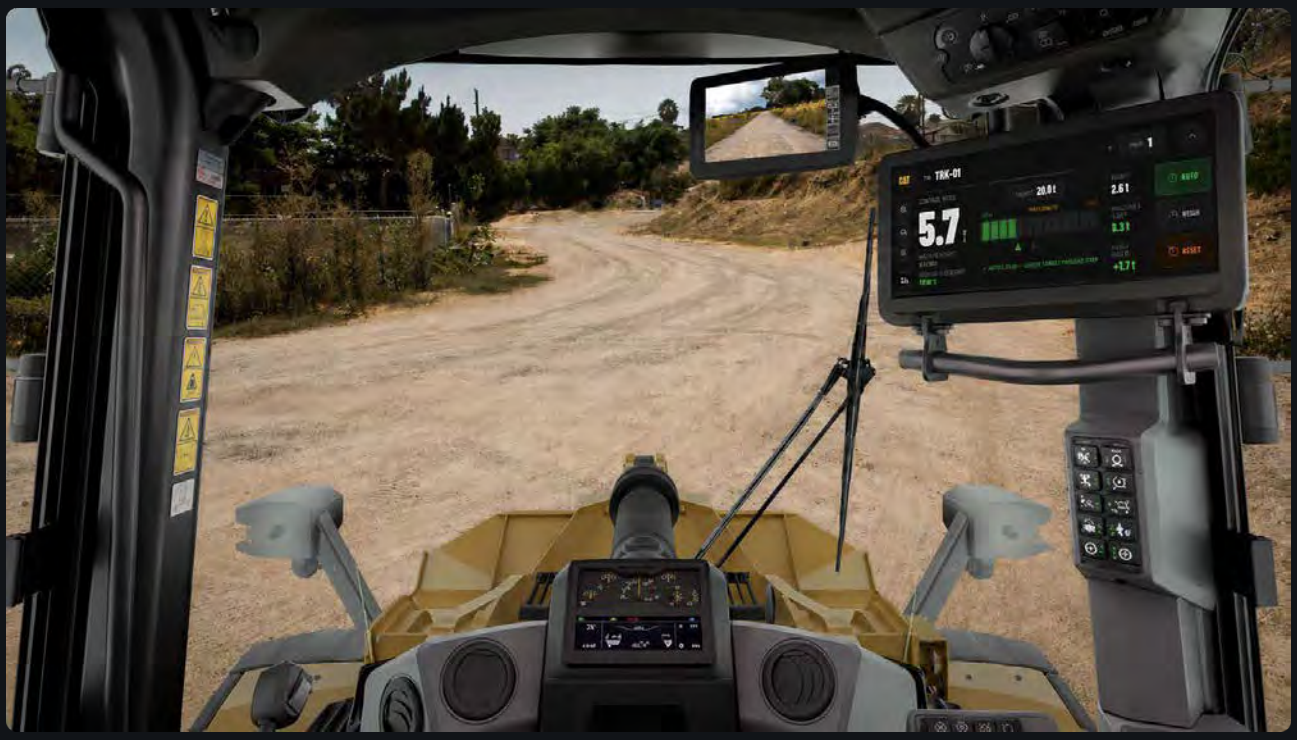
UXD 395 CAPSTONE II CASE STUDY

Reducing CAT CPM Payload Display Footprint



Project thesis
The final redesign reorganizes CAT CPM from a passive telemetry panel into a compact, state-driven decision-support system that reduces display footprint while improving threshold recognition, predictive clarity, and operator confidence.

EXECUTIVE SUMMARY

A smaller payload display needed to become a smarter one

The assignment challenged the redesign to reduce the CPM payload interface footprint by roughly 50% without weakening safety, workflow clarity, or operator confidence.

CORE DESIGN SHIFT

The redesign moves CPM from displaying isolated payload values toward communicating consequence: what happens after the next dump, how much payload remains, and whether the truck is approaching overload risk.

Why the original system created friction

The existing CPM screen displayed truck payload, bucket weight, target values, controls, and machine states, but much of that information carried similar visual importance. Operators still had to interpret the numbers, estimate remaining payload, and decide whether the next pass was safe.

Why the final system works differently

The final interface is state-driven. Safe loading states remain calm, approaching states become more visible, and overload-risk moments override secondary information. Predictive values such as After Dump and Remaining reduce mental calculation during the most critical loading moments.

