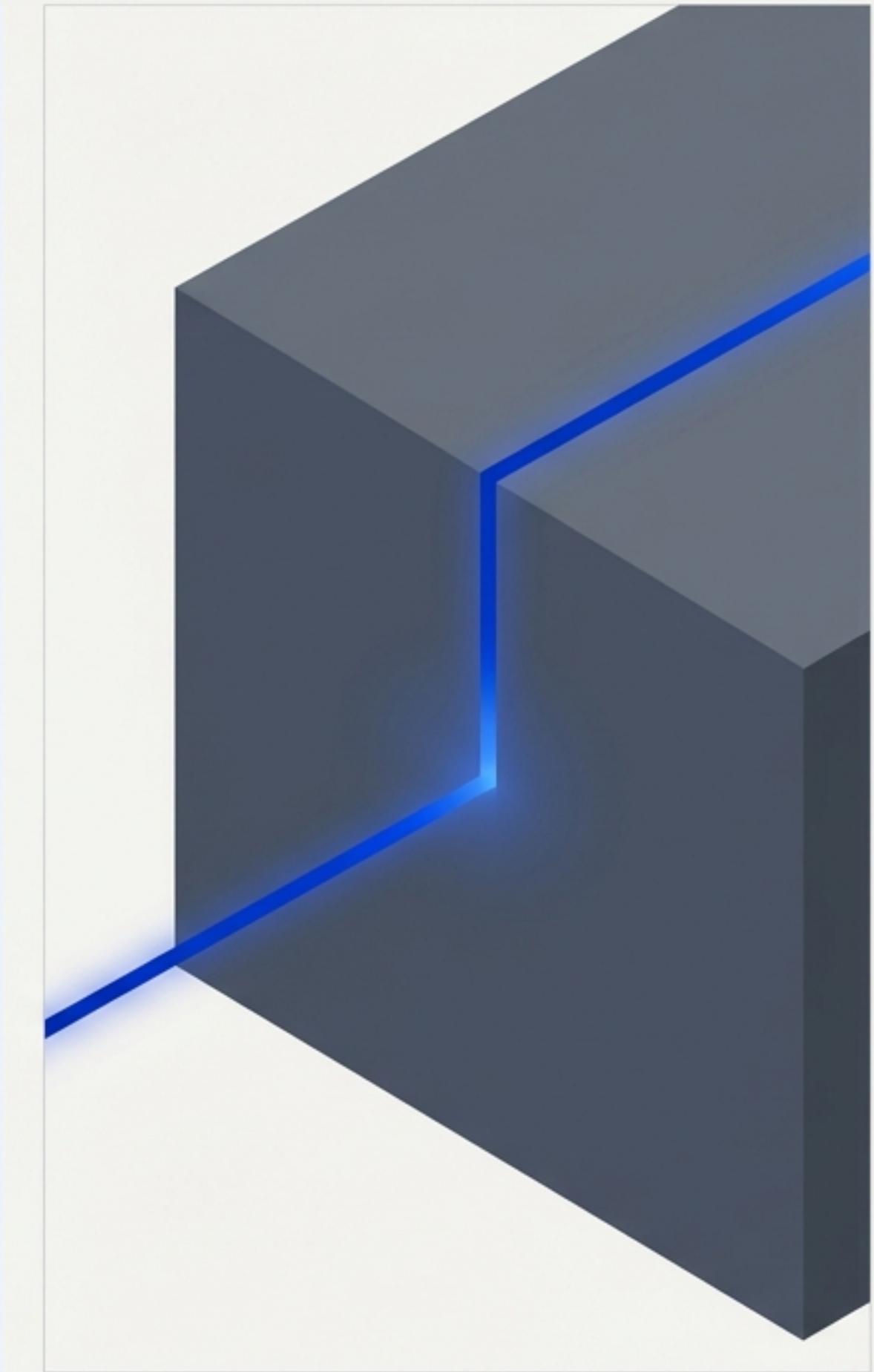


AI-Accelerated Biological Discovery: A Quantitative Forecast (2024–2050)

Identifying Bottlenecks, Predicting Timelines,
and Prioritizing Policy in the Age of AI

MODEL VERSION 1.1 – EXPERT-REVIEWED PARAMETERS (JANUARY 2026)



Executive Summary: The “Reality Gap” in Drug Development

The Forecast

By 2050, AI will compress 74 years of progress into 26 years (2.8x Baseline Acceleration). However, physical constraints limit realized acceleration to ~5.1x over the next decade, even under the aggressive "Amodei Scenario" (10x theoretical target).

