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Part I

A short introduction

First things first: Thanks & How-to

haha
yes



Figure 0: A hedgehog, haha yes

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in the references on whose shoulders I was able to stand and make sense of the world. A special shoutout goes to W. Brian Arthur: He might not recall this, but we sent a few emails back and forth years ago, in which he encouraged me to keep on exploring this topic further. So I did.

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And thanks to everyone who ever taught me something along the way: Be it teaching at school, at work, in conversations, by example, via books, talks, newspapers, essays. To quote the great Charlie Munger here:

'I think a life properly lived is just learn, learn, learn all the time.'

And we definitely live in the best times ever when it comes to learning. So stay curious, and never forget to question your constraints!

Why I wrote this book and what you can expect of it

This book is a collection of data that I have collected over the last ~8 years while closely following Tesla (and mainly SpaceX as Elon Musk's other main venture) as a business analyst (who is not working in banking or at Wall Street though).

The fact that my research turned into a book eventually can be considered rather an accident. The initial intention behind starting it was to really understand what Elon Musk means when he says: '*You have to think about problems from first principles*'. It all started around 2015, when I discovered Musk's interview with Kevin Rose in which he talked about the first principles of battery prices. I found this example fascinating, but it was difficult to grasp what this means in gen-

eral, and how such a thinking approach could be applied to different types of problems.

Most of the material online (blogs, videos) that covered the topic just did the following: It took Musk's battery example (i.e. break it down into its materials and see how much those cost; more on it later) and applied the same logic to different objects, like bikes or toys. While this is interesting, it obviously does not explain what '*first principles*' are and how it can be approached in a more generalized way. Taking a certain example and then drawing analogies to structural similar cases by definition is what Musk in his video calls '*reasoning by analogy*'.

So I went deep into rabbit holes of physics, epistemology, technology, more physics, a bit of philosophy, more epistemology, more technology. Reading books, talking to physicists, watching talks, reading more books. One very helpful early goal post was Tim Urban's (long, but great) essay series about the topic. I still wanted to go deeper and make it more applicable in the context of technology problems. And while trying to understand what people in physics mean when they think about things from first principles, and how this matters for technological innovation, I kept following Tesla and SpaceX closely over the course of the last years. I watched every earnings call, every investor day, every interview with sen-

ior leadership that I could find and that seemed to matter. I went as well back in time and watched every old interview that I could find from the early days of Tesla and SpaceX between 2003 and 2015, before I had started this project. Turns out that the more mainstream and successful both companies became, the more mainstream, PR-style and less informative the public events with company representatives became. But there are still many invaluable nuggets out there. Many of them are listed in the sources appendix.

The fact that it has the shape of a book now is more due to the fact that writing insights down helped me understand better. So I took notes, a lot of notes. Over time I collected hundreds of text snippets, short essays, chapters, even an earlier book draft. It never ended up making holistic sense though. Eventually, in late 2023, an interesting story framework emerged in my mind (keep in mind: the story of Tesla is obviously a narrative, it's not physics).

It turns out that the idea of first principle thinking for problem solving is fascinating, but does not matter much for mundane, everyday-type-of problems. We still will touch on the idea and the 'theory' behind it briefly in section 2 of the book. It is one of Tesla's very central operating patterns that you will come across repeatedly. It might even be worth giving it more dedication separately, at another point in time, in maybe an-

other publication (the appendix might help here). But my eventual key insight was this: Deeply challenging assumptions and pushing the status quo to the limits of what is physically possible only matters when you pursue bold goals - like the one of rebuilding an entire industry from scratch, in the age of software and AI!

So taking this insight and running with it, this book now has two big sections:

Read the first section as a short history of Tesla, baked into a high-level strategic framework that I call ‘*Teslafication of an industry*’: The complete reinvention of industry and hardware manufacturing in the age of software and AI, while going from startup to scaleup. We will explore how the company had to go through different paradigms (defined as: a set of beliefs, values, and practices that shape the way a group of people operates) in order to succeed and lead the global EV industry in early 2024. We will also see how it had to learn valuable lessons from each of the paradigms it went through in order to succeed. And we will understand why it almost got killed in 2018, when drawing the wrong conclusions from the Roadster paradigm (or actually drawing conclusions too early) and then stumbling into the Model 3 paradigm with an almost lethal blindspot. We will do that by going back in reverse-chronological order, starting with what makes Tesla successful in the year 2024.

