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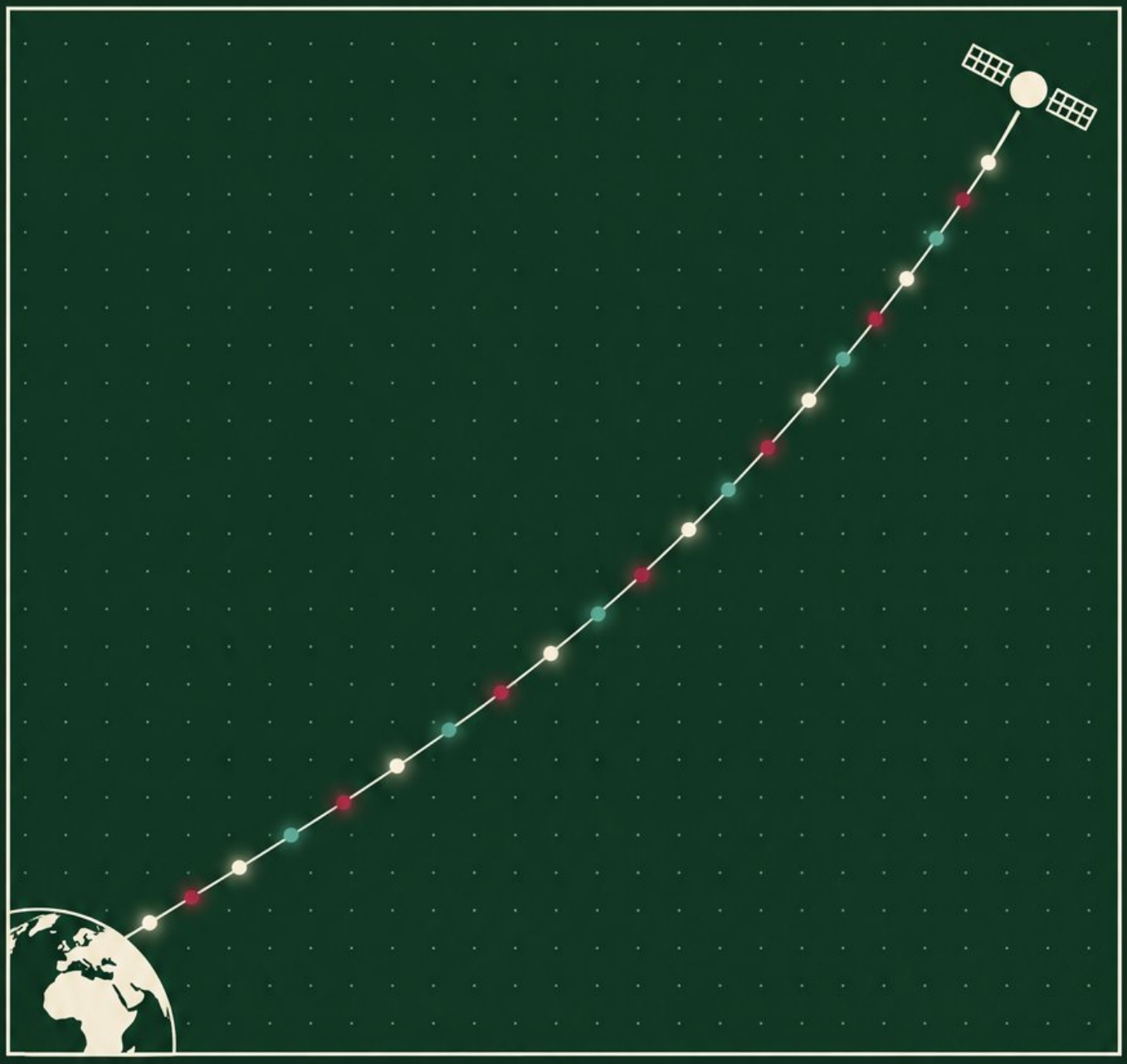

OUTPUT IS DIGITAL

Nvidia, Apple, Google, and the Bit-Stream Economy

COLDCODE SI LABS · HARARE

For every builder who has ever looked at a $3 trillion company and thought: but what do they actually make?

