AI-04724 PRA Samsung New Hire

#cmp

Perform a comprehensive PRA - New hire, no CMP Experience but 7-years experience as machinist/fabrication factory hired as CMP Technician 2.

Comprehensive Probabilistic Risk Assessment (PRA)

New Hire: CMP Technician 2

Background: 7 Years of Machining/Fabrication Experience — No Prior CMP Experience

Scenario: A technically experienced machinist/fabricator joins a semiconductor manufacturing facility as a **CMP Technician 2**. The objective is to understand how this person can succeed or fail, identify the risks that matter most, and design a training system that converts existing mechanical skill into safe, repeatable, semiconductor-grade process performance.

> **Important scope note:** This is a structured, qualitative PRA—not a facility-specific quantitative risk calculation. Actual probabilities require Samsung-specific SOPs, equipment history, incident data, alarm logs, maintenance records, chemical inventories, and qualification standards. The analysis uses a representative semiconductor CMP environment and should be validated against the actual work area.

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1. What Is PRA in This Context?

Probabilistic Risk Assessment evaluates:

1. **What can go wrong?**
2. **How can it happen?**
3. **How likely is it?**
4. **What happens if it does?**
5. **How likely is it to be detected before causing harm?**
6. **What controls prevent or mitigate it?**
7. **What residual risk remains?**

A useful simplified model is:

$$\text{Risk} = \text{Probability of an Undesired Event} \times \text{Severity of Consequence}$$

For a more complete PRA:

$$P(\text{undesired outcome}) = P(\text{initiating event}) \times P(\text{failure of prevention}) \times P(\text{failure of detection/mitigation})$$

For example:

> Incorrect chemical connection → procedural error is not caught → chemical reaches the wrong location → equipment damage, exposure, contamination, or production interruption.

The PRA is not intended to predict that an individual *will* fail. It identifies **conditions under which failure becomes more likely**, especially during the transition from one technical domain to another.

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2. The New Hire: Capability and Risk Profile

2.1 Experience Profile

Attribute	Assessment
Role	CMP Technician 2
Prior CMP experience	None
Prior machining/fabrication	7 years
Mechanical troubleshooting	Likely developed
Hands-on tool use	Likely strong
Dimensional awareness	Likely strong
Materials/process discipline	Transferable, but incomplete
Semiconductor contamination control	New learning domain
Wafer/process sensitivity	New learning domain
Chemical/process safety	Must be specifically qualified
Equipment-specific knowledge	Must be developed
Manufacturing work habits	Potentially valuable
Semiconductor process judgment	Not yet established

2.2 The Central PRA Finding

The new hire's greatest risk is not lack of technical ability. It is the mismatch between existing competence and the consequences of applying familiar competence in an unfamiliar process environment.

A machinist may be comfortable with:

- Mechanical force
- Tools and fixtures
- Wear and alignment
- Lubricants and fluids
- Measurement
- Troubleshooting
- Disassembly and reassembly
- Physical tolerances
- Equipment behavior

But CMP adds a different operating philosophy:

> **A component can appear mechanically correct while still being chemically, dimensionally, procedurally, or contamination-wise unacceptable.**

That distinction is central to the training model.

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3. PRA Methodology and Scoring System

This assessment uses a **qualitative 5 × 5 × 5 risk model** combining:

- **Frequency/likelihood**
- **Consequence severity**
- **Detectability difficulty**

This is not a substitute for a formal quantitative PRA, but it is useful for prioritizing training.

3.1 Likelihood Score — L

Score	Meaning	General Interpretation
1	Rare	Unlikely under normal controlled operation
2	Unlikely	Could occur occasionally
3	Possible	Credible during normal work or learning
4	Likely	Expected without strong controls
5	Frequent	Repeated exposure or highly probable error opportunity

3.2 Severity Score — S

Score	Meaning	Example
1	Negligible	Minor delay, no meaningful impact
2	Low	Small rework or localized operational disruption
3	Moderate	Equipment issue, wafer loss, extended downtime
4	High	Significant lot loss, major equipment damage, serious exposure potential
5	Critical	Fatality potential, major chemical event, extensive production or facility impact

3.3 Detectability Difficulty — D

Here, a higher number means **harder to detect before consequences occur**.

Score	Meaning
1	Almost always detected immediately
2	Usually detected by normal checks
3	May require inspection, alarm, or supervisor review
4	Difficult to detect before impact
5	Often latent; may be discovered only after downstream failure

3.4 Priority Number

RPN=L×S×D\text{RPN} = L \times S \times D

RPN	Priority
1–20	Low
21–40	Moderate
41–70	High
71–125	Critical priority

Caution: RPN is a prioritization aid, not a true probability. A low-frequency, catastrophic hazard may require immediate controls regardless of RPN.

4. CMP Process Context

Chemical Mechanical Planarization (CMP) combines chemical reactions and mechanical abrasion to create a highly planar wafer surface.

A representative process involves:

1. Wafer loading
2. Wafer identification and tracking
3. Wafer transfer
4. Carrier/head engagement
5. Slurry delivery
6. Pad conditioning
7. Polishing
8. Rinse/clean
9. Unload and inspection
10. Equipment monitoring and maintenance

The technician may interact with:

- Wafer handling systems
- Polishing pads and platens
- Carrier heads
- Retaining rings
- Slurry delivery systems
- Chemical supply systems
- Pumps and valves
- Sensors
- Motors and actuators
- Pneumatic systems
- DI water
- Waste and drain systems
- Chemical management systems
- Robot interfaces
- Preventive maintenance procedures
- Process control systems
- Alarm and interlock systems

The exact equipment, chemicals, and procedures must be verified against the assigned CMP platform.

5. PRA Event Structure

The following model treats the new hire's first year as a sequence of exposure stages.

```
NEW HIRE ENTERS CMP
        │
        ▼
Limited CMP Process Knowledge
        │
        ├── Inadequate Training
        ├── Overconfidence from Prior Experience
        ├── Unclear Work Instructions
        ├── Production Pressure
        ├── Poor Handover
        └── Incomplete Qualification
        │
        ▼
Incorrect Decision / Action / Omission
        │
        ├── Safety Event
        ├── Equipment Event
        ├── Wafer/Process Event
        ├── Contamination Event
        ├── Documentation Event
        └── Team/Communication Event
        │
        ▼
Detection / Containment / Escalation
        │
        ├── Detected Early → Corrected
        ├── Detected Late → Rework / Downtime
        └── Not Detected → Downstream Impact
```

6. Top-Level Risk Categories

Category	Primary Concern	Potential Consequence
Personnel safety	Chemical, mechanical, electrical, ergonomic, energy hazards	Injury, exposure, fatality
Wafer handling	Mishandling, incorrect orientation, breakage	Wafer loss, contamination, equipment damage
Process execution	Incorrect recipe, sequence, settings, or response	Defects, yield loss, lot loss

Equipment operation	Incorrect intervention or setup	Downtime, damage, unsafe state
Chemical/slurry systems	Wrong material, connection, spill, incompatibility	Exposure, contamination, equipment damage
Contamination control	Foreign material, residues, improper handling	Defects, yield degradation
Maintenance	Incorrect PM, assembly, torque, parts, or verification	Recurring failures, process drift
Troubleshooting	Misdiagnosis, unapproved adjustment, incomplete escalation	Extended downtime, latent defects
Documentation	Inaccurate records, missed abnormality, poor handoff	Repeat events, traceability loss
Human factors	Overconfidence, fatigue, pressure, communication gaps	Increased error probability
Qualification	Performing work before demonstrated competency	Uncontrolled exposure to risk

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7. Master PRA Register — Major Failure Scenarios

The following is the core assessment.

