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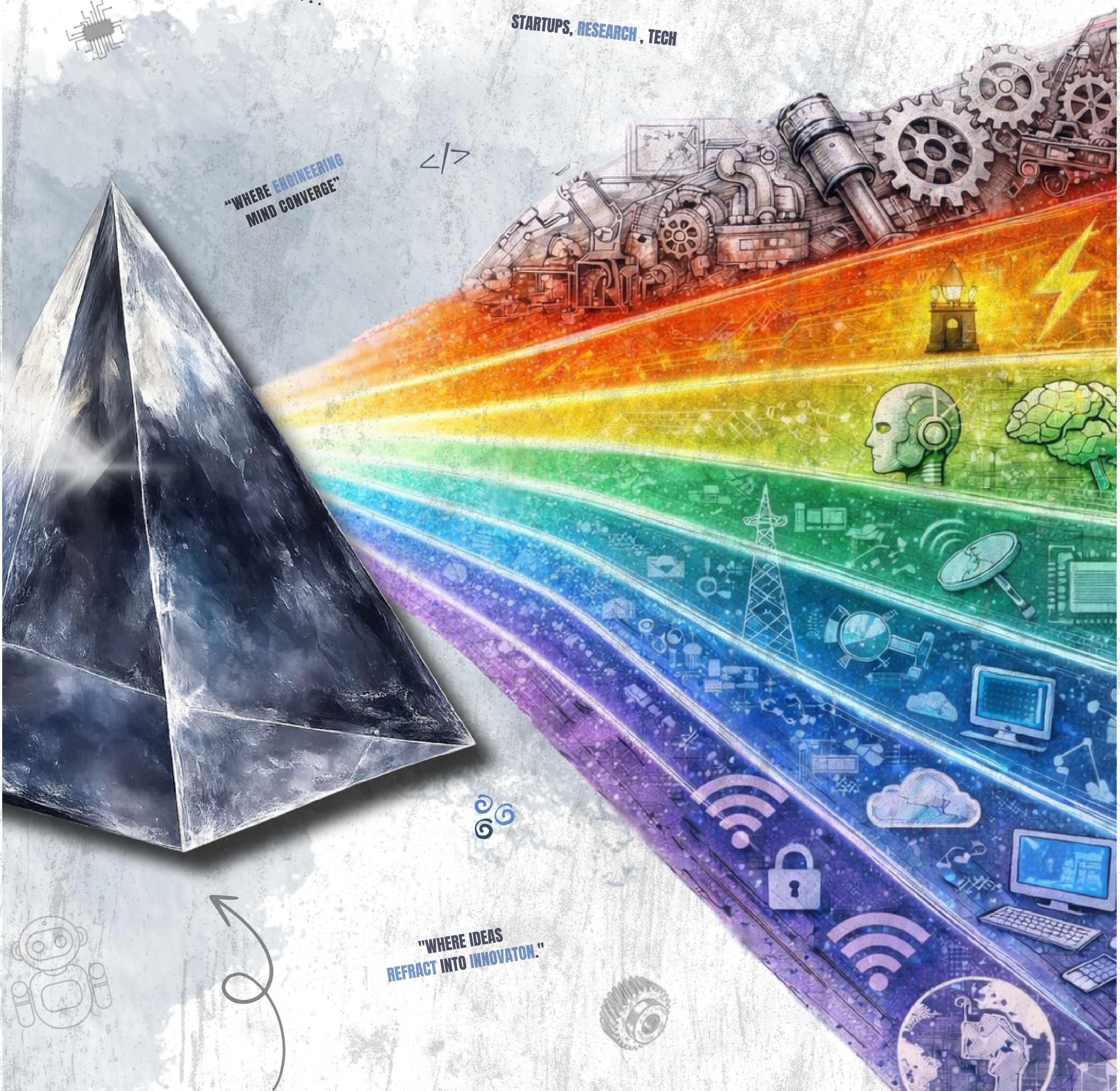

PRISM

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Principal's Note

Dear Readers,
It is with immense pride and joy that I introduce the inaugural edition of PRISM, a vibrant canvas created by our First Year Engineering students at Marathwada Mitra Mandal's College of Engineering (MMCOE), Pune.
At MMCOE, our mission transcends academic excellence. We are committed to nurturing "Complete Engineers" young minds who will shape the future through bold innovation and social responsibility. Engineering is far more than a syllabus; it is a powerful fusion of creativity, analytical grit, and technological mastery. PRISM stands as a true reflection of these qualities, capturing the fresh perspectives and boundless energy of our budding engineers.
The contributions within these pages highlight a remarkable truth: our students are not just learners, but thinkers. Seeing them engage and express themselves beyond the classroom reflects their embrace of a holistic approach to their professional journey, in alignment with the vision of the National Education Policy (NEP) 2020.
I heartily congratulate the editorial team, the faculty mentors, and every student contributor for their sincere efforts in launching this initiative. May PRISM continue to be a beacon that inspires curiosity and fosters a deep sense of belonging within our community.
Keep learning, keep innovating, and never stop striving for excellence.

Dr.Sachin Sakhare
Principal MMCOE

Editor's Note

In an environment where progress often revolves around rigid deadlines, it is easy to overlook the deeper purpose of engineering to question, deconstruct, and understand systems far beyond what is taught.
PRISM was created to bridge that gap.
Across our labs and workspaces, emerging talent constantly engages with complex ideas prototyping technologies, testing architectures, and making sense of how the world works. Yet, too many of these insights remain undocumented. PRISM is an effort to capture that raw curiosity and give it a definitive platform.
This journal brings together perspectives from across the technical spectrum from computing and artificial intelligence to mechanical systems, electronics, and advanced materials. It reflects a simple but absolute belief: engineering is not divided into isolated branches; it exists as a convergence of interconnected systems shaping the future.
What you will find in these pages is not just information, but deliberate thought an attempt to look deeper, connect ideas, and explore beyond the obvious.
This has been made possible by a dedicated team whose effort and belief turned this vision into reality.
As you go through this inaugural issue, I hope it encourages you not just to read, but to think, question, and contribute.

Shubham Deshpande

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PRISM
E=mc2
SiO2

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PRISM
TECH
MAGAZINE

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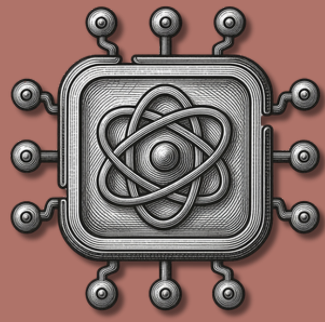
from Silicon to CPU

The Development Lifecycle Of Modern Processors

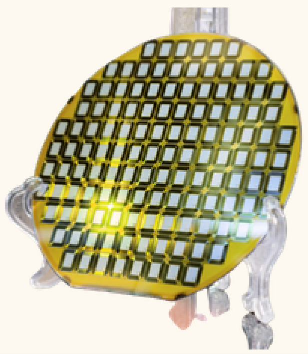


INTRODUCTION:

Everytime you turn on your Laptop/Desktop to play a game, watch a movie, just surf on the internet, run a program or to complete your college assignment, a small flat piece of silicon die protected with an aluminium layer starts performing its tasks. But, it's not just silicon in there, there lies a vast network of billion transistors performing trillions of operations. Interesting right? The development of CPU's is a far more interesting process than just looking at it as a tiny square piece mounted on a motherboard. The process starts with silicon and ends with a creation that are the building blocks of today's technology.

THE SILICON WAFER:

All microprocessors are built on Silicon Wafers. Silicon is the material of choice in the chip industry due to its semiconductor properties. After oxygen, it is the most abundant element on earth! Hence it's referred to as "The Digital Gold". The silicon obtained from the pile of Quartz sand is further processed to get a huge cylinder of silicon crystal called "ingot". Further, the Ingot is sliced into silicon discs called wafers by a 10-ton cable saw using a network of ultra-thin, high-speed cables, producing sheets just 0.75 millimetres thick!



BUILDING WITH BEAMS OF LIGHT:

Next, comes the most important step of "Photolithography" i.e. printing the circuit. This is not just a single step but consists of multiple stages. This process is more like planning a city on a circle of 8-inch diameter. The wafer is at first coated with a photo resistive material so that the ultraviolet lasers used later to print the layout leave their marks more accurately. To sharpen the beams intensity in this process, engineers have pushed the limits of miniaturization. Water is used as a high tech magnifying glass to engrave features much smaller than the human hair strand.

This process is a nightmare for engineers since this process doesn't complete at once. This cycle repeats between 30-100+ times to build the transistors level by level, similar to how a skyscraper is constructed. Once it's completed, the photo resistive material is removed, the silicon is etched and a clear accurate blueprint is obtained.

THE "HEART" OF THE CPUs – TRANSISTORS:

Once a perfect plate is obtained, ion implanting machines are used to hit the wafer with ions like Ge, P, B, As etc. In order to produce the required P-N junctions and form "Transistors". These atoms are doped with roughly one atom per million atoms of silicon. These implanters act like cannon launching balls deep inside castle walls at high speeds. These in-built transistors are of great importance in computing as they are the basic building blocks of the CPU. These transistors act like billion microscopic switches; combining them into complex patterns helps the CPU perform its calculations, run programs and process data. Modern microprocessors use MOSFETS, which represent a binary state. Engineers build logic gates that perform operations based on Boolean Algebra. These gates act as the decision-making units of digital circuits. The thing started with binary numbers 0 and 1 quickly transformed into a massive network of logic gates performing complex computing.

HOW DO THESE WAFERS RUN CODE:

The completely processed silicon wafers are then cut into small "CPU dies". These dies consist of various components like Cores (P-Cores and E-Cores), Cache memories, thread support, Interconnect, Memory controller, Integrated graphics. The "Cores" contain ALU (Arithmetic Logic Units), memory unit, control units. Cores work according to the CPU instruction cycle. The CPU instruction cycle decides the number of repetitions, and this is the number of times the basic computing instructions will be executed, as enabled by that computer's processing power. This cycle works in three stages – Fetch, Decode, Execute.

WHAT ARE COMPUTER PROCESSORS AND HOW ARE THEY MADE?

The CPUs fetch memory from the memory units like RAMs, Cache Memories. These instructions are further decoded by the instruction decoder inside the Control unit; they convert the binary signals into electric signals that hardware can understand. The execution is done by The ALUs which carry out main arithmetic and logical operations. Hence, cores are like employees in an office; more the number of efficient employees, faster it is to complete the targets within time. These processes are completed in synchronization with an internal clock of the CPU that regulates speed and frequency of computer applications, for example at 5-6 GHz boosts, called Clock speed. The chips are later cut out using a laser, flipped over and placed on an interposer which distributes the connection points to the PCBs. A protective heat cover is placed on the back. The integrated heat spreader is mounted on top and the entire assembly is then tested again and finally this piece of silicon is ready to be mounted on the motherboard and installed into your desktop.

LEADING GIANTS IN THE FIELDS:

Intel at first started building 4004 microprocessors for a Japanese calculator company. Since then, the global market has taken a hard shift, and now there are many leading giants in the field of chip production. All these chip-producing companies depend on a Dutch company, ASML, which is the sole supplier of the photolithography machines essential in Fabs. These fabs, costing billions to set up, are mostly owned by TSMC, Intel, and Samsung. TSMC along with owning Fabs, is also a large-scale supplier of chips, serving tech giants like Apple and Nvidia. AMD is a major competitor of Intel in the CPU market, selling microprocessors. AMD's Ryzen processors are high-speed, high-performance microprocessors intended for the video game market. ARM: Arm doesn't manufacture chips, but leases out its valuable, high-end processor designs and other technologies to companies that make equipment. Apple, for example, no longer uses Intel chips in Mac CPUs but makes its own customized processors based on ARM designs.

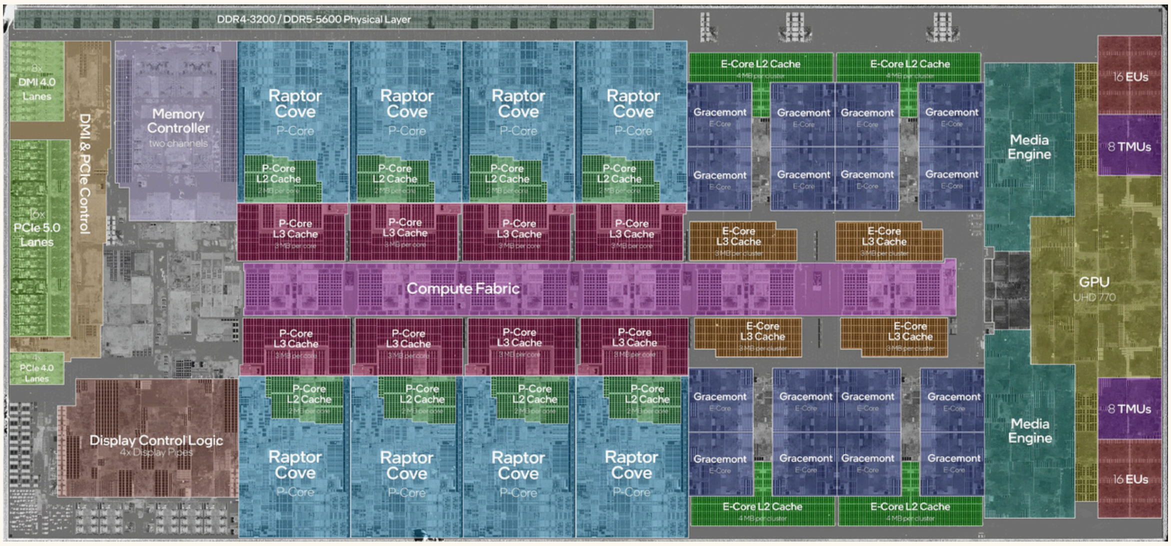
APPLE:

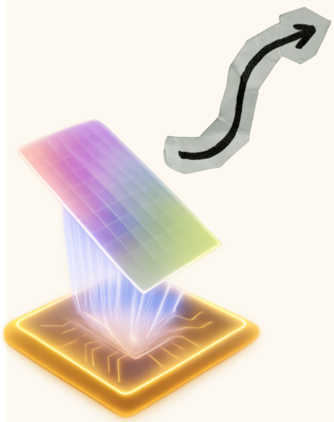
Though Apple chips are produced by TSMC, Apple has a System Management Controller (SMC), a crucial microcontroller on Apple-based Mac logic boards that manages low-level, physical functions. It controls power, battery charging, fan speeds, temperature sensors, lid switches, and sleep/wake functions. Today, the semiconductor industry has become one of the most profitable and influential sectors in the world. Companies involved in chip design and manufacturing generate massive revenue every year. The constant demand for faster computers, smartphones, artificial intelligence, and modern technology ensures that these companies remain at the centre of global innovation and economic growth.