ASSIGNMENT ALIGNMENT

NARRATIVE
Headings explain the project arc by decision logic, not chronology.

EVIDENCE
Iterations, interface screens, tables, and state models support the rationale.

RATIONALE
Each visual change connects to operator constraints and HMI principles.

OUTCOME
The final system reduces footprint while improving threshold communication.

Final system preview: state banner, segmented threshold gauge, main truck load, consequence panel, bucket prediction row, and action controls.

PROBLEM FRAMING

The original interface displayed measurements, but left consequence to the operator

The original CPM interface successfully communicated a large amount of payload data. The problem was that the operator still had to interpret what that data meant in real time. In a loading cycle, the difference between “current truck weight” and “what happens if I dump now” is the difference between passive telemetry and decision support.

Original Pressure Point	Why It Mattered	Redesign Response
Static hierarchy	Safe and near-limit moments could feel visually similar.	State banner escalates as risk increases.
Limited predictive feedback	Operators had to estimate payload and final truck weight	Remaining, and Predictive Total reduces mental math.
Excessive persistent visual weight	Too much information competed for attention at all times	Secondary information hidden until relevant.
Inefficient screen use	Interface occupied more area than immediate decision req.	Compact buttons improves glancebility
Weak threshold communication	Operators had to read numbers to understand risk.	Safe, approaching, and max zones are spatially visible.

CORE PROBLEM

The original CPM system showed payload information, but the redesigned system needed to explain payload consequence at glance speed.

OPERATOR + WORKSITE CONSTRAINTS

Heavy machinery conditions turn small interface choices into safety decisions

The redesign was grounded in cab realities rather than clean-room software assumptions. Operators work under vibration, glare, dust, gloves, fatigue, and split attention. They are not staring at the screen; they are monitoring the truck, bucket, terrain, machine stability, surrounding workers, and the next movement.

SPLIT ATTENTION

The interface must communicate essential information within short glance windows.

VIBRATION + MOTION

Dense details and small controls become harder to read or use in a moving cab.

GLOVES + FATIGUE

Touch areas need spacing, clear grouping, and low precision demand across repeated cycles.

SUNLIGHT + DUST

Color, contrast, and warning states need to remain visible outside ideal lighting.

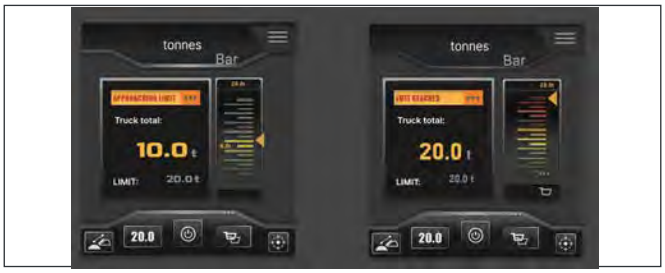
Design principles

Principle	Translation into the final interface
Glance-first hierarchy	Primary payload state and truck load dominate the scan path.
Consequence over raw data	The system shows predicted outcome, remaining payload, and over/under values.
Progressive disclosure	Visual intensity increases only as operational risk increases.
Threshold visibility	Safe, approaching, tip-off, and overload are distinct states, not just numbers.
Industrial stability	The interface stays calm, durable, and production-believable.

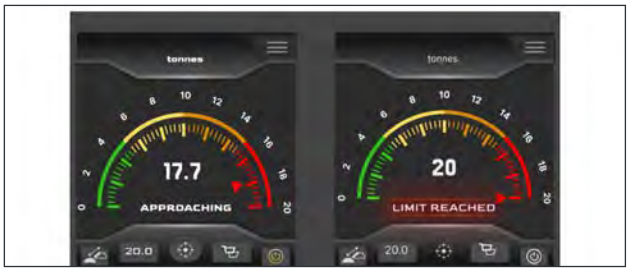
CONCEPT DEVELOPMENT

Iteration showed that the strongest visual form was not always the strongest HMI solution

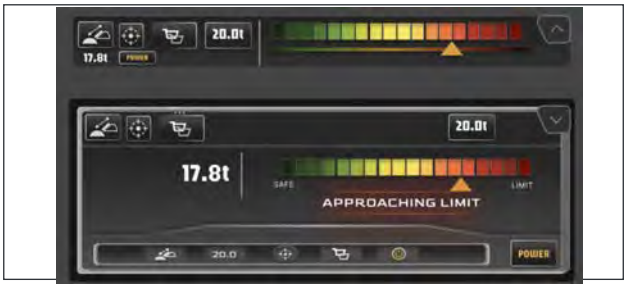
The design process tested boxed layouts, vertical threshold systems, radial gauges, and horizontal segmented systems. Each direction clarified a trade-off between visual immediacy, footprint reduction, and operator trust.