2.8X
Baseline

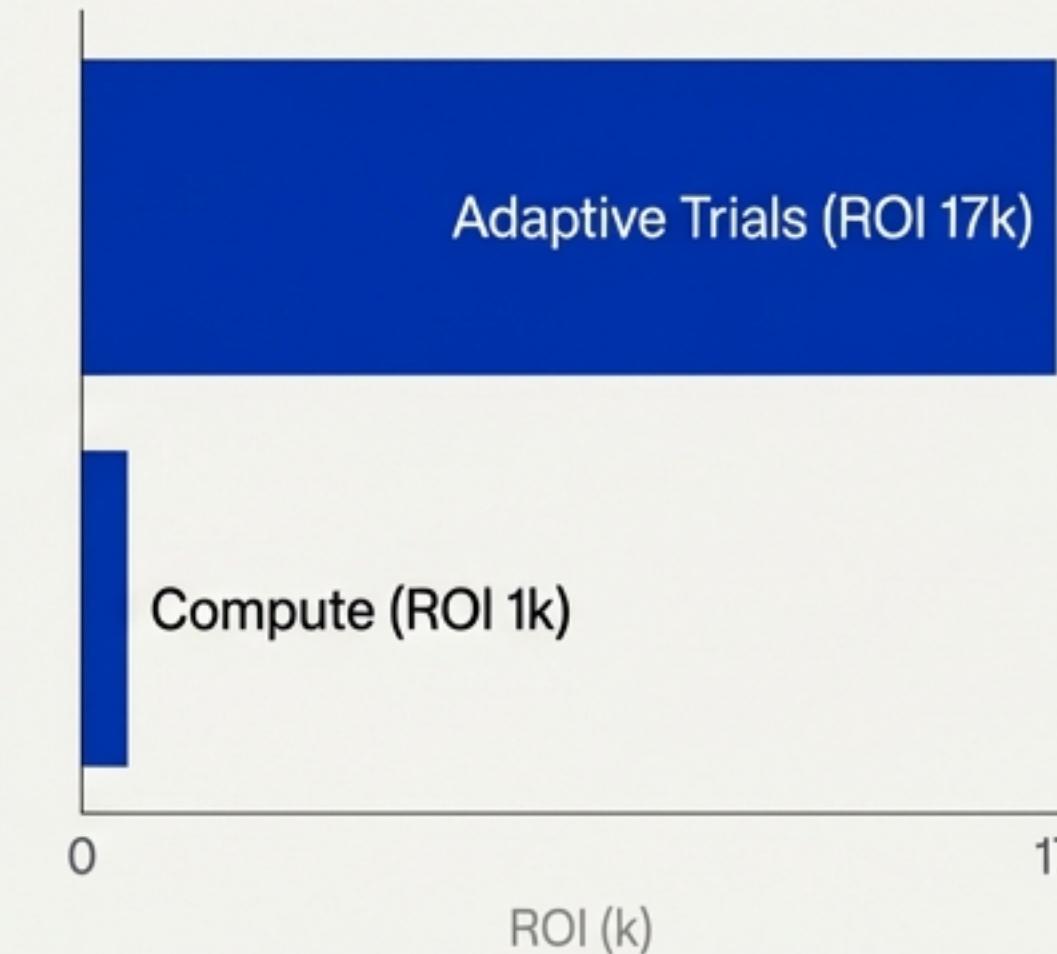
The Bottleneck

Phase II Clinical Trials (Stage 7) remain the persistent rate-limiter. While computational analysis (Stage 4) accelerates ~570x, clinical trials accelerate only ~1.5x to 2.8x due to biological observation times.



The Fix (Policy ROI)

Regulatory Reform, specifically Adaptive Trial Designs, yields 17x higher ROI than purchasing more compute infrastructure. Investment must shift from "faster models" to "flexible regulations".



