Starman' just zipped past Mars in his rapidly-decaying Tesla Roadster

Asiya Salim Pendhari
TY Mechanical

Starman — the dummy riding a cherry-red Tesla Roadster through space — has made his closest approach ever to Mars.

That electric convertible with its mannequin passenger bolted to the top of a Falcon Heavy rocket as a stunt during the SpaceX rocket's first test launch Feb, 6, 2018. (It's common for test launches to include heavy payloads, but they're usually more boring than cherry-red sportscars.) Two years later, the Falcon Heavy upper stage and the vehicle at its tip are making their second trip around the sun. Jonathan McDowell, a Harvard astrophysicist who tracks space objects as a side project, found that Starman passed 4.6 million miles (7.4 million kilometers) from Mars at 2:25 a.m. EDT Oct. 7. That's about 19 times the distance from Earth to the moon, and 35 times closer than anyone on Earth has gotten to Mars.

No one can see the Falcon Heavy upper stage at its current distance. And the strange, beautiful images it once beamed home to Earth have long since ceased. But orbits over periods of a few years are fairly straightforward to predict, and McDowell used data about how the rocket was moving when it left Earth's gravity behind to pinpoint its recent movements.

The Roadster-bearing rocket stage is on an asymmetrical orbital course that takes it as far as 1.66 times Earth's distance from the sun at one end of its trek — out beyond the orbit of Mars — and then back within Earth's orbit at the other end, 0.99 times Earth's distance from the sun

Last time Starman circled the sun, McDowell said, it crossed Mars' orbit while the Red Planet was quite far away. But this time the crossing lined up with a fairly close approach — though still not close enough to feel a strong tug of Martian gravity.

Astonishing AI restoration brings Apollo moon landing films up to speed

Shraddha Sanjay Mahadik
TY Mechanical

Astronauts on NASA's Apollo missions to the moon captured astounding movies of the lunar surface, but recent enhancements with artificial intelligence (AI) have really made the films out of this world.

In remastered movies shared online by byDutchSteamMachine, a YouTube channel run by a film restoration specialist in the Netherlands, details from lunar scenes are astonishingly crisp and vivid; from mission commander Neil Armstrong's first steps on the moon in 1969 to bumpy lunar rover drives during Apollo 15 and 16 in 1971 and 1972, respectively.

The film restorer behind DutchSteamMachine, who also goes by "Niels," used AI to stabilize shaky footage and generate new frames in NASA moon landing films; increasing the frame rate (the number of frames that play per second) smoothed the motion and made it look more like movement in high-definition (HD) video.

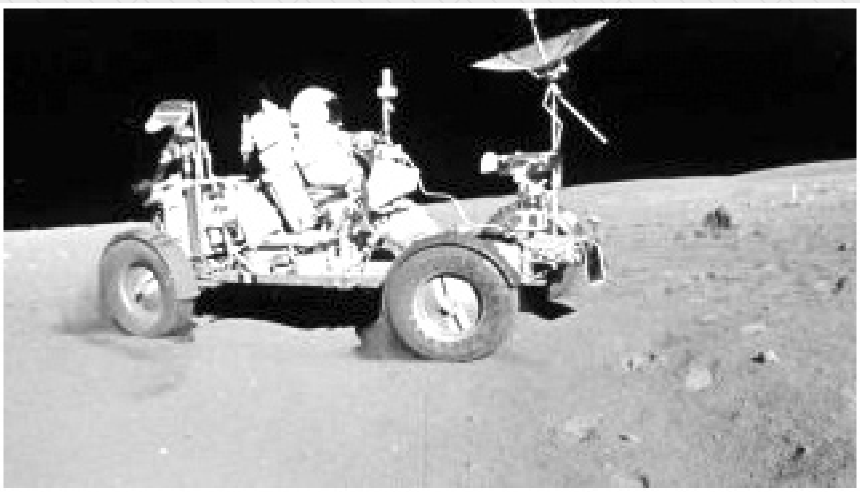
The Apollo program launched 11 lunar spaceflight missions between 1968 and 1972; of those, four missions tested equipment and six landed on the moon, allowing 12 men to walk, drive and/or leap over the dusty, cratered lunar surface, according to NASA. During all of those missions, astronauts captured details of orbits, activities or experiments using 16-millimeter motion picture cameras that were usually advancing the film at 1, 6, or 12 frames per second, or fps — the film industry's standard rate is 24 fps, and HD video cameras shoot 30 or 60 fps.

When old films shot at a lower frame rate are displayed at higher rates, the motion appears sped-up and jittery, "which creates a disconnect between the past and the person watching it," Niels told Live Science in an email.

"I use an open-source artificial intelligence that has been 'trained' with example footage to generate entirely new frames between real ones," Niels said. "It analyzes the difference between real frames, what changed, and is able to 'interpolate' what kind of data would be there if it was shot at a higher frame rate." The AI is called Depth-Aware video frame INterpolation (DAIN), and is a free, downloadable app for Windows that is "currently in alpha and development," according to DAIN's website.

Experts have been remastering old films for decades, but the recent addition of AI has taken results to a new level, Niels said.

"Most remastering/enhancing of old footage has been the removal of dirt and scratches, stabilizing shaky camera



work, sometimes even adding color. But never generating entirely new frames based on data from two consecutive real frames," he explained.

One of the biggest challenges of creating these restorations is finding high-quality source footage; grit, particles and excessive graininess in the film can confuse the algorithm and interfere with AI's interpolation process, Niels said. NASA footage is especially rewarding for AI upgrades because the original frame rate is so low — 6 to 12 fps — that upping it to 24, 50 or 60 fps makes a very dramatic difference. And because movement in the films is so slow, the algorithm can generate more interpolating frames without digital artifacts.

Niels hopes that his videos will bring the moonwalks just a little bit closer to Earthbound viewers, and help them to see and appreciate these landmark events as the astronauts did. He also hopes the remastered footage will inspire more interest in space agencies' upcoming plans for launching crewed missions that fly beyond low-Earth orbit — and even return to the lunar surface — while equipped with cameras capable of shooting in HD.

Did You Know?

U.R. Rao - The man behind The first satellite launched by India

***Aryabhatta**, the name given to the satellite, was an indigenously designed space-worthy satellite that set up tracking and transmitting systems in the orbital sphere. U.R. Rao, the chairman of ISRO at the time was the man behind the launch in 1975 that put India on the world map in terms of space research.*

SubhashMukhopadhyay - Gave life to India's first and the world's second IVF baby

The 3rd of October 1978 saw Subhash performing India's first In vitro fertilisation which resulted in the birth of baby Durga. Tragically, Subhash was only given a posthumous recognition of his achievements in 1986 as the West Bengal Government refused to support his 'unethical' methods.

Quantum internet breakthrough could help make hacking a thing of the past

Rupesh Ingale
TY Mechanical

The advent of mass working from home has made many people more aware of the security risks of sending sensitive information via the internet. The best we can do at the moment is make it difficult to intercept and hack your messages — but we can't make it impossible.

What we need is a new type of internet: the quantum internet. In this version of the global network, data is secure, connections are private and your worries about information being intercepted are a thing of the past.

My colleagues and I have just made a breakthrough, published in Science Advances, that will make such a quantum internet possible by scaling up the concepts behind it using existing telecommunications infrastructure.

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Quantum communication, on the other hand, creates keys using individual particles of light (photons) , which — according to the principles of quantum physics — are impossible to make an exact copy of. Any attempt to copy these keys will unavoidably cause errors that can be detected. This means a hacker, no matter how clever or powerful they are or what kind of supercomputer they possess, cannot replicate a quantum key or read the message it encrypts.

This concept has already been demonstrated in satellites and over fiber-optic cables, and used to send secure messages between different countries. So why are we not already using it in everyday life? The problem is that it requires expensive, specialized technology that means it's not currently scalable.

Previous quantum communication techniques were like pairs of children's walkie talkies. You need one pair of handsets for every pair of users that want to securely communicate. So if three children want to talk to each other they will need three pairs of handsets (or six walkie talkies) and each child must have two of them. If eight children want to talk to each other they would need 56 walkie talkies.

Obviously it's not practical for someone to have a separate device for every person or website they want to communicate with over the internet. So we figured out a way to securely connect every user with just one device each, more similar to phones than walkie talkies.

Each walkie talkie handset acts as both a transmitter and a receiver in order to share the quantum keys that make communication secure. In our model, users only need a receiver because they get the photons to generate their keys from a central transmitter.

This is possible because of another principle of quantum physics called "entanglement". A photon can't be exactly copied but it can be entangled with another photon so that they both behave in the same way when measured, no matter how far apart they are — what Albert Einstein called "spooky action at a distance".

Full network

When two users want to communicate, our transmitter sends them an entangled pair of photons — one particle for each user. The users' devices then perform a series of measurements on these photons to create a shared secret quantum key. They can then encrypt their messages with this key and transfer them securely.

By using multiplexing, a common telecommunications technique of combining or splitting signals, we can effectively send these entangled photon pairs to multiple combinations of people at once.

We can also send many signals to each user in a way that they can all be simultaneously decoded. In this way we've effectively replaced pairs of walkie talkies with a system more similar to a video call with multiple participants, in which you can communicate with each user privately and independently as well as all at once.

We've so far tested this concept by connecting eight users across a single city. We are now working to improve the speed of our network and interconnect several such networks. Collaborators have already started using our quantum network as a test bed for several exciting applications beyond just quantum communication.

We also hope to develop even better quantum networks based on this technology with commercial partners in the next few years. With innovations like this, I hope to witness the beginning of the quantum internet in the next ten years.

Did You Know?

Narinder Singh Kapany - The creator Fiber optics

The process to transfer information freely and almost instantaneously was made possible by the pioneering work of NarinderKalpany. Fiber optics have revolutionised the way we communicate, offering high speed data transfers as well as helping in medical procesdures such as endoscopy and laser surgeries.

Introduction: What is the Goal of AI Research? Emulation or Application

Manasi Prakash Kumbhar
TY Computer Science and Enginering

Goals of artificial intelligence (AI) research were proposed at least 60 years ago, when early conferences brought together those who believed in pursuing Alan Turing's question "can machines think?" [64]. A simplified summary might be that AI is getting computers to do what humans do, especially by emulating (some would say simulating) their perceptual, cognitive, and motor abilities.

This summary encompasses goals such as satisfying the classic Turing test, based on a keyboard and teletype (or screen) conversation in which users cannot tell if they are connected to a human or a machine. Other forms of Turing test include visually representing a human with computer-generated imagery (CGI) in a computer game or Hollywood film and making humanoid robots that think, see, speak, act, and move like a human. Russell energetically argued that AI was "one of the principal avenues for understanding how human intelligence works but also a golden opportunity to improve the human condition—to make a far better civilization."

Emulation research on human perceptual, cognitive, and motor abilities includes pattern recognition (images, speech, facial, signal, etc.), natural language processing, translation of natural language, bipedal robots, emotionally responsive human faces, and game playing (checkers, chess, go, etc.). As the early emulation research evolved, useful applications became possible, but the emulation research that emphasized symbolic manipulation, gave way to statistical approaches, based on deep learning and machine learning, which functioned differently from humans.

The rich history of AI research has many methods and many voices advocating diverse goals. The visionary aspirations of AI researchers led to a range of inspiring projects. Proponents claim that AI is a historical turning point for humanity with great promise and existential dangers. Critics point out that many projects failed, as is common with ambitious new research directions, but others led to widely used applications, such as optical character recognition, speech recognition, and natural language translation. While critics say that AI applications remain imperfect, many applications are impressive and commercially successful.

While bold aspirations can be helpful, another line of criticism is that the AI emulation methods failed, giving way to more traditional engineering solutions, which succeeded. For example, IBM's famed Deep Blue chess-playing program, which defeated world champion, Garry Kasparov, in 1997, is claimed as an AI success. However, IBM's researcher who built Deep Blue, Feng-Hsiung Hsu, makes an explicit statement that the brute-force hardware solution did not use AI methods . Another example is that AI-guided knowledge-based expert systems failed, but carefully engineered rule-based systems with human-curated rule sets succeeded in many business applications .

These debates about AI research goals dramatically influence government research funding, major commercial projects, academic research and teaching, and public impressions. This article simplifies the many goals of AI researchers into these two: 1) emulation and 2) application, and then describes four pairs of contrasting subgoals.The sharply defined emulation and application goals help clarify important distinctions, but individuals are likely to have more complex beliefs, which fall in between these extremes.

These four contrasting subgoals provide this article's structure, as well as a guide to compromise designs. This article is intended to accelerate research on human-centered AI that produces useful applications with widespread benefits for users and society, such as in business, education, healthcare, environmental preservation, and community safety.

Section II describes the emulation goal of understanding human perceptual, cognitive, and motor abilities to build computers that autonomously perform tasks as well as or better than humans. It summarizes the application goal of developing widely used products and services by using AI methods, which ensure human control. Both goals require science, engineering, and design research.

Section III focuses on conflicts that arise when product designers follow the emulation goal of building cognitive computers that they describe as smart, intelligent, knowledgeable, and capable of thinking. The resulting human-like products can be entertaining and appealing to some users, but these designs can exacerbate the distrust, fears, and anxiety that many users have of computers. The application goal community believes that computers are best designed to be powerful tools that amplify, augment, empower, and enhance humans. The compromise strategy could be to design tool-like user interfaces with AI-driven technologies for services, such as text messaging word suggestions and internal operations that transmit optimally across complex networks.

Section IV raises these questions: do designers benefit from thinking of computers as being teammates, partners, and collaborators? When is it helpful and when is there a danger in assuming human–human interaction is a good model for human–robot interaction? Application goal researchers and developers want to build teleoperated devices that extend human capabilities while providing superhuman perceptual and motor support, thereby boosting human performance while allowing human–human teamwork to continue. The compromise strategy could be to use emulation goal algorithms to implement automatic internal services that support the application goal of human control. This approach is implemented in many car driving technologies, such as lane following, parking assist, and collision avoidance.

Section V discusses the conflicts that arise when the emulation goal of autonomous systems leads designers of products and services astray. Rather than autonomous system acting alone, application goal researchers want to support supervisory control (sometimes called human in the loop), in which humans operate highly automated devices and systems. The compromise strategy could be to have emulation goal algorithms for highly automated features, with user interface designs that support human control and oversight by the way of comprehensible, predictable, and controllable user interfaces. This compromise strategy is in use in many NASA, industrial, utility, military, and air traffic control rooms, where rich forms of AI are used to optimize performance, but the operators have a clear mental model of what will happen next.

Section VI covers the many attempts by emulation goal that advocates to build humanoid robots over hundreds of years, which have attracted widespread interest, but limited commercial success. At the same time, mechanoid computers in the form of home appliances, mobile devices, and kiosks are great successes. Application goal champions prefer mechanoid (or mechanical) robots that are seen as steerable instruments, designed to increase flexibility or mobility while being expendable in rescue, disaster, and military situations. The compromise design could be to use limited humanoid services, which have proven acceptance, such as voice-operated virtual assistants embedded in mechanoid designs.

Awareness of how the different goals can produce avoidable conflicts lays the foundation for clearer thinking that leads to reliable, safe, and trustworthy systems [58]. Section VII offers conclusions and possible paths to constructive collaboration between the emulation goal and application goal communities.

SECTION II.

Two Goals for AI Researchers and Developers

AI researchers and developers have offered many goals such as this one in a major textbook: 1) think like a human; 2) act like a human; 3) think rationally; and 4) act rationally [52]. Others see AI as a set of tools to augment human abilities or extend their creativity. For simplicity, this article focuses on two goals: 1) human emulation and 2) useful applications. Of course, some researchers and developers will be sympathetic to goals that fall in both communities or even other goals that fall in between. I repeat the caution that the sharply defined emulation and application goals are meant to clarify important distinctions, but individuals are likely to have more complex beliefs.

A. Emulation Goal

The emulation goal is to understand human perceptual, cognitive, and motor abilities to build computers that perform tasks as well as or better than humans. This goal includes the aspiration for humanoid robots, natural language and image understanding, commonsense reasoning, and artificial general intelligence (AGI).

Those who pursue the emulation goal have grand scientific ambitions and understand that it may take 100 or 1000 years, but they tend to believe that researchers will be able to understand and model humans faithfully . Many researchers in this AI community believe that humans are machines, may be very sophisticated, but eventually building exact emulations of humans is a realistic and worthwhile grand challenge. They are cynical about claims of human exceptionalism or that humans are a separate category from computers. The famed AI 100 Report [60] states that “the difference between an arithmetic calculator and a human brain is not one of kind, but of scale, speed, degree of autonomy, and generality,” which assumes that human and computer thinking are in the same category.