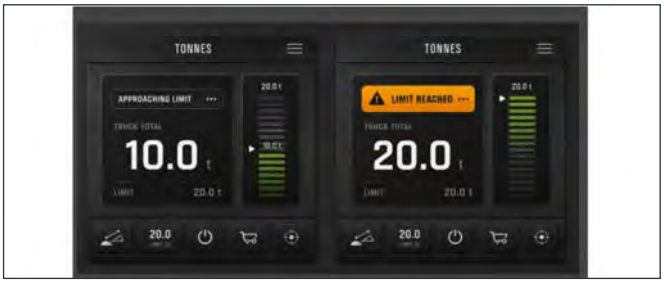
Stage 1: Boxed hierarchy
Improved grouping and introduced threshold proximity, but still consumed too much vertical space.



Stage 3: Radial exploration
Fast warning recognition, but too visually dominant and inefficient for a reduced footprint.



Stage 4: Condensed horizontal
Moved payload communication into a compact lateral scan path and reduced vertical demand.



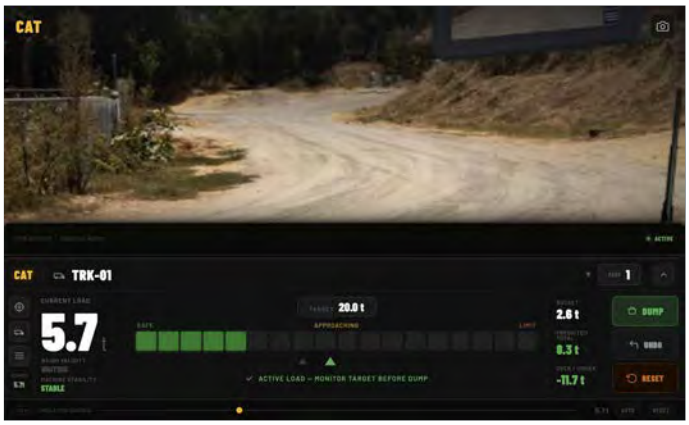
Stage 5: State threshold system
Clarified safe, approaching, and limit states through segmented progression.

ITERATION INSIGHT

Radial gauges created urgency, but horizontal segmented systems better balanced footprint reduction, glanceability, and production realism.

FINAL SOLUTION

The final interface reorganizes CPM around operational state



New final roading-mode preview with compact CPM overlay and action rail.

1. STATE BANN

Primary escalation layer for Ready, Loading, Approaching, Tip-Off, Overload Risk, Bad Weigh, Machine Unstable, and Finalized states.

2. SEGMENTED THRESHOLD GAU

Compact peripheral indicator for safe, approaching, and max payload zones without occupying a large radial display area.

3. COLLAPSED / EXPANDED PAN

The default view keeps the footprint small. Secondary actions expand only when the operator needs them.

4. BUCKET PREDICTION R

Bucket weight, predicted total, and over-under values help judge the next action before committing.

5. GLOVE-FRIENDLY CONTRO

Dump, undo, reset, and extended actions are large, separated, and reachable without precise interaction.