The Discovery Crisis: Moore's Law vs. Eroom's Law

10-15

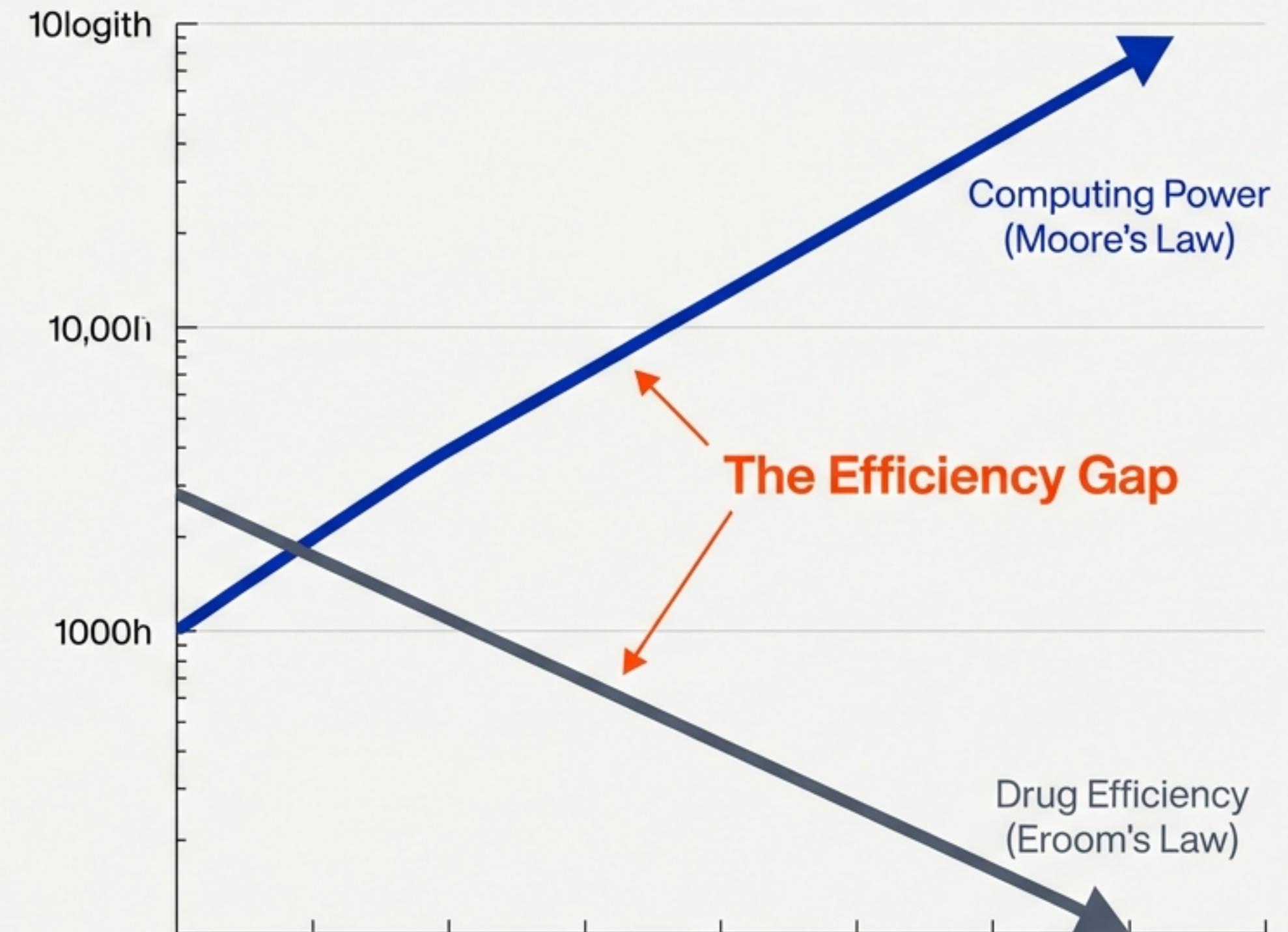
Average time from discovery to market

\$2.6 Billion

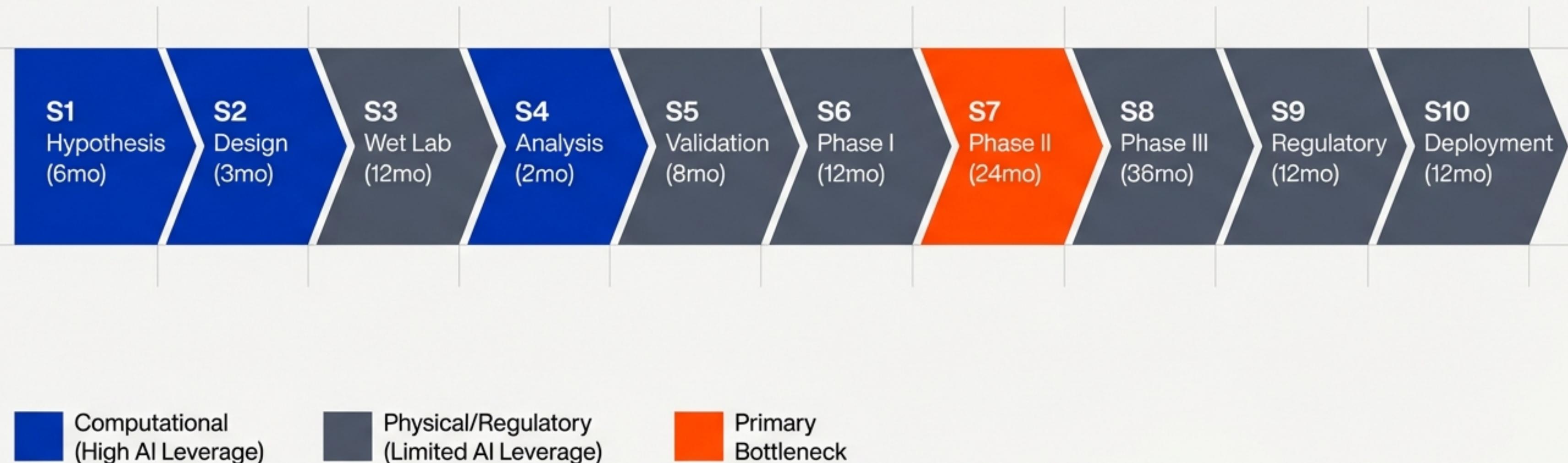
Average cost to develop a single drug

~5%

Overall success rate from Phase I to approval



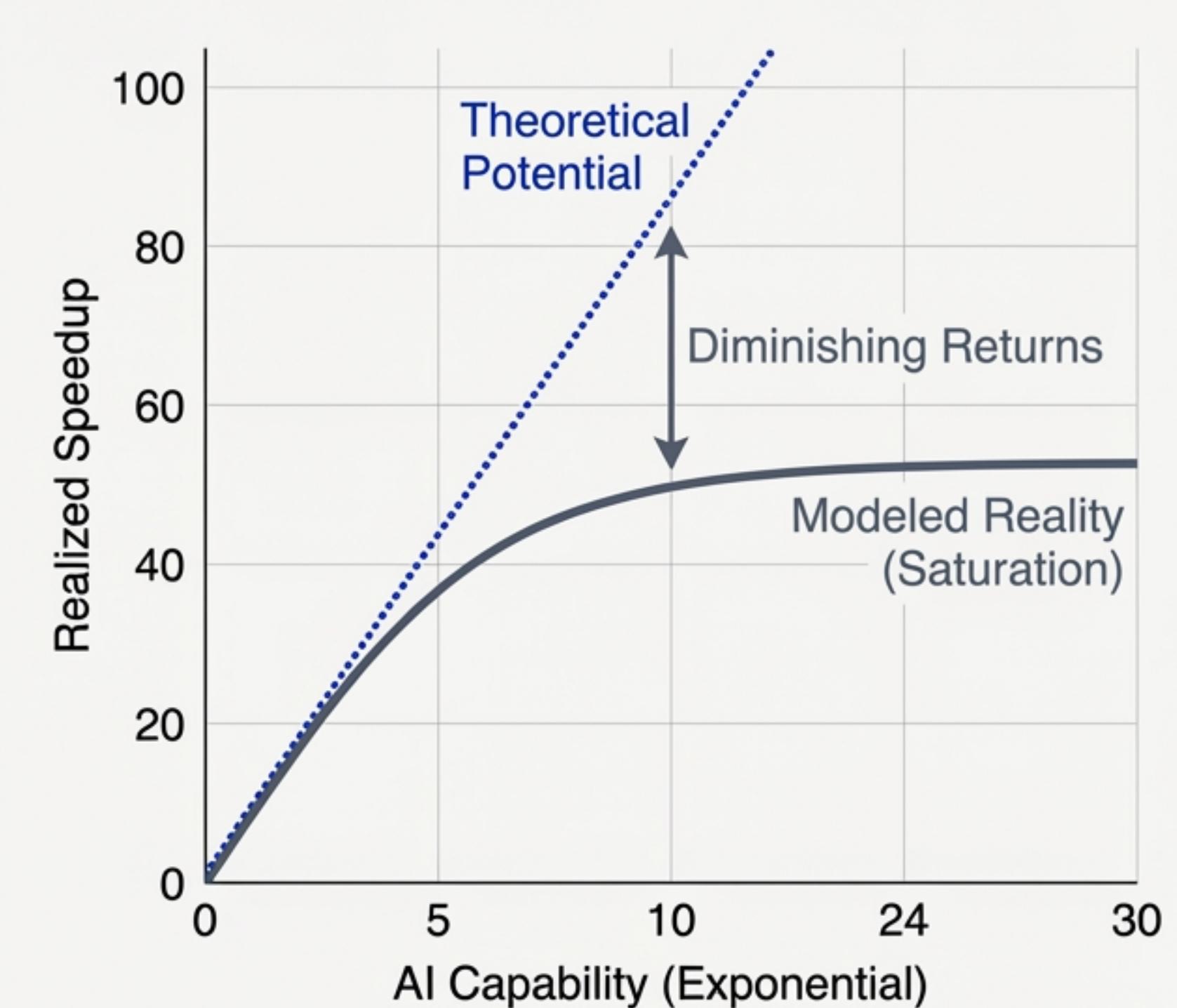
Mapping the Machine: The 10-Stage Discovery Pipeline



The Mathematical Engine: Saturation Dynamics

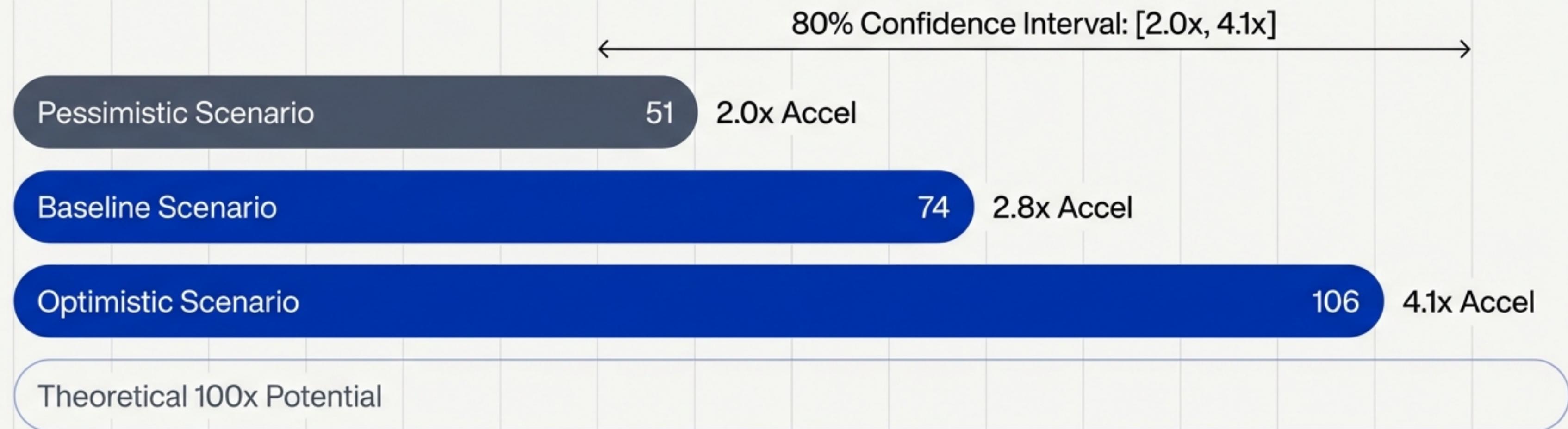
$$M_i(t) = 1 + (M_{\max} - 1) * (1 - A(t)^{-k})$$

- M_{\max} : The physical speed limit (e.g., 100x for Data Analysis, 2.8x for Phase II).
- k : Saturation Rate (How quickly the limit is reached).



The Forecast: The 2.8x Reality (2024–2050)

Equivalent Years of Progress by 2050



Pessimistic: Slow adoption/resistance.

Baseline: Current trends.

Optimistic: Regulatory reform.

The Persistent Bottleneck: Why Phase II Dominates

Stage 4 (Analysis)

570x Faster.
Pure Computation.

VS

Stage 7 (Phase II)

0.46x Effective Rate.
Physical Constraint.