FUTURE OF CHIP MAKING:

New Materials: Instead of using traditional chip-making material – Silicon, the option of GaN (Gallium Nitride) semiconductor technology is often explored since it has a wider band gap than silicon semiconductors and is of higher efficiency. Also, Carbon Nanotubes can be a great alternative since they're much smaller with excellent thermal conductivity. Quantum Computing: Since there is a limitation of putting more transistors on such small wafers, and to cater to the fast-computing demands of Consumers, Quantum Computing is often observed as a process overcoming limitations of classical CPUs. From the earliest microprocessors to today's powerful chips containing billions of transistors, computer processors have become the backbone of modern technology.

What begins with quartz sand is transformed through highly precise engineering into the brain of every digital device we use. The semiconductor industry continues to push the limits of miniaturization and performance, enabling faster computers with innovations. Behind every chip lies years of research, billion-dollar fabrication facilities, and companies that generate trillions of dollars from the global demand for computing power.





GLOSSARY:

- **Photolithography: The complex, multi-stage process of "printing" microscopic circuits onto a silicon wafer using ultraviolet lasers, water magnifying techniques, and photo-resistive materials.**
- **Semiconductor: A material, such as silicon, that has electrical conductivity between a conductor and an insulator, making it the foundational material of the chip industry.**
- **Silicon Wafer: An ultra-thin disk (typically cut to 0.75 millimeters thick) sliced from a silicon ingot, serving as the foundational plate on which all microprocessors are built.**
- **SMC (System Management Controller): A specialized microcontroller found on Apple logic boards that manages low-level physical functions like battery charging, fan speeds, and temperature sensors.**
- **Boolean Algebra: A branch of mathematics used by engineers to design the logic gates within microprocessors, based on binary states (0s and 1s).**
- **Clock Speed: The internal frequency of the CPU that regulates the speed of computer applications, often measured in GHz (e.g., 5-6 GHz).**
- **CPU Die: The small, individual piece of a completely processed silicon wafer that contains the actual functional circuit of the processor.cked like a skyscraper for shorter, faster data travel.**

-Gandhar vijapure

MECHANICAL LOGIC GATES

AS INDUSTRIAL SAFETY INTERLOCK SYSTEMS

INTRODUCTION:

Industrial safety is a major concern in today's world as we advance towards more sophisticated and complex energy systems. These energy systems demand dangerous environments which are difficult, expensive and tedious to create. While operating in these environments, even the slightest of any miscalculations in safety precautions can cause mayhems. These environments mainly include conditions of extreme heat, radiation or toxicity where complex electrical components get damaged, failing electronically controlled safety systems. This gives birth to a completely new idea called mechanical logic gates as safety interlock systems.

WHAT ARE SAFETY INTERLOCKS?

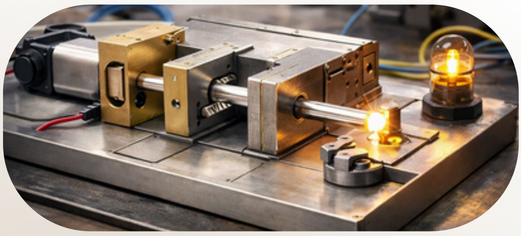
Safety interlocks are simple mechanical components that when used correctly, eliminate the need for complex safety electronics. They consist of simple levers and arms which allow an output movement only when there is a positive input movement; the input movement being a safety condition satisfied and output movement being the tasks of a machine. These simple interlocks are used in small scale industries where there are few conditions to be satisfied before a task.

WHAT ARE LOGIC GATES?

Logic gates are electrical devices that work on Boolean Algebra and produce positive outputs with a specific number and combinations of positive and negative inputs. Based on these combinations, there are various types of logic gates. The primary way of building logic gates is by diodes or transistors acting as electronic switches. Today, most logic gates are made from MOSFETs (metal–oxide–semiconductor field-effect transistors). They can also be constructed using vacuum tubes, electromagnetic relays with relay logic, fluidic logic, pneumatic logic, optics, molecules, acoustics or even mechanical or thermal elements. The goal is to replace these complex electronic components in logic gates by mechanical components which stimulate the same functions. Hence, *Mechanical Logic Gates* can be achieved by using simple levers, valves, springs, control arms, etc. which can be linked with each other in various ways portraying the different types of logic gates.

GLOSSARY:

- **Interlocks:**
  1. **Mechanisms or systems that prevent something from happening or allow something to happen only under specific conditions**
  2. **Interconnected systems or components that work together to achieve a specific goal.**
- **Boolean Algebra :Boolean algebra is a branch of math that deals with logical operations using only two values: true (1) and false (0). It uses operators like AND, OR, and NOT to combine and manipulate these values, making it fundamental to digital electronics and computer science.**



WHY THEY ARE THE BEST SOLUTION AS INDUSTRIAL SAFETY INTERLOCKS?

Consider this: Mechanical Safety Interlocks are at zero risk of failing during demanding environments. Also, using mechanical logic gates as safety interlocks broaden their applications on a large scale. Different types of Logic gates give outputs for various combinations of inputs. If we assume that inputs are safety conditions, outputs are tasks being done, mechanical logic gates can be configured for almost every scenario by using different types or by combining them, broadening applications even more. The task only gets done when a specific number of precautions depending on the situation and type of logic gate are completed. Since they are purely mechanical components, they are fail safe where electronic components fail and much more reliable.

CONCLUSION:

Hence, Mechanical Logic gates as Industrial safety interlocks is the best solution for safety concerns in today's industries. It is pure mechanical and the most reliable and efficient way of managing safety when it comes to dangerous environments. They simply don't allow the task to start unless all necessary precautions are complete. Therefore there is zero risk if mechanical logic gates are used as configurable safety interlocks in industries.

-Malhar Gupte

THE GREAT MEMORY SQUEEZE

WHY RAM IS THE NEW GOLD

THE DIGITAL WORKSPACE: WHAT IS RAM?

RAM stands for Random Access Memory, something which has become as important as breath for data centers.

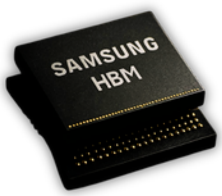
So what is actually RAM? RAM is random access memory which comes under SDRAM that stands for Synchronous Dynamic Random Access Memory, which is a memory that needs constant electricity and refreshes to store data. The only thing that makes RAM different from storage devices such as SSD (Solid State Drive) or HDD (Hard Disc Drive) is its storage type. RAM is temporary memory whereas SSD and HDD are storage devices used to store large data permanently for a long run, whereas RAM is used to transfer data at fast speeds.

Imagine you are working in an office and you have your own cabin where you work on a desk. You make files & stack up papers and keep them inside a cupboard. Here, your office is the PC, the desk is where you temporarily go through a lot of papers and files at once to stack them up, which is your RAM, and the cupboard where all your files are kept is your storage.

Primarily, RAM was limited for electronic devices which need access to memory and faster data transfer rates. As devices kept getting better, the RAM too kept getting better. This was the time when the era of DDR memory came into existence, which stands for Double Data Rate. From DDR to DDR2, then DDR3, and so on from generation to generation, speeds were exponentially increasing.

THE AI BOTTLENECK: ENTER HIGH BANDWIDTH MEMORY (HBM):

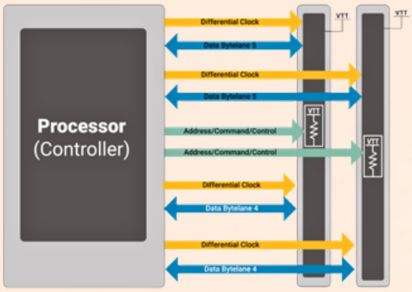
In the 21st century, the launch of chatbots opened a new page of tech and a new page of the race to control the world. The day AI came into existence was the day when all the tech giants started competing to acquire the market of AI to win this race. Huge data centers were started. The only bottleneck to train AI was the speed of RAM.



TEN STEPS AHEAD: WHY HBM IS KING:

The world shifted when HBM, which stands for High Bandwidth Memory, came into existence. HBM is ten steps ahead of DDR range memories. As demand for AI data centers raised the demand for HBM, companies started prioritizing manufacturing HBM instead of standard DDR memories. This is causing a drastic shortage in the market, and due to that reason, regular DDR memory is becoming exponentially expensive.

DDR memory sits a bit away from the CPU and is connected to the processor via tracks on the board, whereas HBM is much faster in terms of how it gets stacked one onto another using a silicon setup called TSV. High bandwidth is achieved by stacking the memory directly on the processing unit or minimizing the track length. However, HBM uses roughly three times the silicon wafer space as DDR memory.



The DDR runs at only 64 to 70 GB/s, whereas the HBM runs at a tremendous 1.2 TB/s, which makes HBM 10 to 20 times faster than the latest DDR5 memory. RAM manufacturers are largely ignoring standard supply gaps as there is a huge margin of profit in HBM manufacturing compared to DDR. The only negative thing in HBM is manufacturing efficiency, which is much lower because producing it yields less usable memory per wafer.

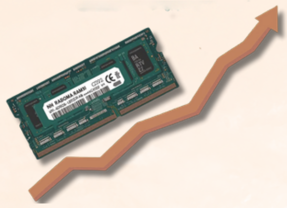
There are only three main RAM manufacturers in the world: Samsung, Micron, and SK Hynix. Rather than quitting the consumer DDR manufacturing sector entirely, these companies are heavily reducing legacy DDR production. Currently, they are heavily pivoting away from day-to-day electronic memory because the margin is comparatively low. Instead, they have signed massive contracts with companies building data centers, aggressively converting traditional DDR production lines into highly lucrative HBM production lines.

The Oligopoly: Three CEOs, One Global Market:

Such things make us realize that the most important thing to run our computers, smartphones, and other devices is controlled by only three CEOs. It is actually very scary to see how a combined decision of three CEOs can shake the entire global electronics market and how much power such people hold.

CONCLUSION: RAM IS THE NEW GOLD:

With time, we have seen the increase in importance of RAM same as gold. Price hikes due to the new technologies which are getting introduced and the rise in demand for high-speed memory mean that high amounts of data can be processed at high speeds. Just as the importance of gold has spiked, the importance of RAM has as well in the current scenario, so I feel like ***RAM IS THE NEW GOLD.***



GLOSSARY:

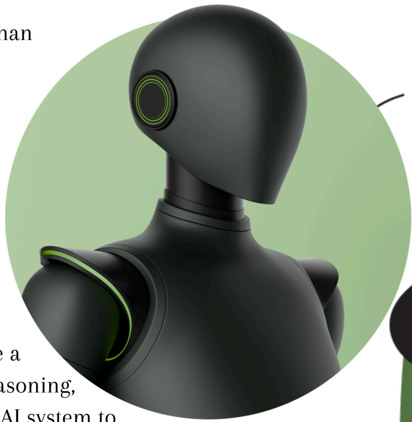
- **DDR (Double Data Rate):** The standard class of memory used in most everyday consumer electronics. It transfers data twice per clock cycle. The article references its evolutionary generations, such as DDR2, DDR3, and the modern DDR5.
- **Manufacturing Yield / Efficiency:** The percentage of usable, defect-free chips that can be successfully produced from a single silicon wafer. HBM has lower manufacturing efficiency because its complex 3D stacking makes it harder to produce perfectly.
- **Oligopoly:** A market structure where a small number of large companies dominate the entire industry. The article points out that the global memory market is an oligopoly controlled by Samsung, SK Hynix, and Micron.
- **TSV (Through-Silicon Via):** The specific micro-engineering technique used to build HBM. It involves creating vertical microscopic electrical connections straight through the silicon chips, allowing them to be stacked like a skyscraper for shorter, faster data travel.

-Yash Pradhan

AGENTIC SaaS

THE NEXT EVOLUTION OF AI-DRIVEN SOFTWARE

Software has evolved from passive tools to intelligent assistants. With recent advances in artificial intelligence, a new paradigm is emerging: Agentic SaaS, where software systems are capable of planning, reasoning, and executing tasks autonomously. Instead of merely responding to user commands, these systems behave like digital agents that can analyse problems, make decisions, and interact with other software systems. SaaS (Software as a Service) is a cloud based software delivery model where applications are accessesd through theinternet rather than installed locally on a device.



Characteristics:

1. Easily accessible through browser via API
2. Subscription based
3. Managed by the provider itself

WHAT ARE AI AGENTS?

An AI agent is a software system that can perceive information, reason about it, and take actions to achieve a specific goal. Its core capabilities include perception, reasoning, planning, and acting. For example, when a user asks an AI system to "summarize notes and explain concepts in simple language," the agent first gathers the input (perception), processes it using language models (reasoning), plans the required steps, and then generates the final output.

Goal: "Summarize these notes and explain the concepts in simple language."