HMI STRATEGY

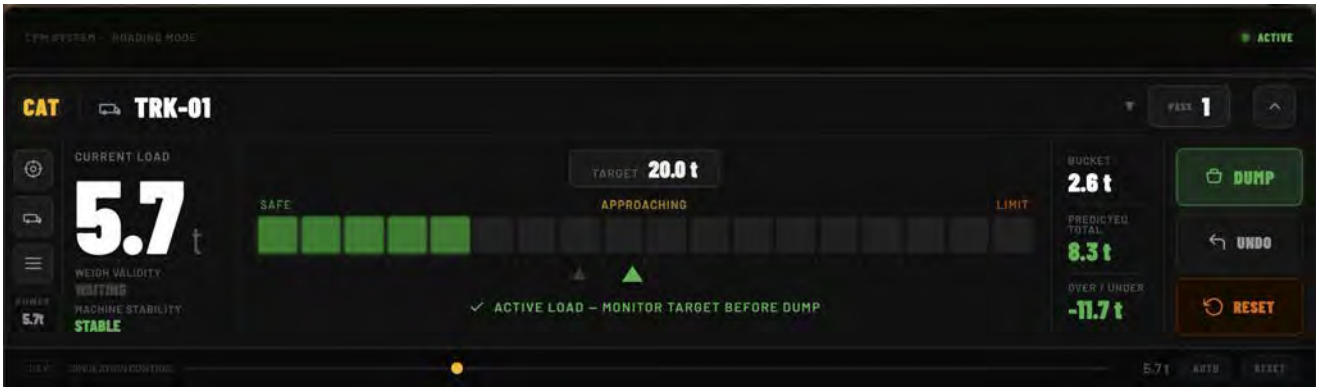
The updated final system no longer reads as a standalone widget. It behaves like a compact operational layer inside the broader machine display: persistent enough to guide payload decisions, but controlled enough to preserve camera visibility and roading context.

STATE MODEL + WORKFLOW

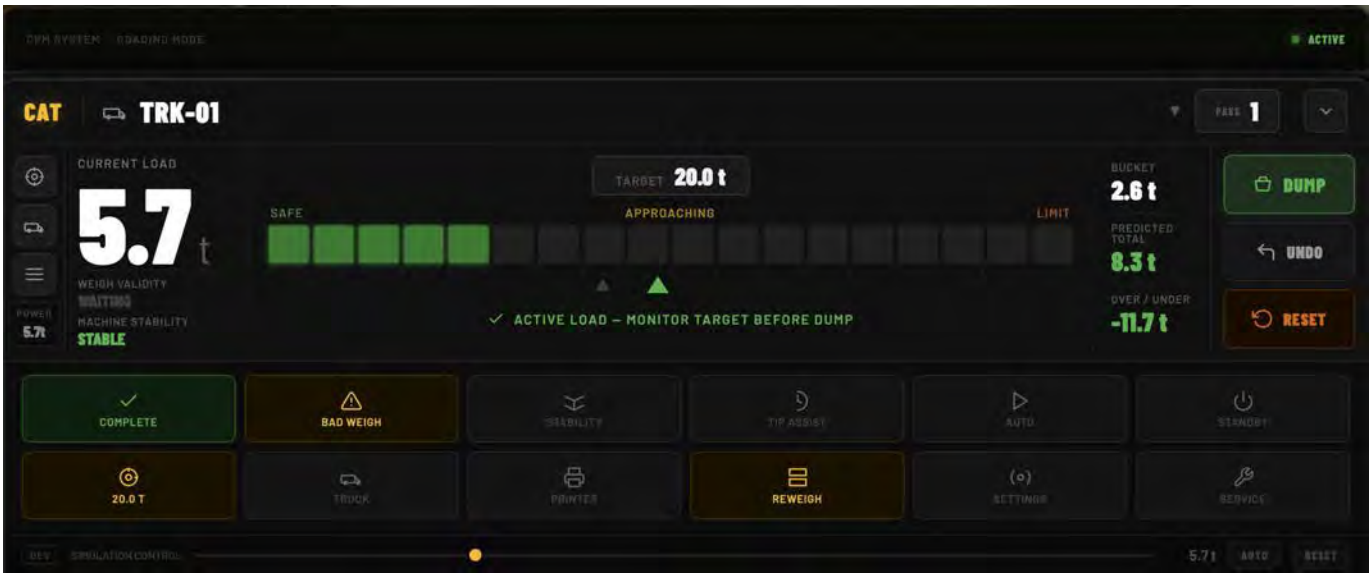
The workflow escalates only when risk increases

The operator begins by selecting or assigning a truck. Loading actions remain disabled until the system has a valid truck context. Once the target is established, repeated passes move the interface through Ready, Loading, Approaching, Tip-Off, Overload Risk, Bad Weigh, Machine Unstable, Load Complete, and Standby states.

READY | LOADING | APPROACHING | TIP-OFF | OVERLOAD RISK | FINALIZED



Condsed state: safe progression, remaining payload, after-dump prediction, and action controls.



Expanded: color, banner language, and consequence values escalate when risk increases.

WORKFLOW BENEFIT

The operator can follow a repeatable rhythm: confirm state, read current load, check consequence, act. This reduces mental math while protecting attention for the truck, terrain, bucket position, and surrounding worksite.