Output Is Digital

Nvidia, Apple, Google, and the Bit-Stream Economy

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ColdCode Si Labs Working Paper · Harare · November 2026 CC BY 4.0

About this essay

In February 2026, Elon Musk sat for a three-hour interview on the Dwarkesh Podcast and said something that should be obvious but isn't: the most valuable companies in the world do not make things. They send files.

Nvidia does not ship chips from Santa Clara. It ships chip designs — files on an SFTP server — to TSMC in Taiwan. Apple does not make phones. It sends design files to contract manufacturers in China and India. Microsoft makes almost nothing physical; Xbox is outsourced. Google's output is search results, advertisements, and code — all bits. Meta's output is bits.

This is not a clever metaphor. It is a statement of fact about where economic value now resides. The companies with the largest market capitalisations in the history of capitalism produce digital output, and the physical manufacturing is done elsewhere, often by companies that earn a fraction of the margin.

This essay is about what that means. It examines Musk's claim in the context of the AI economy, the energy constraints that will define the next decade of computing, the proposition that orbital data centers will be cheaper than terrestrial ones within three years, and the idea — which Musk asserts casually but which carries extraordinary implications — that a "digital human emulator" would be the most valuable company in the world overnight.

This is not a book about Elon Musk. It uses one specific interview as a lens onto a deeper truth about economic value in the bit-stream era. Musk is a useful witness because he operates at the extremes of both bits and atoms — software and rockets, chips and cars, social media and satellites — and his observations, however hyperbolic, are grounded in operational reality rather than analyst reports.

The interview was conducted by Dwarkesh Patel and John Collison on February 5, 2026. The full transcript is available at dwarkesh.com. I have used the transcript extensively and encourage you to read or watch the original. I have also drawn on public reporting about Nvidia's supply chain, Apple's contract manufacturing, TSMC's fabrication capacity, data center power consumption, and the economics of commercial space.

This is a working paper. It is short. It makes an argument. Comments and corrections are welcome.

Harare, November 2026

I · The claim

Three hours into a podcast interview about orbital data centers, Elon Musk said something that made his co-guest, Stripe co-founder John Collison, lean forward in his chair.

They were discussing the business model for xAI, Musk's artificial intelligence company, and why Musk believed a successful "digital human" — an AI that could do knowledge work as competently as a human — would be worth trillions of dollars.

"The most valuable companies currently by market cap, their output is digital," Musk said. "Nvidia's output is FTPing files to Taiwan. It's digital. Now, those are very, very difficult."

"High value files," Collison interjected.

"They're the only ones that can make files that good," Musk continued. "But that is literally their output. They FTP files to Taiwan. Apple doesn't make phones. They send files to China. Microsoft doesn't manufacture anything, even for Xbox — that's outsourced. Again, their output is digital. Meta's output is digital. Google's output is digital."

The observation landed because it is simultaneously undeniable and rarely stated. Take the five largest American companies by market capitalisation in late 2026: Apple, Microsoft, Nvidia, Alphabet (Google), and Amazon. Four of them produce digital output as their primary product. Amazon is the exception, and even Amazon's profit engine (AWS) is digital output — rentable compute, storage, and network capacity.

If you include the next tier — Meta, Tesla, Broadcom, Oracle — the pattern holds. Tesla, which is Musk's own company, makes cars and batteries, but Tesla's software (Full Self-Driving, the vehicle operating system, the Optimus robot control stack) is increasingly what gives its products value. Broadcom, like Nvidia, designs semiconductors; the manufacturing happens at TSMC. Oracle sells database licenses and cloud capacity.

This is not a coincidence. It is the natural economic consequence of two facts. First, digital output has near-zero marginal cost — once you have a design file or a piece of software, the cost of the millionth copy is effectively zero. Second,

the supply of physical manufacturing capacity in the world is large, competitive, and concentrated in jurisdictions where labour and infrastructure are cheap. A company that designs things well can capture the high-value part of the value chain while contracting out the low-margin physical work.

This is the bit-stream economy. It is the world we already live in, and most people have not fully internalised it.