From there I will take you back step by step, in order to understand which past success/failure set Tesla up for success today.

The second section is a collection of patterns (cultural, tactical and operational) that were essential tools for Tesla's (and other companies that *Teslafied* their industries, like SpaceX) success over the years. They in a sense have defined what it means to Teslafy an industry from scratch as a completely software-defined company, and to do so successfully. It is by no means exhaustive. And I have never worked at Tesla. So read it as a collection of short essays, snippets and insights that I have collected over the years and have tried to bring into a sense-making framework that accurately reflects reality (hopefully). It's all pretty evidence-based.

I hope that you can learn something about how Teslafy an industry while reading the book: How to start up a software-defined company (and what to avoid). How to scale it up into a (completely software-defined) global industry leader within a decade. And how ridiculously hard that actually sounds and is. Even if your goal isn't to achieve something of similar magnitude: Many of the patterns are extremely useful even in non-startup environments, or in startups that are setting their sights lower.

And please consider one more thing that's important to note:

For the purposes of this book, we will ignore many of the original founding myths around Tesla (Who actually co-founded it? Who made it a success? Who was forced out by whom, and why?). We will ignore all the ‘controversies’ about Musk’s style of leadership and people management, about his Twitter addiction and his other ventures, including the acquisition of Twitter as a company in 2022. All of those questions have been discussed and answered elsewhere (mainly in the many Elon biographies or many long-form podcasts done with him over the last few years).

And if you as a reader have more to say about the ‘collateral (human) damage’ created by Tesla’s fast-paced achievements and high standards of performance over the years (which definitely can’t be denied), then go ahead and write your own story about it. As you will see in the second part of this book: Everything that humans create are results of trade-off decisions. I picked my trade-off for the purpose of this story. Feel free to pick yours!

And now I hope you enjoy reading it. Thanks for taking the time!

Part II

Teslafication: A strategy playbook

With a blank slate: Hardware in a software age



Figure 1: A blank canvas

The birth of the software-defined EV industry

Tesla is not like any other company. Especially not like any other car manufacturer. There has been a lot written about its mind-boggling achievements since its inception in 2003: The first Roadster, the Model S, the Model X, then nearly dying when going mass market with the Model 3, but eventually making it. Tesla has achieved global dominance in the EV sector with the Model Y as the best-selling car in the entire category, worldwide, in 2023. It was an insane triumphal march against all odds, defying industry standards and convention, stock market logic, the biggest stock short selling position in history and much more headwind.

As I already said in the introduction, we will ignore many de-

tails and not discuss some of the negative sides of the trade-offs that had to be made in order to make Tesla succeed (whatever negative means). What we are going to focus on in this section is a higher-level conceptual framework and many very specific operating principles that emerged out of Tesla's success in the last two decades.

But why Tesla? What is special about it? There have been many spectacularly successful startup companies that have scaled to global scale in the last two decades. Most of them are in the world of software, and most of them are from Silicon Valley: Facebook, Google, Salesforce, Netflix (plus the old guard around Apple, Microsoft or NVIDIA, which all became spectacularly successful again in the last decade). Yes, Tesla makes electric cars, and does so very successfully. But in the year 2024, Tesla stands for more than just a successful electric car company.

Four aspects do matter here, specifically:

- Software-defined hardware - deep tech products
- Software-defined (advanced) manufacturing technology
- Software-defined company building & operations
- Software-defined ecosystem: Shaping a new industry in the age of software and AI

1. Software-defined hardware - deep tech products

It stands for a company that built the first truly software-defined large-scale hardware product(s) of the modern software and internet age (together with Apple):

- Over-the-air improvements of car software that enabled improvements of the physical car hardware
- Advanced driver-assistance software (in early 2024 it's still debatable if already full-self-driving or not)
- A totally advanced infotainment and vehicle operating system
- Software-defined control of basically everything hardware-related in the car, from HVAC to seat positions to battery and power management

A Tesla is a literal computer on wheels (or actually several computers). It's software-defined hardware in the age of powerful computing, cloud, networked software and AI.

*

2. Software-defined (advanced) manufacturing technology

It stands for a company that grew from a small startup into one of the most spectacular hardware manufacturers in the early 21st century that builds several of its cutting-edge models at scale, in the millions: In 2023, the Model Y was the best selling car globally, outcompeting all combustion engine legacy models.

