LUISS

Department of Economics and Finance

Chair of Entrepreneurship, Innovation & Technology

CREATIVE DESTRUCTION AND FAILED PARADIGMS: PAST, PRESENT, AND FUTURE OF INNOVATION IN THE AGE OF AI

Prof. Giuseppe D'Alessandro

SUPERVISOR

Emanuele Margotta

CANDIDATE

ABSTRACT

The foundational idea of this thesis emerged from a lecture by Professor Giuseppe D'Alessandro, which focused on the failures of innovation. This thesis aims to explore the role of failure within technological progress and innovation, not only through historical analysis and theoretical models but, above all, through an in-depth examination of various case studies that best illustrate how major commercial failures can lead to the creation of new value.

Among the case studies analysed, we will give a closer look at the Apple Newton, the Betamax, and the Google Glass. From here, we will then get to the final topic of the thesis, which revolves around the concept of *fail-fast* and how current resource optimization models are likely to evolve even further in the near future.

Through this final analysis, we will investigate whether progress can exist without failure or if failure remains an unavoidable component of the technological and human evolutionary process.

TABLE OF CONTENTS

I. INTRODUCTION

To most people, progress, especially technological progress, is considered inevitable and in constant, linear growth. However, like most things, this is a distorted view which can change if we observe everything from another perspective. Imagine technological progress as a line on a graph. If we look at this graph from a distance, we will only notice that the line has a positive slope and is therefore rising. However, if we move closer and closer, we will see that, despite the upward trend, the line has a more complex and discontinuous structure than it might initially appear.

In this scenario, failure is a key factor, although it is difficult to accept. It should not be seen as an obstacle to progress but as an integral and active part. Given the way human evolution has unfolded over time, we could argue that failure is the true protagonist of advancement in all fields, not just technology. Karl Popper, in his *The Logic of Scientific Discovery*, explicitly states that trying to confirm existing theories is like running in place: it leads nowhere; science progresses through the refutation of paradigms already in use.

This principle also applies to technological innovation: failure is key to figuring out mistakes and improving. We see examples supporting this continuously in our lives: every day, products and innovations of various kinds are launched on the market, only to disappoint expectations and fail; at the same time, we use or witness the use of objects that were born from the previous failure of something once believed to be an innovation.

Even if we consider only the past few decades, the examples are countless, with some more striking than others. Among the most talked-about, we can find the commercial failure of Newton, created by Apple in the early 1990s and launched onto the market in 1993. Even today, it is remembered not only as a colossal defeat for the renowned Cupertino brand but also as one of the most remarkable failures in the history of innovation. As mentioned earlier, Newton is not alone; other attempts at innovation have turned out to be complete disasters once exposed to the reality of the market, for example Sony Betamax or the Glass.

Few theoretical confrontations have shaped our idea of progress as much as the subtle but radical one between the cited Karl Popper and Thomas Kuhn. Two distant and in

some ways opposing visions of knowledge. Both, however, agreed on one fundamental point: without failure, science cannot advance.

In *The Structure of Scientific Revolutions*, Thomas Kuhn states that major changes occur when a commonly accepted paradigm definitively fails and is subsequently replaced by a new one.

It is relevant to highlight how each of these failures has eventually brought benefits, whether for society or the producing company itself; we will cover this in the following chapters.

However, our world is heading toward a period that goes beyond everything just described, a post-failure period, where the concept of failure is left behind to enter an era in which predicting failure becomes the keystone of production.

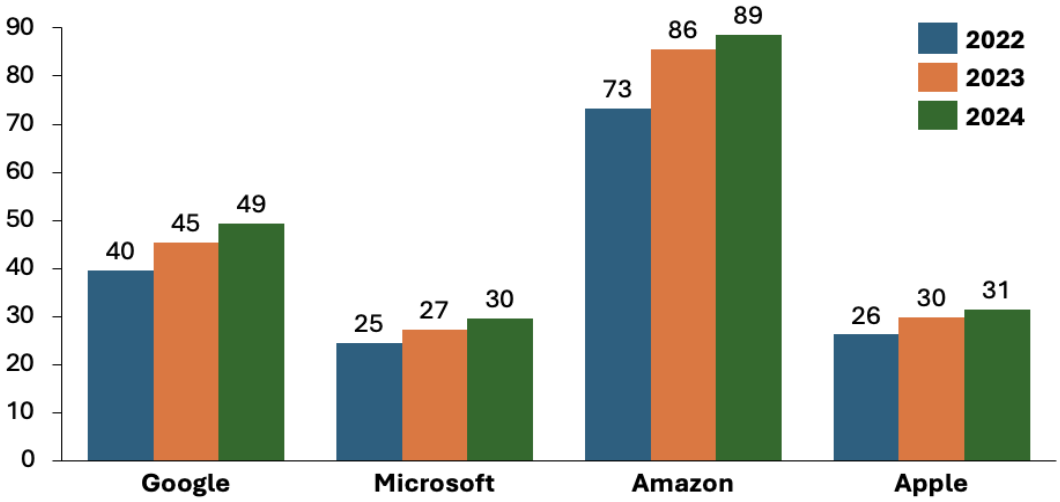

Table 1 - R&D investments in Technological Development ($ billions)

In the years to come, through new tools such as Artificial Intelligence and Quantum Computing, the efforts of thinkers and innovators will likely focus on one main goal: minimizing uncertainties and, therefore, trying to avoid failure. Such a thing could have several effects on humanity, for instance, the speed at which new technologies and humankind develop.

To fully grasp the relevance of failure in today's innovation landscape, it is essential to explore its conceptual foundations and historical significance. This requires a closer look at how failure has been defined, interpreted, and theorized within the evolution of technological progress.

II. THE NATURE OF FAILURE IN INNOVATION

A. FAILURE AND INNOVATION

1. Concepts And Definitions

Innovation is a fundamental driver of today's business world, and it goes beyond the notion of simple invention. Therefore, the first important distinction to make is between *invention* and *innovation*. The two words are semantically related; however, there is a fundamental difference at their core, which anyone interested in business and enterprise should never overlook.

An invention consists of giving life to something new, whereas innovation lies in the ability to generate value from that invention. Without active value generation, a new creation will remain so, never being integrated into the market or being able to have an active impact. Invention lights the spark, but innovation builds the fire. The ancestor of the light bulb probably shone in the laboratory, but it was the entire electrical network that lit up the world. Edison did not limit himself to inventing a mere object: he managed to give light to a new system, to give life to a value, a revolution.

Innovation can take on various forms: product innovation, perhaps the most well-known, focuses on creating new products or improving existing ones. However, other types of innovation also exist, such as process innovation or business model innovation, which aim at optimizing business processes and resources, seeking to create value for customers through radical changes in the production approach of the entity.

Additionally, innovation can be further classified into two main categories:

- Sustaining innovation focuses on improving and updating existing technologies to enhance performance and quality[1].
- Disruptive innovation involves creating something entirely new, opening the door to future business models[2].

The innovation process unfolds in four distinct phases[3]:

---

[1] Clayton M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Boston: Harvard Business Review Press, 1997).
[2] *Ibid.*
[3] Robert G. Cooper, *Winning at New Products: Creating Value through Innovation*, 4th ed. (New York: Basic Books, 2017), 15-18.

1. *Clarification Phase* consists of identifying a common problem and recognizing consumer needs.
2. *Ideation Phase*, where the problem is turned into an opportunity and effective solutions are found through research and analysis.
3. *Development Phase*, where experimentation occurs, and prototypes of the final product come to life; this process allows the identification of potential economic or production drawbacks and the improvement of the initial idea.
4. *Implementation Phase*, in which the product is effectively launched on the market and monitored even after launch to assess its impact.

   As previously mentioned, innovation is neither a linear process nor one free of setbacks. If we imagine it as an engine of progress, then failure is not only its fuel but also the friction and the occasional breakdown that forces a complete redesign, it implies a reassessment of one's strategic or organizational identity, as a person or as a company. Without it, there's no real movement, just illusion.

   According to any dictionary, failure is the direct opposite of success, yet in reality, they could be considered the yin and yang of evolution, two sides of the same coin that coexist and work in synergy. The absence of failure is generally considered to suffocate innovation, likely due to the fact that, looking back, innovation frequently emerges through the lessons learned from prior setbacks. Understanding this dynamic is vital for businesses and individuals navigating an increasingly complex and competitive technological landscape. In the following sections, we will explore how failure has shaped innovation throughout history, analyse key theoretical frameworks, and examine real-world case studies that highlight its indispensable role in driving technological evolution.

2. The Evolution Of Technological Innovation

Taking a broader look at the historical context, technological progress has generally been incremental over the centuries. Just consider the evolution that took place between the Stone Age and the pre-industrial era, which was relatively slow compared to the rapid technological advancement of the modern age.

A pivotal moment in this long historical process was the First Industrial Revolution, which began in the second half of the 18th century in the United Kingdom. During the early 1700s, England was the wealthiest nation in Europe, having secured naval supremacy by outcompeting rival powers such as France[4]. Meanwhile, traditional production could no longer keep up with the increasing demand coming both from the colonies and the growing English population[5]. An immediate change was needed: old methods had to be replaced by systems that could increase production speed and efficiency without inflating costs, which was made possible by developing new machines and adopting mechanized production.

A remarkable breakthrough was the steam engine, an invention by James Watt that used coal to boil water, thus generating steam that powered machines, which revolutionized energy conversion, transforming heat into mechanical motion, and allowing a rapid process of industrialization. Industrialization then quickly spread throughout Europe, particularly in France and Germany, before reaching other parts of the world. Along with the rise of machines, the industry developed at an impressive pace, radically changing the world of work and lifestyle of several nations.

However, history confirms that this had just been the beginning, as a Second Industrial Revolution was meant to emerge in the late XIX century, usually dated between 1870 and 1914[6] depicting a whole new wave of technological breakthroughs. Unlike the first revolution, which had been powered by steam and coal, new energy sources were introduced, such as oil and electricity[7]. Concurrently, the world witnessed a shift in the focus of production: whilst the first revolution was driven by textile manufacturing, this new era saw the explosion of chemical, steel, mechanical, food, and extractive industries, causing an astounding impact, as well as a radical expansion of industrialized nations[8].

Subsequently, in the first half of the XX century, when progress seemed to have reached a hardly improvable pace, a new technological acceleration was observed. Massive

---

[4] Kenneth Pomeranz, *The Great Divergence: China, Europe, and the Making of the Modern World Economy* (Princeton, NJ: Princeton University Press, 2000).
[5] Phyllis Deane, *The First Industrial Revolution* (Cambridge: Cambridge University Press, 1979).
[6] Joel Mokyr and Robert H. Strotz, "The Second Industrial Revolution, 1870–1914", *Storia dell'economia mondiale* 21945, no. 1 (1998).
[7] *Ibid.*
[8] *Ibid.*

strides were made in an incredibly short period, and the two World Wars likely ignited the acceleration of innovation noticed during the first part of the XX century.

In wartime, governments funded military research with exorbitant amounts, stimulating technological innovation in various fields, such as aviation, medicine, chemistry, and communications.

Among the most emblematic innovations of this period, the radio stands out in particular, invented in 1895 and patented in 1897 in London by Guglielmo Marconi[9], along with the television, invented in 1927 by Philo Farnsworth[10], antibiotics, such as penicillin, and the first calculators, the precursors of modern computers.

As previously mentioned, during war times, governments invested massive sums in research, initiating a technological race between states and enabling the first major collaborations between governments, science, and industry. As a result of this technological race, the post-World War II period marked the beginning of a new era: the advent of computerization, which would go on to transform every aspect of modern life.

The foundations of the digital and electronic revolution were laid as early as 1947, when the transistor was introduced, and later with the adoption of the integrated circuit.

Moreover, in conjunction with the Cold War, the so-called *space race* began, which resulted in an incredible stimulus for research in the aerospace and digital fields, at first culminating with Sputnik and Apollo 11, and later with the advent of the Personal Computer in the 1970s and 1980s.

The XX century concluded with the spread of the Internet, which soon became unstoppable and brought along instant communication, economic digitalization, and, given the increasingly affordable price of these technologies, boundless interconnectivity, and globalization.

In the early 2000s, the digital revolution entered a phase of consolidation, setting the stage for what would later be defined as the Fourth Industrial Revolution. Humanity thus commenced its initial steps into the Digital Era, in which we still find ourselves today, marked by unprecedented technologies capable of opening enormous and countless doors to the future.

---

[9]Ambrose Fleming, "Guglielmo Marconi and the Development of Radio-Communication", *Journal of the Royal Society of Arts* 86, no. 4436 (1937).

[10]Albert Abramson, "Pioneers of Television, Philo Taylor Farnsworth", *SMPTE Journal* 101, no. 11 (1992).

Among the most revolutionary innovations of this period, besides the already mentioned unstoppable expansion of the Internet, we find the advent of the first smartphones, cloud computing, and social media, which redefined the concept of interpersonal relationships, shaping a brand new world.

In the 2020s, we are thus inside the aforementioned Fourth Industrial Revolution, characterized by the constant discovery of new ways to exploit technologies that emerged from the second half of the 20th century onwards.

Nowadays we speak of Industry 4.0, marked by the advent of disruptive innovations such as blockchains, cryptocurrencies, virtual reality, robotics, and AI.

As also highlighted in a McKinsey & Co. study on Industry 4.0[11], the capability of firms to continuously update themselves is becoming increasingly valuable. In fact, whenever we talk about *upskilling* we are addressing the capacity of a company's workforce to learn new skills that will be useful to make the company increasingly efficient as they emerge[12].

Besides upskilling, *reskilling* is also becoming increasingly central within a company and is used to identify employee flexibility, namely the ability to cover different roles within the production process[13].

When analysing the historical phases cited, we could notice some trends in technological evolution. The first is the acceleration of progress: each technological revolution has reduced the time required for innovations to spread compared to the previous one, leading to increasingly rapid and impactful advancements.

Secondly, there is an expansion in the scope of innovation: whereas initially, transformations affected specific sectors, today they simultaneously impact multiple industries and the entire global socio-economic system, as already happened with ICT and is now occurring with AI.

Finally, the role of scientific knowledge and diffusion networks is increasing; innovation is increasingly the result of structured scientific research and spreads through global networks, ensuring increasingly widespread access to new technologies.

---

[11] McKinsey & Company, "What Are Industry 4.0, the Fourth Industrial Revolution, and 4IR," McKinsey Digital, 2022, https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-are-industry-4-0-the-fourth-industrial-revolution-and-4ir

[12] *Ibid.*

[13] *Ibid.*

This general overview demonstrates how technological innovation is a cumulative evolutionary process, characterized by innovative advancements in various eras and a continuous growth trend that connects the ancient artisan workshop to today's digital society.

B. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

1. Historical Perspectives On Technological Setbacks

The history of innovation shows that progress and failure are two ends of the same rope. Whatever innovation we consider, it will likely be born from a process of trial, error, and continuous revision. However, while some failures are quickly forgotten, others have generated new ideas, inspired technological revolutions, and, in some cases, transformed entire economic sectors.

But what is the exact role of failure in the innovation process? Can it be theoretically demonstrated that failure is a necessary condition for progress? The answer to these questions emerges from numerous studies that explore the link between failure, organizational learning, and technological growth. In the next section, we will analyse the main theoretical perspectives and models that explain why and how failure can be not only tolerated but valorized as a tool for innovation.

Henry Petroski has addressed the fact that failure should not be considered an obstacle but a main driver of innovation[14]. His work underscores how structural weaknesses, unforeseen boundaries, and innovation collapses are often the very catalysts that push technology and industry forward. Looking at the broader framework of innovation, we can notice that some of the most transformative advancements are born out of failure rather than success.

Historical examples confirm this view. Thomas Edison, who tested thousands of materials before finding the right filament for the light bulb, famously stated:

"I have gotten a lot of results!

[14] Henry Petroski, *To Engineer Is Human: The Role of Failure in Successful Design* (New York: Vintage, 1985).

I know several thousand things that won't work".[15]

His logic becomes evident through the cited statement: according to Thomas Edison, every failed attempt was merely a step forward toward success. Another well-known example is that of the Wright brothers, inventors of the first airplane, whose initial experiments did not give outstanding results. Orville Wright, one of the two brothers, miraculously survived eight crashes[16] before coming up with the final prototype, proving once again that innovation is usually the result of a long series of trials.

These examples are not limited to the distant past, as in more recent years, we have seen similar cases. In 2013, for instance, Google launched its Google Glass[17] on the market, integrating augmented reality into a pair of glasses in an attempt to revolutionize how people interacted with technology. The concept was highly forward looking and presented substantial disruptive potential. However, the project encountered significant technical and market-related obstacles that ultimately sealed its definitive failure: the design was far from appealing, the price was highly exclusive, and, to make matters worse, consumers feared for their privacy due to the always-on cameras mounted on the glasses[18]. Despite the severe commercial flop, the technology developed for the project was not forgotten but later reused in creating new products, such as the very recent Ray-Ban smart glasses by Meta.

Another glaring case was Microsoft Zune[19], a music player launched in 2006 in an attempt to counter the unstoppable spread of the Apple iPod. Even before its release, the product presented a considerable risk, as Apple had already captured most of the market. Microsoft's ecosystem was notably less flexible than Apple's iTunes, and, most importantly, it lacked a clear identity and failed to create value. The product was withdrawn from the market in 2012, but Microsoft learned many lessons from Zune, which later contributed, among other things, to the creation of Xbox Music.

---

[15]Oxford Reference, s.v. "Thomas Edison," *Oxford Reference*, https://www.oxfordreference.com/display/10.1093/acref/9780191826719.001.0001/q-oro-ed4-00003960.
[16]Wright Brothers Aeroplane Company, "Wright Trivia," *Wright Brothers Museum,* https://www.wright-brothers.org/Information_Desk/Just_the_Facts/Trivia/Wright_Trivia.htm
[17]Laith Zuraikat, "Google Glass: A Case Study", *Performance Improvement* 59, no. 6 (2020): 14-20.
[18] Jason Hong, "Considering Privacy Issues in the Context of Google Glass", *Communications of the ACM* 56, no. 11 (2013).
[19] Silicon UK, "Tales in Tech History: Microsoft Zune," *Silicon UK*, 2017, https://www.silicon.co.uk/mobility/smartphones/tales-tech-history-microsoft-zune-210569.