The desire to build computers that match human abilities is an ancient and deep commitment. Broadbent states that: “humans have a fundamental tendency to create, and the ultimate creation is another human.” This belief influences the terminology and metaphors that the emulation goal community feels strongly about. They often think of computers as smart machines, intelligent agents, and knowledgeable actors, and are attracted to the idea that computers are learning and require training. Their work often includes performance comparisons between humans and computers, such as the capability of oncologists versus AI programs to identify breast cancer tumors.

Many emulation goal researchers and developers believe that robots can be teammates, partners, and collaborators and that computers can be autonomous systems that are independent, capable of setting goals, self-directed, and self-monitoring. They see automation as merely carrying out requirements anticipated by the programmers/designs, while autonomy is a step beyond automation to support unanticipated goals and emergent behaviors based on new sensor data. Emulation goal protagonists promote embodied intelligence through humanoid (or anthropomorphic) robots, which are bioinspired (or bionic) to resemble human forms. Finally, the emulation goal work may be influenced by real problems, but their work is often on toy problems or based on synthetic data and testing is often in laboratory conditions.

Some researchers, legal scholars, and ethicists envision a future in which computers will have the responsibility and legal protection of their rights, much as individual humans and corporations . They believe that computers and humanoid robots can be moral and ethical actors and that these qualities can be built into algorithms. This controversial topic is beyond the scope of this article, which focuses on design issues to guide the near-future research and the development of the next generation of technology.

B. Application Goal

The application goal drives researchers to develop widely used products and services by applying AI methods. This goal typically favors tool-based metaphors, teleoperated devices, supervised operation, and mechanoid appliances. These applications are described as instruments, apps, orthotics, prosthetics, utensils, or implements. These AI-guided products and services are built into the cloud, websites, laptops, mobile devices, home automation, kiosks, flexible manufacturing, and virtual assistants, and tailored for diverse application domains. An emulation goal airport assistant might be a mobile human-like robot that engaged in natural language conversation while an application goal airport kiosk would be a fixed device with touchscreen instructions to guide travelers.

Researchers and developers who pursue the application goal study aspects of human behavior and social dynamics, which relate to user acceptance of products and services. These researchers are typically enthusiastic about serving human needs, so they often partner with professionals to work on authentic problems and take pride in widely adopted innovations. They regularly begin by clarifying what the tasks are and thinking about the diverse stakeholders, their values, and societal/environmental impacts .

The application goal community frequently supports high levels of human control and high levels of computer automation, but they understand that there are applications that require rapid fully automatic operation (airbag deployment, pacemakers, etc.) and there are applications in which users prefer full human control (bicycle riding, piano playing, etc.). Between these extremes lie a rich design space that combines high levels of human control and high levels of automation. These researchers normally recognize the dangers of excessive automation and excessive human control, so they introduce interlocks that prevent failures while striving to find a balance that produces reliable, safe, and trustworthy systems .

The desire to make commercially successful products and services means that human–computer interaction (HCI) methods, such as design thinking, observation of users, usability testing, market research, and continuous monitoring of usage, are frequent processes employed by the application goal community. They recognize that users often prefer designs that are comprehensible, predictable, and controllable and that users want to increase their own mastery, self-efficacy, and creative control. They accept that humans need to be "in the loop," respect that users deserve explainable systems, and recognize that humans and organizations are the holders of responsibility, liability, and accountability . They are sympathetic to audit trails, product logs, or flight data recorders to support retrospective forensic analysis of failures to improve reliability and safety, especially for life-critical applications, such as pacemakers, self-driving cars, and aviation .

Sometimes those pursuing the application goal start with emulation goal ideas and then do what is necessary to create successful products and services. For example, speech recognition research was an important foundation of successful virtual assistants, such as Apple's Siri, Amazon's Alexa, Google's Home, or Microsoft's Cortana, but user interface design methods were important complements. Similarly, natural language translation research was integrated into well-designed user interfaces for imperfect, but successful websites and services. The third example is that image understanding research-enabled automatic creation of alt tags, which are short descriptions of images that enable users with disabilities and others to know what is in a website image.

Autonomous humanoid robots with bipedal locomotion and emotionally responsive faces, inspired by the emulation goal make appealing demonstrations and videos. However, these designs often give way to four-wheeled boxes, tread-based mobility, or teleoperated drones without faces, which are needed for success in the application goal . The language of robots may remain, as in "surgical robots," but these are teleoperated devices that allow surgeons to do precise work in tight spaces inside the human body.

Many emulation goal researchers believe that a general purpose humanoid robot can be made, which can serve tea to elders, deliver packages, and perform rescue work. In contrast, application goal researchers recognize that they have to tune their solutions for each context of use. Nimble hand movements, heavy lifting, or movement in confined spaces require specialized designs, which are not at all like a generic multipurpose human hand.

Lewis Mumford's book Technics and Civilization has a chapter titled "The Obstacle of Animism," in which he describes how first attempts at new technologies are misled by human and animal models. He uses the awkward term "dissociation" to describe the shift from human forms to more useful designs, such as recognizing that four wheels have large advantages over two feet in transporting heavy loads over long distances. Similarly, airplanes have wings, but they do not flap like bird wings. Mumford stressed that "the most ineffective kind of machine is the realistic mechanical imitation of a man or other animal." He continues with this observation "circular motion, one of the most useful and frequent attributes of a fully developed machine is, curiously, one of the least observable motions in nature" and concludes "for thousands of years animism has stood in the way of development."

Another important topic for application goal researchers is supporting human connections, e.g., with social media and collaborative software. For example, teleconferencing services expanded dramatically during the COVID crisis as universities shifted to using online instruction with live instructors and AI-guided automated services such as massive online open courses (MOOCs), such as those from Khan Academy, edX, or Coursera. Businesses quickly expanded working from home (WFH) options for their employees and family, friends, businesses, and communities adopted services, such as zoom, to support lectures, discussions, and much more.

Many forms of collaboration are supported by social media platforms, such as Facebook, Twitter, and Weibo, which employ AI-guided services. These platforms have attracted billions of users, who enjoy the social connections, benefit from the business opportunities, connect communities in productive ways, and support teamwork as in citizen science projects. However, many users have strong concerns about privacy and security, as well as the misuse of social media by political operatives, criminals, terrorists, and hate groups to spread fake news, scams, and dangerous messages. AI algorithms and user interface designs have contributed to these abuses, but they also contribute to the solutions.

The brief definitions of AI and the simple emulation and application goals are incomplete and controversial, with many people having more complex beliefs. Still, I believe that they provide a foundation for clearer thinking about the science, engineering, and design of AI research and systems so that societal benefits can be delivered. A common problem occurs when the assumptions tied to the emulation goal are put to work in the application goal. However, there are often compromise designs that benefit each goal's practices, effectively combining AI and HCI methods.

SECTION III.

Intelligent Agent or Powerful Tool?

By the 1940s, as modern electronic digital computers emerged, the descriptions included "awesome thinking machines" and "electronic brains." Dianne Martin's extensive review includes her concern that "the attitude research conducted over the past 25 years suggests that the "awesome thinking machine" myth may have in fact retarded public acceptance of computers in the work environment, at the same time that it raised unrealistic expectations for easy solutions to difficult social problems."

In 1950, Alan Turing provoked huge interest with his essay "Computing Machinery and Intelligence," in which he raises the question: "Can Machines Think?" He proposed what has come to be known as the Turing test or the imitation game [64]. This thoughtful analysis catalogs objections, but he ends with "we may hope that machines will eventually compete with men in all purely intellectual fields." Many AI researchers who pursue the emulation goal have taken up Turing's challenge by developing machines that are capable of carrying out human tasks, such as playing chess, understanding images, and delivering customer support. The January 2016 issue of AI Magazine was devoted to articles with many new forms of Turing tests.

A related early, but more nuanced, vision came in J. C. R. Licklider's 1960 description of "man–computer symbiosis," which acknowledged differences between humans and computers, but stated that they would be cooperative interaction partners with computers doing the routine work and humans having insights and making decisions .

The widespread use of terms, such as smart, intelligent, knowledgeable, and thinking helped propagated terminology, such as machine learning, deep learning, and the idea that computers were being trained. Neuroscience descriptions of human brains as neural networks were taken up enthusiastically as a metaphor for describing AI methods, further spreading the idea that computers were like people.

IBM latched on to the term "cognitive computing" to describe their work on the Watson system. However, IBM's Design Director recently reported it "was just too confusing for people to understand" and added that "we say AI, but even that, we clarify as augmented intelligence." Google has long branded itself as strong on AI, but their current effort emphasizes "people and AI research". It appears that those pursuing the application goal increasingly recognize that the suggestion of computer intelligence should be tempered with a human-centered approach for commercial products and services.

Journalists have often been eager proponents of the idea that computers were thinking and that robots would be taking our jobs. Cover stories with computer-based characters were featured in popular magazines, such as Newsweek in 1980, which reported on "Machines that think," and Time magazine in 1996, which asked "Can Machines Think?"

Graphic artists have been all too eager to show thinking machines, especially featuring human-like heads and hands, which reinforce the idea that humans and computers are similar. A common theme was a robot hand reaching out to grasp a human hand. Popular culture in the form of Hollywood movies offered sentient computer characters, such as HAL in the 1968 film 2001: A Space Odyssey and C3PO in the 1977 Star Wars. Human-like robots also played central roles in films, such as The Terminator, The Matrix, Wall-E, Robot and Frank, Her, and Ex Machina [63].

Computers were increasingly portrayed as independent actors or agents that ("who") could think, create, discover, and communicate. Journalists and headline writers were attracted to these notions producing headlines such as:

"Hubble Accidentally Discovers a New Galaxy in Cosmic Neighborhood (NASA). The Fantastic Machine That Found the Higgs Boson (The Atlantic). AI Finds Disease-Related Genes (ScienceDaily.com). Machines Learn Chemistry (ScienceDaily.com)."

Many writers voiced the alternate view that computers were powerful tools that could amplify, augment, empower, and enhance humans. However, that view never became as popular as the seductive notion that computers were gaining capabilities to match or exceed humans. Nevertheless, some researchers produced influential results, such as Engelbart, who gave an early vision of what it meant to augment human intellect and made a famed demonstration at the Fall Joint Computer Conference .Markoff carefully traces the history of AI versus intelligence augmentation (AI versus IA), describing controversies, personalities, and motivations. There is a growing belief that there are productive ways to pursue both the emulation and application goals.

Application goal developers were more likely to be influenced by designs of tool-like products and services. They were influenced by many guidelines documents, such as The Apple Human Interface Design Guidelines [1], which included two clear principles:

Application developers, who produce three million applications in the Apple and Android stores have largely built tool-like user interfaces, even when there is ample AI technology at work internally. These developers appreciate that users often expect a device that is comprehensible, predictable, and under their control.

The compromise design could be to build emulation goal technologies for internal operations, while the users see empowering interfaces that give them clear choices, as in GPS navigation systems, Web search, e-commerce, and recommender systems. Heer showed three ways of using AI-guided methods in support of human control in data cleaning, exploratory data visualization, and natural language translation. A familiar example of well-designed integration of automated features and human control is the cell phone digital camera. These widely used devices employ AI-guided features, such as high dynamic range lighting control, jitter removal, and automatic focus, but give users control over composition, portrait modes, filters, and social media postings.

SECTION IV.

Simulated Teammate or Teleoperated Device?

A common theme in design for robots and advanced technologies is that human–human interaction is a good model for human–robot interaction [24], [26] and that emotional attachment to embodied robots is an asset [69]. Many designers never consider alternatives, believing that the way people communicate with each other, coordinate activities, and form teams are the only model for design. The repeated missteps stemming from this assumption do not deter others who believe that this time will be different, that the technology is now more advanced, and that their approach is novel. Klein et al. [25] clarified the realistic challenges of making machines that behave as effectively as human teammates.

My objection is that human partners, teammates, and collaborators are very different from computers. I believe that it is helpful to remember that "computers are not people and people are not computers." Boden et al. [4] also made a simple clear statement: "robots are simply not people." The differences include the following.

Responsibility: Computers are not responsible participants, neither legally nor morally. They are never liable or accountable. They are a different category from humans. This continues to be true in our legal system and I think it will remain so. Boden et al. [4] offered this straightforward principle: "humans, not robots, are responsible agents." This principle is especially true in the military, where the chain of command and responsibility is taken seriously.

Pilots of advanced fighter jets with ample automation still think of themselves as in the control of the plane and responsible for their successful missions, even though they must adhere to their commander's orders and the rules of engagement. Astronauts rejected designs of the early Mercury capsules which had no window to eyeball the reentry if they had to do it manually—they wanted to be in control when necessary, yet responsive to mission control's rules. Neil Armstrong landed the Lunar Module on the moon—he was in charge, even though there was ample automation. The Lunar Module was not his partner. The Mars Rovers are not teammates; they are advanced automation with excellent integration of human teleoperation with high levels of automatic operation.

It is instructive that the U.S. Air Force shifted from using the term unmanned autonomous/aerial vehicles (UAVs) to remotely piloted vehicles (RPVs) to clarify responsibility. The Canadian Government has a rich set of knowledge requirements that candidates must have to be granted a license to operate a remotely piloted aircraft system (RPAS).

Designers and marketers of commercial products and services take into account legal issues of accountability and liability, in which humans or organizations are the responsible parties [9]. Commercial activity is further shaped by independent oversight mechanisms, such as government regulation, industry voluntary standards, and insurance requirements.

Distinctive Capabilities: Computers have distinctive capabilities of algorithms, databases, sensors, effectors, etc. To buy into the metaphor of "teammate" has led to many design mistakes, which produce suboptimal performance. One robot rescue design team described their project to program natural language text messages that the robot would send to the operators. The messages described what the robot was "seeing," when a video or photograph could deliver much more detailed information more rapidly. Why settle for a human-like design when designs that make full use of distinctive computer capabilities would be more effective.

Designers who pursue advanced technologies will creatively find ways to empower people to be a 1000 times as effective as they have been—that is what microscopes, telescopes, bulldozers, ships, and planes have done and it is what digital cameras, Google Maps, Web search, etc., have done for people. Cameras, telescopes, cars, dishwashers, and pacemakers are not seen as teammates—they are tools that empower, enhance, amplify, and augment people.

Human Creativity: The human is always the creative force—for discovery, innovation, art, music, etc. Scientific papers are always authored by people, even when powerful computers are used. Artworks and music compositions are credited to humans, even if rich technologies with AI are heavily used.

Those who push the teammate metaphor to the limits are often led down the path of making humanoid designs, which have a long history of appealing robots, but limited commercial successes. I do not think this will change. I do not think rescue robots, bomb disposal, or eldercare robots will be human like—there are better design possibilities. The DaVinci surgical robot is nothing like a human in form or performance; it is not a teammate. It is a well-designed teleoperated machine that enables surgeons to perform precise actions in difficult to reach small body cavities. As Mumford reminds designers, successful technologies diverge from human forms.

In fact, many so-called robotic devices have a high degree of teleoperation, in which an operator controls many aspects. For example, drones, which are often described as an AI-guided technology, are generally teleoperated, even though they have the capacity to automatically hover or orbit at a fixed altitude, return to their take-off point, or follow a series of operator-chosen GPS waypoints. The NASA Mars Rover vehicles also have a rich mixture of teleoperated features and independent movement capabilities, guided by sensors to detect obstacles or precipices, with plans to circumvent them.

The language of "teleoperated instruments" or "telepresence" suggests alternative design possibilities that go beyond autonomy. These instruments enable remote operation, more careful control of devices such as when telepathologists control a remote microscope to study tissue samples. Other terms favored by the application goal community include "orthotics," such as eyeglasses or foot supports to improve performance and "prosthetics" such as replacements for missing limbs and exoskeletons that increase a human's capacity to lift heavy objects. While terms, such as "implement" or "utensil" convey modest capabilities, they constructively clarify that the user is in control.

The compromise design might be to take limited, yet mature and proven features of teammate models and embed them in designs that support human augmentation by direct or teleoperated devices. Emulation goal results can be put to work to handle sensor inputs, make well-understood decisions, and take actions whose results are predictable, leaving higher level choices to human operators.

SECTION V.

Autonomous System or Supervisory Control?

