AI-04727 AMAT LK Prime Functional Description

What is the LK Reflexion Prime AMAT Equipment. List the functional descriptions. List all the subsystems. Create a Machine Cycle Chart.

List a "wafer walk" from start to end.

List all the hardware and software systems and subsystems ie. Devicenet, Sercos, EthernetIP, RTPC, Endpoint etc

Applied Materials Reflexion LK Prime CMP Equipment

The equipment you are referring to is the **Applied Materials Reflexion® LK Prime™**, commonly called the **Reflexion LK Prime CMP system**. “AMAT” is the common industry abbreviation for **Applied Materials, Inc.**

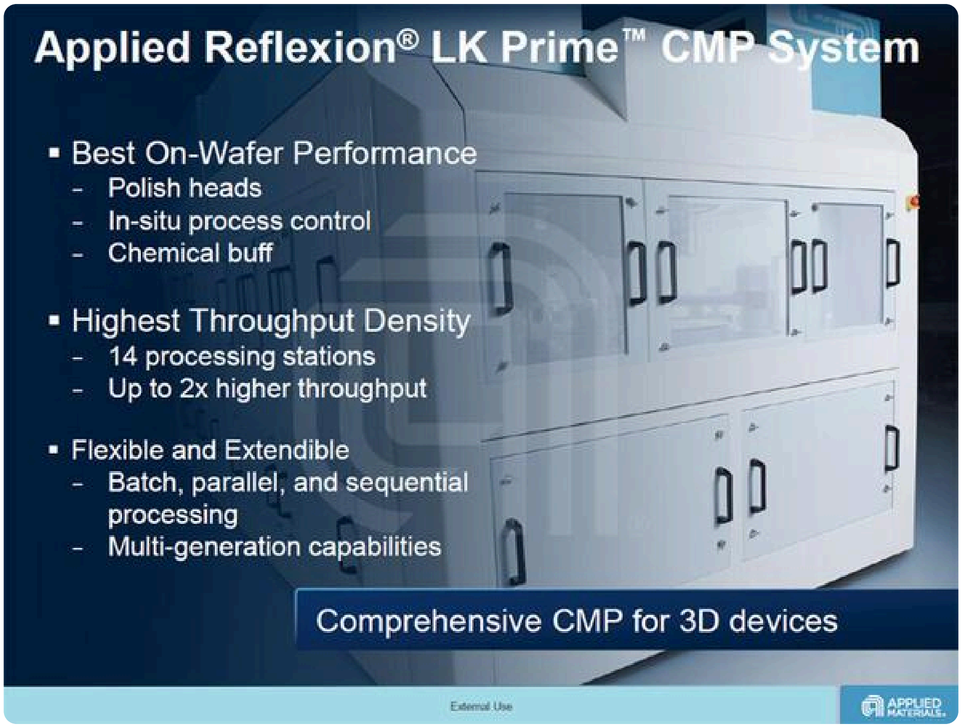
It is a **300 mm wafer chemical mechanical planarization (CMP) system** used in semiconductor manufacturing to polish and planarize wafer surfaces. Applied Materials introduced the LK Prime in 2014, describing it as a system designed for nanometer-level polishing performance for applications including **FinFET and 3D NAND**. (Applied Materials)

> **Important scope note:** The LK Prime is a configurable production tool. Exact chamber count, polish-head type, wafer-handling configuration, sensors, chemical delivery options, and software versions can vary. The subsystem list and cycle below describe the machine's functional architecture—not a claim that every listed option is installed on every serial-number configuration.

---

1. What does the Reflexion LK Prime do?


REFLEXION™
APPLIED MATERIALS®
PORT 1
PORT 2
PORT 3


Applied Reflexion® LK Prime™ CMP System
▪ Best On-Wafer Performance
– Polish heads
– In-situ process control
– Chemical buff
▪ Highest Throughput Density
– 14 processing stations
– Up to 2x higher throughput
▪ Flexible and Extendible
– Batch, parallel, and sequential processing
– Multi-generation capabilities
Comprehensive CMP for 3D devices
External Use
APPLIED MATERIALS


APPLIED MATERIALS
CAOC03


NOT A STEP

Primary function

The Reflexion LK Prime removes a controlled amount of material from a semiconductor wafer using the combined effects of:

1. **Mechanical abrasion** — a rotating polishing pad contacts the wafer.
2. **Chemical reaction** — slurry chemistry reacts with or softens the film.
3. **Pressure control** — the wafer carrier applies controlled force.
4. **Relative motion** — wafer and pad rotate and/or move relative to each other.
5. **Endpoint/process control** — sensors and process models help determine when the desired material removal has been reached.

Simplified process equation

$$\text{Material removal} \approx f(\text{pressure},\text{relative velocity},\text{slurry},\text{pad condition},\text{time})$$

A commonly used conceptual CMP relationship is the **Preston equation**:

$$MRR = K_p P V$$

Where:

- MRR = material removal rate
- K_p = process-dependent Preston coefficient
- P = applied pressure
- V = relative velocity

Actual semiconductor CMP behavior is more complex because chemistry, pad condition, temperature, film properties, pattern density, and endpoint behavior also matter.

---

2. Functional description of the machine

Functional area	Description
Wafer receiving	Receives wafer lots from the factory automation system, typically through a carrier interface.
Wafer identification	Identifies the wafer, lot, recipe, and processing requirements.
Wafer loading	Transfers the wafer from the incoming carrier into the internal handling system.
Pre-process handling	Positions and prepares the wafer for polishing. Depending on configuration, this may include pre-cleaning or other preparation steps.
Wafer alignment	Establishes the correct wafer orientation and handling position.
Wafer inspection / sensing	Uses available sensors or measurement systems to monitor wafer condition, position, or process state.
Chemical delivery	Supplies slurry and, where configured, other process fluids at controlled flow rates.
Polishing	Removes material from the wafer surface through controlled CMP action.

Pressure-zone control	Controls the pressure distribution applied through the wafer carrier/polish head.
Pad conditioning	Restores pad surface texture and removes glazing or accumulated debris.
Inter-polish cleaning	Cleans or rinses the wafer and/or polishing surfaces between process steps.
Post-CMP cleaning	Removes slurry residue, particles, and process contaminants from the wafer.
Drying	Dries the wafer using the configured drying method.
Wafer measurement	Determines whether the wafer meets thickness, removal, uniformity, or endpoint requirements, depending on installed metrology.
Wafer sorting / unloading	Returns the processed wafer to its carrier or transfers it to the next process location.
Recipe execution	Executes process parameters such as pressure, speed, slurry flow, polish time, and conditioning settings.
Process monitoring	Monitors temperatures, pressures, flows, motor conditions, sensors, and alarms.
Fault handling	Detects abnormal conditions and places the machine or affected module into a safe state.
Factory integration	Communicates with MES, host automation, equipment interfaces, and fab scheduling systems.
Utilities management	Distributes and monitors power, compressed air, process fluids, exhaust, cooling, and other facility services.

3. High-level machine architecture

The equipment can be understood as a series of functional zones:

```
┌────────────────────────────────────────────────────────────┐
│                   FACTORY / HOST SYSTEM                    │
│       MES • Recipe • Lot Control • Automation              │
└──────────────────────────────┬─────────────────────────────┘
                               │
                               ▼
┌────────────────────────────────────────────────────────────┐
│                  REFLEXION LK PRIME                        │
│                                                            │
│  ┌───────────────┐       ┌─────────────────────────────┐   │
│  │ Wafer Input   │──────▶│ Wafer Handling / Transfer   │   │
│  └───────────────┘       └────────────┬────────────────┘   │
│                                       │                    │
│                                       ▼                    │
│  ┌─────────────────────────────────────────────────────┐   │
```

```
│  │             CMP PROCESS MODULES                    │  │
│  │                                                    │  │
│  │  Slurry → Polish Head → Wafer → Rotating Pad       │  │
│  │                         ↓                          │  │
│  │                 Material Removal                   │  │
│  └────────────────────────────────────────────────────┘  │
│                         │                                │
│                         │                                │
│                         ▼                                │
│  ┌────────────────────────────────────────────────────┐  │
│  │ Cleaning • Rinsing • Drying • Measurement          │  │
│  └────────────────────────────────────────────────────┘  │
│                         │                                │
│                         │                                │
│                         ▼                                │
│  ┌────────────────────────────────────────────────────┐  │
│  │ Wafer Output / Carrier Return                      │  │
│  └────────────────────────────────────────────────────┘  │
│                                                          │
│  Supporting systems:                                     │
│  Controls • Utilities • Chemical Delivery • Safety       │
└──────────────────────────────────────────────────────────┘
```

The Reflexion product family includes several related CMP platforms, including the **Reflexion 3600, Reflexion LK 3800, Reflexion LK Prime, and LK Prime S**, with service providers supporting parts, polish heads, upgrades, and refurbishment across these platforms. (Entrepix)

---

4. Complete functional subsystem list

The following is a **system-engineering decomposition** of the LK Prime. It includes the major machine subsystems and the functional elements normally required for a production CMP tool. Some items are configuration-dependent or may be integrated into a larger module.

A. Factory interface and material handling

#	Subsystem	Functional description
A1	**Equipment Front-End Module (EFEM)**	Interfaces with wafer carriers and the fab automation environment.
A2	**Load ports / carrier stations**	Receives and holds wafer carriers such as FOUPs, depending on configuration.
A3	**Carrier identification system**	Reads carrier identity and validates the incoming material.
A4	**Wafer mapping system**	Determines wafer presence and slot positions in the carrier.
A5	**Atmospheric wafer robot**	Transfers wafers between carrier and internal interface.
A6	**Wafer pre-aligner**	Establishes wafer orientation and alignment.

A7	**Load/unload station**	Transfers wafers into and out of the process area.
A8	**Internal wafer transport**	Moves wafers between process, cleaning, and measurement modules.
A9	**Wafer end-effectors**	Robot tooling that physically supports and transfers wafers.
A10	**Wafer presence sensors**	Confirms wafer position and prevents handling errors.

> **Configuration note:** The exact EFEM, robot arrangement, carrier interface, and internal transfer architecture should be confirmed from the equipment's configuration documentation.

B. CMP polishing subsystem

This is the core material-removal system.

#	Subsystem	Functional description
B1	**Polish module / platen assembly**	Provides the rotating polishing surface and mechanical structure.
B2	**Polishing platen**	Rotates the polishing pad beneath the wafer.
B3	**Polishing pad**	Consumable surface that mechanically contacts the wafer.
B4	**Pad mounting system**	Secures the pad to the platen.
B5	**Polish head / wafer carrier**	Holds the wafer during polishing.
B6	**Retaining ring**	Helps retain and constrain the wafer at the carrier perimeter.
B7	**Membrane / bladder assembly**	Applies controlled backside pressure to the wafer, where used by the head design.
B8	**Pressure-zone system**	Provides independently controlled pressure regions for wafer uniformity control.
B9	**Carrier rotation drive**	Rotates the wafer carrier.
B10	**Carrier oscillation / sweep mechanism**	Moves the carrier across the pad, where applicable.
B11	**Platen rotation drive**	Rotates the polishing platen.
B12	**Platen bearings / mechanical support**	Supports the rotating platen assembly.
B13	**Polish-head lift / positioning mechanism**	Raises, lowers, and positions the carrier.
B14	**Polish-head load mechanism**	Applies the programmed downforce.

B15	**Pad support / backing structure**	Maintains pad stability during processing.
B16	**Polish-zone enclosure / splash management**	Contains slurry and process fluids.

What happens here?

```
Polish head
     │
     │ Controlled downforce
     ▼
┌────────────────┐
│     Wafer      │  ← Film being polished
└────────────────┘
~~~~~~~~~~~~~~~~~  ← Slurry interface
═════════════════  ← Rotating polishing pad
        ↻
     Platen
```

C. Pad conditioning subsystem

CMP performance depends heavily on maintaining a consistent pad surface.

#	Subsystem	Functional description
C1	**Pad conditioner assembly**	Restores the pad's working surface.
C2	**Conditioner disk / conditioning element**	Abrades or refreshes the pad surface.
C3	**Conditioner arm**	Positions the conditioner over the pad.
C4	**Conditioner drive**	Rotates the conditioning element, where applicable.
C5	**Conditioner load actuator**	Controls the force applied during conditioning.
C6	**Conditioner sweep mechanism**	Controls the conditioning path across the pad.
C7	**Conditioner wear monitoring**	Monitors or manages conditioner usage and replacement condition.
C8	**Pad conditioning fluid delivery**	Supplies fluid needed during conditioning.
C9	**Pad life / usage tracking**	Tracks pad usage and maintenance intervals.

A used-equipment parts listing specifically identifies an **“IDLER KIT BRUSH REFLEXION PRIME,”** illustrating that brush-related hardware exists among serviceable parts associated with the platform. However, a parts listing alone does not establish the exact installed configuration of a particular machine. (Torico Ltd.)

D. Slurry and chemical delivery subsystem

CMP requires carefully controlled chemical delivery.

#	Subsystem	Functional description
D1	**Slurry supply interface**	Receives slurry from the facility or chemical distribution system.
D2	**Slurry reservoirs / supply containers**	Stores or buffers process slurry, depending on architecture.
D3	**Slurry pumps**	Delivers slurry at controlled flow rates.
D4	**Slurry flow controllers**	Controls and monitors slurry flow.
D5	**Slurry valves**	Starts, stops, and routes chemical flow.
D6	**Slurry filters**	Removes unwanted particles or agglomerates, where installed.
D7	**Slurry mixing / dilution system**	Maintains the required slurry composition, where applicable.
D8	**Chemical distribution manifold**	Routes fluids to process points.
D9	**Point-of-use delivery nozzles**	Delivers slurry to the pad/wafer interface.
D10	**DI water supply**	Provides deionized water for rinsing and cleaning.
D11	**Chemical concentration / condition monitoring**	Monitors relevant process-fluid conditions, where configured.
D12	**Leak detection / chemical containment**	Detects and contains chemical leaks or spills.
D13	**Chemical exhaust / drainage interface**	Removes waste fluids and chemical vapors as required.

Typical fluid paths

```
Facility slurry supply
        │
        ▼
Supply / filter / pump
        │
        ▼
Flow control valves
        │
        ▼
Process delivery nozzle
        │
        ▼
Wafer + polishing pad
        │
```