It didn't do so by revitalizing the old ways of manufacturing. It did so by completely reinventing manufacturing in the age of advanced software and software development practices applied to hardware:

- Tons of custom-made machinery and equipment (e.g. the Gigapress for die casting almost entire cars)
- Custom-made materials (alloys, glass)
- The factory as the product (*'the machine that builds the machine'*), with its own manufacturing operating system
- Heavily automated production lines with tons of AI and robotics (that now actually work!)
- An integrated *'DevOps'* approach to product design and manufacturing in the world of hardware, therefore
 - Fast product and production system iteration cycles

- Design for automated manufacturing in order to reduce manufacturing complexity from the get-go when starting product design
- Value-stream-aligned teams: integrating vertically backwards all the way until the lithium mining operations

*

3. Software-defined company building & operations

It stands for a company that, over the last 1.5 decades, has built (among other things) its own proprietary

- Online vehicle ordering system and car configurator for end customers
- Company-wide Enterprise Resource Planning and logistics management system
- Several heavily automated and software-defined Gigafactories for both car and battery manufacturing, with an integrated manufacturing operating system layer
- Sophisticated hardware-in-the-loop software testing infrastructure for its R&D teams
- All vehicle-related firm- and software (e.g. Electronic Control Unit firmware, battery management, vehicle operating system, infotainment)
- End-2-end neural network architecture for Full Self-driving AI capabilities with millions of production cars that produce million miles of real-world training data per year
- Supercomputer ('Dojo') based on its own customer-designed D1 chip for self-driving AI training purposes in order to become '*really good at video training*' (Musk)

- Another neural net training cluster consisting of 10000 Nvidia GPU units
- Top notch data centers
- Lithium ion battery design and fully automated manufacturing system
- Insurance software for its vehicles (with proprietary driving data)
- A global supercharger network, with proprietary charging hardware and software, that now serves as the new charging standard approach in North America, joined by nearly all legacy auto companies

It's a truly software-defined company, with a software-native approach to all kinds of problems. And now it is switching gears, going into AI-first mode.

*

4. Software-defined ecosystem: Shaping a new industry in the age of software

Tesla today stands for a globally available, software-driven car brand (with 5 models for sale in early 2024) and a software-driven manufacturing giant (with several Gigafactory plants on 3 continents). It makes 2 million cars per year, after having had a compounded growth of more than 50% over the last decade. It makes billions of dollars in annual profit. It's not the new entrant anymore, but leading the electric mobility industry as the most advanced company in terms of software-defined car experiences, manufacturing approaches and future growth potential into new domains (like energy storage, factory automation technology, AI software and robotics).

Last but not least however, it stands for a software-informed supply chain network operator and node. It has co-created, shaped and influenced an entire new global electric mobility and green energy industry supply chain, from raw materials mining (lithium) to battery manufacturing to battery recycling to energy generation and storage. It has established different localized supplier networks around its factories all over the world.

It now even has flipped the power dynamics around: Being ne-

glected by many automotive suppliers a decade ago because of a more than uncertain future, it today collaborates with the broader industry to make green mobility broadly accessible:

- It basically open-sources comprehensive design approaches (e.g. for 48V power architectures for cars) because the legacy industry is moving too slowly
- It sends supplier industrialization engineers on site to its suppliers for several months in order to help them re-invent their approach to effective and efficient manufacturing, thereby carrying the torch with its lessons learned into the novel electric mobility ecosystem
- All its patents have been and are still open source, since 2014
- It is involved in every step of entire end-to-end value stream, from mining and raw materials refining to battery recycling and partners with other companies to push the industry forward
- And much more

It's not merely about building a great company. It's now about shaping a new industry.

*

The Teslification of hardware: A blueprint for repetition

Tesla did not ‘transform’ the automotive industry that existed in 2003. It rebuilt it from scratch, by de facto industrializing a new product category that did not exist before: that of software-defined mass market battery electric vehicles. It reinvented it by leveraging the power of software (and AI) at every step along the way. And it did all of that within just one-and-a-half decades.

That’s why I think that the Tesla playbook is one that will yield fruit in other industries in the next decade(s). It’s important to note that Musk has both repeated and co-written this playbook at his other major venture, SpaceX, mainly via intense cross-pollination between the two companies in order

to exchange and transfer learnings and capabilities. So I guess you could call it well SpaceX-ification. But Teslification is probably the catchier name for a book. Nevertheless I will probably refer to a SpaceX example as well, because both companies took the software-defined everything approach to hardware and rebuilt an entire new industry (commercial space transportation) from scratch.