Computer autonomy is an attractive emulation goal for many AI researchers, developers, journalists, and promoters. Computer autonomy has become a widely used term to describe an independently functioning machine, not directly under human control. The U.S. Defense Science Board makes this definition:

"Autonomy results from delegation of a decision to an authorized entity to take action within specific boundaries. An important distinction is that systems governed by prescriptive rules that permit no deviations are automated, but they are not autonomous. To be fully autonomous, a system must have the capability to independently compose and select among different courses of action to accomplish goals based on its knowledge and understanding of the world, itself, and the situation."

However, the U.S. Defense Science Board cautioned that:

"Unfortunately, the word "autonomy" often conjures images in the press and the minds of some military leaders of computers making independent decisions and taking uncontrolled action. It should be made clear that all autonomous systems are supervised by human operators at some level, and autonomous systems' software embodies the designed limits on the actions and decisions delegated to the computer. Autonomy is, by itself, not a solution to any problem."

This warning highlights the reality that humans and machines are embedded in complex organizational and social systems, making interdependence an important goal as well. Since humans remain as responsible actors (legally, morally, and ethically), should not computers be designed in ways that assure user control? The compromise design is that some features can be made autonomous if they are comprehensible, predictable, and controllable while giving the users the overall control that they expect.

While enthusiasm for fully autonomous systems remains high and may be valuable as a research goal, the realities of usage have been troubling. Autonomous high-speed financial trading systems have produced several billion-dollar financial crashes, but more troubling are deadly outcomes, such as the Patriot missile system shooting down two friendly aircraft during the Iraq War or the 2016 crash of a Tesla while on Autopilot [. Maybe the most dramatic examples are the 2018 and 2019 crashes of the Boeing 737 MAX crashes, caused by the autonomous MCAS system, which took over some aircraft controls without even informing the pilots .

Some of the problems caused by autonomy are captured in Robin Murphy's Law of autonomous robots: "any deployment of robotic systems will fall short of the target level of autonomy, creating or exacerbating a shortfall in mechanisms for coordination with human problem holders" .

Those who faced the realities of dealing with application goals have repeatedly described the dangers of full computer autonomy. An early commentary in 1983 gently described the ironies of autonomy, which instead of lightening the operator's workload increased their workload because continuous monitoring of the autonomous computer was necessary. These operators are unsure of what the computer will do, yet they are responsible for the outcome.

Other concerns were the difficulty of humans remaining vigilant when there was little for them to do, the challenge of rapidly taking over when problems arose, and the struggle to maintain skills when they need to take over operations. These ironies of vigilance, rapid transition, and deskilling of operators remain relevant because the operators are responsible for the outcomes .

Bradshaw et al. made more forceful comments in a strongly worded paper on the "seven deadly myths of autonomous systems," which makes the bold statement that "there is nothing worse than a so-called smart machine that cannot tell you what it is doing, why it is doing something, or when it will finish. Even more frustrating—or dangerous—is a machine that is incapable of responding to human direction when something (inevitably) goes wrong." Bradshaw et al. also made the devastating remark that believers in full computer autonomy "have succumbed to myths of autonomy that is not only damaging in their own right but are also damaging by their continued propagation, because they engender a host of other serious misconceptions and consequences."

Even human factor specialists who support the autonomy goal describe conundrums: "as more autonomy is added to a system, and its reliability and robustness increase, the lower the situation awareness of human operators and the less likely that they will be able to take over manual control when needed" .

A consequential debate continues around the dangers of lethal autonomous weapons (LAWS), which could select targets and launch deadly missiles without human intervention. A vigorous effort to ban these weapons, much as land mines have been banned, has attracted almost 5000 signatures. A regular United Nations Convention on Certain Conventional Weapons in Geneva attracts representatives of 125 countries who are drafting a treaty restricting the use of LAWS. Their case is bolstered by reports from cognitive science researchers [19], who document the failures, dangers, and costs of autonomous weapons. However, some military leaders do not wish to be limited, when they fear that adversaries will adopt autonomous weapons.

In contrast, supervisory control supports human operation and oversight by providing continuous situation awareness, clear mental model, rich control panel, and extensive feedback from actions. Supervisory control, telerobotics, and automation were extensively described by Sheridan [54], who sought to define the space between detailed manual and fully automatic control, to clarify human responsibility for the operation of industrial control rooms, robots, elevators, and washing machines.

Supervisory control suggests human decision making for setting goals with computers carrying out predictable tasks with low-level physical actions guided by sensors and carried out by effectors. Automobile automatic transmissions are a familiar example. In electronic systems, such as e-mail or e-commerce, users carry out their tasks of sending messages or ordering products, getting feedback on what has happened, with alerts if an e-mail bounces or a product shipment is delayed. In mature systems, users have a clear mental model of what the device or system is doing, with interlocks to prevent unintended actions, alerts when problems arise, and the capacity to intervene when undesired actions occur.

Contemporary versions of supervisory control have richer designs in which there may be several forms of human control. For example, aircraft pilots and co-pilots in airplanes work closely with air traffic controllers based in local centers (Terminal Radar Approach Control, TRACON) and 20 regional control rooms (Air Route Traffic Control Center, ARTCC) to coordinate flights in the national airspace. Similarly, hospital, transportation, power, stock market, military, and other complex systems have multiple layers of supervisory control, within which there may be many AI-guided components.

SECTION VI.

Humanoid Robots or Mechanoid Appliances?

Visions of animated human-like robots go back at least to ancient Greek sources, but maybe one of the most startling successes was in the 1770s. Swiss Watchmaker Pierre Jaquet-Droz created elaborate programmable mechanical devices with human faces, limbs, and clothes. The writer used a quill pen on paper, the musician played a piano, and the draughtsman drew pictures, but these became only museum pieces for the Art and History Museum in Neufchatel.

The idea of human-created characters gained acceptance with classic stories such as the Golem created by the 16th-century rabbi of Prague and Mary Shelley's Frankenstein in 1818. Children stories tell of the puppet-maker Geppettowhose wooden Pinocchio comes to life and the anthropomorphic Tootle the Train character who refuses to follow the rules of staying on the track. In Goethe's Sorcerer's Apprentice, the protagonist conjures up a broomstick character to fetch pails of water, but when the water begins to flood the workshop, he cannot shut it down. Worse still, splitting it in half only generates twice as many broomsticks. In the 20th century, the metaphors and the language used to discuss animated human-like robots are usually traced back to Karel Capek's 1920 play Rossum's Universal Robots.

These examples illustrate the idea of humanoid robots, some are mechanical, biological, or made from materials, such as clay or wood, but they usually have human characteristics, such as two legs, a torso, arms, and a face with eyes, nose, mouth, and ears. They may make facial expressions and head gestures, while speaking in human-like voices, expressing emotion and showing personality .

These captivating humanoid robots have strong entertainment value that went beyond mere puppets because they seemed to operate autonomously. Children and many adults are enthusiastic about robots as film characters, engaged with robot toys, and eager to build their own robots . But moving from entertainment to devices that serve application goals has proven to be difficult, except for medical mannequins and crash test dummies.

One example of how humanoid robot concepts were misleading is the design or early robot arms. The arms were typically 18 in long, had five fingers, had a wrist that rotated only 270°, and could lift about 20 pounds. Eventually, the demands of industrial automation led to flexible manufacturing systems and powerful dexterous robot arms, without humanoid forms, just as Lewis Mumford would predict.

Serious researchers, companies, and even government agencies have created humanoid robots. The U.S. Postal Service created a life-sized human-like Postal Buddy in 1993 with plans to install 10 000 machines. However, they shut down the project after consumers rejected the 183 Postal Buddy kiosks. Many designs for anthropomorphic bank tellers disappeared because of consumer disapproval. Contemporary banking systems, usually shun the name automatic teller machines, in favor of automatic transaction machines or cash machines, which support patrons getting their tasks done quickly without distracting conversation or human bank teller avatars.

Other related missteps were Microsoft's 1995 BOB, in which friendly characters would help users do their tasks and Microsoft's Office 1997 Clippy (Clippit), a too chatty character that popped up to offer help. Ananova, a Web-based news reading avatar, launched in 2000, was terminated, but the idea was revived by Chinese developers for the state news agency Xinhua in 2018 [27]. Even cheerful on-screen characters, such as Ken the Butler in Apple's famed 1987 Knowledge Navigator video and avatars in Intelligent Tutoring Systems have vanished. They distracted users from the tasks they were trying to accomplish. A careful review of 52 studies of robot failures provides guidance that could lead to greater success.

Manufacturer Honda created an almost life-sized humanoid robot named Asimo, which was featured at trade events and widely reported in the media, but no commercial products are planned. A recent dramatic news event was when David Hanson's Social Robotics company, whose motto is "we bring robots to life," produced a talking robot named Sophia, which gained Saudi Arabian citizenship . These publicity stunts draw wide attention from the media, but they have not led to commercial successes. Cynthia Breazeal's two decades of heavily promoted demonstrations of emotive robots, such as Kismet, culminated in a business startup, Jibo, which closed in 2019. Another social robot startup, Mayfield Robotics, produced Kuri, but it also closed in 2019.

Some companies are managing to turn impressive demonstrations into promising products. Boston Dynamics, which began with two-legged two-armed humanoid robots, have shifted to wheel-driven mechanoid robots with vacuum suction for picking up packages in

Since its 2014 introduction, the Pepper robot, a four-foot high humanoid shape, with expressive head, arm, and hand movements, has a three-wheeled base for mobility. It is described as "pepper was optimized for human interaction and is able to engage with people through conversation and his touch screen". Its appealing design and conversational capacity generated strong interest, leading to sales of 15 000 units. Pepper is promoted for tasks, such as customer welcoming, product information delivery, exhibit or store guide, and satisfaction survey administration .

In Japan, which is often portrayed as eager for gadgets and robots, a robot-staffed hotel, closed in 2019 after a few months. The company president remarked "when you actually use robots you realize that there are places where they are not needed—or just annoy people" [15]. At the same time, traditional mechanoid automated soft drink, candy, and other dispensers are widely successful in Japan and elsewhere.

Controversy continues around the uses of humanoid robots for autism therapy. Some studies report benefits from using robots with children who may have difficulty with human relationships, but eagerly engage with robots, possibly paving the way for improved relationships with people . Critics suggest that the focus on technology, rather than the child, leads to early successes, but less durable outcomes. McBride worried that "if we view the human as something more than a machine, we cannot possibly devolve the responsibility for a therapeutic relationship to a mechanical toy."

Other controversies deal with eldercare social robots, especially for those with cognitive disorders and dementia. Small studies of newly introduced social robots (some humanoid and some mechanoid) have elicited sympathy from many users, especially in nursing homes, but long-term evidence is still needed to respond to the critics. The PARO therapeutic robot is a synthetic fur-covered white seal-like robot that has touch, light sound, temperature, and posture sensors so that it "responds as if it is alive, moving its head and legs, making sounds, and imitates the voice of a real baby harp seal."

PARO has been approved by the U.S. Food and Drug Administration as a Class 2 medical device. Some studies conducted during 15 years report successes in producing positive responses from patients ("it is like a buddy," "it is a conversation piece," and "it makes me happy") and indications of potential therapeutic improvements . However, these are typically short-term studies at the introduction of PARO, when patients are intrigued by the novelty, but the long-term use is still to be studied. SONY's dog robot, AIBO, remains a popular demonstration but has limited commercial success.

A notable consumer success comes from irobot, especially, Roomba, a floor-cleaning machine, and related products for mopping floors, mowing lawns, and cleaning swimming pools (Fig. 4). These mechanoid robots have mobility, sensors, and complex algorithms to map spaces while avoiding obstacles. Many kinds of mechanoid robots, often remotely controlled, have been used for bomb disposal, military applications in Afghanistan, and disaster response.

A notable success for the emulation goal is the speech-based virtual assistants, such as Apple's Siri, Amazon's Alexa, Google's Home, or Microsoft's Cortana. The designers have produced modestly reliable speech recognition and question answering systems, with high-quality speech generation that have gained consumer acceptance. This success may suggest other opportunities , but these devices are typically simple cylinders, but no human forms. Humanoid virtual assistants have yet to prove successful. Even talking dolls have failed to draw consumer success, from Thomas Edison's efforts in the 1880s to the Mattell Talking Barbie in 1992 and a more ambitious Hello Barbie version in 2015 .Mattell has no plans to pursue a talking Barbie.

Despite the modest commercial adoption of humanoid robots, many researchers and entrepreneurs still believe that they will eventually succeed. The academic research reports present a mixed view with studies from developers showing user satisfaction and sometimes delight, while others studies show the preference for more tool-like mechanoid designs, which adhere to the principles of giving users control of comprehensible, predictable, and controllable interfaces . An academic survey of 1489 participants studied fear of autonomous robots and AI (FARAI). This fear, dubbed robophobia [59], ranged from slight afraid to afraid for 20.1% and afraid to very afraid for 18.5% . Milder forms of concern over the uncanny valley, where near-human designs are distrusted, are a more common response .

Human willingness to engage with social robots was the focus of dozens of studies conducted by Clifford Nass, a Stanford psychologist, and his students [49]. They found that people were quick to respond to social robots, accepting them as valid partners in interactions. However, the central question remains: would people perform more effectively and prefer a more tool-like mechanoid design? Human control and operation of interfaces is a key concept in millions of applications that are based on direct manipulation. It is also the lesson from developers of banking machines and almost all other mobile devices, household appliances, office technologies, and e-commerce websites.

Early anthropomorphic designs and humanoid robots gave way to functional banking machines that support user control, without the deception of having a human-like bank teller machine or screen representation of a human bank teller. This deception led bank users to wonder how else their bank was deceiving them, thereby undermining the trust needed in commercial transactions. Even leading AI researchers, such as Russell , clearly state that: "there is no good reason for robots to have humanoid form … they represent a form of dishonesty."

These historical precedents can provide useful guidance for contemporary designers pursuing the application goal since many still believe that improved designs of humanoid robots based on the emulation goal will eventually succeed. A commonly mentioned application is elder care in which users wishing to live independently at home will need a humanoid robot to use a kitchen with implements designed for humans, to navigate hallways and stairs, and to accommodate tasks, such as administering medications or offering a cup of tea. Inspired by the emulation goal, they see humanoid robots as the only way to provide these services, especially when the requirement is to work in environments built for human activity. However, I believe that if the imagination of these designers was more open they would see new possibilities. A pointed scenario is that if transported back to 1880, they would have proposed clothes washing robots that picked up a bar of soap and a washboard to scrub clothes, rinsed them in a sink, and hung them on a clothesline to dry. Designers of modern washer/dryers have gone well beyond humanoid robots to make mechanoid successes.

Similarly, Amazon fulfillment centers have many robots for moving products and packing boxes, but none of them are humanoid (https://www.amazonrobotics.com). Robin Murphy, a leader in developing, testing, and fielding rescue robots advocates agile mechanoid robots that can go under buildings or through ventilation ducts and teleoperated drones that can fly into dangerous places to provide video for human decision makers [44].

The compromise strategy could be to use limited humanoid services, which have proven acceptance, such as voice-operated virtual assistants embedded in mechanoid designs. Exploration of pet-like or human-like devices for therapeutic and commercial services could be further refined with long-term studies to understand what solutions remain appealing over time while being safe and effective.

SECTION VII.

Conclusion

In summary, this article focused on a simplified version of just two prominent AI research goals. The first is the emulation goal for understanding human perceptual, cognitive, and motor skills to build computers that match or exceed human performance. The second is the application goal, which does HCAI research for developing successful and widely used commercial products and services. Both make valuable contributions, which researchers should pursue to bring societal benefits.

Problems arise when assumptions from one goal are used to drive work on the other goal. For example, humanoid robots remain a popular emulation goal, but humanoid robots have had far less commercial success than tool-like appliances or teleoperated devices. Understanding the mismatches could lead to designs for widely used products and services. Four such mismatches in conception and terminology were discussed: 1) intelligent agent or powerful tool; 2) simulated teammate or teleoperated device; 3) autonomous system or supervisory control; and 4) humanoid robot or mechanoid appliance.

The emulation goal inspires many researchers and creates widespread public interest. Powerful AI methods, such as machine learning, make possible recommender systems, speech recognition, image understanding, and natural language processing. When designer combine these AI methods with HCI-based user requirements gathering, design iteration, guidelines reviews, and usability testing, valuable products and services often emerge. Many other principles guide successful outcomes, such as supporting human self-efficacy, encouraging human creativity, and facilitating social participation.

Design compromises, which combine AI with HCI methods, need to be further shaped by the contextual needs of each application domain and thoroughly tested with real users. Then, the resulting products and services have a high chance of serving human needs in business, education, healthcare, environmental preservation, and community safety.