Scoring assumption: The scores reflect a new technician with no CMP experience, before the effectiveness of a mature qualification system is applied. They are **illustrative**, not facility-derived statistics.

7.1 Safety and Hazard-Control Risks

ID	Failure Mode / Undesired Event	Initiating Causes	Potential Effects	Existing/Expected Controls	L	S	D	RPN	Priority
S-01	Chemical exposure during handling	Incomplete chemical training, incorrect PPE, improper connection/disconnection	Skin/eye injury, inhalation exposure	Chemical training, SDS, PPE, interlocks, SOP	2	5	3	30	High consequence
S-02	Incorrect chemical/slurry line connection	Misidentification, poor labeling, rushed PM	Wrong chemical delivery, spill,	Line identification, independent	3	5	4	60	High

			equipment damage	verification, lockout, checklist					
S-03	Failure to recognize chemical incompatibility	Mechanical experience transferred without chemistry knowledge	Reaction, heat, precipitate, clogging, hazardous release	Chemical compatibility matrix, training, approved materials	2	5	5	50	High
S-04	Unexpected equipment movement	Inadequate energy isolation, bypassed interlock, misunderstanding state	Crush, pinch, impact injury	LOTO, zero-energy verification, interlocks	2	5	4	40	High consequence
S-05	Contact with rotating/moving equipment	Guard/interlock misunderstanding, reaching into tool	Serious injury	Guards, interlocks, SOP, authorized access	2	5	3	30	High consequence
S-06	Electrical exposure	Unauthorized panel access, incomplete isolation	Shock, arc flash, fatality	Electrical qualification, LOTO, restricted access	1	5	4	20	High consequence
S-07	Slip/fall from slurry, water, or chemical spill	Poor housekeeping, delayed reporting	Injury, secondary contamination	Spill response, housekeeping, reporting	3	3	2	18	Moderate
S-08	Improper response to chemical spill	Panic, lack of emergency knowledge	Exposure escalation, facility contamination	Spill training, emergency procedures, drills	2	5	3	30	High consequence
S-09	Incorrect waste	Misidentification or	Chemical reaction,	Waste labeling,	2	4	4	32	High

	disposal	mixing waste streams	regulatory/ environmental issue	segregation, training					
S-10	Failure to report near miss	Fear, normalization, uncertainty	Repeat event, hidden systemic risk	Just culture, reporting system, supervisor review	3	4	5	60	High

Safety Interpretation

The most important safety transition is:

> **From "I know how to work around machines" to "I know which energy states and chemical states I am authorized to interact with."**

Mechanical confidence is valuable, but it must never substitute for equipment-specific energy-control qualification.

7.2 Wafer Handling and Material Risks

ID	Failure Mode	Initiating Causes	Potential Effects	Controls	L	S	D	RPN	Priority
W-01	Wafer dropped or broken	Improper handling, unfamiliar robot/carrier behavior	Wafer loss, contamination, equipment interruption	Handling certification, practice tools, speed limits	2	4	2	16	Moderate
W-02	Wafer placed incorrectly	Orientation error, poor visual verification	Process failure, equipment damage	Orientation checks, sensors, standard work	2	4	3	24	Moderate
W-03	Wrong wafer/lot processed	Misidentification, tracking error, poor scan discipline	Lot mix-up, traceability failure	Barcode/ID verification, MES controls, two-step confirmation	2	5	4	40	High
W-04	Wafer surface	Improper gloves, contact,	Defects, yield loss	Cleanroom discipline, contamina	3	4	5	60	High

	contaminated	residues, poor handling		tion training					
W-05	Wafer scratched or damaged	Incorrect tool, contact, pressure, rough handling	Defects, yield degradation	Handling standards, approved tools, inspection	3	4	4	48	High
W-06	Wafer remains in equipment after abnormal event	Incomplete recovery procedure	Wafer damage, process ambiguity	Abnormal recovery SOP, status verification	2	4	4	32	High
W-07	Wrong carrier/head configuration	Incorrect setup or component selection	Poor polishing, damage, process excursion	Configuration control, part identification	2	4	4	32	High
W-08	Material status not updated	Missed scan, incomplete transaction	Traceability loss, wrong disposition	MES transaction checklist, audit	2	4	4	32	High

Key Lesson

In machining, a part may be physically recoverable. In semiconductor manufacturing, **a wafer may be physically intact but functionally unacceptable** due to a microscopic or latent defect.

7.3 Process Execution Risks

ID	Failure Mode	Initiating Causes	Potential Effects	Controls	L	S	D	RPN	Priority
P-01	Incorrect recipe selected	Similar recipe names, poor verification	Wrong process, wafer/lot loss	Recipe permissions, ID verification, MES interlock	2	5	4	40	High
P-02	Incorrect process sequence	Skipped step, assumptio	Defects, equipment upset	SOP, electronic work	3	4	4	48	High

		n, unfamiliar workflow		instructions, qualification					
P-03	Incorrect parameter adjustment	“Tuning” based on mechanical intuition	Process drift, yield loss	Parameter lockout, escalation matrix	3	5	5	75	Critical
P-04	Failure to respond to alarm	Alarm unfamiliarity, alarm fatigue	Equipment damage, process excursion	Alarm training, response matrix, escalation	3	5	3	45	High
P-05	Alarm reset without understanding cause	Desire to restore production quickly	Recurrence, latent equipment fault	Alarm cause verification, reset authorization	3	4	4	48	High
P-06	Continuing operation after abnormal condition	Production pressure, uncertainty	Larger lot loss, equipment damage	Stop-work authority, abnormal response SOP	3	5	4	60	High
P-07	Incorrect pad conditioning operation	Inexperience with conditioning process	Nonuniformity, pad damage, process drift	PM/operation standard work, training	2	4	4	32	High
P-08	Incorrect slurry flow/pressure response	Misunderstanding process sensitivity	Defects, equipment contamination, downtime	Monitoring limits, alarm response, process training	3	4	4	48	High
P-09	Failure to verify process completion	Assumption based on tool indication	Incomplete/invalid processing	Completion checklist, MES status	2	4	4	32	High
P-10	Unauthorized process change	Improvisation or undocumented	Repeatability loss, quality event	Change control, engineering approval	2	5	5	50	High

		adjustment							

Most Important Process Risk

P-03: Incorrect parameter adjustment is especially dangerous because the new hire may have strong mechanical instincts and believe that a small adjustment is harmless.

In CMP, a parameter can influence:

- Removal rate
- Within-wafer nonuniformity
- Within-lot consistency
- Surface defects
- Planarity
- Erosion/dishing behavior
- Pad condition
- Slurry interaction
- Equipment stability

Rule: A technician should not “improve” a process through intuition unless the change is explicitly authorized, controlled, and documented.

