Definitional Exit and Ratio Calcification: Two Failure Modes of Labour-Defined Statutory Categories Under Automation

A registry of United States regulatory headcount floors, and what four historical contests establish about how they resolve

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Companion files: floor registry and precedent database (`floors_v1.py`); Denver-Boulder autonomous ride-hail case study

ABSTRACT

A large body of United States law and contract defines obligations by reference to a human worker performing a task. Such categories fail under automation, and they fail in two opposite directions that have not, to our knowledge, been treated together.

Definitional exit occurs when an obligation attaching to a human role simply ceases to attach once the role is automated. No actor decides this. No proceeding opens. No dispute arises, because a dispute requires a party with standing and a grievance, and the disappearance of an obligation creates neither. **Ratio calcification** is the mirror image: a rule setting employment as a ratio to a served population becomes economically binding as worker productivity rises, producing a contest that is loud, well-documented, and slow.

We catalogue **11.8 million** United States workers in sectors carrying an explicit headcount floor, of which **10.5 million** sit behind a floor that binds today. All four bases on which these floors rest (statutory, regulatory, contractual, licensing) are political rather than economic: productivity does not move them, and a legislature, agency or bargaining table can.

Four historical ratio contests are examined. The median time to resolution among settled cases is **20 years**, and in every settled case the resolving mechanism was attrition or capital replacement rather than argument about whether the role remained necessary. We identify the United States military as the pure boundary case: a statutory floor binding at one hundred percent produces approximately 23% task reallocation with zero displacement, which is the cleanest available natural experiment in what a fully binding floor does.

We recommend that jurisdictions audit their statute books for operative categories defined by the presence of a human worker. Such an audit is inexpensive, sits within existing executive authority, and requires no position on whether automation is desirable. We do *not* recommend removing any floor: several encode substantive safety findings, and the analysis here is about how categories behave, not about whether they should exist.

1. The problem

Automation is usually analysed as an economic event: tasks move from labour to capital, costs fall, employment adjusts. That framing misses a class of consequence that is legal rather than economic and that operates on a different clock.

Consider a fee that attaches to a service connecting riders to *drivers*. A driverless fleet does not fit the language. The fee does not attach. No one has decided that it should not attach; no agency has waived it; no operator has argued for exemption. The obligation has simply stopped applying, because the operative noun in the statute describes a person who is no longer present.

Now consider a rule requiring one nurse per four patients on a given unit. Automation of some nursing tasks does not make the rule inapplicable, it makes it *expensive*. The nurse becomes more productive; the ratio does not move; the gap between what is required and what is economically necessary widens. That produces a dispute, and the dispute is loud.

Both are the same underlying object failing: a legal category whose operative terms presume a human worker. They fail in opposite directions, on different timescales, with different detectability. This paper treats them together because doing so yields a single diagnostic question that a legislature can ask of its own statute book, and because the two failure modes require opposite institutional responses.

