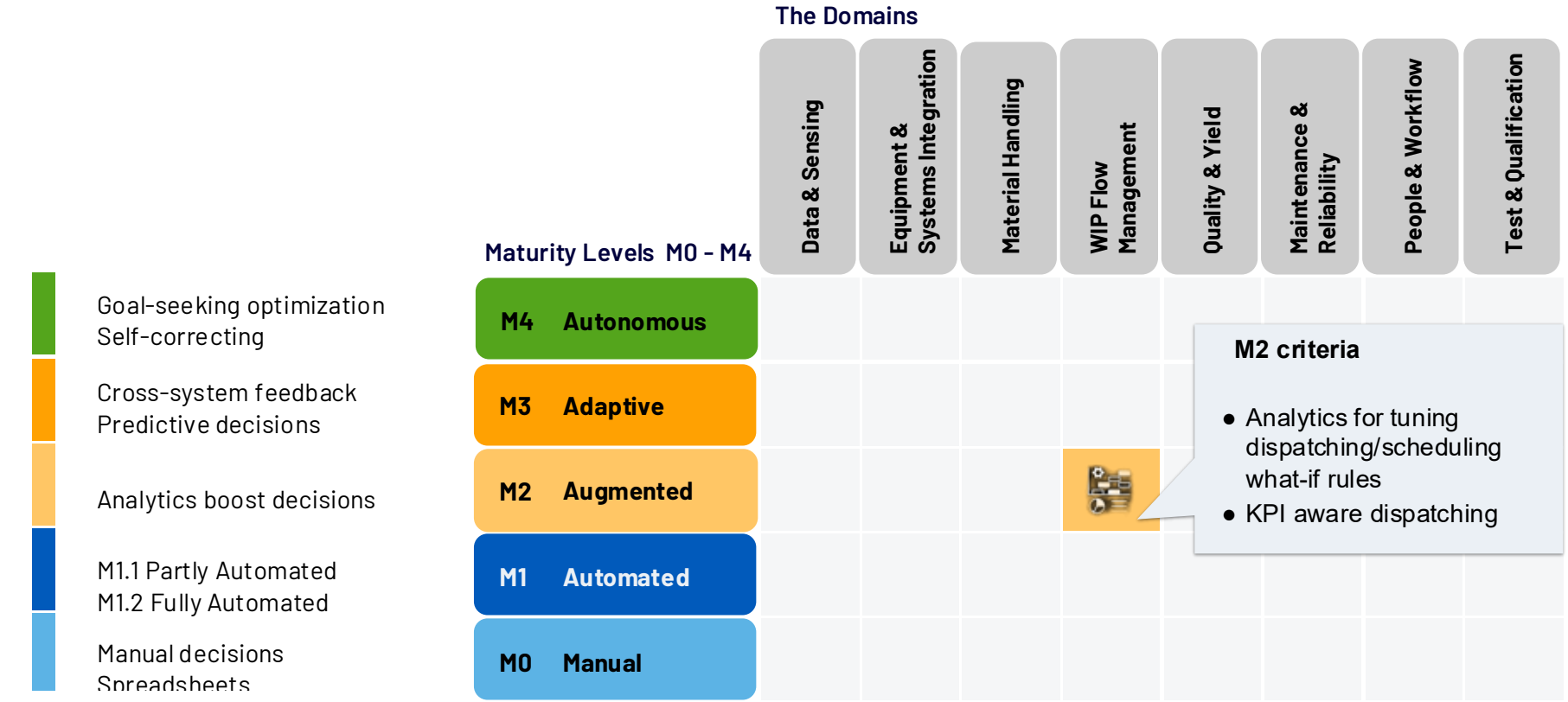