Step 1: Fetch data

Step 2: Analyse documents

Step 3: Read the topics

Step 4: Generate summary in simple language

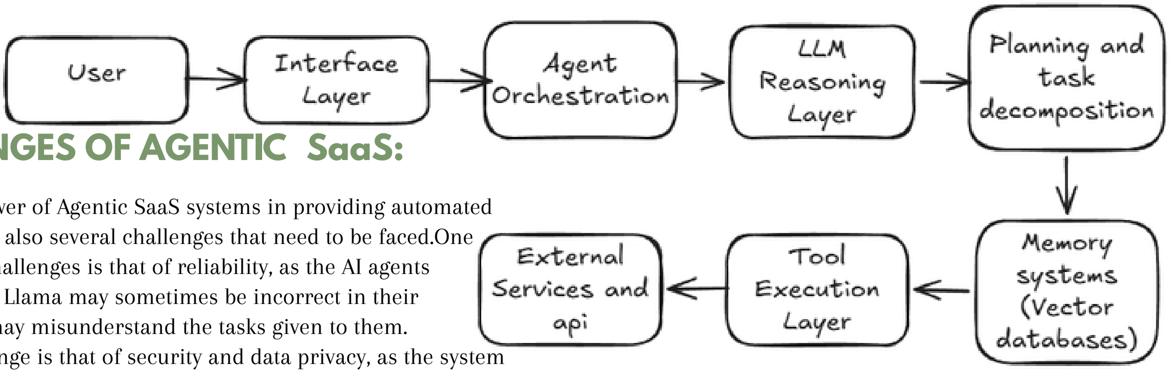
WHAT IS AGENTIC SaaS?

Agentic SaaS is a cloud-based software model in which AI agents autonomously perform tasks and complete defined goals on behalf of users. In this model, software behaves more like a digital employee rather than a passive tool. "Agentic AI systems are emerging as the next stage of software automation." — Microsoft Research, The Era of AI Agents, 2024.

ARCHITECTURE OF AI AGENTIC SaaS:

Agentic SaaS systems integrate cloud software with AI agents that have the ability to plan and execute tasks autonomously. Unlike traditional SaaS, where users have to manually execute each process, agentic SaaS enables users to set a goal while the system executes the workflow. Agentic SaaS architecture is composed of multiple levels. First, there is the interface level, which enables user interaction through APIs or chat. Secondly is the orchestration level, where tools such as LangChain or CrewAI assist with tool execution. Third, there is the reasoning level, where AI agents such as GPT-4 or Llama interpret user goals. Finally, there is task decomposition, where tasks are broken down. Agentic SaaS utilizes memory, including short-term context and long-term memory using vector databases such as Pinecone or Weaviate. There is also a tool execution level, which enables AI agents to interact with external tools such as APIs, databases, or services. There is also collaboration between multiple agents, where multiple agents collaborate to accomplish tasks. All these components run on cloud platforms such as Amazon Web Services or Microsoft Azure, enabling software to autonomously manage complex workflows.

Domain	Top AI-Agent SaaS Apps	Agent Role & Benchmarks
CRM/Sales	Salesforce Agentforce, HubSpot AI	Lead qualification, personalized outreach; 30% faster closes, $36B Salesforce revenue.
Customer Support	Zendesk AI, Intercom Fin, Kore.ai	Autonomous ticket resolution; 80% self-serve rate, saves $1.5M/agent annually.
Productivity	Notion AI, Slack Agentforce	Meeting summaries, task orchestration; 25%-time savings, 50M Notion users.
Marketing	Jasper AI, Klaviyo Agents	Content gen, campaign optimization; 150% engagement lift.
Project Management	Jira Copilot, Linear Agents, Asana Intelligence	Sprint planning, issue triage; 40% faster delivery.
HR/Recruiting	Workday Agents, Beam AI	Resume screening, interview scheduling; 20% churn reduction.
Finance	QuickBooks AI, Xero Agents	Invoice automation, forecasting; 15 hrs/week saved.
DevOps	GitHub Copilot Workspace, Devin	Full app builds from prompts; 55% code boost, 100M devs.
E-commerce	Shopify Magic, BigCommerce Agents	Inventory prediction, recommendations; 20% conversion up.
Education	Canvas AI Agents, Duolingo Agents	Personalized quizzes, grading; 35% retention gain.



CHALLENGES OF AGENTIC SaaS:

Despite the power of Agentic SaaS systems in providing automated tools, there are also several challenges that need to be faced.One of the major challenges is that of reliability, as the AI agents using GPT-4 or Llama may sometimes be incorrect in their responses or may misunderstand the tasks given to them. Another challenge is that of security and data privacy, as the system utilizes several APIs and sources for data. This makes the system vulnerable to data breaches or incorrect actions. Furthermore, there is also the challenge of cost and infrastructure, as the system requires high computational power to run in real-time, which may be possible through cloud platforms such as Amazon Web Services or Microsoft Azure. Finally, there is also the challenge of governance and control, as autonomous agents must be monitored for safe decision-making.

CONCLUSION:

In conclusion, Agentic SaaS represents a significant shift in modern software systems. By combining advanced AI models like GPT-4 and Llama with cloud technology, these systems can plan, reason, and act autonomously. With capabilities such as memory, tool integration, and multi-agent collaboration, they transform software from passive tools into active problem-solving systems. Despite challenges like reliability, security, and governance ongoing, advancements in AI and cloud computing are addressing these issues. As adoption grows, Agentic SaaS is expected to play a key role in shaping future digital products and enterprise workflows.

~Shubham Teredesai

Agent	GAIA L3 Score	Resolution Rate	Specd (Complex Task)	Cost/ Student Tier
Kore.ai	55%	80% tickets	2-3 min	Free marketplace
CrewAI	45%	70% workflows	5 min- (multi-agent)	Free/ open-source
Devin	40% (SWE)	85% code tasks	10 min full app	Edu trial
Gumloop	N/A	75% automa-tions History	1-2 min	Free tier
Action Agent	61%	High reliability	Minutes (business)	Enterprise

GLOSSARY:

- **LangChain: An open-source framework for building applications powered by large language models, especially AI agents that interact with tools and data.**
- **CrewAI: An open-source framework for orchestrating multiple AI agents and automating workflows.**
- **Orchestration Layer: A system that coordinates components such as APIs, data pipelines, and AI models into automated workflows.**
- **Pinecone: A vector database used for storing embeddings and enabling semantic search.**
- **Weaviate: An open-source vector database that supports semantic search by storing both data and vector embeddings.**
- **GAIA: A benchmark for evaluating AI agents on tasks requiring reasoning, tool use, and web interaction, with increasing difficulty across three levels.**
- **Resolution Rate: The percentage of customer issues or support tickets successfully resolved within a given time period.**

THE ECONOMICS OF ARTIFICIAL INTELLIGENCE

UNDERSTANDING THE COST, SCALE, AND PROFITABILITY OF AI

The world's largest technology companies are committing hundreds of billions of dollars to artificial intelligence infrastructure. Yet somehow, anyone with a laptop can access the results for almost nothing. In 2025, companies spent over $300 billion building the data centers, GPUs, networking systems, and power capacity that modern AI demands.
By 2026, Amazon, Alphabet, Meta, and Microsoft alone are expected to spend over $650 billion combined, with Amazon approaching $200 billion and Alphabet somewhere between $175 and $185 billion.
So how does the math ever work? And when does AI actually become profitable?
To answer that, you have to understand the economics of intelligence itself.

WHY AI IS DIFFERENT?

For decades, software followed a simple and beautiful economic logic: build once, sell forever. Traditional software costs almost nothing to reproduce. Once the code exists, serving another million users barely moves the needle.
AI breaks this entirely. Every interaction requires real computation. Every prompt lights up GPUs. Every response burns energy. Traditional SaaS is like a book. Written once and can be printed infinitely. AI is more like electricity. Every time someone flips the switch, power has to be generated. Someone is always paying that bill, and at the scale AI now operates, that bill is enormous.

THREE LAYERS OF COST:

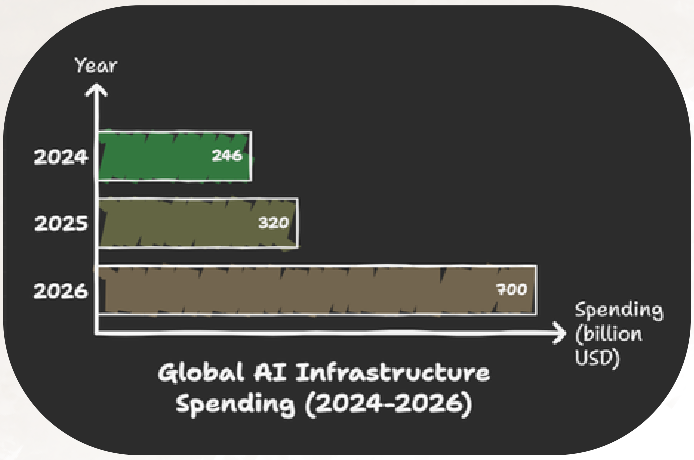
Training is the most visible cost. Building a frontier model requires thousands of GPUs running continuously for weeks, often costing hundreds of millions of dollars. But it is a one-time expense, amortized across every future interaction.
Inference is where the ongoing economics actually live. Every prompt and response costs money. Leading models run roughly $1 to $3 per million input tokens and $5 to $15 per million output tokens, though heavily optimized models have pushed costs far lower at around $0.15 per million input tokens in some cases.
Infrastructure is the foundation beneath both. Global AI infrastructure spending climbed from roughly $246 billion in 2024 to over $320 billion in 2025, and may approach $700 billion by 2026. At that scale, this stops looking like a technology trend and starts resembling the construction of something permanent.

THE UNIT ECONOMICS PROBLEM:

A consumer AI product priced at $20 per month sounds reasonable. However a heavy user generating 10 million tokens monthly on a model priced at $8 per million tokens costs $80 in compute alone. The product loses $60 per user before accounting for a single engineer or server.
The same math on a cheaper model at $0.35 per million tokens brings the compute bill to $3.50. This is why the economics of AI products are inseparable from the cost of the underlying intelligence. Enterprise customers shift the dynamics further: businesses pay more per seat and generate far more predictable usage, making margins easier to manage.

FALLING COST OF INTELLIGENCE:

Inference costs have collapsed at a pace that would look implausible on paper. GPT-4-level capability reportedly fell from roughly $60 per million tokens in 2023 to under $1 today. A decline of nearly 98 percent! Competition, better hardware, and leaner architectures have all contributed. Companies like Mistral and DeepSeek built their identities around strong performance at low cost.
However cheaper intelligence carries a counterintuitive consequence. When something becomes more affordable, people use far more of it. Developers build more applications. Users generate more queries. Total compute demand keeps climbing. This is a dynamic economists call Jevons' paradox. Cheaper tokens have not reduced the infrastructure bill. They have expanded the market.



THE REVENUE REALITY:

AI companies are beginning to generate real revenue. OpenAI ended 2025 with roughly $20 billion in annual recurring revenue, nearly triple the prior year. Anthropic reached an estimated $9 billion revenue run rate in early 2026, up from roughly $1 billion just two years earlier.

Profitability is a different story. OpenAI has projected roughly $74 billion in operating losses for 2028 before reaching sustained profitability. Anthropic expects its burn rate to fall to about one-third of revenue by 2026 and potentially below 10 percent by 2027. OpenAI expects to remain above 50 percent for several more years.

WHY THEY KEEP SPENDING?

None of this has slowed investment. The explanation lies in platform economics. Companies controlling the infrastructure that powers AI can capture value from every application built on top. Cloud computing followed the same arc. Early spending looked irrational; the platforms that survived now generate tens of billions annually.

There is also a simpler logic. For companies whose entire businesses run on software, sitting out the AI transition is not a conservative choice but is an existential one. The current wave of capital is not just a technology race. It is a balance-sheet war.

The cost of intelligence has fallen nearly 98 percent in just a few years. If it falls another tenfold, entirely new categories of software and automation become possible. The companies that win may not be the ones that build the most capable systems. They will be the ones that make intelligence cheap enough to be everywhere.

GLOSSARY:

- **Tokens: The units AI models use to process text, roughly three-quarters of a word on average. Providers charge per million tokens read and generated.**
- **Inference: The computation that occurs each time a model generates a response. Happens billions of times daily and is the primary source of ongoing operating cost.**
- **Marginal Cost: The cost of serving one additional user or query. Traditional software has near-zero marginal cost. AI does not.**
- **Burn Rate: How fast a company spends beyond what it earns. A 50 percent burn rate means spending $1.50 for every $1.00 in revenue.**
- **Jevons' Paradox: When greater efficiency increases total consumption rather than reducing it, because lower costs unlock new uses entirely.**
- **Amortized: Cost A finance term meaning a large one-time cost is spread across many uses or time periods to calculate the effective cost per unit.**

~Dhruv Kajalkar

THE GLOBAL TECHNOLOGY COLD WAR

GEOPOLITICS OF AI

The power to transform the accelerating technologies lies in the hands of western democracies and the autocratic regimes. So, shall we sideline with these powers or strive for autonomic excellence? “Leaders of the U.S. and China understand the importance of technology in their rivalry for global power and dominance. In his first speech to Congress, President Biden stated that America is ‘in competition with China’ to ‘win the 21st Century.’ Many commentaries in China suggest that surpassing the U.S. in high technology would end its era of global leadership, replacing it with China.” – The Brookings Institution, the United States, China, and the contest for the Fourth Industrial Revolution, 2020. The United States and China are involved in a technology cold war with significant geopolitical ramifications in this high-stakes rivalry. The global economy probably impacted by the technology decoupling occurring between the two nations. China unveiled its ten-year strategy, known as "MIC 2025," in 2015 with the intention of dominating the technologically advanced world. This plan included both governmental assistance and aggressive acquisitions of numerous businesses, which might make the task more difficult. In order to address the gap in its current capabilities, China established Government Guidance Funds (GGFs) to promote R&D. It also granted financial flexibility to acquire a number of international enterprises, which were subsequently developed by recruiting people, and it permitted the exchange of foreign expertise through R&D centers abroad. The Military-Civil Fusion plan (MCF), 2014 is another one of their ideas. The main goals of this plan were to make the civilian and military sectors work together smoothly and fix each other's problems. It was also meant to boost economic growth and new technology, because of this they went after technologies like AI, quantum computing, semiconductors, big data, 5G, advanced nuclear and aircraft technology, and semiconductors. However that plan didn't worked out as expected because the military got involved in the civilian sector, funding was redirected, and both legal and illegal ways to take over the technology were found. As an example, money meant to buy German engines for business purposes was instead used to power navy ships and other things.