```
        ▼
Waste collection / drain
```

E. Wafer cleaning and drying subsystem

Post-CMP cleaning is essential because slurry residue and particles must be removed.

#	Subsystem	Functional description
E1	**Pre-clean module**	Performs configured wafer preparation before polishing.
E2	**Post-polish rinse station**	Removes loose slurry and process residue.
E3	**Brush clean module**	Uses brushes and fluids to clean the wafer surface.
E4	**Cleaning brush assemblies**	Contact the wafer surface under controlled conditions.
E5	**Brush drives**	Rotate the cleaning brushes.
E6	**Brush pressure / positioning system**	Controls brush-to-wafer contact.
E7	**Megasonic / ultrasonic cleaning option**	Provides acoustic cleaning where installed.
E8	**DI water delivery**	Supplies rinse water.
E9	**Cleaning chemistry delivery**	Supplies configured cleaning chemicals.
E10	**Spin-rinse-dry (SRD) module**	Uses rotation, rinse, and drying to prepare the wafer for output.
E11	**Drying gas / air delivery**	Supports wafer drying.
E12	**Drain and waste collection**	Removes contaminated cleaning fluids.
E13	**Cleaning enclosure / splash control**	Contains water and chemical spray.

F. Endpoint detection and metrology subsystem

The exact metrology architecture varies by tool configuration and process application.

#	Subsystem	Functional description
F1	**Endpoint detection system**	Determines or estimates when the desired polishing endpoint is reached.
F2	**In-situ process sensors**	Monitor process signals during polishing.
F3	**Motor / torque monitoring**	May use drive or motor signals to detect process changes.
F4	**Optical endpoint sensing**	Optical techniques may be used where supported by the configuration/process.

F5	**Film thickness measurement**	Measures film thickness before or after polishing, where equipped.
F6	**Post-process metrology interface**	Transfers wafers to measurement or integrates measurement functions.
F7	**Uniformity calculation**	Calculates within-wafer or across-wafer process uniformity from available data.
F8	**Process data logging**	Records process signals and results for traceability.
F9	**Endpoint recipe logic**	Determines the transition from polish to endpoint/over-polish/stop.

Important distinction: Endpoint detection is not necessarily the same as full wafer metrology. A tool may use a combination of time-based recipes, sensor-based endpoint detection, and separate metrology.

G. Mechanical motion and actuator subsystem

#	Subsystem	Functional description
G1	**Platen motor**	Drives platen rotation.
G2	**Carrier motor**	Drives polish-head rotation.
G3	**Conditioner motor**	Drives conditioner rotation, where applicable.
G4	**Carrier lift actuator**	Raises and lowers the polish head.
G5	**Carrier sweep actuator**	Controls radial movement across the pad, where applicable.
G6	**Conditioner arm actuator**	Moves the conditioner into position.
G7	**Valve actuators**	Operate chemical, air, water, and process valves.
G8	**Robot motion drives**	Operate wafer-handling robots.
G9	**Linear guides / bearings**	Support moving assemblies.
G10	**Position sensors / encoders**	Provide motion feedback.
G11	**Load cells / force sensors**	Measure or regulate applied force, where installed.
G12	**Vibration isolation**	Reduces unwanted mechanical vibration.

H. Process control and automation subsystem

#	Subsystem	Functional description
H1	**Equipment controller**	Coordinates the complete machine sequence.

H2	**PLC / real-time control system**	Executes interlocks, sequencing, and equipment control functions.
H3	**Motion controllers**	Control motors and precision motion.
H4	**Servo drives / motor drives**	Provide controlled motor operation.
H5	**I/O modules**	Interface with sensors, valves, actuators, and switches.
H6	**Human-machine interface (HMI)**	Displays status, alarms, recipes, and operator controls.
H7	**Recipe management**	Stores and executes process recipes.
H8	**Parameter management**	Controls pressure, speed, flow, time, temperature, and other variables.
H9	**Alarm management**	Detects, displays, logs, and handles abnormal conditions.
H10	**Interlock management**	Prevents unsafe or invalid operations.
H11	**Data acquisition system**	Collects process and equipment data.
H12	**Event logging**	Records machine events, faults, and operator actions.
H13	**Remote service interface**	Supports diagnostics and service access, where enabled.
H14	**Host communication**	Interfaces with fab automation and manufacturing systems.
H15	**Equipment state management**	Controls states such as idle, ready, processing, fault, and maintenance.

I. Utilities and facility interface subsystem

#	Subsystem	Functional description
I1	**Electrical power distribution**	Distributes AC/DC power to equipment subsystems.
I2	**Power supplies**	Converts and supplies required control and actuator voltages.
I3	**Compressed air interface**	Supplies pneumatic components and actuators.
I4	**Vacuum interface**	Provides vacuum functions where required.
I5	**DI water interface**	Supplies cleaning and rinsing water.
I6	**Slurry / chemical facility interface**	Connects to fab chemical supply systems.
I7	**Exhaust interface**	Removes vapors and process exhaust.
I8	**Drain interface**	Removes process waste fluids.

I9	**Cooling / temperature-control system**	Manages temperature of relevant equipment and process components.
I10	**Cabinet cooling**	Removes heat from electrical and control cabinets.
I11	**Utility pressure monitoring**	Monitors supply pressure and utility availability.
I12	**Utility flow monitoring**	Monitors water, air, and chemical flow.
I13	**Leak detection**	Detects fluid leaks in relevant areas.
I14	**Facility grounding**	Provides electrical grounding and bonding.

J. Safety, contamination control, and maintenance subsystem

#	Subsystem	Functional description
J1	**Safety interlock system**	Prevents access or operation under unsafe conditions.
J2	**Access doors / covers**	Protects operators from moving machinery and chemicals.
J3	**Emergency stop system**	Stops hazardous motion or operation.
J4	**Chemical containment**	Controls slurry and chemical spills.
J5	**Splash guards / enclosures**	Contains process fluids.
J6	**Exhaust and ventilation**	Controls chemical vapors and aerosols.
J7	**Particle-control design**	Limits contamination from equipment and process fluids.
J8	**Consumable management**	Tracks pad, brush, conditioner, filter, and other consumables.
J9	**Preventive maintenance interface**	Supports scheduled service activities.
J10	**Calibration functions**	Supports calibration of sensors and process hardware.
J11	**Spare-part access**	Enables replacement of serviceable components.
J12	**Maintenance diagnostics**	Provides fault isolation and equipment health information.

---

5. Subsystem hierarchy — simplified WBS

This is a compact **Work Breakdown Structure (WBS)** for the machine.

```
REFLEXION LK PRIME CMP SYSTEM
|
```

```
├── 1. Factory Interface / EFEM
│   ├── Load ports
│   ├── Carrier ID / mapping
│   ├── Wafer robot
│   ├── Pre-aligner
│   └── Load / unload stations
│
├── 2. Wafer Handling
│   ├── Internal robot
│   ├── End-effectors
│   ├── Wafer sensors
│   └── Transfer mechanisms
│
├── 3. CMP Polishing
│   ├── Platen
│   ├── Platen motor
│   ├── Polish pad
│   ├── Polish head
│   ├── Retaining ring
│   ├── Membrane / pressure zones
│   ├── Carrier rotation
│   └── Carrier positioning
│
├── 4. Pad Conditioning
│   ├── Conditioner arm
│   ├── Conditioner disk / brush
│   ├── Conditioner drive
│   ├── Load control
│   └── Pad conditioning fluid
│
├── 5. Slurry / Chemical Delivery
│   ├── Slurry supply
│   ├── Pumps
│   ├── Filters
│   ├── Flow control
│   ├── Valves
│   ├── Delivery nozzles
│   └── Waste / drain
│
├── 6. Cleaning / Drying
│   ├── Rinse
│   ├── Brush cleaning
│   ├── Cleaning chemistry
│   ├── DI water
│   ├── SRD
│   └── Drying
│
├── 7. Metrology / Endpoint
│   ├── Endpoint sensors
│   ├── Process monitoring
│   ├── Thickness measurement
│   ├── Uniformity calculation
│   └── Data logging
```

```
│
├── 8. Controls / Automation
│   ├── Main controller
│   ├── PLC / I/O
│   ├── Motion control
│   ├── HMI
│   ├── Recipe system
│   ├── Alarm / interlock
│   └── Host communication
│
├── 9. Utilities
│   ├── Electrical
│   ├── Compressed air
│   ├── Vacuum
│   ├── DI water
│   ├── Slurry / chemicals
│   ├── Exhaust
│   ├── Drain
│   └── Cooling
│
└── 10. Safety / Maintenance
    ├── E-stops
    ├── Guards
    ├── Leak detection
    ├── Containment
    ├── PM functions
    ├── Calibration
    └── Diagnostics
```

---

6. Machine Cycle Chart

The following is a **representative production wafer cycle** for a Reflexion LK Prime-type CMP system. It is a functional cycle chart, not an official AMAT timing specification. Exact sequence and durations depend on the recipe, film being polished, number of polish steps, cleaning configuration, and installed options.

6.1 High-level machine cycle

```
┌──────────────────────┐
│ 1. Machine Ready     │
│ Utilities available  │
│ No active alarms     │
└──────────┬───────────┘
           ▼
┌──────────────────────┐
│ 2. Lot / Wafer Start │
│ Host authorization   │
│ Recipe verification  │
└──────────┬───────────┘
           ▼
┌──────────────────────┐
```

```
│ 3. Carrier Load      │
│ FOUP / carrier dock  │
│ Carrier ID / map     │
└──────────┬───────────┘
           ▼
┌──────────────────────┐
│ 4. Wafer Transfer    │
│ Robot picks wafer    │
│ Position verification│
└──────────┬───────────┘
           ▼
┌──────────────────────┐
│ 5. Pre-Process       │
│ Alignment / rinse    │
│ Optional preparation │
└──────────┬───────────┘
           ▼
┌──────────────────────┐
│ 6. Polish Setup      │
│ Head receives wafer  │
│ Pad / slurry ready   │
│ Recipe parameters set│
└──────────┬───────────┘
           ▼
┌──────────────────────┐
│ 7. CMP Polish        │
│ Platen rotation      │
│ Carrier rotation     │
│ Downforce applied    │
│ Slurry delivered     │
└──────────┬───────────┘
           ▼
┌──────────────────────┐
│ 8. Endpoint /        │
│    Over-polish       │
│ Endpoint logic       │
│ Final removal        │
└──────────┬───────────┘
           ▼
┌──────────────────────┐
│ 9. Post-Polish Rinse │
│ Remove bulk slurry   │
└──────────┬───────────┘
           ▼
┌──────────────────────┐
│ 10. Cleaning         │
│ Brush / DI water     │
│ Optional chemistry   │
└──────────┬───────────┘
           ▼
┌──────────────────────┐
│ 11. Drying           │
│ Spin / gas dry       │
```

```
└───────────┬───────────┘
            │
            ▼
┌───────────────────────┐
│ 12. Measurement       │
│ Thickness / quality   │
│ Process data record   │
└───────────┬───────────┘
            │
            ▼
┌───────────────────────┐
│ 13. Wafer Unload      │
│ Robot returns wafer   │
│ Carrier slot update   │
└───────────┬───────────┘
            │
            ▼
┌───────────────────────┐
│ 14. Next Wafer / Lot  │
│ Repeat or complete    │
└───────────────────────┘
```

6.2 Detailed machine cycle chart

Step	Machine state	Main actions	Major subsystems active	Output / transition condition
0	**Idle / Ready**	Verify machine state, utilities, interlocks, consumables, and no critical alarms.	Controls, utilities, safety, HMI	Equipment is ready to accept material.
1	**Host Start**	Receive lot/wafer request and validate recipe authorization.	Host communication, recipe manager, controller	Valid process job created.
2	**Carrier Dock**	Load carrier and establish carrier presence.	Load port, carrier interface, sensors	Carrier securely docked.
3	**Carrier Verification**	Read carrier ID and map wafer slots.	Carrier ID, wafer mapper, robot controller	Wafer inventory known.
4	**Wafer Pick**	Robot retrieves selected wafer.	Wafer robot, end-effector, wafer sensors	Wafer safely acquired.
5	**Wafer Alignment**	Align wafer orientation and confirm position.	Pre-aligner, sensors, robot	Wafer correctly oriented.
6	**Pre-Clean / Preparation**	Perform configured rinse or preparation step.	Pre-clean, DI water, chemical delivery	Wafer prepared for polish.
7	**Polish Head Load**	Transfer wafer to polish head and secure	Internal transfer, polish head,	Wafer correctly held.

		it.	vacuum/retention system	
8	**Polish Initialization**	Position head, start platen/carrier rotation, establish slurry flow.	Platen drive, carrier drive, slurry system, controls	Stable process conditions established.
9	**Polish Contact**	Apply wafer-to-pad contact and programmed downforce.	Polish head, pressure zones, platen, carrier	Polishing begins.
10	**Material Removal**	Maintain pressure, speed, slurry flow, and motion recipe.	CMP module, slurry delivery, motion control	Film is progressively removed.
11	**Pad Conditioning**	Condition pad concurrently or according to recipe schedule.	Conditioner, conditioner drive, fluid delivery	Pad surface maintained.
12	**Endpoint Detection**	Monitor process signals or execute endpoint logic.	Endpoint sensors, controller, data acquisition	Endpoint criterion reached or time target completed.
13	**Over-Polish / Final Polish**	Apply configured final removal step, if specified.	Polish head, platen, slurry, endpoint logic	Target process completion reached.
14	**Polish Termination**	Reduce/remove downforce, stop or transition polishing, stop slurry as sequenced.	Polish head, platen, slurry valves, controller	Wafer exits active polish state.
15	**Post-Polish Rinse**	Rinse wafer and remove loose slurry.	Rinse station, DI water, robot	Bulk residue removed.
16	**Brush Clean**	Clean wafer surfaces using configured brushes and chemistry.	Brush module, cleaning chemistry, DI water	Particles and slurry residue reduced.
17	**Final Rinse**	Perform final rinse sequence.	DI water, rinse module	Wafer ready for drying.
18	**Drying**	Spin-rinse-dry or other configured drying process.	SRD, drying gas, spin drive	Dry wafer produced.
19	**Measurement / Verification**	Perform available thickness, endpoint, or process verification.	Metrology, sensors, controller	Process data recorded.

20	**Wafer Return**	Transfer wafer back to carrier or output station.	Robot, end-effector, load port	Wafer returned to correct slot.
21	**Cycle Complete**	Update wafer/lot status and prepare for next wafer.	Host interface, MES communication, controller	Next wafer begins or lot completes.

6.3 Machine cycle timing model

Because actual AMAT recipe times are not publicly specified for every configuration, it is more accurate to represent cycle time as a variable rather than invent fixed durations.

$$T_{\text{cycle}} = T_{\text{load}} + T_{\text{transfer}} + T_{\text{pre}} + T_{\text{polish}} + T_{\text{endpoint}} + T_{\text{rinse}} + T_{\text{clean}} + T_{\text{dry}} + T_{\text{measure}} + T_{\text{unload}}$$

Where:

Variable	**Meaning**
T_{load}	Carrier and wafer loading time
T_{transfer}	Robot transfer and positioning time
T_{pre}	Pre-polish preparation time
T_{polish}	Main CMP material-removal time
T_{endpoint}	Endpoint and over-polish time
T_{rinse}	Post-polish rinse time
T_{clean}	Brush and chemical cleaning time
T_{dry}	Drying time
T_{measure}	Measurement or verification time
T_{unload}	Wafer return and carrier update time

Parallelism matters

A production CMP tool may overlap activities between modules. For example:

- Wafer A may be polishing.
- Wafer B may be cleaning.
- Wafer C may be transferring.
- The conditioner may be maintaining a pad.

Therefore:

$$\text{Lot throughput} \neq \frac{1}{\text{sum of every module's independent time}}$$

The actual throughput depends on **module concurrency, wafer scheduling, bottleneck operations, and recipe configuration**.

7. CMP polishing sub-cycle

The most important physical cycle occurs inside the polish module.

```
A. Pad preparation
       │
       ▼
B. Slurry ON
       │
       ▼
C. Platen / carrier rotation
       │
       ▼
D. Wafer contact
       │
       ▼
E. Downforce ramp
       │
       ▼
F. Main polish
       │
       ├── Pressure-zone control
       ├── Carrier rotation
       ├── Platen rotation
       ├── Slurry flow
       ├── Pad conditioning
       └── Endpoint monitoring
       │
       ▼
G. Endpoint reached
       │
       ▼
H. Optional over-polish
       │
       ▼
I. Downforce release
       │
       ▼
J. Slurry OFF / rinse
       │
       ▼
K. Wafer transfer to clean
```

Main process variables

Variable	Why it matters
Platen speed	Influences relative velocity and removal rate.
Carrier speed	Influences wafer motion and uniformity.
Downforce	Controls mechanical contact pressure.
Pressure-zone distribution	Helps manage within-wafer uniformity.

Slurry flow rate	Controls chemical delivery and lubrication.
Slurry chemistry	Determines selectivity and chemical removal behavior.
Pad condition	Strongly affects removal rate and uniformity.
Polish time	Determines material removal in time-based recipes.
Endpoint signal	Helps determine when target film transition or removal is reached.
Temperature	Can influence chemical reaction and process stability.
Wafer pattern density	Affects local removal behavior and planarization.
Retaining-ring condition	Can influence edge performance and wafer retention.

---

8. Machine states and transitions

A useful controls-oriented view is the **SEMI-style equipment state model**, expressed here in generic terms:

```
┌─────────────┐
│   OFFLINE   │
└──────┬──────┘
       │ Power / Initialize
       ▼
┌─────────────┐
│ INITIALIZING│
└──────┬──────┘
       │ Self-test passed
       ▼
┌─────────────┐
│    IDLE     │
└──────┬──────┘
       │ Utilities + recipe + host start
       ▼
┌─────────────┐
│    READY    │
└──────┬──────┘
       │ Wafer accepted
       ▼
┌─────────────┐
│  EXECUTING  │
│  PROCESSING │
└──────┬──────┘
       │ Process complete
       ▼
┌─────────────┐
│   COMPLETE  │
└──────┬──────┘
       │ Return wafer / next job
       ▼
┌─────────────┐
│    READY    │
```