All the examples mentioned do nothing but confirm a fundamental principle: failure is not the end of innovation, but often the moment when the foundations for are laid.

2. Learning From Failure: Models And Theories

While historical cases help illustrate the recurrence of failure in innovation, theoretical models provide a deeper understanding of its mechanisms and significance.

Schumpeter was among the first pioneers to put on the table the concept of the centrality of entrepreneurial innovation in economic development[20], a concept that was then reworked and redefined as *creative destruction*. Schumpeter thus concluded that innovations destroy the old economic order to create a new and more efficient one. He confirms once again that innovation is not only invention but the ability to combine in a new way existing resources by entrepreneurs-innovators. The entire process often leads to temporary monopolies that are later diluted thanks to the diffusion of the idea and the advent of new competitors.

Another illustrious thinker who dealt with these topics, although less directly, was the aforementioned Karl Popper, who introduced the concept of falsifiability[21]. But what does this mean exactly? According to Popper, a theory is scientific only if it can be refuted; this is in contrast with proper scientific theories, usually considered valid after going through a process of constant and iterated confirmation. Although this may be questionable, especially from the point of view of those who tend to observe the world around us rationally, it is a concept that, reworked, can be useful in the economic and entrepreneurial fields. In this field, Popper's theory takes on a further meaning: it is about being able to question the surrounding system and existing paradigms, taking on risks and uncertainties, and thus being able to create something brand new[22]. All this is achieved by continually questioning oneself through experimentation, practical experience, and facts, and at the same time learning from failure, identifying it as a further step towards improvement.

---

[20] Christopher Ziemnowicz, "Joseph A. Schumpeter and Innovation", in *Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship* (Cham: Springer, 2020).
[21] Karl R. Popper, "Science as Falsification", in *Conjectures and Refutations* (London: Routledge, 1963).
[22] Robert Winter, "Popper's Theory of Falsification: A Pillar of Adaptive Leadership," blog, 2024, https://robert.winter.ink/poppers-theory-of-falsification-a-pillar-of-adaptive-leadership/.

Furthermore, Thomas Kuhn, previously mentioned, developed a theory that continues to inspire debate and inquiry among scholars across disciplines. His vision was that scientific progress is not due to the accumulation of new knowledge or the simple updating of existing theories but to scientific revolutions[23]. According to the physicist, a paradigm, absorbed by the scientific community yet repeatedly overwhelmed by a series of anomalies and unexplainable phenomena, is subverted through a process of revolution to make room for a completely new one. The new vision does not necessarily follow rationality and is not necessarily guided by logical reasons; according to Kuhn, it is thus destined to face resistance from the scientific community. Similarly, many inventions are destined to fail and are discarded regardless since they conflict with the dominant paradigm, as the market and those who are part of it will tend to defend their habits and certainties. An innovation is, therefore, more likely to succeed when able to establish itself as a new paradigm, convincing or forcing the community to change perspective. Following Kuhn's reasoning, progress is not an improvement of something already existing but rather a rupture with the past; to truly innovate, one must be ready to challenge dominant beliefs.

If, on one hand, innovating means breaking with the past and challenging paradigms, as emerged from the analysis of previous theories, on the other, the method of learning and improvement of companies is fundamental to determine whether such breaks are bound to succeed or not. The model introduced in 1976 by Chris Argyris offers an interesting interpretation, bringing to the table the concepts of Single-Loop and Double-Loop Learning[24]. These are valuable for understanding the process that leads some companies to question themselves and adapt to new schemes, and others to correct only superficial errors, remaining trapped in obsolete paradigms. Single-Loop Learning is identified by Argyris as the most widespread typology: companies do not question themselves and do not try to solve problems at the root; instead, they try to improve efficiency by acting on minute superficial errors that are immediately understandable[25]. A clear example of this is before our eyes whenever a company facing a drop in sales decides to lower prices

[23] Gopesh Anand, Eric C. Larson, and Joseph T. Mahoney, "Thomas Kuhn on Paradigms", *Production and Operations Management* 29, no. 7 (2020).
[24] Chris Argyris, "Single-Loop and Double-Loop Models in Research on Decision Making", *Administrative Science Quarterly* 21, no. 3 (1976).
[25] *Ibid.*

without asking itself whether the product is still suitable for the market or what defects may have led to the drop in revenue.

In contrast, Double-Loop Learning consists of digging deeper. Correcting gross errors is no longer enough; strategies, objectives, entire products, or even the identity of the company are called into question[26]. When faced with a drop in sales like the one mentioned above, a company that reasons according to this model is led to ask itself if the product is still ideal for the market in which it operates, possibly going to touch up elements of production or the business model. Argyris thus concluded that if an organization is not capable of performing self-criticism and identifying structural errors, and instead keeps operating as usual, pointing to the surrounding market as the culprit, innovation is suffocated and becomes impossible.

To complete this list of illustrious visions, Nassim Nicholas Taleb in his *Antifragile* introduces the concept of antifragility: it is not enough to be resilient or robust, it is necessary to benefit from stress, uncertainty and failure[27]. An antifragile system grows and strengthens when it is exposed to variability and errors. From an entrepreneurial point of view, applying antifragility means designing organizations and products with redundancy: small local failures not only do not compromise the bigger picture, but generate experiential learning and new opportunities. In this way, the company does not limit itself to avoiding the error or learning from it but designs its system to improve thanks to stress.

Taken together, these theories suggest a common conclusion: failure is not merely an obstacle but a huge opportunity for progress. Schumpeter demonstrated that innovation destroys previous paradigms to create new ones, Popper highlighted the importance of questioning certainties, Kuhn explained that actual change comes from breaking with old models, Argyris clarified that only organizations capable of learning at a deep level can truly adapt and innovate, Taleb reminds us that truly innovative organizations turn uncertainty into an advantage for growth. Consequently, we can conclude that innovation is not simply the fruit of a brilliant idea but of a company's ability to know how to fail in the right way: not limiting itself to correcting minor surface errors but questioning its strategies and visions. Only by following this path is it possible to

[26] *Ibid.*

[27] Nasim Nicholas Taleb, “Antifragility, How to benefit from chaos” , (2014).

transform failure into a gateway for success, accepting uncertainty and the need to change perspective to create something genuinely new.

These theoretical insights suggest that failure is not merely accidental but structurally integrated within the process of innovation. To understand how this plays out in reality, the next chapter examines specific technological case studies in which failure served as a catalyst for transformation or reorientation.

III. CASE STUDIES OF TECHNOLOGICAL DEBACLES

Theory alone cannot capture the full complexity of failure. To bridge the gap between abstract models and real-world dynamics, this chapter presents three emblematic case studies, Apple Newton, Sony Betamax, and Google Glass, each demonstrating how failure manifests in practice and what lessons it can teach. Each of these technological failures followed different paths: Newton brought us the iPhone, Betamax reshaped Sony's strategy, and Glass gave life to internal learning loops that changed Google's innovation culture.

A. APPLE NEWTON

1. Development And Launch

In the early 1990s, Apple was going through the most challenging period in its history. John Sculley had been CEO of Apple for nine years, while Jobs had left the company following a boardroom coup seven years earlier. Sales were down, and, after the Macintosh, the company had barely tried to create something innovative, mainly relying on the success of existing products. Therefore, there was a need for something new, a revolution, capable of relaunching Apple on the market and ensuring more stable profitability. The original Newton idea came from an engineer named Steve Sakoman. Sakoman had already participated in developing the HP 110, the first real PC created by HP, which, unlike previous models, had a built-in battery that allowed the consumer to operate it anywhere[28]. Sakoman's work attracted the attention of Steve Jobs, who in 1984 decided to offer him a job in a new development team, intending to create a portable version of the Macintosh[29]. After Jobs was pressured to leave the company, Sakoman had to be begged to stay, forming a team to experiment with new ideas. The design and development of the device began in 1987: the team moved to an abandoned

[28] Hewlett-Packard Computer Museum, "The HP Portable: HP's First Laptop," *Hewlett-Packard Computer Museum*, http://www.hewlettpackardhistory.com/item/hewlett-packards-first-laptop/.
[29] Jesus Diaz, "The Story Behind Apple's Newton", *Gizmodo*, 20 January 2010, https://gizmodo.com/the-story-behind-apples-newton-5452193.

warehouse near Cupertino and named the project after Isaac Newton, a figure present in the first Apple logo[30].

Sakoman and his team attempted to ride the wave of recent technological developments, trying to integrate a touch screen, handwriting recognition, hard disk, and infrared into a device of minimum size for the time. While in the warehouse they were trying to overcome obstacles due to a technology that was not yet advanced enough to fulfill their ambitions, other engineers at Apple headquarters were trying to develop the Pocket Crystal, an idea similar to the Newton, brought to the table in 1989 by Marc Porat[31]. The Pocket Crystal project was too complex to realize and would have cost the company around $8,000 each; therefore, when the idea of the Newton was first presented to John Sculley in 1991 by Michael Tchao, Apple's product marketer, the CEO was enthusiastic about it and decided to defer once and for all the Pocket Crystal project[32].

In 1992, during a speech at the Consumer Electronics Show in Las Vegas, Sculley, after coining the term *Personal Digital Assistant*[33], declared that the Newton would soon radically change the world of technology, stating:

"The Apple Newton is nothing less than a revolution".[34]

However, there was one small issue: the device itself did not exist when it was unveiled. Apple did not have a prototype that even remotely worked at the time of the announcement, but only a conglomerate of software features[35]. Sculley's decision to unveil the device at CES in 1992 would later be called catastrophic by many, who said

---

[30] *Ibid.*

[31] Commoncog Case Library, "General Magic: The Future, Too Early," *Commoncog Case Library*, https://commoncog.com/cases/general-magic-the-future-too-early.

[32] Christina Bonnington, "Remembering the Apple Newton's Prophetic Failure and Lasting Impact", *Wired*, 2 August 2013, https://www.wired.com/2013/08/remembering-the-apple-newtons-prophetic-failure-and-lasting-ideals/.

[33] Ewan Spence, "For the Record, Apple's Newton Was Not the First PDA", *Forbes*, 3 June 2012, https://www.forbes.com/sites/ewanspence/2012/06/03/for-the-record-apples-newton-was-not-the-first-pda/.

[34] Bloomberg Television, "Apple Newton's Flop | On This Day," YouTube video, 2024, https://www.youtube.com/watch?v=kXTGdx8UjdQ.

[35] John Markoff, "Apple to Give the Public Its First Look at Newton", *New York Times*, 29 May 1992, https://www.nytimes.com/1992/05/29/business/company-news-apple-to-give-the-public-its-first-look-at-newton.html.

it was premature, raised consumer expectations and conceded competitors time to develop similar products.

At that point, engineers working on the project tried to speed up the work, often having to work grueling hours. During this intense development period, countless problems began to emerge, starting with the initial processor, which was discarded in favor of an ARM processor, a type of chip that was very efficient and low in power consumption[36]. However, the capability of the processor was not the only impediment to overcome; in fact, there were problems with infrared, cables, overheating, and even with the boasted handwriting recognition.

Apple decided to stick to the deadline and present the product in April 1992 in Chicago, which was now renamed Newton MessagePad. Although some small promises seemed not to have been kept, the press was enthusiastic about the presentation and the new product, and was finally ready to welcome it. In reality, it is correct to say that they would have been keen to welcome it if only Apple had been actually ready to launch it on the market. The employees were working tirelessly to try and solve the enormous amount of problems of Newton and make it a product acceptable to the average consumer, and the company opted to postpone the commercialization to August 1993, almost a year later. In addition, Apple had to introduce a mental support program since the efforts of those who were working on the project, in addition to seeming useless, led the employees to neglect themselves and the surrounding world, leading them on the path of total alienation and, in some cases, even suicide[37]. Despite the enormous efforts of the staff, the problems persisted and kept manifesting even the day before the presentation.

Finally, Newton was officially presented, but were there any problems during the unveiling? No, because the presentation was almost entirely scripted: the engineers had been working on a demo tailored for the unveiling to present an innovation worthy of the name. Therefore, the press was enthusiastic, even more than the previous time, and the product officially entered the Beta Testing phase before being formally released to the global market.

---

[36] Muhammad Nabeel Asghar, "A Review of ARM Processor Architecture: History, Progress and Applications", *Journal of Applied and Emerging Sciences* 10, no. 2 (2020).

[37] Newton Glossary, s.v. "Ko Isono", Newton Glossary, https://newtonglossary.com/terms/ko-isono.

The Newton MessagePad was finally launched on the market in August 1993, during the MacWorld, when the initial enthusiasm had already exhausted itself. The flagship features announced by Sculley the previous year were either broken or not implemented at all, and the price was nothing short of exorbitant.

2. Impact On Subsequent Successes

The first commercially available Newton MessagePad model was priced at $699, or about $1,540 if you factor in inflation over the past 32 years[38]. In addition to the price, the problems mentioned above persisted, even becoming the subject of ridicule among the public; even in a scene from an episode of The Simpsons, Newton was lampooned for its failing handwriting recognition[39]. Apple gradually attempted to address these problems, releasing new, reworked models every year. Thus were born the MessagePad 100, MessagePad 110, MessagePad 120, and MessagePad 130. From here on, they will move to an even more powerful processor, the StrongARM 110, which will allow the release of new and radically evolved models: the MessagePad 2000 and the MessagePad 2100, released in November 1997.

[38] Etan Cohen, "Newton Attracts Curiosity, Not Buyers", *The Harvard Crimson*, 28 September 1993, https://www.thecrimson.com/article/1993/9/28/newton-attracts-curiosity-not-buyers-papple/.
[39] Chris Matyszczyk, "The Simpsons' 'Eat Up Martha' Was the First Autocorrect Fail", *CNET*, 3 October 2013, https://www.cnet.com/tech/services-and-software/the-simpsons-eat-up-martha-was-the-first-autocorrect-fail/.

Table 2 - Comparison Between Nasdaq (in red) and Apple Share Value (in blue) 1991-1997, Yahoo Finance

In the meantime, Apple had as its new CEO Gil Amelio, who found himself with a company in free fall, with sales and profits constantly declining, which was continuing to collect failures. Therefore, Amelio took a drastic decision, acquiring the recently founded company NeXT, owned by Steve Jobs, for 427 million dollars[40]. It seemed like an irrational acquisition, especially in such a complicated period for the company, but Amelio had made the right choice: buying NeXT to bring Jobs back into Apple, create a new vision, give the right direction to the company, and attempt a complete recovery. After initially taking on the role of advisor to Gil Amelio and following a subsequent boardroom coup, Steve became the new CEO of the company he founded in 1976.

Jobs immediately took drastic decisions, attempting to get the company back on track, such as firing over 4,000 employees or accepting a $150 million investment from long-time rivals of Microsoft[41].

Among these decisions, there was the permanent interruption of the production and development of Newton MessagePads in 1998, which, from the first model in 1993 until then, had sold just 200,000 units, including all models[42].

There were multiple factors behind this decision: first and foremost, the rivalry with John Sculley, promoter of the idea. Steve probably felt betrayed when he was distanced from the Board of Directors of the company he created, back in 1985, likely since he himself had tried in every way to snatch Sculley from PepsiCo two years earlier. Furthermore, Jobs was confident that, to take a new direction toward innovative products, it was first necessary to free oneself from the past and obsolete products: the Newton line was therefore blocked to make room for new products and free up engineers who would not otherwise have had the opportunity to develop new ideas.

Finally, in addition to the aforementioned commercial flop, Steve is said to have had a natural aversion to the stylus and was trying in every way to completely revolutionize

[40] Adam Sutherland, *The Story of Apple* (New York: Rosen Publishing Group, 2012).
[41] Business Insider, "Steve Jobs' Life and Apple Career, from Cofounder to CEO," *Business Insider*, 2024, https://www.businessinsider.com/steve-jobs.
[42] *Ibid.*

the paradigm, trying to replace the stylus with direct human interaction, through the fingers[43].

Although Apple's Personal Digital Assistant was a total flop in terms of revenues, it opened the doors to a new world of technology, which was not even remotely imaginable in 1993, when the first model was launched.

The first of these features is undoubtedly the interface, which was entirely touchscreen; Steve had a problem with keys and buttons, in addition to the aversion to styluses[44], and therefore decided to start working on a device that would overcome these problems. The idea was to seek a product with a bar aesthetic, which would place particular emphasis and give proper relevance to the screen, aspects inevitably attributable to what had been the Newton MessagePad. Furthermore, implementing a System on Chip based on the ARM architecture proved to be an incredibly farsighted choice by Sculley and the team since the ARM architecture is today the beating heart of most mobile devices, including, of course, the iPhone. Even the choice of the LCD, a type of liquid crystal display that uses the optical properties of crystals to modulate light and display images with low energy consumption[45], was not a consolidated habit. Lastly, another innovation that opened the doors to the future brought by Apple was to equip the MessagePad with a 336x240 pixel screen, a relatively large display for the time, which allowed for greater interactivity. Over the following years, this innovation took on an ever-increasing importance, culminating with the advent of the iPhone, which demonstrated to the world that the screen no longer had to be limited to support the interface but could become the center of the user experience.

B. BETAMAX

1. Vision And Strategy: Behind The Betamax

[43] Alex Hern, "The iPhone Only Exists Because Steve Jobs 'Hated This Guy at Microsoft'", *The Guardian*, 21 June 2017, https://www.theguardian.com/technology/2017/jun/21/apple-iphone-steve-jobs-hated-guy-microsoft-says-scott-forstall.

[44] Victor Luckerson, "Steve Jobs Totally Dissed the Stylus Eight Years before Apple Pencil", *Time*, 10 September 2015, https://time.com/4029142/steve-jobs-stylus/.

[45] Lenovo, "What Is a Liquid Crystal Display (LCD)?", https://www.lenovo.com/us/en/glossary/what-is-lcd/.