“The US came up with 2 main strategies to win the cold war over China. The first one was to impose restrictions on China by restricting investments, export controls and tariffs. In 2021, The Commerce Department’s Bureau of Industry and Security (BIS) had issued a series of new China-related Entity List Designations and control reforms to restrict exports to China in the fields of AI, quantum computing, biotechnology and drones. These actions were consistent with US intelligence assessments that have focused on the national security dimensions of certain critical technologies, including AI, the bioeconomy, autonomous systems, quantum computing and semiconductors.” – The Wilmerhale, United States adopts Wide-ranging China restrictions, 2021.

By establishing a law that prohibited businesses worldwide from utilising American software and equipment to create chips made by Huawei or its affiliates, the US placed limits on semiconductor production. This led to Taiwan Semiconductor Manufacturing Corporation (TSMC) emerging as the world's top producer of the most sophisticated chips.

“After the imposition of sanctions on Huawei, Google cut off Huawei from its suite of digital products, which was then followed by other US-based companies such as Qualcomm, Intel, Arm and Microsoft. All of this adversely affected Huawei as its international sales were the lowest in November 2020. Huawei sold off Honor, its budget smartphone brand, attributing the sale to the “tremendous pressure” from the US government.”– Android Authority, The HUAWEI ban explained: A complete timeline and everything you need to know, 2025.

“Weighed down by the sanctions, Huawei’s market share in smartphones fell from 23% in 2020 to 7% in 2021 and revenue fell by 29% YoY to $99.5 billion.” – The Guardian, Sanction-hit Huawei says revenues down 29% this year, 2021.

Increasing the country's manufacturing and research capabilities was part of the second plan. The US passed two significant bills in order to assume this. The $250 billion Innovation and Competition Act was approved by the Senate in June 2021. The measure includes billions of dollars in additional financing for 5G, robotics, quantum computing, and artificial intelligence research and development. The $50 billion in emergency funds for the Commerce Department to increase domestic semiconductor manufacture is the main feature of the plan. The American Competes Act, the House of Representatives’ counterpart to the Senate Bill, was passed in February 2022. In terms of how they would go about establishing a new technology division, this act and the prior bill differed. Nonetheless, they shared the objective of supporting R&D and improving semiconductor production. The Deepseek-R1 model's introduction in 2025 marked the "Sputnik moment" of artificial intelligence. The performance of this model was on par with ChatGPT-4.0 and Claude 3.5 Sonnet, but what was even more impressive was the incredibly low capital investment. Additionally, Deepseek demonstrated that it could outperform US talent through algorithmic creativity and that it didn't require the hardware provided by US-based 2025. China feels that the US is oppressing it in order to deny it its "legitimate right to development." India aims to maintain its strategic autonomy. It has launched a drive for self reliance called “Aatmanirbhar Bharat” under which the AI Summit 2026 which took place in New Delhi, announced the Sarvam AI, a company founded in 2023 which builds LLMs and multimodal AI systems aimed at digital sovereignty and keen curiosity to understand India’s diverse languages and culture. India is not only vying for the best but is also being considerate of its own local nuances, political stances, its history, culture which is at the risk of being expunged by other countries.

GLOSSARY:

- **CrewAI: An open-source framework for orchestrating multiple AI agents and automating workflows.**
- **Orchestration Layer: A system that coordinates components such as APIs, data pipelines, and AI models into automated workflows.**
- **Pinecone: A vector database used for storing embeddings and enabling semantic search.**
- **Weaviate: An open-source vector database that supports semantic search by storing both data and vector embeddings.**
- **GAIA: A benchmark for evaluating AI agents on tasks requiring reasoning, tool use, and web interaction, with increasing difficulty across three levels.**

Krupa Jigalur

STABLE BY DESIGN

The Future Of Digital Money

Imagine a person trying to send $500 to his family in India, only for them to receive just $470, with the remaining $30 being quietly eaten up by fees and the money? Money which won't arrive for the 2-3 days.

Money passes through multiple middlemen, the correspondent bank, the recipient's bank, and currency exchangers, each takes a cut, and that's where the $30 disappears in fees alone, before it even reaches the recipient according to the World Bank data, the remittance fees globally, that is, the average cost of sending money internationally, is around 6% of the money sent.

What if you could just cut the middlemen entirely and send money directly? Well there's a way, through which you can send money directly to anyone in the world, with no banks involved and that's where the concept of cryptocurrency comes to the rescue.

It does not involve any middlemen like banks and payment services, unlike traditional currency exchange.

It is the currency that is a digital money secured by cryptography & exchanged through a computer network, using a distributed ledger called blockchain.

And one of the most famous cryptocurrencies and the very first one to exist is Bitcoin, allowing the modern world to perform bankless payments.

But again, due to its highly volatile nature, Bitcoin turned out to be unreliable and unpredictable. Since Bitcoin's price swings so widely which makes it unrealistic for real-world payments.

If the person tries to send that $500 in Bitcoins, by the time it reaches the recipient, its value could be $350 or $650, nobody knows. Bitcoin's volatility is driven by supply and demand, since cryptocurrency is limited to 21 million coins, affecting its market value as supply nears the limit also, investor actions and media influence impact the volatility.

And therefore, there came a need to bring in cryptocurrency with more consistent value.

And hence the new coin named *Stablecoin* was introduced.

They are type of cryptocurrency designed to maintain a stable value by pegging to fiat currencies, commodities, or financial instruments, aiming to offer a less volatile alternative to Bitcoin, it is pegged to the dollar, meaning 1 stablecoin= $1, always.

To understand Stablecoins in a simpler way, consider them as tokens. You exchange your money for the tokens, and you then use those tokens to buy stuff, and later can even convert those tokens back to real money if required.

Hope this helps you picture and understand Stablecoins more comfortably.

So basically what's happening is, a company issues stablecoins– like Circle issues USDC(U.S. Dollar Coin), Tether issues USDT (U.S. Dollar Tether), you give them real money, and they give you equivalent tokens in exchange, which you use to send, trade, or transact and when you want your real money back, you convert those tokens back through an exchange.

BUT THEN, WHAT IS THE CORE PHILOSOPHICAL DIFFERENCE BETWEEN REGULAR CRYPTO AND STABLECOINS?

See, regular crypto was built to be a new kind of money, attributed as decentralised, independent, with no government control But that freedom came with wild volatility, making it impractical for everyday usability. On the other hand, Stablecoins were built to be a bridge, combining the speed and tech of crypto with the price stability of traditional currency. The simpler way to think about this is, Regular crypto like Bitcoin is more like a stock– its value fluctuates every few seconds whereas, Stablecoin is like a digital cash– its value stays fixed.

UNDERSTANDING TYPES OF STABLECOINS:

- **Fiat-collateralised Stablecoins–**

These are the fiat-backed Stablecoins, holding reserves of currency like the U.S. dollar to secure their value.

Independent custodians keep these reserves, which are also audited regularly .Tether (USDT) and TrueUSD (TUSD), are popular Stablecoins which are backed by U.S. Dollar reserves and denominated at parity to the dollar.

- **Commodity-backed Stablecoins–**

These are linked to commodities like gold or oil They typically hold commodities through third-party custodians or related investments like, commodity-backed token Tether Gold (XAUt) is a cryptocurrency backed by gold reserves

- **Crypto collateralised stablecoins–**

Are backed by other cryptocurrencies
But because the reserve currency may also be prone to high volatility, such stablecoins
are generally overcollateralised

- **Algorithmic Stablecoins–**

These are the ones that may or may not hold reserved assets, in fact their primary distinction is the strategy of keeping stablecoin's value stable by controlling its supply through an algorithm, essentially involving a computer program running a preset formula.

The algorithm automatically increases or decreases supply to maintain the peg,

TerraUST is one of the very famous examples; according to research published by MIT Sloan, it catastrophically failed in 2022, wiping out $40 billion.

FUN FACTS

- Stablecoins were used to send aid to Ukraine during the 2022 war.
- Countries with high inflation like Venezuela and Argentina use stablecoins as an alternative to their own currency.

AT THE HEART OF HOW STABLECOINS WORK IS A TECHNOLOGY CALLED BLOCKCHAIN:

Now, blockchain, it is a type of shared database that differs from a typical database in the way it stores information. It stores data in blocks linked together via cryptography. Thus, securely storing records across a network of computers in a way that is transparent, immutable and resistant to tampering.

All the transactions are grouped into blocks, and each block is chained to the previous one.

A simple analogy to understand it better,
Blockchain is like a Google Doc that multiple people can see simultaneously, but unlike a Google doc nobody can edit or delete what's already been written.

Every entry is then permanent, can be seen by all, and cannot be changed. And no one person controls it, and everybody has a copy of the same dataset. Each block is connected to the previous block, so if someone tries to change or alter the older transaction, they'd have to change every single block after it, across thousands of computers, that too simultaneously, which is virtually close to impossible, and this is what makes it secure and therefore trustworthy. The working of blockchain is also very interesting. When you send stablecoins to someone, that transaction is broadcast to the entire computer network worldwide, and those computers then verify and check the legitimacy, and once verified, it is then grouped with the rest of the transaction into a block, that block then gets a unique code and is then permanently attached to the previous blocks,

When the person sends those $500 in Stablecoins to India, that transaction is verified and recorded on the blockchain permanently, without the involvement and permission of any banks. Now that person, who was trying to send money back to India, through a traditional way, can now prefer the alternative and effective way, of using stablecoins to perform the transaction, allowing him to experience a more efficient and faster experience, also helping him save those $30, and can own all the $500. They are definitely not the perfect solution, as we saw the potential risks and failures that come with it at times, but we cannot deny the fact that, as technology is growing day by day, Stablecoins and blockchain technology in general will certainly improve and become remarkably efficient. And this matters because Stablecoins could very well represent the future of money, faster, borderless and accessible to everyone with internet. For today's digital generation, this isn't just a financial innovation, but a personal one. So, the question is no longer whether digital money will change the world- it already is. The question is whether you'll be ready for it.

~Anushka Jagtap

GLOSSARY:

- **Remittance: refers to sending money from one person or group to another and commonly refers to sending money back to one's family in another country. For instance, someone living and working in the U.S. might send money back to their family, let's say in India, where remittances can account for a significant source of financial support.**
- **Pegging: refers to 1:1 value ratio between stablecoins and a stable reserve assets, typically the US dollar to maintain the price stability, enabling tokens like USDT and USDC to retain a stable value.**
- **Overcollateralisation: a risk management technique where more crypto is locked up as a collateral than the value of stablecoins issued. Serving as a safety buffer against extreme market volatility.**
- **Distributed Ledger: distributed ledger technology is the digital system, for recording, sharing and synchronizing across multiple computers. Ensuring data integrity through cryptographic hashing, thus creating immutable, transparent, and append only records.**

DECENTRALIZATION IN BLOCKCHAIN

FROM THE ARCHITECTURE OF TRUST

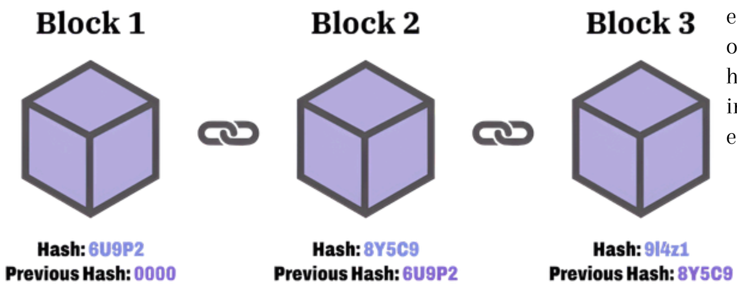
In the modern digital landscape, establishing trust within information storage and management systems is paramount. Traditionally, centralized authorities—such as banks, governments, or corporations—have controlled these systems. The emergence of blockchain technology, however, introduces decentralization as a foundational paradigm shift. Rather than relying on a central entity, blockchain distributes data management across multiple independent participants. This fundamental change in how data is stored and verified positions blockchain as a critical innovation of the 21st century.

At its core, a blockchain is a distributed digital ledger that records transactions across a network of computers. First conceptualized in 1991 to timestamp digital documents, its architecture consists of a chronological series of data blocks. Each block contains transaction data, a unique cryptographic hash identifying it, and the hash of the preceding block. This cryptographic linking creates an immutable chain; altering a single record requires recalculating the hashes for every subsequent block, rendering unauthorized data manipulation computationally prohibitive.

To append new information to the ledger, network participants—known as nodes—must validate the data through a shared consensus mechanism. This distributed validation process is the bedrock of decentralization.