Figure 1. Two failure modes of a labour-defined statutory category

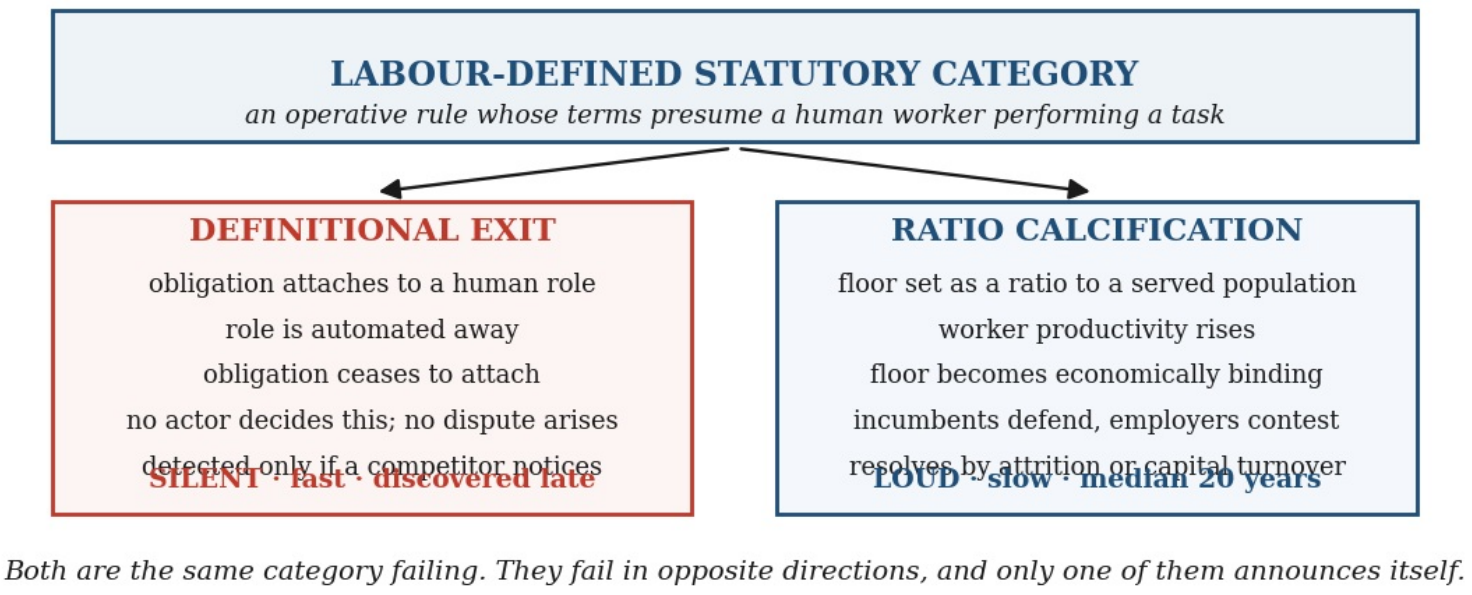

Figure 1. The two failure modes. Both begin from the same category and diverge according to whether the human worker disappears entirely or merely becomes more productive.

2. Definitional exit

The mechanism is best shown in a live instance. Colorado imposes a per-ride fee on transportation network companies, defined in Title 40 around an entity using a digital network to connect riders to *drivers*. In July 2026 an autonomous operator began rider-only service in Denver. On the statutory text a driverless service is not a transportation network company, and the fee does not attach.

What makes the case instructive is not the gap but the *response* to it. The operator did not seek an exemption or a declaratory ruling. It obtained a luxury limousine permit, a Limited Regulation Carrier authorisation that presumes prearranged, app-dispatched service, is not rate-regulated, and carries none of the minimum-fare or public-service obligations attached to taxi operation. The Public Utilities Commission granted it. Incumbent taxi operators intervened within days, against a related vehicle waiver rather than against the classification itself.

> **Finding 1.** The consequence of a definitional gap is not a regulatory vacuum. It is *category substitution*: the operator locates the nearest existing category that fits, and proceeds. This is materially harder to detect than an absence, because service operates, a permit exists, an agency has acted, and the statutory purpose has quietly stopped being served. Nothing appears to be wrong.
>
> Detection in this instance came from a competitor bearing the heavier obligations, not from the regulator and not from the public. That is a fragile and accidental mechanism, and it exists only where an incumbent survives to notice. In a sector without one, or in an unbounded software deployment, there may be no party positioned to raise the objection at all.

3. The floor registry

The second failure mode requires knowing where floors exist. We catalogue sectors in which employment is set by a ratio to a served population rather than by output volume.