In the late 1960s and early 1970s, Sony was one of the most innovative and respected consumer electronics companies in the world. Founded in 1946 by Masaru Ibuka and Akio Morita, the Japanese company had become known for its capability to transform complex technologies into accessible products, launching devices that, until then, had been reserved only for connoisseurs[46]. The company had established itself globally thanks to revolutionary products such as the transistor radio in 1955, which made music portable for the first time, the first portable transistor TV in 1960, and The Walkman, which would only come in 1979 even though the design mentality was already there[47].
In the 1960s, Sony had already embarked on a well-defined strategy: always be the first to launch a new technological standard, counting on its innovative strength to impose it on the market. This approach as a leader in the company was based on a strong technical pride and a vision of technology as a tool for improving society.
This internal culture was combined with a substantial autonomy: Sony tended to develop both hardware and standards internally. As Akio Morita, co-founder, and soul of the company, stated:

"Our plan is to lead the public with new products rather than ask them what kind of products they want".[48]

After the positive experience of the U-Matic, Sony decided to bring video recorder technology into homes. The demand for recording television programs was growing, and the concept of watching a program after it had been broadcast, was starting to have enormous commercial potential.
Therefore, Sony thought it was the ideal time to launch a compact home video format that would be simple to use and have excellent image quality; Betamax was thus born. The project was driven by the ambition to replicate the success of the Trinitron, a kind of TV made by Sony able to show clearer and more colorful pictures because of a special design of the screen[49], and become a leader in the nascent home video sector.

[46] John Nathan, *Sony* (Boston: Houghton Mifflin Harcourt, 2001).
[47] Sony Corporation, "Product & Technology Milestones", https://www.sony.com/en/SonyInfo/CorporateInfo/History/sonyhistory.html.
[48] AZQuotes, "Akio Morita , Quotations", https://www.azquotes.com/author/20128-Akio_Morita.
[49] Brian Santo, "The Consumer Electronics Hall of Fame: Sony Trinitron", *IEEE Spectrum*, 13 August 2018, https://spectrum.ieee.org/the-consumer-electronics-hall-of-fame-sony-trinitron.

However, Sony did not just want to sell VCRs: the company wanted to define the global standard for future home entertainment by making every video cassette a Betamax cassette. In other words, Sony did not see Betamax as a product but as a proprietary ecosystem destined to dominate home audiovisual.

However, this autarchic and confident strategy would later prove fatal in the new competitive context. The market was changing, and cooperation between industries, openness to shared standards, and the centrality of the end user were becoming decisive elements. Blinded by its reputation and the evident technical superiority of its product, Sony underestimated the actual market preferences.

Sony launched the Betamax format in May 1975, introducing the first home video cassette recorder, a pioneering system based on 1/2-inch video cassettes, a derivative of the earlier professional U-Matic standard. From the beginning, Betamax offered high-quality images for its time but favored video definition at the expense of recording time: in Beta I mode, it could only record 1 hour of content per cassette.

The company went on to promote Betamax as a device for television time-shifting, banking on the idea that users would record TV programs for later viewing. Furthermore, the first Betamax, LV-1901, was sold along with a 19-inch Trinitron television, underlining the system's immediate home use[50]. Building on its technological reputation, Sony was confident that Betamax's superior audio-video quality would persuade consumers to pay the premium price of about $1,295[51].

At about the same time, competitor JVC introduced the rival Video Home System format, VHS, in 1976, starting the so-called *format wars* in the VCR market. Unlike Sony's "premium" approach, JVC took a more pragmatic, consumer oriented strategy: VHS cassettes offered 2 hours of recording time at a slight sacrifice in video resolution. This tradeoff paid off: many users preferred longer recording times to slightly higher quality. JVC also designed VHS with simplicity and cost in mind. In 1977, RCA launched a VHS video recorder on the American market for about $995, about $300 less

[50] Samuel Gibbs, “Betamax Is Dead, Long Live VHS”, *The Guardian*, 10 November 2015, https://www.theguardian.com/technology/2015/nov/10/betamax-dead-long-live-vhs-sony-end-production.
[51] Joshua M. Greenberg, *From Betamax to Blockbuster: Video Stores and the Invention of Movies on Video* (Cambridge, MA: MIT Press, 2016).

than the equivalent Sony Betamax[52]. Within a few years, VHS cassettes with 4 to 6-hour capacities were introduced, allowing long events such as sports games to be recorded on a single medium.

Strategically, Sony initially hoped to establish Betamax as the industry standard[53]. In 1974, it introduced the technology to other Japanese companies, expecting a general agreement. For a short time, the Japanese government even tried to promote a unified format for the sake of consumers. However, Sony's offer to license Betamax to competitors was met with skepticism. JVC had thus decided to develop VHS as an open format to avoid a situation of dependence on Sony. Later on, by convincing the giant Matsushita, Panasonic's parent company, and other Japanese manufacturers to adopt VHS, JVC effectively created an industrial alliance opposed to Sony, inducing the government to withdraw the project of a single standard and initiating the true commercial clash between the two formats.

VHS thus had a much larger network than Betamax. JVC deliberately maintained a low-cost, open licensing policy: it offered VHS technology to any interested manufacturer, preferring to gain market share rather than maximizing short-term profits from royalties. This strategy quickly attracted numerous partners: by 1984, 40 companies were producing VHS video recorders, while Betamax's supporters were reduced to around 12 smaller manufacturers. On the other hand, Sony initially kept Betamax as a closed standard, limiting itself to producing VCRs and only selling expensive licenses to a few partners.

The approach made the difference. The most considerable VHS manufacturer base generated significant economies of scale and launched various models on the market, lowering prices for end users and accelerating VHS's global adoption.

Sony's strategy also had weaknesses in terms of content and partnerships. In the early years, few film catalogs were available for purchase or rental on cassette for either format, as Hollywood studios feared that home video would erode movie revenues. Sony even faced a lawsuit in 1979, in which the major studios attempted to ban the sale

---

[52] The New York Times, "RCA Introduces Video Cassette Recorder For $300 Less Than Sony Competitor", 24 August 1977, https://www.nytimes.com/1977/08/24/archives/rca-introduces-video-cassette-recorder-for-300-less-than-sony.html

[53] Legacy Box, "Betamax vs. VHS: History of the Videotape Format War", https://www.legacybox.com/blogs/analog/betamax-vs-vhs-history.

of Betamax VCRs, accusing them of promoting piracy[54]. Although Sony won the case in the Supreme Court in 1984, these initial frictions made Sony's relationship with the film industry difficult. On the other hand, JVC was able to work with Hollywood, striking deals with major studios to encourage the distribution of films on VHS, which soon resulted in an increasing supply of VHS titles at stores and video rentals.

An often-cited factor in the defeat of Betamax was the role of the pornography industry: in fact, according to an urban legend, Sony would have prevented the distribution of adult films on Betamax, thus favoring the mass choice of VHS by consumers. In reality, this factor had a secondary weight. The main reasons for the triumph of VHS were not technical but commercial and strategic nature, spanning from longer recording duration and a more accessible cost to a generally wider licensing and industrial support, which resulted in higher availability of content.

By the early 1980s, the market balance had shifted significantly in favor of VHS. Although Betamax had a 100% share of the nascent VCR industry in 1975, by 1980, VHS had controlled about 60% of the North American market, which had risen to 75% in the United States by 1981. In 1988, Sony, after being abandoned by most partners, announced that it would begin producing VHS-compatible video recorders, marking the official defeat of Betamax[55].

In the end, 13 years after Betamax's launch, about 170 million VHS video recorders were sold worldwide, while Betamax units peaked at just 20 million.

The last Betamax recorder came out in 2002, whereas blank cassettes were produced until 2016 before being withdrawn forever from the market.

---

[54] Cornell Law School, "SONY CORPORATION OF AMERICA, et al., Petitioners v. UNIVERSAL CITY STUDIOS, INC., etc., et al.", https://www.law.cornell.edu/supremecourt/text/464/417#:~:text=After%20a%20lengthy%20trial%2C%20the,2d%201409%20(1983).

[55] Michael Cusumano, Yiorgos Mylonadis, and Richard S. Rosenbloom, "Strategic Maneuvering and Mass-Market Dynamics: The Triumph of VHS over Beta", *Business History Review* 66, no. 1 (1992).

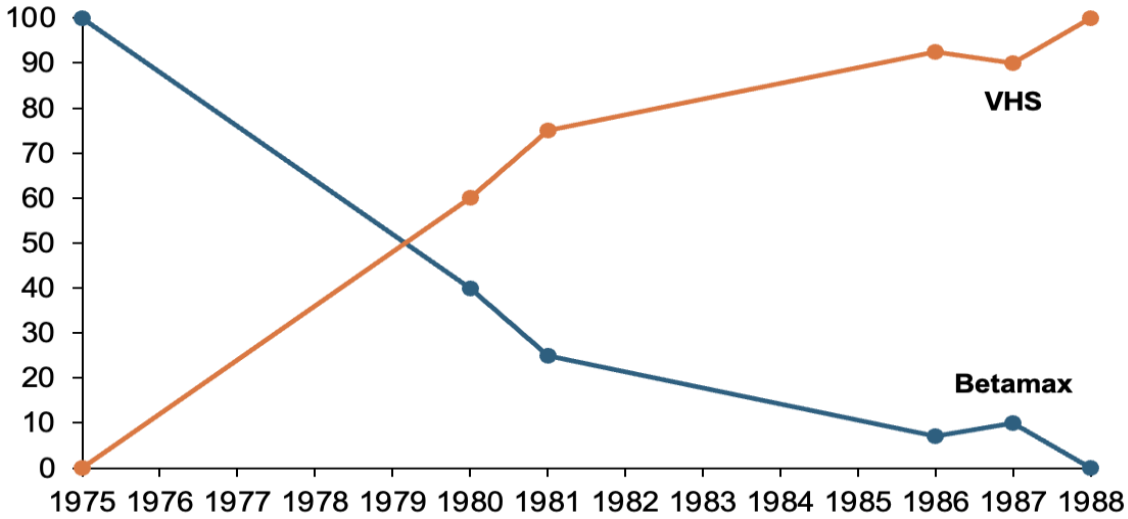

Table 3 - VCR Market Share Comparison (1975-1988)

2. Reshaping The Strategic Identity

Despite the significant failure of Betamax, Sony learned some important lessons and upscaled future strategic decisions, finally acknowledging that market success and disruptive innovation do not always go hand in hand. At the end of the story, the company thus learned a fundamental lesson: having the best technology does not imply a guaranteed victory unless the standard is widely adopted by the global market[56].

Therefore, Sony updated its approach in the following years, balancing the pursuit of innovation with more open and collaborative strategies. One initiative was to collaborate in defining new technological standards rather than developing and imposing them alone. In the years immediately following the VHS vs. Betamax war, Sony actively participated in consortia and partnerships to prevent other format wars from happening again. In 1982, Sony helped Philips to develop the Compact Disc, an optical media used to store digital data, such as music or files, made of plastic and read by a laser.

Rather than imposing its own proprietary standard, Sony chose to join forces with another giant and publish open specifications, making the CD a universal standard,

[56] Max Greene Movies, "Home Video Wars", 5 May 2019, https://maxgreenemovies.com/2019/05/05/home-video-wars/.

which was soon adopted by the entire music industry and quickly became the global successor to vinyl.

Similarly, in the 1990s, Sony was a major player in the development of DVD, the digital video disc: together with Philips, Panasonic, and other firms, Sony agreed on a single format that replaced analog video cassettes[57]. Thanks to this industrial alliance, DVD was launched in 1995 as a shared standard, saving consumers from a new format conflict and guaranteeing Sony a share of the broader success instead of risking another individual failure.

In parallel, Sony took cover on the multimedia content front, recognizing the importance of having the support of the entertainment industry to impose a format. In 1989, the company made a dramatic move by acquiring the major Hollywood company Columbia Pictures for 3.4 billion dollars[58]. With this operation, unprecedented at the time for a Japanese electronics company, Sony also transformed itself into a major producer of films and TV programs, and Sony Pictures Entertainment was born.

The acquisition of Columbia gave Sony direct access to a vast catalog of content and relationships with other studios, bridging that gap between hardware and content that had been costly for Betamax[59]. In other words, Sony learned that if it could not beat Hollywood, it would be better to join it. By owning a film studio, the company could both protect itself from potential boycotts on new formats and actively promote its own technologies. After Betamax, Sony was now pursuing a new strategy, attempting to control the entire user experience, from consumer electronics to the content they actually consumed.

About thirty years later, Sony was involved in another home video format war: Blu-ray vs. HD-DVD, and this time, the lessons learned from the previous conflict were evident[60]. When high definition became available in the early 2000s, two groups within the industry put forth opposing optical standards for high-definition DVDs.

---

[57] *Ibid.*

[58] Krows Digital, "The Rise of Sony: From a Humble Start to a Global Giant", https://krows-digital.com/the-rise-of-sony-from-a-humble-start-to-a-global-giant/.

[59] NetQuest, "Legendary Products: VHS vs. Beta", https://www.netquest.com/en/blog/blog/en/legendary-products-vhs-vs-beta.

[60] Julian P. Christ and André Slowak, "Why Blu-ray vs. HD-DVD Is Not VHS vs. Betamax: The Co-evolution of Standard-Setting Consortia", working paper, 2009.

Sony led the development of the Blu-ray Disc with an opposed approach to the one it had taken in the Betamax days. The company thus formed the Blu-ray Disc Association, an open consortium of many leading companies, partnering up with Panasonic, Philips, Samsung, Dell, HP, and others, to better and more efficiently promote its widespread adoption. Ensuring the support of the film industry was also essential, and remembering the importance of content, Sony was able to get most Hollywood studios to line up behind Blu-ray by offering profitable licensing deals.

As a result, Blu-ray had the support of major studios such as Disney, Fox, Warner, MGM, and Lionsgate at its launch in 2006, while rival HD-DVD had the backing of just one major studio. This meant that many top films would only be released on Blu-ray, putting HD-DVD at a content disadvantage.

Furthermore, Sony adopted a clever marketing strategy in order to accelerate Blu-ray's adoption: the company decided to bundle a Blu-ray player with every PlayStation 3 console it produced, thus providing consumers with both a video game console and an HD movie player for the price of a single device[61]. Millions of users thus purchased a "hidden" Blu-ray player with their PS3 without having to pay the additional cost of a dedicated player. This move gave Blu-ray a huge advantage[62]. Microsoft's counterpart took a much less effective approach to HD-DVD: the Xbox 360's HD-DVD player was sold separately as an optional accessory for around $200, and few users purchased it.

Within two years, Sony's strategy paid off: Blu-ray discs became the preferred standard for high definition, and by early 2008, HD-DVD disappeared.

We previously mentioned the PlayStation, useful to point out that the most important impact of the Betamax failure was a change in Sony's corporate culture regarding networks and platforms. In the 1990s, Sony ventured into new areas, partly applying the lessons of Betamax, and the most emblematic case is that of the PlayStation console. Until then, Sony had no direct experience in the video game market, dominated by Nintendo and Sega, but decided to enter it with an innovative approach. Instead of shutting down the system, Sony designed the PlayStation as an attractive platform for third-party developers and adopted standard technologies such as CD-ROM as a

[61] Sony Computer Entertainment Inc., press release, “Sony Computer Entertainment Inc. Adopts Blu-ray Disc ROM for Next-Generation PlayStation”, 21 September 2004.

[62] Don Lindich, “Sound Advice: Blu-ray Wins Format War, but at What Cost?”, *Pittsburgh Post-Gazette*, 12 January 2008.

medium for games. The original PlayStation, launched in 1994, became a global success quickly: it offered terrific graphics for the time, accessible tools for developers, and a huge catalog thanks to the support of all the major software houses of the time. This rich third-party network, fruit of Sony's open strategy, pushed PlayStation sales past 100 million units worldwide, making it one of the best-selling consoles ever.

PlayStation turned Sony into a main player in the video game industry, as we can see also nowadays, and entered a string of successes based on a well studied balance between innovative hardware and strong support from third-party developers.

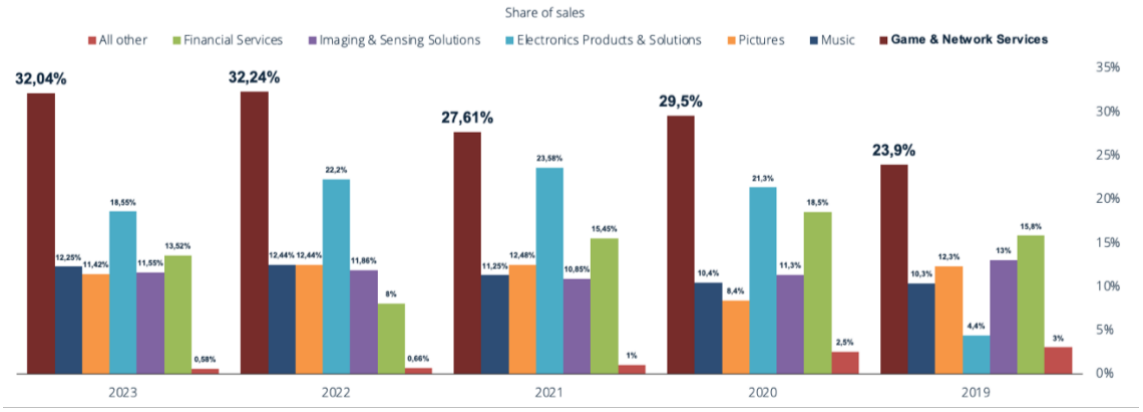

Table 4 - Share of Sony's Sales and Operating Revenue by Segment in Fiscal Years 2019 to 2023, Statista

In short, the Betamax case taught Sony a painful yet vital lesson about the centrality of the market and alliances in technological decisions. After that defeat, Sony became wiser about its choices: it learned to cooperate with other companies to establish common standards, to involve external partners and communities and to listen to the audience in the design phase. Somehow, the huge commercial failure of Betamax helped set the stage for the firm's future success. The Betamax setback thus made Sony more receptive to the market, leading it to major hits such as the PlayStation's console dominance and Blu-ray's final victory in the HD format war. These are all results achieved thanks to a more collaborative, and end-user focused strategy, born from the experience of that losing format of the 1980s. It is, therefore, safe to say that Betamax didn’t just teach Sony how to lose. It taught it how to listen.

C. GOOGLE GLASS

1. Vision And Public Experimentation

At the dawn of the 2010s, Google wasn't just a tech giant, it was a colossus dreaming in code, after reshaping the web with its search engine and colonizing everyday life through a series of smart choices, such as the acquisition of YouTube in 2006[63]. The aforementioned operation, along with others, allowed the company to diversify its portfolio and dominate even emerging markets, imposing itself as a main character in many key technological fields. The integration of already successful platforms consolidated Google's dominant position in the technology sector and created new sources of revenue and expansion opportunities for the company. The network created by the company became so massive and interconnected that it could reach billions of users worldwide following many different paths, reshaping the concept of accessible technology. Now, it was no longer enough to organize the world's information. Google wanted to reimagine the human-machine relationship itself. The success of the already established platforms, supported by a business model revolving around monetization through advertising and offering free, high-quality services, allowed Google to invest significantly in the creation of new projects, fueling a corporate culture strongly oriented towards experimentation[64]. This vision came to reality when Google X, a laboratory designed and created to constantly look for revolutionary opportunities, thinking outside the box, and overcoming the limits of conventional technologies, was created.