Irreducible Constraints



Human Biology
(Metabolic timescales)



Safety Periods
(Mandatory observation)

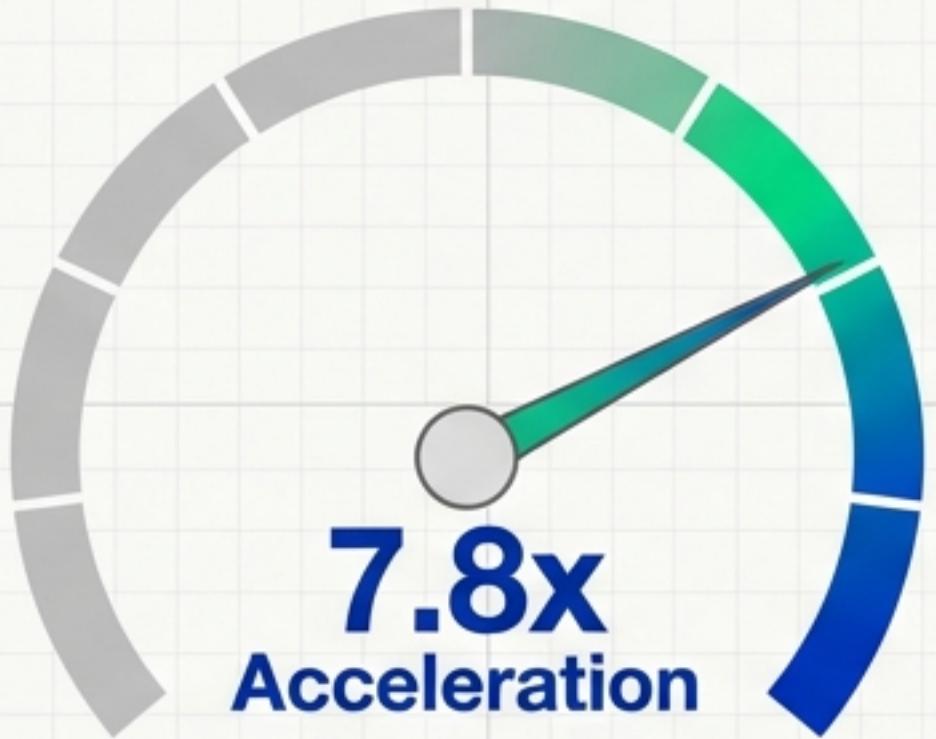


Enrollment
(Recruitment limits)

“Computational stages run ~1,200x faster than clinical stages.”

Asymmetric Acceleration: Not All Diseases Move at the Same Speed

Oncology



Infectious Disease



Alzheimer's / CNS



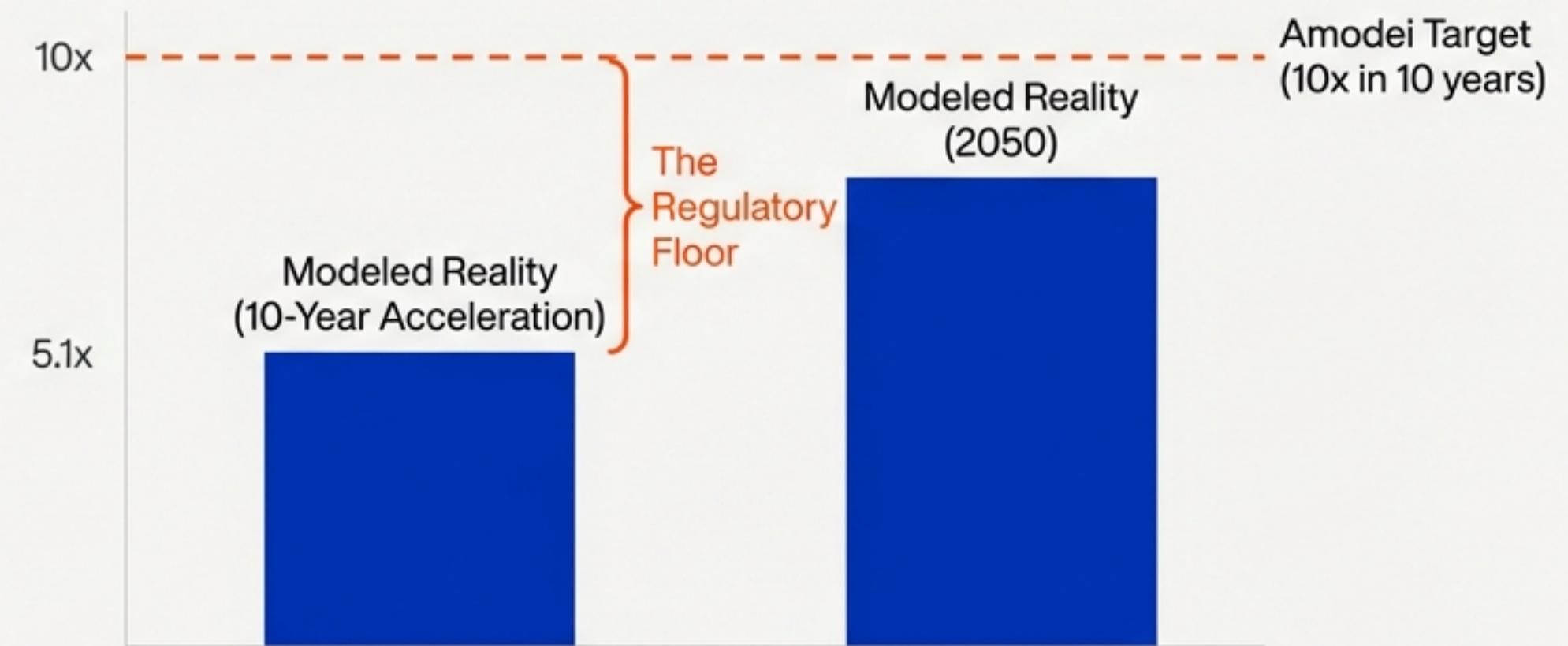
Key Insight: AI acts as a '**Biomarker Engine**'. Fields with digital surrogates accelerate **2x faster** than those relying on behavioral endpoints.