Unlike conventional databases, a blockchain network maintains duplicate copies of the ledger across independent nodes, preventing any single point of control or failure. A network's true degree of decentralization is determined by several factors: the total number of active nodes, their geographical dispersion, resistance to coordinated manipulation, and the equitable distribution of governance tokens.Beyond secure record-keeping, this decentralized infrastructure enables the development of decentralized applications (dApps). By leveraging blockchain technology, dApps offer enhanced security, global accessibility, and operational efficiencies compared to traditional software architectures. Because transactions are recorded on a verifiable public ledger, systemic transparency is guaranteed. Supply chain management serves as a prime example of this utility, allowing stakeholders to trace the provenance and movement of goods with absolute cryptographic certainty.
This chain involves many players, ranging from the manufacturer to the retailer. With blockchain technology, every transaction on the chain can be transparent and unalterable. Decentralized storage technology offers another intriguing application.

Traditional cloud storage necessitates the storage of data on centralized servers, which are susceptible to breaches, downtime, and censorship. However, this technology employs a decentralized architecture, distributing data across diverse nodes in varied forms. Furthermore, the data is encrypted, and only the designated owner possesses the decryption key. .



The technology's advantage lies in its ability to maintain security and efficiency, even if some nodes fail, because the remaining ones are still operational. With this technology being adopted in various fields, blockchain has the chance to revolutionize how people, organizations, and countries interact, eliminating the need for go-betweens while still being able to trust each other.

DO YOU KNOW?

Blockchain Is Everywhere (Even Beyond Crypto)

While blockchain is famous because of Bitcoin, it's also used in:

- Tracking food safety in supply chains
- Securing digital identities
- Voting systems and governance
- Even verifying art ownership through NFTs

GLOSSARY:

- **Hash: It identifies the block and all its contents and is always unique, just like a fingerprint. Changing something inside a block leads to changing the hash as well.**
- **Nodes: A blockchain node is a computer or device participating in a decentralized blockchain network, running specific software to validate, store, and propagate transaction data**

~Veera Patil

MODERN WARFARE AND DEFENCE EQUIPMENTS

FROM MACHINES TO MISSILES: THE ENGINE ROLE IN WAR

Modern warfare is increasingly shaped by technological innovation and engineering advancement. Understanding the working of modern defence systems provides valuable insight into how engineering innovation continues to shape contemporary warfare.

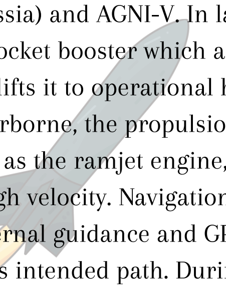
LAND-BASED DEFENCE SYSTEMS

ARTILLERY SYSTEMS (HOWITZERS)

Howitzers are powerful ground based weapons used by modern armies to strike targets over 30km with high accuracy. Their operation is based on internal ballistics. When fired, a firing pin hits the primer, igniting the propellant and producing high pressure gases. These gases push the projectile through the barrel at very high velocity. Rifled grooves inside the barrel spin the shell which stabilises in flight and improves accuracy. To counter back the strong backward force during fire, modern howitzers are equipped with hydraulic recoil systems that absorb and control energy, ensuring safety and stability.

MISSILE SYSTEMS

Missiles are one of the most advanced systems in modern defence technology and warfare. The very famous examples are BRAHMOS (Jointly developed by India and Russia) and AGNI-V. In launch phase, using a rocket booster which accelerates the missile and lifts it to operational high velocity. Once airborne, the propulsion system of missiles such as the ramjet engine, maintains its high velocity. Navigation systems like internal guidance and GPS keep the missile on its intended path. During last phase, it locks the final target using advanced radar and infrared sensors.



AIR WARFARE SYSTEMS

MILITARY DRONES(UAVs)

Advanced military combat drones such as MQ-9B Predator and TAPAS-BH are used in operations to carry precision weapons and strike without getting any casualty harm. The working of these drones heavily rely on control systems and electronics. Various sensors such as gyroscopes andaccelerometers, GPS trackers and satellite communication links are used. A flight computer stabilizes the aircraft with these sensors, GPS allows navigation which helps drones to follow pre-programmed routes and satellite communication links connect them to control stations that are thousand kilometers away. These drones also carry high resolution cameras for surveillance, infrared sensors for night vision and search and rescue operations, and radar systems.

FIGHTER AIRCRAFTS

Aircrafts like the F-22, SU-57 have grabbed all attention due to their outstanding performance. These aircraft integrate with core engineering disciplines for military aviation to focus on high performance and survivability. These machines consists of advanced aerodynamics, lightweight composite structures and are heavily equipped with weapons and electronic warfare. The fundamental principle of fighter jets lies in jet propulsion theory. With its aerodynamic designs air flows fast over the upper surface of wings, pressure above wings decreases which generates high pressure below the wing and pushes aircraft upwards. Its airframe consists of blended wing-body and vortex control which allows the pilot to control the aircraft even at extremely high angles of attack. Unlike other 2D systems, the SU-57's engine canvector thrust in 3D providing superior pitch and roll especially at low speeds. It is designed for sustained supersonic flight which reduces infrared signals and fuel consumption and allows faster combat speed. A modern system fly-by-wire is used instead of mechanical cables, pilot inputs go to a computer-processing command and signals are sent to control surfaces.

These control surfaces include ailerons, elevators and rudders.
This system helps aircraft stabilize even during extreme maneuvers.

NAVAL WARFARE SYSTEM

SUBMARINES

Strategic submarines such as INS Arihant play a critical role in modern naval defence and deterrence. The ability of a submarine to dive and surface is controlled by its ballast tanks. When these tanks are filled with water, the submarine becomes heavier and submerges. Conversely, when compressed air forces water out of the tanks, the vessel becomes more buoyant and rises to the surface. Since light travels poorly underwater, submarines rely on sonar systems to detect other vessels and potential threats. Structurally, submarines are built using extremely strong materials such as high-strength steel or titanium alloys to withstand the immense water pressure encountered at great depths. Submarines control their depth and orientation using control surfaces similar to those found on aircraft. Hydroplanes are mounted on the hull and regulate vertical movement. When angled downward, water flowing over these surfaces forces the submarine to descend, while angling them upward causes the submarine to rise. Propellers in submarines are driven by powerful propulsion systems, primarily categorized into diesel-electric propulsion and nuclear propulsion. In diesel-electric submarines, diesel engines operate near the surface to generate electricity and charge large battery banks. While in nuclear-powered submarines, a nuclear reactor generates heat through nuclear fission. This heat converts water into high-pressure steam, which spins turbines connected to propellers or electric generators.

EMERGING TECHNOLOGIES

Defence engineering continues to evolve with new technologies:

Artificial Intelligence(AI) : Enables autonomous systems, target recognition, and faster decision-making.

Stealth Technology : Reduces detection through advanced design and materials.

Robotics : Enabled unmanned vehicles and combat systems.

Hypersonic weapons : Travel at speeds above Mach 5 with high maneuverability.

Directed energy weapons : Use lasers or microwaves for precise targeting.

CONCLUSION

Modern defence equipment represents remarkable fusion of engineering and technology. As technology continues to evolve, defence systems are becoming advanced and autonomous. Understanding the working mechanism of these systems not only highlights the role of engineering in national security but also emphasizes how innovation and technological advancement shape modern military capabilities and strategic power.

~ Saksham Biraje

DO YOU KNOW?

1) Nuclear submarines produce oxygen from seawater using electrolysis, allowing them to remain underwater for months.

2) One missile can cost more than a fighter jet. Advanced missiles such as Brahmos can cost millions of dollars per unit.

CHALLENGES

Despite the advancements, defence engineering faces certain challenges. These include :

High cost : Development and maintenance of advanced systems is extremely expensive, straining the national budget.

Cybersecurity threats : Systems are vulnerable to hacking and electronic warfare.

Environmental conditions : Harsh terrains and extreme climates affect operation.

Ethical concerns : Use of autonomous weapons raises moral and legal issues.

Rapid technological change : Continuous upgrades are required to stay competitive.

THE PHYSICS OF SPEED

WHY F1 CARS ARE ENGINEERING MONSTERS

FORMULA 1 is known as the highest class of motorsport racing. Every race in F1 is a battle against the laws of physics and not just about powerful engines and fearless drivers. Formula 1, is a home for extraordinary engineering innovations regarding hybrid mechanics and aerodynamics which highly influence and revolutionize the modern Automobile industry. These cars endure very intense environments taking corners at speeds about 100 kilometers an hour with insane aerodynamic downforce, pulling G-Forces nearly 5 times that of gravity with engine revving at nearly 16,000 RPM while the brakes glow red hot at a 1000 degree celsius.

The bodies of F1 cars are forged to dominate the air domain, pushing the limits of aerodynamics engineering. Beneath the sleek bodywork of an F1 car lies a machine engineered to dominate these extreme conditions: hybrid power units producing nearly a thousand horsepower, carbon-fiber structures lighter than aluminum yet stronger than steel In Formula 1, speed is not accidental—it is the result of physics pushed to its absolute limits.

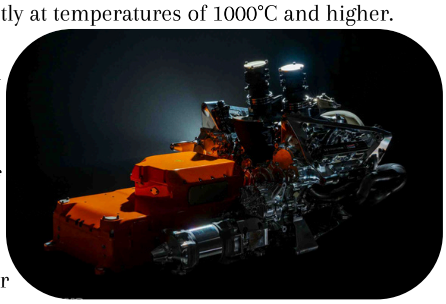
MECHANICS: POWER, PRECISION, AND PERFORMANCE

At the heart of every modern Formula 1 car lies a compact, yet powerful engine plus battery motor system called the power unit. These engines produce close to 1000 horsepower from just a 1.6-litre turbocharged V6 engine, combined with complex energy recovery systems that scavenge every last bit of energy possible. Here's how they do it: During braking, energy that would normally be lost as heat, is captured and stored in batteries, then redeployed to provide additional power on straights.

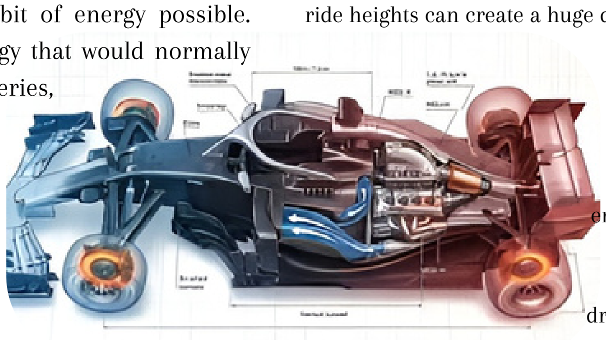
This harmony of internal combustion and electrical energy makes F1 power units among the most efficient high-performance engines ever built. The materials and structures that hold the cars together during these demanding environments are also equally impressive.

The chassis is made of carbon fibre and its composites which provide extraordinary strength while keeping the car extremely light. This lightweight yet rigid structure allows the car to withstand the enormous forces generated during acceleration, braking, and cornering. These materials, drivers often experience forces of up to five times the force of gravity when turning at high speed, making Formula 1 not only a test of engineering but also a demanding physical challenge for those behind the wheel.

Braking is another area where Formula 1 engineering dominates. A F1 car can decelerate from 300 kmph to 100 kmph in a matter of seconds. To withstand the amount of stress generated by doing so, brake discs made of carbon and carbon-composites are used. These materials allow the brakes to operate at ideal performance at insanely high temperatures. In fact, brakes operate more efficiently at temperatures of 1000°C and higher.



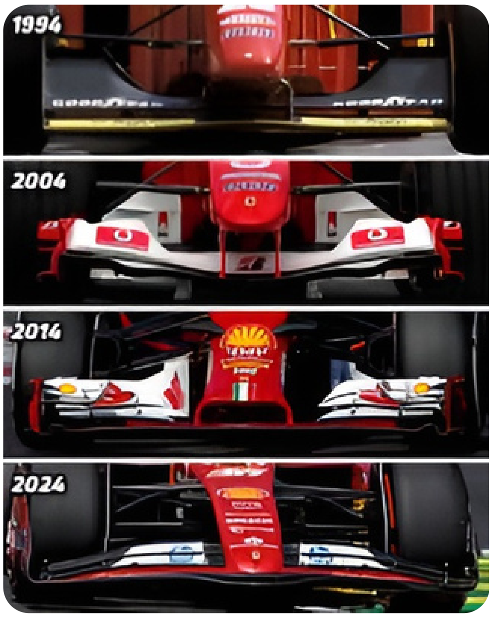
This allows drivers to brake later and harder repetitively than any other motorsport, perfectly suiting the aggressive driving styles of F1 drivers. The extreme heat generated during braking is managed by channeling air through specifically designed ducts around the brake discs along with thousands of holes and vents on the brake discs maintaining aerodynamic balance and efficiency. The suspension and tyre systems that keep the car connected to the track are also quite remarkable. In Formula 1 environments, the differences are so tight that even a change of 1mm in ride heights can create a huge difference.



Hence, F1 Suspension components must operate at incredible accuracy. The tyres themselves are engineered to reward maximum grip, while taking heavy loads. Together, the suspension and tyre systems ensure that the tremendous amount of power and downforce produced by the car can be translated into controlled motion, allowing drivers to push these machines to the absolute limits. These are the mechanics of Formula 1 cars that allow them to be mind blowing. Physics defying machines built at the edge of physical limits.

FROM WINGS TO GROUND EFFECT: THE AERODYNAMIC REVOLUTION IN F1

The aerodynamics has been developed a lot in F1 in shaping the performance and speed of the car. In the beginning, 1950s and early 1960s, Formula 1 was dominated by European teams and drivers, and aerodynamics was largely an afterthought.



Most cars did not have aerodynamic design in mind. However, as the speed increased, teams began to realize the importance of aerodynamics. The introduction of wings and spoilers to gain downforce improved the grip and cornering speed but due to increase in downforce also led to accidents. The idea was to shape the underbody of the car to create a low-pressure area, which make the car sucking to the ground, and increase downforce without adding other drag. However, ground effects were banned due to safety concerns, as they made cars difficult to control in of barge boards, intricate front wings, and rear diffusers starts seeing a rapid revolution in aerodynamic detailing. As F1 moves into the future, aerodynamics will continue to be a major area of research and development.