II · The companies

Let us examine the claim, company by company.

Nvidia

Nvidia is the most consequential technology company of the AI era. At its peak in 2025–2026, its market capitalisation exceeded $3 trillion.

Nvidia does not own a factory that fabricates semiconductors. It does not operate a wafer fab. It does not employ the thousands of clean-room technicians who wear bunny suits and run the machines that turn silicon ingots into working chips.

What Nvidia does is design chips. The H100, the H200, the B100, the B200, the GB200, the GB300 — these are designs. They are extraordinarily complex designs, involving tens of thousands of engineer-years of work in CUDA cores, tensor cores, memory hierarchies, interconnect fabrics, and packaging. But they are designs. They exist as files. Those files are transferred (Musk said "FTPed"; the modern term would be SFTP or a secure file transfer service) to TSMC in Hsinchu, Taiwan, where they are etched onto silicon wafers. The fabricated chips are then packaged and tested by TSMC, by Amkor, by ASE, and others, and shipped to customers or to system integrators like Supermicro.

The margin on this business is extraordinary. Nvidia's gross margins in 2025 were approximately 75%. TSMC's gross margins on advanced-node fabrication are closer to 50–55%. The contract assemblers further down the chain operate at single-digit margins. The company that produces the file captures most of the value; the companies that turn the file into a physical object capture a smaller share.

"They're the only ones that can make files that good," Collison said, and he was right. That is the moat. The file is the product.

Apple

Apple is the most profitable company in history. In the fiscal year ending September 2025, it reported approximately $391 billion in revenue and roughly $125 billion in operating income.

Apple does not manufacture an iPhone. The components come from dozens of suppliers — Samsung for displays, TSMC for the A-series and M-series chips, Sony for camera sensors, Foxconn, Pegatron, and Luxshare for assembly. Foxconn's Zhengzhou facility, at its peak, produced approximately half of the world's iPhones. Apple designed the phone. Apple specified every component. Apple wrote the operating system. Apple designed the silicon. But Apple does not screw the phones together.

The iPhone is a set of files — industrial design files, CAD files, CAM files, firmware, operating system code — that are sent to a global network of contract manufacturers, who execute them at scale. Apple's margin on the iPhone is approximately 45%. Foxconn's margin on assembling that same iPhone is approximately 2–4%.

Again: the file is the product.

Microsoft

Microsoft's largest business in 2026 is Azure, its cloud platform. Cloud computing is the ultimate bit-stream business: you are renting compute cycles and storage that exist as digital services running on hardware you own but that the customer never touches. Microsoft also sells software licenses — Windows, Office, SQL Server, Dynamics — which are pure digital goods. Xbox consoles are designed by Microsoft and manufactured by contract manufacturers in Asia. Surface computers are designed in Redmond and built by others.

Microsoft's gross margins across the company are approximately 70%. The cloud business runs gross margins around 65–70%. Software licensing runs at gross margins above 90%.

Google and Meta

Google's output is search results, advertisements, YouTube videos, and cloud services. Meta's output is social feeds, advertising, Reels, and messaging. Both companies operate enormous data centers full of hardware, but the hardware is the means, not the product. The product is digital — advertising impressions, algorithmic feeds, AI inferences.

Meta's gross margins are approximately 80%. Google (Alphabet)'s gross margins are approximately 55–60%, depressed by the heavy capital

expenditure of running Google Cloud. The advertising business — the core of both companies — runs at gross margins above 80%.

The pattern

The pattern is consistent. The companies that capture the most economic value produce designs, algorithms, software, brands, and protocols — digital goods — and use the global manufacturing base to execute the physical part at contract margins.

This is not new. It has been true for decades. But the rise of AI has sharpened it to an extraordinary degree. An AI model, once trained, can be copied and run at near-zero marginal cost. The cost of training a frontier model may be $100 million to $1 billion — enormous fixed cost, similar to the R&D cost of a new jet engine or a new semiconductor node. But the marginal cost of an inference is a fraction of a cent, converging to zero as chips get cheaper.

This is exactly the economic structure that produced Microsoft, Google, and Meta, scaled up by an order of magnitude.