The Lithium-Ion Battery With Built-In Fire Suppression

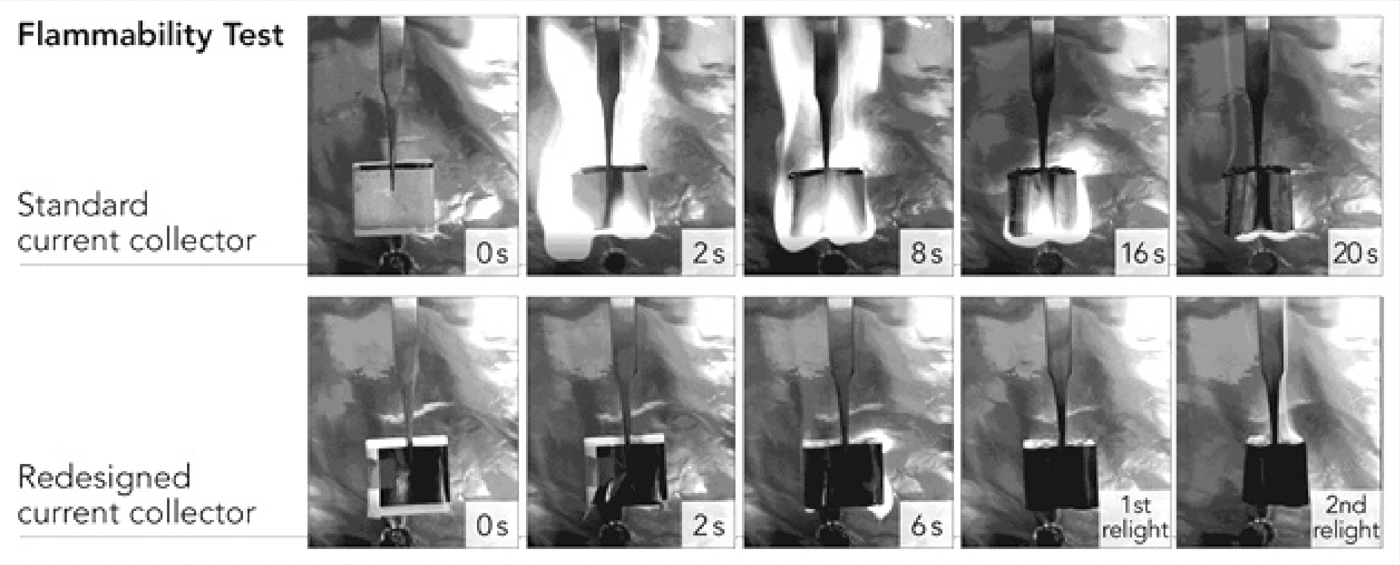
Shubham Shirole
SY Mechanical

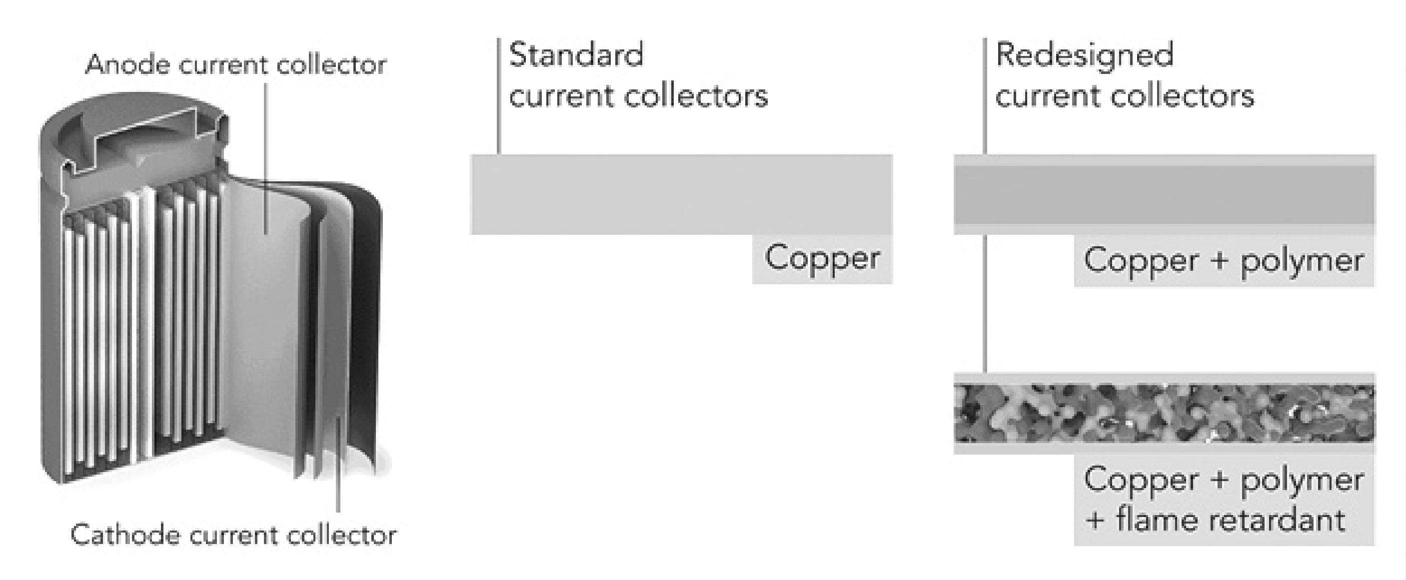
If there are superstars in battery research, you would be safe in identifying at least one of them as Yi Cui, a scientist at Stanford University, whose research group over the years has introduced some key breakthroughs in battery technology.

Now Cui and his research team, in collaboration with SLAC National Accelerator Laboratory, have offered some exciting new capabilities for lithium-ion batteries based around a new polymer material they are using in the current collectors for them. The researchers claim this new design to current collectors increases efficiency in Li-ion batteries and reduces the risks of fires associated with these batteries.

Current collectors are thin metal foils that distribute current to and from electrodes in batteries. Typically these metal foils are made from copper. Cui and his team redesigned these current collectors so that they are still largely made from copper but are now surrounded by a polymer.

The Stanford team claim in their research published in the journal Nature Energy that the polymer makes the current collector 80 percent lighter, leading to an increase in energy density from 16 to 26 percent. This is a significant boost over the average yearly increase of energy density for Li-ion batteries, which has been stuck at 5 percent a year seemingly forever.





cientists at Stanford and SLAC redesigned current conductors, thin metal foils that distribute current to and from electrodes, to make lithium-ion batteries lighter, safer and more efficient. They replaced the all-copper conductor, middle, with a layer of lightweight polymer coated in ultrathin copper (top right), and embedded fire retardant in the polymer layer to quench flames (bottom right).

This method of lightening the batteries is a bit of a novel approach to boosting energy density. Over the years we have seen many attempts to increase energy density by enlarging the surface area of electrodes through the use of new electrode materials—such as nanostructured silicon in place of activated carbon. While increased surface area may increase charge capacity, energy density is calculated by the total energy over the total weight of the battery.

The Stanford team have calculated the increase of 16 to 26 percent in the gravimetric energy density of their batteries by replacing the commercial copper/aluminum current collectors (8.06 mg/cm2 for copper and 5.0 mg/cm2 for aluminum) with their polymer collections current collectors (1.54 mg/cm2 for polymer-copper material and 1.05 mg/cm2 for polymer-aluminum).

"Current collectors don't contribute to the total energy but contribute to the total weight of battery," explained Yusheng Ye, a researcher at Stanford and co-author of this research. "That's why we call current collectors 'dead weight' in batteries, in contrast to 'active weight' of electrode materials."

y reducing the weight of the current collector, the energy density can be increased, even when the total energy of the battery is almost unchanged. Despite the increased energy density offered by this research, it may not entirely alleviate so-called "range anxiety" associated with electric vehicles in which people have a fear of running out of power before reaching the next charge location. While the press release claims that this work will extend the range of electric vehicles, Ye noted that the specific energy improvement in this latest development is based on the battery itself. As a result, it is only likely to have around a 10% improvement in the range of an electric vehicle.

"In order to improve the range from 400 miles to 600 miles, for example, more engineering work would need to be done taking into account the active parts of the batteries will need to be addressed together with our ultra-light current collectors," said Ye.

Beyond improved energy density efficiency, the polymer-based charge collectors are expected to help reduce the fires associated with Li-ion batteries. Of course, traditional copper current collectors don't contribute to battery combustion on their own. The combustion issues in Li-ion batteries are related to the electrolyte and separator that are not used within the recommended temperatures and voltage windows.

"One of the key innovations in our novel current collector is that we are able to embed fire retardant inside without sacrificing the energy density and mechanical strength of the current collector," said Ye. "Whenever the battery has combustion issues, our current collector will instantaneously release the fire retardant and extinguish the fire. Such function cannot be achieved with traditional copper or aluminum current collector."

The researchers have patented the technology and are in discussions with battery manufacturers for commercialization. Cui and his team have already worked out some of the costs associated with adopting the polymer and they appear attractive. According to Ye, the cost of the polymer composite charge collector is around $1.3 per m2, which is a bit lower than the cost of copper foil, which is around $1.4 per m2. With these encouraging numbers, Ye added: "We are expecting industry to adopt this technology within the next few years."

Did You Know?

Dr. HomiJehangirBhabha - The father of the Indian Nuclear Research Programme

India achieved nuclear capability thanks to the efforts of Homi, thereby avoiding certain conflict simply through non aggression treaties. This also made us one of the few nations to have atomic power as a source of energy as well as a way to weaponise.

Print These Electronic Circuits Directly Onto Skin

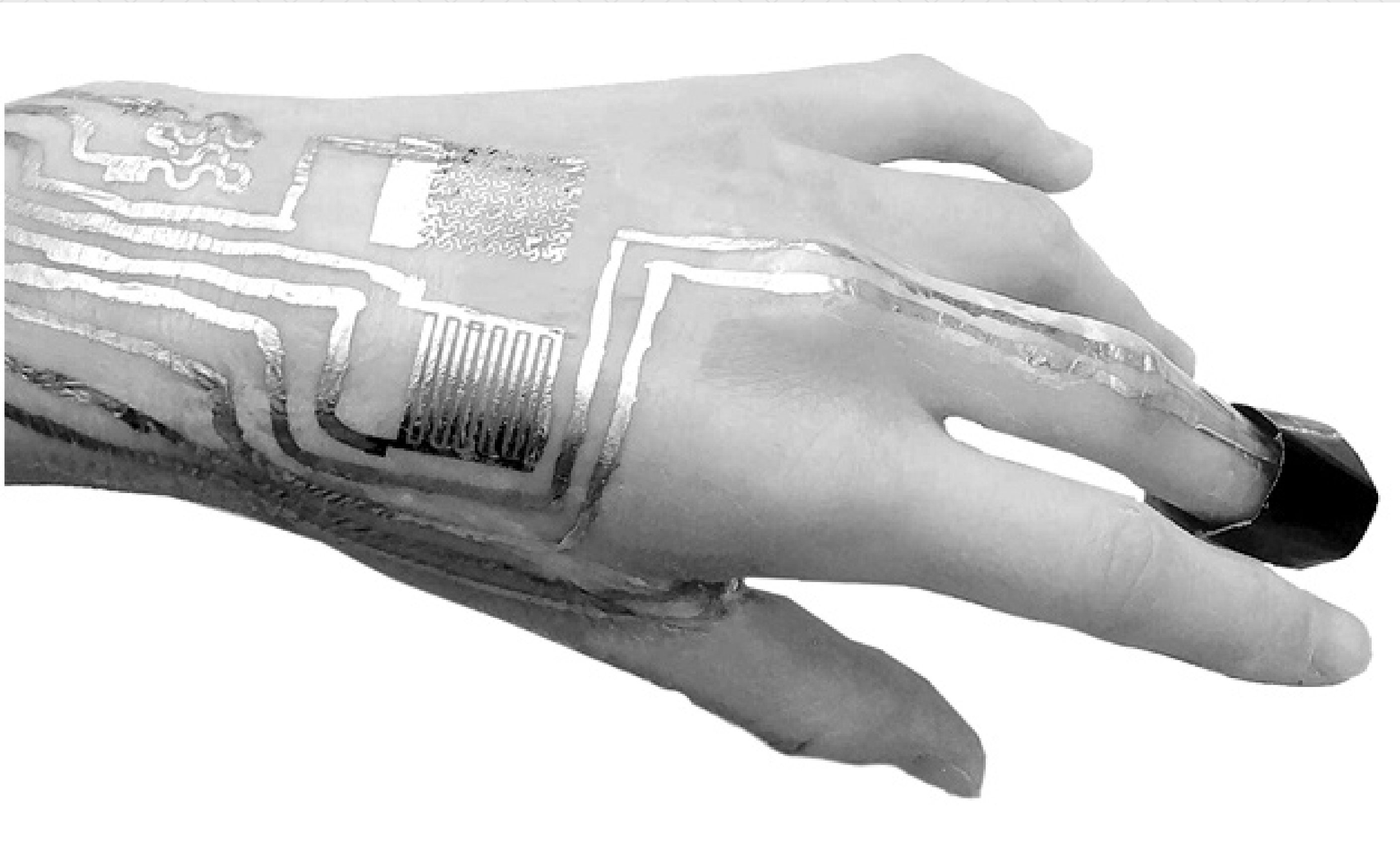
Nilprabha Namdev Yadav
T.Y. (Mechanical Engg.)

New circuits can get printed directly on human skin to help monitor vital signs, a new study finds.

Wearable electronics are growing increasingly more comfortable and more powerful. A next step for such devices might include electronics printed directly onto the skin to better monitor and interface with the human body.

Scientists wanted a way to sinter—that is, use heat to fuse—metal nanoparticles to fabricate circuits directly on skin, fabric or paper. However, sintering usually requires heat levels far too high for human skin. Other techniques for fusing metal nanoparticles into circuits, such as lasers, microwaves, chemicals or high pressure, are similarly dangerous for skin.

In the new study, researchers developed a way to sinter nanoparticles of silver at room temperature. The key behind this advance is a so-called a sintering aid layer, consisting of a biodegradable polymer paste and additives



such as titanium dioxide or calcium carbonate.

Positive electrical charges in the sintering aid layer neutralized the negative electrical charges the silver nanoparticles could accumulate from other compounds in their ink. This meant it took less energy for the silver nanoparticles printed on top of the sintering aid layer to come together, says study senior author Huanyu Cheng, a mechanical engineer at Pennsylvania State University.

The sintering aid layer also created a smooth base for circuits printed on top of it. This in turn improved the performance of these circuits in the face of bending, folding, twisting and wrinkling.

In experiments, the scientists placed the silver nanoparticle circuit designs and the sintering aid layer onto a wooden stamp, which they pressed onto the back of a human hand. They next used a hair dryer set to cool to evaporate the solvent in the ink. A hot shower could easily remove these circuits without damaging the underlying skin.

After the circuits sintered, they could help the researchers measure body temperature, skin moisture, blood oxygen, heart rate, respiration rate, blood pressure and bodily electrical signals such as electrocardiogram (ECG or EKG) readings. The data from these sensors were comparable to or better than those measured using conventional commercial sensors that were simply stuck onto the skin, Cheng says.

The scientists also used this new technique to fabricate flexible circuitry on a paper card, to which they added a commercial off-the-shelf chip to enable wireless connectivity. They attached this flexible paper-based circuit board to the inside of a shirt sleeve and showed it could gather and transmit data from sensors printed on the skin

“With the use of a novel sintering aid layer, our method allows metal nanoparticles to be sintered at low or even room temperatures, as compared to several hundreds of degrees Celsius in alternative approaches,” Cheng says. “With enhanced signal quality and improved performance over their commercial counterparts, these skin-printed sensors with other expanded modules provide a repertoire of wearable electronics for health monitoring.”

The scientists are now interested in applying these sensors for diagnostic and treatment applications “for cardiopulmonary diseases, including COVID-19, pneumonia, and fibrotic lung diseases,” Cheng says. “This sensing technology can also be used to track and monitor marine mammals.”

Did You Know?