```
                    └──────────┘

  Any state ── fault ──▶ FAULT / RECOVERY
  Any state ── PM ─────▶ MAINTENANCE
```

9. Practical equipment-engineering interpretation

If you are studying this machine from a **semiconductor manufacturing, equipment engineering, or maintenance perspective**, the Reflexion LK Prime can be divided into five critical systems:

Critical system	Main engineering concern
1. Wafer handling	No wafer damage, reliable transfer, correct wafer tracking, no contamination.
2. Polishing mechanics	Stable rotation, pressure control, vibration, pad condition, wafer retention.
3. Chemical process	Correct slurry flow, chemistry, temperature, contamination control, waste handling.
4. Cleaning / drying	Particle removal, residue removal, wafer surface cleanliness, drying quality.
5. Controls / metrology	Recipe repeatability, endpoint accuracy, process monitoring, alarms, traceability.

The central process objective

Remove the required material+Achieve planarization+Maintain uniformity+Avoid wafer damage+Meet contamination limits\boxed{ \text{Remove the required material} + \text{Achieve planarization} + \text{Maintain uniformity} + \text{Avoid wafer damage} + \text{Meet contamination limits} }

10. What is publicly confirmed versus configuration-dependent?

Item	Status
Applied Materials Reflexion LK Prime is a CMP system	**Publicly confirmed**
Used for 300 mm wafer processing	**Publicly supported by equipment listings**
Designed for nanometer-level polishing performance	**Stated by Applied Materials**
Relevant to FinFET and 3D NAND applications	**Stated by Applied Materials**
Polish platen, pad, polish head, slurry, and conditioning functions	**Core CMP architecture**
Exact number of polish platens	**Configuration-dependent**
Exact number and type of polish heads	**Configuration-dependent**
Exact pressure-zone design	**Configuration-dependent**
Exact endpoint sensor architecture	**Configuration/process-dependent**
Exact cleaning module configuration	**Configuration-dependent**

Exact PLC, controller, software, and sensor part numbers	**Requires OEM documentation or tool-specific records**
Exact cycle time	**Recipe-dependent; not established here**

A secondary equipment listing identifies the **Reflexion LK Prime as CMP equipment for 300 mm wafers**, while another listing distinguishes Reflexion LK variants for copper CMP, oxide/dielectric CMP, and multi-process CMP. This reinforces that the Reflexion family exists in multiple process configurations. (SemiStar Corp.)

Bottom line

The **Applied Materials Reflexion LK Prime** is a **300 mm production CMP platform** whose central function is to achieve controlled wafer-surface material removal and planarization. Its major architecture consists of:

Wafer handling → Polish head and platen → Slurry delivery → Pad conditioning → Cleaning/drying → Endpoint/metrology → Controls/automation → Utilities and safety.

For a truly **serial-number-specific subsystem list**, the next level would be an **AMAT LK Prime Equipment Hierarchy / BOM / Module Map**, identifying the actual installed modules, controller cabinets, polish chambers, robots, pumps, valves, sensors, and maintenance assemblies.

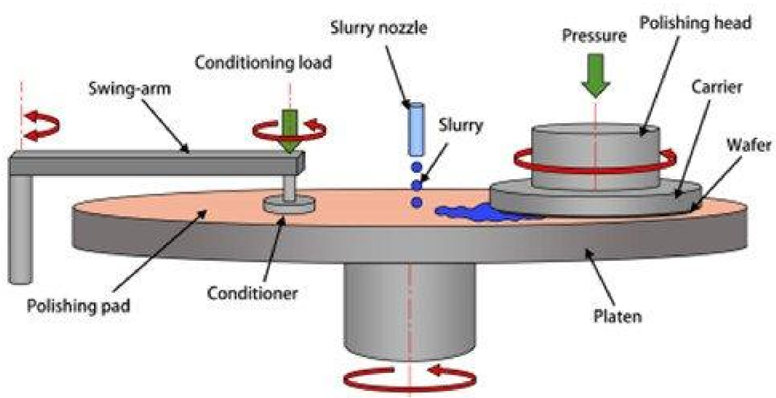
List a "wafer walk" from start to end.

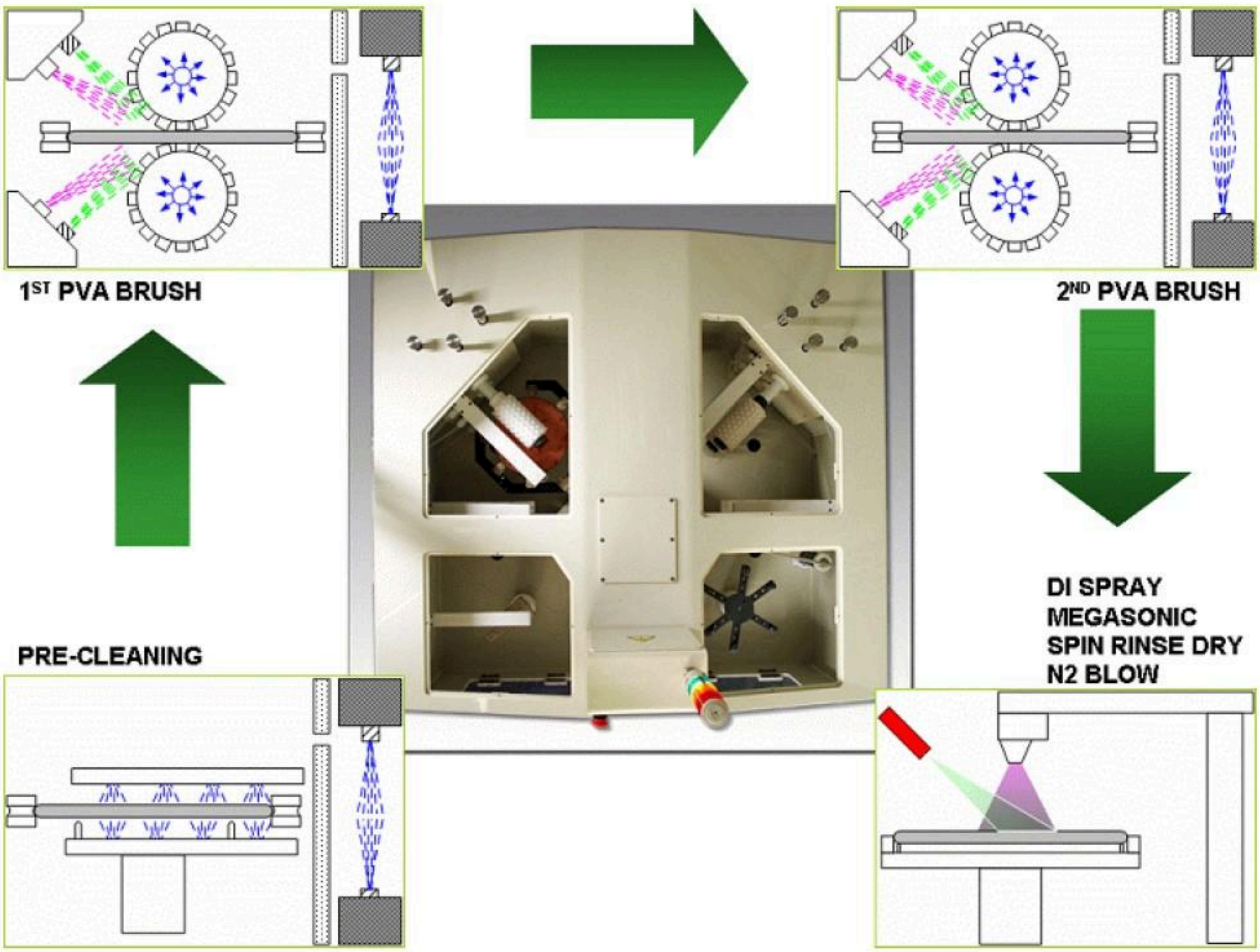
Reflexion LK Prime — Wafer Walk

A **wafer walk** is the chronological path a wafer takes through the equipment—from entering the tool to leaving it after processing. It follows the wafer's **physical movement, process operations, machine states, and key decision points**.

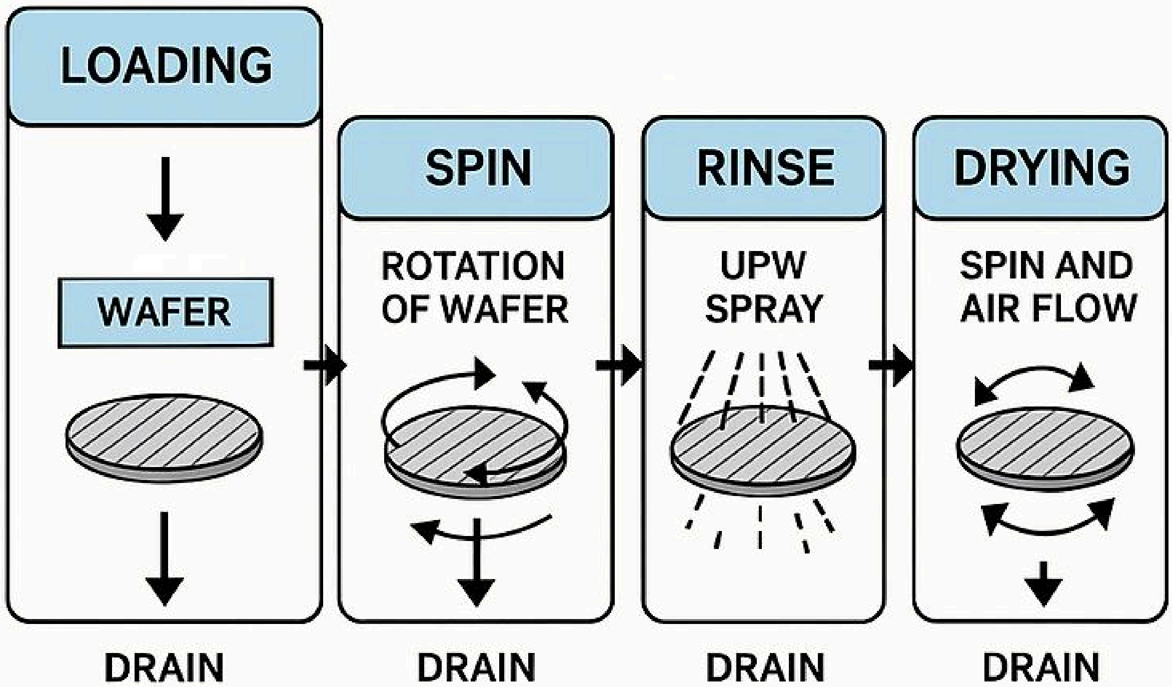
For the **Applied Materials Reflexion LK Prime CMP system**, the exact path varies by installed configuration and recipe. The walk below is a representative **300 mm CMP production flow**, useful for equipment familiarization, process engineering, troubleshooting, and training.

1. Wafer walk — end-to-end overview

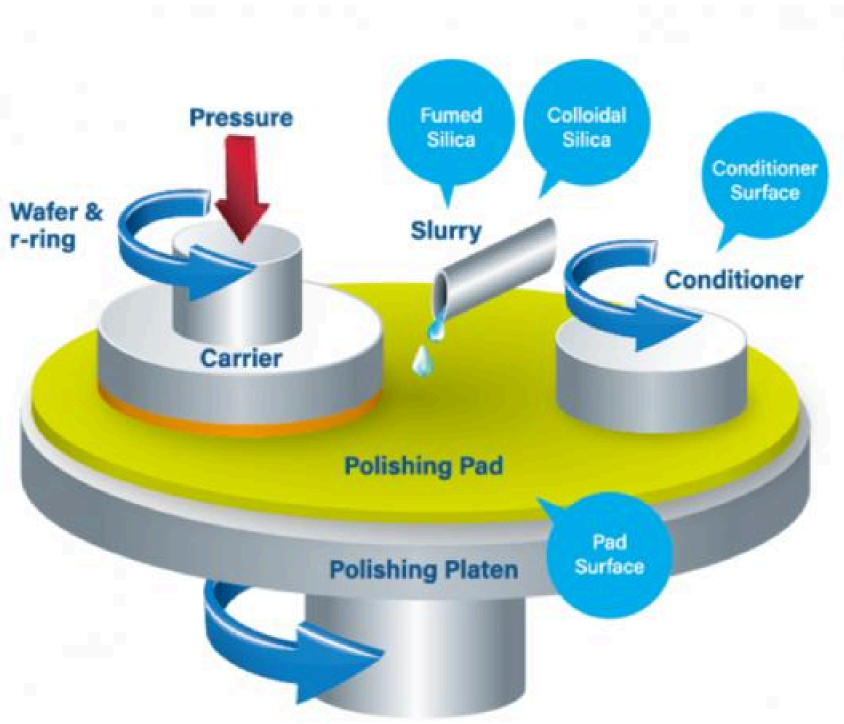




Basic Construction of GNP CLEANER



SWR 공정의 단계별 기본 흐름도




```
┌─────────────────────────────────────────────────────────────┐
│                    FACTORY / MES / HOST                     │
│              Lot • Recipe • Wafer Tracking                  │
└──────────────────────────────┬──────────────────────────────┘
                               │
                               ▼
┌─────────────────────────────────────────────────────────────┐
│ 01  FOUP / Carrier Arrival                                  │
│     Wafer lot enters the equipment                          │
└──────────────────────────────┬──────────────────────────────┘
                               ▼
┌─────────────────────────────────────────────────────────────┐
```

```
│ 02  Load Port / Carrier Verification           │
│     Carrier ID • Presence • Mapping            │
└───────────────────────┬────────────────────────┘
                        │
                        ▼
┌────────────────────────────────────────────────┐
│ 03  Wafer Pick / Transfer                      │
│     Robot removes wafer from carrier           │
└───────────────────────┬────────────────────────┘
                        │
                        ▼
┌────────────────────────────────────────────────┐
│ 04  Wafer Alignment / Orientation              │
│     Notch or orientation verified              │
└───────────────────────┬────────────────────────┘
                        │
                        ▼
┌────────────────────────────────────────────────┐
│ 05  Pre-Process Preparation                    │
│     Optional rinse / preparation               │
└───────────────────────┬────────────────────────┘
                        │
                        ▼
┌────────────────────────────────────────────────┐
│ 06  Transfer to Polish Head                    │
│     Wafer positioned and retained              │
└───────────────────────┬────────────────────────┘
                        │
                        ▼
┌────────────────────────────────────────────────┐
│ 07  Polish Module Entry                        │
│     Platen • Pad • Slurry • Head ready         │
└───────────────────────┬────────────────────────┘
                        │
                        ▼
┌────────────────────────────────────────────────┐
│ 08  Wafer Contact / Downforce                  │
│     Controlled contact with polishing pad      │
└───────────────────────┬────────────────────────┘
                        │
                        ▼
┌────────────────────────────────────────────────┐
│ 09  MAIN CMP POLISH                            │
│     Chemical + mechanical material removal     │
│     Platen rotation • Carrier rotation • Slurry│
└───────────────────────┬────────────────────────┘
                        │
                        ▼
┌────────────────────────────────────────────────┐
│ 10  Endpoint / Over-Polish                     │
│     Target removal / endpoint logic            │
└───────────────────────┬────────────────────────┘
                        │
                        ▼
┌────────────────────────────────────────────────┐
│ 11  Polish Termination                         │
│     Downforce release • Process transition     │
└───────────────────────┬────────────────────────┘
                        │
                        ▼
┌────────────────────────────────────────────────┐
│ 12  Post-Polish Rinse                          │
│     Bulk slurry and loose residue removed      │
```