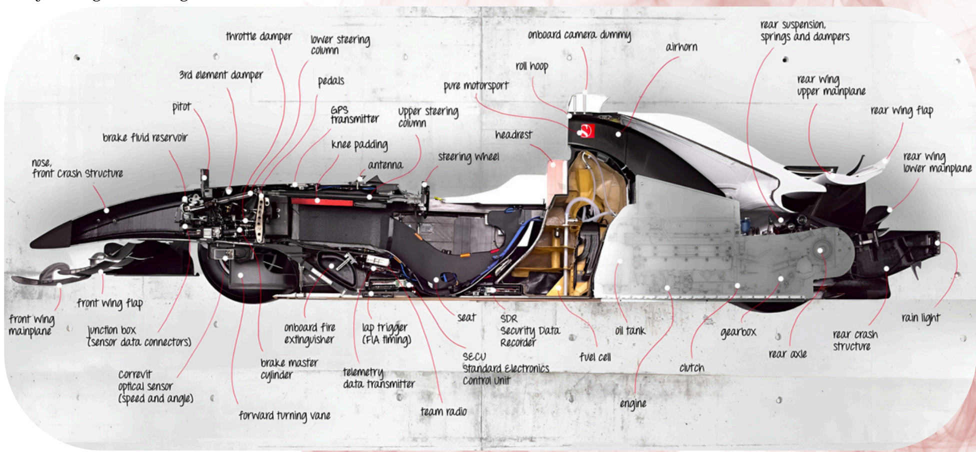
Wings can produce downforce and increase the tires grip on the road better. The wing contributes to about 25-30% of the overall downforce.

As the front wing and the rear wing have to be balanced, due to the stability of the car, which avoids the car suffering corner entry oversteering. Since Colin Chapman brought wings and downforce on F1 cars, resulting 'Team Lotus' becoming three times world champions in the 1960s. However these rare wings failed due to accidents. In 1968 highly mounted rear wings were banned by the Federation International de l'Automobile (FIA).

The ground effect is a kind of aerodynamic phenomenon where the airflow between the car's underbody and the track surface is accelerated, creating an area of low pressure beneath the car. The car is sucked on the track, providing increased traction and allowing for higher cornering speed. This effect also can be called as Venturi effect, which is a result of Bernoulli's principle.

Utilizing the Venturi effect, when a fluid flows through a narrowed region, its speed accelerates while its static pressure drops. A pressure difference exists with higher pressure on top and lower pressure beneath the car. The ground effect began in the 1970s. During the late 1970s and early 1980s, cars utilizing ground effect technology were predominant, especially with Team Lotus under Colin Chapman's leadership paving the way.

The Drag Reduction System (DRS) was introduced to Formula 1 in the 2011 season. The main purpose of DRS was to aid overtaking. In the 2000s, overtaking became very difficult due to the aerodynamic turbulence (dirty air) produced by front cars. The DRS works by adjusting the angle of a moveable flap on the car's rear wing. When activating, it reduces the drag on the car, allowing it to achieve higher straight-line speeds. A multi-element rear wing tested in free-flow conditions saw an 83% decrease in aerodynamic drag. Ground-effect tested multi-element front wings experienced a 70% drop. Combined, these two mechanisms led to a 53% overall reduction in the car's aerodynamic resistance. The front wing of the 2022 model is designed to be more aerodynamically stable, allowing a driver to maintain performance when closely following another car and producing less turbulent airflow. Moreover, the 2022 rear wing has been notably redesigned, featuring curved tips at the top instead of linear endplates and extra components at the bottom. This updated design aims to redirect the aerodynamic wake upwards and over the trailing car, rather than sending it straight into it, addressing the current challenges faced by drivers when following closely behind another vehicle.



For the ground effect, the floor is also redesigned by the racing team. They employ contoured underfloor channels rather than a tiered floor. This change allows the car to produce a large amount of downforce and less disruptive airflow for the car behind at the same time.

They employ contoured underfloor channels rather than a tiered floor. This change allows the car to produce a large amount of downforce and less disruptive airflow for the car behind at the same time.

The front wing's proximity to the ground amplifies the downforce due to ground effects from the wing's shape.

CONCLUSION:

Aerodynamics plays a pivotal role in shaping the sport's evolution. The continuous quest for speed and performance has led teams to push the boundaries of aerodynamic efficiency, leading to some of the most intricate and sophisticated car designs in F1 history. The introduction of technologies like DRS and ground effect principles showcases the sport's adaptability to evolve for better competition and closer racing.

With the increasing influence of sustainable technologies and the push for eco-friendly racing solutions, future aerodynamic developments might also consider factors like energy efficiency and minimal environmental impact.

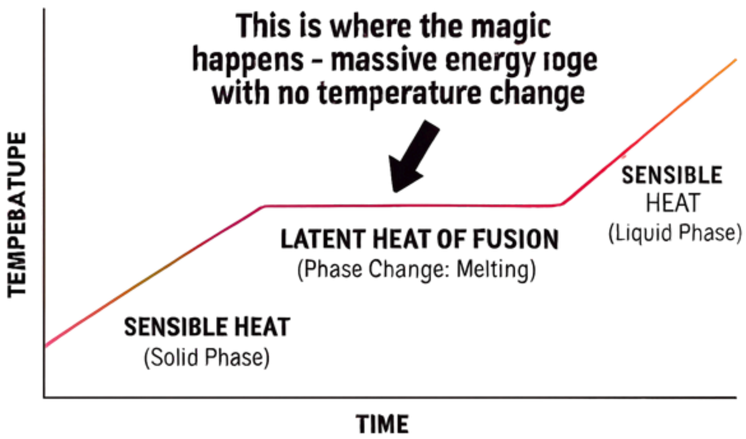
~ Ishan Pagare & Malhar Gupte

PHASE CHANGE MATERIALS

The Shape-Shifting Super Power

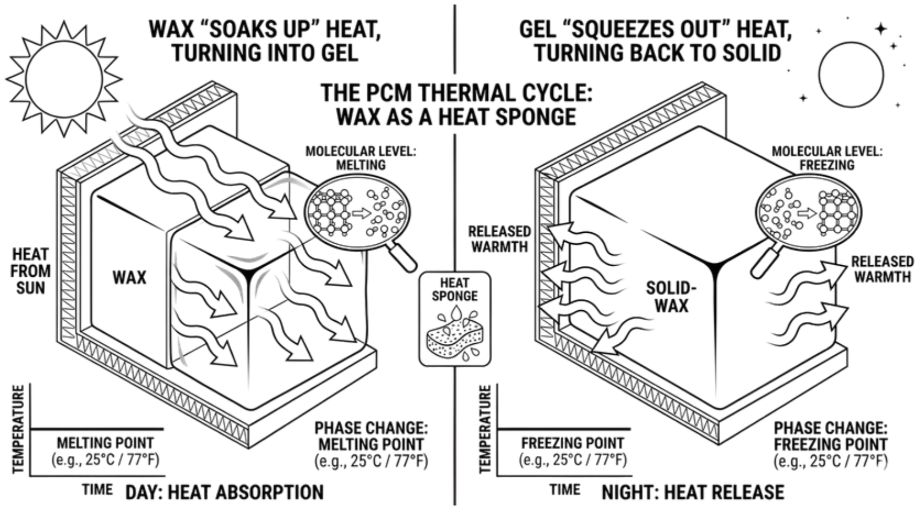
WHY PHASE CHANGE MATERIALS ARE THE FUTURE:

Have you ever wondered why a glass of ice water stays ice-cold until it melts?
Even on a hot day, that water doesn't gradually warm up while the ice is still there. This happens because of a cool scientific trick called latent heat. Scientists are now using this "hidden energy" to create Phase Change Materials (PCMs). They can store massive amounts of heat and even act as high-tech computer memory.



THE SECRET OF "HIDDEN" HEAT:

When you heat something, usually the temperature goes up. This is "sensible heat"—you can feel it. However when a material reaches its melting point, it stops getting hotter. Instead, it soaks up all that energy just to turn from a solid to a liquid. Think of it like a sponge. A PCM "soaks up" heat as it melts and "squeezes" it back out when it freezes. As it does this at a constant temperature, it is the perfect tool for keeping things steady.



KEEPING OUR BUILDINGS (AND LATTES) AT THE PERFECT TEMP:

The most common use for PCMs is in thermal storage. Imagine if your room walls were lined with these materials.

During a hot afternoon:
The walls would absorb the heat from the sun and start to melt internally. Your room stays cool because the wall is "eating" the heat.

During a cold night:
The walls start to solidify. As they turn back into a solid, they release all that stored heat back into the room.

PCMs aren't just for big buildings. They are showing up in our everyday lives in ways we might not realize. Have you ever burned your tongue on a hot coffee, only for it to be lukewarm ten minutes later? New "smart mugs" use a layer of PCM between the stainless-steel walls. When you pour in boiling coffee, the PCM melts, quickly dropping the drink to a perfect 60°C. It then holds it at that exact temperature for hours by slowly releasing hat heat back into the liquid. On a more serious note, PCMs are life-savers in the medical world. Many vaccines must stay between 2°C and 8°C. If they get too warm or importantly—if they freeze, they are ruined.
Specialized PCM shipping containers act like a "thermal lock," ensuring that even if if a truck breaks down in the desert, the medicine inside stays at the perfect temperature for days without needing a plug.

THE DIGITAL TWIST: MEMORY THAT NEVER FORGETS

Now, let's pivot from the "macro" world of heat to the "micro" world of computers. The same concept of changing states is being used to reinvent how we store data. This is called Phase Change Memory (PCM or PCRAM). In a traditional hard drive or USB stick, we store data using electrical charges or magnets. However, these can be slow or wear out over time. PCM uses a microscopic bit of "chalcogenide glass"—the same stuff used in rewritable DVDs.

CHALCOGENIDE

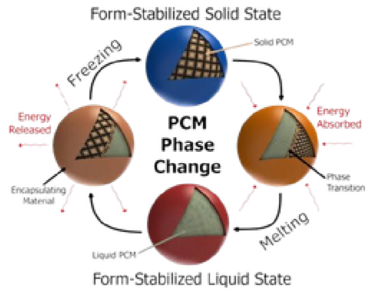
Chalcogenides are inorganic compounds containing at least one chalcogen anion (sulfur, selenium, tellurium, or polonium) and a more electropositive element, such as germanium, arsenic, or a metal

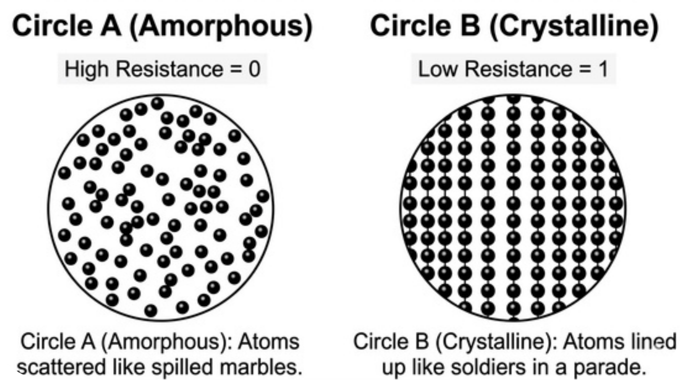
Property	NAND Flash	Phase Change Memory
Write endurance	~10K–100K cycles	~100 million cycles
Write speed	Slow (must erase block first)	Fast (cell-level writes)
Data retention	Can degrade over time	10+ years, no power needed
Scalability	Struggles below 10 nm	Works at smaller nodes

Instead of using heat to warm a room, we use tiny zaps of electricity to change the "state" of this glass:

The Messy State (0): We hit the material with a quick, hot burst of electricity and then cool it instantly. The atoms get stuck in a messy, "amorphous" blob. This blob blocks electricity (high resistance).

The Neat State (1): We heat it up just a little bit for a longer time. This gives the atoms a chance to line up in a neat "crystalline" pattern. This neat pattern lets electricity flow easily (low resistance).





INTEL OPTANE:

Intel's most famous trial with Phase Change Memory was 3D X Point, marketed as Optane. Instead of traditional transistors, Intel used a specialized glass that flipped between messy (amorphous) and neat (crystalline) states to store data.

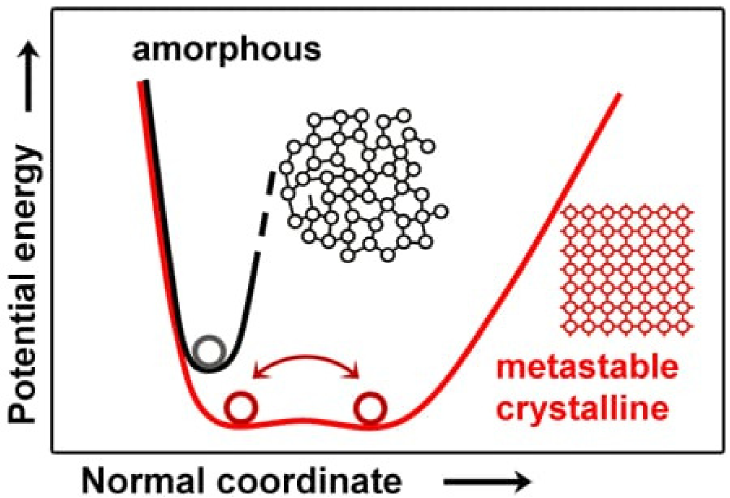
This allowed the memory to be 1000 times faster than standard flash drives while remaining "non-volatile," meaning it didn't forget data when powered off. While Intel eventually halted production due to high manufacturing costs, they proved that PCM could successfully bridge the gap between slow storage and expensive RAM.