Figure 2. 11.8 million US workers sit behind an explicit headcount floor; 10.5 million bind today

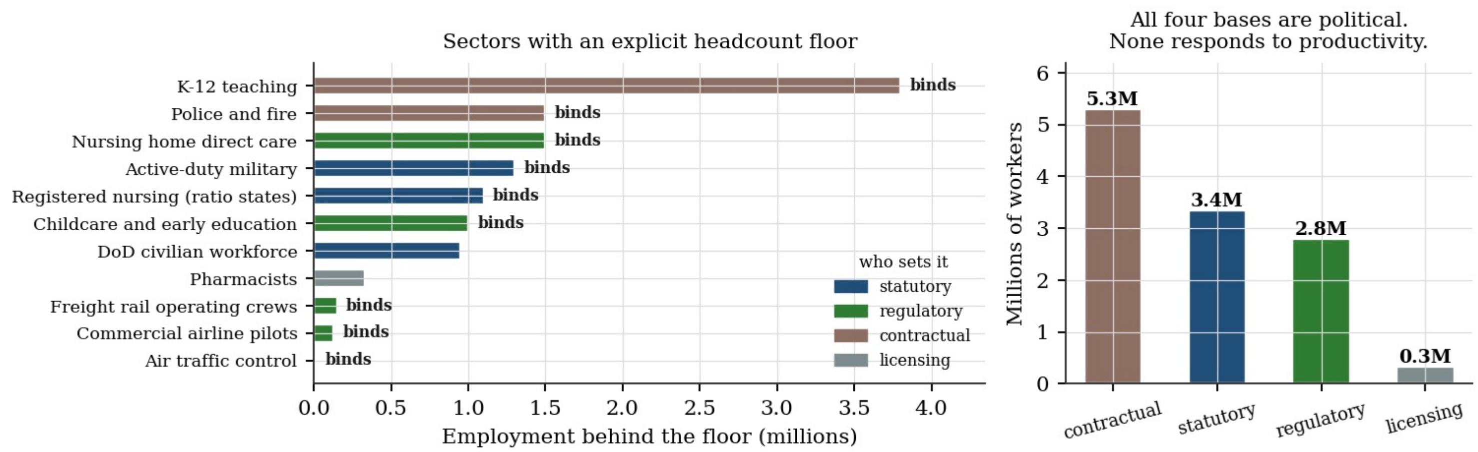

Figure 2. Employment behind explicit headcount floors, by sector and by the basis on which the floor is set. Bars marked "binds" are floors that constrain today rather than sitting slack.

Sector	Employment	Floor	Basis	Set by	Rule	Contest	Binds
K-12 teaching	3,800,000	92%	contractual	State law and district bargaining	Enrolment divided by contractual class size, plus the custodial requirement that an adult be present.	moderate	yes
Nursing home direct care	1,500,000	88%	regulatory	CMS minimum staffing standards	Minimum hours of direct nursing care per resident day.	high	yes
Police and fire	1,500,000	93%	contractual	Municipal charter, ordinance, union agreement	Minimum staffing per shift, per apparatus, per district.	moderate	yes
Active-duty military	1,300,000	100%	statutory	Congress, annual NDAA	End-strength is voted as a number. Not a ratio to anything.	low	yes
Registered nursing (ratio states)	1,100,000	90%	statutory	State legislatures; California AB 394 is the template	Minimum nurse-to-patient ratios by unit acuity.	low	yes
Childcare and early education	1,000,000	95%	regulatory	State licensing	Staff-to-child ratios by age band.	low	yes
DoD civilian workforce	950,000	85%	statutory	Congress, appropriations and caps	Civilian personnel ceilings and floors set in authorisation language.	moderate	no
Pharmacists	330,000	85%	licensing	State boards of pharmacy	Pharmacist-on-duty requirements and technician supervision ratios.	moderate	no
Freight rail operating crews	150,000	90%	regulatory	FRA rulemaking and union agreements	Two-person crew requirements.	high	yes
Commercial airline pilots	130,000	100%	regulatory	FAA, 14 CFR	Two-pilot minimum crew for transport-category aircraft.	low	yes
Air traffic control	14,000	95%	regulatory	FAA staffing standards	Controller-to-position and facility staffing minimums.	low	yes

3.1 All four bases are political

Basis	Employment	Character
`statutory`	3.4M	Set in legislation. Changing it requires a legislative act.
`regulatory`	2.8M	Set by an agency rule. Changeable through rulemaking, with notice and comment.
`contractual`	5.3M	Set in collective bargaining. Changeable at contract renewal, with leverage.
`licensing`	0.3M	Set by a professional or licensing body, often with statutory backing.
`physical`	0.0M	Set by the nature of the work. NOT a choice variable at all, and should never be reasoned about as though it were political.