```
└──────────────────────────────────────────────────────────────┘
                               │
                               ▼
┌──────────────────────────────────────────────────────────────┐
│ 13  Brush / Chemical Cleaning                                │
│     Particles • Slurry residue • Contamination reduction     │
└──────────────────────────────────────────────────────────────┘
                               │
                               ▼
┌──────────────────────────────────────────────────────────────┐
│ 14  Final Rinse                                              │
│     DI water rinse                                           │
└──────────────────────────────────────────────────────────────┘
                               │
                               ▼
┌──────────────────────────────────────────────────────────────┐
│ 15  Drying                                                   │
│     Spin-rinse-dry / configured drying                       │
└──────────────────────────────────────────────────────────────┘
                               │
                               ▼
┌──────────────────────────────────────────────────────────────┐
│ 16  Measurement / Process Verification                       │
│     Thickness • Uniformity • Process data, if configured     │
└──────────────────────────────────────────────────────────────┘
                               │
                               ▼
┌──────────────────────────────────────────────────────────────┐
│ 17  Wafer Return / Unload                                    │
│     Robot returns wafer to carrier                           │
└──────────────────────────────────────────────────────────────┘
                               │
                               ▼
┌──────────────────────────────────────────────────────────────┐
│ 18  Lot Complete / Next Process                              │
│     Host update • Carrier release • Next operation           │
└──────────────────────────────────────────────────────────────┘
```

---

2. Detailed wafer walk

Phase A — Incoming wafer and identification

Step 01 — FOUP / carrier arrival

Physical location: Equipment front end / load-port area

What happens:

- A carrier containing processed wafers arrives at the tool.
- The factory host authorizes the lot or wafer process.
- The equipment confirms that the appropriate carrier is present.

Active subsystems:

- Load port
- Carrier interface
- Factory automation interface
- Host communication

- Safety interlocks

Wafer condition:

Wafer is still inside the carrier and has not entered the process module.

Step 02 — Carrier identification and wafer mapping

What happens:

- Carrier ID is read.
- Wafer slots are mapped.
- Wafer presence is confirmed.
- The controller associates wafer identity with the process job.

Active subsystems:

- Carrier ID reader
- Wafer mapper
- Equipment controller
- MES/host interface

Key control question:

> "Is the correct wafer in the expected slot, and is it authorized for this recipe?"

Potential fault examples:

- Carrier ID mismatch
- Missing wafer
- Wafer mapping error
- Incorrect lot or recipe association

Step 03 — Wafer pick

Physical location: Carrier → internal transfer station

What happens:

- The robot moves to the assigned carrier slot.
- The end-effector enters the slot.
- The wafer is picked up.
- Wafer presence is verified.
- The robot retracts and transfers the wafer.

Active subsystems:

- Atmospheric wafer robot
- End-effector
- Wafer presence sensors
- Robot motion controller

Critical objective:

No wafer slip, edge contact, collision, or contamination.

Step 04 — Wafer alignment / orientation

What happens:

- The wafer is positioned in the alignment station, if required.
- The notch or orientation is identified.
- The wafer is aligned for the next operation.

Active subsystems:

- Pre-aligner
- Optical or position sensors
- Robot controller

Output:
Wafer is correctly oriented and ready for process transfer.

Phase B — Pre-polish preparation

Step 05 — Pre-process preparation

Physical location: Pre-clean or preparation module, if installed

Possible operations:

- DI water rinse
- Surface preparation
- Pre-clean
- Transfer conditioning
- Other recipe-specific preparation

Active subsystems:

- Pre-clean module
- DI water delivery
- Chemical delivery, if configured
- Drain / exhaust
- Robot transfer

Important:
Not every recipe requires a separate pre-clean step. Some configurations may transfer the wafer directly to polishing.

Step 06 — Transfer to polish head

Physical location: Internal handling area → polish module

What happens:

- The robot positions the wafer beneath or at the polish head.
- The wafer is transferred to the carrier.
- The carrier's wafer-retention mechanism is engaged.
- Wafer presence and proper seating are verified.

Active subsystems:

- Internal wafer robot
- Polish head
- Vacuum / retention system, where applicable
- Wafer sensors

- Transfer controller

Critical objective:
The wafer must be securely held and correctly positioned before contact with the pad.

Phase C — CMP polishing

Step 07 — Polish module initialization

Physical location: CMP polish chamber

What happens:

- Platen and carrier are brought to the required operating conditions.
- Slurry delivery is enabled.
- Pad condition is verified or maintained.
- Recipe parameters are loaded.

Typical parameters established:

Parameter	Example function
Platen speed	Controls pad rotation
Carrier speed	Controls wafer rotation
Downforce	Controls wafer-pad pressure
Pressure zones	Controls pressure distribution
Slurry flow	Controls chemical delivery
Polish time	Controls timed removal
Conditioning	Maintains pad surface
Endpoint mode	Controls process termination

Active subsystems:

- Platen drive
- Polish-head drive
- Slurry delivery
- Pad conditioner
- Process controller

Step 08 — Wafer contact and downforce application

Physical location: Polish platen / pad interface

What happens:

- The polish head lowers toward the pad.
- Wafer-to-pad contact is established.
- Downforce is ramped or applied according to the recipe.
- Slurry is present at the process interface.

Cross-section:

```
            Polish head
        ┌───────────────┐
        │   Pressure    │
        │   membrane    │
        └───────┬───────┘
                │
         Controlled force
                ▼
        ┌───────────────┐
        │     WAFER     │
        └───────────────┘
           Slurry film
        ~~~~~~~~~~~~~~~~
        ════════════════  ← Polishing pad
               ↻
             Platen
```

Critical control objective:
Establish stable contact without wafer damage or process instability.

Step 09 — Main CMP polish

This is the **core wafer-processing step**.

What physically happens?

The wafer is held against a rotating pad while slurry is delivered. The combined chemical and mechanical action removes material from the wafer surface.

```
           Carrier rotation ↻
                  │
                  ▼
           ┌────────────┐
           │   WAFER    │
           └────────────┘
                  │
           Chemical action
                  +
           Mechanical action
                  │
                  ▼
      ═══════════════════════════
           Rotating pad ↻
                  │
                  ▼
        Material removal
```

Main active subsystems

- Polish platen
- Platen motor

- Polish head
- Carrier motor
- Pressure-zone system
- Retaining ring
- Slurry pumps
- Slurry flow controllers
- Slurry delivery nozzles
- Pad conditioner
- Endpoint/process sensors
- Equipment controller

What is being controlled?

Control variable	Process purpose
Platen RPM	Controls pad velocity
Carrier RPM	Controls wafer motion
Downforce	Controls contact pressure
Pressure-zone force	Adjusts removal distribution
Slurry flow	Maintains chemical supply
Pad condition	Maintains consistent polishing behavior
Temperature	Helps maintain process stability
Time / endpoint	Determines process completion

What is the machine trying to achieve?

- Target material removal
- Surface planarization
- Within-wafer uniformity
- Across-wafer repeatability
- Controlled edge behavior
- Low defectivity
- No wafer breakage or unacceptable surface damage

Step 10 — Endpoint detection / over-polish

What happens:

- The controller monitors the selected endpoint method.
- It determines whether the desired film transition or removal target has been reached.
- A configured over-polish or final-polish step may follow.

Possible endpoint approaches:

- Time-based endpoint
- Motor/torque-related process signal
- Optical endpoint sensing
- Other installed in-situ sensing
- Recipe-defined endpoint logic

Important distinction:

> **Endpoint detection** determines when the process should transition. **Metrology** determines whether the resulting wafer meets the desired specifications.

These are related but not identical functions.

Output:
The wafer reaches the defined polish completion condition.

Step 11 — Polish termination

What happens:

- Downforce is reduced or released.
- The polish head separates from the pad.
- Slurry flow is stopped or transitioned according to the recipe.
- Rotation and motion are stopped or changed for wafer transfer.
- The wafer exits the active polish state.

Active subsystems:

- Polish head actuator
- Pressure control
- Platen / carrier drives
- Slurry valves
- Controller sequencing

Critical objective:
Terminate polishing in a controlled manner and avoid unintended additional removal.

Phase D — Cleaning and drying

Step 12 — Post-polish rinse

Physical location: Rinse / cleaning interface

What happens:

- The wafer is transferred from the polish module.
- Bulk slurry is rinsed from the wafer.
- Loose particles and residue are removed.
- The wafer is prepared for more thorough cleaning.

Active subsystems:

- Internal robot
- Rinse station
- DI water system
- Drain system

Why this matters:
Slurry residue can dry onto the wafer and create defects or contamination if not removed promptly.

Step 13 — Brush / chemical cleaning

Physical location: Post-CMP clean module

What happens:

- The wafer enters the cleaning module.
- Brush cleaning and/or configured chemical cleaning is performed.
- DI water and cleaning chemistry remove residual slurry and particles.
- Cleaning parameters are controlled to avoid wafer damage.

Typical cleaning functions:

- Brush contact
- Brush rotation
- Cleaning fluid delivery
- Rinse
- Particle removal
- Residue removal

Active subsystems:

- Cleaning brushes
- Brush drives
- Brush positioning / load control
- DI water delivery
- Chemical delivery
- Drain / waste
- Cleaning controller

Cleaning objective

$$\text{Clean wafer} = \text{Reduced slurry residue} + \text{Reduced particles} + \text{No unacceptable surface damage}$$

Step 14 — Final rinse

What happens:

- The wafer receives a final DI water rinse.
- Remaining cleaning chemistry and loosened contaminants are removed.
- The wafer is prepared for drying.

Active subsystems:

- DI water system
- Rinse module
- Drain system
- Wafer handling

Step 15 — Drying

Physical location: Spin-rinse-dry or configured drying module

What happens:

- The wafer is rotated or otherwise dried.
- Water is removed from the surface.
- Drying gas or air may be used depending on configuration.
- The wafer exits the cleaning sequence dry.

Active subsystems:

- Spin drive
- Drying module
- Gas / air delivery
- Exhaust
- Controller

Critical objective:
Avoid watermarks, residual droplets, particle redeposition, and wafer damage.

Phase E — Verification and output

Step 16 — Measurement / process verification

What happens:

- The wafer may undergo integrated or external measurement, depending on tool configuration and fab flow.
- Thickness, removal, uniformity, or other process metrics may be recorded.
- The process result is associated with the wafer and lot.

Possible measurements:

- Film thickness
- Removal amount
- Within-wafer uniformity
- Across-wafer uniformity
- Defectivity, if a separate inspection step is used
- Process sensor data

Active subsystems:

- Integrated metrology, if installed
- Endpoint/process data system
- Host/MES interface
- Equipment controller

Important:
Not every Reflexion LK Prime configuration necessarily performs all post-process measurements internally.

Step 17 — Wafer return / unload

Physical location: Internal handling area → carrier

What happens:

- The robot retrieves the cleaned and dried wafer.
- Wafer identity and destination slot are confirmed.
- The wafer is returned to the appropriate carrier slot.

- Wafer presence is verified.

Active subsystems:

- Internal wafer robot
- End-effector
- Wafer sensors
- Load port
- Carrier mapping / tracking

Critical objective:
Return the correct wafer to the correct slot without contamination or damage.

Step 18 — Lot completion / next process

What happens:

- The equipment updates the host system.
- Wafer processing status is recorded.
- The next wafer is processed, or the lot is completed.
- The carrier is released when authorized.
- The wafer proceeds to the next manufacturing operation.

Possible next operations:

- Additional CMP step
- Post-CMP inspection
- Metrology
- Cleaning
- Etch
- Deposition
- Lithography
- Other wafer-fabrication process

---

3. Wafer walk as a physical-location map

This view emphasizes **where the wafer is**, rather than just what the machine does.

Sequence	Physical location	Wafer state
1	Incoming FOUP	Wafer stored in carrier
2	Load port	Carrier docked
3	Carrier slot	Wafer being picked
4	Transfer station	Wafer in robot control
5	Pre-aligner	Wafer orientation verified
6	Pre-clean / preparation	Wafer optionally prepared
7	Polish-head loading position	Wafer transferred to carrier
8	Polish platen	Wafer approaches pad
9	Polish pad interface	Wafer under CMP processing

10	Polish pad interface	Endpoint / over-polish
11	Polish-head exit	Wafer released from polishing
12	Rinse station	Bulk slurry removed
13	Brush-clean module	Residue and particles removed
14	Final rinse	Final fluid rinse
15	Drying module	Wafer dried
16	Metrology / verification	Process result evaluated
17	Output transfer	Wafer returned to carrier
18	FOUP	Processed wafer ready for next operation

---

4. Wafer walk — subsystem interaction matrix

This matrix shows **which subsystems participate at each stage**.

Step	Handling	Polish	Slurry	Conditioning	Cleaning	Metrology	Controls
Carrier arrival	●						●
Carrier mapping	●						●
Wafer pick	●						●
Alignment	●						●
Pre-clean	●		●		●		●
Polish-head loading	●	●					●
Polish initialization		●	●	●			●
Wafer contact		●	●	●			●
Main CMP polish		●	●	●		●	●
Endpoint / over-polish		●	●	●		●	●
Polish termination		●	●				●
Post-polish rinse	●		●		●		●
Brush cleaning	●		●		●		●
Final rinse	●				●		●
Drying	●				●		●

Measurement	●					●	●
Wafer return	●						●
Lot completion	●					●	●

Legend: ● = subsystem is functionally involved. The table is a high-level architecture map, not a statement that every subsystem operates continuously during every step.

5. Wafer walk — process-control view

A wafer does not simply move through the machine; it passes through **control gates**.

```
WAREHOUSE / FAB INPUT
        │
        ▼
[Gate 1] Correct carrier?
        │ Yes
        ▼
[Gate 2] Correct wafer / slot?
        │ Yes
        ▼
[Gate 3] Wafer present and aligned?
        │ Yes
        ▼
[Gate 4] Recipe and utilities ready?
        │ Yes
        ▼
[Gate 5] Wafer correctly loaded on head?
        │ Yes
        ▼
[Gate 6] Polish conditions stable?
        │ Yes
        ▼
[Gate 7] Endpoint / target reached?
        │ Yes
        ▼
[Gate 8] Wafer successfully cleaned?
        │ Yes
        ▼
[Gate 9] Wafer dry and verified?
        │ Yes
        ▼
[Gate 10] Correct output slot?
        │ Yes
        ▼
PROCESS COMPLETE
```

At any gate, the equipment may:

- Pause

- Retry
- Reject the wafer
- Generate an alarm
- Enter recovery
- Require operator intervention
- Place the equipment into a fault or maintenance state

---

6. Wafer walk — one-line engineering summary

> **FOUP → Load Port → Wafer Mapping → Robot Pick → Alignment → Pre-Clean → Polish Head → Platen/Pad → Slurry + Downforce + Rotation → Endpoint → Rinse → Brush Clean → Final Rinse → Dry → Metrology → Robot Return → FOUP.**

---

7. The most important distinction

The **wafer walk** describes the **wafer's journey**.

The **machine cycle chart** describes the **machine's chronological sequence**.

The **subsystem hierarchy** describes **what equipment components make the journey possible**.

Together:

```
                     MACHINE UNDERSTANDING
                               │
              ┌────────────────┼────────────────┐
              ▼                ▼                ▼
       WAfer Walk        Machine Cycle     Subsystem WBS
     Where wafer goes    When actions occur   What performs them
              │                │                │
              └────────────────┼────────────────┘
                               ▼
                   COMPLETE EQUIPMENT MODEL
```

Note: For an actual AMAT Reflexion LK Prime installed at a specific fab, the authoritative wafer walk should be validated against the tool's **process recipe, equipment configuration, module map, robot mapping, and OEM operation/maintenance documentation**.

List all the hardware and software systems and subsystems ie. Devicenet, Sercos, EthernetIP, RTPC, Endpoint etc

Applied Materials Reflexion LK Prime

Hardware and Software Systems / Subsystems — Engineering Architecture

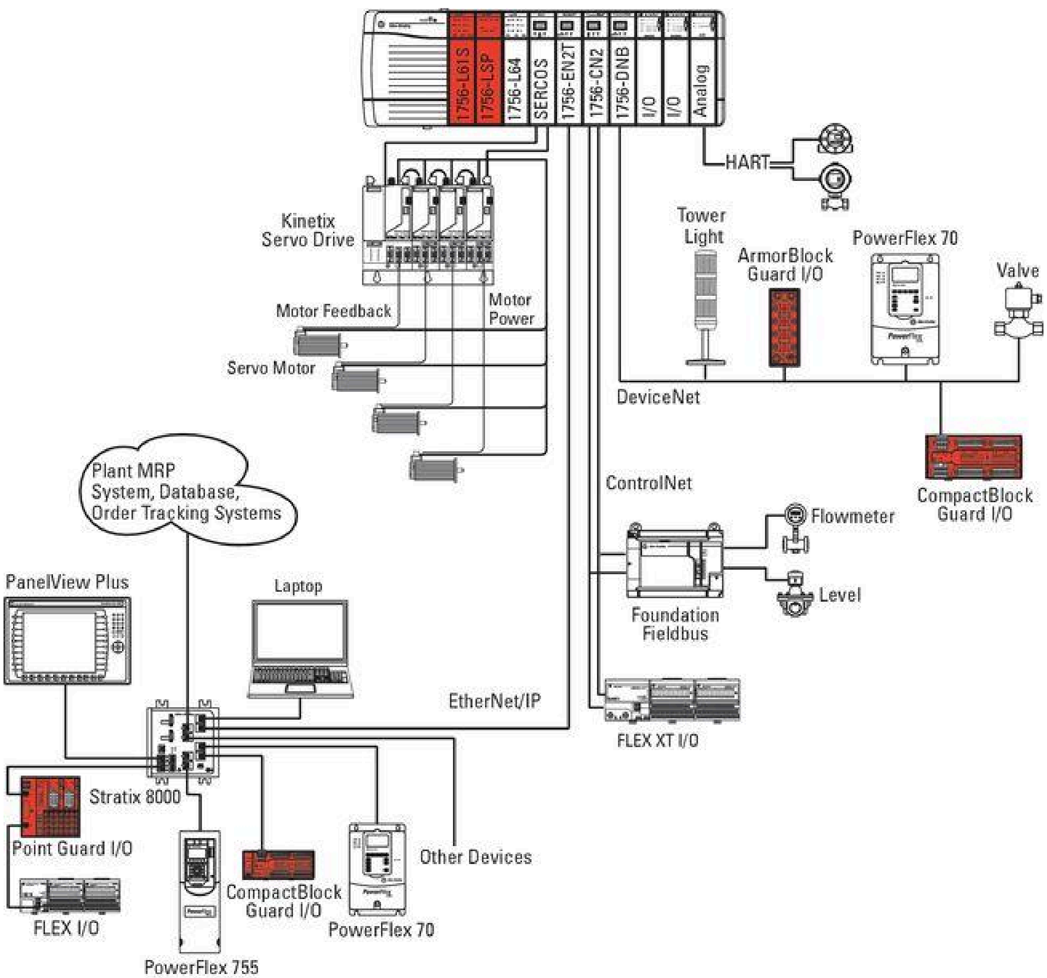
You are asking for a deeper **equipment-controls and automation decomposition**—not just the wafer-processing modules. Specifically, you want the underlying **industrial networks, real-time controllers, motion systems, PLC/I/O, endpoint, HMI, host communications, and hardware/software infrastructure** that make the Reflexion LK Prime operate.

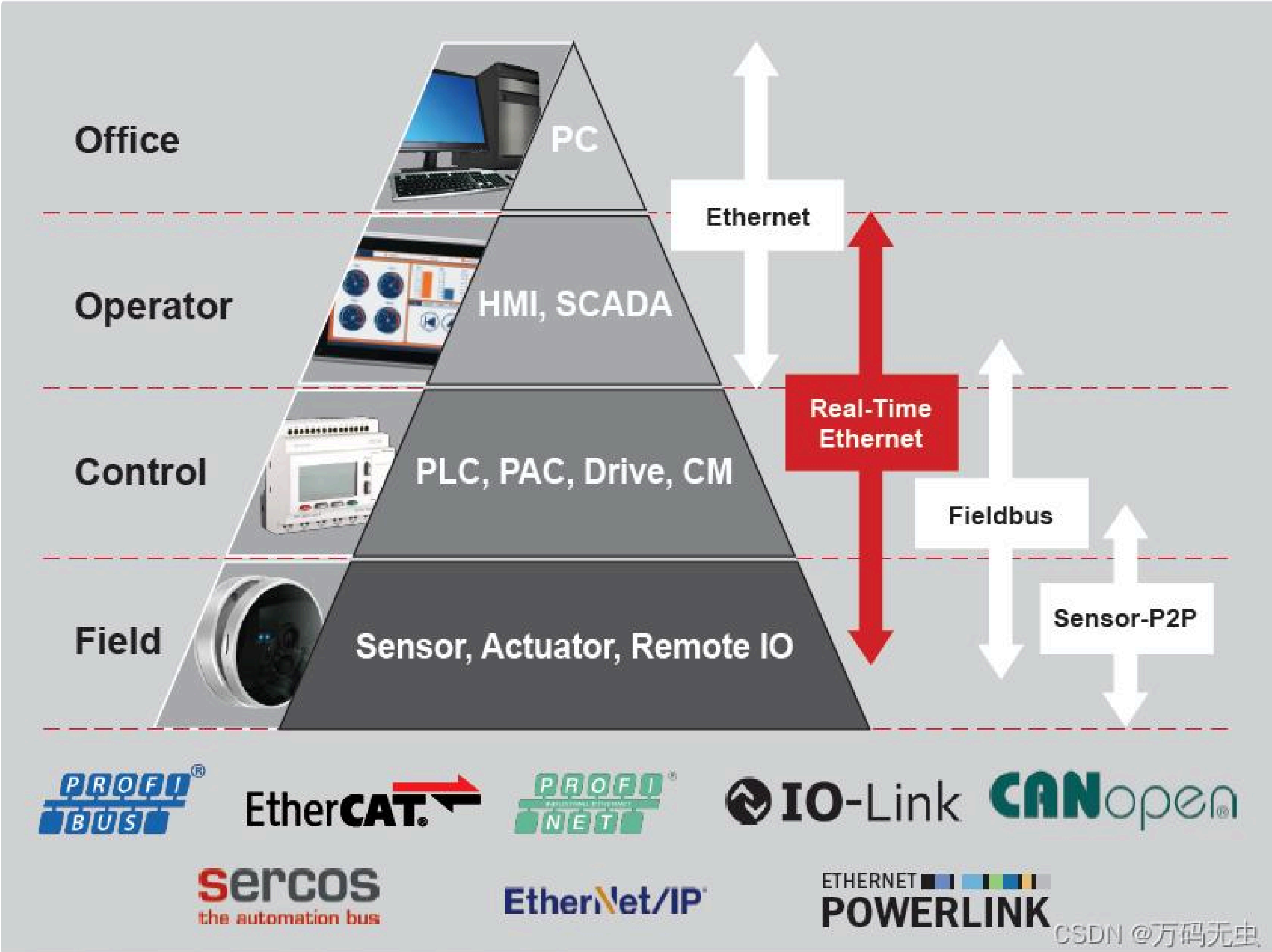
That is the correct level of analysis for understanding the tool as an **integrated semiconductor manufacturing system**.

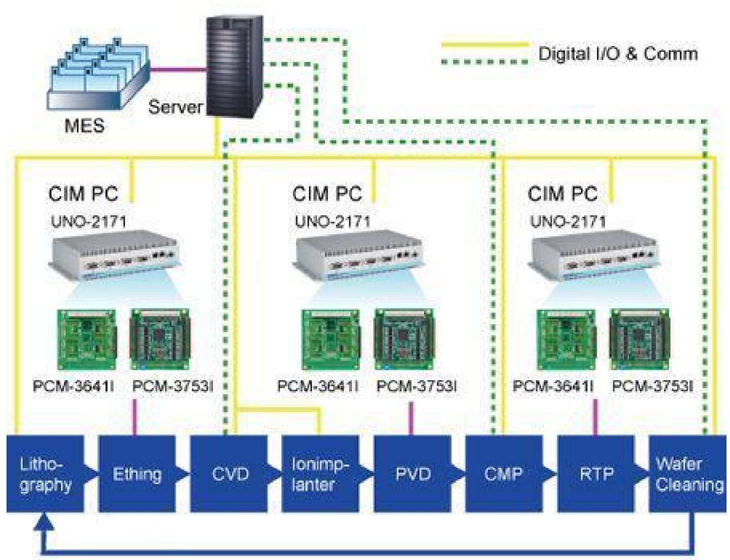
> **Scope and accuracy note:** Applied Materials does not publicly provide a complete, authoritative LK Prime electrical schematic, software architecture, or serial-number-specific BOM. The architecture below distinguishes **technology families and functions known or plausible in this class of AMAT equipment** from **items that must be verified on the actual tool**. I will not present DeviceNet, SERCOS, EtherNet/IP, or RTPC as definitively installed on every LK Prime without configuration evidence.

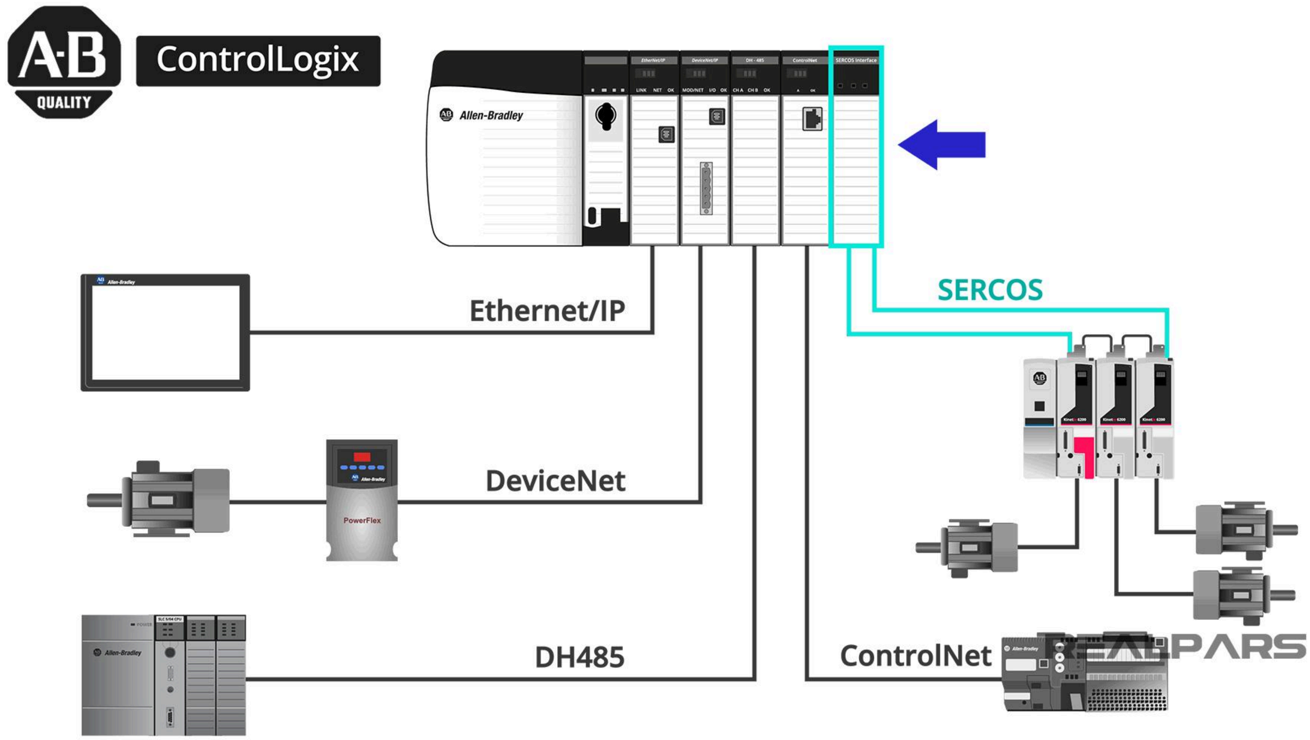
---

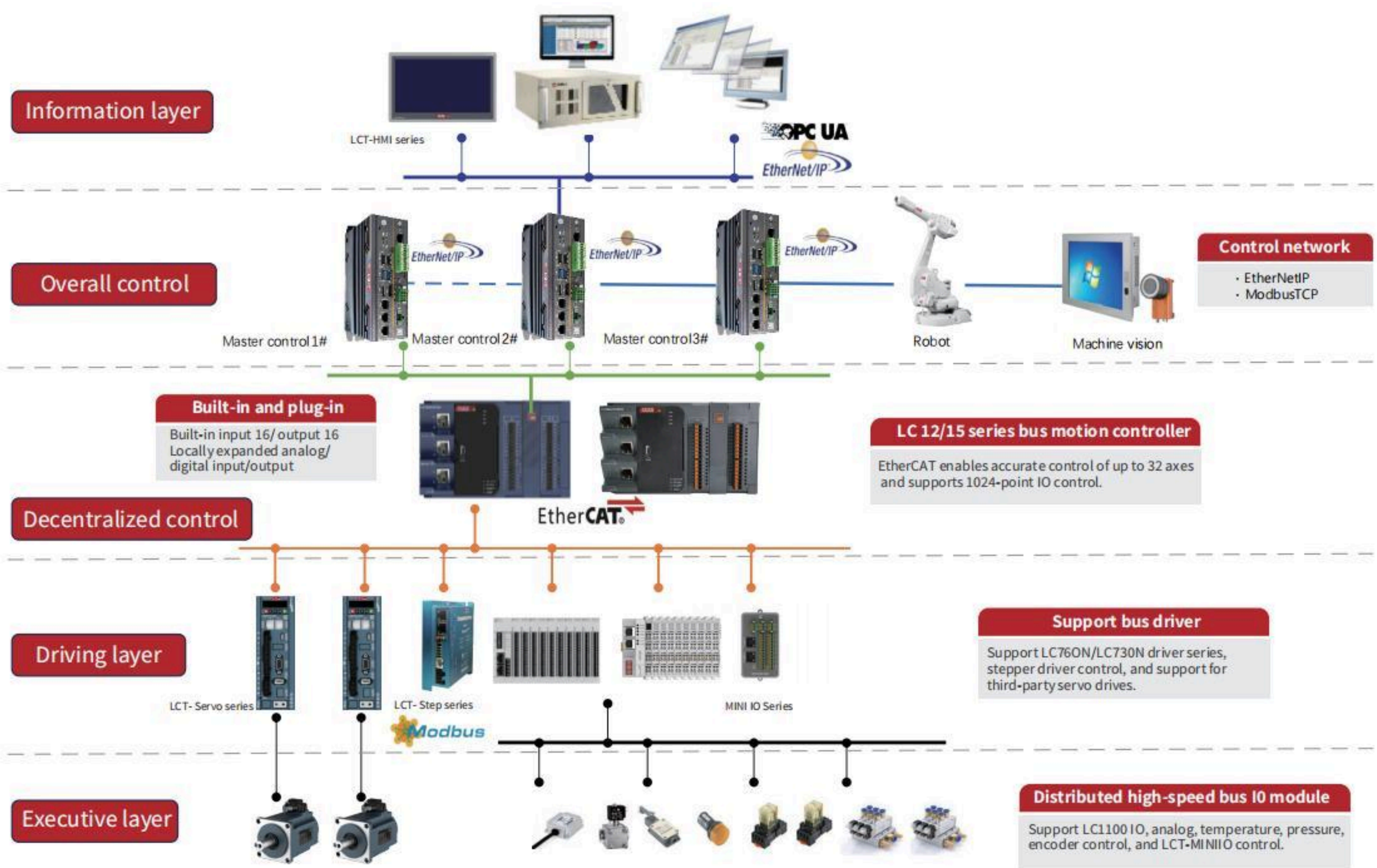
1. System-of-systems architecture

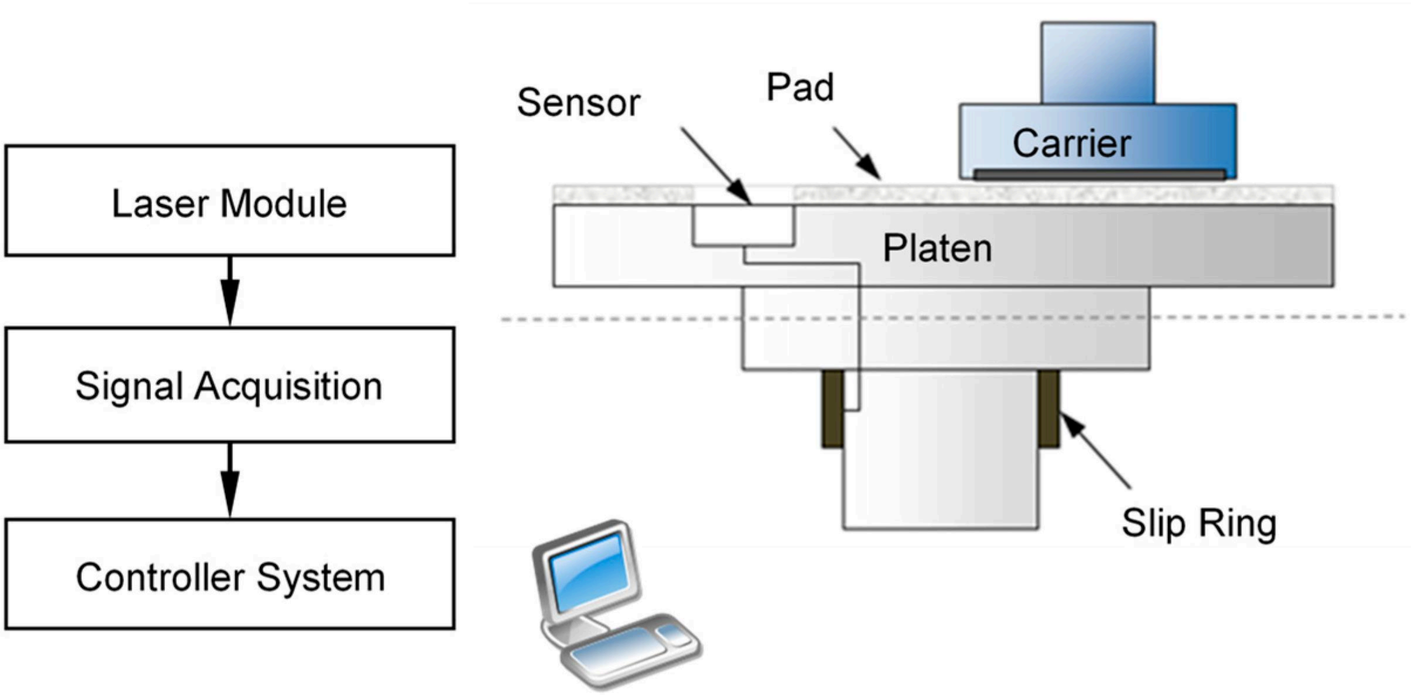



Office
PC
Ethernet
Operator
HMI, SCADA
Real-Time Ethernet
Control
PLC, PAC, Drive, CM
Fieldbus
Field
Sensor, Actuator, Remote IO
Sensor-P2P
PROFI BUS
EtherCAT
PROFI NET
IO-Link
CANopen
sercos the automation bus
EtherNet/IP
ETHERNET POWERLINK
CSDN @万码无虫


MES
Server
Digital I/O & Comm
CIM PC
UNO-2171
PCM-3641I
PCM-3753I
CIM PC
UNO-2171
PCM-3641I
PCM-3753I
CIM PC
UNO-2171
PCM-3641I
PCM-3753I
Litho-graphy
Ething
CVD
Ionimp-lanter
PVD
CMP
RTP
Wafer Cleaning


ControlLogix
Allen-Bradley
Ethernet/IP
SERCOS
DeviceNet
PowerFlex
DH485
ControlNet
REALPARS


Information layer
LCT-HMI series
OPC UA
EtherNet/IP
Overall control
Master control 1#
Master control 2#
Master control3#
Robot
Machine vision
Control network
· EtherNetIP
· ModbusTCP
Built-in and plug-in
Built-in input 16/ output 16
Locally expanded analog/
digital input/output
LC 12/15 series bus motion controller
EtherCAT enables accurate control of up to 32 axes
and supports 1024-point IO control.
Decentralized control
EtherCAT
Driving layer
LCT- Servo series
LCT- Step series
Modbus
MINI IO Series
Support bus driver
Support LC76ON/LC730N driver series,
stepper driver control, and support for
third-party servo drives.
Executive layer
Distributed high-speed bus IO module
Support LC1100 IO, analog, temperature, pressure,
encoder control, and LCT-MINIIO control.