Dr. A. SivathanuPillai - Oversaw the creation of Indigenously developed missile systems

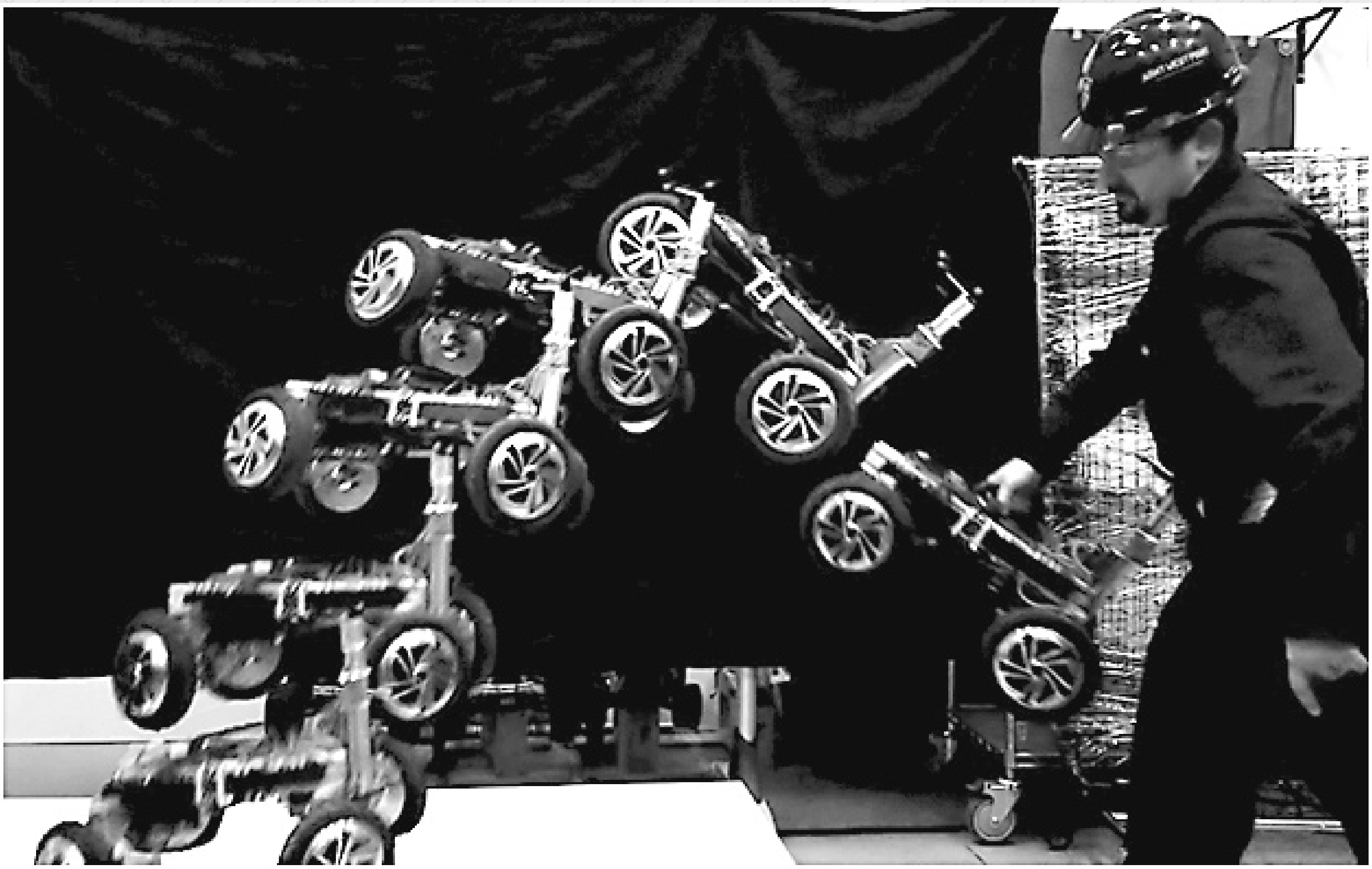
India’s self sustaining missile developing programme is called BrahMOS. Dr. Pillai developed the concept of the joint venture BrahMOS, which makes India one of the few countries to develop it’s own ballistic missiles as well as produce and supply missiles in other key areas of the world. The onset of BrahMOS led to the negation of the absolute power held by Western countries.

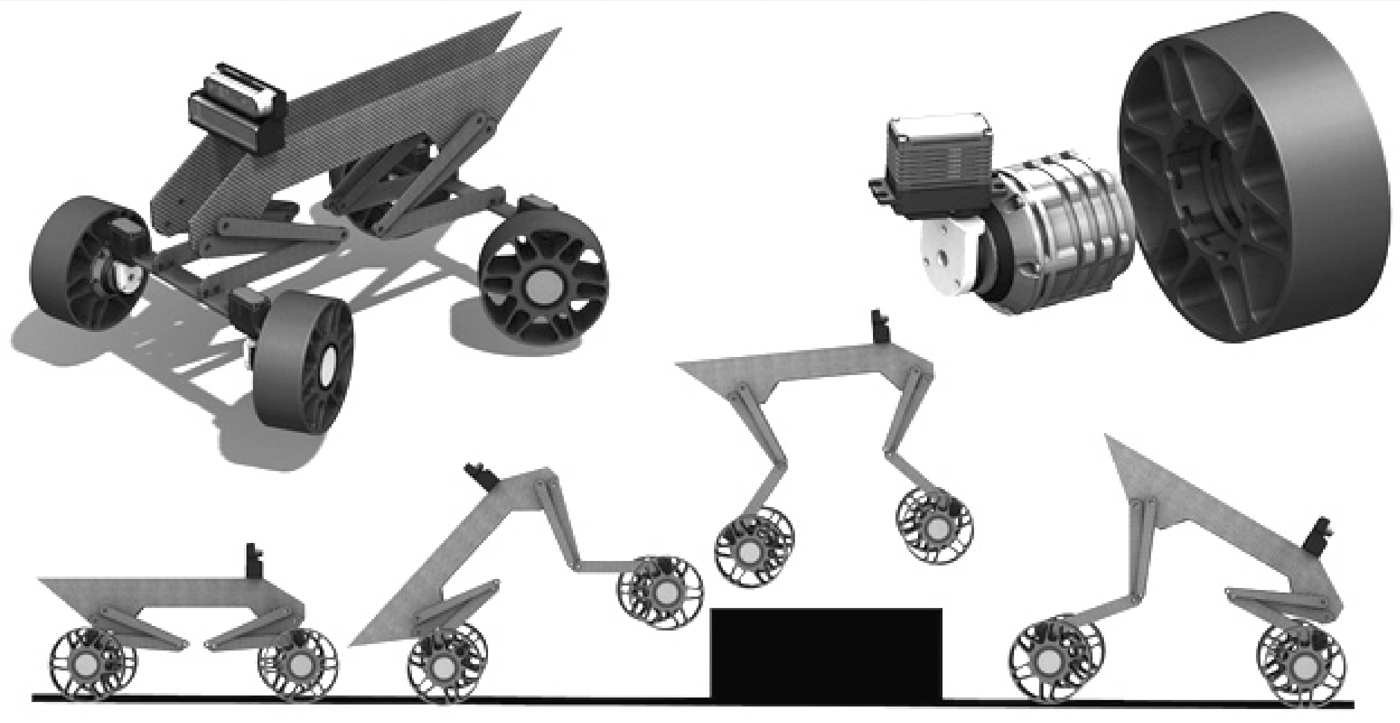
Throwable Robot Car Always Lands on Four Wheels

Hrishikesh Gajanan Mane
TY Mechanical

Throwable or droppable robots seem like a great idea for a bunch of applications, including exploration and search and rescue. But such robots do come with some constraints—namely, if you're going to throw or drop a robot, you should be prepared for that robot to not land the way you want it to land. While we've seen some creative approaches to this problem, or more straightforward self-righting devices, usually you're in for significant trade-offs in complexity, mobility, and mass.

What would be ideal is a robot that can be relied upon to just always land the right way up. A robotic cat, of sorts. And while we've seen this with a tail, for wheeled vehicles, it turns out that a tail isn't necessary: All it takes





is some wheel spin.

The reason that AGRO (Agile Ground RObot), developed at the U.S. Military Academy at West Point, can do this is because each of its wheels is both independently driven and steerable. The wheels are essentially reaction wheels, which are a pretty common way to generate forces on all kinds of different robots, but typically you see such reaction wheels kludged onto these robots as sort of an afterthought—using the existing wheels of a wheeled robot is a more elegant way to do it.

Four steerable wheels with in-hub motors provide control in all three axes (yaw, pitch, and roll). You'll notice that when the robot is tossed, the wheels all toe inwards (or outwards, I guess) by 45 degrees, positioning them orthogonal to the body of the robot. The front left and rear right wheels are spun together, as are the front right and rear left wheels. When one pair of wheels spins in the same direction, the body of the robot twists in the opposite way along an axis between those wheels, in a combination of pitch and roll. By combining different twisting torques from both pairs of wheels, pitch and roll along each axis can be adjusted independently. When the same pair of wheels spin in directions opposite to each other, the robot yaws, although yaw can also be derived by adjusting the ratio between pitch authority and roll authority. And lastly, if you want to sacrifice pitch control for more roll control (or vice versa) the wheel toe-in angle can be changed. Put all this together, and you get an enormous amount of mid-air control over your robot.

According to a paper that the West Point group will present at the 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), the overall objective here is for the robot to reach a state of zero pitch or roll by the time the robot impacts with the ground, to distribute the impact as much as possible. AGRO doesn't yet have a suspension to make falling actually safe, so in the short term, it lands on a foam pad, but the mid-air adjustments it's currently able to make result in a 20 percent reduction of impact force and a 100 percent reduction in being sideways or upside-down.

The toss that you see in the video isn't the most aggressive, but lead author Daniel J. Gonzalez tells us that AGRO can do much better, theoretically stabilizing from an initial condition of 22.5 degrees pitch and 22.5 degrees roll in a mere 250 milliseconds, with room for improvement beyond that through optimizing the angles of individual wheels in real time. The limiting factor is really the amount of time that AGRO has between the point at which it's released and the point at which it hits the ground, since more time in the air gives the robot more time to change its orientation.

Given enough height, the current generation of AGRO can recover from any initial orientation as long as it's spinning at 66 rpm or less. And the only reason this is a limitation at all is because of the maximum rotation speed of the in-wheel hub motors, which can be boosted by increasing the battery voltage, as Gonzalez and his colleagues, Mark C. Lesak, Andres H. Rodriguez, Joseph A. Cymerman, and Christopher M. Korpela from the Robotics Research Center at West Point, describe in the IROS paper, "Dynamics and Aerial Attitude Control for Rapid Emergency Deployment of the Agile Ground Robot AGRO."

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While these particular experiments focus on a robot that's being thrown, the concept is potentially effective (and useful) on any wheeled robot that's likely to find itself in mid-air. You can imagine it improving the performance of robots doing all sorts of stunts, from driving off ramps or ledges to being dropped out of aircraft. And as it turns out, being able to self-stabilize during an airdrop is an important skill that some Humvees could use to keep themselves from getting tangled in their own parachute lines and avoid mishaps.Before they move on to Humvees, though, the researchers are working on the next version of AGRO named AGRO 2. AGRO 2 will include a new hybrid wheel-leg and non-pneumatic tire design that will allow it to hop up stairs and curbs, which sounds like a lot of fun to us.

Fuel Cells a Power Up

Neha Vijay Bhosale
B.Tech ETC

When ShouzhongZou and his team at the Department of Chemistry, American University, decided to try spinach as way to improve the performance of fuel cells, even they were a little surprised at how well it worked. In their proof-of-concept experiments, they used spinach—bought from local supermarkets—to make a carbon-rich catalyst that can be used in fuel cells and metal-air batteries.

The spinach was a used a precursor for high-performance catalysts required for the oxygen reduction reactions (ORRs) in fuel cells. Traditionally, fuel cells have used platinum-based catalysts, but not only is platinum very expensive and difficult to obtain, it can be vulnerable to chemical poisoning in certain conditions. Consequently, researcher have looked into biomass-derived, carbon-based, catalysts to replace platinum, but there have been bottlenecks in preparing the materials in a cost-effective and non-toxic way. "We were a little bit lucky to pick up spinach," says Zou, because of its high iron and nitrogen content. "At this point [our method] does require us to add a little bit more nitrogen into the starting material, because even though [spinach] has a lot of nitrogen to begin with, during the preparation process, some of this nitrogen gets lost."

Zou and his team weren't the first to discover the electrochemical wonders of spinach, of course, even though other studies have used the leafy greens for other purposes. For example, a 2014 study harvested activated carbon from spinach to create capacitor electrodes, while a more recent paper tackled spinach-based nanocomposites as photocatalysts. Spinach, apart from being abundant in iron and nitrogen (both essential in ORRs), is easy to cultivate, and "definitely cheaper than platinum," Zou adds.

The preparation of the spinach-based catalyst sounds as first suspiciously like a smoothie recipe at first—wash fresh leaves, pulverize into a juice, and freeze-dry. This freeze-dried juice is then ground into a powder, to which melamine is added as a nitrogen promoter. Salts like sodium chloride and potassium chloride—"pretty much like the table salt that we use in our kitchen," says Zou—are also added, necessary for creating pores that increase the surface area available for reactions. Nanosheets are produced from the spinach–melamine–salt composites by pyrolyzing them at 900 C a couple of times. "Obviously… we can optimize how we prepare this material [to make it more efficient]."

An efficient catalyst means a faster, more efficient reaction. In the case of fuel cells, this can increase the energy output of batteries. This is where the porosity of the nanosheets helps. "Even though we call them nanosheets," Zou says, "when they are stacked together, it's not like a stack of paper that is very solid." The addition of salts to create tiny holes that allows oxygen to penetrate the material rather than access only the outer surfaces. "We need to make it porous enough that…all the active sites can be used."

The other factor that favorably disposed the American University team towards spinach was that it is a renewable source of biomass. "Sustainability is a very important factor in our consideration," says Zou. The big question to explore, he adds, is how can we avoid competition "with the dinner table". (Biofuel production has already raised concerns about food crops being diverted away from hungry mouths.) "And the second is, how do we keep the carbon footprint down in terms of his catalyst preparation…because currently we do use high temperatures in our preparation procedure?… If we can find different ways to do these to achieve the same type of material, that will cut back the energy consumption and reduce significantly the carbon footprint."

Even though the results are promising, there is yet a long way to go. Zou cautions that the study so far is only a proof-of-principle. "We need to be very careful when we talk about practical applications because something that shows excellent performance in [lab] conditions could become more challenging when we implement them in the real device." Another aspect that needs further study, he adds, is that while the spinach-derived catalyst outperforms platinum-based catalysts in alkaline conditions, the performance in an acidic medium is not as efficient. "So obviously, there is still some tuning we need to do to see if they can work through a range of pH."

A complete prototype is obviously a next step—testing the catalyst derived from spinach in a fuel cell. "That's the kind of expertise I don't have in my lab at this point," Zou admits. "We are thinking about collaborating with other groups, or we can build up our expertise in this area, because it's a necessary step."

Airbus Plans Hydrogen-Powered Carbon-Neutral Planes by 2035. Can They Work?

Shubham Shivaji Patil
BE Mechanical Engg.

Imagine that it is December 2035 – about 15 years from now – and you are taking an international flight in order to be at home with family for the holidays. Airports and planes have not changed much since your childhood: Your flight is late as usual. But the Airbus jet at your gate is different. It is a giant V-shaped blended-wing aircraft, vaguely reminiscent of a boomerang. The taper of the wings is so gentle that one cannot really say where the fuselage ends and the wings begin. The plane is a big lifting body, with room for you and 200 fellow passengers.

One other important thing you notice before you board: The plane is venting vapor, a lot of it, even on a crisp morning. That, you know, is because the plane is fueled by liquid hydrogen, cooled to -253 degrees C, which boils off despite the plane's extensive insulation. This is part of the vision Airbus, the French-based aviation giant, presents as part of its effort against global climate

change.

Airbus is now betting heavily on hydrogen as a fuel of the future. It has just unveiled early plans for three "ZEROe" airliners, each using liquid hydrogen to take the place of today's hydrocarbon-based jet-fuel compounds.

"It is really our intent in 15 years to have an entry into service of a hydrogen-powered airliner," says Amanda Simpson, vice president for research and technology at Airbus Americas. Hydrogen, she says, "has the most energy per unit mass of…well, anything. And because it burns with oxygen to [yield] water, it is entirely environmentally friendly."

But is a hydrogen future realistic for commercial aviation? Is it practical from an engineering, environmental, or economic standpoint? Certainly, people at Airbus say they need to decarbonize, and research on battery technology for electric planes has been disappointing. Meanwhile, China, currently the world's largest producer of carbon dioxide, pledged last month to become carbon neutral by 2060. And 175 countries have signed on to the 2015 Paris agreement to fight global warming.

According to the European Commission, aviation alone accounts for between 2 and 3 percent of the world's greenhouse gas emissions – about as much as entire countries like Japan or Germany.