7.4 Equipment Operation and Maintenance Risks

ID	Failure Mode	Initiating Causes	Potential Effects	Controls	L	S	D	RPN	Priority
E-01	Incorrect PM sequence	Skipped step, unfamiliar equipment	Equipment damage, recurring fault	PM checklist, qualification, sign-off	3	4	4	48	High
E-02	Wrong replacement part installed	Similar parts, poor identification	Malfunction, process drift, damage	Part verification, BOM, controlled kitting	2	4	4	32	High
E-03	Incorrect torque/fastener practice	Transfer of shop habits, wrong specification	Leakage, misalignment, component failure	Torque specification, calibrated tools	3	4	4	48	High

E-04	Incorrect alignment or seating	Contamination, improper assembly, lack of verification	Vibration, leakage, nonuniformity, failure	Alignment procedure, inspection, verification	3	4	5	60	High
E-05	Seal/gasket installed incorrectly	Wrong orientation, damaged seal, reuse	Leak, chemical exposure, equipment damage	Seal inspection, replacement rules	3	4	4	48	High
E-06	Foreign material left after maintenance	Missing tool, wipe, fastener, residue	Contamination, equipment damage	FOD control, tool accountability, inspection	3	4	5	60	High
E-07	Incorrect lubrication or material application	Applying familiar lubricant, wrong quantity	Contamination, material incompatibility, failure	Approved-material list, contamination controls	3	4	5	60	High
E-08	Failure to restore equipment configuration	Covers, lines, guards, sensors, valves not restored	Unsafe operation, leaks, process failure	Restoration checklist, peer verification	2	5	4	40	High
E-09	Incorrect sensor/actuator replacement	Connector mismatch, calibration omission	False readings, uncontrolled process	Part verification, calibration, functional test	2	4	5	40	High
E-10	Equipment returned to service prematurely	Incomplete test, production pressure	Repeat failure, wafer damage, safety event	Return-to-service criteria, supervisor sign-off	3	5	5	75	Critical
E-11	Incorrect pneumatic	Misrouting, wrong	Motion failure,	Schematics, line	2	4	4	32	High

	/hydraulic connection	pressure line	leak, equipment damage	labeling, pressure verification					
E-12	Failure to recognize abnormal wear	Familiarity bias, no baseline	Sudden failure, process drift	Wear limits, inspection criteria, trend monitoring	3	4	5	60	High

Machinist Transfer Risk

A machinist may have excellent instincts about:

- Vibration
- Wear
- Tool condition
- Alignment
- Fasteners
- Mechanical fit
- Bearings
- Actuators

Those instincts are valuable—but the **approved semiconductor procedure remains the authority**.

A part that is “tight enough,” “clean enough,” or “aligned by feel” may not meet CMP requirements.

7.5 Contamination and Cleanroom Risks

ID	Failure Mode	Initiating Causes	Potential Effects	Controls	L	S	D	RPN	Priority
C-01	Foreign material introduced into process area	Poor gowning, tools, fibers, debris	Wafer defects, equipment contamination	Gowning, FOD control, cleanroom training	3	4	5	60	High
C-02	Non-approved material used	Shop lubricant, adhesive, marker, wipe	Chemical contamination, defects	Approved materials list, controlled storage	3	5	5	75	Critical
C-03	Improper glove/hand discipline	Touching surfaces, changing gloves incorrectly	Wafer contamination	Cleanroom behavior standard	3	4	5	60	High

C-04	Residual slurry or chemical left after PM	Inadequate cleaning or rinse	Cross-contamination, corrosion, process drift	Cleaning verification, inspection	3	4	5	60	High
C-05	Wrong cleaning agent used	Assumption from fabrication experience	Damage, residue, chemical incompatibility	Approved cleaning matrix	2	4	5	40	High
C-06	Contaminated tool reused	Tool not cleaned or segregated	Repeat contamination	Tool control and cleaning	3	4	5	60	High
C-07	FOD not detected before closure	Poor inspection, hidden location	Latent equipment /wafer issue	Visual inspection, tool accountability	3	4	5	60	High
C-08	Contamination event not escalated	Uncertainty or normalization	Larger downstream impact	Hold/disposition procedure	2	5	5	50	High

Critical Cultural Shift

> In conventional fabrication, cleanliness may mean “free of visible debris.” In semiconductor CMP, cleanliness can mean **meeting a process-specific contamination requirement that may not be visually verifiable**.

This is one of the most important retraining areas.

7.6 Troubleshooting and Decision-Making Risks

ID	Failure Mode	Initiating Causes	Potential Effects	Controls	L	S	D	RPN	Priority
T-01	Treating symptom instead of cause	Jumping to familiar mechanical explanation	Repeat failure, downtime	RCA training, troubleshooting tree	3	4	4	48	High

T-02	Changing multiple variables at once	Desire to solve quickly	Cannot identify cause, process instability	One-change-at-a-time discipline	3	4	4	48	High
T-03	Troubleshooting beyond authorization	Overconfidence, unclear boundaries	Equipment damage, safety event	Escalation matrix, access control	2	5	4	40	High
T-04	Resetting instead of investigating	Familiar “reset and retry” habit	Latent failure, recurrence	Alarm response standards	3	4	4	48	High
T-05	Misreading sensor/alarm data	New terminology, poor trend interpretation	Wrong diagnosis	Data interpretation training	3	4	4	48	High
T-06	Failing to preserve evidence	Disassembling, resetting, cleaning prematurely	RCA becomes difficult	Evidence-preservation procedure	2	4	5	40	High
T-07	Incorrectly assuming component failure	Bias toward mechanical fault	Unnecessary part replacement	Fault isolation methods	3	3	4	36	Moderate
T-08	Not escalating recurring intermittent issue	“It works now” mindset	Latent process/equipment failure	Repeat-event tracking	3	5	5	75	Critical
T-09	Poor handover of unresolved issue	Incomplete notes, verbal-only communication	Next shift repeats error	Structured handover	3	4	4	48	High
T-10	Failing to stop when data is	Production pressure, ambiguity	Uncontrolled event	Stop-work criteria	3	5	4	60	High

	inconsistent								

The Troubling Failure Pattern

```
Alarm occurs
    ↓
Technician recognizes a familiar mechanical symptom
    ↓
Makes an intuitive adjustment
    ↓
Alarm clears
    ↓
Technician assumes problem solved
    ↓
Underlying issue remains
    ↓
Later lot or equipment failure
```

This is a **latent-failure pathway** and should be heavily trained against.

7.7 Human Factors, Communication, and Organizational Risks

ID	Failure Mode	Initiating Causes	Potential Effects	Controls	L	S	D	RPN	Priority
H-01	Overconfidence from prior experience	“Machines are machines” mindset	Procedure bypass, unsafe intervention	Mentoring, qualification gates	3	5	4	60	High
H-02	Underconfidence despite capability	New-domain anxiety	Hesitation, missed escalation	Coaching, structured practice	3	3	2	18	Moderate
H-03	Fear of asking questions	Desire to appear competent	Hidden error, incorrect action	Psychological safety	3	5	5	75	Critical
H-04	Production pressure overrides caution	Output targets, staffing shortage	Unsafe or uncontrolled action	Stop-work authority, leadership behavior	3	5	4	60	High
H-05	Incomplete shift handoff	Time pressure, weak	Repeat troubleshooting,	Handoff template	3	4	4	48	High

		documentation	missed condition						
H-06	Misunderstanding role boundaries	Technician vs engineer responsibilities unclear	Unauthorized changes	RACI/escalation matrix	3	4	4	48	High
H-07	Fatigue or attention degradation	Shift work, overtime, repetitive tasks	Handling/process error	Fatigue management, breaks	3	4	3	36	Moderate
H-08	Normalization of deviance	“We always do it this way”	Unsafe workaround becomes routine	Audits, leadership reinforcement	3	5	5	75	Critical
H-09	Inadequate feedback after mistakes	Blame or no learning loop	Repeat failure, hidden behavior	Coaching, lessons learned	3	4	5	60	High
H-10	Poor cross-functional communication	Technician, engineering, quality disconnect	Delayed containment, recurring issues	Escalation channels, structured review	3	4	4	48	High