Testing the “Amodei Scenario”: The Limits of Optimism

The Inputs (Upper Bound)

- AI Growth (g) = **0.75**
- Regulatory Reform Cap = **3.5x**
- Parallelization = **1.5x**

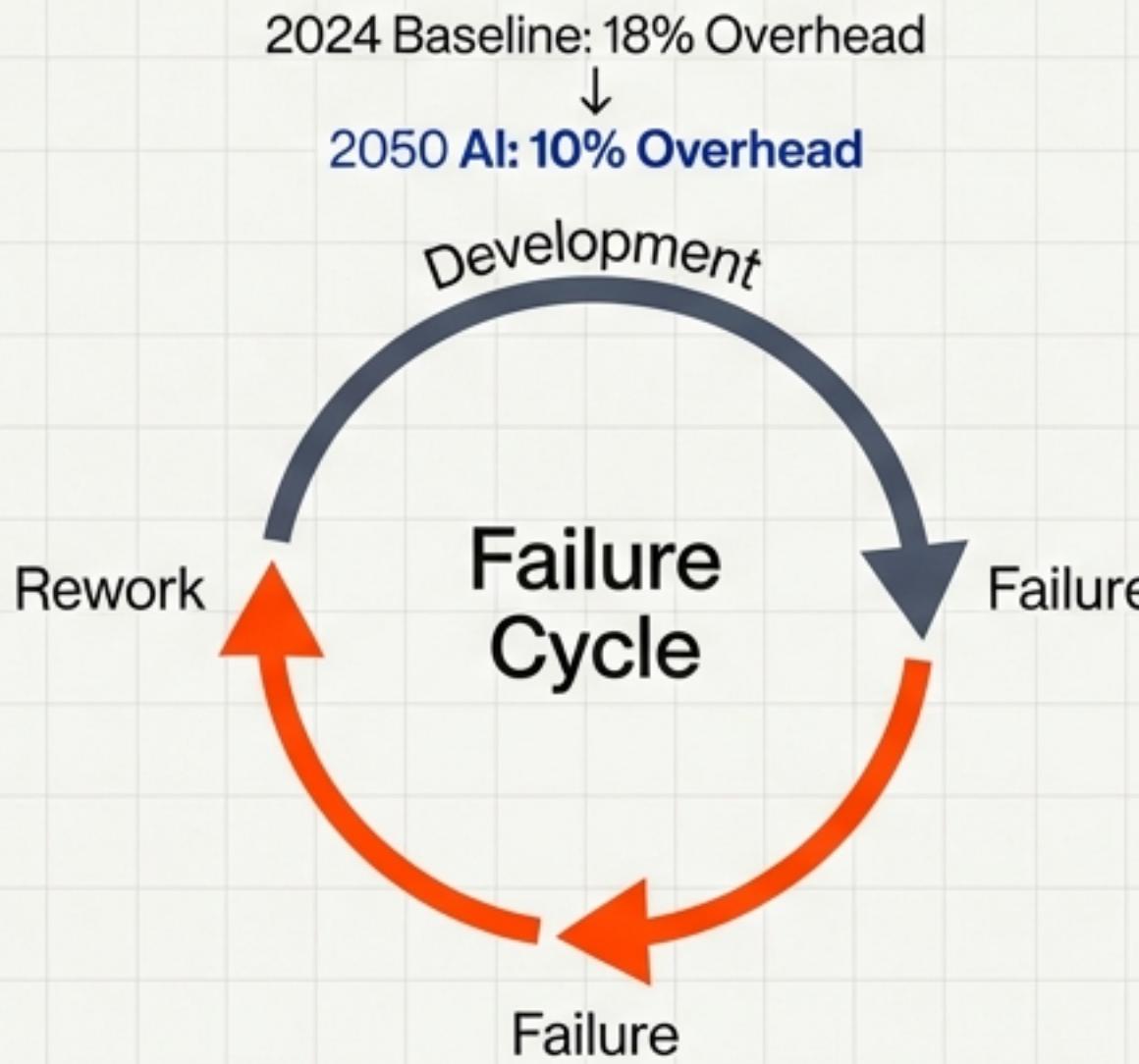
The Results



Even with near-perfect AI and aggressive deregulation, we hit a physical wall. We cannot compress a 2-year safety observation into 2 months without redefining “safety”.