The distinction that matters is not statutory versus regulatory but political versus physical. A class-size rule is a choice; a legislature can change it. The requirement that an adult be physically present with small children is not a choice, and should never be reasoned about as though it were. Childcare sits at that boundary and is recorded here as regulatory, with the caveat noted, precisely because the regulatory rule and the physical constraint nearly coincide.

> **Finding 2.** 11.8 million United States workers, roughly seven percent of employment, sit behind an explicit headcount floor, and 10.5 million behind one that binds today. In these sectors the employment consequence of automation is not determined by economics. It is determined by whether the floor holds, which is a political question with a political answer.

4. Ratio calcification, and how contests resolve

A floor set for one technology becomes costly under another. The resulting contest is nothing like definitional exit: it is public, adversarial, well-documented, and slow. Four cases are instructive, three settled and one live.

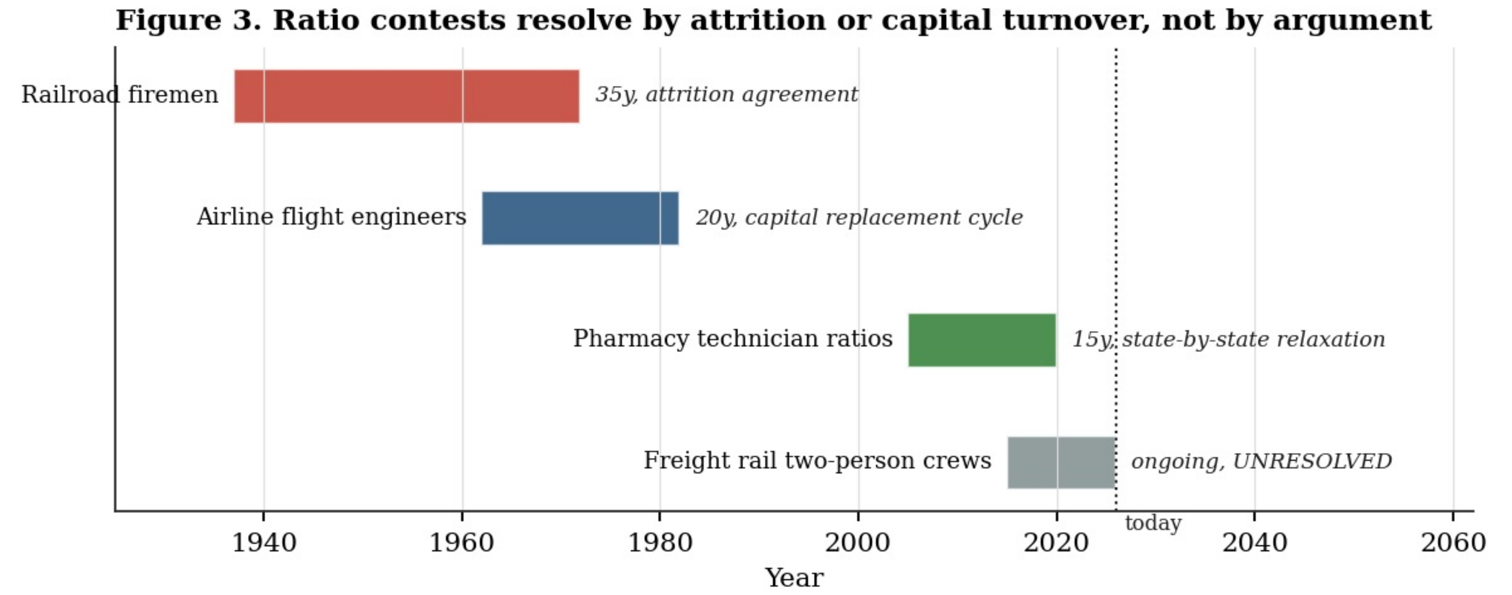

Figure 3. Four ratio contests. In each settled case the resolving mechanism was attrition or capital turnover.