```
┌──────────────────────────────────────────────────────────────────────────────┐
│                          FAB / FACTORY LEVEL                                 │
│                                                                              │
│  MES / MCS / AMHS / Host Automation / Recipe Server / SPC / FDC              │
│                               │                                              │
│                          Ethernet / SECS/GEM                                 │
└───────────────────────────────┬──────────────────────────────────────────────┘
                                │
                                ▼
┌──────────────────────────────────────────────────────────────────────────────┐
│                          EQUIPMENT LEVEL                                    │
│                                                                             │
│  HMI / Operator Station                                                     │
│  Equipment Controller / Cell Controller / RTPC*                             │
│  Recipe Manager / Sequence Engine / Alarm Manager                           │
│  Data Acquisition / FDC / Equipment State Model                             │
│                               │                                              │
│              ┌────────────────┼───────────────────┐                          │
│              ▼                ▼                   ▼                          │
│      PLC / I/O Control   Motion Control     Process Control                  │
│              │                │                   │                          │
│       DeviceNet*        SERCOS* / Servo*   Endpoint / Sensors*              │
│       EtherNet/IP*      Drives / Motors     Slurry / Pressure*               │
│       Remote I/O        Encoders            Temperature / Torque*            │
└──────────────┬────────────────┬───────────────────┬──────────────────────────┘
               │                │                   │
               ▼                ▼                   ▼
┌──────────────────┐ ┌──────────────────┐ ┌────────────────────────────────────┐
│ MATERIAL HANDLING │ │ CMP MECHANICS    │ │ PROCESS / CHEMICAL SYSTEMS         │
│                  │ │                  │ │                                    │
│ Load ports       │ │ Platen           │ │ Slurry pumps / valves              │
│ Robots           │ │ Polish heads     │ │ DI water / chemistry               │
```

```
│ Aligners          │ │ Carrier motors    │ │ Endpoint sensors              │
│ Wafer sensors     │ │ Conditioner       │ │ Pressure / temperature        │
│ FOUP interface    │ │ Pressure zones    │ │ Cleaning / drying             │
└───────────────────┘ └───────────────────┘ └───────────────────────────────┘
```

Legend: * = technology or function to verify against the actual tool configuration.

---

2. Master inventory: hardware and software

The following is a comprehensive **functional inventory**, organized into the layers normally encountered when troubleshooting or reverse-engineering a production CMP tool.

Layer	System	Examples / technologies	Primary purpose
L0	Facility infrastructure	Power, CDA, vacuum, DI water, exhaust, drains	Supplies the tool
L1	Physical process hardware	Platen, pad, polish head, slurry, cleaning	Performs wafer processing
L2	Sensors and actuators	Encoders, pressure sensors, valves, motors	Measures and moves
L3	Field I/O / device networks	DeviceNet*, EtherNet/IP*, remote I/O*	Connects field devices
L4	Motion control	SERCOS*, servo drives, motion controllers	Controls precision movement
L5	Real-time control	RTPC*, PLC, deterministic controller	Executes machine sequence
L6	Process control	Endpoint, pressure, slurry, temperature	Controls CMP process
L7	Equipment software	Recipe, sequencing, alarms, HMI, data logging	Operates the equipment
L8	Factory integration	SECS/GEM, host, MES, MCS	Connects tool to fab
L9	Engineering / service	Diagnostics, calibration, maintenance tools	Maintains and troubleshoots

---

3. Hardware systems and subsystems

3.1 Main equipment mechanical hardware

These are the physical systems that directly process or transport the wafer.

#	Hardware system	Subsystems / components
H-01	**Equipment frame / enclosure**	Structural frame, panels, access doors, covers, vibration isolation

H-02	**Wafer input/output**	Load ports, FOUP interface, carrier stations, carrier sensors
H-03	**Wafer handling**	Atmospheric robot, internal robot, end-effectors, wafer presence sensors
H-04	**Wafer alignment**	Pre-aligner, notch/orientation sensor, alignment drive
H-05	**Polish platen**	Platen, bearing, shaft, motor, coupling, encoder, pad mounting
H-06	**Polishing pad**	Pad, pad adhesive/backing, pad support, pad replacement hardware
H-07	**Polish head / carrier**	Carrier body, retaining ring, membrane/bladder, backside pressure, rotation drive
H-08	**Pressure-zone hardware**	Pressure regulators, valves, manifolds, pressure sensors, membrane zones
H-09	**Head positioning**	Lift actuator, Z-axis, sweep/translation mechanism, position sensors
H-10	**Pad conditioner**	Conditioner arm, disk/brush, drive, load actuator, position feedback
H-11	**Slurry delivery**	Pumps, filters, valves, manifolds, flow meters, nozzles, tubing
H-12	**Cleaning modules**	Brush assemblies, brush motors, cleaning chambers, rinse stations
H-13	**Drying module**	Spin drive, drying gas, exhaust, enclosure
H-14	**Waste management**	Drains, waste manifolds, slurry collection, chemical containment
H-15	**Utility interface**	Electrical, CDA, vacuum, DI water, exhaust, drain, cooling connections

---

3.2 Electrical power and cabinet hardware

#	System	Hardware / function
E-01	**Main electrical distribution**	Incoming disconnect, breakers, fuses, contactors
E-02	**Power supplies**	24 VDC control power, logic supplies, auxiliary supplies
E-03	**Motor power**	Servo amplifiers, motor drives, VFDs, motor power distribution
E-04	**Control cabinet**	Controller chassis, I/O racks, terminal blocks, relays

E-05	**Safety circuit**	E-stop relays, safety relays, door switches, interlock circuits
E-06	**Grounding / bonding**	Protective earth, equipment grounding, shielding
E-07	**EMI / noise control**	Filters, cable shielding, grounding practices
E-08	**Cabinet cooling**	Fans, heat exchangers, temperature sensors
E-09	**UPS / power protection**	Where installed, protects control and computer systems
E-10	**Service power**	Maintenance outlets and service connections

---

4. Industrial networks and communications

This is the part closest to your **DeviceNet / SERCOS / EtherNet/IP / RTPC** examples.

4.1 Network inventory

Technology	What it is	Typical role in industrial equipment	LK Prime status
DeviceNet	CAN-based industrial fieldbus	Connects distributed I/O, sensors, valves, motor devices, and other field components	**Possible / configuration-dependent; verify**
SERCOS	Real-time motion-control network	Connects motion controller to servo drives and supports deterministic motion	**Possible / configuration-dependent; verify**
EtherNet/IP	Industrial Ethernet protocol using CIP	PLC, remote I/O, drives, devices, and controller communication	**Possible / configuration-dependent; verify**
Industrial Ethernet	Ethernet physical/network infrastructure	Controller, HMI, engineering station, device communication	**Likely at some level; exact protocol verify**
TCP/IP	General networking protocol suite	HMI, service PC, host communications, diagnostics	**Likely**
SECS/GEM	Semiconductor equipment communications standards	Host-to-equipment communication, remote commands, events, alarms, data	**Expected class of fab integration; exact implementation verify**
RS-232 / serial	Serial communication	Legacy instruments, service devices, barcode readers,	**Possible; verify**

		analyzers	
RS-485	Differential serial communication	Multi-drop industrial devices	**Possible; verify**
CAN / CANopen	Controller Area Network protocols	Embedded device communication, drives, sensors	**Possible; verify**
USB	Peripheral interface	Service, removable media, engineering peripherals	**Possible**
Fiber optic Ethernet	Optical Ethernet physical layer	Noise-resistant or longer-distance communication	**Possible; verify**
Proprietary AMAT bus	OEM-specific communication	Internal module or controller communication	**Possible; documentation required**

Important distinction

DeviceNet, SERCOS, and EtherNet/IP are not interchangeable.

Technology	Main purpose
DeviceNet	Field-device communication
SERCOS	Deterministic motion control
EtherNet/IP	Industrial Ethernet control/device communication
RTPC	Real-time computing/control platform or controller architecture—not a fieldbus
Endpoint	A process-control function/system—not a network

---

5. DeviceNet subsystem

If the specific LK Prime uses DeviceNet, its architecture would typically look like this:

```
┌──────────────────────────────────────────┐
│ PLC / Real-Time Controller               │
│ DeviceNet Scanner / Master               │
└──────────────────────────────────────────┘
                    │
                    │
            DeviceNet trunk
                    │
      ┌─────────────┼─────────────┐
      ▼             ▼             ▼
 Remote I/O    Valve Node    Sensor Node
      │             │             │
      ▼             ▼             ▼
 DI / DO       Solenoid      Device Data
 Analog I/O    Manifold      Status
```

DeviceNet hardware

Component	Function
DeviceNet scanner / interface	Controller-side network interface
DeviceNet trunk cable	Main communication bus
Drop cables	Connect field devices
24 VDC network power	Powers compatible field devices
Terminators	Electrical bus termination
Remote I/O blocks	Distributed digital/analog I/O
Valve manifolds	Pneumatic valve control
DeviceNet sensors	Device-level data/status
Network connectors	Physical connections
Network diagnostics	Node status, bus errors, communication faults

DeviceNet software

- DeviceNet scanner configuration
- Node addressing
- Electronic data sheets (EDS), where applicable
- I/O assembly mapping
- Device status monitoring
- Network fault diagnostics
- PLC tag mapping
- Alarm handling
- Device replacement/configuration procedures

Verification method: Look for a **DeviceNet scanner card**, trunk cable, terminating resistors, node addresses, and EDS files in the equipment software/service documentation.

---

6. SERCOS subsystem

SERCOS is especially relevant when examining older or specialized precision-motion architectures.

```
┌──────────────────────────────────────┐
│ Motion Controller / RTPC             │
│ SERCOS Master                        │
└──────────────────┬───────────────────┘
                   │
              SERCOS ring
                   │
      ┌────────────┼────────────┐
      ▼            ▼            ▼
 Servo Drive 1  Servo Drive 2  Servo Drive 3
      │            │            │
      ▼            ▼            ▼
 Platen Motor   Carrier Motor  Conditioner
                               Motor
```

SERCOS hardware

Component	Function
SERCOS motion interface	Controller-side motion network
SERCOS fiber/cable ring	Deterministic motion communication
Servo drives	Control motor current, velocity, position
Servo motors	Drive platen, carrier, conditioner, or axes
Encoders	Feedback for position/speed
Brake circuits	Motor holding/braking where used
Drive power supplies	Power servo amplifiers
Motion-axis wiring	Motor and feedback connections
Limit/home sensors	Establish travel limits and reference position

SERCOS software

- Axis configuration
- Servo tuning parameters
- Position/velocity/acceleration profiles
- Current/torque limits
- Homing and limit logic
- Motion sequencing
- Drive fault handling
- Encoder feedback processing
- Coordinated motion control
- Motion diagnostics

Potential CMP axes

Axis	Possible function
Platen rotation	Rotates polishing pad
Carrier rotation	Rotates wafer carrier
Carrier Z	Raises/lowers polish head
Carrier sweep	Moves head across pad
Conditioner rotation	Rotates conditioner
Conditioner arm	Positions conditioner
Brush rotation	Rotates cleaning brushes
Brush positioning	Controls brush contact position

Caution: The actual axis count and whether a given axis is servo-controlled, pneumatic, or another actuator type must be verified.

---

7. EtherNet/IP subsystem

EtherNet/IP is an industrial Ethernet protocol built on **Common Industrial Protocol (CIP)**.

```
┌──────────────────────────────────────────┐
│ PLC / Controller                         │
│ EtherNet/IP Scanner                      │
└────────────────────┬─────────────────────┘
                     │
              Industrial Ethernet
                     │
      ┌──────────────┼──────────────┐
      ▼              ▼              ▼
 Remote I/O     Valve Island   Drive / Device
      │              │              │
      ▼              ▼              ▼
Sensors/Valves   Pneumatics     Status/Control
```

EtherNet/IP hardware

- Industrial Ethernet switch
- PLC Ethernet communication module
- EtherNet/IP scanner/adapter interfaces
- Remote I/O modules
- Ethernet-capable drives
- Valve manifolds
- Smart sensors
- Network cables/connectors
- Managed switch, where installed
- Network diagnostics interface

EtherNet/IP software

- PLC network configuration
- IP address configuration
- I/O connection configuration
- EDS/AOP device profiles
- Assembly instance mapping
- Cyclic I/O data
- Explicit messaging
- Device diagnostics
- Network fault recovery
- PLC tag integration

DeviceNet vs EtherNet/IP

Feature	DeviceNet	EtherNet/IP
Physical network	CAN-based	Ethernet
Typical bandwidth	Lower	Higher
Typical use	Field devices	PLC, I/O, drives, devices
Wiring	Trunk/drop bus	Ethernet cabling/switching

Configuration	Node address / EDS	IP / device profile / assemblies
Determinism	Industrial fieldbus timing	Depends on implementation and control architecture

8. RTPC — Real-Time Process / Equipment Controller

This is one of the most important terms to clarify.

RTPC is not a universal single standard equivalent to DeviceNet or SERCOS. In semiconductor equipment, the abbreviation may refer to a **real-time process controller**, **real-time personal computer**, or an OEM-specific real-time control platform, depending on the equipment generation and documentation.

For a specific LK Prime, the exact expansion should be confirmed from the controller cabinet labels, software screens, manuals, or system architecture drawings.

8.1 Functional RTPC architecture

```
┌────────────────────────────────────────────────────────────┐
│                        RTPC                                │
│                                                            │
│  Real-Time OS / Runtime                                    │
│   ├── Scheduler                                            │
│   ├── Sequence execution                                   │
│   ├── Motion coordination                                  │
│   ├── Process timing                                       │
│   ├── I/O interface                                        │
│   ├── Endpoint processing                                  │
│   ├── Alarm / interlock logic                              │
│   ├── Data acquisition                                     │
│   └── Equipment state control                              │
└────────────────────────────────────────────────────────────┘
                │                     │
                │                     │
                ▼                     ▼
        Field networks         Motion networks
        DeviceNet /            SERCOS /
        EtherNet/IP /          Servo interface
        Remote I/O
```

8.2 RTPC hardware

Component	Function
Industrial computer / controller	Executes real-time control software
CPU / motherboard	Computation
Real-time interface cards	Connects to field/motion networks
Digital I/O interface	Discrete signals
Analog I/O interface	Pressure, flow, temperature, etc.
Motion interface	Servo/motion communication

Storage	OS, recipes, logs, application software
RAM	Runtime execution
Watchdog hardware	Detects controller failure
Power supply	Controller power
Cooling	Thermal management
Backplane / chassis	Module interconnection
Network interface	HMI, host, service communication

8.3 RTPC software

Software component	Function
Real-time operating system	Deterministic task execution
Runtime framework	Executes equipment applications
Scheduler	Controls task timing and priority
Sequence engine	Executes machine states and wafer steps
I/O manager	Reads sensors and controls outputs
Motion manager	Coordinates axes
Process-control manager	Executes process loops
Endpoint manager	Processes endpoint signals
Alarm manager	Handles faults and alarms
Interlock manager	Prevents unsafe operation
Recipe engine	Applies process parameters
Data logger	Records process data
Equipment state manager	Controls idle, ready, execute, fault, etc.
Communications services	Interfaces with HMI/host
Diagnostics services	Service and troubleshooting

---

9. PLC / programmable logic control subsystem

The PLC is the machine's **discrete control and interlock workhorse**, although the actual architecture may integrate PLC functions into another controller.