Two of the planes Airbus has shown in artist renditions would barely get a second glance at today's airports. One—with a capacity of 120-200 passengers, a cruising speed of about 830 kilometers per hour (kph), and a range of more than 3,500 km—looks like a conventional twin-engine jet. The second looks like almost any other turboprop you've ever seen; it's a short-haul plane that can carry up to 100 passengers with a range of at least 1,800 km and a cruising speed of 612 kph. Each plane would get electric power from fuel cells. The company said it won't have most other specifications for several years; it said to think of the images as "concepts," meant to generate ideas for future planes.

he third rendering, an illustration of that blended-wing aircraft, showed some of the potential—and potential challenges—of hydrogen as a fuel. Airbus said the plane might have a cruising speed of 830 kph and a range of 3,500 km, without releasing carbon into the air. Liquid hydrogen contains about three times as much energy in each kilogram as today's jet fuel. On the other hand, a kilogram of liquid hydrogen takes up three times the space. So, a plane would need either to give up cabin space or have more inside volume. A blended wing, with its bulbous shape, Airbus says, may solve the problem. And as a bonus, blended wings have shown they can be 20 percent more fuel-efficient than today's tube-and-wing aircraft.

"My first reaction is: Let's do it. Let's make it happen," says Daniel Esposito, a chemical engineer at Columbia University whose research covers hydrogen production. He says hydrogen can be handled safely and has a minimal carbon footprint if it's made by electrolysis (splitting water into hydrogen and oxygen) using renewable electricity. Most industrial hydrogen today is extracted from natural gas, which negates some of the carbon benefit, but the International Energy Agency says that with renewable electricity capacity quickly growing (it passed coal as a power source in 2019), the cost of carbon-free hydrogen could drop.

"It can be done," he says. "It's just a matter of the political will and the will of companies like Airbus and Boeing to take the lead on this."

Others have their doubts. "A lot of these things, you can; the question is, should you?" says Richard Pat Anderson, a professor of aerospace engineering at Embry-Riddle Aeronautical University. "When we say, 'Should you?' and you get into economics, then it becomes a much more difficult conversation." Anderson says battery-powered aircraft are likely to become practical later in this century, and it is a dubious proposition to build the massive – and costly – infrastructure for hydrogen power in the meantime.

But in a warming world, Airbus says, the aviation sector needs to get going. McKinsey & Company, the consulting firm, surveyed airline customers last year and found 62 percent of younger fliers (under age 35) "really worried about climate change" and agreed that "aviation should definitely become carbon neutral."

So, you're on that jetway 15 years from now, on the way home. What will power the plane you're boarding?

"Hydrogen is coming," says Simpson at Airbus. "It's already here."

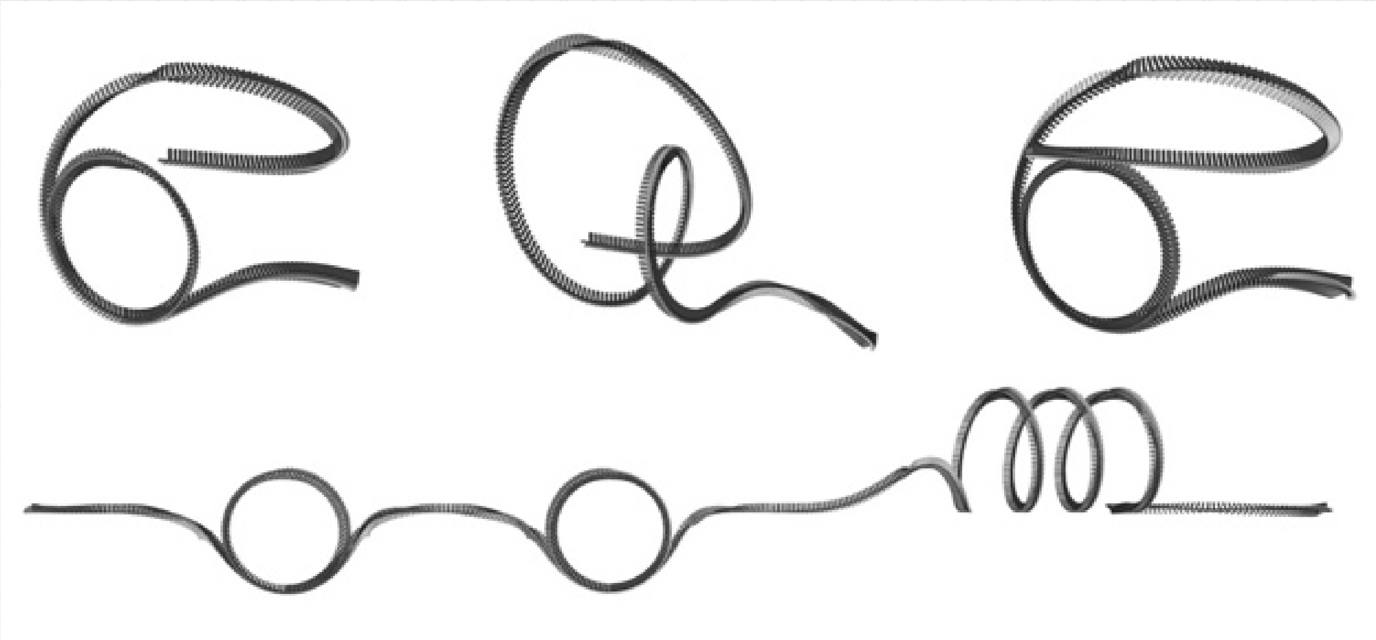
AI-Powered Drone Learns Extreme Acrobatics

Priyanka Mahajan
B.Tech CSE

Quadrotors are among the most agile and dynamic machines ever created. In the hands of a skilled human pilot, they can do some astonishing series of maneuvers. And while autonomous flying robots have been getting better at flying dynamically in real-world environments, they still haven't demonstrated the same level of agility of manually piloted ones.

Now researchers from the Robotics and Perception Group at the University of Zurich and ETH Zurich, in collaboration with Intel, have developed a neural network training method that "enables an autonomous quadrotor to fly extreme acrobatic maneuvers with only onboard sensing and computation." Extreme.

There are two notable things here: First, the quadrotor can do these extreme acrobatics outdoors without any kind of external camera or motion-tracking system to help it out (all sensing and computing is onboard). Second, all of the AI training is done in simulation, without the need for an additional simulation-to-real-world (what researchers call "sim-to-real") transfer step. Usually, a sim-to-real transfer step means putting your quadrotor into



one of those aforementioned external tracking systems, so that it doesn't completely bork itself while trying to reconcile the differences between the simulated world and the real world, where, as the researchers wrote in a paper describing their system, "even tiny mistakes can result in catastrophic outcomes."

To enable "zero-shot" sim-to-real transfer, the neural net training in simulation uses an expert controller that knows exactly what's going on to teach a "student controller" that has much less perfect knowledge. That is, the simulated sensory input that the student ends up using as it learns to follow the expert has been abstracted to present the kind of imperfect, imprecise data it's going to encounter in the real world. This can involve things like abstracting away the image part of the simulation until you'd have no way of telling the difference between abstracted simulation and abstracted reality, which is what allows the system to make that sim-to-real leap.

The simulation environment that the researchers used was Gazebo, slightly modified to better simulate quadrotor physics. Meanwhile, over in reality, a custom 1.5-kilogram quadrotor with a 4:1 thrust to weight ratio performed the physical experiments, using only a NvidiaJetson TX2 computing board and an Intel RealSense T265, a dual fisheye camera module optimized for V-SLAM. To challenge the learning system, it was trained to perform three acrobatic maneuvers plus a combo of all of them:

All of these maneuvers require high accelerations of up to 3 g's and careful control, and the Matty Flip is particularly challenging, at least for humans, because the whole thing is done while the drone is flying backwards. Still, after just a few hours of training in simulation, the drone was totally real-world competent at these tricks, and could even extrapolate a little bit to perform maneuvers that it was not explicitly trained on, like doing multiple loops in a row. Where humans still have the advantage over drones is (as you might expect since we're talking about robots) is quickly reacting to novel or unexpected situations. And when you're doing this sort of thing outdoors, novel and unexpected situations are everywhere, from a gust of wind to a jealous bird.

Use Your Bike as a Backup to Your Backup Power Supply

Vaibhav Niwas Patil
B.Tech Mechanical

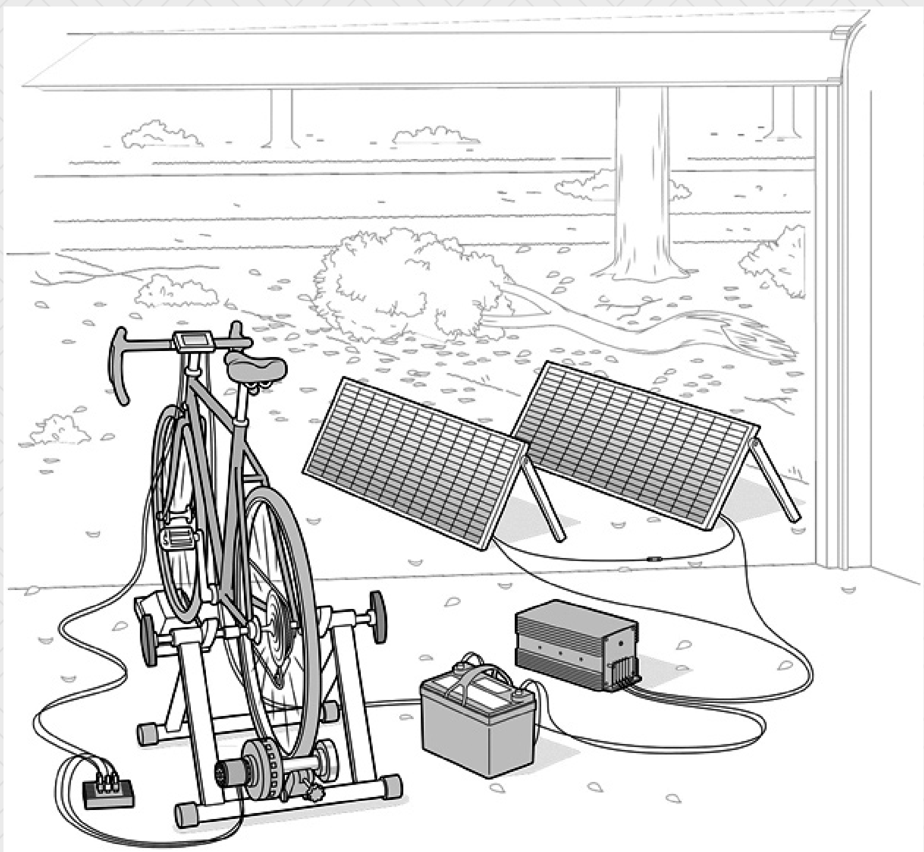
As this article goes to press, Hurricane Delta is making landfall not far from where Hurricanes Sally and Laura came ashore earlier in the season. I live on the East Coast of the United States, and fairly far inland, so such storms are not as frequent or intense as they are in states bordering on the Gulf of Mexico. But they are still a concern, if only because they can topple trees and cause widespread power outages. And ice storms during the winter here are also apt to bring down power lines.

I don't mind the resulting darkness so much. What I really don't relish, though, is losing Internet access—especially now that it is my main connection to the world due to the pandemic. And the pandemic is reducing the number of field crews available to fix power lines, making outages last that much longer. So this year, I figured I'd get prepared for a blackout in the most self-sufficient way possible.

I could, of course, just purchase a conventional small gasoline-powered generator. But I didn't want to do that for a few reasons. In particular, I recalled stories about what went on after Hurricane Sandy in 2012, when many people using such backup generators had trouble finding fuel, including the IEEE Operations Center, in New Jersey.

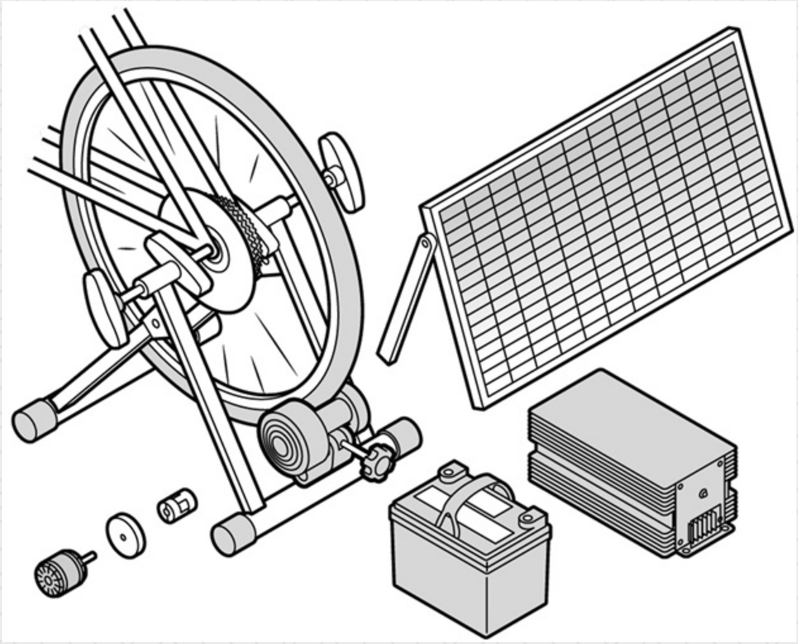
My first thought was to use photovoltaics, so I purchased two 100-watt panels on Amazon for less than US $1/W. I had a 35-ampere DC-to-DC converter from an earlier project to use as a charge controller, so my next step was to spec out a deep-cycle lead-acid battery to keep things going at night.

Some experiments with a watt meter led me to conclude that a battery of at least 300 watt-hours capacity could keep four laptops, a cable modem, and a wireless router running for about 4 hours, while also charging the family's phones and flashlights. That should get us through dark evenings. It would also suffice at a reduced



load if the sun were hidden behind clouds all day. So I purchased a 12-volt, 35-ampere-hour battery (which nominally can store 420 Wh).

But what if skies remained gray for many days in a row? Rather than trying to purchase enough battery storage to cover all reasonable eventualities, I decided that my backup source of electricity needed a backup itself, one that I could use to charge that battery during times when my photovoltaic panels won't function. When necessary, I'd simply detach the battery from the panels and attach it to my backup source to be recharged. I briefly considered whether a wind turbine might serve that role, but then opted for something I figured would be more dependable: my two legs.



Parallel Power: My system primarily relies on photovoltaic panels to charge a deep-cycle lead-acid battery via a DC-DC converter. When there's not enough sunlight to use the panels, I switch over to a generator driven by the back wheel of a conventional bike mounted in a stand. This requires a rectifier and a meter mounted on the handlebars to monitor the power produced and fed into the battery.

I cycle regularly for about an hour a day, during which I probably put out an average of 80 W, based on some rough calculations (I'm small and typically cycle around 22 kilometers per hour). That 80 Wh is only a fraction of what my solar panels can provide in a day, but it would be enough to keep my laptop connected to the Internet for a few hours, charge phones, and so forth. And pedaling my own power seemed like a healthy, stress reducing, activity to pass the time during a power outage.

I discovered from one blogger that it wouldn't be hard to modify a stationary bike stand to generate electrical power. Although I had a bike stand already, mine provides frictional drag using a fluid-filled chamber, which I was reluctant to crack open. Instead, I purchased one similar to the one that the blogger used, which employs magnets and eddy currents to create drag forces on a shaft that presses against the back wheel to increase exercise intensity.

I ripped out all that drag-inducing stuff and attached a brushless motor to the shaft using a flexible coupler and a wooden spacer. Then I connected the three leads of the motor—originally intended to motorize a skateboard and now acting as a generator—to a three-phase bridge rectifier. The output of the rectifier in turn is connected to my battery through a Drok meter. This meter allows me to monitor the voltage, current, wattage, and total energy produced.

Testing my power-producing bicycle stand quickly revealed a flaw in my logic. Pedaling at a comfortable pace, meaning one that I could keep up for a long time, produced only about 60 W, not 80. In retrospect, I decided that I had failed to consider the inefficiencies of power conversion, which surely are significant because my motor/generator gets pretty hot after a while. But even 60 Wh would do in a pinch. And there's no rule that says I couldn't cycle for longer than an hour. Even better, I can get my kids to contribute a little sweat to support their phone and computer use during the gray days of a winter power outage.

Actually, generating power with their muscles provides a valuable lesson for kids, whether or not the power goes out. Every time they switch on a lightbulb or a television, they will think more about what this energy consumption means, given the considerable effort it takes to produce those watts yourself.