Case	Duration	Trigger	Resolution	Lesson
Railroad firemen 1937-1972	35 yr	Diesel locomotives removed the task the role existed to perform.	Resolved by attrition agreement, not by argument. Existing firemen kept their positions; the role was closed to new entrants. Took roughly three decades from technical obsolescence to full resolution.	*The floor did not fall. It was allowed to decay through hiring freeze.*
Airline flight engineers 1960s-1980s	20 yr	Two-person cockpit certification made the third seat unnecessary.	Presidential commission, then aircraft-by-aircraft certification. New aircraft types were certified for two; existing fleets kept three until retired.	*Resolution followed the CAPITAL replacement cycle, not the labour argument. The fleet turned over and the issue disappeared.*
Pharmacy technician ratios 2000s-present	15 yr	Automated dispensing changed what supervision meant.	Gradual state-by-state relaxation of technician-to-pharmacist ratios, without changing the pharmacist-on-duty requirement.	*The floor moved on the SUPPORTING role while the credentialed role held. Ratios are more contestable than licences.*
Freight rail two-person crews 2015-present	ongoing	Positive train control and remote monitoring.	UNRESOLVED. Federal rulemaking has moved in both directions across administrations; state laws conflict.	*Live case. Watch this one, because it is the closest running analogue to what automation will trigger elsewhere.*

Finding 3. Median time to resolution among settled cases is **20 years**, and in none of them did the contest resolve on the merits of whether the role remained necessary. Railroad firemen were not argued out of existence; the role was closed to new entrants and allowed to decay through hiring freeze over three decades. Flight engineers were not persuaded away; new aircraft were certified for two-person cockpits and existing fleets kept three until they retired. The resolving mechanism was *attrition or capital replacement* in every case.

The flight-engineer precedent is the most transferable, because it identifies the clock. That contest resolved on the fleet turnover cycle, not on the labour argument. Where automation arrives through new capital, the capital cycle sets the pace. Where it arrives as software with no equipment to replace, the mechanism that historically resolved these disputes is absent, which could mean faster resolution, or could mean no resolution at all and an indefinite standoff.

The pharmacy case adds a refinement worth noting: the floor moved on the *supporting* role while the credentialed role held entirely. Technician-to-pharmacist ratios were relaxed state by state; the pharmacist-on-duty requirement was not touched. Ratios attached to unlicensed support staff appear substantially more contestable than requirements attached to a licence.

Freight rail two-person crews is the live case and the closest running analogue to what automation will trigger elsewhere. It has been in active dispute for over a decade, federal rulemaking has moved in both directions across administrations, and state laws conflict. Anyone wishing to forecast how an automation-driven staffing contest will proceed should watch it.

5. The pure case: a floor binding at one hundred percent

The United States military is the cleanest available natural experiment, because every economic mechanism is suppressed simultaneously. Active-duty end-strength is voted annually by Congress as a number, not derived from a ratio and not responsive to productivity. There is no price for the output, so no demand curve. There is no customer, so no pass-through. Defence output is measured entirely at input cost in the national accounts, so labour-saving productivity reduces measured output one-for-one.

The consequence is that automation there produces *zero displacement and pure task reallocation*.