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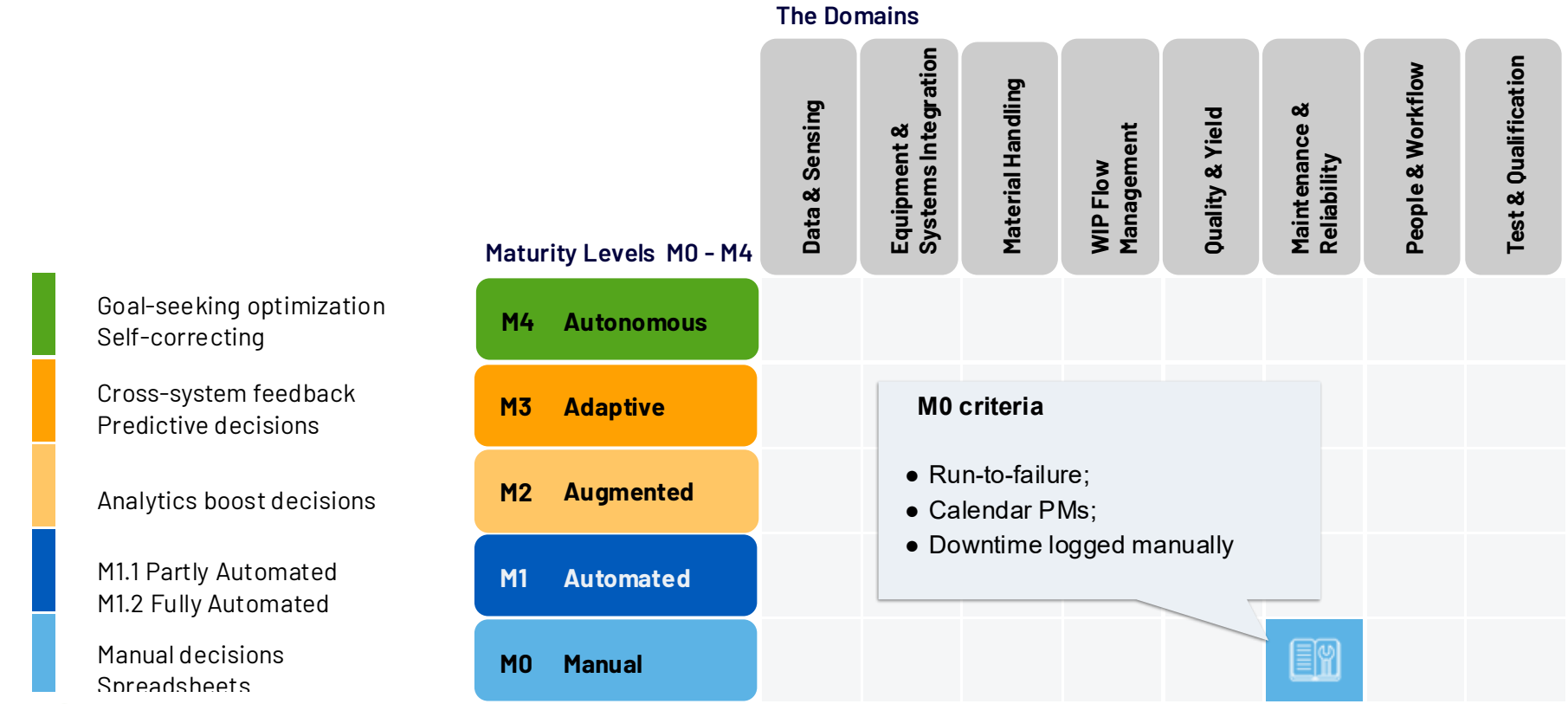

