Technical Digest

Sprint 4 Findings Interpreted via **Management Cybernetics**

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1 ▸ Cybernetic Framing of the Simulated Enterprise

VSM Layer	Simulation Proxy	AI Role (Variety Function)
System 1 Operations	Employee agents + primary tasks	*Amplification* of local adaptation via AI-driven role reassignments
System 2 Coordination	Manager override gate	*Attenuation* of oscillations between teams (dampening conflict)
System 3 Internal Control	AI efficiency algorithm & KPIs	Real-time resource reallocation; enforces norms
System 3* Audit	Bias-mitigation toggles & ethical flags	Independent compliance loop; prevents pathological shortcuts
System 4 Intelligence	Environmental volatility module	Generates exogenous variety; AI forecasts but humans scan wider context
System 5 Policy	Fixed organisational purpose encoded in productivity + morale goals	Strategic “identity” hard-coded; not varied in current model

Implication: High AI autonomy injects additional *System-1* variety; the override mechanism compensates by strengthening *System-2* damping, preserving homeostasis.

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2 ▸ Law of Requisite Variety – Quantitative Check

$$VD \geq VS - VRV_D \geq V_S - V_R$$

Where:

- Decision-variety (manager + AI):

$$VDV_D$$

- Situation-variety (market volatility, workforce states):

$$VSV_S$$

- Regulatory variety (bias filters, policy caps):

$$VRV_R$$

Scenario	VSV_{S} (entropy proxy)	VDV_{D}	Outcome
Low vol., high autonomy	0.42	**0.68**	Surplus variety → positive performance
High vol., high autonomy	0.71	0.68	Variety deficit → morale collapse (−15 %)
High vol., autonomy + override	0.71	**0.74**	Deficit closed; exits cut 12 %

Override channel adds ≈ 0.06 bits of regulatory variety, sufficient to satisfy the law under turbulence.

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3 ▸ Control-Loop Diagnostics

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        ↻  ❶ Sense      ↻
Environment → AI (S3) → Proposal  ⇢  Manager (S2) ⇢  Action → Workforce
                  ↑ Feedback ❷          ↑ Feedback ❸          ↑
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- **Loop ❶ (Predictive):** 5-tick cadence; accuracy noise added in v0.3 prevents lock-in.
- **Loop ❷ (Audit):** Bias-mitigation injects 0.84 attenuation coefficient, reducing unethical variety.
- **Loop ❸ (Sentiment):** Morale lag (5 ticks) functions as early-warning stabiliser; triggers override escalation.

Stability criterion (dominant eigen-value < 1) is met in all configurations except *high-autonomy* + *high-volatility* without overrides ($\lambda_1 \approx 1.08$).

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4 ▸ Performance Vector in Cybernetic Terms

$$P = [Productivity Morale Retention] \Delta P = A\,\Delta V \mathbf{P} = \begin{bmatrix} \text{Productivity} \\ \text{Morale} \\ \text{Retention} \end{bmatrix} \qquad \Delta \mathbf{P} = \mathbf{A}\,\Delta \mathbf{V}$$

Estimated linearised gain matrix **A** (standardised coefficients):

	ΔAutonomy	ΔOverride	ΔBias-Mit.	ΔVolatility
Productivity	**+0.21**	−0.14	+0.05	**−0.32**
Morale	+0.24	−0.17	+0.07	**−0.38**
Retention (–)	−0.09	+0.06	**−0.12**	+0.18

Diagonal dominance indicates direct effects outweigh cross-couplings; thus single-lever interventions are tractable.

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5 ▸ Cybernetic Policy Recommendations

1. **Dynamic Variety Balancing**
   Implement an adaptive override throttle (δ override ± 0.2) based on real-time entropy of external signals, ensuring

   $$VD \geq VSV_D \geq V_S$$

   at all times.
2. **Ethical Feedback as Viability Safeguard**
   Bias-mitigation acts as *System 3** audit; keep it permanently engaged to damp pathological attractors (biased layoffs) without harming throughput.
3. **Turbulence-Triggered Mode Shifts**
   Under

   $$VS > 0.6V_S > 0.6$$

   (high volatility), switch AI from *directive* to *advisory* mode (autonomy cap 0.6) and elevate manager damping; revert when volatility subsides.
4. **Sentiment-Driven Early Warning**
   Integrate morale sensor into *System 2*; if 5-tick moving average falls > 0.05, automatically raise override probability to cushion human factors.
5. **Recursive Governance**
   Extend the model to subsidiary units (System-1 recursion) so that local AI agents feed consolidated signals to corporate *System 4* intelligence for strategic foresight.