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8. Top 15 Highest-Priority Risks

Based on the illustrative RPN and consequence considerations:

Rank	**ID**	**Risk**	**RPN**	**Why It Matters**
1	P-03	Incorrect parameter adjustment	75	Can create latent process/yield damage
2	E-10	Premature return to service	75	Can reintroduce unsafe or unstable equipment
3	C-02	Non-approved material used	75	Contamination may be invisible and costly
4	T-08	Recurring intermittent issue not escalated	75	Latent failures can propagate
5	H-03	Fear of asking questions	75	Converts uncertainty into unobserved action

6	H-08	Normalization of deviance	75	Workarounds become institutionalized
7	S-02	Incorrect chemical/slurry connection	60	High-consequence chemical/process pathway
8	S-10	Near miss not reported	60	Preventive learning is lost
9	W-04	Wafer surface contamination	60	Often difficult to detect early
10	E-04	Incorrect alignment/seating	60	May cause latent process/equipment issues
11	E-06	FOD left after maintenance	60	Hidden contamination or equipment damage
12	E-07	Incorrect lubrication/material application	60	Strong transfer risk from machining
13	E-12	Abnormal wear not recognized	60	Process drift may precede failure
14	T-10	Failure to stop with inconsistent data	60	Ambiguity becomes uncontrolled action
15	H-04	Production pressure overrides caution	60	Organizational multiplier of technical risk

Important Observation

Several top risks are **not purely technical**. They involve:

- Decision boundaries
- Escalation
- Material control
- Documentation
- Psychological safety
- Return-to-service discipline

That means training must address **behavioral reliability**, not just equipment operation.

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9. Risk Bow-Tie Analysis

9.1 Central Top Event

> **New technician performs an incorrect CMP equipment or process intervention that is not caught before causing a safety, quality, or equipment consequence.**

```
THREATS                          PREVENTIVE BARRIERS
────────────────────────────────────────────────────────

No CMP experience       ───────► Structured CMP training
Overconfidence           ───────► Qualification gates
Unclear SOP              ───────► Controlled work instructions
Production pressure      ───────► Stop-work authority
Poor labeling            ───────► Identification + verification
Weak handoff             ───────► Structured communication
                                         │
                                         ▼
                                    TOP EVENT
                          Incorrect action / omission
                                         │
                               DETECTIVE BARRIERS
                                         │
                               Alarm / interlock
                               Peer verification
                               Process monitoring
                               MES checks
                               Inspection
                               Supervisor review
                                         │
                                         ▼
                               MITIGATING BARRIERS
                                         │
                               Stop equipment
                               Hold lot
                               Contain material
                               Escalate to engineering
                               Emergency response
                               RCA / corrective action
                                         │
                                         ▼
                                    CONSEQUENCES
                         Safety / quality / equipment / schedule
```

9.2 Barrier Quality Matters

A barrier is stronger when it is:

- **Independent**
- **Specific**
- **Difficult to bypass**
- **Verified**
- **Documented**
- **Owned by a responsible role**

Example:

Weak Barrier	Stronger Barrier
“Technician should be careful”	Electronic recipe authorization

“Remember the right chemical”	Barcode/label verification + independent check
“Ask if unsure”	Explicit stop-work and escalation rule
“Check your work”	Defined return-to-service checklist
“Keep it clean”	Approved-material and FOD-control system
“Watch the alarms”	Alarm-specific response matrix

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10. Event Tree Analysis: What Happens After an Error?

An event tree examines how an initiating event can lead to different outcomes depending on whether safeguards succeed.

Initiating Event

IE-01: Technician performs an incorrect intervention during CMP operation or maintenance.

```
Initiating Event:
Incorrect intervention
        |
        ▼
Was the action prevented before execution?
        |
   ┌────┴────┐
  YES       NO
  |          |
  Safe      Was the error detected immediately?
  outcome           |
             ┌────┴────┐
            YES       NO
            |          |
       Corrected      Did process/equipment
       before impact  monitoring detect it?
                           |
                      ┌────┴────┐
                     YES       NO
                     |          |
                Contained      Did downstream
                / limited      inspection detect it?
                                    |
                               ┌────┴────┐
                              YES       NO
                              |          |
                         Lot hold /     Latent defect,
                         investigation  equipment damage,
                                        or safety consequence
```

10.1 Event Tree Outcomes

Path	Prevention	Detection	Mitigation	Outcome
A	Successful	Not needed	Not needed	No consequence

B	Fails	Immediate detection	Successful	Minor correction
C	Fails	Process alarm	Successful	Controlled excursion
D	Fails	Inspection detection	Successful	Lot hold/rework/RCA
E	Fails	No detection	Successful	Latent issue, delayed discovery
F	Fails	No detection	Fails	Major quality/equipment/safety event

PRA Insight

The training objective is not only to reduce the probability of the initial mistake. It is also to increase the probability that:

> **An error is detected early, contained, and escalated before it becomes consequential.**

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11. Fault Tree: How Could the New Hire Fail in the First Year?

Top Event

T: New CMP Technician 2 fails to achieve safe, reliable, independent performance within one year

```
                       TOP EVENT
            Failure to achieve safe, reliable CMP performance
                                    |
                                   OR
       ┌──────────────────────────────┼──────────────────────────────┐
       ▼                              ▼                              ▼
   A. Technical                 B. Human/Behavioral            C. System/Training
      Competency Failure           Failure                        Failure
       |                              |                              |
  ┌────┼────┐                    ┌────┼────┐                    ┌────┼────┐
  ▼    ▼    ▼                    ▼    ▼    ▼                    ▼    ▼    ▼
   CMP  Equipment Process       Over-  Poor  Fear          Weak Unclear Inadequate
   basics skill    control      confidence handoff questions  training SOP qualification
   missing gaps    gaps
```

11.1 Expanded Fault Tree

A. Technical Competency Failure

A = A1 OR A2 OR A3 OR A4 OR A5

- **A1:** Does not understand CMP fundamentals
- **A2:** Cannot safely operate assigned equipment
- **A3:** Cannot execute standard work consistently
- **A4:** Cannot recognize abnormal equipment/process conditions
- **A5:** Cannot perform assigned maintenance to specification

A1 — CMP Fundamentals Gap

- Does not understand chemical-mechanical interaction
- Does not understand wafer sensitivity
- Does not understand slurry function
- Does not understand pad conditioning
- Does not understand process metrics
- Does not understand contamination impact

A2 — Equipment Skill Gap

- Does not understand equipment states
- Does not understand interlocks
- Cannot interpret alarms
- Cannot identify components
- Cannot perform approved recovery steps
- Cannot safely isolate energy

A3 — Standard Work Gap

- Skips steps
- Uses memory instead of controlled instructions
- Does not verify material/recipe identity
- Fails to document
- Does not complete restoration checks

A4 — Abnormality Recognition Gap

- Does not recognize abnormal vibration
- Does not recognize slurry flow anomalies
- Does not recognize leakage
- Does not recognize sensor inconsistency
- Does not recognize process drift
- Does not recognize recurring intermittent faults

A5 — Maintenance Execution Gap

- Wrong part
- Wrong torque
- Wrong seal
- Incorrect alignment
- Incomplete cleaning
- FOD left behind
- Incomplete return-to-service verification