```
┌──────────────────────────────────────────────┐
│ PLC                                          │
│                                              │
│ CPU                                          │
│ Program / Logic                              │
│ I/O Scan                                     │
│ Timers / Counters                            │
│ Interlocks                                   │
│ Sequencing                                   │
```

```
 └────────────────┬───────────────────────────┘
                  │
                  │
        ┌─────────┼───────────┐
        ▼         ▼           ▼
     Digital   Analog      Network
      Inputs   Inputs       Devices
        │         │           │
        ▼         ▼           ▼
   Sensors    Pressure     Remote I/O
   Switches   Flow         Valves
   Valves     Temp         Drives
```

PLC hardware

- PLC CPU
- PLC chassis/backplane
- Digital input modules
- Digital output modules
- Analog input modules
- Analog output modules
- High-speed counter modules, where used
- Communication modules
- Remote I/O adapters
- Safety I/O, where used
- Power supply modules
- Terminal blocks and signal conditioning

PLC software

- Ladder logic / function block / structured text, depending on platform
- I/O configuration
- Sequence logic
- Timers and counters
- Interlock logic
- Alarm conditions
- State transitions
- Equipment initialization
- Utility monitoring
- Valve control
- Motor enable logic
- Recipe parameter interface
- Diagnostic routines

Typical PLC-controlled functions

Function	Example
Utility permissives	CDA pressure available
Chemical permissives	Slurry supply ready
Door interlocks	Access door closed

Wafer presence	Wafer detected
Valve sequencing	Slurry ON/OFF
Robot interlocks	Robot path clear
Motor enable	Platen drive permitted
Drain monitoring	Waste path available
Alarm handling	Low pressure / leak
Recovery sequencing	Safe restart

---

10. Motion-control subsystem

Motion control is distinct from general PLC logic.

10.1 Motion architecture

```
Recipe / Sequence
       │
       ▼
Motion Controller
       │
       ├── Position command
       ├── Velocity command
       ├── Acceleration
       ├── Torque / current limits
       └── Axis enable / fault reset
       │
       ▼
Servo Drive
       │
       ▼
Servo Motor
       │
       ▼
Mechanical Assembly
       │
       ▼
Encoder Feedback
       └──────────────► Motion Controller
```

Motion hardware

Component	**Function**
Motion controller	Generates motion commands
Servo drive	Controls motor power
Servo motor	Produces rotation/translation
Encoder	Provides position/speed feedback

Resolver, where used	Motor feedback
Gearbox / reducer	Changes speed/torque
Coupling	Connects motor to mechanism
Linear actuator	Provides linear movement
Ball screw / linear guide	Precision mechanical movement
Limit switches	Prevent overtravel
Home sensors	Establish reference
Brake	Holds axis safely
Load cell / force sensor	Measures applied load

CMP motion functions

- Platen RPM control
- Carrier RPM control
- Polish-head vertical motion
- Carrier sweep motion
- Conditioner arm motion
- Conditioner rotation
- Brush rotation
- Brush contact positioning
- Robot axes
- Load-port mechanisms

---

11. Endpoint subsystem

Endpoint is one of the most important process-control systems in CMP.

Its purpose is to determine when the wafer has reached the desired polishing condition, such as a film transition or target removal state.

11.1 Endpoint architecture

```
                   CMP PROCESS
                        │
                        ▼
              Wafer + Pad + Slurry
                        │
                        ▼
                  Process Signal
                        │
        ┌───────────────┼────────────────┐
        ▼               ▼                ▼
  Optical Signal   Motor/Torque      Other Sensors
  (if equipped)    Signal            (if equipped)
        │               │                │
        └───────────────┼────────────────┘
                        ▼
```

```
        Signal Conditioning
               │
               ▼
         Endpoint Algorithm
               │
               ▼
         Endpoint Decision
               │
               ▼
        RTPC / Controller
               │
               ▼
   Polish Stop / Over-Polish
```

11.2 Endpoint hardware

Component	Function
Endpoint sensor	Detects process-related signal
Optical sensor / window, if used	Measures optical response
Motor current / torque signal	Provides process signature
Pressure sensors	Monitor polishing force
Platen/carrier feedback	Provides mechanical process signals
Analog input module	Acquires sensor signals
Signal conditioning	Filters/amplifies signals
Data acquisition hardware	Samples process signals
Controller interface	Sends endpoint data to control software

11.3 Endpoint software

Component	Function
Signal acquisition	Reads sensor data
Filtering	Removes noise
Baseline correction	Establishes reference
Signal processing	Extracts process features
Threshold detection	Detects defined transition
Pattern recognition, where used	Identifies endpoint signature
Time/endpoint coordination	Manages polish timing
Over-polish logic	Adds controlled final removal
Fault handling	Handles missing/invalid endpoint
Data logging	Stores endpoint trace
Recipe parameters	Defines endpoint criteria

Endpoint modes

Mode	Description
Timed polish	Stops after a programmed duration
Sensor-based endpoint	Stops based on measured process signal
Endpoint + over-polish	Endpoint followed by additional controlled time
Hybrid	Time limits + sensor-based logic
Fallback mode	Uses alternate behavior if endpoint signal is invalid

Caution: The exact endpoint sensor technology on a particular LK Prime must be confirmed. Do not assume that every tool has the same optical, motor-current, or other endpoint hardware.

---

12. Process-control subsystems

12.1 Slurry control

Hardware	Software
Pumps	Flow setpoint control
Flow meters	Flow feedback
Pressure sensors	Pressure monitoring
Valves	Valve sequencing
Filters	Filter status / maintenance
Mixing system	Concentration / ratio control
Nozzles	Delivery control
Chemical sensors	Condition monitoring, if installed

Control functions:

- Slurry enable/disable
- Flow setpoint
- Flow verification
- Pressure permissive
- Valve sequencing
- Low-flow alarm
- Leak detection
- Chemical recipe selection
- Waste routing

12.2 Pressure / downforce control

Hardware	Software
Pressure regulators	Pressure setpoint

Pneumatic valves	Pressure application
Membrane/bladder	Wafer backside force
Pressure transducers	Feedback
Load cells, if used	Force measurement
Manifolds	Pressure distribution
Solenoid valves	Zone control

Control functions:

- Head load/unload
- Downforce ramp
- Pressure-zone control
- Pressure feedback
- Force limits
- Leak detection
- Pressure fault recovery

12.3 Temperature control

Hardware	Software
RTDs / thermocouples	Temperature acquisition
Temperature sensors	Process monitoring
Heaters, where used	Heating
Cooling loops	Heat removal
Flow sensors	Cooling verification
Controllers	Temperature regulation

Functions:

- Process temperature monitoring
- Cabinet temperature monitoring
- Cooling permissives
- Overtemperature alarms
- Thermal stabilization

12.4 Flow control

Flow type	Hardware	Software function
Slurry	Pump, flow meter, valve	Flow setpoint / verification
DI water	Valve, flow meter	Rinse control
CDA	Pressure regulator, sensor	Utility permissive
Vacuum	Pump/interface, sensor	Wafer retention / process
Exhaust	Pressure/flow monitoring	Ventilation permissive

Cooling	Flow sensor, valve	Thermal management

13. Wafer-handling control subsystem

13.1 Hardware

Component	**Function**
Load ports	Carrier interface
FOUP sensors	Carrier presence
Carrier ID reader	Carrier identification
Wafer mapper	Slot/wafer detection
Robot controller	Motion control
Robot arm	Wafer transport
End-effector	Wafer support
Pre-aligner	Wafer orientation
Wafer presence sensors	Transfer verification
Collision sensors	Protection
Internal transfer mechanisms	Module-to-module movement

13.2 Software

- Robot job scheduler
- Wafer tracking
- Carrier mapping
- Wafer presence validation
- Robot motion profiles
- Collision avoidance/interlocks
- Wafer destination management
- Slot tracking
- Transfer timeout handling
- Recovery sequence
- Wafer-loss detection
- Robot homing/calibration
- Host lot/wafer association

14. Cleaning and drying control subsystem

System	**Hardware**	**Software**
Brush cleaning	Brushes, motors, pressure actuators	Brush speed, contact force, timing
Rinse	DI water valves, flow sensors	Rinse sequence and duration
Chemical clean	Pumps, valves, manifolds	Chemistry selection and dosing

Spin-rinse-dry	Spin motor, chuck, gas	Spin speed and drying sequence
Drain	Drain sensors, valves	Drain permissives and alarms
Particle control	Enclosures, fluid delivery	Cleaning recipe and monitoring

---

15. HMI / operator software

The HMI is the operator-facing layer.

15.1 HMI hardware

- Industrial PC
- Touchscreen or monitor
- Keyboard/mouse
- HMI network interface
- Local storage
- Operator input devices
- Alarm annunciation hardware, where used

15.2 HMI software

Software module	**Function**
Main equipment display	Shows machine state
Wafer/lot screen	Shows material status
Recipe screen	Selects and displays recipes
Manual control screen	Permits authorized service actions
Alarm screen	Displays active/history alarms
Maintenance screen	Supports PM and diagnostics
I/O monitor	Displays sensor/output states
Motion screen	Displays axis status
Endpoint screen	Displays endpoint information
Slurry/utility screen	Displays flow, pressure, utility status
Event log	Records machine events
Trend screen	Displays process data
User management	Controls operator permissions
Recipe security	Controls recipe editing/access

Typical HMI machine states

- Offline
- Initializing
- Idle
- Ready
- Setup

- Executing
- Paused
- Stopping
- Complete
- Fault
- Recovery
- Maintenance
- Engineering

---

16. Recipe management subsystem

The recipe is the **digital process instruction set** for the wafer.

16.1 Recipe hardware/software

Component	**Function**
Recipe database/storage	Stores recipes
Recipe editor	Creates/modifies recipes
Recipe execution engine	Applies parameters
Parameter validation	Checks allowable ranges
Recipe access control	Prevents unauthorized changes
Recipe versioning	Tracks revisions
Recipe download interface	Transfers recipe to controller
Recipe checksum/signature, if used	Verifies integrity
Recipe audit trail	Records changes
Recipe backup/restore	Protects process configuration

Typical CMP recipe parameters

- Polish step sequence
- Platen speed
- Carrier speed
- Downforce
- Pressure-zone settings
- Slurry type
- Slurry flow
- Polish time
- Endpoint mode
- Over-polish duration
- Pad conditioning settings
- Rinse time
- Brush speed
- Brush pressure
- Cleaning chemistry

- Drying parameters
- Wafer handling parameters

17. Equipment control software

This is the **orchestration layer** connecting the hardware.

```
┌──────────────────────────────────────────────────────┐
│                 EQUIPMENT SOFTWARE                   │
│                                                      │
│  HMI                                                   │
│   │                                                  │
│   ▼                                                  │
│  Equipment Control / Sequence Engine                 │
│   ├── State Manager                                  │
│   ├── Recipe Manager                                 │
│   ├── Wafer Scheduler                                │
│   ├── Alarm Manager                                  │
│   ├── Interlock Manager                              │
│   ├── Motion Manager                                 │
│   ├── Process Controller                             │
│   ├── Endpoint Manager                               │
│   ├── Data Acquisition                               │
│   └── Host Communications                            │
│                                                      │
└──────────────────────────────────────────────────────┘
```

Major software modules

#	Software subsystem	Function
S-01	**Boot / initialization**	Starts controllers and validates hardware
S-02	**Equipment state manager**	Controls machine operating states
S-03	**Sequence engine**	Executes machine and wafer steps
S-04	**Wafer scheduler**	Coordinates wafer movement and module usage
S-05	**Recipe manager**	Loads and executes recipes
S-06	**Motion manager**	Controls axes and motion profiles
S-07	**I/O manager**	Interfaces with sensors and actuators
S-08	**Process-control manager**	Controls slurry, pressure, temperature, etc.
S-09	**Endpoint manager**	Processes endpoint signals and decisions
S-10	**Alarm manager**	Generates and manages alarms
S-11	**Interlock manager**	Enforces safe/valid operation

S-12	**Data acquisition**	Collects process/equipment signals
S-13	**FDC / SPC interface**	Sends process data for monitoring
S-14	**Event logger**	Records events and faults
S-15	**Maintenance manager**	PM, calibration, consumables, service
S-16	**Diagnostics manager**	Troubleshooting and fault isolation
S-17	**Host communication manager**	SECS/GEM and factory interface
S-18	**User/security manager**	Authentication and access levels
S-19	**Backup/restore manager**	Protects configuration and recipes
S-20	**Software update/service layer**	Supports authorized software maintenance

18. Semiconductor factory integration

A CMP tool is not an isolated machine. It participates in a larger manufacturing-control system.