Hidden Constraints: Data Quality & Pipeline Rework

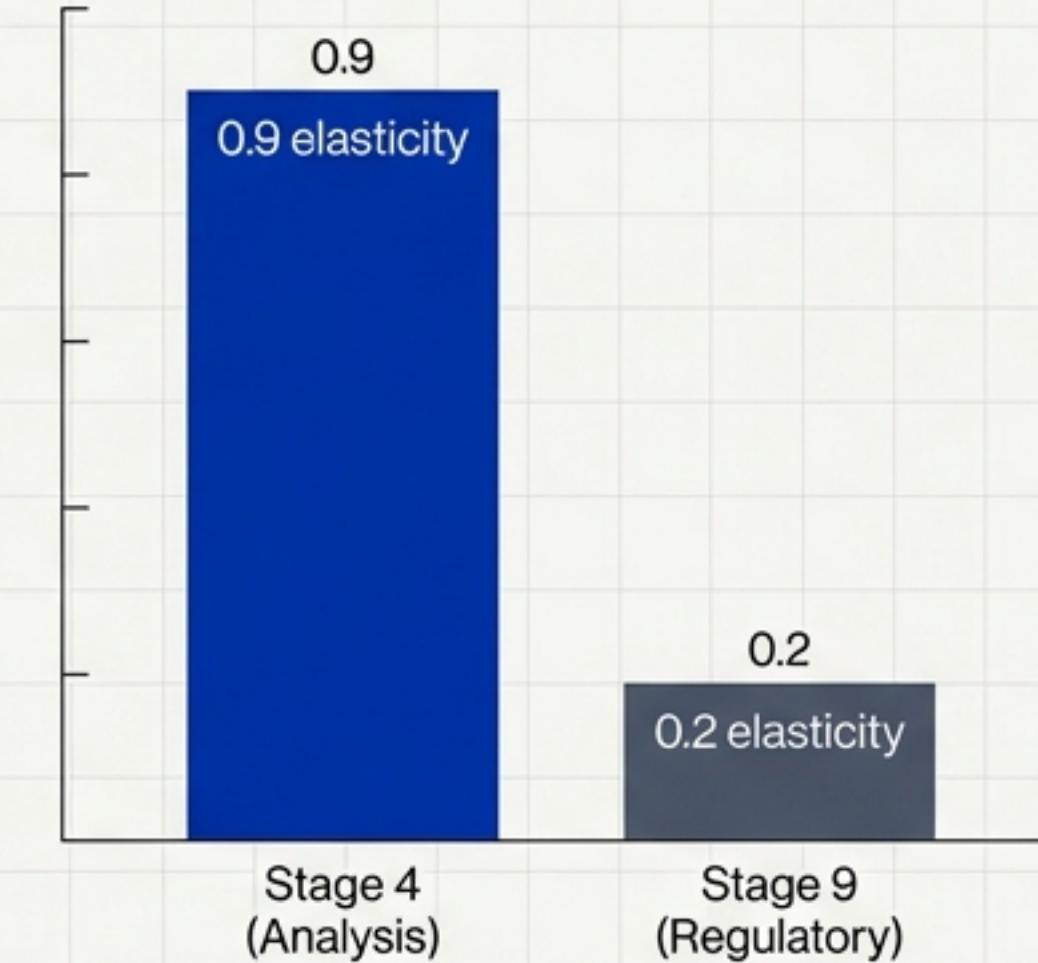
The Rework Loop



AI's value is preventing failure.