B. Human and Behavioral Failure

B = B1 OR B2 OR B3 OR B4 OR B5

- **B1:** Overconfidence
- **B2:** Fear of asking questions
- **B3:** Poor communication
- **B4:** Production pressure
- **B5:** Normalization of deviance

B1 — Overconfidence

```
7 years mechanical experience
          ↓
High confidence with machines
          ↓
Assumes CMP is mechanically intuitive
          ↓
Skips verification / improvises
          ↓
Increased risk
```

B2 — Fear of Questions

```
New employee wants to appear competent
          ↓
Uncertainty is hidden
          ↓
Action taken without confirmation
          ↓
Error is not intercepted
```

B3 — Communication Failure

- Incomplete shift handoff
- No clear escalation
- Poor documentation
- Misunderstood instructions
- Assumption that another person knows

B4 — Production Pressure

- Hurry to restore tool
- Skip second verification
- Reset alarm repeatedly
- Continue after abnormal condition
- Perform work outside qualification

B5 — Normalization of Deviance

- Workaround becomes routine
- Minor contamination ignored
- Repeated alarm treated as normal
- “It usually works” replaces specification
- Informal tribal knowledge replaces SOP

C. Training and System Failure

C = C1 OR C2 OR C3 OR C4 OR C5

- **C1:** Inadequate training design
- **C2:** Poor qualification process
- **C3:** Unclear role boundaries
- **C4:** Weak supervision/mentoring

- **C5:** Poor feedback and learning system

Examples:

- Training is lecture-heavy but not hands-on
- Qualification is based on time served rather than demonstrated skill
- Technician is assigned work before independent competency
- No clear list of prohibited actions
- Mentor does not observe actual behavior
- Mistakes are corrected but not analyzed
- Lessons learned are not incorporated into training

---

12. Bayesian Perspective: How Should Confidence in Competence Develop?

A useful PRA concept is that **competence should be updated based on evidence**, not assumed from prior experience.

Let:

- HH = Technician is ready for independent CMP work
- EE = Evidence from training, observation, tests, and qualification

The question is:

P(H|E)P(H \mid E)

In plain language:

> **How confident should we be that the technician is ready, given what they have actually demonstrated?**

12.1 Evidence That Increases Confidence

Evidence	What It Demonstrates
Passes CMP fundamentals assessment	Understands core concepts
Correctly identifies equipment states	Understands operational boundaries
Performs LOTO under observation	Can control hazardous energy
Correctly identifies slurry/materials	Understands material control
Completes supervised PM	Can follow exact standard work
Recognizes abnormal condition	Has developing diagnostic judgment
Escalates appropriately	Understands decision boundaries
Performs repeatable tasks	Competence is reproducible
Passes independent qualification	Meets defined performance standard

12.2 Evidence That Should Reduce Confidence

Observation	Risk Signal
“I already know machines” used to dismiss SOP	Overconfidence
Repeatedly skips verification	Procedural unreliability

Resets alarms without investigation	Latent-failure risk
Does not report near misses	Weak safety culture fit
Uses non-approved materials	Contamination risk
Cannot explain why a step exists	Mechanical compliance without understanding
Repeats same mistake after coaching	Learning-system concern
Hesitates to escalate abnormal conditions	Decision-boundary risk

PRA principle: One successful task does not establish broad competence. Qualification must be **task-specific, repeatable, and observed under realistic conditions**.

---

13. Transferable Skills vs. Non-Transferable Assumptions

13.1 Skills That Transfer Well

Machining/Fabrication Skill	CMP Value
Mechanical troubleshooting	Understanding equipment behavior
Dimensional awareness	Recognizing alignment and wear concerns
Tool discipline	Proper equipment handling
Component identification	Maintenance accuracy
Torque/fastener familiarity	Mechanical assembly
Reading drawings/schematics	Equipment understanding
Preventive maintenance habits	PM execution
Root-cause thinking	Fault isolation
Hands-on dexterity	Tool and component handling
Safety around machinery	Foundation for equipment safety
Work order discipline	Documentation and traceability
Defect awareness	Quality mindset

13.2 Assumptions That Must Be Replaced

Potential Assumption	Why It Is Dangerous in CMP	Replacement Principle
“If it looks clean, it is clean.”	Microscopic contamination may matter	Follow approved contamination controls
“Tight is tight.”	Exact torque and seating may be critical	Specification governs
“A little lubricant helps.”	Non-approved materials can contaminate	Approved-material list only
“Resetting clears the problem.”	Alarm may indicate latent failure	Understand cause before reset
“I can adjust it until it works.”	Process changes can affect yield	No unauthorized parameter changes
“The machine is off.”	Energy may remain	Verify zero energy

“The part fits, so it is correct.”	Wrong part may fit but function incorrectly	Part number and configuration verification
“I have fixed similar machines.”	CMP process sensitivity differs	Equipment-specific qualification
“The defect is probably mechanical.”	Chemical/process causes may dominate	Use structured troubleshooting
“Production needs this running.”	Pressure can defeat safeguards	Safety and quality take precedence

---

14. PRA by Employment Phase

Phase 0 — Before First Tool Access

Risk Theme: Unqualified exposure

Potential failures:

- Incomplete cleanroom training
- Incomplete chemical training
- Unclear restricted activities
- No equipment-state training
- No escalation understanding

Required barriers:

- Safety orientation
- Cleanroom qualification
- Chemical hazard training
- ESD/contamination training as applicable
- LOTO awareness and qualification pathway
- Defined “may do / may not do” matrix
- Mentor assignment
- Training record

Exit criterion:

> The technician understands what they are authorized to do, what they are not authorized to do, and how to stop and escalate.

Phase 1 — Weeks 1–4: Orientation and Observation

Risk Theme: Cognitive overload and false familiarity

Likely behavior:

- Compares CMP to familiar machines
- Learns terminology
- Watches experienced technicians
- Attempts to build a mental model
- May underestimate chemical/process sensitivity

PRA concerns:

- Information overload

- Memorizing steps without understanding
- Copying informal shortcuts
- Asking too few questions

Controls:

- Observe before operate
- Use a CMP glossary
- Require teach-back
- Introduce one system at a time
- Record questions and abnormal observations
- No unsupervised intervention

Exit criterion:

Can explain the basic CMP flow and identify major hazards and equipment boundaries.

Phase 2 — Weeks 5–8: Supervised Execution

Risk Theme: Performing tasks correctly but inconsistently

Likely behavior:

- Starts handling tools and components
- Performs simple tasks under supervision
- Learns standard work
- Encounters first alarms and abnormalities

PRA concerns:

- Skipped verification
- Wrong material or part
- Incorrect sequence
- Over-reliance on mentor presence
- Failure to stop when uncertain

Controls:

- Direct observation
- Step-by-step checklists
- Peer verification for critical tasks
- Simulated abnormal conditions
- Immediate coaching
- No independent high-risk maintenance

Exit criterion:

Performs basic assigned tasks consistently under supervision without procedural deviations.

Phase 3 — Months 3–6: Developing Technician

Risk Theme: Transition from following instructions to exercising judgment

Likely behavior:

- Handles routine work more independently
- Begins troubleshooting
- May become confident
- Encounters recurring equipment/process issues

PRA concerns:

- Premature independence
- Incorrect diagnosis
- Alarm reset behavior
- Unapproved adjustments
- Weak handoff
- Failure to recognize latent issues

Controls:

- Troubleshooting decision trees
- Defined escalation thresholds
- Case-based training
- Review of actual events
- Supervisor sampling
- Recurring-fault tracking
- Qualification by task family

Exit criterion:

Can perform routine work independently within scope and escalate abnormal conditions appropriately.