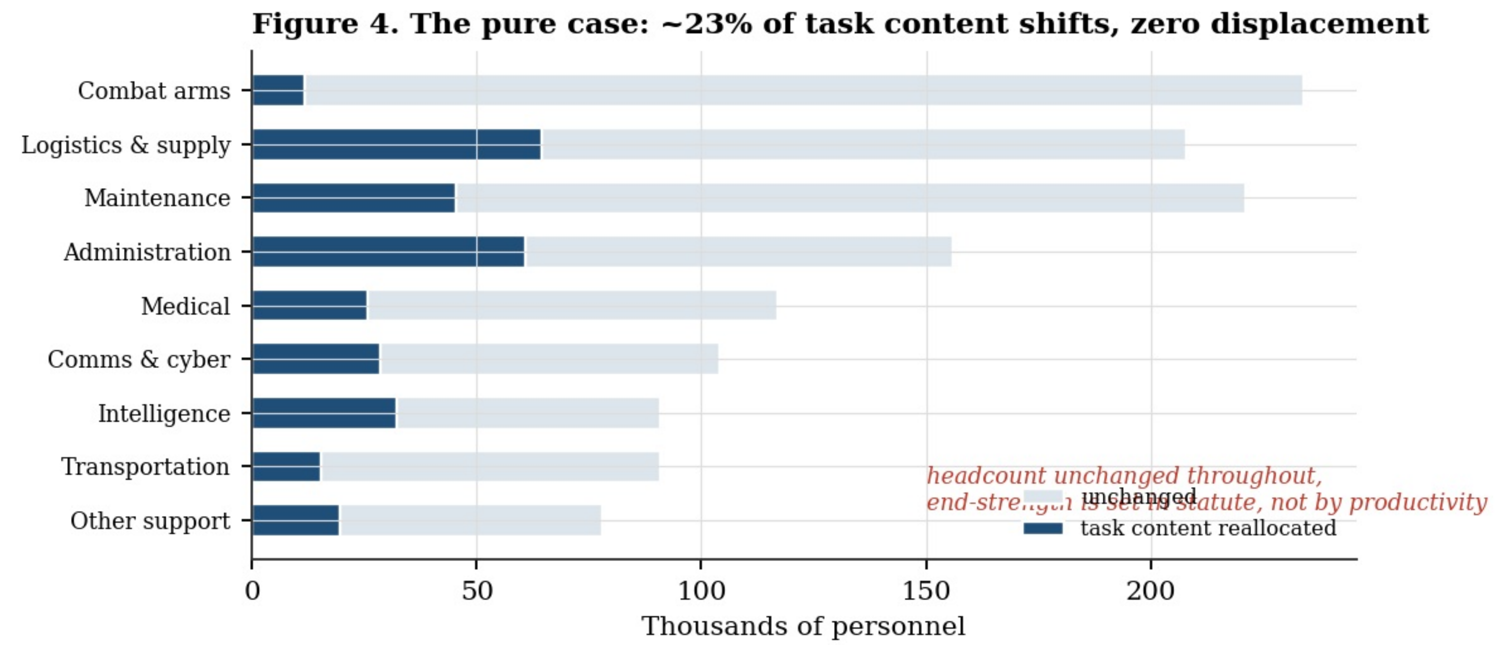

Figure 4. Task content reallocated by specialty family under a statutory headcount floor. Shares and exposure estimates are the authors'; the structural result does not depend on their precise values.

Applying occupational exposure estimates to the specialty mix suggests roughly 23% of active-duty task content shifts while headcount remains unchanged. The tooth-to-tail asymmetry is instructive: direct combat roles are the *least* exposed, while the support functions constituting the large majority of the force (logistics, administration, intelligence analysis, maintenance) are heavily exposed. The tail does not shrink. It changes what it does.

Finding 4. The defence record is also the strongest available evidence on reinstatement. Sensor and surveillance proliferation *increased* analyst demand rather than reducing it, because more collection produced more material requiring human judgement. Uncrewed aviation did not shrink air forces; it created operators, sensor operators, maintainers and mission coordinators as new career fields. Each automation wave has been absorbed as specialty-mix change inside a roughly constant congressionally-set headcount.

This is task reinstatement running at a ratio near unity *because the institutional constraint forces it to*. It is what a fully binding floor produces: the people stay, the tasks change, and the composition shifts entirely.