Google X thus came to life to explore the so-called *moonshot projects*, ambitious and risky projects designed to change society through radical innovation[65]. This approach was emblematic of a corporate philosophy based on exploration and the disruption of consolidated paradigms. Most importantly, these projects often involved deliberate early failures, strategically thought as a way to quickly test hypotheses, grasp data, and recalibrate decisions based on real-world feedback. In the heart of Google X, the

---

[63] Lucilla Tomassi, "The Story of Google: How Two Students Created an Empire", *Codemotion*, 2023, https://www.codemotion.com/magazine/infographics/the-story-of-google-infographic/.
[64] Firdaus Khan, "Google Moonshots , A Bridge Across Forever", 2013.
[65] Anne-Laure Mention, João José Pinto Ferreira, and Marko Torkkeli, "Moonshot Innovations: Wishful Thinking or Business-as-Usual?", *Journal of Innovation Management* 7, no. 1 (2019).

moonshot factory where the absurd was ordinary and the impossible was just a deadline, Google Glass was born. The genesis and development of this product can be divided into two main phases: the *Explorer* program, from 2012 to 2015, and the *Enterprise* implementation, from 2017 to 2023.

Project Glass, the original name of the project, was launched on the market in 2012. It came with a promotional video published on Google+ and along with ambitious statements, promising a device capable of integrating smoothly into users' daily lives. The idea was utterly innovative and aimed to reshape the relationship between man and technology forever. The hardware consisted of a pair of glasses with a small prismatic screen positioned at the top corner of the frame, through which digital information such as messages, calls, maps, and photographs were projected. The aim was, therefore, to bring to life an artificial extension of human capacities[66]. Google Glass officially debuted at the Google I/O conference in 2012, with a spectacular demonstration.

At 10,000 feet, a tethered skydiver broadcasts live. The audience cheers. Google Glass is the future[67]. The event immediately got the attention of the media, fueling unprecedented enthusiasm for what seemed like a true technological revolution. At the same time, a bunch of people from the developing team of the device began integrating it in their daily routines. Their life sort of became a laboratory, used to push the product to its limits and test its capabilities. This living laboratory was eventually extended to the public in 2013 with the *Glass Explorer* program[68], which allowed a limited number of users to test the device in exchange for a fee of $1,500[69]. The initiative aimed to collect data on daily usage and public reception of the product, as well as to stimulate the creation of a small ecosystem of developers and testers capable of finding problems and solutions to improve Glass. During the already cited Google conference in 2012, about 2,000 units were distributed, demonstrating the high level of public interest in this emerging technology.

---

[66] Thad Starner, "Project Glass: An Extension of the Self", *IEEE Pervasive Computing* 12, no. 2 (2013).
[67] Google, "Project Glass Demo: Hangouts in Air", *Official Google Blog*, 2012, https://blog.google/alphabet/project-glass-demo-hangouts-in-air/.
[68] X (Alphabet), "Google Glass , A Google X Moonshot", https://x.company/projects/glass/.
[69] BBC News, "Google Glass to Go on Sale for One Day", 15 April 2014, https://www.bbc.com/news/technology-26987972.

2. Pivoting Towards Enterprise

In spite of the initial enthusiasm, Google Glass had to face much criticism when it was made available to the general public. In fact, privacy concerns were remarkable[70]: the device had an always-on camera technology, which inevitably raised fears about being filmed or photographed during daily activities, in public or private spaces, without consent. An ethical debate was thus ignited and culminated with many commercial activities even banning the device in order to protect the privacy of their customers[71].
Furthermore, apart from privacy concerns, Google Glass also failed from an aesthetic point of view. The voluminous and asymmetric design led to the coinage of the term *Glasshole*, used to identify people who wore the device in public without considering its visual impact[72]. Summing that with a poor battery life, unreliable voice commands, and a bad camera, the user experience was definitely much worse than what was expected after the unveiling conference.

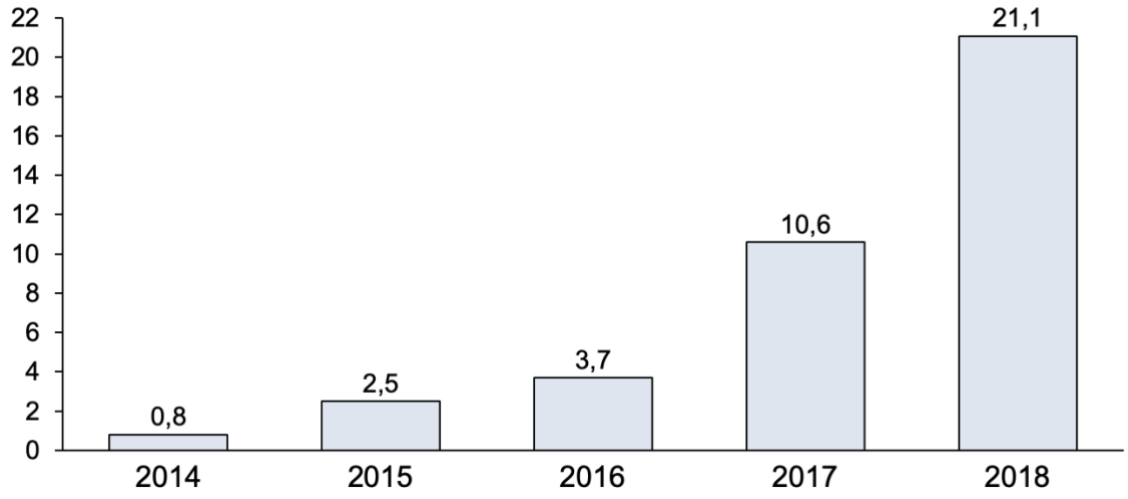

Table 5 - Forecast of Annual Google Glass Sales, Statista, 2013

These critical issues condemned Google Glass in the consumer market. Google eventually decided to discontinue the project in its original form without even properly launching it to the mass market, and in January 2015, the company announced the end

[70] Jason Hong, "Considering privacy issues in the context of Google glass". *Communications of the ACM* 56.11 (2013)
[71] Olya Kudina and Peter-Paul Verbeek, "Ethics from Within: Google Glass, the Collingridge Dilemma, and the Mediated Value of Privacy", *Science, Technology, & Human Values* 44, no. 2 (2019).
[72] Brian L. Due, "The Social Construction of a Glasshole: Google Glass and Multiactivity in Social Interaction", *PsychNology Journal* 13, no. 2 (2015).

of Glass production. The *Explorer program* was shut down, and the device was withdrawn from all online stores, joining the list of revolutionary tech products that failed to find their initial niche[73]. The real problem wasn't the battery, or privacy, or design, but the lack of purpose. No one really knew why they wanted Glass. Maybe not even Google.

In light of what has emerged, if the story of Google Glass had stopped at the original project, it would have to be classified only as a flop. In reality, we can see how that failure planted the seeds for future technological successes of the company. Google itself, after this enormous setback, did not give up, instead adopting an approach of learning from mistakes, reworking Glass technologies in new contexts, and learning valuable lessons for the development of subsequent projects. Glass had therefore not a been waste, even if many labeled it as such, but a necessary step to boost innovation.

Eventually, the Glass found new life with the launch of a brand new project, strictly linked to the previous one but radically different in many various details: the *Google Glass Enterprise Edition*.

This project represented a turning point for Google, fundamental for the company to recover the technological investment made with the Explorer project, whose poor reception from the consumer market had radically highlighted the need to redefine the target and the actual value of the device. The initial attempt to penetrate the general consumer market had failed. Now, the Enterprise version was thus oriented towards the professional field, a context with specific needs and more inclined to invest in an innovative and advanced product capable of offering concrete advantages in terms of efficiency, safety, and optimization of resources. The device was relaunched in 2017, in a period marked by technological and digital changes aimed at optimizing workflows and the advent of Industry 4.0. Google had managed to understand that the main obstacle that had prevented the Explorer version from succeeding in the market did not lie in the technology but rather in the incorrect segmentation that had been made before the launch and, consequently, in the lack of a clear value of use that justified its adoption on a large scale.

The Glass was thus redirected towards professional contexts, following the realization that, in the workplace, the ability to access information without using hands and to

[73] Victor Luckerson, "Google Will Stop Selling Glass Next Week", *Time*, 15 January 2015, https://time.com/3669927/google-glass-explorer-program-ends/.

communicate with experts in real time could represent a competitive advantage that should not be overlooked, the added value of the product. The utility of the device was, therefore, completely rethought. It was now a tool intended to optimize productivity and minimize mistakes at work rather than a gadget made for the average consumer.

Google began a search for ideal industrial sectors in which the benefits brought by the device could actually be life changing for those who worked there. At the end of the research, the most relevant areas to focus on were contexts where workers often need to access checklists, instructions, and manuals while working with both hands. The Glass Enterprise Edition could thus appear as a fundamental tool for increasing efficiency. Following roughly the same reasoning, the device could be used in the healthcare sector to immediately consult clinical data or for remote assistance[74].

In 2019, with the release of the *Glass Enterprise Edition 2*, further steps forward were made, paying particular attention to enhancing computational capabilities, battery life, which had previously been a radical problem, and interconnectivity[75]. Furthermore, following the negative feedback that led to the withdrawal of the original product, the integrated camera was upgraded and could now offer an higher resolution and a greater light sensitivity[76].

3. Strategic Failure And Lasting Impact

The repositioning implemented by Google, which led the product to orbit around the corporate market, was therefore motivated by the need to solve the fundamental problems that had compromised acceptance by the general public. The average customer did not know what to use the device for. The cost, although justified, was undoubtedly high and it was difficult to ignore the problems related to privacy. By addressing companies where privacy was less of an issue and productivity and efficiency justified the investment, Google narrowed the circle to a much more receptive segment.

---

[74]Oliver J. Muensterer et al., "Google Glass in Pediatric Surgery: An Exploratory Study", *International Journal of Surgery* 12, no. 4 (2014).
[75] Google Developers, "Glass Enterprise Edition 2", https://developers.google.com/glass-enterprise.
[76] *Innovation Post*, "Google Glass Enterprise Edition 2: More Powerful and Cheaper", 21 May 2019, https://www.innovationpost.it/tecnologie/google-glass-enterprise-edition-2-piu-potenti-ed-economici/.

But this was not all. One of the founding goals of the Glass project had always been to provide information about what the user saw. This concept was then wisely reworked and successfully implemented with the advent of Google Lens, launched in 2017 as a smartphone app. In short, while Glass was finding its definitive dimension in the corporate world, Google Lens aimed more at the mass market, the same mass market that a few years earlier had sunk the Glass project. The significant change consisted of the fusion of two different technological worlds. Now, the medium for this type of technology was no longer expensive futuristic glasses, but the camera of one's phone, used to recognize texts, objects and places, and offer helpful information[77]. Lens was thus realizing many of the promises made by Google Glass on the phone, but in a more mature and accessible way.

Google's strategy for AR thus shifted after Glass to mobile devices. In 2014, the company had already experimented with the smartphone AR *Project Tango*. After replacing it with simple software solutions, in 2017, it released the *ARCore* platform for AR without distinction on millions of Android phones and other devices[78][79].

By 2019, six years had passed since the pioneering attempt of Glass and two years since the introduction of Google Lens, a sign that the original vision had been pursued through the smartphone camera. Computer vision technologies refined thanks to Glass have undoubtedly helped power services like Google Lens and AR functions in Google products.

Finally, it is not wrong to affirm that Google Glass has opened the door in a field that other companies have continued to explore in the following years.

For example, in 2021, the Facebook company, now Meta, launched, in partnership with Luxottica, Ray-Ban Stories glasses, the first smart glasses aimed at the general public with a strong focus on aesthetics and style. These glasses resemble the historic Ray-Ban Wayfarer but are equipped with a dual camera, microphone, and integrated speakers to take photos, shoot short videos, listen to music, and interact with the voice assistant. Although they have much more limited functionality than Google Glass, not offering any AR technology, they represent a drastic attempt to make technology penetrate

[77] Google, “Google Lens , Search What You See”, https://lens.google/howlensworks/.
[78] Google Developers, “ARCore”, https://developers.google.com/ar.
[79] Gheorghe-Daniel Voinea et al., “Exploring Cultural Heritage Using Augmented Reality through Google’s Project Tango and ARCore”, in *VR Technologies in Cultural Heritage* (Cham: Springer, 2018).

everyday life without the social acceptance problems that plagued Glass at the time. Furthermore, great attention has been paid to privacy: for example, a front LED lights up when recording is taking place, to warn people around. This once again shows how the industry has learned from the lessons of Google Glass when designing the new generation of smart glasses.

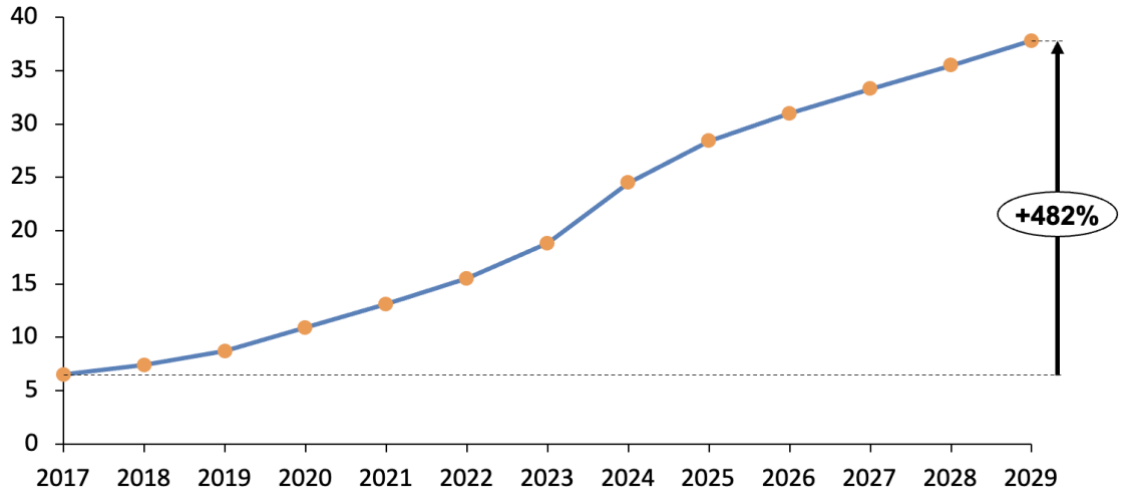

Table 6 - Augmented Reality B2C Market Revenue (in $ Billions) Worldwide from 2017 to 2029, Statista, 2024

In conclusion, the initial failure of Google Glass can be interpreted as a particular case in which the failure was not only tolerated but partly foreseen and desired by the company itself. Astro Teller, head of the Google X laboratory, explained that Glass was conceived mainly as a public experiment rather than a finished product destined for immediate success[80]. The goal of the Explorer Program was to quickly collect accurate data on social acceptability, technical limitations and possible uses, elements that are difficult to observe in a laboratory[81].

The real mistake? According to Teller, it had been to generate unrealistic expectations in the public too early, making them believe that Glass was already ready for the mass

[80] Astro Teller, "Why We Developed Google Glass", *CNN*, 4 June 2014, https://edition.cnn.com/2014/06/04/opinion/teller-google-glass/index.html.
[81] Tarun Wadhwa, "Google's Glass Explorer Program Was a Social Experiment That Backfired", *Forbes*, 24 April 2014, https://www.forbes.com/sites/tarunwadhwa/2014/04/24/the-google-glass-explorer-program-was-a-social-experiment-that-backfired/.

market[82]. However, for Google, this early failure was a deliberate strategy: the company knew that an open experiment would significantly speed up the collection of critical feedback to guide future development.

As shown above, the lessons learned from Glass actually allowed Google to accelerate the development of artificial intelligence, augmented reality, and industrial applications. The Glass case thus represents an example of strategic failure, in which failure was consciously used as a tool for accelerated learning, demonstrating how even a calculated defeat can set the stage for successful future innovations. Glass was not born to win immediately, but to lose well. To fail quickly and learn before others.

[82] *Ibid.*

IV. FROM FAILURE TO INNOVATION

A. Learning from Failure Today

What about today? We have long been moving towards an era in which the market changes faster than smartphone notifications. In this perpetual motion, learning and reinventing oneself is no longer a bonus but rather a matter of survival. Looking around, while we see a general praise of the concept of *wisdom born from failure*, most organizations continually stumble over the same obstacles, repeating their mistakes, unable to transform them into fuel for the next race[83].

In recent years, however, companies have begun to rely on various frameworks, re-adapting and reworking them to better fit their corporate identity. Organizations have learned to manage innovation before unexpected challenges overwhelm them.

For example, the Lean Startup speaks the language of rapid experimentation: it launches small "rockets" into the market, carefully measures the trajectory, and, if something "explodes", calls it *validated learning*[84]. Following Agile methodologies, however, time becomes the key: fail early, correct the course immediately and restart lighter and more confident[85]. Or again Design Thinking, which builds prototypes of all kinds in order to wrest truth from customers and transform every "it doesn't work" into a step forward[86].

Alongside these pillars of exploration, we also find the masters of continuous improvement, such as Kaizen and Deming's PDCA cycle, useful for filing away thousands of invisible defects until the engine runs like clockwork[87]. Finally, in the background, the previously mentioned Double-Loop Learning by Argyris, which invites teams to question not only their actions, but also the beliefs that generated them, and therefore themselves[88].

---

[83] Chris Argyris, "Teaching Smart People How to Learn", *Harvard Business Review* 69, no. 3 (1991): 99-109.
[84] Eric Ries, *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses* (New York: Crown Business, 2011).
[85] Kent Beck et al., "Manifesto for Agile Software Development" (Snowbird, UT, 2001), http://agilemanifesto.org
[86] Tim Brown, *Change by Design: How Design Thinking Creates New Alternatives for Business and Society* (New York: HarperBusiness, 2009).
[87] Masaaki Imai, *Kaizen: The Key to Japan's Competitive Success* (New York: Random House, 1986).
[88] W. Edwards Deming, *Out of the Crisis* (Cambridge, MA: MIT Press, 1982).