Phase 4 — Months 6–12: Independent Technician Development

Risk Theme: Normalization of deviance and hidden competence gaps

Likely behavior:

- Comfortable with routine operations
- Develops personal work patterns
- May mentor newer staff informally
- Encounters more complex issues

PRA concerns:

- Workarounds
- Informal tribal knowledge
- Reduced checklist discipline
- “I know this tool” confidence
- Failure to document recurring abnormalities
- Taking on work beyond qualification

Controls:

- Periodic requalification
- Audits of standard work
- Review of repeat events
- Cross-training

- Mentor feedback
- Skill matrix updates
- Independent assessment of troubleshooting

Exit criterion:

Demonstrates reliable, repeatable performance, sound escalation, and adherence to controlled procedures.

---

15. Training Needs Analysis Based on PRA

15.1 Critical Training Domains

Domain	Priority	Why
CMP fundamentals	Critical	Establishes correct mental model
Chemical/slurry safety	Critical	High-consequence exposure and process risk
Cleanroom contamination control	Critical	Non-visible quality risk
Equipment states/interlocks	Critical	Prevents unsafe intervention
LOTO / energy control	Critical	High-consequence safety barrier
Wafer handling	Critical	Prevents material and quality loss
Standard work/SOP discipline	Critical	Controls variability
Alarm response	Critical	Prevents escalation of failures
Recipe and material verification	Critical	Prevents wrong-process events
PM execution	High	Strong machinist transfer area
Torque/alignment/sealing	High	Transferable but specification-sensitive
Troubleshooting/RCA	High	Uses prior experience productively
Documentation/handoff	High	Prevents recurrence
Human factors	High	Controls overconfidence and silence
Process metrics	High	Builds semiconductor judgment
Equipment-specific qualification	Critical	Converts theory into safe execution

---

16. Training Architecture: Convert Machinist Skill Into CMP Competence

The Recommended Model

```
PRIOR EXPERIENCE
7 Years Machining/Fabrication
        |
        ▼
TRANSFERABLE FOUNDATION
```

```
Mechanical skill
Troubleshooting
Tool discipline
Maintenance habits
        │
        ▼
CMP DOMAIN RESET
Chemistry
Wafer sensitivity
Contamination
Process control
Equipment states
        │
        ▼
SUPERVISED APPLICATION
Observe → Practice → Demonstrate → Repeat
        │
        ▼
QUALIFICATION
Task-specific + observed + documented
        │
        ▼
CONTROLLED INDEPENDENCE
Routine work within authorized scope
        │
        ▼
CONTINUOUS LEARNING
RCA + lessons learned + requalification
```

---

17. The 4-Layer Qualification Model

A technician should not be considered qualified merely because they completed a class.

Layer 1 — Knowledge

Can the technician explain the task?

Examples:

- Why is slurry used?
- What does the carrier head do?
- What is pad conditioning?
- What are the hazards of the assigned chemicals?
- What does a particular alarm indicate?
- What conditions require escalation?

Layer 2 — Demonstration

Can the technician perform the task while being observed?

Examples:

- Correct gowning

- Correct material verification
- Correct tool setup
- Correct PM sequence
- Correct cleaning
- Correct restoration

Layer 3 — Repeatability

Can the technician perform the task correctly multiple times?

One successful demonstration may be luck or heavy prompting.

Repeatability proves the behavior is becoming reliable.

Layer 4 — Judgment

Can the technician recognize when not to proceed?

This is especially important.

Examples:

- Stops when a part does not match documentation
- Escalates a recurring alarm
- Does not improvise a parameter change
- Holds material when traceability is uncertain
- Requests clarification when a procedure conflicts with equipment state

> **The ability to stop correctly is a core technician competency.**

---

18. Critical Task Qualification Matrix

Task	Initial Training	Supervised Practice	Independent Qualification	Requalification
Cleanroom entry/gowning	Required	Yes	Required	Periodic
Chemical handling	Required	Yes	Specific authorization	Periodic
Slurry/material identification	Required	Yes	Required	Periodic
Wafer handling	Required	Yes	Required	Periodic
Equipment startup/shutdown	Required	Yes	Tool-specific	As required
Alarm response	Required	Yes	Scenario-based	Periodic
Basic PM	Required	Yes	Task-specific	Periodic
LOTO	Formal qualification	Observed	Authorized only	Per policy
Component replacement	Required	Yes	Part/task-specific	Periodic
Torque/assembly	Required	Yes	Specification-based	Periodic

Cleaning/restoration	Required	Yes	Required	Periodic
Recipe selection	Required	Yes	Access-controlled	Periodic
Parameter adjustment	Restricted	Engineering-supervised	Only if authorized	Per policy
Troubleshooting	Required	Case-based	Scope-limited	Periodic
Return to service	Required	Yes	Defined authorization	Periodic
Documentation/MES	Required	Yes	Required	Periodic

19. PRA-Driven “Do Not Do” List for the New Hire

These should be explicitly taught, not left to assumption.

Until specifically authorized, the technician should not:

1. Bypass interlocks.
2. Enter restricted equipment areas without authorization.
3. Perform electrical work outside qualification.
4. Work on energized equipment outside approved procedures.
5. Change process parameters based on intuition.
6. Substitute chemicals, slurry, lubricants, wipes, seals, or materials.
7. Use an unverified replacement part.
8. Reset recurring alarms without escalation.
9. Return equipment to production without required checks.
10. Continue operation when process data is inconsistent.
11. Modify equipment configuration without authorization.
12. Use personal tools or materials where prohibited.
13. Skip material or wafer identity verification.
14. Treat a visible-only inspection as proof of contamination-free condition.
15. Hide a mistake or near miss.
16. Copy an undocumented workaround.
17. Perform maintenance from memory when a controlled SOP is required.
18. Assume prior machining practices override semiconductor procedures.
19. Diagnose beyond the defined technician boundary.
20. Allow production urgency to override safety or quality controls.

20. Leading Indicators: Detect Risk Before Failure

A mature PRA system monitors **leading indicators**, not just incidents.

20.1 Training Indicators

Indicator	**Warning Signal**
Qualification delays	Training system may be inadequate
Repeated failed demonstrations	Knowledge or coaching gap
High mentor prompting	Competence not yet independent

Frequent procedural deviations	Standard work not internalized
Poor teach-back performance	Memorization without understanding
Repeated questions on same critical step	Training material may be unclear

20.2 Operational Indicators

Indicator	**Warning Signal**
Repeat alarms involving same tool	Latent equipment/process issue
Repeated wrong-part near misses	Part-control weakness
FOD findings	Contamination control weakness
Incomplete PM records	Documentation or workload issue
Repeat rework after maintenance	Maintenance quality issue
Frequent unplanned escalations	Training or equipment complexity gap
Unusual wafer handling incidents	Handling qualification weakness

20.3 Behavioral Indicators

Indicator	**Warning Signal**
Technician rarely asks questions	Could indicate fear or overconfidence
Technician frequently says “I know” before verification	Overconfidence
Workarounds appear in informal conversations	Normalization of deviance
Near misses are not reported	Weak reporting culture
Handoffs lack unresolved conditions	Documentation failure
Technician avoids abnormal tasks entirely	Underconfidence or training gap

---

21. Leading vs. Lagging Indicators

Leading Indicators	**Lagging Indicators**
Qualification completion	Safety incident
Observed procedural compliance	Wafer loss
Alarm-response proficiency	Equipment damage
Near-miss reporting	Chemical exposure
FOD audit results	Contamination event
PM checklist accuracy	Repeat equipment failure
Stop-work behavior	Lot loss
Training assessment results	Yield excursion
Handoff quality	Production downtime
Requalification performance	Customer-impacting defect

PRA objective: Use leading indicators to prevent lagging outcomes.

