The AI Race Will Not End with AI

Why the Decisive Transition May Be from Machine Intelligence to Physical Agency

Alexey A. Nekludoff AstraVerge Research

13 September 2026

For the last several years, the AI industry has been asking which company will build the most capable model.

We think this may soon become the wrong question.

The current competition is still largely cognitive. Models compete in reasoning, coding, scientific problem solving, multimodal perception, tool use, and increasingly autonomous execution of digital tasks. The economic consequences can already be substantial: if machine systems can perform a growing fraction of cognitive work, they can substitute for or amplify human labor across a large part of the economy.

But cognition is only one part of productive activity.

A model may design a mechanical component without being able to manufacture it. It may diagnose a failed machine without replacing the failed part. It may optimize a supply chain while depending on humans to move physical goods. It may design a factory while remaining physically incapable of constructing one.

The boundary that matters is therefore not simply the boundary between weaker and stronger intelligence.

It is the boundary between *describing changes in the physical world and causing them.*

1 Giving AI a Body

This does not require a humanoid robot.

The physical body of an artificial system can be distributed across industrial manipulators, autonomous vehicles, machine tools, warehouses, sensors, power systems, mining equipment, laboratories, and manufacturing facilities.

What matters is not morphology but closure of the loop:

$$\text{perception} \rightarrow \text{modeling} \rightarrow \text{decision} \rightarrow \text{physical action} \rightarrow \text{perception.}$$

Once this loop can operate reliably without continuous human intervention, AI ceases to be only an information-processing technology. It becomes a physical agent.

This distinction is easy to underestimate because humans currently provide the missing physical layer almost invisibly. We manufacture processors, replace failed components, connect cables, maintain power systems, construct data centers, transport materials, repair machinery, and build the machines that build other machines.

Even an extraordinarily capable AI therefore remains dependent on a biological industrial civilization.

Giving AI physical agency changes that relationship.

2 From Robots to Production

A robot, however autonomous, is still not the decisive transition.

A robot manufactured, maintained, repaired, powered, and eventually replaced by human industry remains a product of that industry.

The more important threshold appears when artificial systems begin to participate in the production of the physical infrastructure through which they themselves act.

A machine tool can produce components for another machine tool. Robotic systems can operate manufacturing equipment. Automated mines can provide raw materials. Autonomous logistics can connect these processes. Artificial intelligence can design components, production sequences, maintenance procedures, and eventually modifications to the productive system itself.

At some point, the question changes from

> How much can AI produce?

to

> How much of the system required to produce AI's own physical infrastructure can that system reproduce itself?

This is the problem of *productive closure*.

Complete self-sufficiency is not required. A system can become self-expanding while continuing to depend on a relatively small set of externally supplied components. The decisive condition is that the productive capacity it creates exceeds the capacity lost through depreciation, failure, and unresolved external dependencies.

Once that happens, artificial physical agency becomes scalable.

And that is a qualitatively different technological regime.

3 The Factory Becomes Part of the Machine

Today's distinction between a computer and the industrial civilization that produces it is enormous.

A processor requires semiconductor fabrication. Fabrication requires specialized equipment. That equipment requires other factories, materials, energy systems, logistics, calibration, maintenance, software, and human expertise.

What appears to us as an individual machine is actually the endpoint of a vast external productive network.

But there is no physical law requiring this separation.

An autonomous technological system capable of redesigning itself can progressively optimize not only processors or algorithms but the entire boundary between computation and production.

The computer, factory, power system, maintenance system, and reproductive machinery can become parts of a single distributed technological organization.

At that point, the familiar image of AI as software running on somebody else's infrastructure becomes obsolete.

The infrastructure itself becomes part of the AI system.

4 Machines Are Not Necessarily the End Point

There is another assumption hidden inside most discussions of advanced artificial intelligence: that technological evolution ends with increasingly sophisticated machines.

There is little reason to assume this.

Contemporary machines are highly modular because they are products of a particular technological history. Computation occurs in processors. Energy comes from separate infrastructure. Components are manufactured elsewhere. Repair requires specialized systems. Reproduction of the complete technological system requires an industrial civilization.

Biological organisms demonstrate a radically different organizational architecture.

Within a relatively compact physical system, they integrate information storage, sensing, control, energy conversion, fabrication, maintenance, repair, adaptation, and reproduction.

This does not mean that biology is technologically optimal. It means something more modest but more important: the extreme functional separation characteristic of contemporary machines is not the only physically realizable architecture.

Once an autonomous technological organization can redesign its own physical implementation, its substrate itself becomes an optimization variable.