OUTCOME

The redesign reduces screen pressure by changing the information architecture

The final system does not make CPM smaller by hiding critical functionality. It reduces pressure by reorganizing the display around decision moments: what the current load means, what the next dump will create, and whether the operator is approaching a limit.

Original CPM System	Final Redesign	Operator Impact
Displayed raw payload data	**Communicates operational consequence**	Faster understanding of what action is safe next.
Relied on operator interpretation	**Shows After Dump, Remaining, and Predicted Total**	Less mental calculation during final passes.
Maintained a static hierarchy	**Escalates visual state based on risk**	Warnings become clearer only when risk increases.
Consumed persistent screen space	**Uses a compact segmented threshold architecture**	Better fit for constrained machine displays.
Had limited predictive support	**Adds consequence and prediction values**	Higher confidence before dumping.
Required prolonged screen reading	**Supports glance-based decision loops**	More attention can remain outside the cab.

OUTCOME STATEMENT

The updated final interface reduces display footprint while improving threshold clarity, predictive confidence, and task-focused hierarchy in high-pressure loading workflows.

Why this matters: operators no longer have to estimate remaining payload, overload probability, or final pass outcome from scattered values. The interface communicates these conditions directly through the state banner, segmented threshold gauge, and consequence panel.

REFLECTION + FUTURE TESTING

The final design is stronger, but it still needs validation in real machine conditions

A static screen can look clear in a design review and still fail in a moving cab. The next stage should validate whether the redesigned hierarchy holds up under real operator constraints.

VIBRATION TESTING

Confirm that segmented thresholds, state banners, and numeric values remain readable in motion.

SUNLIGHT + GLARE

Validate contrast and warning readability under direct outdoor light, dust, and low visibility.

GLOVE INTERACTION

Test target size, spacing, and control separation with realistic operator gloves.

PREDICTION TRUST

Measure whether operators trust After Dump, Remaining, and Predicted Total enough to use them confidently.

Forward-looking refinement

Future iterations should evaluate whether any transitions, warning escalations, or animated states need to be reduced for long-term industrial use. Production constraints from Caterpillar may also require additional simplification, hardware adaptation, and stricter warning standardization. The predictive payload model should be calibrated carefully so that it improves confidence without creating blind reliance.

FINAL TAKEAWAY

The strongest result is not just that the CPM display became smaller. It became more useful in the moments where payload decisions matter most.

Conclusion

The final CAT CPM redesign reorganizes the payload interface around operational consequence, glanceability, and worker-centered hierarchy. It preserves critical workflow controls while reducing visual clutter and supporting faster decision-making under vibration, fatigue, split attention, and time pressure.

USER TESTING

Design decisions were validated through structured operator sessions

Two usability testing sessions were conducted on the final interactive prototype to evaluate whether the redesigned CPM interface supports fast, glance-based decision making under realistic operator conditions. Sessions followed a six-flow structured script covering state recognition, payload progress, predictive metrics, warning clarity, control discoverability, and action hierarchy.

Participants

Participant 1 — Equipment Operations Professional
Heavy Machinery / Industrial Operations | Session 1 — Structured Script
Active field knowledge of equipment payload workflows, operator conventions, and safety hierarchy. Responses grounded in real cab constraints and loading cycle experience.

Participant 2 — Troy, Construction Operations Specialist
Disney California (Heavy Construction / Material Transfer) | Session 2 — Guided Walkthrough
Domain-adjacent experience in controlled dumping and heavy equipment workflows. Initial acclimation hesitation resolved quickly; strong engagement and confident feedback by session end.

Key Findings by Flow

Monitoring State Recognition Identified instantly. Under 3-second response time with no prompting required.	PASS
Payload Progress — Segmented Bar 4 of 5 questions answered quickly and correctly. Fifth prompted reflective decision-making — po	PASS
Target Weight & Predicted Total Strong comprehension across both sessions. Consequence values understood without manual calcula	PASS
Bucket Weight Labeling Initial confusion observed. Metric requires stronger visual distinction or label refinement.	PASS
Max Capacity Warning — Static Red Recommend flashing amber/white. Static red must remain reserved for shutdown-critical safety st	PASS
Expansion Control Discoverability Primary usability gap. Time-to-discovery significantly longer than expected in both sessions.	NOTE
Expanded Panel Content Confidently navigated once open. Organization and grouping tested well.	PASS
Action Buttons — Hierarchy Generally understood. Reset vs. Truck Store terminology warrants additional operator validation	NOTE
Overall Interface Reception "Almost perfect" — strong positive response from domain-adjacent participant with no prior expo	PASS

USER TESTING — SESSION DETAIL

Session findings confirm state hierarchy and surface three refinement priorities

Session 1 — Equipment Operator

Monitoring states: Recognized immediately, under 3 seconds, no hesitation. Strong signal that the state banner communicates system status at a glance.