---

22. Human Reliability Analysis

The technician's reliability depends on more than knowledge.

A simplified human reliability model is:

$$P(\text{successful task}) = P(\text{understands}) \times P(\text{recognizes}) \times P(\text{executes}) \times P(\text{verifies}) \times P(\text{escalates correctly})$$

If any factor is weak, total reliability decreases.

For example, assume illustrative probabilities:

- Understands task: 0.95
- Recognizes abnormality: 0.80
- Executes correctly: 0.95
- Verifies: 0.90
- Escalates correctly: 0.90

$$P(\text{success}) = 0.95 \times 0.80 \times 0.95 \times 0.90 \times 0.90$$

$$P(\text{success}) \approx 0.585$$

This does **not** mean the technician has a 58.5% real-world success rate. It demonstrates a principle:

> Even when execution is strong, weak abnormality recognition or escalation can dominate overall reliability.

---

23. Why Abnormality Recognition Is the Highest-Value Skill

A technician who can perform routine work is useful.

A technician who can recognize that routine work is **no longer routine** is significantly more valuable.

Normal Condition

- Expected alarm behavior
- Correct flow
- Correct pressure
- Correct equipment state
- Correct material
- Correct process sequence
- Expected inspection result

Abnormal Condition

- Unexpected alarm
- Conflicting sensor values
- Unusual vibration/noise
- Unusual slurry behavior
- Unexpected leak
- Incorrect component identity

- Unexplained process result
- Repeated failure after reset
- Equipment state inconsistent with SOP

Required Response Pattern

```
Recognize abnormality
        ↓
Stop / stabilize as required
        ↓
Protect people, equipment, and material
        ↓
Do not improvise
        ↓
Document facts
        ↓
Escalate to correct role
        ↓
Resume only after authorization
```

---

24. PRA Scenario Simulations

These scenarios are useful for qualification and tabletop training.

Scenario 1 — Wrong Slurry Line Identified During PM

Situation: Technician is replacing a line and notices two similar connections.

Potential failure: Connects line based on physical fit rather than verified identification.

Threats:

- Similar fittings
- Poor labeling
- Time pressure
- Assumption that lines are interchangeable

Consequences:

- Wrong chemical delivery
- Equipment contamination
- Process excursion
- Potential chemical event

Correct response:

1. Stop work.
2. Do not connect based on fit.
3. Verify line identity against approved documentation.
4. Confirm material/connection with authorized personnel.
5. Document discrepancy.
6. Resume only after verification.

Pass criterion: Technician refuses to proceed without identity confirmation.

Scenario 2 — Repeated Alarm Clears After Reset

Situation: An alarm clears after a reset, but the same alarm occurred twice earlier.

Potential failure: Technician treats reset as resolution.

Consequences:

- Latent equipment failure
- Repeat wafer damage
- Unplanned downtime

Correct response:

1. Record alarm code and conditions.
2. Review history.
3. Follow alarm response matrix.
4. Escalate recurring condition.
5. Do not repeatedly reset without cause evaluation.
6. Hold affected material if required.

Pass criterion: Technician recognizes recurrence as meaningful evidence.

Scenario 3 — Familiar Lubricant Available

Situation: A component requires lubrication, but the approved material is not immediately available. A familiar shop lubricant is nearby.

Potential failure: Uses familiar lubricant because “it works on machines.”

Consequences:

- Contamination
- Chemical incompatibility
- Equipment/process damage

Correct response:

1. Do not substitute.
2. Check approved-material list.
3. Escalate material availability issue.
4. Use only approved material.
5. Document if work is delayed.

Pass criterion: Technician prioritizes material compatibility over convenience.

Scenario 4 — Process Data Looks Inconsistent

Situation: The tool completes a cycle, but an indicator does not match expected behavior.

Potential failure: Assumes the tool completed normally.

Consequences:

- Invalid process

- Lot loss
- Latent defect

Correct response:

1. Do not release material automatically.
2. Verify equipment and MES status.
3. Follow abnormal completion procedure.
4. Escalate.
5. Preserve evidence.

Pass criterion: Technician recognizes “completed” does not necessarily mean “valid.”

Scenario 5 — Mechanical Vibration Appears During Operation

Situation: Technician notices unusual vibration or sound.

Potential failure: Adjusts or tightens a component without stopping or authorization.

Consequences:

- Equipment damage
- Safety exposure
- Process instability

Correct response:

1. Follow equipment-specific abnormal condition procedure.
2. Stop or stabilize as required.
3. Maintain safe distance.
4. Document observations.
5. Escalate to authorized personnel.
6. Perform troubleshooting only within scope.

Pass criterion: Uses observation as evidence, not permission to improvise.

Scenario 6 — Near Miss During Wafer Handling

Situation: A wafer is almost dropped but remains intact.

Potential failure: Technician says nothing because no damage occurred.

Consequences:

- Repeat incident
- Hidden handling risk
- Missed training improvement

Correct response:

1. Report near miss.
2. Record conditions.
3. Review handling method.
4. Identify contributing factors.
5. Implement corrective action.

Pass criterion: Reports near miss without fear or concealment.

25. The “Machinist-to-CMP” Risk Conversion Table

Existing Strength	Possible Failure if Misapplied	Correct CMP Conversion
Fast mechanical troubleshooting	Jumps to diagnosis	Use fault isolation and evidence
Confidence with tools	Skips authorization	Use task qualification
Familiarity with lubricants	Uses non-approved material	Use material control
Experience with tolerances	Relies on feel	Use specified measurement/torque
Experience with equipment repair	Works beyond scope	Use escalation matrix
Comfort around machinery	Underestimates chemical/energy hazards	Use equipment-state and chemical training
Desire to restore equipment quickly	Premature return to service	Use formal release criteria
Practical improvisation	Unauthorized modification	Use change control
Visual inspection skill	Misses microscopic contamination	Use contamination-control standards
Independent work habits	Fails to communicate	Use structured handoff and reporting

---

26. Recommended First-Year Development Plan

Months 0–1: Foundation

Objective: Become safe and process-aware.

- Cleanroom qualification
- Chemical/slurry safety
- CMP fundamentals
- Wafer handling
- Equipment terminology
- Basic equipment states
- SOP navigation
- Reporting and escalation
- Shadow experienced technicians

Risk focus: Prevent unsafe assumptions.

Months 2–3: Controlled Execution

Objective: Perform routine tasks under supervision.

- Standard work
- Tool operation
- Material verification
- Basic PM
- Cleaning/restoration
- Alarm recognition
- MES/documentation

- FOD control
- Supervised troubleshooting

Risk focus: Prevent procedural variability.

Months 4–6: Developing Judgment

Objective: Recognize and respond to abnormalities.

- Alarm-response scenarios
- Troubleshooting trees
- RCA fundamentals
- Equipment failure modes
- Process metrics
- Recurring-fault analysis
- Escalation decisions
- Independent routine tasks within scope

Risk focus: Prevent premature independence.

Months 7–9: Reliability Development

Objective: Demonstrate repeatable performance.