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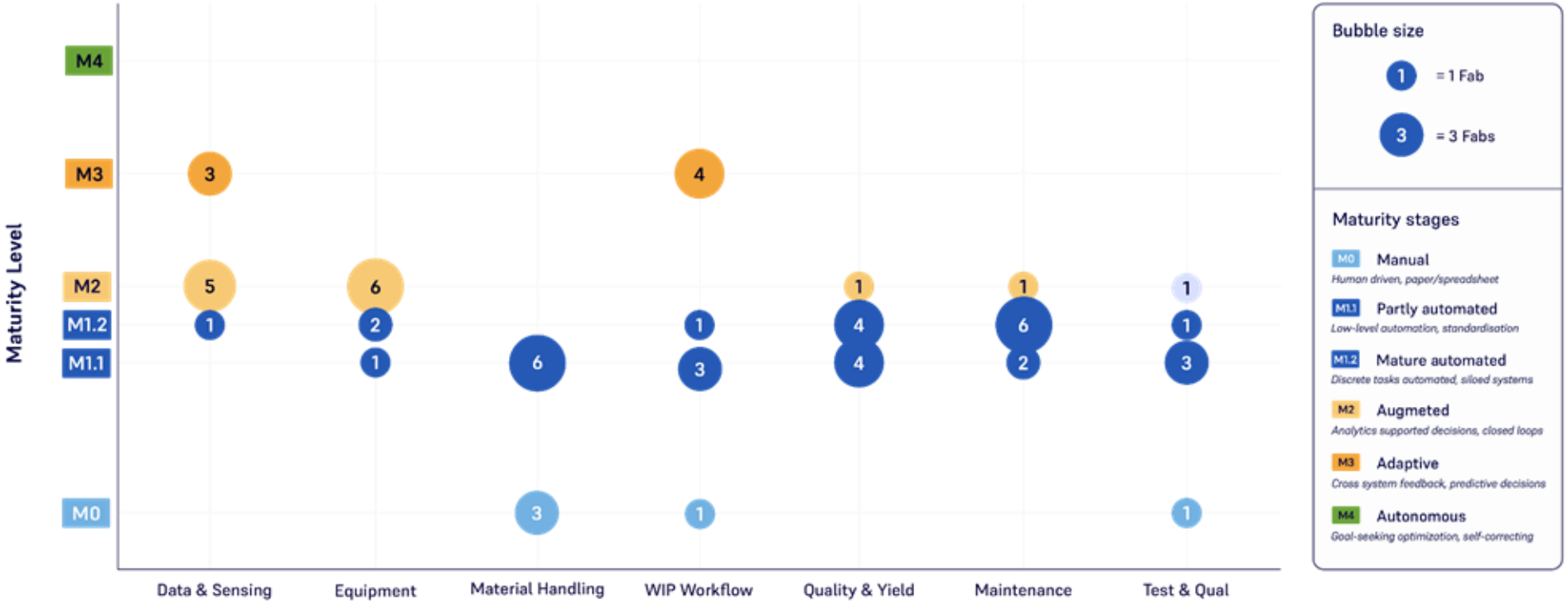
Assessment phase

Process:

- Contacting & interviewing 200mm fabs, esp. fabs in transition
- Surveying operational team (***confidentiality & data anonymity assured***)
- Collating & analyzing data of individual/all fabs
- Identifying & sharing individual automation opportunities & benefits (capacity & ROI)
- Developing & sharing benchmarking report