Where can the playbook be applied?

Venture investor Zach Coelius phrased it this way:



Zach Coelius @zachcoelius

Watching Anduril run the Tesla and SpaceX
playbook is a thing of beauty.

Find an old locked up industry where the
incumbents suck and the engineers are unable
to innovate.

Build a platform for them to come build the toys
they always dreamed of.

Crush the incumbents

Figure 2: A Zach Coelius tweet

While this was and is definitely true for SpaceX, structurally (a risk-averse, more or less government-owned sector like defense/space with no prior pressure to move forward in any meaningful direction, because profits were guaranteed through tax payer money), I would disagree in the Tesla case.

Legacy auto did innovate. Gradually. At least in Europe. But it's basically the innovator's dilemma by the book: the legacy competition can't compete anymore because they are part of a legacy supply network and industry organization model that forces legacy constraints and cost structures onto the OEMs. That is something that you can't easily change - unless you start from scratch, on a conceptual green field, with green field cost structures, and grow (once again), together with the entire industry.

This takes time, resources, a huge-risk appetite and drive. None of those items are in large supply within century-old multinational corporations. In any given LargeCo, you will be rewarded for low-risk, 0.1% improvements and fired for any kind of outsized risk taken. So one could sum up the Tesla playbook like this:

Go where there previously was no private industry (like SpaceX) or where private industry did not have meaningful new competition for decades (like legacy automotive). That is where disruptive technology (a.k.a. software, software-defined hardware/ manufacturing) will generate decisive leverage over incumbents.

From this definition alone you can already predict which industries will be ripe next, in the next 1-2 decades: Battery manufacturing and its entire value stream, healthcare, biotechnology, new materials design and advanced manufacturing automation / robots in general. But more about a future outlook at the very end of section I.

In order to understand how the entire Teslafication playbook will play out in other hard tech industries in the next decade or two, it's worth starting - as always - with the end in mind! Looking at how the playbook works in full effect (after a 1.5 decade ride) and then going back in time, step by step to look at the details, can teach us many lessons about what needs to be considered earlier on when starting and scaling not only a company, but shaping an entire emerging industry. With the power of hindsight we can learn from the many mistakes made along the way, and the learnings that have been implemented and that have shaped a unique DNA and culture.

It has set up Tesla for much more future success. And more importantly, it has shaped the entire industry and industry ecosystem to a significant degree, and keeps on doing so.

The approach to the next chapters: Looking backwards at history

So in the next section, we will explore the Tesla-fication playbook from a high level - starting at the end.

In early 2024 Tesla is a highly profitable EV giant that still operates at startup speed. It just started delivering the highly controversial, unconventional but spectacular Cybertruck, where it applied many of the painful lessons it had to learn in the last decades, while going from 200 to 2 million cars sold per year within 15 years. It works on advanced AI and robotics projects. It has a '*everything is possible*' mindset. So we will first take a look at the characteristics of their pretty unique, software-defined status quo approach to design, manufacturing and innovation.

Tesla itself constantly highlighted these differentiating factors in 2023. In order to understand why they are doing so, it's necessary to go back and recap the wild journey of scaling manufacturing to millions of cars per year between 2016 and 2020. This period of great success (with the Model 3 and Y) despite brutal initial production failures shaped how Tesla operates today. It defined the company's breakout from an automotive niche into the mainstream market.

From the Model 3/Y days we then will work our way backwards to the successful days of the Model S/X development and production ramp (between 2008 and 2016). This period was highly successful back then and shaped how Tesla operates as a software-defined company today! But it as well strongly influenced Tesla's misguided initial approach to the Model 3 ramp in 2016. So it is vital to understand which false conclusions about mass market success with the Model 3 Tesla drew from that period.

Finally we will briefly jump back to the years of the first Roadster between 2003 and 2008. This period will give you some insights about how it all started, about Tesla's early core DNA, and what shaped its initial worldview towards design, manufacturing and the interdependency of the two. Only then will we be able to understand how and why Tesla kicked off the Model S/X paradigm the way it did - and why it basically

had propagated forward the false assumptions about the Model 3 ramp approach all the way from the early Roadster days.

Virgil Abloh once said:

Art is made in hindsight

So let's use the power of hindsight that we have at hand and study the playbook Tesla has laid out in the last 15 years. Let's jump into it, shall we?

*