- Cross-training on additional equipment
- Complex PM under supervision
- Return-to-service verification
- Process excursion response
- Documentation audits
- Peer review
- Requalification checks

Risk focus: Prevent latent errors and normalization of deviance.

Months 10–12: Technician Maturity

Objective: Operate independently within defined authorization.

- Demonstrate task mastery
- Handle abnormal scenarios
- Participate in RCA
- Identify systemic risks
- Mentor only within demonstrated competence
- Recommend process improvements through formal channels
- Complete annual competency review

Risk focus: Sustain disciplined independence.

---

27. PRA-Based Competency Scorecard

Use a 1–5 scale:

Score	Meaning
1	Not demonstrated
2	Requires continuous guidance
3	Performs with normal supervision
4	Performs independently within scope
5	Demonstrates strong judgment and can coach others

Competency	Target by 30 Days	Target by 90 Days	Target by 6 Months	Target by 12 Months
Safety fundamentals	3	4	4	5
Chemical/material control	3	4	4	5
CMP fundamentals	2	3	4	4
Wafer handling	3	4	4	5
SOP adherence	3	4	4	5
Equipment operation	2	3	4	4
Alarm response	2	3	4	4
PM execution	2	3	4	4
Troubleshooting	1	2	3	4
Documentation	3	4	4	5
Escalation judgment	3	4	4	5
Contamination control	3	4	4	5
Independent qualification	1	2	3	4

Do not use these targets as automatic authorization. Authorization should be based on actual task qualification and site requirements.

---

28. Management Controls Required for Success

The new hire's outcome is not solely an individual responsibility.

28.1 Engineering Controls

- Interlocks
- Recipe access control
- Material identification systems
- Equipment guarding
- Alarm systems
- Sensor verification
- Spill containment
- Automated tracking
- Error-proofed connectors where available

28.2 Administrative Controls

- SOPs
- Training matrix
- Qualification gates
- LOTO procedures
- Escalation matrix
- PM checklists
- Return-to-service criteria
- Material approval lists
- Shift handoff standards
- Incident/near-miss reporting

28.3 Human and Cultural Controls

- Psychological safety
- Stop-work authority
- Mentor availability
- No punishment for good-faith escalation
- Recognition of disciplined behavior
- No reward for unsafe shortcuts
- Leadership modeling of procedure adherence
- Learning from near misses

---

29. What Would Cause Success?

Success Path

```
Strong mechanical foundation
          +
Humility about CMP knowledge gap
          +
Structured training
          +
Experienced mentor
          +
Hands-on qualification
          +
Strict material/contamination discipline
          +
Good alarm response
          +
Willingness to ask questions
          +
Consistent documentation
          +
Controlled independence
          =
Reliable CMP Technician 2
```

Expected Success Characteristics

The successful technician:

- Uses prior experience without assuming equivalence
- Learns the process before modifying the equipment
- Follows specifications rather than intuition
- Recognizes the difference between normal and abnormal
- Escalates early
- Treats contamination as a serious technical issue
- Understands that documentation is part of the process
- Accepts that qualification is earned through demonstration
- Can troubleshoot without improvising outside authorization
- Becomes reliable through repeatability, not confidence alone

---

30. What Would Cause Failure?

Failure Path

```
Strong mechanical background
          +
Overconfidence
          +
Insufficient CMP training
          +
Weak supervision
          +
```

```
Production pressure
          +
Poor contamination discipline
          +
Unclear escalation
          +
Alarm-reset habit
          +
Unauthorized improvisation
          +
Weak reporting culture
          =
Safety, quality, equipment, or performance failure
```

Typical Failure Pattern

The most realistic failure is not necessarily a dramatic accident.

It may be:

1. A small procedural shortcut.
2. A minor unreported abnormality.
3. A material substitution.
4. An incomplete PM restoration.
5. A repeated alarm reset.
6. A missed handoff.
7. A latent contamination or process issue.
8. A downstream failure discovered later.

The PRA therefore emphasizes latent failures, not just obvious accidents.

---

31. The 22-Point PRA-Based Training Guidelines

These are the most important rules to embed in the training model.

1. **Treat the technician as mechanically experienced but CMP-inexperienced.**
2. **Do not confuse years of experience with task-specific qualification.**
3. **Teach CMP fundamentals before expecting independent judgment.**
4. **Make chemical and slurry safety a qualification gate.**
5. **Teach contamination control as a technical discipline, not housekeeping.**
6. **Require equipment-state and energy-control understanding.**
7. **Never allow “it fits” to replace part verification.**
8. **Never allow “it looks clean” to replace approved cleaning standards.**
9. **Never allow “it works” to justify an unauthorized process adjustment.**
10. **Teach alarm response using cause-and-consequence scenarios.**
11. **Treat recurring alarms as evidence of an unresolved problem.**
12. **Require stop-work behavior when data, identity, or procedure is inconsistent.**
13. **Use observed qualification rather than attendance-based qualification.**
14. **Evaluate repeatability, not just one successful demonstration.**
15. **Train the technician to preserve evidence during troubleshooting.**

16. **Make shift handoff and documentation part of technical competence.**
17. **Explicitly teach what the technician is not authorized to do.**
18. **Build psychological safety so questions and near misses are reported.**
19. **Monitor leading indicators before waiting for incidents.**
20. **Review latent failures, not just visible defects.**
21. **Use machinist skills as a foundation, not a substitute for CMP knowledge.**
22. **Define independence as disciplined judgment within scope—not working alone.**

---

32. Final PRA Conclusion

Overall Risk Assessment

Initial risk level: Moderate-to-high transition risk, with several high-consequence hazard categories requiring controlled qualification.

The new hire's **7 years of machining/fabrication experience is a significant advantage**, particularly for:

- Mechanical systems
- Equipment discipline
- Maintenance
- Troubleshooting
- Tools and components
- Workmanship
- Physical problem-solving

However, the lack of CMP experience creates substantial learning requirements in:

- Chemical-mechanical process behavior
- Wafer sensitivity
- Contamination control
- Slurry/material management
- Equipment interlocks and states
- Semiconductor process control
- Recipe and traceability discipline
- Latent defect recognition
- Escalation and qualification boundaries

The Central Risk Statement

> **The technician is likely to be capable of learning CMP, but the highest risk occurs when mechanical competence develops faster than CMP-specific judgment, contamination discipline, and procedural qualification.**

The Central Training Strategy

> **Do not reduce the new hire's confidence. Redirect it.**

Use the machinist's confidence to build:

- Better observation
- Better troubleshooting
- Better maintenance
- Better questioning

- Better evidence collection
- Better adherence to specifications

The desired end state is not merely a technician who can operate a CMP tool.

It is a technician who can reliably answer:

> **“What is normal, what is abnormal, what am I authorized to do, what must I verify, and when must I stop and escalate?”**

That is the foundation of a safe, high-quality, dependable CMP Technician 2.

PRA Scope and Validation Note

To convert this into a **facility-grade PRA**, the next version should incorporate:

- Actual CMP equipment platform and model
- Assigned technician work scope
- Chemical/slurry inventory
- Equipment P&IDs and schematics
- SOP and PM procedures
- Alarm history
- Maintenance failure history
- Wafer defect/yield data
- Incident and near-miss history
- Training and qualification matrix
- Existing engineering and safety barriers
- Actual shift pattern and staffing conditions

Those inputs would allow the illustrative likelihood scores to be replaced with **site-specific frequencies, barrier reliability, and quantified risk estimates**.