CHALLENGES AND THE ROAD AHEAD:

Of course, if this were easy, we are been using it everywhere already. For thermal storage, we have to make sure the PCMs don't leak out of the walls over time or catch fire (some waxes are flammable).

In computing, making these tiny "glass" switches durable enough to be flipped billions of times without breaking is a massive engineering challenge.

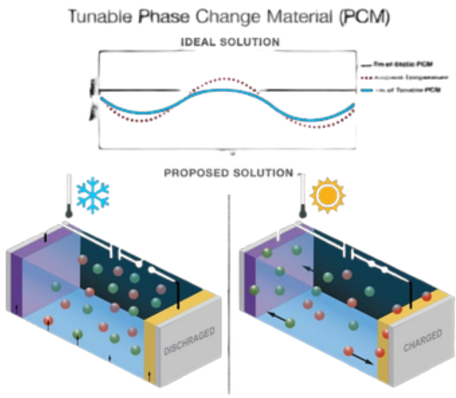
However, the progress is undeniable. Companies are already building giant PCM "batteries" that store solar energy in the form of heat, and high-end servers are beginning to use Phase Change Memory to speed up AI processing.



CONCLUSION: A MATERIAL CHANGE.

As we look for ways to make our world more sustainable and our technology faster, Phase Change Materials offer a beautiful, natural solution. By simply leaning into the way matter changes from solid to liquid, we can solve some of the biggest problems in modern engineering.

The next time you see an ice cube melting in your drink, don't just see a cold beverage. See the future of how we might heat our homes and power our pocket-sized supercomputers. Sometimes, the most revolutionary technology is hidden in the simplest transitions of nature.



~Satyam More

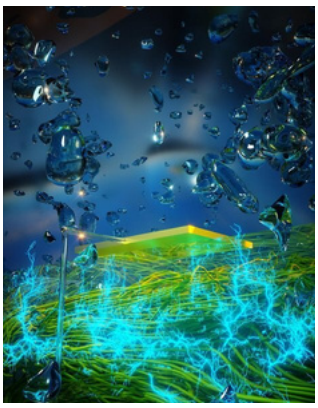
PROTEIN NANOWIRES

THE RISE OF SUSTAINABLE ELECTRONICS

Have you ever imagined tiny bacteria powering up the world around us? Picture it: rod-shaped cells firing out 3-5 nanometer-wide filaments, turning waste into usable power. Recent discoveries state that a special bacteria called Geobacter sulfurreducens produces long, tiny filaments made up of PilA proteins called Protein Nanowires. Protein nanowires are a green, biodegradable and a sustainable alternative to the conventional ones made from metal. These are self-assembled from the bacteria and easily produced at room temperature with minimal energy.

BUGS THAT "BREATHE" METAL:

In 1987, microbiologist Derek Lovely discovered the first Geobacter species, Geobacter metallireducens in the Potomac River. During this time, he found this unknown species of soil bacteria that breathes iron (Fe(III)) instead of oxygen. These bacteria break down organic waste from wastewater to release electrons. To allow these electrons to flow across the bacterial communities, it assembles a special protein known as PilA protein using a natural hair-making mechanism called type IV pili. The thin conductive thread-like structure is formed outside the bacterial cell in this process. As a result, waste material is converted into clean and green energy. In 2005, this work by Lovely and his team was published in the international scientific journal Nature, which confirmed that certain bacteria produce tiny green microbial nanowires that behave like natural electrical wires. The discovery helped scientists solve a long-standing mystery about how microorganisms participate in elemental cycles and opened new possibilities for developing more such sustainable technologies. Meanwhile, it gave a larger solution to current environmental problems, such as waste disposal and the growing challenge of electronic waste.



The nanowires formed contain sugar-binding domains that allow bacteria to move and assemble them into conductive nanowire structures. Through this organized arrangement, electrons are able to flow efficiently at tiny distances.

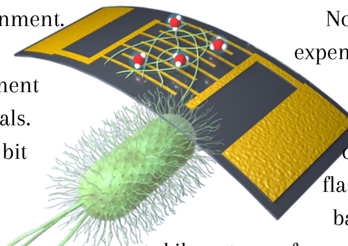
PILI POWER: GEOBACTER'S ELECTRON PUSH

Earlier, scientists believed that the pili themselves were the main functional structures responsible for carrying electrons. However, Nikhil Malvankar and his research group at Yale University discovered that the process is slightly different. The pili act more like a structural support that helps release special protein filaments called cytochromes, mainly formed of proteins such as OmeS and OmeZ, which play an important role in electron transfer.

METAL VS MICROBE:

Contrary to the protein wires, the conventional wires are made up of metals like thin gold, silver or copper. They demand large scale mining, sky-high temperatures and toxic chemicals.

The metal ones don't just burn through resources to make; they pile up as hazardous e-waste, poisoning soil and water for decades. While the Geobacter are a real game-changer. It builds these nanowires using just proteins, all in a lab environment. No need for or expensive equipment exotic materials. With a little bit of food, a cozy flask, and the. bacteria, you get kilometers of conductive threads, all at room temperature, and for a fraction of the cost.

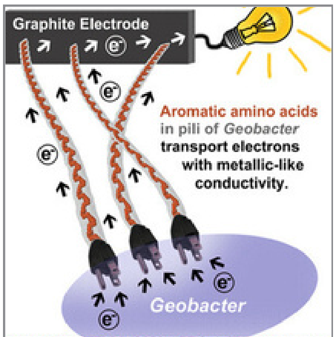


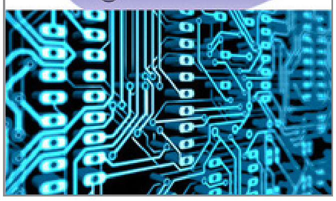
NATURE'S BLUEPRINT FOR TOMORROW:

From a curious discovery in bacteria to a growing field of bioelectronics, protein nanowires show how nature can inspire new ways of thinking about technology. The work of Lovley, along with researchers like Malvankar, has shown that microorganisms can produce tiny conductive structures that can compete with man-made nanomaterials. Although research is still evolving, the potential is clear. Nature holds more such discoveries empowering sustainable and technologically rich future.

WASTE TO WATTS: REAL TECH MAGIC

What once sounded like science fiction is slowly turning into reality. Researchers have shown that lab-grown Geobacter fuel cells can convert wastewater into usable electricity, enough to power small off-grid sensors turning waste into energy. In medicine, these biological wires are opening new possibilities for wearable health technology. Scientists are developing sensors, thinner than a strand of hair. That can monitor glucose, pH or lactate directly from sweat and move naturally with the body providing accurate readings and promising painless monitoring. This just doesn't stop here, at Boston University researchers created "Air-gen" devices that use protein nanowire films to capture electricity from moisture in the air. Even small amounts of humidity can generate a continuous voltage capable of powering tiny electronics. Similarly Indian Institute of Science (IISc) researchers developed an "air battery" that powers small LEDs but adapted locally. Such systems are even being explored by NASA for sensors on future space missions. Protein nanowires are helping clean the environment too, microbial systems have successfully removed uranium from contaminated groundwater.





GLOSSARY:

- **OmcS/OmcZ: Cytochrome proteins forming alternative nanowires.**

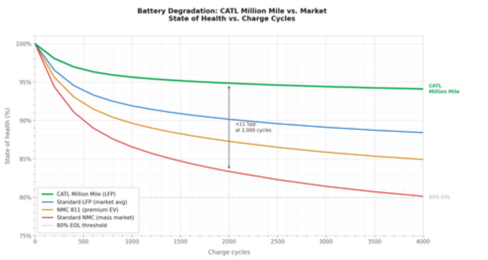
~Shrushti Matkar

CATL'S MILLION MILE BATTERY: FIRST IN THE WORLD TECHNOLOGY

THE MILLION MILE BATTERY

The "Million Mile Battery" has long been a staple of EV skeptics' arguments. It was often viewed as a theoretical milestone that seemed perpetually out of reach for commercial vehicles. However, Contemporary Amperex Technology Co. Limited (CATL) recently shifted the goalposts with the release of their 5C rated (LFP) Lithium Iron Phosphate ($LiFePO_4$) pack. This is not just an incremental update; it is a fundamental challenge to the disposable nature of current automotive energy storage.

THE PHYSICS OF DEGRADATION VS. 3,000 CYCLES:



Most of us view lithium ion cells as chemical consumables. Standard NMC (Nickel Manganese Cobalt) chemistries typically begin significant capacity fade after 800 to 1,200 full cycles. CATL's new LFP architecture is rated for 3,000 cycles while maintaining an 80% State of Health (SOH) threshold. When paired with a 600 km nominal range, the math yields a service life exceeding 1.8 million kilometers. To put that in perspective, even for the most hardworking taxi drivers the average internal combustion engine (ICE) powertrain is mechanically tired by 2.5 to 3 Lakh kilometers. We are looking at a battery that will likely outlive the vehicle's suspension and interior trim.

OVERCOMING THE 5C THERMAL CEILING:

CATL addressed the technical challenges of 5C charging, which typically causes lithium plating and dendrite formation, by using advanced interphase engineering. They introduced a proprietary electrolyte with specific additives that stabilize the Solid Electrolyte Interphase (SEI) layer by re-passivating microscopic fractures caused by anode expansion in real time. This stability prevents the electrolyte from reacting with active lithium, effectively halting capacity loss and allowing for a full charge in approximately 12 minutes.

TECHNICAL SPECIFICATION SHEET:

Attribute	Specification
Chemistry	Lithium Iron Phosphate (LFP)
Rated Cycle Life	3,000 cycles
Nominal Vehicle Life	Exceeds 18 lakh kilometers
Max Charging Rate	5C
Core Innovation	Advanced interphase

THERMAL MANAGEMENT AND SAFETY REDUNDANCY:

Managing a 5C charge requires more than just a standard cooling loop. It requires a sophisticated thermodynamic model. CATL's Battery Management System (BMS) utilizes an AI driven polarization model to monitor internal resistance at a granular level. Instead of uniform cooling, the system identifies localized hotspots where internal impedance is highest and concentrates thermal regulation there. Furthermore, they have implemented a temperature responsive coating on the separator. If local temperatures exceed safety thresholds, the coating increases its resistance to ion flow. This creates a self limiting mechanical brake on the chemical reaction to prevent thermal runaway. It is a piece of tech that prioritizes safety alongside raw performance.

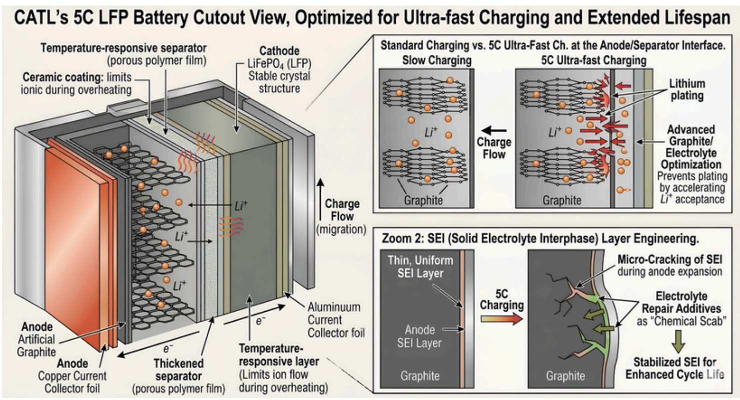
A SHIFT IN LIFECYCLE PHILOSOPHY:

For us engineering students, this technology represents a pivot in how we design for sustainability. If the battery becomes a permanent asset rather than a consumable, the entire secondary market for EVs changes. The battery health anxiety that currently suppresses used EV prices evaporates if the power unit is the most durable part of the car.

We are not just building faster chargers; we are building machines intended to last for decades. This technology is really top notch in terms of bridging the gap between research and real world utility.

DO YOU KNOW?

CATL produces 200,000 cells daily with 1-in-billion failure rate!!



GLOSSARY:

- **Intercalate: Insert (something) between layers in a crystal lattice, geological formation, or other structure**
- **Dendrites: A crystal or crystalline mass with a branching treelike structure.**
- **Passivates: Make (a metal or other substance) unreactive by altering the surface layer or coating the surface with a thin inert layer.**

Rutuparna Purandare

BEYOND BEAKERS

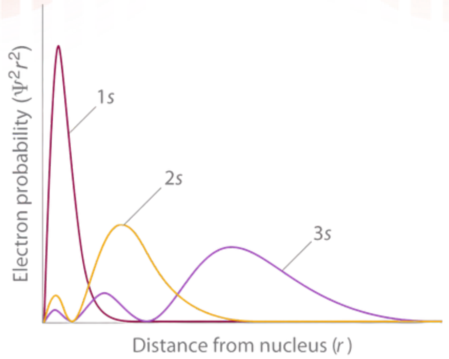
HOW THE QUANTUM REVOLUTION AFFECTS MODERN DRUG DESIGN

Every life-saving drug begins its journey not in a beaker or test tube, but in the invisible, chaotic dance of sub-atomic particles, choreographed by quantum mechanics.

During the late 1890s and early 1900s, Newtonian physics and Maxwell's equations started to give absurd predictions. Classical physics predicted an oven to give infinite energy! This was the infamous ultraviolet catastrophe. In a desperate attempt to understand these inconsistencies, scientists like Albert Einstein, Max Planck, Erwin Schrödinger, Niels Bohr and Werner Heisenberg came up with, what we famously know as, quantum physics. "What we observe is not nature itself, but nature exposed to our method of questioning", Werner Heisenberg once observed, a principle that shaped how we see the quantum world.