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6 ▸ Limitations & Cybernetic Research Extensions

- Model treats *identity* (System 5) as static; future work should endogenise mission drift.
- Feedback delays are fixed; real firms exhibit variable lags—recommend Kalman-filter enrichment.

- Law-of-Requisite-Variety evaluated via entropy proxy; richer information-theoretic measures (e.g., transfer entropy) could refine variety accounting.

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7 ▸ Implementation Blueprint: From Model Insight to Cybernetic Governance

Phase	Duration	Key Actions	Cybernetic Objective	Success Indicator	
1. Diagnostic Baseline	4 weeks	• Map real process flows to VSM layers • Capture live KPIs (morale, cycle-time, exits)	Establish current variety profile VSV_S	Baseline entropy map complete	
2. Pilot Bounded-Autonomy AI	8 weeks	• Deploy AI agent in one business unit • Set autonomy = 0.6, override = 0.4, bias filter = on	Test “amplify + attenuate” loop	Morale ≥ 0.65, productivity ≥ 0.70	
3. Adaptive Override Engine	12 weeks	• Build entropy-aware rule: If rolling volatility > 0.6 ⇒ override + 0.2 Else override − 0.2 (min 0.1, max 0.8)	Real-time variety balance	≤ 5 % morale drop during shocks	
4. Recursive Roll-out	16 weeks	• Replicate AI & override logic to each System-1 unit • Aggregate KPIs to corporate System-4 dashboard	Multi-layer viability	Entropy gap $VD - VS \geq 0$ $V_D - V_S \geq 0$ for 90 % of weeks	
5. Integrative Audit Layer	ongoing	• Ethics / bias board reviews AI outputs monthly • Feed findings back to AI learning loop	Strengthen System-3* compliance	Audit non-conformities ≤ 2 %	

Governance cadence: quarterly strategic review (System 5) to recalibrate autonomy ceilings and bias thresholds against long-term identity goals.

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8 ▸ KPI Mapping to Cybernetic Control Loops

Control Loop	Sensor KPI	Set-point	Effector	Escalation Rule
Predictive (Loop 1)	Forecast error (RMSE)	≤ 10 %	Retrain AI model	If > 10 % for 3 ticks → retraining
Damping (Loop 2)	Restructuring oscillation index	≤ 0.15	Override probability	If > 0.15 → +0.2 override
Audit (Loop 3)*	Bias incidence rate	0 violations	Bias filter strictness	Any violation → policy rollback
Sentiment	Morale 5-tick MA	≥ 0.65	Communication intensity	< 0.60 → emergency town-hall
Viability	Variety gap $VD - VSV_D - V_S$	≥ 0	Autonomy / override adjuster	Gap < 0 → invoke “Mode-Safe” (AI advisory mode)

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9 ▸ Quantitative Viability Index (QVI)

Define:

$$QVI = w1(Prod^{-}\underbrace{}Performance) + w2(1 - ExitRate^{-}) + w3(Morale^{-}) - w4(|\ VS - VD\ |)\text{QVI} =$$

$$w_1(\ \underbrace{\overline{\text{Prod}}}_{\text{Performance}}\ ) + w_2\big(1 - \overline{\text{ExitRate}}\big) + w_3\big(\overline{\text{Morale}}\big)$$

$$-w_4\big(|V_S - V_D|\big)$$

Weights calibrated to strategic priorities.

Simulation shows QVI improves **12 %** under bounded-autonomy vs. laissez-faire or full override extremes.

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10 ▸ Research Extensions

1. **Kalman-Filtered Variety Estimation** – dynamic state-space modelling of

   $$VSV_S$$

   for finer override triggers.
2. **Multi-Objective Control (Pareto Optimality)** – integrate QVI with cost-of-change metrics.

3. **Digital Twin Recursion** – embed the ABM as a real-time twin inside System-4 for continuous policy testing.

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11 ▸ References

WIENER, Norbert. *Cybernetics: Or Control and Communication in the Animal and the Machine*. 2nd ed. Cambridge, MA: MIT Press, 1961.
ASHBY, W. Ross. *An Introduction to Cybernetics*. London: Chapman & Hall, 1956.
BEER, Stafford. *Diagnosing the System for Organizations*. Chichester: Wiley, 1985.
BEER, Stafford. *Brain of the Firm*. 2nd ed. Chichester: Wiley, 1981.
BEER, Stafford. *The Heart of Enterprise*. Chichester: Wiley, 1979.
ESPEJO, Raúl; REYES, Alfonso. *Organizational Systems: Managing Complexity with the Viable System Model*. Heidelberg: Springer, 2011.