III · The hard lesson

The Dwarkesh interview took place on February 5, 2026. It was published a few days later. The first hour was not about business models but about power — specifically, the electricity required to run AI data centers at the scale Musk believes the world is heading toward.

Here the conversation took a turn that surprised many listeners. Rather than the swashbuckling futurist promising Mars colonies and a world of abundance, the Musk who spoke about power generation was a weary, grounded operations man.

"Those who have lived in software land don't realize they're about to have a hard lesson in hardware," he said. "It's actually very difficult to build power plants. You don't just need power plants. You need all of the electrical equipment. You need the electrical transformers to run the AI transformers."

The pun was unintentional but revealing. Musk was pointing out that the world is about to hit a wall that software people, accustomed to the infinite elasticity of cloud computing and the exponential growth of chips, have not internalised. That wall is energy, and the physical equipment required to generate and deliver it at scale.

The numbers

Consider the arithmetic. At Musk's xAI, the Colossus 2 cluster in Memphis was built to consume roughly a gigawatt of electricity at the generation level. To get to a gigawatt of usable compute, xAI had to string together dozens of gas turbines, negotiate interconnection agreements with utility companies in Tennessee (which failed, leading them to cross the border into Mississippi), run high-voltage power lines for miles, and size the system for peak cooling on the hottest days of a Memphis summer — which adds approximately 40% to the power requirement for cooling alone. On top of that, another 20–25% margin is required to allow for generators being taken offline for servicing.

"Every 110,000 GB300s — inclusive of networking, CPU, storage, cooling, margin for servicing power — is roughly 300 megawatts," Musk said. "What you probably need at the generation level to service 330,000 GB300s is roughly a gigawatt."

A gigawatt is the output of a large nuclear power plant or approximately five to six large gas-fired power stations. It is roughly half of the average electricity consumption of the entire United Kingdom. It is what the United States as a country adds in new electricity generation approximately every two to three years. Musk's point is that if AI data centers begin consuming multiple gigawatts each, and multiple companies build such clusters, the world will need to add electrical generation capacity at a rate it has not managed since the post-World War II industrial expansion.

And here is the hardware problem: it is not just power plants. The limiting factor at a more granular level is the cast single-crystal turbine blades and vanes inside gas turbines — a specialised manufacturing process that very few factories in the world can execute. Gas turbines suitable for utility-scale generation have lead times extending to 2030. They are sold out. Solar panels are cheap in China ($0.25–0.30 per watt, by Musk's estimate) but face enormous tariffs in the United States, and domestic American solar production is, in his word, "pitiful."

Electrical transformers — the devices that step voltage up and down between power stations, transmission lines, and end users — have multi-year lead times. They are the chokepiest chokepoint in the electrical supply chain.

The noob error

Musk reserved specific scorn for what he called "noob" estimates of data center power consumption — estimates that simply multiply the power draw of the GPUs by the number of GPUs and call that the answer.

"Wake up. That's a total noob, you've never done any hardware in your life before. Besides the GPU, you've got to power all of the networking hardware. There's a whole bunch of CPU and storage stuff that's happening. You've got to size for your peak cooling requirements."

The multiplier is not 1x. It is 2.5x to 3x, when cooling, networking, storage, redundancy, and servicing margins are all included. A cluster whose GPUs nominally draw 300 MW requires approximately 1 GW of generation capacity. People who have only ever rented cloud instances — who click a button to provision a GPU and have never seen the building it sits in, the transformer it connects to, or the gas turbine that spins the generator that feeds the transformer — underestimate this by a factor of three.

This is the hard lesson Musk predicted for people who have lived entirely in software land: the physical world has constraints that cannot be coded around. Bits may be infinitely copyable, but the electricity to process them must be generated by real machines made of real metal and silicon, manufactured in real factories with real lead times, and connected by real wires.

For a builder in Harare reading this, the lesson is not abstract. Zimbabwe has lived with the consequences of under-invested electrical infrastructure for two decades. Load-shedding is not a theoretical risk; it is the daily operating environment. When Americans begin complaining that they cannot get data center power because turbines are sold out through 2030, they are discovering what African operators have known for years: electricity is a hard physical constraint, not a service that materialises from a plug.