January 2026: Fab Maturity Assessment

Initial survey results across 9 semiconductor fabs



Source: SEMI Fab Maturity Survey, January 2026

January 2026: Fab Maturity Assessment

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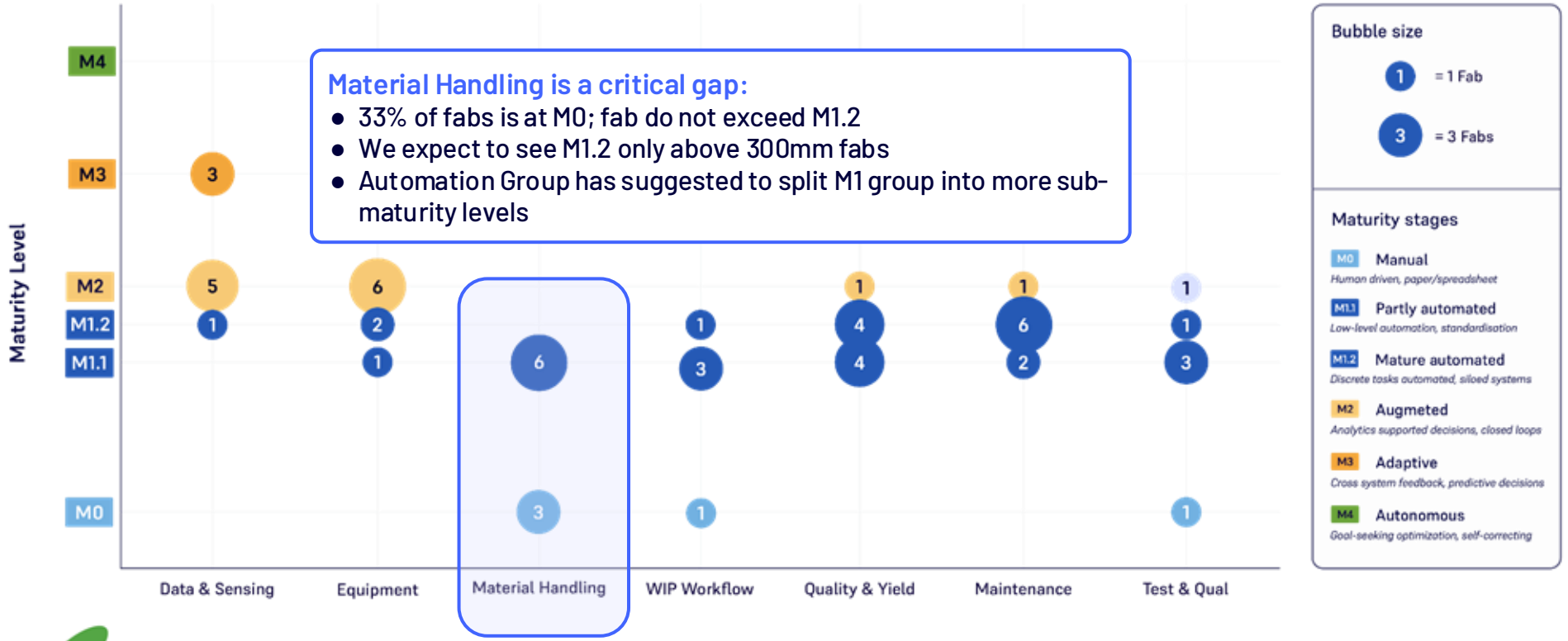

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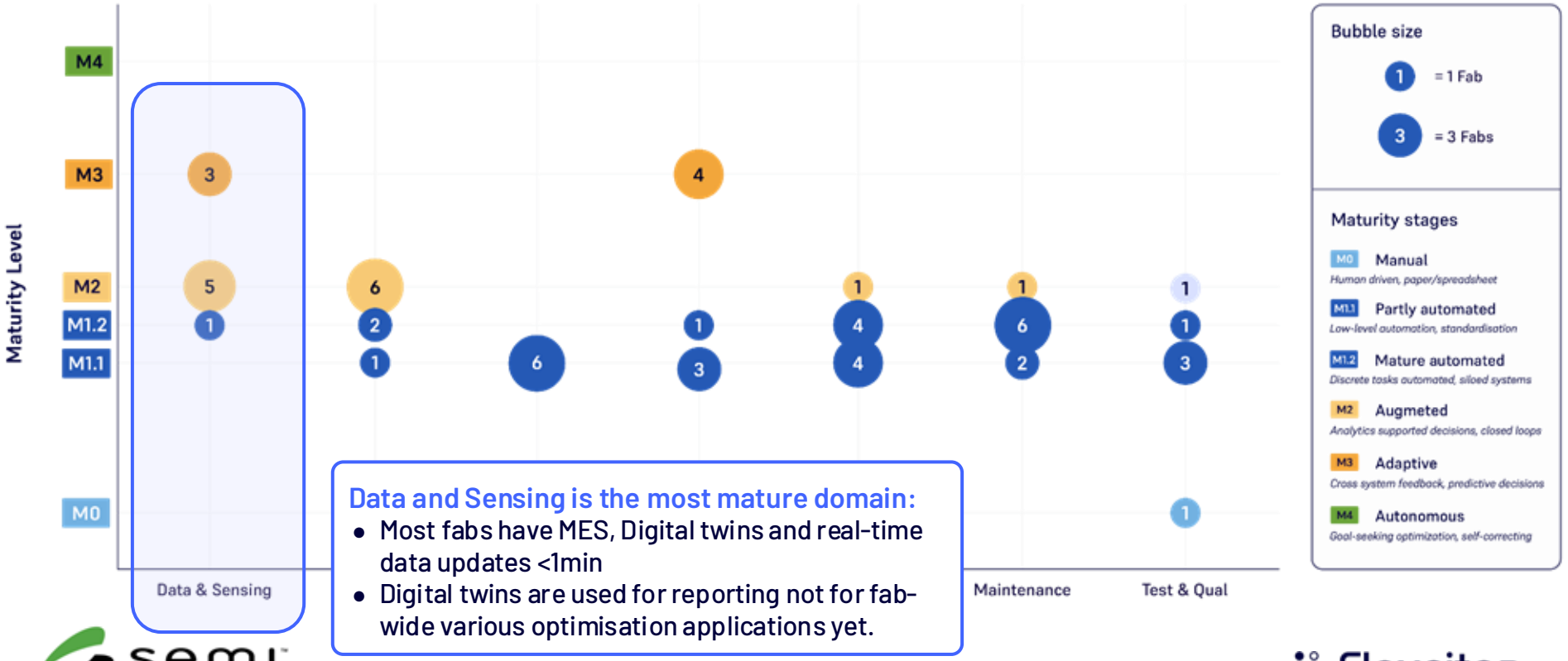