In order to discuss future scenarios and potential changes, a thorough analysis of the past, of history and of the events that have characterized it, is needed, topics covered in the previous chapters. However, it is also necessary to have a limpid picture of the present and the current panorama. Only by understanding who we are can we discover in which direction we are moving. As stated by Søren Kierkegaard:

"Life can only be understood backwards, but it must be lived forwards.[89]*"*

Before we explore how innovation and failure are evolving, people must understand why a failed MVP teaches us more than a thousand guesses, or how a blame free retrospective is helpful in avoiding reiteration of past mistakes. All of this is aimed at demonstrating how, nowadays, failure still represents the crack through which the light of change shines through, the shock that forces companies to stop surviving and start evolving.

1. Rapid-Experimentation Frameworks: Lean Startup & Agile Methodologies

The *Lean Startup* was born in 2011 from the mind of Eric Ries, who had been looking for the antidote to the waste that has always devoured emerging companies[90]. This approach treats the birth of a business as a permanent scientific experiment. Every new function, every market idea, becomes a small hypothesis to be put under the glass of the actual laboratory: the customer[91]. From here, the famous Build-Measure-Learn cycle takes shape. First, the bare minimum is built, that Minimum Viable Product that does not win beauty contests but is sufficient to end up in the hands of users[92], then their reaction is measured and, finally, learning[93]. In this context, learning means discovering whether the intuition is worth it or whether it deserves the bin.

---

[89] Søren Kierkegaard, *The Journals of Søren Kierkegaard*, ed. J. E. A. Ditlevsen (Princeton: Princeton University Press, 1958).
[90] James J. Chrisman, Ed McMullan, and Jeremy Hall, "The Influence of Guided Preparation on the Long-Term Performance of New Ventures", *Journal of Business Venturing* 20, no. 6 (2005).
[91] Rafael F. Bortolini et al., "Lean Startup: A Comprehensive Historical Review", *Management Decision* 59, no. 8 (2021).
[92] Steve Blank and Bob Dorf, *Startup: Manual do Empreendedor* (São Paulo: Alta Books, 2012).
[93] *Ibid.*

In the Lean world, every iteration is a laboratory test. Progress is not counted in lines of code or functions but in validated knowledge: concrete data that tell us whether the idea solves a problem, whether the price is affordable, whether it is destined to take off or stagnate. When the numbers prove the project right, the team continues but if they show a dead end, a sharp change of direction is conducted, changing the customer segment, revenue model, or even the very essence of the product. This is how the trap of sunk costs can be avoided: giving up an illusion today is better than seeing it sink tomorrow.

From this perspective, failure is not an accident to be swept under the carpet but a true goldmine of data. Hence the "fail fast, learn faster" approach: fail quickly to avoid a bigger disappointment in the advanced phase. Every negative result becomes a valuable note in the innovation notebook. The team analyses the metrics and asks itself: “have we perhaps misdefined the consumer problem?”; “Have we chosen the wrong channel?”; “Is there a useless gear in the mechanism to be cut?”.

Nevertheless, when the recipe works, the benefits are clear. The organization becomes flexible: it changes strategy smoothly, manages to stay glued to the user's actual needs, and embraces a culture where errors are not punished but studied. In other words, the Lean Startup inoculates the company against the paralysis of perfectionism: better an imperfect prototype in the hands of the customer than a masterpiece locked in a drawer.

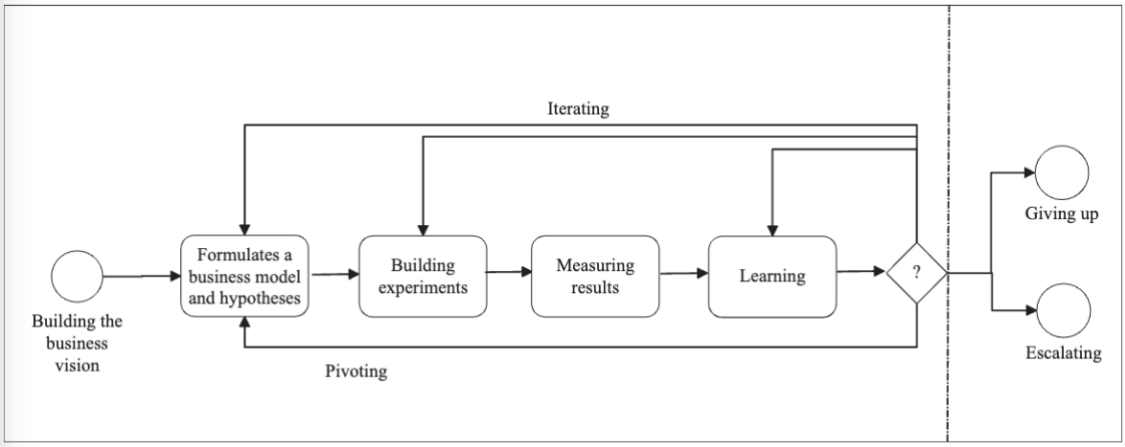

Figure 1 - The Lean Startup process, Bortolini, Rafael Fazzi, et al. "Lean Startup: a comprehensive historical review." Management decision 59.8 (2021)

However, there is a downside. The obsession with short cycles risks confining ambitions to a short horizon. Sight of the moon can be lost by constantly improving inch by inch, and genuinely disruptive innovations may be given up[9495]. Furthermore, immediate feedback can sometimes be deceiving. A revolutionary idea can seem like a flop when the market starts falling asleep and being discarded prematurely[96]. Then there are areas, think of healthcare or aerospace, where 'failing early' is a dangerous luxury. Experimentation must deal with regulations, safety, and costs that do not allow light-hearted testing in these industries.

In short, the Lean Startup is a powerful tool for turning failure into progress, but it requires contextualization, discipline in analysing the numbers and a broader vision that goes beyond the next sprint. When these conditions align, failure becomes the spark that ignites the next great idea.

However, the Lean Startup is not the only Rapid-Experimentation Framework. Born in 2001 from the initiative of a group of software developers and *organizational anarchists*[97], the Agile Manifesto, quickly emancipated itself from the technological sphere to establish itself as a flexible project management architecture in different sectors. It is important to remark that Agile is not a monolithic methodology: Scrum, Kanban, Extreme Programming, and many other practices embody its common philosophy. Developing iteratively and incrementally, shortening the cycle that separates the idea from honest feedback and, above all, treating change as an ally rather than as an unforeseen event to be kept outside the door[98]: these are all core aspect of the methodology.

The method works in short cycles, each ending with a usable product update. Each release thus becomes a small, independent experiment: stakeholders test it in the field, measure its impact, and if a deviation from the objectives emerges, the requirements are refined before the error takes root. This routine of inspection and adaptation is completed with two ritual moments: the *Sprint Review*, where users and product owners

---

[94] Adam Fishman, "Challenges with the Lean Startup Methodology", *Reforge Blog*, Oct 18 2019, https://www.reforge.com/blog/lean-startup-methodology-problems.
[95] Tom Eisenmann, "What the Lean Startup Method Gets Right and Wrong", *Harvard Business Review*, Oct 2019, https://hbr.org/2019/10/what-the-lean-startup-method-gets-right-and-wrong.
[96] Ted Ladd, "The Limits of the Lean Startup Method", *Harvard Business Review*, March 2016 https://hbr.org/2016/03/the-limits-of-the-lean-startup-method
[97] Supra note 86
[98] Supra note 86

judge the value created, and the *Sprint Retrospective*. In this protected space, the group analyses what worked and what needs to be corrected in the work process[99]. The result is a continuous learning circuit that brings to light hidden inefficiencies and prevents their crystallization[100].

On the technical side, continuous integration and automated testing transform the code into a constantly monitored organism. A test that fails immediately enlightens potential issues, the correction occurs while it is still hot, and the developer learns the lesson while it is still fresh. On the value side, frequent interaction with the end user reduces the classic "surprise effects" of blind deliveries: if the new feature does not solve the problem, the team discovers it in days, not quarters, and can realign to the actual need. The impact of this way of working is two sided. On one hand, it drastically reduces the probability of catastrophic failures: errors emerge in small doses and are treated before they become unmanageable debts. On the other hand, it spreads a culture of continuous experimentation in the organization[101]. Each sprint becomes a tiny laboratory in which one observes, measures, and improves. It is no coincidence that many companies, after adopting Agile in IT, extend the model to functions such as marketing or operations, transforming the entire company into a system sensitive to market signals.

However, some challenges remain. Agile methodologies risk slipping into empty formalities without genuine management. On a large scale, coordinating dozens of autonomous teams requires scaling methods, and if applied with excessive bureaucracy, these can suffocate the agility they are supposed to safeguard[102]. Furthermore, iterating without a strategy sometimes leads to circular paths: tactics prevail over vision, and the product risks losing coherence[103].

Agile thus implants an organic learning mechanism in organizations that transforms errors from accidents to be avoided into signals to be processed. Where this mechanism is followed by consistent leadership and smart strategies, the company can evolve as

---

[99] Adam Przybyłek et al., "Game-Based Sprint Retrospectives: Multiple Action Research", *Empirical Software Engineering* 27, no. 1 (2022).

[100] See Harvard Business Review, Strategies for Learning from Failure, https://hbr.org/2011/04/strategies-for-learning-from-failure

[101] See Zenkit, What is Agile Methodology? (An Overview), https://zenkit.com/en/blog/agile-methodology-an-overview/#:~:text=Agile%20Methodology%20Definition,a%20climate%20of%20continuous%20improvement.

[102] See PremierAgile, Scaling Agile Challenges, https://premieragile.com/scaling-agile-challenges/

[103] See The knowledge Academy, 8 Agile Project Management Challenges: A Comprehensive Guide, https://www.theknowledgeacademy.com/blog/agile-project-management-challenges/

quickly as the competitive environment, capitalizing on every positive or negative feedback to refine the product, process, and strategy.

2. Human-Centred Prototyping: Design Thinking

Design Thinking has its roots in the world of industrial design and architecture[104]. However, IDEO, together with Stanford's *d.school*, transformed it into a proper grammar of user-centered innovation[105]. The process unfolds in five recursive steps: Empathize, Define, Ideate, Prototype, and Test[106]; these should not be looked at as boxes to be ticked in sequence but rather as stations on a circular path in which each result, positive or negative, fuels the next step. As said, it all starts with empathy: the team steps down from the expert's podium and immerses itself in people's lives to grasp their desires, fears, and limitations. From this immersion comes a definition of the problem rooted in reality, which triggers a generation of ideas free from premature feasibility constraints.

Up to this point, the theory might remind us of other creative methodologies; what distinguishes Design Thinking is the promptness with which ideas take shape. The prototype, whether it is a cardboard mock-up, a digital wireframe, or a simulated video, becomes the language with which we communicate with the user. David Kelley has summed up the essence of this practice in a now famous motto:

"Fail early to succeed sooner.[107]*"*

Every imperfect model placed in the hands of a real user offers the possibility of a small failure devoid of the economic consequences that the same error discovered after the launch would have. This is why tolerance for error is not a benevolent concession but a

---

[104] See ArchDaily, The Rise of the Design Thinking Movement and its Relation to Architecture, https://www.archdaily.com/975341/the-rise-of-the-design-thinking-movement-and-its-relation-to-architecture

[105] Rikke Friis Dam. and Yu Siang Teo. 2022. *The History of Design Thinking*, from https://www.interaction-design.org/literature/article/design-thinking-get-a-quick-overview-of-the-history

[106] Rikke Friis Dam. 2025. *The 5 Stages in the Design Thinking Process*, https://www.interaction-design.org/literature/article/5-stages-in-the-design-thinking-process

[107] See Stanford Social Innovation Review, Fail Faster, Succeed Sooner, https://ssir.org/articles/entry/fail_faster_succeed_sooner

methodological pillar[108]: a disappointing prototype shines a spotlight on wrong assumptions and correcting them is still cheap.

The cycle continues with the test, a moment of radical listening in which the team suspends its design ego to record every hesitation, every puzzled look, every sentence that begins with "I do not understand". These signals, often more eloquent than any questionnaire, guide the next iteration. Thus, the project advances through successive refinements, each supported by qualitative data that arise from direct observation. In this dynamic, failure is not only allowed: it is desired, as long as it happens early, on a small scale, and with a watchful eye on the why.

The benefits of such an approach are reflected on multiple levels. Regarding market outcome, products tend to meet authentic needs, reducing the risk of a dry release. On a cultural level, the constant practice of prototyping generates a climate in which risk becomes a natural component of creative work; participants, accustomed to treating errors as raw material for learning, become more inclined to experiment and share insights between different functions. It is not uncommon for historically siloed departments to discover a new common lexicon based on user experience after a few Design Thinking sessions.

Of course, the method is not free from critical issues. Without adequate skills, it can be reduced to an *innovation theater*[109]: lively workshops followed by ornamental prototypes that never reach the implementation phase. Furthermore, not all problems require it: challenges with very defined technical requirements or areas in which the regulatory variable is dominant will often benefit more from analytical approaches such as Six Sigma. Then there is the issue of time: iterating requires patience and a certain willingness to navigate ambiguity; organizations accustomed to rigid schedules may perceive Design Thinking as slow if they do not grasp its strategic return.

Measuring impact adds another layer of complexity: while Lean Startup works with numerical metrics, learning is often narrative and qualitative here.

Design Thinking thus introduces a form of experimentation that brings the error to the drawing board when it is still minor and instructive, rather than letting it explode on the

---

[108] See Harvard Business Review, Design Thinking Comes of Age, https://hbr.org/2015/09/design-thinking-comes-of-age

[109] See Karel Vredenburg, Innovation Theater vs. Design Thinking Mastery, https://www.karelvredenburg.com/home/2021/3/15/innovation-theatre-vs-design-thinking-mastery

market. Organizations that assimilate its logic not only develop more relevant products but also train a cultural muscle of continuous attention to the user and willingness to question their certainties.

3. Continuous Improvement Loops: Kaizen & PDCA

In the collective imagination, innovation often coincides with spectacular advancements: a new product that goes around the world, an algorithm that overturns an industry overnight. Nevertheless, there is another path, quieter, that has proven to generate equally solid competitive advantages over the last seventy years. It is the path of Kaizen, the Japanese philosophy, which has been mainly adopted and codified by Toyota, in an attempt to change for the better every day, one defect at a time.

The historical genesis is significant. In post-war Japan, resources were scarce, international demand was uncertain, and quality was an existential imperative. In that context, Taiichi Ohno and his colleagues understood that they would not be saved with a single disruptive invention but by trusting daily discipline, capable of removing friction from every gear in the production system[110]. Thus, was born the Toyota Production System, of which Kaizen is the backbone: every deviation, a defective part, a useless waiting time, even a superfluous manual gesture, should be considered a "negative treasure", a precious clue on where to intervene to reduce waste[111].

W. Edwards Deming's lesson, formalized in the famous PDCA cycle[112]: Plan, Do, Check, Act, helped to set this vision in a rigorous method. People start by planning a micro-improvement, then experiment with it on a small scale, measuring its effects, and only if the data confirms its effectiveness can it finally be standardized[113]. At that point, the circle closes but does not stop. Today's "Act" becomes tomorrow's "Plan" in a perpetual motion of empirical learning. The tension towards improvement becomes a daily habit, almost a physiological rhythm of the organization.

---

[110] Jinichiro Nakane and Robert W. Hall. "Ohno's method." Target 18.1 (2002)

[111] See Faster Capital, Kaizen: The Path to TQM Success, https://fastercapital.com/it/contenuto/Filosofia-Kaizen--Kaizen--il-percorso-verso-il-successo-TQM.html#Introduzione-alla-filosofia-Kaizen

[112] See DNV, PDCA: Full Cycle Of Risk Management, https://www.dnv.com/assurance/articles/pdca-full-cycle-of-risk-management/

[113] *Ibid.*

In the Toyota plant, this principle materializes in the andon cord, the rope that any worker can pull to stop the line if they notice an anomaly[114]. The act, which elsewhere would seem like insubordination, here represents the start of a real-time micro-PDCA. The team leader rushes to the scene; then, the *five whys* technique is applied to dig to the root of the problem; a temporary solution is immediately tested, and if it works, it is codified in the work standard[115]. Rather than being seen as a loss of productivity, each stoppage becomes an embodied and shared lesson: knowledge that passes from the individual to the entire production system.

The practical effects are evident. On the operational level, waste changes from hidden costs to margin opportunities: shorter production cycles, more consistent quality, and scrap reduced to a minimum: all indicators that, in the long term, sculpt a competitive advantage that is difficult to copy. Moreover, on the cultural level, widespread involvement reverses the traditional verticality: the press operator is authorized and encouraged to suggest any process changes; the manager is required to follow up on the idea, verifying the results in numbers. This creates a climate of co-responsibility in which the error is not a fault to be hidden but a fact of life to be understood.

Of course, Kaizen and PDCA are not panaceas. They require discipline, consistent analysis, and leadership willing to measure success not by the immediate peak but by the curve of improvement over time Furthermore, if the strategic horizon is dominated by quarterly deadlines, the value of incremental improvements may seem too slow to those seeking immediate returns.

Nevertheless, where cultural coherence holds, the logic of continuous improvement produces an organization that learns in the most literal sense. Every deviation feeds the collective knowledge capital; every standard becomes the basis for the following standard, and every individual becomes a quality sensor and an idea generator.

In a competitive environment where the speed of adaptation is worth as much as the brilliant idea, the Kaizen muscle ends up becoming an invisible but formidable advantage: the company is used to changing before the change is imposed on it.

---

[114] See Systems Thinker, Pulling the Andon Cord: Toyota Responds to Challenge and Change, https://thesystemsthinker.com/pulling-the-andon-cord-toyota-responds-to-challenge-and-change/#:~:text=Each%20andon%20call%20is%20an,the%20results%20and%20the%20process

[115] See Oakland University, % whys Problem Solving, https://www.oakland.edu/Assets/upload/docs/Pawley/Lean-Enrichment-Activities/LEA---5-Whys.pdf

4. Organisational Learning and Intelligent Failure

The content reviewed thus far reveals a rather evident common thread: in the contemporary, fast-paced economy, only those organizations that adeptly transform each setback into a source of collective learning are able to survive and prosper.