IV · Space

Musk's answer to the terrestrial power constraint is space. This is the part of the interview that generated the most headlines.

"My prediction is that it will be by far the cheapest place to put AI," he said. "It will be space in 36 months or less. Maybe 30 months."

The argument for orbital data centers rests on a few facts about space that are well-understood in aerospace but rarely considered in Silicon Valley:

Solar is five to ten times more effective in space. A solar panel in geostationary or low Earth orbit receives sunlight 24 hours a day, unfiltered by atmosphere, unaffected by weather, clouds, or seasons. The atmosphere alone reduces solar irradiance at ground level by approximately 30%. The absence of a day-night cycle eliminates the need for battery storage, which roughly doubles the effective power per panel (because you don't need to build twice the nameplate capacity and store half in batteries). Combined, these factors mean a solar panel in space can generate five to ten times more useful energy than the same panel on the ground.

There is no weather in space. Solar panels in space do not need glass, heavy aluminium framing, wind load ratings, hail resistance, or mounting hardware. They can be thinner, lighter, and cheaper to manufacture. (Musk noted that SpaceX and Tesla are building toward 100 gigawatts per year of solar cell production, and that space-grade cells are cheaper to make than terrestrial ones because of reduced structural requirements.)

There is no cooling problem of the terrestrial kind. Waste heat in space is rejected through radiation, not through chillers and cooling towers that consume enormous amounts of electricity. The 40% cooling overhead Musk described for Memphis disappears in a vacuum.

There is no NIMBY problem. Orbital data centers do not require permits from county commissions, environmental impact statements, interconnection agreements, or permission from neighbours who do not want a data center next to their subdivision. They do not consume land or water.

There are, of course, objections. Radiation hardening. Heat rejection in vacuum. Servicing. Bandwidth back to Earth (solved in part by Starlink laser

links). Launch cost. Musk addressed some of these in the interview; others he did not. The servicing problem, he argued, is overstated: GPUs that survive infant mortality are quite reliable, and you can burn them in on the ground before launch. The bandwidth problem is solvable with optical laser inter-satellite links of the kind Starlink already operates.

The enabling assumption is Starship. For orbital data centers to be economical, the cost of mass to orbit must drop by roughly two orders of magnitude from the Falcon 9 era — which is what Starship is designed to achieve. At a marginal launch cost of hundreds of dollars per kilogram (rather than thousands), the economics of lifting thousands of GPUs and solar arrays into orbit become plausible.

If Musk is correct — if in 36 months orbital AI is cheaper than terrestrial AI — the geopolitical and industrial implications are enormous. It means the companies that control cheap access to space (SpaceX) and cheap space-grade solar (potentially Tesla/SpaceX vertically) will control the cheapest compute on Earth, even though the compute is not on Earth. It means the terrestrial power bottleneck is route-aroundable. It means countries without the permitting or transmission infrastructure to build gigawatt data centers can, in principle, access cheap space-based compute via a satellite dish.

If he is wrong — if orbital AI remains a distant prospect, and the servicing, radiation, and bandwidth problems prove more intractable than he believes — then the world will face a terrestrial energy crunch that constrains AI growth for years.

Either way, the claim is testable. We will know within 36 months.

V · The digital human

Musk's business argument for xAI rested on a single claim: once you can build a "digital human" — an AI that can perform knowledge work as competently as a human being — you have access to trillions of dollars in revenue.

His reasoning was the bit-stream thesis stated directly. If the most valuable companies in the world produce digital output, and you can create a digital entity that can produce digital output at human or superhuman levels, you can create the most valuable company in the world overnight. You do not need to build factories. You do not need to hire thousands of people. You need one working digital human, and you can scale it to millions of instances at near-zero marginal cost.

This is the same economic argument I made in Zero Marginal Cost, applied to labour itself. When the product is bits, and the producer of bits can be replicated for the cost of running inference on a GPU, the economics of knowledge work look like the economics of software.