Data Elasticity

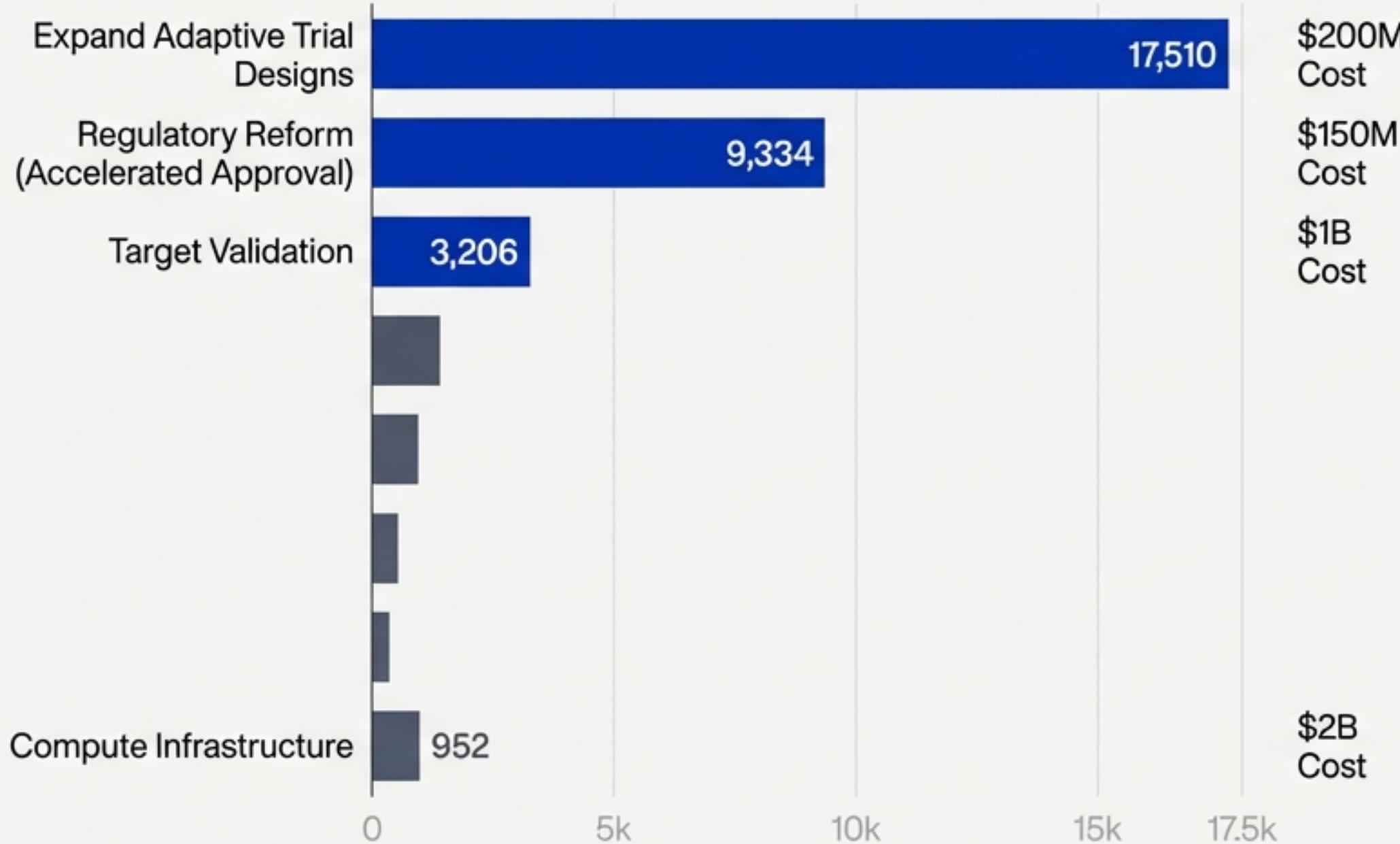
Sensitivity to Data Quality



Better data accelerates analysis, but barely impacts bureaucracy.

Strategic Implications: The ROI of Intervention

Return on Investment (ROI)



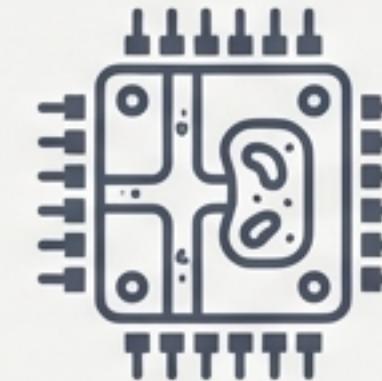
**The Pivot:
Investing in
“Process”
(Regulation)
yields 17x
higher returns
than investing
in ‘Compute’.**

Conclusion: Bridging the ‘Bits to Atoms’ Divide



Short Term (Now)

AI optimizes existing processes.
2.8x Speedup.



Long Term (Future)

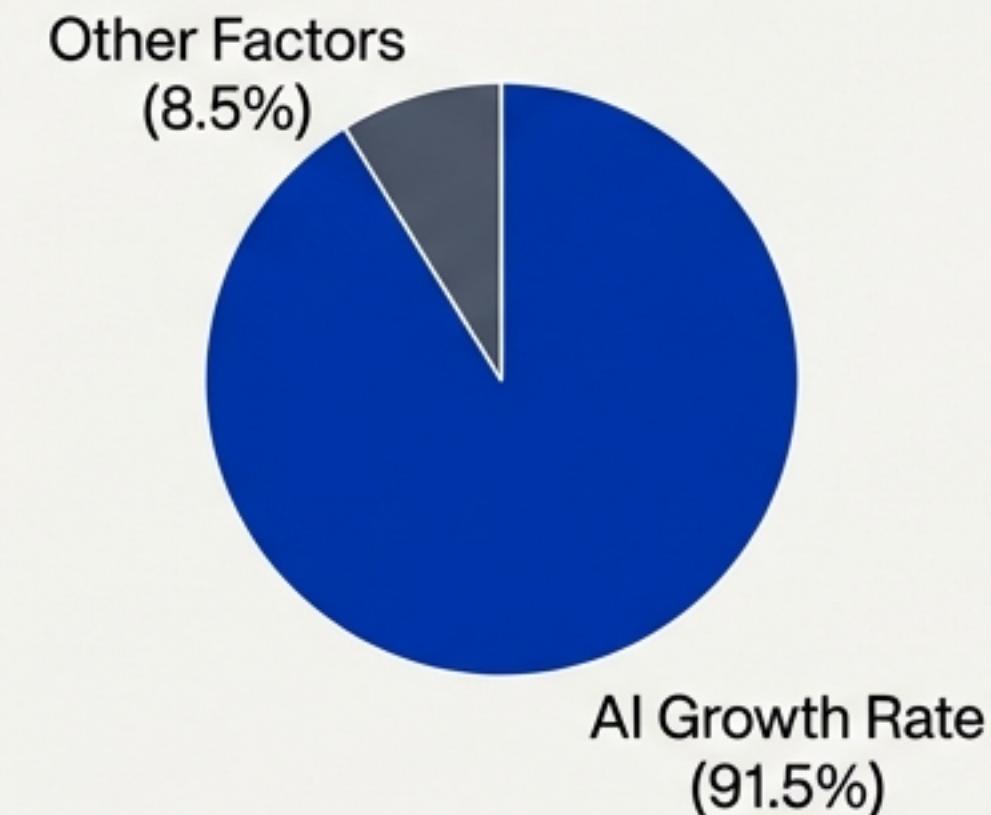
Redesign physical pipeline
(Organ-on-chip, In-silico trials).

“The future of biological discovery isn’t limited by our ability to generate answers, but by our capacity to validate them in the physical world.”

Appendix: Model Parameters (v1.1)

Parameter	Value	Notes
M_max (Hypothesis S1)	50x	Cognitive Task
M_max (Analysis S4)	100x	Pure Compute
M_max (Phase II S7)	2.8x	Physical Bottleneck
Success Rate (S1)	0.40	Expert Revised
Success Rate (S7)	0.33	Baseline

Variance Explained
(Sobol Index)



Parameters validated by 15-Expert Simulated Review Panel.