Data and Sensing is the most mature domain:

- Most fabs have MES, Digital twins and real-time data updates <1min
- Digital twins are used for reporting not for fab-wide various optimisation applications yet.

Source: SEMI Fab Maturity Survey, January 2026

January 2026: Fab Maturity Assessment

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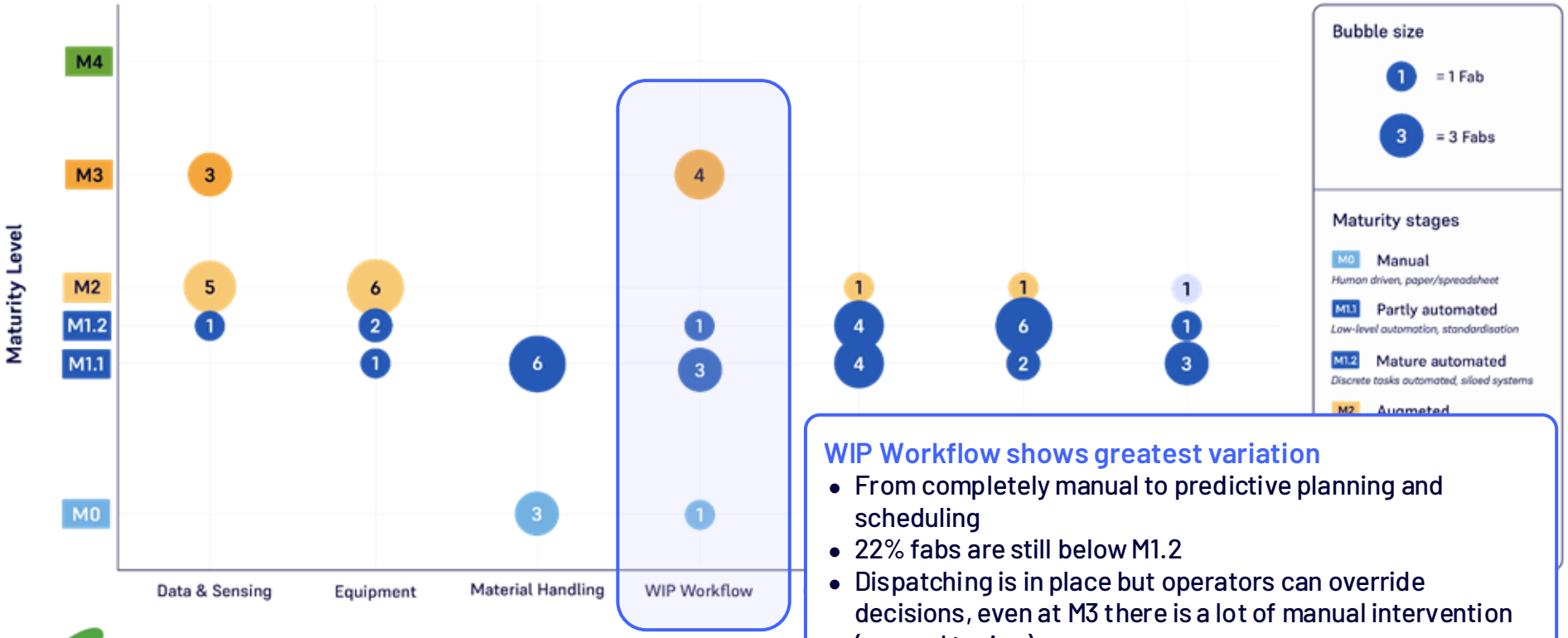