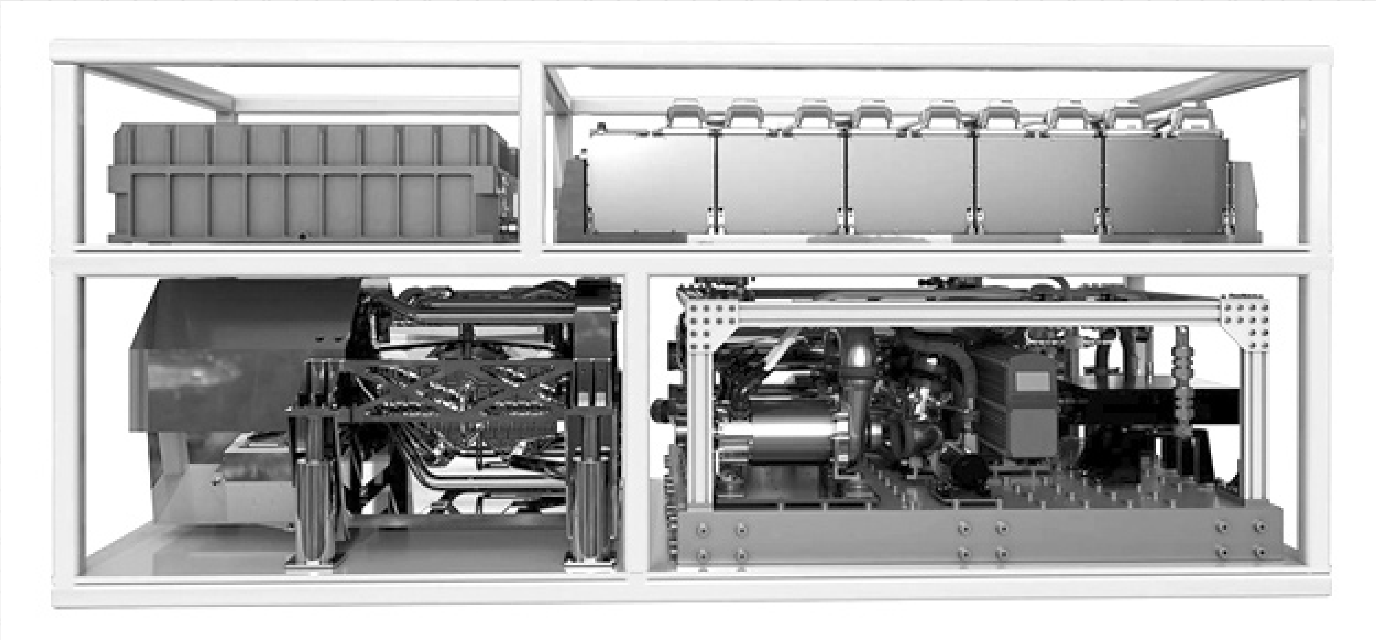
Liquid Lasers Challenge Fiber Lasers as the Basis of Future High-Energy Weapons

Pankaj Pundlik Kadam
T.Y. (Mechanical Engg.)

Despite a lot of progress in recent years, practical laser weapons that can shoot down planes or missiles are still a ways off. But a new liquid laser may be bringing that day closer.

Much of the effort in recent years has focused on high-power fiber lasers. These lasers usually specially doped coils of optical fibers to amplify a laser beam, and were in originally developed for industrial cutting and welding. Initially, fiber laser were dark horses in the Pentagon's effort to develop electrically powered solid-state laser weapons that began two decades ago. However, by 2013 the Navy was testing a 30-kilowatt fiber laser on a ship. Since then, their ability to deliver high-energy beams of excellent optical quality has earned fiber lasers the leading role in the current field trials of laser weapons in the 50- to 100-kilowatt class. But now aerospace giant Boeing has teamed with General Atomics—a defense contractor also known for research in nuclear fusion—to challenge fiber lasers in achieving the 250-kilowatt threshold that some believe will be essential for future generations of laser weapons. Higher laser powers would be needed for nuclear missile defense.

The challenging technology was developed to control crucial issues with high energy solid-state lasers: size, weight and power, and the problem of dissipating waste heat that could disrupt laser operation and beam quality. General Atomics "had a couple of completely new ideas, including a liquid laser. They were considered completely crazy at the time, but DARPA funded us," said company vice president Mike Perry in a 2016 interview. Liquid lasers are similar to solid-state lasers, but they use a cooling liquid that flows through channels integrated into the solid-state laser material. A crucial trick was ensuring that the cooling liquid has a refractive index exactly the same as that of the solid laser material. A perfect match of the liquid and solid could avoid any refraction or reflection at the boundary between them. Avoiding reflection or refraction in the the cooling liquid also required making the fluid flow smoothly through the channels to prevent turbulence.



The system promised to be both compact and comparatively lightweight, just what DARPA wanted to fit a 150-kW laser into a fighter jet. The goal was a device that weighed only 750 kilograms, or just 5 kg/kW of output. The project that went through multiple development stages of testing that lasted a decade. In 2015, General Atomic delivered the HELLADS, the High Energy Liquid Laser Area Defense System, rated as 150-kW class, to the White Sands Missile Range in New Mexico for live fire tests against military targets. A press release issued at the time boasted the laser held "the world's record for the highest laser output power of any electrically powered laser." At the time, General Atomics described it as a modular laser weapon weighing in at four kilograms per kilowatt.

Distributed gain laser modules can combine to produce over 250 kilowatts of laser output

Development has continued since then. A spokesperson says General Atomics is now on the seventh generation of their "Distributed gain laser heads," modules which can be combined to generate over 250 kW of laser output from a very compact package. Improvements over the past two years have enhanced beam quality and the ability to emit high-energy beams both continuously or in a series of pulses, giving more flexibility in attacking targets.

Sustaining good beam quality at that power level is important. Mike Griffin, former undersecretary of defense for research and engineering, told Congress that current fiber laser technology could be scaled to 300 kilowatts to protect air force tankers. However, that may be pushing the upper limits of how many beams from separate fiber lasers emitting at closely spaced wavelengths can be combined coherently to generate a single high-energy laser beam of high quality.

The agreement calls for use General Atomics to supplyintegrated thermal management equipment and a high-density modular high-power lithium-ion battery system able to store three megajoules of energy as well as the laser. Boeing will supply a beam director and software for precision acquisition and pointing technology that Boeing developed and supplied for other experimental laser weapon testbeds, including the Air Force's megawatt-class Airborne Laser, the last big chemically-powered gas laser, scrapped in 2014. "Together, we're leveraging six decades of directed energy experience and proven, deployed technologies," said NormTew, Boeing Missile and Weapon Systems vice president and general manager, and Huntsville site senior executive, in a statement.

UV Light Might Keep the World Safe From the Coronavirus—and Whatever Comes Next

Prajwal Pradip Chougule
T.Y. Mechincal Engg.

In this otherwise-ordinary Toronto-area office suite, you can disinfect your keys, phone, and other portables at the reception area's ultraviolet-sterilization stand. In cooler months, the air you breathe is cleansed of mold and bacteria in UV-sterilized heating units as well as blasted by UV fixtures in the office air ducts to eliminate viruses. In-room UV fixtures pointing at the ceiling disinfect the air, while other UV lights that turn on only when no one's in the room zap pathogens on desks, keyboards, and high-touch surfaces in bathrooms and work spaces.

The office, says PrescientX founder and CEO Barry Hunt, represents a possible future in which pandemics like COVID-19 are more commonplace—but in which germicidal ultraviolet light is one of the most potent weapons we have to face them down.

For nearly a century and a half, scientists have been investigating ultraviolet light's deadly effect on germs. In recent times, UV was deployed as a disinfectant against deadly coronavirus particles during the SARS outbreak in 2003. And as soon as the new coronavirus began spreading in earnest in China late last year, UV returned as a potentially powerful weapon to fight this new scourge. While antiviral drugs and vaccines concentrate on minimizing and repelling infections in the body, the ultraviolet systems being deployed focus on killing the virus in the environment, before it has a chance to infect anyone.

Germicidal UV technology is now being used to sterilize air, surfaces, and personal protective equipment like N95 masks. Meanwhile, experts in the field are devoting much of their time to educating the public about the technology's effectiveness against the coronavirus—and outbreaks and pandemics yet to come. The main hurdle for germicidal UV, says Dean Saputa, vice president and cofounder of UV Resources, a Santa Clarita, Calif.–based UV technology company, "is overcoming the lack of...understanding about this technology."

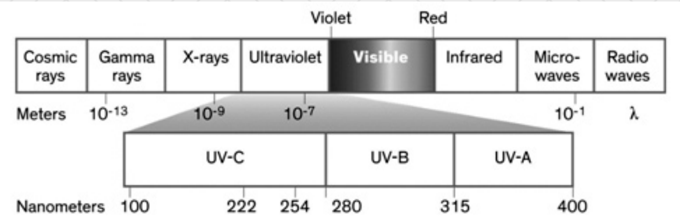
For starters, experts point out, not all ultraviolet rays are created equal. Ultraviolet light lies in a region of the electromagnetic spectrum beyond indigo and violet. Anyone who's read the label on a bottle of sunscreen knows the UV wavelengths that give you a suntan or a sunburn are called UV-A (with wavelengths between 400 and 315 nanometers) and UV-B (315 to 280 nm). Germicidal UV tech focuses on shorter, more energetic UV wavelengths, known as UV-C, which lie between 280 and 100 nm. The Earth's ozone layer prevents virtually all UV-C light from

reaching us. So microbes and viruses (and everything else, really) evolved for millions and billions of years without ever being exposed to these wavelengths.

That changed in 1901, with the invention of the mercury-vapor lamp. It produces a potent wavelength of UV-C light—254 nm—that has proved devastating for nearly any genetic material in its path, including that of a coronavirus or a human.

Much of the trick to wielding germicidal UV light against the spread of disease lies in finding a way to keep people safe from that light. Those involved have already built up a lot of expertise in that area, but new technology could make the job of using UV-C in occupied spaces easier.

While UV-C light has been used successfully against germs for more than a century, it's only recently that researchers have understood why it's so successful. In DNA's four-letter alphabet of nucleotides, thymine (T) and cytosine (C) are particularly susceptible to UV. The UV knocks an electron loose and causes two T molecules or two C molecules to bond together, introducing an error into a string of DNA. Humans have genetic self-repair mechanisms, including a molecule called p53. This protein (sometimes referred to as the "guardian of the genome") patrols DNA strands and looks for just this kind of nucleotide damage. But p53 can do only so much. Too



much damage overwhelms it and can lead to cancer.

Death Rays: UV-C is at the far end of the ultraviolet portion of the spectrum. Most UV-C products use mercury-vapor lamps, which shine at 254 nanometers. Scientists are exploring another wavelength, 222 nm, because it may be safer for use around humans.

SARS-CoV-2, the virus that causes COVID-19, lacks such sophisticated self-repair mechanisms, and its genetic material is made up of RNA rather than DNA. RNA contains uracil instead of thymine, but the effect of UV-C is essentially the same: Genetic damage accumulates and the virus is destroyed.

The main hitch with UV-C light in the 254-nm range is that it penetrates human skin and eyes, leading to ski n cancer and cataracts. So UV-C's DNA-smashing effect means that any disinfecting device that uses it has to be designed to operate either when no one is in the room or in a self-contained space where humans can't go.

Researchers have been trying to balance the benefits and dangers of UV-C for decades. In the late 1930s and early 1940s, the U.S. epidemiologist William F. Wells installed UV-C–emitting mercury-vapor lamps in Philadelphia schools to combat an outbreak of measles, as a follow-up to his groundbreaking work that showed airborne bacteria and viruses could cause infection. The fixtures were designed to irradiate the air only in the upper portion of the room, to protect students and staff from exposure to the rays. And they worked. Schools that had the air-sanitizing equipment experienced a 13.3 percent infection rate compared with 53.6 percent for the population at large.

Germicidal UV in most commercial and industrial settings today still comes from mercury-vapor lamps, says PrescientX's Hunt. These devices have a spectral peak at 254 nm. That emission is the result of an arc of electricity that ionizes (typically) argon gas and vaporizes liquid mercury. Glass would block the radiation, so these lamps are made of quartz instead.

UV-C–emitting LEDs, made from alloys of aluminum nitride, are much newer and have a number of potential advantages over mercury lamps—no toxic mercury, greater durability, faster startup, and emission at a diversity of wavelengths, which may aid in their germicidal role. Most important, though, is UV-C LEDs' theoretical potential for higher efficiency. That potential is as yet unrealized, however. Jae-hakJeong, technical research fellow and vice president at Seoul Semiconductor, told IEEE Spectrum that today's mercury lamps have a higher wall-plug efficiency—electrical power in versus optical power out—than the UV-C LEDs on the market now. But mercury lamps' advantage is not expected to last, because researchers predict UV-C LEDs to improve in much the same way that blue LEDs did to reach their dominant position in lighting. For now though, UV-C LEDs aren't powerful enough to sterilize more than small

volumes of air or nearby surfaces.

Recent experience with UV-C light confirms what Wells found in the 1930s: Air disinfection with 254-nm UV light is “very effective,” Hunt says. Direct illumination of the air in the upper part of a room produces better throughput than irradiating the air inside HVAC units, he adds. According to the Illuminating Engineering Society, 17 milliwatts of 254-nm-lamp radiation per cubic meter of upper-air space is the evidence-based dose developed to control tuberculosis. However, some bacteria, viruses, and other microorganisms are more resistant to UV-C light than others.

The Air Up There: AeroMed Infinity germicidal UV-C fixtures installed near the ceilings at Kings County Hospital Center, in New York City, help keep aerosolized coronavirus particles from spreading where patients wait.

At that dose, upper-air fixtures can destroy germs in the lamps’ direct line of sight “in a matter of seconds,” says Saputa of UV Resources. To keep humans safe, the fixtures, which typically cost a few thousand dollars each, are placed at heights above 2 meters, and nonreflective baffles direct the ultraviolet energy upward and outward. (UV-C reflects poorly off of most surfaces, so there’s little danger of exposure from rays bouncing off ceilings and other fixtures; nonetheless, installers must make sure by using UV-C meters.) Such installations can be used in a variety of settings, including patient rooms, waiting rooms, lobbies, stairwells, and emergency-room entrances and corridors.

Air isn’t the only thing that needs disinfecting. During the pandemic, UV-wielding robots in hospitals and UV germ zappers in airplanes and subway cars have joined a host of technologies being rolled out to disinfect surfaces.

The main difference between these systems and UV air sterilizers is that the former can’t operate when people are present, so they're not continuously keeping areas virus-free. "Design engineers must keep in mind disinfection only lasts until people are placed into that hospital bed or sit in that airplane seat," says Saputa.

But sporadic disinfection is preferable to none at all. Before this year, Carlsbad, Calif.–based Cleanbox Technology had been developing a UV-C LED box to sterilize virtual-reality and augmented-reality headsets. The company's system was readily adaptable to sterilizing N95 masks, says Cleanbox's chief technology officer and cofounder David Georgeson.