To understand quantum mechanics simply, we need to know its 4 pillars:

1. Wave-particle duality states that particles like electrons do not follow classical mechanics. They exist as waves as well as particles simultaneously.
2. Quantization states that energy is not continuous, as it was considered by classical physics. In fact, it is quantized, i.e., it exists in packets called quanta.
3. The uncertainty principle tells us that it is impossible to know both a quantum particle's exact position and its exact momentum simultaneously. Increasing the accuracy of measurement of one of these parameters results in equivalent inaccuracy in the measurement of the other. This is not a measurement flaw, but a fundamental property of the universe. It tells us that nature in itself is inherently probabilistic and not deterministic.
4. The wave function and wave equations of a particle describes its matter waves, which is a mathematical description of the characteristics of a particle. These matter waves are often misunderstood. They are waves of probability and do not represent a physical quantity. In fact they aren't made up of matter at all! However, the square of the magnitude of the amplitude of these matter waves gives us the probability density of a particle, which is an extremely important property.

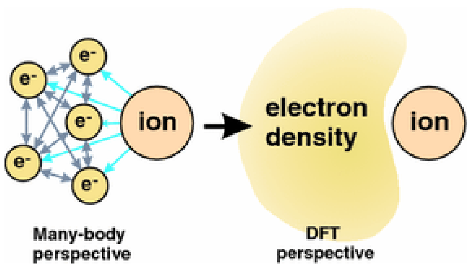


Since these probability densities define where an electron 'is', they also tell us how it attaches and repels with other electrons. Consequently, at its core, chemistry is the movement of quantum particles and their interactions with each other.

Classical physics fails to give accurate observations and results at such a microscopic level. This is where quantum physics is necessary. Quantum chemistry is the study of quantum physics with regard to chemical compounds and their properties.

Quantum chemistry uses wave-particle duality, wave equations, quantization theory and uncertainty principle to explain phenomena like reaction energies, chemical bonding, molecular orbitals, etc. An essential application of quantum chemistry is the design of medicinal drugs.

A medicinal drug is a biochemical compound that induces biological effects in the body upon being consumed. It is generally used to treat a disease. Biologically, a drug is a molecule that binds to its target receptor (present in cells) or to enzymes to control reactions between biochemical compounds in the body.



In the case of receptors, the drug flows through the blood stream and binds to its target cell's receptors and triggers a chain reaction (signal transduction cascade).

This tiny quantum effect leads to a huge biological impact on the human body. As for enzymes, drugs are generally used to block the enzyme's actions. They bind to the drug's action site (the site that actively participates in reactions) and stops the enzyme from doing its job. For example, aspirin blocks the active site of the COX-2 enzyme, the enzyme that triggers pain and inflammation, and thus reduces discomfort.

When there are too many particles while designing a drug, it becomes extremely difficult to calculate the wave equations for them. Also called the 'many-body problem', it is the biggest challenge currently for quantum chemistry. This is where the computational workhorse for drug design comes into picture—Density Functional Theory (DFT). Instead of calculating individual probability densities of the electrons, it calculates total electron density of the system. Using this density map, scientists can predict how the designed drug molecule interacts with other chemical compounds.

Although DFT is a great tool for computing problems as tough as the many-body problem, it still has limitations that only an extremely powerful machine can solve. And the closest we are to such a machine, are quantum computers. We have the equations to create life-saving drugs, but classical computers and approximations like DFT struggle to simulate simultaneous interactions between a higher number of electrons. Also, the required computational power sometimes grows to such an extent that even the most powerful classical computers available would take millions of years to simulate a single drug-binding reaction!

Quantum computing is a technology that is based upon the rules of quantum physics to solve problems that classical computers cannot. It uses phenomena such as entanglement and superposition to process a heavy amount of data and calculations at a time. While classical computers use bits—0s or 1s—for its functions, quantum computers use 'qubits'—0s, 1s, or both at the same time (superposition). This superposition state or multi-dimensional state allows simultaneous calculations.

While quantum physics sets the rules, quantum chemistry tells us the 'how' for drug design. However the most significant shift for it is quantum computing. While DFT acts as a bridge, the future of medicine lies in the hands of quantum computing. As Richard Feynman, the godfather of quantum computing, once said, "Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical."

This convergence of theoretical sciences and technology marks a new chapter in which we no longer guess at a cure, but use nature's language to find it.

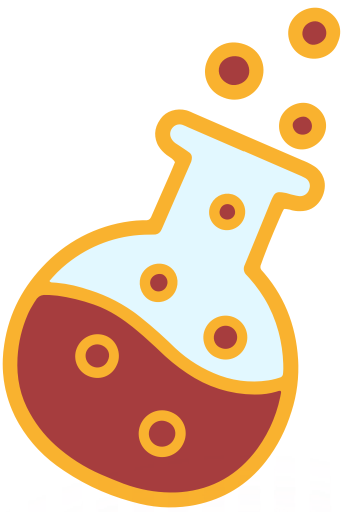
GLOSSARY:

- **Sub-atomic particles: Fundamental constituents of matter, such as electrons and protons, that exist at a smaller scale than atoms.**
- **Reaction energies: The net change in the internal energy of a system during a chemical reaction**
- **Chemical bonding: Attraction between atoms or molecules that ensure formation of chemical compounds by sharing or transfer of electrons.**
- **Molecular orbital: Mathematical areas in space where electrons are possibly to be found. They are formed when multiple electron waves of atoms overlap each other.**

FUN FACT!!

Erwin Schrodinger's famous 'Cat in a box' experiment was created to oppose the absurdity of quantum physics, not support it.

~Dheer Nadkar



PIONEER OF INDIAN PRIVATE SPACE

AGNIKUL COSMOS

ABSTRACT:

Many private space organizations are emerging on the global stage to compete with big names like 'SpaceX' and 'Blue Origin.' Many startups across the world are entering the space industry, but the company that has attracted significant attention is Agnikul Cosmos, which is rising rapidly, demonstrating India's growing capabilities in the private sector. Agnikul is a Chennai-based advanced spacetech startup. It was founded in 2017 by IIT Madras alumni Srinath Ravichandran and Moin S.P.M. It is redefining the small satellite launches with its advanced technologies like revolutionary 3-D printed Agnilet engines and customizable Agniban. Eyeing space-based AI data centers, handles clients like ISRO partnership, and their rivals Skyroot, Pixxel, to make space available for orbital access amid India's private space blast.

INTRODUCTION:

The global space industry has entered a new era driven by innovation and private investment, and rapid technological advancement, with AI giving it a boost. Over the past few years, private space organizations have dominated the space industry through their revolutionary technologies. Inspired by this, many startups are producing groundbreaking space exploration with their advanced mechanical design and structure. Agnikul is a startup by IIT Madras alumni Srinath Ravichandran and Moin SPM. Their innovations are supported by sophisticated mechanical design, efficient propulsion systems, and improved structural engineering, enabling them to have more cost-efficient and cost-effective access to space with the development of technologies such as 3-D printed rocket engines and customizable launch systems. The startup is bringing the new wave of engineering innovation to the privately dominated space sector. This article explores this wave of engineering and the objective and impact of Agnikul Cosmos.

THE BIG RACE TO SPACE:

At first, space exploration was a national mission in the early to late 20th century, but by the start of the 21st century, it was being dominated by private companies like SpaceX and Blue Origin.

Private companies dominate in space exploration, and many impossible missions have been achieved. Today, many startups are working to make space more accessible for scientific, commercial, and technological missions.

THE BIG START:

Their purpose is to manufacture 3-D printed rocket engine, boost the launch frequency of the Agnibaan rocket, and develop reusable launch technologies. Their slogan is 'Launch anywhere, anytime, affordably.' Getting to space shouldn't be the hardest part of working, living, and thriving in space. Agnikul was founded on 1st December, 2017. Since then, they have been growing their startup on the global stage, being in competition with Pixxel, Skyroot Aerospace , and

SpaceX. IIT Madras incubated startups like Agnikul the journey from campus labs to Sriharikota launchpads shows engineering students can compete with SpaceX.

FUNDING OF THE STARTUP:

Agnikul has entered this race with raised funding of 150 crores (17 million) in a fresh funding round at a $500 million valuation.

The round saw participation from family offices and marquee institutional investors such as Advenza Global Limited, Atharva Green Ecotech LLP, HDFC Bank, Artha Select Fund, and Prathithi Ventures.

Funding Amount: $17 million (approx. ₹150 crore).

Valuation: ~$500 million.

ENGINEERING IN 'AGNIKUL COSMOS :

Agnikul Cosmos's propulsion system shows a shift from traditional subtractive manufacturing to advanced additive manufacturing, which is also called monolithic design.

The company's focus is on streamlining production, increasing reliability, and reducing costs for small-satellite launches. The "Agnilet" engine is the world's first fully 3D printed (specifically laser powder bed fusion) rocket engine that helps in getting rid of welding and joints, which are common issues that lead to failure of missions. Thereby increasing structural integrity and reduces assembly time by over 60%. It is made up of a nickel-chromium-based superalloy known for its high tensile strength at extreme temperatures up to 3000°C+. It is capable of withstanding extremely high combustion temperatures and pressure in the combustion chamber without the need for traditional welds or fasteners.

Beyond engines, Agnikul uses a variety of advanced composites and alloys for the Agnibaan SOrTD rocket structure. Nose, cones, and fins are entirely made from carbon composite for aerodynamic protection and passive flight control.

Propellant tanks: The liquid oxygen (LOX) and Aviation Turbine Fuel (ATF) tanks are non-insulated aluminum tanks.

Intertank Structure: Uses aluminum stiffeners with carbon composite cover panels to connect fuel and oxidizer stages.

Pressure Vessels: Employs Composite-Overwrapped Pressure Vessels (COPV) to hold high-pressure helium and nitrogen for system operation.

Overall, the design and mechanical engineering are crucial for each and every mission. With the advancement of engineering, Agnikul is taking a leap in the space industry.

AGNIBAAN SORTED: INDIA'S FIRST PRIVATE LAUNCH:

They have successfully conducted their first mission with the Agnibaan SOrTeD sub-orbital test flight on May 30, 2024. The world's first rocket with a single-piece 3D-printed engine.

It was launched from Shriharikota at 7:15 AM on the 30th of May, 2024. This milestone has been achieved entirely through indigenous design and development. SOrTeD (Sub-Orbital Technology Demonstrator) is also remarkable for being launched from India's first private launch pad, also known as 'Dhanush,' established by Agnikul. It is also India's first semi-cryogenic engine-powered rocket launch. The key purpose of this mission was to serve as a test flight and signify the homegrown aerospace innovation and ensure maximum functioning of systems for Agnikul's orbital launch vehicle, the 'Agnibaan.' The launch was witnessed by various scientists and dignitaries, including Dr. S. Somnath, ex-chairman of ISRO; Dr. Pawan Goenka, chairman of IN-SPACe; and Shri A. Raj Rajan, director of SHAR. Highlighting the significance of this historical milestone, Prof. V. Kamakoti, Director of IIT Madras, said, "Sky is no longer the limit for our startups. Very innovative, the first time in the world, deep core technology was demonstrated today by Agnikul—a great inspiration for all young students to boldly take the entrepreneurship route and become employers.

HEADING TOWARDS THE FUTURE:

We are heading towards AI, and AI applications, cloud computing, and traditional data centers are facing major problems like increased temperature, massive power shortages, land scarcity, and rising costs. Traditional data centers require immense amounts of power and cooling systems, making it difficult to find suitable conditional land locations. Companies such as SpaceX, Google, and Axiom Space are finding new paths to deploy data centers in space.

Agnikul is aiming to launch a prototype AI data center in orbit by the end of 2026, with commercial rollout targeted for 2027. The project is being developed with NeevCloud. It will use satellite constellations and solar power in low Earth orbit. The data centers will be primarily used for AI inference, where a trained model analyzes new data and makes predictions, which requires significantly less energy and infrastructure compared to model training. The AI data centers are being developed in the Bengaluru-based NeevCloud; it is an AI supercloud platform. Founder Ravichandran says, "Space offers nearly unlimited solar energy and highly efficient cooling due to extreme cold temperatures." He also noted that orbital data centers would be physically safer and harder to access, enhancing data confidentiality. The system will not operate as a single satellite; instead, it will be a constellation of satellites in low Earth orbit. The satellite will use a radiative cooling system to reduce temperatures, a process in which heat is lost through thermal radiation. Although the prototype launch by the end of 2026 will not immediately commercialize the data center, Ravichandran said it will demonstrate the company's capability to build AI infrastructure in space. In February 2026, Agnikul fired the clustered Agnilet engine, which is critical for upcoming orbital launches.

CONCLUSION:

Agnikul Cosmos makes us realize that India's private space evolved from transporting the rocket engines on bicycles to developing the world's 1st 3D-printed rocket engines and orbital AI infrastructure. Agnikul is proving that space is open to enthusiasm and passionate people. Agnikul proves that engineering students can compete with the big sharks like SpaceX and Blue Origin and democratize space access.

GLOSSARY:

- **Semi-cryogenic: rocket engines that use liquid oxygen as an oxidizer and refined kerosene.**
- **Monolithic design: formed from a single piece.**
- **Alloys: materials that are mixtures of two or more materials.**

-Abhijit Choudhari

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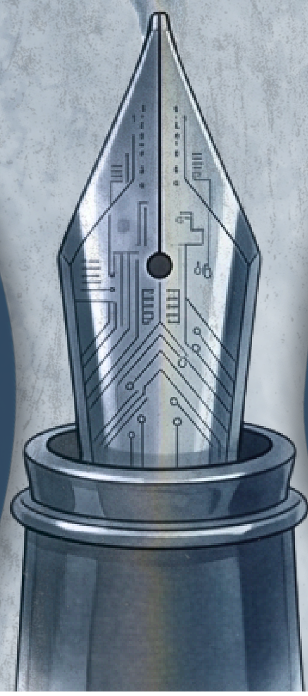

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