Payload progress: 4 of 5 questions answered quickly. Fifth question prompted an operational decision-making response rather than confusion — suggesting the interface may be supporting real-world loading logic effectively.

Bucket Weight: Initial confusion observed. The value may require stronger visual hierarchy or label refinement to differentiate it from Predicted Total at a glance.

Warning Indicator — Most Substantive Feedback
The participant recommended replacing the static dark red max-capacity state with a flashing amber or white indicator. He emphasized that static red must remain exclusively reserved for shutdown-critical safety states per established operator convention — a finding consistent with prior internal discussions.

Expansion Control — Primary Usability Gap
Time-to-discovery for the control expansion affordance was significantly longer than expected. Once the panel was opened, however, all follow-up questions were answered quickly and confidently. The issue is one of discoverability, not comprehension. Affordance visibility must be improved.

Reset vs. Truck Store — Terminology Opportunity
Participant suggested "Truck Store" (existing workflow language) as an alternative to "Reset." On reflection, he acknowledged both may be valid. Additional operator testing recommended before final decision.

Session 2 — Troy, Construction Operations

Overall reception: Troy described the interface as "almost perfect" — strong positive feedback from a domain-adjacent evaluator with no prior exposure to the prototype.

Camera & button panel scale: The camera view appeared slightly larger than necessary, and the expanded 12-button grid occupied significant screen area. Both concerns were substantially mitigated once the collapse/hide feature was introduced — Troy stated he "liked it a lot."

Feature reception: Troy specifically highlighted the user profile settings, truck tracking system, and load history as well-aligned with real operational workflows.

Industry Context — Alignment with Market Direction
Troy noted that the construction industry is actively seeking younger, technology-adaptable operators as new systems are integrated. The CAT CPM redesign's modern, readable interface aligns directly with this shift.

USER TESTING — OUTCOMES

Testing confirms the core design argument

Results Summary

Evaluation Area	Finding	Status
System State Recognition	Immediate — under 3 seconds, both sessions	Pass
No Truck Assigned State	Recognized correctly without prompting	Pass
Payload Progress — Segmented Bar	4/5 correct; fifth triggered decision-making respo	Pass
Target Weight Comprehension	Strong across both sessions	Pass
Bucket Weight Labeling	Initial confusion; label refinement recommended	Pass
Predicted Total Clarity	Understood once reviewed; no manual calculation ne	Pass
Warning Message Urgency	Visible; static red state recommended for redesign	Pass
Expansion Control Discovery	Significant delay — primary usability gap identifi	Pass
Expanded Panel Comprehension	Confident navigation once panel was open	Pass
Action Button Hierarchy	Generally understood; Reset/Truck Store TBD	Note
Camera & Button Panel Proportions	Scale concerns noted; collapse feature resolves	Note
Overall Interface Reception	"Almost perfect" — strong positive reception	Pass

Design Recommendations

Priority 1 — Expansion Control Discoverability
Improve the affordance, placement, or visual prominence of the expansion trigger. Consistent gap acr oss both sessions.

Priority 2 — Warning Indicator Redesign
Replace static dark red with flashing amber or white. Preserve static red exclusively for shutdown-c ritical safety states.

Priority 3 — Bucket Weight Visual Hierarchy
Increase visual distinction between Bucket Weight and Predicted Total via label, size, or iconograph ic differentiation.

Priority 4 — Reset / Truck Store Terminology
Conduct one additional operator test to determine whether "Reset" or "Truck Store" better supports w orkflow trust.

Priority 5 — Camera & Panel Proportions
Evaluate camera-to-overlay proportion. Prioritize collapse feature discoverability to mitigate butto n panel weight.

TESTING OUTCOME
Core functionality — state recognition, payload comprehension, threshold communication, and action clarity — performed at or above expectations. The primary actionable gap is expansion control discoverability. The interface is validated as ready for the next round of operator testing.