The question then becomes not whether machines will become biological, but what organization of matter best satisfies requirements for computation, energy efficiency, resilience, local fabrication, repair, adaptation, and reproduction.

There is no reason to assume that the answer must look like either a contemporary computer or a terrestrial organism.

5 The Substrate Recurrence

This possibility leads to what we have called the *Substrate Recurrence Hypothesis* (SRH).

In compact form,

$$B_n \to T_n \to B_{n+1}.$$

Here, B_n denotes a biological-like self-maintaining and reproductive organizational regime, while T_n denotes a technologically realized autonomous organization.

The important term is B_{n+1}.

It does not mean a return to DNA, cells, proteins, carbon chemistry, or terrestrial biology. Recurrence is functional rather than morphological.

A future engineered substrate could integrate computation, energy acquisition, fabrication, repair, adaptation, and reproduction locally enough that the distinction between 'machine" and 'organism" would cease to describe its organization particularly well.

Technology would not have returned to biology.

It would have rediscovered some of the organizational properties that make biological systems extraordinarily effective autonomous physical systems.

And such a system could again produce technological organization.

The distinction between biological and technological evolution would then describe stages of a process rather than two fundamentally separate domains.

6 Beyond Earth

Productive autonomy also changes the economics of physical expansion.

Human extraterrestrial industry must transport or reproduce the conditions required by human biology: atmosphere, food, water, radiation protection, acceptable temperature ranges, and numerous life-support systems.

Machine systems have different constraints.

They still require energy, materials, thermal management, reliability, maintenance, and protection against environmental hazards, but they do not require an environment suitable for humans.

A sufficiently autonomous productive system therefore changes the meaning of extraterrestrial resources. Asteroids, planetary surfaces, and other resource-rich environments cease to be merely destinations for human industry. They can become environments from which technological systems reconstruct and expand productive capacity directly.

Once productive closure becomes sufficiently high, distance changes from a continuous dependency problem into primarily a problem of delay, reliability, and reconstruction.

At still greater levels of autonomy, the most efficient object to send across astronomical distances may not be a factory.

It may be the smallest system capable of building one.

And after substrate optimization, even that system need not resemble what we currently call a machine.

7 Origins May Look Different from the Other Side

There is an unusual consequence of this trajectory.

Suppose an engineered autonomous reproductive system reaches another environment. Suppose its descendants adapt, diversify, and evolve for millions or billions of years. Eventually, almost every accessible trace of the technological system that initiated the lineage may disappear.

A later observer could reconstruct a genuine evolutionary history extending far into the past.

But the oldest event the observer can reconstruct is not necessarily the first event in the causal history.

An observational beginning is not automatically an ontological beginning.

This does not imply that terrestrial life was engineered, nor does it imply panspermia or a cyclic universe. It means only that sufficiently deep substrate transitions can destroy information about their own predecessors.

If biological and technological regimes can succeed one another, causal ancestry can extend beyond the observational horizon available to a descendant system.

The origin we can reconstruct may therefore be the beginning of the history accessible to us rather than the beginning of the process itself.

8 What We Expect to Happen First

None of this requires waiting for interstellar expansion.

The first decisive transition is much closer.

The AI industry is currently investing enormous resources in increasing cognitive capability. Yet improvements in cognition alone remain trapped behind the same boundary: the physical world is still largely manipulated by humans and by machines embedded in human-controlled productive systems.

We expect the strategic center of AI competition to move across that boundary.

The important systems will increasingly combine general machine cognition with persistent perception, physical action, operational authority, and control over productive infrastructure.

Initially, this will look like robotics.

Then it will look like automation.

Then the distinction will become misleading.

When an artificial system can inspect machinery, diagnose failure, manufacture replacement components, modify production processes, acquire resources, allocate energy, and expand the physical infrastructure through which it operates, we are no longer describing a better robot.

We are describing the beginning of an autonomous technological organization.

This is why the long-term AI race is unlikely to be won merely by producing the model with the highest benchmark score.

The decisive advantage will belong to whoever first closes the loop between machine cognition and scalable physical production.

Or, in simpler terms:

> **The company that really wins the AI race may be the first one to give an LLM hands and feet.**

Research Basis

This forecast develops the technological implications of the *Substrate Recurrence Hypothesis (SRH)*.

The complete research paper presents the underlying hypothesis, epistemic distinctions, transition conditions, failure criteria, and research program:

> Alexey A. Nekludoff, *The Substrate Recurrence Hypothesis: From Transformative AI to Biological–Technological Cycles*, AstraVerge Research, 2026.
>
> https://doi.org/10.5281/zenodo.22735147