The argument should be treated with caution. The claim that we are close to a "digital human" is disputed by many AI researchers. Current models can generate text, code, and images; they cannot perform end-to-end complex professional work without human supervision; they hallucinate; they fail on novel tasks; they do not have the common-sense reasoning of a human being. The gap between "good at writing code in response to prompts" and "can replace a software engineer end-to-end" is wide.

But the direction of travel is clear. Models get better every year. Even if a full digital human is ten years away rather than three, the bit-stream economics of the intermediate states are real. A model that can handle 50% of a junior engineer's work is valuable even if it cannot replace that engineer entirely. A model that can draft legal documents, produce marketing copy, triage customer support tickets, or write basic software functions is already producing digital output that companies will pay for.

The important observation is not "digital humans are here" (they are not) or "digital humans are impossible" (that has not been proven) but rather that the economic structure of the existing economy is already set up to reward digital output at scale, and a sufficiently capable digital worker would be the most

valuable single piece of software ever built. That is why the AI industry is investing tens of billions of dollars per year.

VI · The manufacturing question

If output is digital, does that mean manufacturing does not matter? That would be a dangerous misreading of the argument.

Musk's own career contradicts it. Tesla is one of the few large American technology companies that manufactures physical products at scale. SpaceX builds rockets. The Gigafactories produce batteries and cars at volumes that few other manufacturers can match. The entire discussion of data center power was a recognition that hardware — the turbines, transformers, solar panels, chips, and cooling systems — is the binding constraint on the AI economy.

What "output is digital" means is not that manufacturing disappears but that the high-margin, value-capturing layer of the economy is the digital design layer. Manufacturing still exists. It still requires enormous skill and capital. But it is increasingly a service — executed by contract manufacturers and speciality foundries — rather than the source of durable competitive advantage for the companies that capture most of the value.

The exception that proves the rule is TSMC itself. TSMC is a manufacturing company, but its competitive advantage is in the extraordinary precision of its manufacturing process, which is itself a kind of digital knowledge — process recipes, yield data, fabrication techniques that exist as files and institutional know-how. TSMC's gross margins (50–55%) are higher than most software companies' because its manufacturing is so difficult that it effectively operates as a digital monopoly on physical production.

For countries and companies that want to participate in the bit-stream economy, there are several strategic positions to occupy:

- **Design.** Producing the files that others manufacture. This is where Nvidia, Apple, and the design houses sit. It requires deep engineering talent, strong IP, and ecosystems (like CUDA for Nvidia) that lock in developers.
- **Advanced fabrication.** TSMC's position. Extremely capital-intensive, extremely difficult, very few players.
- **Contract assembly.** Foxconn, Pegatron, Flex. High volumes, low margins.

- **Energy.** The companies and countries that can supply reliable, cheap electricity at scale will be the Saudi Arabia of the AI era. This is why Saudi Arabia, the UAE, Norway, Iceland, Quebec, and certain parts of the American Southwest are aggressively courting data center investment.
- **Application layer.** Building software and services on top of the models. This is the layer most accessible to small teams and developers in the periphery.

VII · For builders outside the centre

This essay is written from Harare. The bit-stream economy looks different from here than it does from Silicon Valley. Several observations follow.

First, the good news: software still has near-zero marginal cost, and that fact still favours small operators in low-cost locations. A developer in Harare writing code produces the same digital output as a developer in San Francisco. The file is identical. The Internet, when it works, delivers it to the same customers at the same speed. The cost structure of a solo studio in Harare (I have written about this at length in The One-Person Studio) is dramatically lower than that of a San Francisco startup, while the product, being bits, can be identical.

Second, the bad news: the chokepoints of the bit-stream economy — energy, advanced chip fabrication, launch capacity, frontier AI model training — are increasingly concentrated. Training a GPT-5-class model requires a gigawatt-scale data center and billions of dollars in capital expenditure. That is not something a Harare startup can do. That is not something most governments can do. The frontier will be set by a small number of companies and countries for the foreseeable future.