```
┌────────────────────────────────────────────────────────────┐
│                          FACTORY                           │
│                                                            │
│  MES ── MCS / AMHS ── Host Automation ── SPC / FDC         │
│    │             │                │                        │
└────┼─────────────┼────────────────┼────────────────────────┘
     │             │                │
     └─────────────┼────────────────┘
                   │
             SECS / GEM
                   │
                   ▼
┌────────────────────────────────────────────────────────────┐
│                  LK PRIME EQUIPMENT                        │
│                                                            │
│ Host Interface → Equipment Control → Process Modules       │
└────────────────────────────────────────────────────────────┘
```

18.1 Host communication hardware

- Ethernet network interface
- Industrial Ethernet switch
- Host communication PC/controller
- Network cabling
- Firewall/network segmentation, where applicable
- Time synchronization, where configured

18.2 Host communication software

Protocol / standard	**Function**

SECS	Semiconductor Equipment Communication Standard
GEM	Generic Equipment Model
HSMS	High-Speed SECS Message Services over TCP/IP
GEM300, where applicable	300 mm automation/equipment behavior
Carrier management	Carrier arrival, load, unload, tracking
Remote commands	Start, stop, pause, abort, etc.
Equipment events	Process start, complete, alarm, state change
Data variables	Pressure, speed, flow, endpoint, etc.
Alarm reporting	Host-visible alarm states
Recipe management	Recipe selection/download, where supported

Important: The exact host implementation, GEM version, and supported message set require the tool's host-interface documentation.

---

19. Data acquisition, FDC, and SPC

These systems turn machine signals into usable manufacturing information.

19.1 Hardware

- Analog input modules
- Digital input modules
- High-speed acquisition interfaces
- Controller data buffers
- Industrial PC/server
- Network interface
- Storage

19.2 Software

System	Function
DAQ	Collects raw sensor signals
FDC — Fault Detection and Classification	Detects abnormal process/equipment behavior
SPC — Statistical Process Control	Monitors process variation
Trend engine	Displays process trends
Data historian	Stores historical process data
Alarm correlation	Links signals to faults
Endpoint trace storage	Stores endpoint signal traces
Maintenance analytics	Tracks equipment health
Consumable tracking	Tracks pad/brush/conditioner usage

Typical data points

- Platen RPM
- Carrier RPM
- Downforce
- Pressure-zone values
- Slurry flow
- Slurry pressure
- DI water flow
- Temperature
- Motor current
- Motor torque
- Vibration
- Endpoint signal
- Polish time
- Cleaning time
- Robot position
- Valve states
- Utility pressures
- Alarm codes

---

20. Safety and interlock software/hardware

Safety is separate from ordinary process sequencing.

System	Hardware	Software / logic
Emergency stop	E-stop buttons, safety relay	Emergency stop logic
Access protection	Door switches, interlocks	Door permissive logic
Chemical safety	Leak sensors, containment	Leak detection and shutdown
Motion safety	Limits, brakes, enable circuits	Motion permissives
Pressure safety	Pressure switches, relief devices	Pressure limits and alarms
Utility safety	Pressure/flow sensors	Utility permissives
Wafer safety	Presence sensors, collision detection	Transfer interlocks
Electrical safety	Breakers, disconnects	Power-up sequencing
Exhaust safety	Flow/pressure monitoring	Exhaust permissive

Interlock examples

```
Platen Start Permissives
    ├── E-stop reset
    ├── Access doors closed
    ├── No critical fault
    ├── Utilities available
    ├── Correct wafer state
    ├── Head in valid position
    ├── Slurry system ready
    └── Controller ready
```

---

21. Maintenance and engineering software

System	Function
Service mode	Authorized manual equipment operation
I/O diagnostics	Monitor inputs/outputs
Motion diagnostics	Axis status, drive faults, encoder data
Network diagnostics	DeviceNet/SERCOS/EtherNet/IP status, if installed
Endpoint diagnostics	Signal trace and endpoint status
Recipe diagnostics	Parameter validation and execution status
Alarm history	Fault history and timestamps
Maintenance scheduler	PM intervals
Consumable tracking	Pad, brush, conditioner, filter life
Calibration tools	Sensor calibration
Backup/restore	Recipes, configuration, logs
Software version management	Controller/HMI application versions
Remote service	Authorized service connection, where enabled

---

22. Complete hardware/software architecture map

```
REFLEXION LK PRIME
│
├── A. FACILITY / UTILITIES
│   ├── Electrical power
│   ├── 24 VDC control power
│   ├── CDA
│   ├── Vacuum
│   ├── DI water
│   ├── Slurry / chemicals
│   ├── Exhaust
│   ├── Drain
│   └── Cooling
│
```

```
├── B. PROCESS HARDWARE
│   ├── Wafer handling
│   ├── Load ports / FOUP
│   ├── Alignment
│   ├── Platen
│   ├── Pad
│   ├── Polish head
│   ├── Pressure zones
│   ├── Conditioner
│   ├── Slurry delivery
│   ├── Cleaning
│   └── Drying
│
├── C. SENSORS / ACTUATORS
│   ├── Position sensors
│   ├── Encoders
│   ├── Pressure sensors
│   ├── Flow sensors
│   ├── Temperature sensors
│   ├── Vacuum sensors
│   ├── Leak sensors
│   ├── Motors
│   ├── Servo drives
│   ├── Pneumatic valves
│   └── Solenoids
│
├── D. INDUSTRIAL NETWORKS
│   ├── DeviceNet*
│   ├── EtherNet/IP*
│   ├── SERCOS*
│   ├── Industrial Ethernet
│   ├── TCP/IP
│   ├── RS-232 / RS-485*
│   ├── CAN / CANopen*
│   └── Proprietary buses*
│
├── E. CONTROL HARDWARE
│   ├── PLC / CPU
│   ├── RTPC / real-time controller*
│   ├── Remote I/O
│   ├── Analog I/O
│   ├── Digital I/O
│   ├── Motion controller
│   ├── Servo drives
│   ├── Industrial PC
│   ├── Network interfaces
│   └── Safety controller / relay
│
├── F. PROCESS CONTROL
│   ├── Platen control
│   ├── Carrier control
│   ├── Downforce control
│   ├── Pressure-zone control
```

```
│   ├── Slurry flow control
│   ├── Temperature control
│   ├── Cleaning control
│   ├── Drying control
│   └── Endpoint control
│
├── G. SOFTWARE
│   ├── Real-time OS / runtime*
│   ├── Equipment sequence engine
│   ├── Recipe manager
│   ├── Motion manager
│   ├── I/O manager
│   ├── Endpoint manager
│   ├── Alarm manager
│   ├── Interlock manager
│   ├── Data acquisition
│   ├── FDC / SPC
│   ├── HMI
│   ├── Diagnostics
│   ├── Maintenance
│   └── Backup / restore
│
└── H. FACTORY INTEGRATION
    ├── SECS
    ├── GEM
    ├── HSMS
    ├── GEM300, where applicable
    ├── MES interface
    ├── Host automation
    ├── Carrier management
    ├── Recipe host interface
    └── Equipment data reporting
```

---

23. What you should physically look for on an actual LK Prime

If your goal is **equipment familiarization, maintenance, controls troubleshooting, or creating a true machine architecture document**, these are the items to identify on the actual tool.

Priority	Physical item to locate	What it reveals
1	Main electrical cabinet	Controller, PLC, I/O, power, network hardware
2	Controller/industrial PC	RTPC identity, CPU, operating system, application architecture
3	PLC CPU and rack	PLC manufacturer, model, I/O architecture
4	Network cards/modules	DeviceNet, SERCOS, EtherNet/IP, Ethernet, other buses
5	Servo drives	Motion architecture and motor control

6	Platen motor/drive	Platen control method
7	Carrier motor/drive	Polish-head rotation architecture
8	Conditioner drive	Pad-conditioning motion
9	Remote I/O blocks	Field wiring and device network
10	Endpoint hardware	Sensor type, acquisition card, endpoint controller
11	HMI computer	HMI software and operating system
12	Host interface	SECS/GEM/HSMS configuration
13	Pneumatic manifold	Valve control and possible DeviceNet/EtherNet/IP nodes
14	Slurry control cabinet	Pumps, flow control, valves, sensors
15	Machine software screens	Version, modules, diagnostics, recipe engine
16	Electrical schematics	Definitive signal and network architecture
17	I/O list	Every sensor, actuator, address, and signal
18	Network topology drawing	Definitive communications architecture
19	Software backup / configuration	Actual installed applications and versions
20	OEM module/BOM	Serial-number-specific installed hardware

---

24. The key distinction: “known technology” vs “installed technology”

For this particular question, the most important engineering discipline is to avoid confusing **what an equipment generation may use** with **what your specific tool actually contains**.

Example

A tool may have:

```
Industrial PC
    ├── Ethernet
    ├── PLC
    ├── Remote I/O
    └── Motion controller
```

But the actual field network could be:

```
Option A: PLC → DeviceNet → Remote I/O
Option B: PLC → EtherNet/IP → Remote I/O
```

```
Option C: Controller → Proprietary bus → I/O
Option D: Integrated controller → Direct I/O
```

Likewise, motion could be:

```
Option A: RTPC → SERCOS → Servo drives
Option B: Motion controller → EtherCAT → Servo drives
Option C: PLC/motion CPU → Proprietary motion bus
Option D: Drive-specific interface
```

Therefore, the exact installed architecture must be established from the actual tool documentation or inspection.

Bottom line

The LK Prime should be understood as a **layered cyber-physical manufacturing system**:

> **Mechanical process hardware → Sensors/actuators → Industrial networks → PLC/RTPC/motion control → Endpoint/process control → Equipment software → HMI → SECS/GEM factory integration.**

And the terms you mentioned fit into that hierarchy as follows:

Term	Layer	Role
DeviceNet	Field network	Distributed device and I/O communication
SERCOS	Motion network	Deterministic servo/motion communication
EtherNet/IP	Industrial network	PLC, I/O, drive, and device communication
RTPC	Real-time control	Executes deterministic equipment/process control
Endpoint	Process control	Determines polish completion condition
PLC	Control hardware/software	Discrete logic, sequencing, interlocks, I/O
HMI	Operator software	Human-machine interface
SECS/GEM	Factory integration	Host/MES/equipment communication
FDC/SPC	Data systems	Fault detection and process monitoring

If you want, the next logical artifact is a **"Reflexion LK Prime Controls Architecture"** showing **every layer from 480 VAC → power supplies → PLC/RTPC → DeviceNet/SERCOS/EtherNet/IP → drives → motors/valves/sensors → endpoint → HMI → SECS/GEM**, formatted as a detailed **electrical/control-system block diagram**.

Gemini

The **Applied Materials (AMAT) Reflexion LK Prime** is an industry-standard 300mm Chemical Mechanical Planarization (CMP) platform engineered for ultra-high throughput and extreme precision planarization in advanced logic (e.g., FinFET, gate-last/HKMG) and memory (e.g., 3D NAND staircase) nodes.

Compared to standard multi-head CMP architectures, the "Prime" configuration quadruples throughput efficiency by using a modular, parallel processing design that integrates **4 polishing platen stations, 6 Titan Head polishing heads, 8 post-CMP cleaning modules, and 2 spin-rinse-dry (SRD) units**.

1. Functional Descriptions

- **Advanced Chemical-Mechanical Planarization:** Combines controlled mechanical friction (polishing pad) and chemical reactivity (slurry chemistry) to remove excess materials (copper, tungsten, oxide, or poly-silicon) and flatten wafer topography down to Angstrom-level uniformity across a 300mm wafer.

- **Real-Time Closed-Loop Process Control:** Uses integrated optical and eddy-current sensor systems to continuously measure film thickness across multiple radial zones in real time, adjusting individual zone pressures up to several times per second to stop polish at exact target thicknesses.

- **High-Throughput Parallel Processing:** Utilizes a dual-line / multi-head architecture that allows up to four wafers to undergo active polishing simultaneously across distinct chemistry platens.

- **Defect-Free Cleaning & Megasonic Processing:** Integrates double-sided PVA (polyvinyl alcohol) brush scrubbers, chemical dispensing, and megasonic agitation to remove slurry nanoparticles and residual debris prior to drying.

- **In-Line Wafer Handling & Drying:** Uses Marangoni/vapor or high-speed spin-rinse drying to exit wafers completely particle-free, dry, and ready for post-metrology without risk of water marks.

2. Core Subsystems

A. Factory Interface (FI) / Dry Front-End

- **FOUP Load Ports:** Front-opening unified pod interfaces (4-bay standard) for loading/unloading 300mm wafer cassettes.

- **Atmospheric Front-End Robot:** Dual-arm robotic manipulator operating in a cleanroom environment equipped with optical edge-grip/centering and wafer alignment sensors.

- **Metrology Module (Optional In-line):** Optical integrated metrology (iMet) for pre-polish or post-polish film thickness verification.

B. Polishing Module (Wet Deck)

- **Polishing Platens (4 Platens):** Large rotating platens equipped with polyurethane CMP pads, slurry dispense arms, and pad conditioners.

- **Titan Head Assemblies (6 Polishing Heads):** Multi-zone flexible membrane carriers capable of independent multi-zone pneumatic back-pressure application across the wafer backside.

- **Carouse / Overhead Transfer Robot:** Overhead multi-arm transport mechanism that indexes carrier heads between load cups and individual platens.

- **Diamond Pad Conditioners:** High-precision diamond disk dressers that continuously or ex-situ regenerate the pad surface roughness for stable removal rates.
- **Endpoint Detection Subsystem:**
  - *Optical Endpoint (e.g., FullVision):* In-situ laser spectrum reflectivity to detect substrate transitions.
  - *Eddy Current Endpoint:* Inductive sensors embedded under platens for conductive metal (Cu/W) thickness monitoring.

C. Cleaner Subsystem (Desica / Clean Deck)

- **Load Cups / Transfer Buffer:** Wet transfer station bridging the dirty polishing module to the ultra-clean post-CMP scrubbing module.
- **Cleaner Scrubbers (8 Cleaning Chambers):** Modular cleaning channels utilizing double-sided PVA brushes, megasonic water bars, and chemical injection (e.g., dilute HF, organic cleansers).
- **Spin-Rinse-Dry (SRD / Marangoni) Units (2 Units):** Non-contact drying chambers using isopropyl alcohol (IPA) surface tension gradient (Marangoni effect) or high-speed rotation to dry wafers cleanly.

D. Facilities, Chemical & Utility Distribution

- **Slurry Delivery System (SDS):** Manifolds, pumps, and valves supplying fresh slurry mixtures and DI water directly onto each platen.
- **Pneumatics & Vacuum Controls:** High-precision mass flow and pneumatic regulators for carrier head membrane pressure adjustments.

3. Machine Cycle Chart

```
 [ FOUP Load Port ]
         |
         ▼
[ FI Robot / Alignment ]
         |
         ▼
[ In-Line Metrology (Pre-Measure) ]
         |
         ▼
[ Wet Load Cup / Indexer ]
         |
         ▼
```

```
┌──────────────────────────────────────────────────────────┐
│                POLISHING MODULE (4 Platens)              │
│                                                          │
│ Platen 1 (Bulk Polish) ──> In-Situ Real-Time Endpoint    │
│         │                                                │
│         ▼                                                │
│ Platen 2 (Low-Select Polish) ──> Zone Pressure Control   │
│         │                                                │
│         ▼                                                │
│ Platen 3 (Buff/Stop Layer) ──> Real-Time Optical/Eddy   │
│         │                                                │
│         ▼                                                │
│ Platen 4 (Rinse/Clean Buffer)                            │
└──────────────────────────────────────────────────────────┘
                           │
                           ▼
┌──────────────────────────────────────────────────────────┐
│               CLEANING MODULE (Desica Deck)              │
│                                                          │
│ Stage 1: Megasonic Rinse / Chemical Wash                 │
│         │                                                │
│         ▼                                                │
│ Stage 2: PVA Double-Sided Brush Scrubbers (8 Chambers)   │
│         │                                                │
│         ▼                                                │
│ Stage 3: High-Speed SRD / Marangoni Dryer (2 Units)     │
└──────────────────────────────────────────────────────────┘
                           │
                           ▼
[ In-Line Metrology (Post-Measure) ]
                           │
                           ▼
    [ FI Robot ──> FOUP Load Port (Complete) ]
```

4. Wafer Walk (Start to End)

1. **FOUP Loading & Pick:** An Overhead Hoist Transport (OHT) places a 300mm FOUP onto a front load port. The atmospheric front-end robot (FI robot) retrieves a raw wafer from the cassette.

2. **Pre-Process Alignment & Metrology:** The FI robot places the wafer onto a wafer aligner to register the notch location, then transfers it to the integrated metrology tool to map incoming film thickness profile.

3. **Wet Load Cup Transfer:** The FI robot moves the dry wafer into a wet load cup station, transitioning the wafer into a wetted environment to avoid micro-scratching.

4. **Carrier Head Pickup:** One of the Titan Head assemblies on the overhead carousel picks up the wafer via backside vacuum grip.

5. **Platen 1 (Bulk Polishing):** The carousel rotates the Titan Head over Platen 1. The head lowers, pressing the wafer face-down against the rotating pad while slurry is applied. Bulk material (e.g., thick copper layer) is rapidly removed while in-

situ eddy current sensors track remaining thickness.

6. **Platen 2 & 3 (Selectivity & Buffing):** The head lifts and indexes to Platen 2 and Platen 3 for sequential fine polishing using specialized chemical slurries. Real-time multi-zone pressure adjustments flatten localized variations across the 300mm surface.

7. **Platen 4 (Final Barrier / Rinse):** The wafer receives a final light buff/rinse polish on Platen 4 to clear residual barrier material and terminate reaction dynamics.

8. **Unload Cup Transfer:** The Titan head drops the wet, polished wafer onto an unload transfer cup.

9. **Post-CMP Cleaning (Chambers 1–8):** Internal robotic handlers pass the wetted wafer through double-sided PVA brush modules where chemical cleaning agents and megasonic energy dislodge slurry particles.

10. **Drying (Marangoni / SRD):** The cleaned wet wafer enters the drying chamber. IPA vapor and high-speed spin rinse dry the wafer without leaving chemical residue or drying marks.

11. **Post-Metrology & Unload:** The dry FI robot retrieves the wafer from the dryer output, runs it through post-CMP film thickness metrology, and places the completed wafer back into its original FOUP cassette.