WIP Workflow shows greatest variation

- From completely manual to predictive planning and scheduling
- 22% fabs are still below M1.2
- Dispatching is in place but operators can override decisions, even at M3 there is a lot of manual intervention (manual tuning)

Source: SEMI Fab Maturity Survey, January 2026

January 2026: Fab Maturity Assessment

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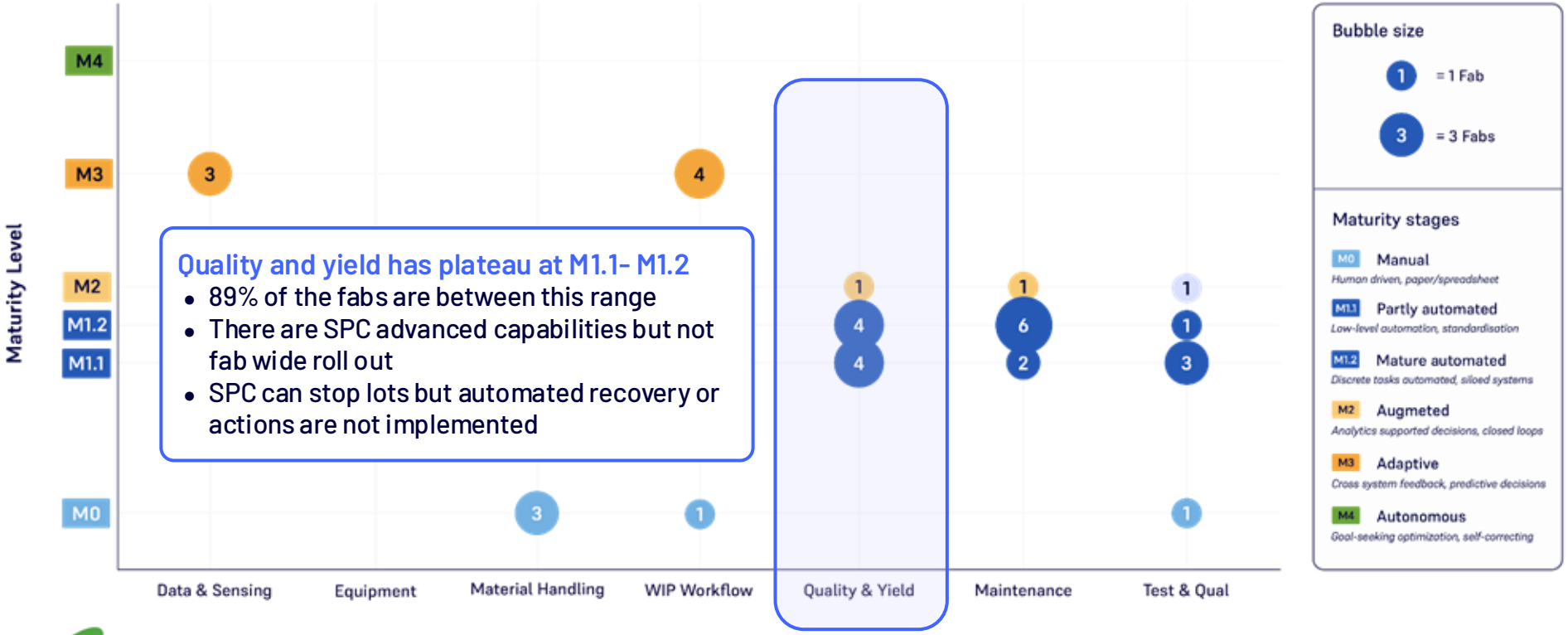