It is not enough to fall in love with a single methodology; a cultural habit is needed, supported by concrete systems, that makes failure not a cost to be hidden but a resource to be capitalized. The literature on organizational learning offers the conceptual framework to read this phenomenon. From Argyris's argument on Double-Loop Learning to the previously mentioned Taleb's notion of antifragility, the recurring idea is that the company that integrates error into its decision making circuits becomes stronger.

Contemporary examples speak clearly. Netflix, foreseeing the obsolescence of postal rental, converted a potential collapse into a winning race towards streaming[116]. On the other hand, Amazon has made permanent experimentation its DNA: a Fire Phone gone wrong, or a service quietly closed are not failures to be concealed but triala that feed the subsequent bets. Jeff Bezos recalled:

> *" Staying in Day 1 requires you to experiment patiently, accept failures, plant seeds, protect saplings, and double down when you see customer delight.[117]"*

crystallizing in one sentence the logic of a project portfolio that accepts losing small battles to win significant wars.

Of course, these results do not fall from the sky: they must be designed with the same care that a product is designed for the end user. Hence, the spread, even outside the military sphere, of the *After Action Review*. Four questions, expectations, reality, gap,

---

[116] Ryan Kim, "Netflix Sees the Future, and It's Digital", *San Francisco Chronicle*, December 24, 2008, para. 14, https://www.sfgate.com/business/article/Netflix-sees-the-future-and-it-s-digital-3257129.php.

[117] Jeff Bezos, "2016 Letter to Shareholders", Exhibit 99.1 to Amazon.com, Inc., Current Report on Form 8-K, filed April 12, 2017, U.S. Securities and Exchange Commission, https://www.sec.gov/Archives/edgar/data/1018724/000119312517120198/d373368dex991.htm.

turning point, and a blame free debrief: this is how the World Bank has reduced the repetition of errors in its international projects[118].

Another pillar concerns incentives. Google has institutionalized the "20%" of time dedicated to personal exploration[119]; other companies go further, rewarding the "best failure" of the year to celebrate those who have dared and learned the most[120]. These signals tell employees that, between the risk of making a mistake and complete inertia, an organization chooses the first.

None of this would hold up without transparent leadership in admitting mistakes. A top manager who makes a strategic error public and illustrates the solution gives the idea that growth continues even at the top. If, on the other hand, those in charge punish the mistakes of others but do not recognize their own, *learned helplessness* is triggered: people stop reporting critical issues, depriving the company of the internal sensors that make it adaptive.

From the discipline of AARs to the systematic sharing of lessons learned, from incentives that reward boldness to transparency at the top, everything converges towards one goal: preventing a failure from being wasted. Every mistake paid for once must become a collective saving for the future. From this perspective, today's major frameworks, such as the analysed Lean Startup, Agile, Design Thinking, or Kaizen, are not to be considered rival schemes but rather pieces of a mosaic that fuels the error-learning-adaptation cycle. Lean teaches how to make small mistakes, Agile to make early mistakes, Design Thinking to make creative mistakes, and Kaizen to never make the same mistake twice. In other words, together, they build an organization that learns by doing and views failure as an expected step on the path to discovery.

No recipe is universal: each company will have to dose exploration and exploitation, radical innovation, and incremental improvement, depending on its history and its market. However, the cases of Amazon, Toyota, and Google demonstrate that where the culture is consistent with these principles, curiosity and experimentation become virtues. The ability to learn faster than the competition, extracting value from every

---

[118] Independent Evaluation Group, *Learning and Results in World Bank Operations: How the Bank Learns* (Washington, DC: World Bank Group, 2014), https://ieg.worldbankgroup.org/sites/default/files/Data/reports/chapters/learning_results_eval.pdf

[119] Ryan Tate, "Google Couldn't Kill 20 % Time Even if It Wanted To", *Wired*, August 21 2013, https://www.wired.com/2013/08/20-%-time-will-never-die/

[120] "Tata Innovista, The One Tata Way", Tata Group Newsroom, April 2023, https://www.tata.com/newsroom/business/tata-innovista-one-tata-spirit

setback, proves to be the only competitive advantage that is truly sustainable in the long term.

B. Failure and Innovation in the Age of AI

1. The Future Of Innovation: Is The Promise Of An Error-Free World Sustainable?

Now that we have comprehensive overview of present and past scenarios, frameworks, theories, cases, what about the future? At the root of the new enthusiasm for AI is a simple and powerful promise, a promise that whispers of a world where nothing breaks, nothing surprises and every variable bows to the logic of the machine: if data can "talk" to us in real time, then we can neutralize many of the surprises that have always shaken plans and budgets. IoT sensors integrated in presses and motors continuously send micro-information to predictive maintenance platforms in factories. The algorithms, by observing vibrations and temperatures, anticipate when a bearing will start to fail; machine downtime is scheduled before it happens. According to estimates by McKinsey, these interventions reduce unplanned downtime by between 30 and 50% and extend the useful life of the plants by up to 40[121]: numbers that, in a sector with thin margins like automotive original equipment, equate to tens of millions saved in a single year of production.

The same principle is replicated in logistics, where demand-sensing models absorb orders, weather, social media posts, and marketing campaigns in real time; they predict booms or busts and adjust inventory accordingly[122]. In finance, neural networks classify transactions at millisecond granularity, flag anomalous patterns, and stop fraud before it breaks the bank[123]. On the surface, failure, or at least its classic form of blunders, sudden breakdowns, and wild predictions, seems to be heading toward a sweet retirement.

However, attention must be shifted a few degrees to spot the crack in the narrative. AI models are, ultimately, statistical inference machines: they extrapolate patterns from

[121] Dilda, Valerio, et al. "Manufacturing: Analytics unleashes productivity and profitability". Report, McKinsey & Company (2017).
[122] Knut Alicke, Jürgen Rachor, and Andreas Seyfert, "*Supply Chain 4.0 – The Next-Generation Digital Supply Chain*", McKinsey & Company, October 27, 2016.
[123] Mastercard, "Mastercard Supercharges Consumer Protection with Gen AI", press release, February 1, 2024.

what has already happened and deduce the probability that those same patterns will recur[124]. They work wonderfully within the perimeter of the "already seen", much less so when the context goes beyond the historical frame. Economists and data scientists increasingly speak of a *jagged technological frontier*: an irregular line that separates domains where AI guarantees superhuman performance from those, only apparently similar, in which results collapse.

An experiment conducted at Harvard Business School makes the issue tangible. Groups of business consultants were divided in two: half worked with the assistance of a large language model, half without[125]. In tasks in which the model had been trained on similar cases, the productivity and accuracy of the "augmented" colleagues took off. 12.2% more task completed, 25.1% finished much earlier than the other group, 40% more accuracy and overall work quality[126]. Nevertheless, when the challenge went beyond the patterns in the dataset, the opposite happened: the consultants guided by AI were 19% less likely to find the correct solution than their "analogic" colleagues[127]. Statistical intelligence, in short, reduces known uncertainty and, paradoxically, can amplify unknown uncertainty if used with excess confidence.

What emerges is a new taxonomy of risk. Basic errors born from distraction, inexperience, and lack of data become fewer as algorithms advance. However, on the other hand, new kinds of error are making their way: biases that hide in datasets limit not contemplated scenarios. These are rarer failures, perhaps less spectacular in a single episode, but capable of spreading quickly because the software distributes them on a large scale and because, used to delegating, humans tend to notice them late.

So, the conclusion celebrated by some: "Failure is about to disappear", appears not only ingenuous but potentially harmful. If organizations rely on technology alone to contain every risk, they may stop paying attention to threats, leaving themselves vulnerable in areas where machines can't intervene. Instead, it becomes essential to develop dual

---

[124] Ajay Agrawal, Joshua Gans, and Avi Goldfarb, *Prediction Machines: The Simple Economics of Artificial Intelligence* (Boston: Harvard Business Review Press, 2018).

[125] Fabrizio Dell'Acqua et al., "*Navigating the Jagged Technological Frontier: Field Experimental Evidence of the Effects of AI on Knowledge-Worker Productivity and Quality*", Harvard Business School Working Paper no. 24-013, September 22, 2023, https://www.hbs.edu/faculty/Pages/item.aspx?num=64700#:~:text=We%20suggest%20that%20the%20capabilities,others%2C%20though%20seemingly%20similar

[126] *Ibid.*

[127] *Ibid.*

skills: on the one hand, exploiting AI to cleanse the landscape of repetitive errors; on the other, cultivating a critical literacy that brings human judgment back to the center.

Here comes another lesson, dear to the literature on organizational learning: a minimal dose of error is inevitable and desirable. Sitkin already spoke in the 1990s of *intelligent failures*: targeted experiments in unknown territories, conducted with limited resources and precise metrics, which generate knowledge regardless of the outcome[128]. Amy Edmondson, more recently, has refined this intuition by distinguishing between avoidable errors, complex errors to be mitigated, and intelligent errors to be encouraged[129]. In this scheme, AI becomes the cure for the former and an adjuvant for the latter, but it cannot and should not eradicate the latter. On the contrary, reducing routine "noise" frees up energy to invest in more ambitious and, at the same time, more controlled experimentation.

The future of failure, then, is not that of a slow extinction but of a mutation. There will be more logic failures, fewer errors of distraction and more errors of perspective, fewer accidents due to ignorance of the data, and more slips born from hasty interpretations of the data themselves. Governing this metamorphosis does not mean preaching a nostalgic return to "pure" intuition but recognizing that no predictive model will ever be able to replace the exquisitely human task of deciding where it is worth going beyond the map.

Therefore, the real question is not whether technology will be able to eliminate every slip but rather what type of failure will continue to survive in a context dominated by predictive models. Because once the glitter of predictive accuracy is removed, what remains is a timeless truth: Failure, cannot be eliminated, only redirected. Literature has long distinguished three forms of failure. The first is the banal failure, the one that derives from negligence or lack of information, the typing error in the code, the procedure skipped due to distraction. The second category is the complex failure, the result of chains of events that escape control and are enough to trigger a domino effect, because systems are full of interdependencies. Finally, there is the intelligent failure, the

[128] Sim B. Sitkin, "Learning Through Failure: The Strategy of Small Losses", *Research in Organizational Behavior* 14 (1992): 231–266.

[129] Amy C. Edmondson, "Strategies for Learning from Failure", *Harvard Business Review* (April 2011), esp. section "A Spectrum of Reasons for Failure".

deliberate experiment in still unexplored territories that, thanks to risk, generates learning and opens up new paths.

Artificial Intelligence has a very different impact on each of these manifestations of error. On the front of banal failures, the effect is disruptive: automation, real-time controls, and monitoring systems largely reduce oversights and raise essential quality. Complex failures can also be mitigated because simulation algorithms and predictive models help identify critical issues before they degenerate. But when we enter the realm of intelligent failures, the story changes: eliminating the possibility of making mistakes altogether would mean giving up the very engine of exploration. Amy Edmondson, in a recent work, emphasizes that a good organization must reduce avoidable errors, mitigate systemic ones and, at the same time, incentivize controlled experiments that generate new insights[130].

Therefore, rather than pursuing a world without failure, the challenge is to make failure selective. Routine errors that drain resources without providing knowledge must be banned, but situations into which people can fall without losing reputation or balance sheets must be cultivated. The task of leaders is to draw this line: on one hand, exploiting the power of AI to erase sterile mistakes, on the other, designing safe zones in which to test hypotheses, accepting minor deviations as the price of learning. It is in this balance, between algorithmic rigidity and freedom of exploration, that error retains its evolutionary function, sustaining innovation rather than impeding it.

2. AI as Creativity Amplifier and Always-On Innovation Engine

The most spectacular impact of Artificial Intelligence on innovation is measured not much in correcting basic errors but in the breathtaking expansion of the space of possibilities. In the laboratory, deep learning models scour entire molecular scenarios in search of new families of compounds: the case of the antibiotic Halicin, identified at MIT after analysing over one hundred million molecules in a few days, demonstrates how AI is able to compress years of experimental research into a handful of hours of

[130] Amy C. Edmondson, *Right Kind of Wrong: The Science of Failing Well* (New York: Atria Books, 2023).

calculation[131]. For what concerns the engineering field, Stefano Pontecorvo, president of Leonardo, in a recent conference held at LUISS Guido Carli, made a strong statement: Leonardo would not work so efficiently without the help of AI. He also affirmed, to provide the audience with a tangible example, that the newest attack helicopter was to be created within 5 years, but the organization managed to build it in just 8 months, with one fifth of the original budget.

This massive exploration does not cancel out human creativity; on the contrary, it amplifies it. The designer stops manually sifting through hypotheses and takes on the role of curator: he chooses the initial parameters, interprets the algorithm's proposals, and decides which paths deserve further physical prototyping. Regarding the economy of innovation, we could say that AI halves the marginal cost of an "attempt" and multiplies by orders of magnitude the portfolio of ideas to exercise human judgment. The same is true in the more immaterial sphere of creativity: generative language models, such as large language models, have already earned a place in the brainstorming sessions of design agencies and R&D centers. Preliminary studies indicate that, when used in the divergent phase of the process, these tools increase the number of proposals on the table and ensure greater semantic variety, introducing combinations that the group alone would have struggled to formulate.

However, this capacity for exploration entails a less visible yet substantial risk: algorithmic convergence. Models are trained on data representing the past, so they reproduce already successful patterns. If the organization delegates the final selection to them, it chooses solutions that fall within the "hot zones" of history, automatically discarding radically new options. The danger is to produce extraordinarily efficient but orthodox innovation, an infinite optimization of the existing without deviations capable of changing the game's rules.

The pivotal point then becomes the filtering role that humans exercise. To avoid creative leveling, processes are needed to reintroduce variability: heterogeneous teams, development paths not based on mainstream data, and decision making moments based on the algorithms. Some companies, for example, ask AI to produce hundreds of concepts but assign designers to select an outsider, a bizarre proposal, or one poorly

[131] Anne Trafton, "Artificial intelligence yields new antibiotic", MIT News, February 2020, https://news.mit.edu/2020/artificial-intelligence-identifies-new-antibiotic-0220

supported by data to bring to the prototype. It is a way to keep the window of serendipity open.

A second area of concern concerns the biases inherent in datasets. If the historical base reflects consolidated market preferences, the algorithm will perpetuate exclusions of emerging niches or less represented groups. Consequently, innovation governance will have to include periodic audits of training data and, sometimes, the injection of "creative noise": deliberately eccentric portions of datasets that act as a stimulus for non-standard solutions.

Finally, AI changes the temporality of development. With iteration times that collapse from months to days, the constraint shifts from ideation to decision: the bottleneck is no longer generating ideas but choosing which ones to focus physical and reputational resources on. This is where strategic leadership comes into play. It is not uncommon for organizations equipped with highly advanced tools to slow down because approval processes do not keep pace with the new technological clock beat. In other words, AI pushes for rapid cycles, but if the top management does not review its decision making cadence the advantage will evaporate in burocracy.

Ultimately, AI does not replace human creativity, it redesigns it. On one hand, it provides computing power to explore previously inaccessible design spaces. In contrast, it requires even higher levels of discernment and entrepreneurial courage: discernment to recognize the genuinely new idea behind the statistical noise and courage to invest in it when the algorithm suggests "safer" solutions. If well orchestrated, this combination allows us to accelerate progress and, paradoxically, preserve the possibility of those intelligent failures that generate the most unexpected discoveries.

If, until now, innovation was a project that alternated long research phases with episodic launches on the market, the combination of IoT sensors, cloud, and Artificial Intelligence is blowing up that intermittent rhythm. Data flows in real time from products in use, production lines, and even the environment in which goods are consumed. Every click, temperature variation, or micro-vibration returns to the central servers like a thread stretched between the product's life and its original laboratory. In this continuous flow, AI identifies patterns, deviations, and opportunities for micro improvement with a granularity that is impossible for the human eye.

The most visible effect is the dissolution of the frontier between development and operations. In electric vehicles, for example, Tesla releases "over the air" updates that modify efficiency parameters introduce infotainment functions, and sometimes even increase the declared autonomy without touching a single hardware component[132]. Each patch results from millions of kilometers of usage data that the onboard software pours into the central AI platform, which simulates possible optimizations before returning the code to users. The result is a model of innovation for small gradients: no longer a restyling every three years, but dozens of valuable iterations in a few months, often invisible until the user finds them active the following day.

This logic extends to manufacturing. In cutting edge plants like Adidas' Speed Factories, machines run the production cycle and simultaneously provide AI with data on vibrations, surface quality, and energy consumption[133]. The software analyses these streams to propose parameter corrections in near real time, and if the line manager approves, the change goes into production within half an hour. McKinsey estimates that in such environments, the speed of introducing new SKUs can increase by up to 50%, with waste reduced by more than a third thanks to model driven process adjustments[134]. The result is that each batch is a finished product and a prototype for the next batch.

The "always-on" paradigm does not simply improve what already exists; it reshapes the ideation phase. *Digital twin* tools allow the creation of virtual copies of an entire factory or a product in use. Testing a new design or a different material recipe involves acting on the digital twin. AI runs thousands of scenarios and returns the optimal configuration, often with parameters that escape human intuition. Roland Berger estimates that thanks to these simulation cycles, the average development time for a new mechanical component can be reduced by more than 60%[135]. At the same time, physical prototyping costs fall, in some cases, below 30% of the historical budget.

---

[132] Charles Benoit, "Tesla Model 3 0–60 mph Times, Then and Now, All Trims Compared", Electrek, November 17 2019, https://electrek.co/2019/11/17/tesla-model-3-0-60mph-times-then-and-now-all-trims-compared/.

[133] Rowland Manthorpe, "To Make a New Kind of Shoe, Adidas Had to Change Everything", Wired, October 4 2017, https://www.wired.com/story/adidas-speedfactory-made-for-london-trainers/.

[134] Dinu de Kroon, Enno de Boer, and Rahul Shahani, "The Continuing Evolution of the Global Lighthouse Network", McKinsey & Company, January 2025, https://www.mckinsey.com/capabilities/operations/our-insights/the-continuing-evolution-of-the-global-lighthouse-network.