6. Implications

6.1 The audit

The practical recommendation is narrow and cheap. A jurisdiction should direct each principal department to identify statutes and rules whose operative category presumes a human worker, and report which of those are load-bearing. Departments know their own statutes; a central body does not.

Two properties make this unusually easy to justify. It requires *no position* on whether automation is desirable, or on when it will arrive, or in which sectors. And it produces a prioritised list for a legislature rather than an open-ended request, which is the difference between an actionable finding and a study.

The audit should look for *both* failure modes. Definitional exit is the harder to find, because nothing appears wrong: the search is for obligations whose operative noun names a person. Ratio calcification is easier to spot but slower to fix, and the twenty-year median suggests that identifying which floors will bind is worth doing well before they do.

6.2 A tension that does not resolve

The same institutional features that make an automation transition socially manageable make it commercially harder to fund. Floors convert displacement into task reallocation, the military case is 23% task churn with zero job loss, which is a shock absorber working exactly as designed. It is also a mechanism by which labour cost savings never materialise, and therefore never become available to pay a technology vendor.

A policymaker concerned with transition stability should want floors. An investor underwriting an automation buildout against displaced labour cost should read them as a headwind. Both positions are correct simultaneously. Treating this as a contradiction to be resolved, rather than as a genuine trade-off with two defensible sides, is how the question gets argued badly.

6.3 What the floors do not block

Floors block the *displacement* channel. They do not block augmentation. A teacher who prepares lessons faster is still worth a licence fee, and a district can purchase one without altering headcount. Where a floor binds, the economic effect of automation appears as improved service or reduced workload rather than as reduced employment, which is invisible in employment statistics and, in cost-measured sectors, invisible in output statistics as well.

7. Limitations

1. **Employment figures are approximate** and drawn from secondary compilation. They should be replaced with Bureau of Labor Statistics occupational data before any figure here is quoted.
2. **Floor shares are judgements.** The share of employment that cannot fall is estimated, not measured. The K-12 figure of 92% implies an eight percent reduction is achievable within a decade; a figure of 85% would nearly double the modelled effect. These values carry real weight and no empirical backing beyond reasoning about class-size rules and contractual practice.
3. **The registry is not exhaustive.** It covers sectors we identified; others certainly exist, particularly in state-level licensing and municipal ordinance.
4. **Novelty is not established.** An evidence review found extensive sector-specific literatures (nurse-patient ratios, class size, the two-pilot rule) but no unified treatment of regulatory headcount floors as a single category with automation interaction. That is weak evidence of novelty and should be read as "not found to duplicate" rather than "confirmed original."
5. **The military exposure estimates are ours.** Specialty shares and exposure scores are constructed, not sourced. The structural finding, that a statutory floor produces reallocation rather than displacement: does not depend on them, but the 23% figure does.
6. **This is not legal advice**, and the classification questions raised in Section 2 require counsel and agency interpretation in the relevant jurisdiction.
7. **No position is taken on whether any floor should exist.** Several encode substantive safety findings supported by outcome evidence, particularly in nursing and childcare. The analysis concerns how categories behave under automation, not whether they are justified.

8. Conclusion

Legal and economic frameworks that define a service by the presence of a human worker do not fail gracefully when the worker is removed, and they do not fail in a single direction. One failure mode is silent, fast, and detected only by accident. The other is loud, slow, and resolved by attrition over roughly two decades rather than by any argument about necessity.

Roughly seven percent of United States employment sits behind an explicit floor of the second kind. In those sectors the employment consequence of automation is a political outcome rather than an economic one, and the historical record suggests it will be settled by hiring freezes and equipment replacement cycles rather than by evidence.

The recommendation that follows is modest and should be uncontroversial: find out which categories in the statute book are defined by the presence of a human worker, and which of those matter. The exercise costs little, requires no forecast, and has the useful property that it is worth doing whether or not any particular prediction about automation turns out to be correct.

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27 July 2026. Working paper, not legal advice. Quantitative results are conditional on the registry and estimates documented in the companion file, which permits full inspection and re-parameterisation.