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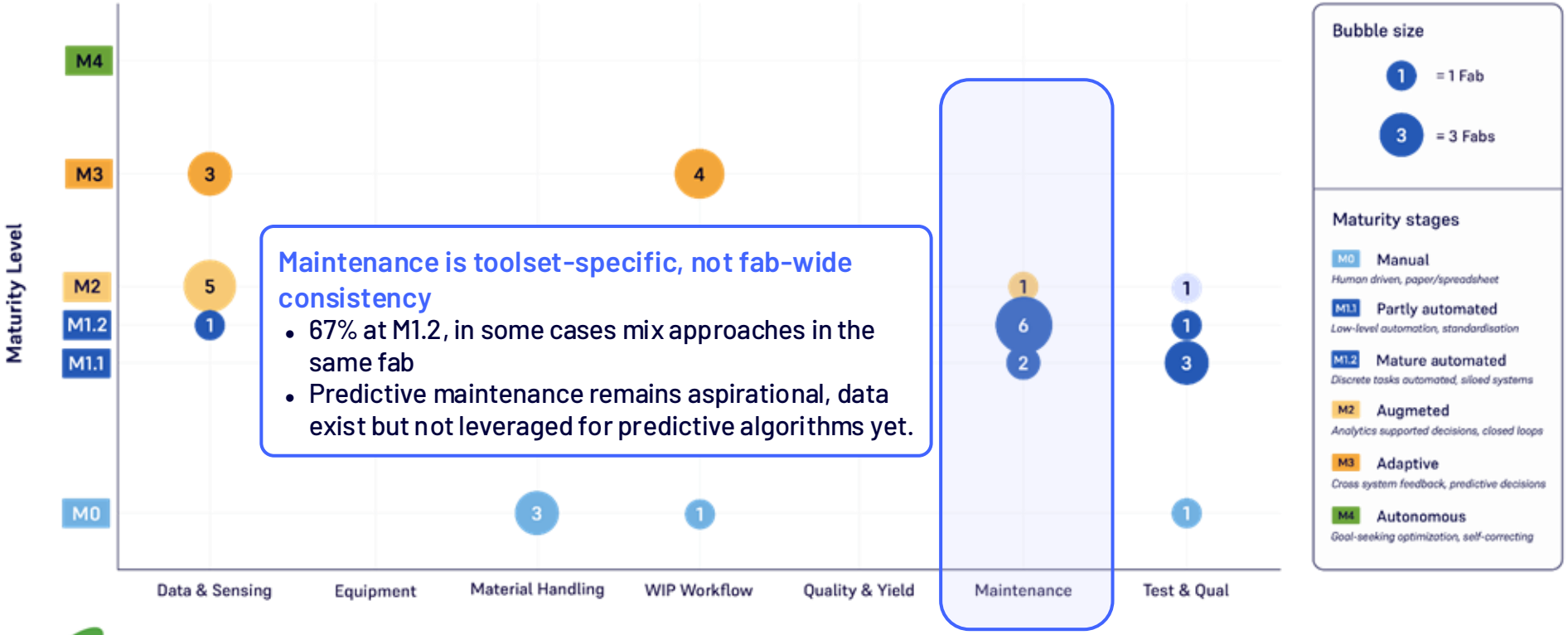

Source: SEMI Fab Maturity Survey, January 2026

Fab insights summary

- 200mm fab have not been designed for automation and autonomy
- Data infrastructure is mature and ready to enable advanced capabilities
- Capability vs implementation gap opportunities - in many areas technology exists but hasn't been deployed yet (quality and yield, predictive maintenance)
- Biggest gap is material handling systems, explore trade-off of investment and longer term benefit
- High variance in WIP Flow Management, next possible action to ensure locking decisions (robust and optimal algorithms required)

Automation framework next steps

- Domain Leads developing rigorous and objective criteria for each maturity level with clear distinctions between levels, allowing for more standarised and autonomous assessments.
- Reviewing classification criteria in Material Handling domain now; 200mm fabs require more granularity between M0 and M1.
- Aiming to assess more front-end fabs; increase from N=9 to N=40 fabs.
- Working on unlocking the value of the framework:
  - Providing self-assessment of fabs with playbooks
  - Providing tools e.g. ROI calculators and datasets use cases
- Publish a series of white papers in 2026
- Start working on backend fabs (potentially H2 2026)

If you want to get involved

Reach out to us!

If you work in fab management or are an semiconductor industry expert, get in touch with us at dennis.xenos@flexciton.com

Thank you!

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