[135] Roberto Argolini, Federico Bonalumi, Johannes Deichmann, and Stefania Pellegrinelli, "Digital Twins: The Key to Smart Product Development", McKinsey & Company, July 31 2023,

The nature of the relationship with the customer is also changing: a cosmetics brand that integrates humidity sensors into bottle caps can collect home use data and have AI release hyper personalized recommendations on the ideal dosage; a medical device manufacturer uses telemetry to refine both the detection algorithm and the maintenance service, with simultaneous benefits for the user and for its own R&D. In all these examples, the customer becomes, in fact, a codeveloper: the field of use provides such timely feedback that the classic distinction between *test phase* and *market phase* loses meaning.

However, this new structure requires a profound review of organizational mechanisms. The first issue is speed: approval processes designed for annual product cycles risk suffocating a system that generates weekly improvement proposals. Some companies are, therefore, adopting streamlined evaluation committees, delegating a wide margin of decision making to line teams within codified risk thresholds. The second issue concerns data quality: to prevent continuous innovation from turning into chaotic iteration, reliable data, rigorous updating of AI models, and clear criteria are needed.

Finally, there is the cultural aspect. In an environment where the product is constantly changing, skills must be updated at the same speed. This pushes towards a continuous upskilling model: short online training modules, internal communities of practice, and platforms that recommend micro-courses based on tasks performed in the factory or office. In essence, the “always-on” company grafts the logic of the learning organization into its operational fabric, but with the novelty that the feedback cycle is mediated by algorithms that never sleep.

This horizon does not decree the end of heroic radical innovation projects. It supports them with a second path made of continuous staking of the present. The two methods do not exclude each other but feed each other: the constellation of small improvements generates real performance that, in the long run, guides even the most innovative investment choices. In this sense, Artificial Intelligence does not replace strategic vision but instead offers a precise speedometer that allows to correct course without waiting to hit the iceberg.

---

[135] https://www.mckinsey.com/industries/industrials-and-electronics/our-insights/digital-twins-the-key-to-smart-product-development.

3. Hybrid Teams, Governance and the Ethics of Algorithmic Bias

When Artificial Intelligence becomes a stable partner of creative work, adding a few more data scientists to a traditional organizational chart is not enough: the very identity of innovation teams changes. The first case studies show two operational archetypes, partly borrowed from science fiction vocabulary but now rooted in corporate practice: *centaurs* and *cyborgs*[136].

The *centaur* model recalls the mythological figure half man and half horse but with a clear boundary between the two natures. In the company, this translates into an equally clear division of labor. AI explores an almost unlimited space of solutions, simulating product variants, generating drafts and scenarios; the human being intervenes at the end, filtering the proposals with his or her own aesthetic, ethical and strategic judgment.

The *cyborg* model, on the other hand, involves a more intimate fusion. The human delegate does not simply choose from ready-made options. He interacts with the AI in real time, as one would with a colleague at the following table. In software development, this happens when an engineer uses AI pair programming systems[137] that suggest samples or tests as he writes: the line between algorithmic proposal and human decision thus becomes thin because the "write-evaluate-accept" cycle happens in a few seconds. The same happens in advanced materials laboratories, where machine learning platforms guide the experiment by indicating the most promising chemical combination. The researcher adjusts the parameters, the model recalculates, and they advance jointly.

These kinds of hybrid teams are suited to another emerging paradigm: anticipatory innovation. While traditional R&D phases responded to manifest needs, predictive analytics now allows us to intercept hidden signals even before they actually become a market. This approach reverses the relationship between exploration and planning: we no longer wait for the market to express a need but formulate hypotheses on latent needs, prototype, measure, and act rapidly if the signals are consistent. Speed of iteration is back at the center: those who have the richest data sources and the quickest decision making infrastructure will be able to take over even before a real competition

---

[136] Ethan Mollick, "*Centaurs and Cyborgs on the Jagged Frontier*", One Useful Thing (blog), September 16, 2023, https://www.oneusefulthing.org/p/centaurs-and-cyborgs-on-the-jagged.

[137] GitHub, "Research: Quantifying GitHub Copilot's Impact in the Enterprise with Accenture", July 14, 2023, https://github.blog/news-insights/research/research-quantifying-github-copilots-impact-in-the-enterprise-with-accenture/.

comes into existence. In this sense, the real lacking resource is not the idea but the organizational delay between intuition by the algorithm and human action on the market.

However, a governance question remains: how can AI predictive view be prevented from becoming too restricted, cutting out each and every non-linear path? Some companies have introduced *serendipity windows*: time intervals, for example, two sprints per quarter, in which teams can explore insights not supported by data. Others practice a portfolio criterion, allocating a fixed share of the R&D budget to seemingly crazy projects proposed by researchers who bet against the algorithm.

The success of centaur or cyborg models and anticipatory innovation ultimately depends on a cultural substrate: mutual trust between roles, widespread awareness on AI limits and threats, and willingness to update decision making schemes. When these ingredients are missing, technology produces more frustration than advantage. Algorithms generate advice that no one dares to implement, or managers ask analysts to force data to confirm decisions already made.

Where harmony holds, however, the company discovers it can move forward on two different levels: AI expands the field of opportunities, and human capital, freed from lots of mechanical research, can dedicate itself to what machines still cannot do. Intuiting contexts, negotiating visions, telling meanings, these are all examples of the most advanced form of competitive advantage in the data-driven era.

When an organization decides to entrust an increasing share of its operational strategic decisions to predictive machines, it suddenly finds itself in front of a paradox: the more objective the algorithm seems, the more it is necessary to monitor its hidden subjectivity. In fact, data is not an objective reflection of the world but it relies on past decisions, facts and biases. If this issue remains hidden, the system that is meant to reduce errors ends up silently amplifying them, replicating them on an industrial scale.

The first warning signs were seen in models that penalized social categories that were poorly represented in historical datasets[138], in facial recognition systems with triple false

[138] Nicol Turner Lee, Paul Resnick, and Genie Barton, "Algorithmic Bias Detection and Mitigation: Best Practices and Policies to Reduce Consumer Harms", Brookings Institution, May 22, 2019, https://www.brookings.edu/articles/algorithmic-bias-detection-and-mitigation-best-practices-and-policies-to-reduce-consumer-harms/.

favorable rates for dark skin[139], or in employee selection algorithms that, trained on CVs from a decade ago, discarded brilliant but atypical candidates[140]. These events have put the spotlight on a need for AI governance that is not limited to technical checklists: an institutional design capable of integrating expertise, ethical sensitivity, and regulatory capacity is needed.

Pioneering companies are equipping themselves along three lines. The first concerns the quality and supply chain of data. It is not enough to accumulate terabytes: we need a transparent mapping that says where each database column comes from, which filters have been applied, and which segments are underrepresented. Some multinationals have introduced real *data passports*, documents accompanying a dataset throughout its life cycle[141], as a way to guarantee traceability and reliability.

The second line concerns algorithmic auditing. Just as a balance sheet is certified by third parties, predictive models are starting to be subjected to independent reviews that test their robustness, fairness, and credibility. Big Tech has already released *model cards* that explain the scope of the algorithm and the known limitations[142]. The European Union, with the AI Act, is pushing in this direction. High-risk systems will have to pass compliance procedures similar to those of medical devices or aircraft[143].

The third line is organizational culture. Statistically flawless AI is of little use if humans experience it with uncritical reverence or paralyzing skepticism. Terms such as *algorithmic aversion*, the tendency to discard the algorithm's decision after the first error[144], even if the overall performance remains superior, or *automation complacency*,

---

[139] Joy Buolamwini and Timnit Gebru, "Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification", Proceedings of Machine Learning Research 81 (2018): 1–15, https://www.media.mit.edu/publications/gender-shades-intersectional-accuracy-disparities-in-commercial-gender-classification/.

[140] Jeffrey Dastin, "Amazon Scraps Secret AI Recruiting Tool That Showed Bias against Women", Reuters, October 11, 2018, https://www.reuters.com/article/us-amazon-com-jobs-automation-insight/amazon-scraps-secret-ai-recruiting-tool-that-showed-bias-against-women-idUSKCN1MK0AG.

[141] Open Ethics, "Open Ethics Data Passport (OEDP)", https://openethics.ai/oedp/.

[142] Margaret Mitchell et al., "Model Cards for Model Reporting", Proceedings of the Conference on Fairness, Accountability, and Transparency (FAccT) 2019: 220–29, https://research.google/pubs/model-cards-for-model-reporting/.

[143] European Parliament, "EU AI Act: First Regulation on Artificial Intelligence", last updated February 19, 2025, https://www.europarl.europa.eu/topics/en/article/20230601STO93804/eu-ai-act-first-regulation-on-artificial-intelligence.

[144] Berkeley J. Dietvorst, Joseph P. Simmons, and Cade Massey, "Algorithm Aversion: People Erroneously Avoid Algorithms after Seeing Them Err", *Journal of Experimental Psychology: General* 144, no. 1 (2015), https://psycnet.apa.org/doiLanding?doi=10.1037%2Fxge0000033.

the excess of trust that leads to disinterest in the correctness of the results[145], are now circulating in companies. Both drifts are dangerous. The first prevents an actual capitalization on the benefits of AI, while the second exposes us to the risk of silent catastrophes or death of human reasoning, because no one notices when the model takes a wrong path or simply does not care.

In order to avoid these extremes, a shared alphabet between technical and business functions is needed. Some companies organize quarterly "clinics" in which data scientists present real cases of discovered and corrected bias, explaining both the mathematical part and the impact on the end customer[146]. In other situations, product managers follow basic machine learning courses to understand the limits of the models they use daily. The point is not to turn everyone into a programmer but to create a common ground of sensible questions: "Is that 97% accuracy distributed evenly across segments?", or "What are the costs of a false positive in this context?", or "How many iterations are needed to get the model back on track if the market changes abruptly?".

Finally, leadership transparency remains the multiplying factor. A CEO who personally recounts an algorithmic assessment error, explaining how the bias was identified and what safeguards are now in place[147], communicates more than any behavior manual: error is allowed, but silence about the error is not. In contrast, when management covers under the bed flops or blames analysts for bad data, it creates a learned helplessness that redefines failure as a career risk.

The outcome of this journey is not a regulatory framework that suffocates innovation but a set of safety tracks within which AI can run faster without derailing, hand in hand with humanity. In a landscape where decisions are taken fast, the ability to slow down when necessary, to question an outlier or an unprecedented pattern, becomes the other side of competitive advantage.

In conclusion, AI does not erase failure; it shifts it. Under its lens, basic errors disappear, but invisible errors emerge, hidden biases, decisions taken out of context, and anomalies that indicate new paths. In this scenario, advantage will not go to those who

---

[145] Raja Parasuraman and Victor Riley, "Humans and Automation: Use, Misuse, Disuse, Abuse", Human Factors 39, no. 2 (1997): 230–53, https://journals.sagepub.com/doi/10.1518/001872097778543886.

[146] Google AI, *2022 AI Principles Progress Update*. Mountain View, October 5, 2022, 4-5. https://ai.google/static/documents/ai-principles-2022-progress-update.pdf.

[147] Dan Milmo and Alex Hern. "Google chief admits 'biased' AI tool's photo diversity offended users". The Guardian, February 28, 2024. https://www.theguardian.com/technology/2024/feb/28/google-ai-photo-diversity.

chase infallibility but to those who know how to listen to mistakes and failures transform them into signs of innovation. Reducing routine errors is necessary, eliminating all risks is not short of illusory. Therefore, cultivating small, smart failures, even in a world dominated by algorithms and machine learning, remains the most human and strategic way to gain real competitive advantage.

V. CONCLUSION

From the artisan press of the First Industrial Revolution, when master printers spent months perfecting each gear, to the aforementioned modern *digital twins*, a single thread runs through the history of innovation. Every lasting progress is based on an error understood, studied, sometimes even admitted, and transformed into an opportunity. Think of the numerous unsuccessful prototypes inhibited by seemingly insurmountable challenges before actually managing to inaugurate new human eras. Popper's ideas on falsifiability, Kuhn's on the crisis of paradigms, and Schumpeter's on *creative destruction, these* theories have all found support in the analysed cases of Newton, Betamax, and Google Glass. Every time failure has been welcomed as a source of learning and an opportunity to grow, the stage has been set for real revolutions. Today, in a context of predictive models and virtual simulations, machine errors and forecasts become vital inputs for refining processes, improving products, foreseeing new technological frontiers and invest in new markets.

AI is accelerating innovation at an astounding pace, removing impenetrable bottlenecks through predictive diagnostics and automation. In factories, sensor networks analyse data and temperatures to predict maintenance needs and reducing downtime by 30-50%. In logistics, forecasting tools quickly pull together sales, weather, and social media data to better manage inventory and shipping. In finance, machine learning models monitor transaction flows and individuate frauds in milliseconds, while in marketing, AI customizes offers and advertising campaigns based on individual user behavior and big-data analysis.

However, it is precisely in this new geography of data that other types of failure emerge: those distortions hidden in datasets that, if overlooked, can produce misleading decisions and out-of-context applications that may turn a winning strategy based on statistics into the wrong choice. The clash between precise algorithms and the complexity of real-world data is changing how errors are classified. Superficial errors are now handled by automation, complex errors are addressed through simulations, and finally, genuinely strategic errors are used to open the door to new scenarios and opportunities.

Therefore, the real issue does not reside in the concept of “man versus machine” but in the quality of their alliance, in finding the right balance. On one hand, AI runs millions of simulations in the blink of an eye, yet human intelligence is still irreplaceable in decoding ambiguous contexts, attributing the right value to results, and recognizing anomalies that escape any kind of statistical pattern. Without this balance, we risk two opposite deviations: abdication, in which every strategic decision is delegated to the algorithm, or rejection, which means technology is turned down for fear of losing control, leaving a potential advantage on the table.

The alternative is a *centaur-cyborg alliance.* On one hand, the machine broadens the range of opportunities, while on the other, the human being selects the truly significant paths, evaluates their ethics, impact, and decides whether it is the right choice to move against what suggested by data and statistics. Only a conscious integration between calculation and judgment can make us move faster without going off track.

To translate this vision into action, four essential conditions are needed. First, spaces of psychological safety in which those who raise doubts or report problematic data are not reprimanded but encouraged. Only in a context in which dissonant opinions are valued can signs of intelligent failure emerge and be solved before they become insurmountable obstacles.

Second, reflection, periodic retrospectives, *five whys* sessions, and After-Action Reviews, through which lessons learned are systematically collected. These prevent learning from being lost in everyday life and transform every mistake into a collective treasure.

Third, traceability infrastructures: *dataset passports* that document their origin and reliability, and data panels accessible to all on the outcomes of each experiment. Without transparency, data-driven innovation risks becoming a black hole in which responsibility and organizational memory are lost.

Fourth, incentives for curiosity: time slots dedicated to exploration and recognition for those who actively document their mistakes or rewarding “best failures” make it clear that smart errors are not a taboo but the very condition for taking a step forward.

These four pillars create the environment in which the alliance between man and machine can unlock its full potential.

Thus, rather than suffocating innovation, AI multiplies its prospects. Algorithms and machine learning tools reduce the cost of error and spare energy to experiment further. Organizations that effectively combine algorithmic rigor and creative courage will thus transform every minor misstep into a gateway, remaining not only resilient but embodying Taleb's concept of antifragility. Imperfection is not a defect to be corrected but the spark from which the next great technological and economic revolution can emerge.

BIBLIOGRAPHY

1. Clayton M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Boston: Harvard Business Review Press, 1997).
2. Robert G. Cooper, *Winning at New Products: Creating Value through Innovation*, 4th ed. (New York: Basic Books, 2017), 15–18.
3. Kenneth Pomeranz, *The Great Divergence: China, Europe, and the Making of the Modern World Economy* (Princeton, NJ: Princeton University Press, 2000).
4. Phyllis Deane, *The First Industrial Revolution* (Cambridge: Cambridge University Press, 1979).
5. Joel Mokyr and Robert H. Strotz, "The Second Industrial Revolution, 1870–1914," *Storia dell'economia mondiale* 21, no. 1 (1998).
6. Ambrose Fleming, "Guglielmo Marconi and the Development of Radio-Communication," *Journal of the Royal Society of Arts* 86, no. 4436 (1937).
7. Albert Abramson, "Pioneers of Television, Philo Taylor Farnsworth," *SMPTE Journal* 101, no. 11 (1992).
8. Henry Petroski, *To Engineer Is Human: The Role of Failure in Successful Design* (New York: Vintage, 1985).
9. Laith Zuraikat, "Google Glass: A Case Study," *Performance Improvement* 59, no. 6 (2020): 14–20.
10. Jason Hong, "Considering Privacy Issues in the Context of Google Glass," *Communications of the ACM* 56, no. 11 (2013).
11. Christopher Ziemnowicz, "Joseph A. Schumpeter and Innovation," in *Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship* (Cham: Springer, 2020).
12. Karl R. Popper, "Science as Falsification," in *Conjectures and Refutations* (London: Routledge, 1963).
13. Gopesh Anand, Eric C. Larson, and Joseph T. Mahoney, "Thomas Kuhn on Paradigms," *Production and Operations Management* 29, no. 7 (2020).
14. Chris Argyris, "Single-Loop and Double-Loop Models in Research on Decision Making," *Administrative Science Quarterly* 21, no. 3 (1976).
15. Nasim Nicholas Taleb, *Antifragility: How to Benefit from Chaos* (London: Allen Lane, 2014).

16. Adam Sutherland, *The Story of Apple* (New York: Rosen Publishing Group, 2012).
17. John Nathan, *Sony* (Boston: Houghton Mifflin Harcourt, 2001).
18. Joshua M. Greenberg, *From Betamax to Blockbuster: Video Stores and the Invention of Movies on Video* (Cambridge, MA: MIT Press, 2016).
19. Michael A. Cusumano, Yiorgos Mylonadis, and Richard S. Rosenbloom, "Strategic Maneuvering and Mass-Market Dynamics: The Triumph of VHS over Beta," *Business History Review* 66, no. 1 (1992).
20. Julian P. Christ and André Slowak, "Why Blu-ray vs. HD-DVD Is Not VHS vs. Betamax: The Co-evolution of Standard-Setting Consortia," working paper, 2009.
21. Anne-Laure Mention, João José Pinto Ferreira, and Marko Torkkeli, "Moonshot Innovations: Wishful Thinking or Business-as-Usual?" *Journal of Innovation Management* 7, no. 1 (2019).
22. Thad Starner, "Project Glass: An Extension of the Self," *IEEE Pervasive Computing* 12, no. 2 (2013).
23. Olya Kudina and Peter-Paul Verbeek, "Ethics from Within: Google Glass, the Collingridge Dilemma, and the Mediated Value of Privacy," *Science, Technology, & Human Values* 44, no. 2 (2019).
24. Brian L. Due, "The Social Construction of a Glasshole: Google Glass and Multiactivity in Social Interaction," *PsychNology Journal* 13, no. 2 (2015).
25. Oliver J. Muensterer et al., "Google Glass in Pediatric Surgery: An Exploratory Study," *International Journal of Surgery* 12, no. 4 (2014).
26. Gheorghe-Daniel Voinea et al., "Exploring Cultural Heritage Using Augmented Reality through Google's Project Tango and ARCore," in *VR Technologies in Cultural Heritage* (Cham: Springer, 2018).
27. Chris Argyris, "Teaching Smart People How to Learn," *Harvard Business Review* 69, no. 3 (1991): 99–109.
28. Eric Ries, *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses* (New York: Crown Business, 2011).