Third, the infrastructure news is mixed. If orbital compute arrives on the timeline Musk predicts — three years — it could, paradoxically, benefit the periphery. If the cheapest place to put AI is in space, accessible via a satellite terminal, then a developer in Harare with a Starlink dish and a power source has the same access to cheap compute as a developer in Silicon Valley. Geography would cease to matter for AI inference in the same way it already does not matter for static file hosting. If orbital compute does not arrive, and terrestrial power constraints slow AI growth, then the cost of compute may remain high for longer, and the periphery will remain at a disadvantage.

Fourth, the application layer remains open. The frontier model companies will sell inference as a commodity (they are already doing so). The value will migrate to those who can build useful applications on top of those models — tools for specific industries, specific geographies, specific languages, specific use cases. This is where small teams have an advantage: they understand the local context in ways that OpenAI and Google cannot. A developer who knows

how small traders operate in Mbare Market can build an AI bookkeeping tool that serves that market better than anything designed in Mountain View.

Fifth, energy is a strategic priority for every country. Musk is correct that the world is sleepwalking into an energy shortage. For African countries with abundant solar and wind resources — Zimbabwe has excellent solar irradiance; much of the Sahel does as well — there is an opportunity to build energy capacity that serves both local demand and, potentially, data center load. The challenge is transmission infrastructure, capital, and political stability. These are hard problems, but they are not harder than building a semiconductor fab from scratch.

VIII · Lessons

A few lessons emerge from the bit-stream thesis:

The file is the moat. If your competitive advantage resides in a digital artifact — a design, an algorithm, a model, a piece of software, a brand — that advantage can be protected, scaled, and defended in a way that physical infrastructure cannot. Build the file. Own the file. Protect the file.

Manufacturing is a service, not a trap. Contracting out physical manufacturing does not make you "fake" or "hollow." Apple is the most valuable company in the world and it does not screw together its own phones. But you must be good enough at specifying what you want that manufacturers cannot replace you. The file must be difficult to produce. If anyone can write the file, anyone can hire the same manufacturer, and your margin collapses.

Hardware will assert itself. Anyone building in the AI era who does not understand electricity, cooling, networking, and chip fabrication is going to be surprised by reality. Software people who treat compute as an infinite resource that comes from an API are in for a hard lesson — and it will be delivered by a turbine shortage or a transformer lead time.

Energy is the next bottleneck. The companies and countries that solve for abundant, cheap, clean electricity will be the next centres of power. The rest will be customers.

The digital human changes everything if it arrives, and changes a lot even if it doesn't. Full human emulation may be five years away, ten years away, or never. But even partial automation of knowledge work — at 30%, 40%, 50% — will reshape companies, labour markets, and profit pools, because the marginal cost of digital output is zero.

Orbital compute is a real possibility, not science fiction. Treat it as such. Plan for a world where the cheapest inference is available from orbit via a satellite terminal. That world is either 30 months away or it isn't, but it is a scenario worth designing for.

IX · Coda

In 1985, a young programmer named Richard Stallman published the GNU Manifesto and argued that software should be free because copying it costs nothing. In 2026, the world's most valuable companies are built on that observation. Nvidia is a $3 trillion company because its files — chip designs that cost enormous amounts to produce but almost nothing to copy — are sent to Taiwan, etched onto silicon, and sold back to the world at extraordinary margins. Apple is a $3 trillion company because its design files, sent to China, produce devices that the world will pay a premium for. Google and Meta and Microsoft are trillion-dollar companies because their output — search results, advertisements, software, cloud services — is bits.

The bit-stream economy is not a vision of the future. It is the present. The output is digital. The question for anyone building anything is: what file do you produce that is valuable enough that people will pay for it, and difficult enough that they cannot produce it themselves?

Answer that, and you have a business.

Answer it at the level of Nvidia or Apple, and you have an empire.

The files travel at the speed of light. The energy to process them comes from gas turbines and solar panels and, soon, from panels in orbit that never see a cloud. The manufacturers wait for the designs. The world waits for the product.

The file is the thing.

About the author

Courage Garikai builds and runs autonomous business systems from Harare, Zimbabwe, and writes about what actually works. The Coldcode Si Labs Library is the written record of that practice — forty-six titles and counting, each one built to be finished, kept, and passed on.

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