29. Kent Beck et al., “Manifesto for Agile Software Development,” (Snowbird, UT, 2001).
30. Tim Brown, *Change by Design: How Design Thinking Creates New Alternatives for Business and Society* (New York: HarperBusiness, 2009).
31. Masaaki Imai, *Kaizen: The Key to Japan’s Competitive Success* (New York: Random House, 1986).
32. W. Edwards Deming, *Out of the Crisis* (Cambridge, MA: MIT Press, 1982).
33. Søren Kierkegaard, *The Journals of Søren Kierkegaard*, ed. J. E. A. Ditlevsen (Princeton: Princeton University Press, 1958).
34. James J. Chrisman, Ed McMullan, and Jeremy Hall, “The Influence of Guided Preparation on the Long-Term Performance of New Ventures,” *Journal of Business Venturing* 20, no. 6 (2005).
35. Rafael F. Bortolini et al., “Lean Startup: A Comprehensive Historical Review,” *Management Decision* 59, no. 8 (2021).
36. Steve Blank and Bob Dorf, *Startup: Manual do Empreendedor* (São Paulo: Alta Books, 2012).
37. Adam Przybyłek et al., “Game-Based Sprint Retrospectives: Multiple Action Research,” *Empirical Software Engineering* 27, no. 1 (2022).
38. Sim B. Sitkin, “Learning Through Failure: The Strategy of Small Losses,” *Research in Organizational Behavior* 14 (1992): 231–66.
39. Amy C. Edmondson, *Right Kind of Wrong: The Science of Failing Well* (New York: Atria Books, 2023).
40. Anne Trafton, “Artificial Intelligence Yields New Antibiotic,” *MIT News*, February 2020.
41. Ajay Agrawal, Joshua Gans, and Avi Goldfarb, *Prediction Machines: The Simple Economics of Artificial Intelligence* (Boston: Harvard Business Review Press, 2018).

SITOGRAPHY

1. McKinsey & Company, “What Are Industry 4.0, the Fourth Industrial Revolution, and 4IR,” McKinsey Digital, 2022, https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-are-industry-4-0-the-fourth-industrial-revolution-and-4ir.
2. Oxford Reference, s.v. “Thomas Edison,” Oxford Reference, https://www.oxfordreference.com/display/10.1093/acref/9780191826719.001.0001/q-oro-ed4-00003960.
3. Wright Brothers Aeroplane Company, “Wright Trivia,” Wright Brothers Museum, https://www.wright-brothers.org/Information_Desk/Just_the_Facts/Trivia/Wright_Trivia.htm.
4. Silicon UK, “Tales in Tech History: Microsoft Zune,” Silicon UK, 2017, https://www.silicon.co.uk/mobility/smartphones/tales-tech-history-microsoft-zune-210569.
5. Hewlett-Packard Computer Museum, “The HP Portable: HP’s First Laptop,” Hewlett-Packard History, http://www.hewlettpackardhistory.com/item/hewlett-packards-first-laptop/.
6. Jesus Diaz, “The Story Behind Apple’s Newton,” Gizmodo, January 20, 2010, https://gizmodo.com/the-story-behind-apples-newton-5452193.
7. Commoncog Case Library, “General Magic: The Future, Too Early,” Commoncog Case Library, https://commoncog.com/cases/general-magic-the-future-too-early.
8. Christina Bonnington, “Remembering the Apple Newton’s Prophetic Failure and Lasting Impact,” Wired, August 2, 2013, https://www.wired.com/2013/08/remembering-the-apple-newtons-prophetic-failure-and-lasting-ideals/.
9. Ewan Spence, “For the Record, Apple’s Newton Was Not the First PDA,” Forbes, June 3, 2012, https://www.forbes.com/sites/ewanspence/2012/06/03/for-the-record-apples-newton-was-not-the-first-pda/.
10. Bloomberg Television, “Apple Newton’s Flop | On This Day,” YouTube video, 2024, https://www.youtube.com/watch?v=kXTGdx8UjdQ.

11. John Markoff, “Apple to Give the Public Its First Look at Newton,” New York Times, May 29, 1992, https://www.nytimes.com/1992/05/29/business/company-news-apple-to-give-the-public-its-first-look-at-newton.html.
12. Newton Glossary, s.v. “Ko Isono,” Newton Glossary, https://newtonglossary.com/terms/ko-isono.
13. Etan Cohen, “Newton Attracts Curiosity, Not Buyers,” The Harvard Crimson, September 28, 1993, https://www.thecrimson.com/article/1993/9/28/newton-attracts-curiosity-not-buyers-papple/.
14. Chris Matyszczyk, “The Simpsons’ ‘Eat Up Martha’ Was the First Autocorrect Fail,” CNET, October 3, 2013, https://www.cnet.com/tech/services-and-software/the-simpsons-eat-up-martha-was-the-first-autocorrect-fail/.
15. Business Insider, “Steve Jobs’ Life and Apple Career, from Cofounder to CEO,” Business Insider, 2024, https://www.businessinsider.com/steve-jobs.
16. Alex Hern, “The iPhone Only Exists Because Steve Jobs ‘Hated This Guy at Microsoft,’” The Guardian, June 21, 2017, https://www.theguardian.com/technology/2017/jun/21/apple-iphone-steve-jobs-hated-guy-microsoft-says-scott-forstall.
17. Victor Luckerson, “Steve Jobs Totally Dissed the Stylus Eight Years before Apple Pencil,” Time, September 10, 2015, https://time.com/4029142/steve-jobs-stylus/.
18. Lenovo, “What Is a Liquid Crystal Display (LCD)?,” Lenovo Glossary, https://www.lenovo.com/us/en/glossary/what-is-lcd/.
19. Sony Corporation, “Product & Technology Milestones,” Sony History, https://www.sony.com/en/SonyInfo/CorporateInfo/History/sonyhistory.html.
20. AZQuotes, “Akio Morita — Quotations,” AZQuotes, https://www.azquotes.com/author/20128-Akio_Morita.
21. Brian Santo, “The Consumer Electronics Hall of Fame: Sony Trinitron,” IEEE Spectrum, August 13, 2018, https://spectrum.ieee.org/the-consumer-electronics-hall-of-fame-sony-trinitron.
22. Samuel Gibbs, “Betamax Is Dead, Long Live VHS,” The Guardian, November 10, 2015, https://www.theguardian.com/technology/2015/nov/10/betamax-dead-long-live-vhs-sony-end-production.

23. The New York Times, “RCA Introduces Video Cassette Recorder For $300 Less Than Sony Competitor,” August 24, 1977, https://www.nytimes.com/1977/08/24/archives/rca-introduces-video-cassette-recorder-for-300-less-than-sony.html.
24. Legacy Box, “Betamax vs. VHS: History of the Videotape Format War,” Legacy Box Blog, https://www.legacybox.com/blogs/analog/betamax-vs-vhs-history.
25. Cornell Law School, “SONY CORPORATION OF AMERICA, et al., Petitioners v. UNIVERSAL CITY STUDIOS, INC., etc.,” Cornell LII, https://www.law.cornell.edu/supremecourt/text/464/417.
26. Max Green Movies, “Home Video Wars,” May 5, 2019, https://maxgreenemovies.com/2019/05/05/home-video-wars/.
27. Krows Digital, “The Rise of Sony: From a Humble Start to a Global Giant,” https://krows-digital.com/the-rise-of-sony-from-a-humble-start-to-a-global-giant/.
28. NetQuest, “Legendary Products: VHS vs. Beta,” NetQuest Blog, https://www.netquest.com/en/blog/blog/en/legendary-products-vhs-vs-beta.
29. Sony Computer Entertainment Inc., press release, “Sony Computer Entertainment Inc. Adopts Blu-ray Disc ROM for Next-Generation PlayStation,” September 21, 2004.
30. Lucilla Tomassi, “The Story of Google: How Two Students Created an Empire,” Codemotion, 2023, https://www.codemotion.com/magazine/infographics/the-story-of-google-infographic/.
31. Google, “Project Glass Demo: Hangouts in Air,” Official Google Blog, 2012, https://blog.google/alphabet/project-glass-demo-hangouts-in-air/.
32. X (Alphabet), “Google Glass, A Google X Moonshot,” https://x.company/projects/glass/.
33. BBC News, “Google Glass to Go on Sale for One Day,” April 15, 2014, https://www.bbc.com/news/technology-26987972.
34. Google Developers, “Glass Enterprise Edition 2,” https://developers.google.com/glass-enterprise.

35. Innovation Post, “Google Glass Enterprise Edition 2: More Powerful and Cheaper,” May 21, 2019, https://www.innovationpost.it/tecnologie/google-glass-enterprise-edition-2-piu-potenti-ed-economici/.
36. Google, “Google Lens, Search What You See,” https://lens.google/howlensworks/.
37. Google Developers, “ARCore,” https://developers.google.com/ar.
38. Astro Teller, “Why We Developed Google Glass,” CNN Opinion, June 4, 2014, https://edition.cnn.com/2014/06/04/opinion/teller-google-glass/index.html.
39. Tarun Wadhwa, “Google’s Glass Explorer Program Was a Social Experiment That Backfired,” Forbes, April 24, 2014, https://www.forbes.com/sites/tarunwadhwa/2014/04/24/the-google-glass-explorer-program-was-a-social-experiment-that-backfired/.
40. Harvard Business Review, “Strategies for Learning from Failure,” April 2011, https://hbr.org/2011/04/strategies-for-learning-from-failure.
41. Zenkit, “What Is Agile Methodology? (An Overview),” https://zenkit.com/en/blog/agile-methodology-an-overview/#:~:text=Agile%20Methodology%20Definition,a%20climate%20of%20continuous%20improvement.
42. PremierAgile, “Scaling Agile Challenges,” https://premieragile.com/scaling-agile-challenges/.
43. The Knowledge Academy, “8 Agile Project Management Challenges: A Comprehensive Guide,” https://www.theknowledgeacademy.com/blog/agile-project-management-challenges/.
44. ArchDaily, “The Rise of the Design Thinking Movement and Its Relation to Architecture,” May 19, 2020, https://www.archdaily.com/975341/the-rise-of-the-design-thinking-movement-and-its-relation-to-architecture.
45. Rikke Friis Dam and Yu Siang Teo, “The History of Design Thinking,” 2022, Interaction Design Foundation, https://www.interaction-design.org/literature/article/design-thinking-get-a-quick-overview-of-the-history.
46. Rikke Friis Dam, “The 5 Stages in the Design Thinking Process,” 2025, Interaction Design Foundation, https://www.interaction-design.org/literature/article/5-stages-in-the-design-thinking-process.

47. Stanford Social Innovation Review, “Fail Faster, Succeed Sooner,” https://ssir.org/articles/entry/fail_faster_succeed_sooner.
48. Harvard Business Review, “Design Thinking Comes of Age,” September 2015, https://hbr.org/2015/09/design-thinking-comes-of-age.
49. Karel Vredenburg, “Innovation Theater vs. Design Thinking Mastery,” March 15, 2021, https://www.karelvredenburg.com/home/2021/3/15/innovation-theatre-vs-design-thinking-mastery.
50. Faster Capital, “Kaizen: The Path to TQM Success,” https://fastercapital.com/it/contenuto/Filosofia-Kaizen--Kaizen--il-percorso-verso-il-successo-TQM.html#Introduzione-alla-filosofia-Kaizen.
51. DNV, “PDCA: Full Cycle Of Risk Management,” https://www.dnv.com/assurance/articles/pdca-full-cycle-of-risk-management/.
52. The Systems Thinker, “Pulling the Andon Cord: Toyota Responds to Challenge and Change,” https://thesystemsthinker.com/pulling-the-andon-cord-toyota-responds-to-challenge-and-change/.
53. Oakland University, “5 Whys Problem Solving,” Lean Enrichment Activities, https://www.oakland.edu/Assets/upload/docs/Pawley/Lean-Enrichment-Activities/LEA---5-Whys.pdf.
54. Ryan Kim, “Netflix Sees the Future, and It’s Digital,” San Francisco Chronicle, December 24, 2008, https://www.sfgate.com/business/article/Netflix-sees-the-future-and-it-s-digital-3257129.php.
55. Jeff Bezos, “2016 Letter to Shareholders,” Exhibit 99.1 to Amazon.com, Inc., Current Report on Form 8-K, filed April 12, 2017, U.S. Securities and Exchange Commission, https://www.sec.gov/Archives/edgar/data/1018724/000119312517120198/d373368dex991.htm.
56. Independent Evaluation Group, *Learning and Results in World Bank Operations: How the Bank Learns* (Washington, DC: World Bank Group, 2014), https://ieg.worldbankgroup.org/sites/default/files/Data/reports/chapters/learning_results_eval.pdf.
57. Ryan Tate, “Google Couldn’t Kill 20 % Time Even if It Wanted To,” Wired, August 21, 2013, https://www.wired.com/2013/08/20-%-time-will-never-die/.

58. Tata Group Newsroom, “Tata Innovista, The One Tata Way,” April 2023, https://www.tata.com/newsroom/business/tata-innovista-one-tata-spirit.
59. Fabrizio Dell’Acqua et al., “Navigating the Jagged Technological Frontier: Field Experimental Evidence of the Effects of AI on Knowledge-Worker Productivity and Quality,” Harvard Business School Working Paper no. 24-013, September 22, 2023, https://www.hbs.edu/faculty/Pages/item.aspx?num=64700.
60. Charles Benoit, “Tesla Model 3 0–60 mph Times, Then and Now, All Trims Compared,” Electrek, November 17, 2019, https://electrek.co/2019/11/17/tesla-model-3-0-60mph-times-then-and-now-all-trims-compared/.
61. Rowland Manthorpe, “To Make a New Kind of Shoe, Adidas Had to Change Everything,” Wired, October 4, 2017, https://www.wired.com/story/adidas-speedfactory-made-for-london-trainers/.
62. Dinu de Kroon, Enno de Boer, and Rahul Shahani, “The Continuing Evolution of the Global Lighthouse Network,” McKinsey & Company, January 2025, https://www.mckinsey.com/capabilities/operations/our-insights/the-continuing-evolution-of-the-global-lighthouse-network.
63. Roberto Argolini, Federico Bonalumi, Johannes Deichmann, and Stefania Pellegrinelli, “Digital Twins: The Key to Smart Product Development,” McKinsey & Company, July 31, 2023, https://www.mckinsey.com/industries/industrials-and-electronics/our-insights/digital-twins-the-key-to-smart-product-development.
64. Ethan Mollick, “Centaurs and Cyborgs on the Jagged Frontier,” One Useful Thing (blog), September 16, 2023, https://www.oneusefulthing.org/p/centaurs-and-cyborgs-on-the-jagged.
65. GitHub, “Research: Quantifying GitHub Copilot’s Impact in the Enterprise with Accenture,” July 14, 2023, https://github.blog/news-insights/research/research-quantifying-github-copilots-impact-in-the-enterprise-with-accenture/.
66. Nicol Turner Lee, Paul Resnick, and Genie Barton, “Algorithmic Bias Detection and Mitigation: Best Practices and Policies to Reduce Consumer Harms,” Brookings Institution, May 22, 2019, https://www.brookings.edu/articles/algorithmic-bias-detection-and-mitigation-best-practices-and-policies-to-reduce-consumer-harms/.

67. Joy Buolamwini and Timnit Gebru, “Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification,” Proceedings of Machine Learning Research 81 (2018): 1–15, https://www.media.mit.edu/publications/gender-shades-intersectional-accuracy-disparities-in-commercial-gender-classification/.
68. Jeffrey Dastin, “Amazon Scraps Secret AI Recruiting Tool That Showed Bias against Women,” Reuters, October 11, 2018, https://www.reuters.com/article/us-amazon-com-jobs-automation-insight/amazon-scraps-secret-ai-recruiting-tool-that-showed-bias-against-women-idUSKCN1MK0AG.
69. Open Ethics, “Open Ethics Data Passport (OEDP),” https://openethics.ai/oedp/.
70. Margaret Mitchell et al., “Model Cards for Model Reporting,” in Proceedings of the Conference on Fairness, Accountability, and Transparency (FAccT) 2019: 220–29, https://research.google/pubs/model-cards-for-model-reporting/.
71. European Parliament, “EU AI Act: First Regulation on Artificial Intelligence,” last updated February 19, 2025, https://www.europarl.europa.eu/topics/en/article/20230601STO93804/eu-ai-act-first-regulation-on-artificial-intelligence.
72. Berkeley J. Dietvorst, Joseph P. Simmons, and Cade Massey, “Algorithm Aversion: People Erroneously Avoid Algorithms after Seeing Them Err”, *Journal of Experimental Psychology: General* 144, no. 1 (2015), https://psycnet.apa.org/doiLanding?doi=10.1037%2Fxge0000033.
73. Raja Parasuraman and Victor Riley, “Humans and Automation: Use, Misuse, Disuse, Abuse”, *Human Factors* 39, no. 2 (1997): 230–53, https://journals.sagepub.com/doi/10.1518/001872097778543886.
74. Google AI, 2022 AI Principles Progress Update (Mountain View), October 5, 2022, https://ai.google/static/documents/ai-principles-2022-progress-update.pdf.
75. Dan Milmo and Alex Hern, “Google Chief Admits ‘Biased’ AI Tool’s Photo Diversity Offended Users,” The Guardian, February 28, 2024, https://www.theguardian.com/technology/2024/feb/28/google-ai-photo-diversity.