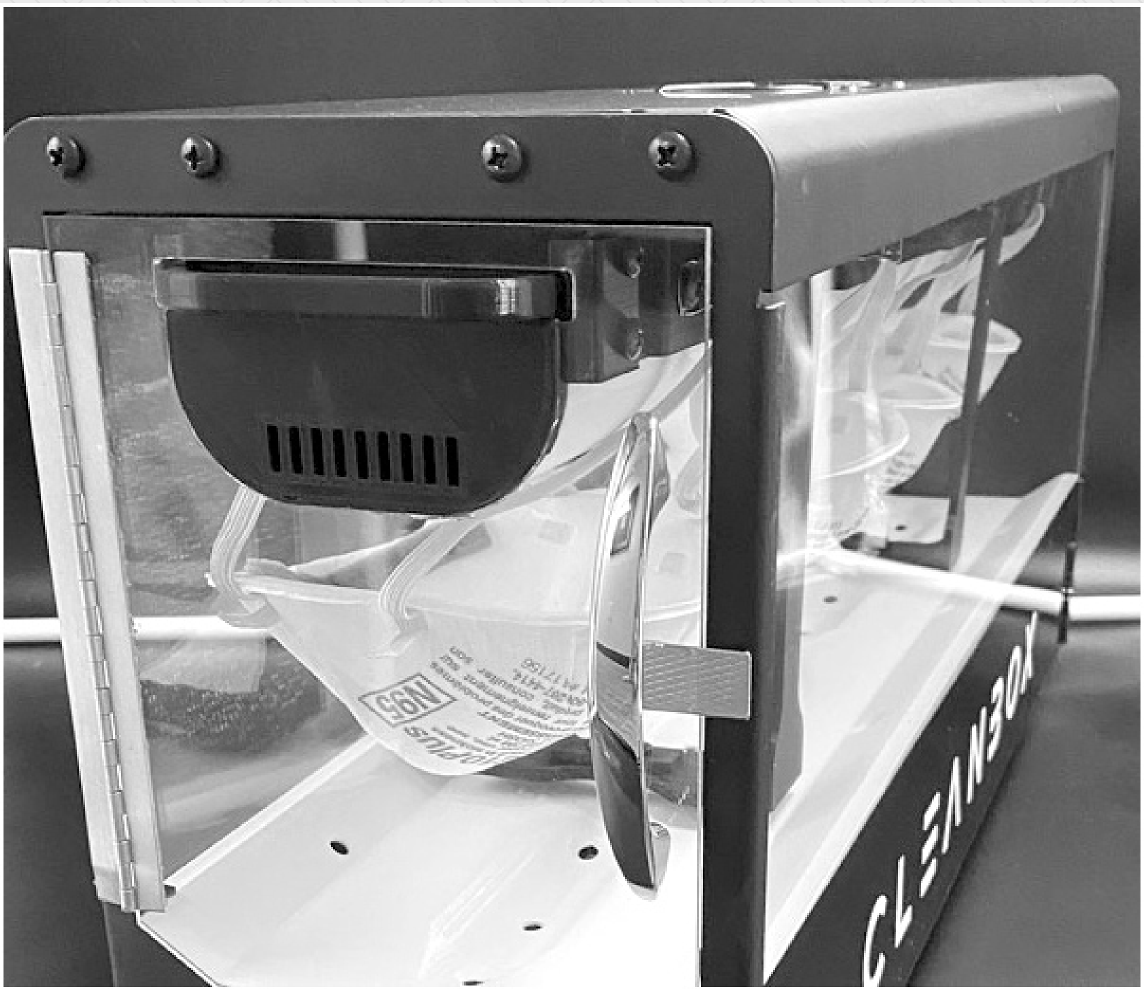
The result, the CleanDefense N95 sanitizing light box, can hold four masks at a time. The box is portable and powered from the wall or a battery bank, enabling use in mobile environments like ambulances and airplanes as well as in health care settings, restaurants, and shopping centers.

The challenge with this technology and any other type of UV disinfection is that "the radiation has to actually strike the virus to break the [RNA] and inactivate it," says Robert Karlicek, director of Rensselaer Polytechnic Institute's Center for Lighting Enabled Systems & Applications, in Troy, N.Y. "If those virus particles are sitting behind dirt or covered by another fiber, you'd have to scatter a lot of light before you got a good kill rate."

The problem is illustrated by what's called the "canyon wall" effect. To bacteria and viruses, textural features on common surfaces can be like 100-meter-deep canyons would be to us. In experiments with surfaces having submillimeter texture, UV-C's kill rate against the bacteria Staphylococcus aureus varied as much as 500-fold depending on the angle at which the mercury lamp's light fell.

That dependence on angle is why it typically takes three UV systems to disinfect a hospital room, according to Marc Verhougstraete, assistant professor of public health at the University of Arizona. Even then, there are still unexposed areas. So for that application, UV-C surface sanitizers should be part of a system that includes routine surface disinfection, hand hygiene, and air treatment, he says.

Getting a thorough dosage from more than one angle is key to sanitizing N95 masks for reuse. Karlicek and his team developed a mercury-lamp N95-mask sterilizer that was tested at Mount Sinai Hospital in New York City. It



uses two sets of UV lamps to irradiate the front and back of the masks at the same time. PrescientX is also getting into the N95-mask-sterilization business with a UV-C light box called Terminator CoV. And there are other systems in various states of development and commercialization as well.

The precise UV-C dose needed to inactivate a SARS-CoV-2 virus particle is yet to be determined, says PrescientX CEO Hunt. But, he adds, a number of peer-reviewed studies have looked at UV-C doses for the H5N1 and H1N1 strains of influenza and for previous coronavirus outbreaks, including MERS and SARS. Experts think it's reasonable to assume that a similar amount of energy will inactivate the coronavirus that causes COVID-19.

Those studies all found that irradiating masks with 1 to 2 joules of UV-C energy per square centimeter was sufficient to inactivate between 99.9 and 99.99 percent of the virus particles on the mask. That said, eliminating coronavirus particles is not just a numbers game. If the sterilization unit casts any shadows on the mask, that mask will not be fully disinfected. That's why these systems are designed with fasteners and hooks that stretch the mask and minimize shadows.

"You need intensity and geometry to get rid of the virus," Hunt says.

Given the harmful effects of 254-nm UV-C, scientists are exploring the higher-energy wavelength of 222 nm, in the far-UV region. This wavelength has been found to kill viruses and bacteria, and initial studies show that it's substantially safer than photons in the 254-nm range. In fact, far-UV may be able to safely bathe an entire room in sterilizing light, even with people present.

Far-UV light at 222 nm "hardly penetrates the outer layer of skin," says David Sliney, retired manager of the U.S. Army's Laser and Optical Radiation Program at the Army Public Health Center, near Baltimore. "It's heavily absorbed by protein. But there is some evidence that it may even be more effective against airborne viruses" than other UV light. The wavelength appears to be safe for the eyes as well because it penetrates no deeper than the layer of tears that coat the eye. A 2019 study of albino rats in Japan found prolonged far-UV exposure induced no skin or eye damage.

At present, far-UV is generated by krypton-chlorine excimer lamps. ("Excimer" is a portmanteau of "excited" and "dimer," meaning an excited state of a two-part molecule.) Inside the sealed quartz-glass chamber of such a lamp, krypton and chlorine are heated by electric discharge whose energy is sufficient to momentarily create a KrClexcimer, which spits out a 222-nm spectral line before dissociating again.

However, these light sources don't just give off far-UV light. "Excimer lamps produce a peak at 222 nm, but they also produce [longer]-wavelength light," explains David Brenner, director of Columbia University's Center for Radiological Research, in New York City. "And that is damaging, because it doesn't have the protective properties of 222 nm. It can penetrate [skin] and damage DNA."

Filters can eliminate the extraneous wavelengths, but Brenner says a better solution would be a far-UV LED lamp with a narrow spectral profile right at 222 nm. Such an LED does not yet exist. "LEDs have been coming down in wavelength for a long time," he says. "Once you go down below 250, 240, 230 [nm], the efficiency falls off dramatically. It's like a cliff."

So in the near term, excimer lamps are the best hope. Brenner expects such lamps to be on the market by the end of this year or early 2021.

Despite this arsenal of ultraviolet technologies—UV-C LEDs, mercury vapor lamps, and KrClexcimer lamps—the current pandemic may yet come and go before the world has rolled out germicidal UV broadly enough to make a big impact. And so experts are already planning for the next dangerous pathogen, and when it comes, they hope to greet it with a phalanx of UV air purifiers and surface sterilizers in hospitals, airports, public transit, offices, schools, nursing homes, stores, restaurants, elevators, and elsewhere. The ubiquity of UV technology should make it much harder for an outbreak to spread, perhaps preventing a lethal contagion from ever becoming a pandemic.

Coming Soon to a Processor Near You: Atom-Thick Transistors

Rohan Kumar Kumbhar
B.Tech ETC

If there's one thing about Moore's Law that's obvious to anyone, it's that transistors have been made smaller and smaller as the years went on. Scientists and engineers have taken that trend to an almost absurd limit during the past decade, creating devices that are made of one-atom-thick layers of material.

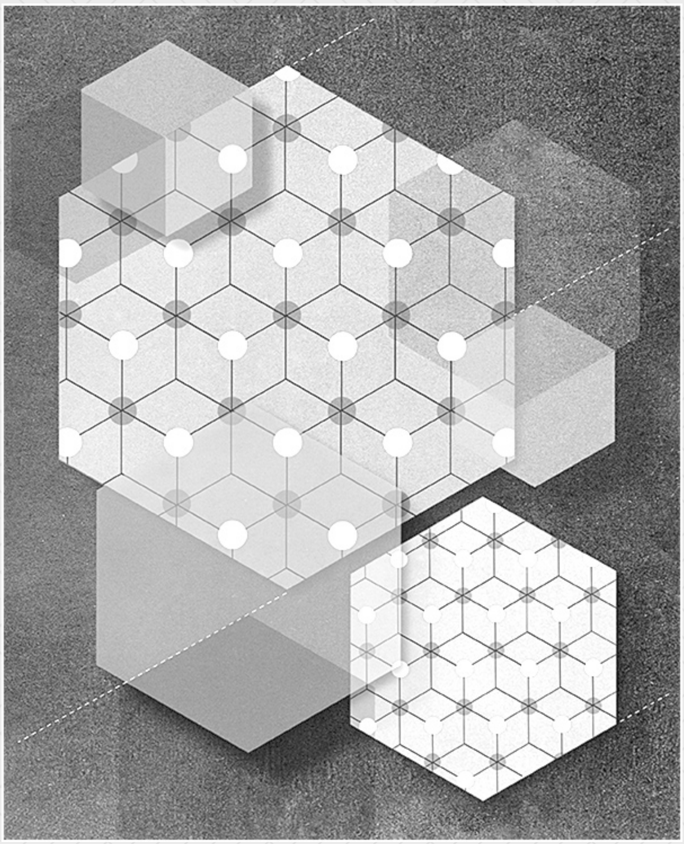
The most famous of these materials is, of course, graphene, a hexagonal honeycomb-shaped sheet of carbon with outstanding conductivity for both heat and electricity, odd optical abilities, and incredible mechanical strength. But as a substance with which to make transistors, graphene hasn't really delivered. With no natural bandgap—the property that makes a semiconductor a semiconductor—it's just not built for the job.

Instead, scientists and engineers have been exploring the universe of transition metal dichalcogenides, which all have the chemical formula MX2. These are made up of one of more than a dozen transition metals (M) along with one of the three chalcogenides (X): sulfur, selenium, or tellurium. Tungsten disulfide, molybdenum diselenide, and a few others can be made in single-atom layers that (unlike graphene) are natural semiconductors. These materials offer the enticing prospect that we will be able to scale down transistors all the way to atom-thin components long after today's silicon technology has run its course.

While this idea is really exciting, I and my colleagues at Imec believe 2D materials could actually show up much sooner, even while silicon still remains king. We've been developing a technology that could put 2D semiconductors to work in silicon chips, enhancing their abilities and simplifying their designs.

Devices made with 2D materials are worth all the scientific and engineering work we and other researchers around the world have put into them because they could eliminate one of the biggest problems with today's transistors. The issue, the result of what are called short-channel effects, is a consequence of the continual shrinking of the transistor over the decades.

A metal-oxide semiconductor field-effect transistor



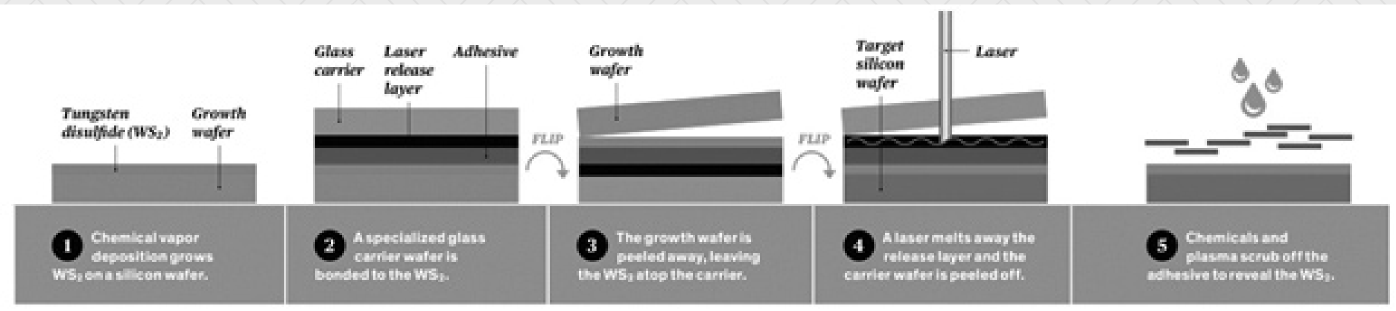
"I have not failed. I've just found 10,000 ways that won't work." -Thomas A. Edison

(MOSFET), the type of device in all digital things, is made up of five basic parts: The source and drain electrodes; the channel region that connects them; the gate dielectric, which covers the channel on one or more sides; and the gate electrode, which contacts the dielectric. Applying a voltage at the gate relative to the source creates a layer of mobile charge carriers in the channel region that forms a conductive bridge between the source and drain, allowing current to flow.

But as the channel was made smaller and smaller, current would increasingly leak across it even when there was no voltage on the gate, wasting power. The change from the planar designs of the 20th century to the FinFET transistor structure used in today's most advanced processors was an attempt to counter this important short-channel effect by making the channel region thinner and having the gate surround it on more sides. The resulting fin-shaped structure provides better electrostatic control. (The coming move to the nanosheet transistor is a furthering of this same idea.

Certain 2D semiconductors could circumvent short-channel effects, we think, by replacing the silicon in the device channel. A 2D semiconductor provides a very thin channel region—as thin as a single atom if only one layer of semiconductor is used. With such a restricted pathway for current to flow, there is little opportunity for charge carriers to sneak across when the device is meant to be off. That means the transistor could continue to be shrunk down further with less worry about the consequences of short-channel effects.

These 2D materials are not only useful as semiconductors, though. Some, such as hexagonal boron nitride, can act as gate dielectrics, having a dielectric constant similar to that of silicon dioxide, which was routinely used for that job until about a decade ago. Add graphene in place of the transistor's metal parts and you've got a combination of 2D materials that forms a complete transistor. Indeed, separate groups of researchers built such devices as far back as 2014. While these prototypes were much larger, you could imagine scaling them down to the size of just a few nanometers.



As amazing as an all-2D transistor that's a fraction of the size of today's devices might be, that won't be the first implementation of 2D materials in electronic circuits. Instead, 2D materials will probably arrive in low-power circuits that have more relaxed performance requirements and area constraints.

The set of circuits we're targeting at Imec are built in the so-called back-end-of-line. Chipmaking is divided into two parts: the front-end-of-line part consists of processes—many of them requiring high temperatures—that alter the silicon itself, such as implanting dopants to define the parts of a transistor. The back-end-of-line part builds the many layers of interconnects that link the transistors to form circuits and deliver power.

With traditional transistor scaling becoming more and more difficult, engineers have been looking for ways to add functionality to the interconnect layers. You can't do this simply by using ordinary silicon processes because the heat involved would damage the devices and interconnects beneath them. So, many of these schemes rely on materials that can be made into devices at relatively low temperatures.

A specific advantage of using 2D semiconductors instead of some other candidates is the potential ability to build both p-type (carrying positive charges) and n-type (carrying electrons) devices, a necessity in CMOS logic. CMOS circuits are the backbone of today's logic because, ideally, they consume power only when switching from one state to the other. In our preferred 2D semiconductor, we've demonstrated n-type transistors but not yet p-type. However, the physics underlying these materials strongly suggests we can get there through engineering the dielectrics and metals that contact the semiconductor.

Being able to produce both p- and n-type devices would allow the development of compact back-end logic circuits such as repeaters. Repeaters essentially relay data that must travel relatively far across a chip. Ordinarily, the transistors involved reside on the silicon, but that means signals must climb up the stack of interconnects until they reach a layer where they can travel part of the distance to their destination, then go back down to the silicon to be repeated and up again to the long-distance interconnect layer. It's a bit like having to exit the highway and drive into the center of a crowded city to buy petrol before getting back on the highway.

A repeater up near the long-distance interconnect layer is more akin to a motorway petrol station. It saves the time it would take the signal to make the two-way vertical trip and also prevents the loss of power due to the resistance of the vertical interconnects. What's more, moving the repeater to the interconnect layer saves space on the silicon for more logic.

Repeaters aren't the only potential use. A 2D material could also be used to build other circuits, such as on-chip power-management systems, signal buffers, and memory selectors. One thing these circuits all have in common is that they don't require the device to drive a lot of current, so one layer of 2D material would probably be sufficient.

Neither future supersmall 2D devices nor the less demanding back-end-of-line circuits will be possible without a fabrication process compatible with industry-standard 300-millimeter silicon wafers. So our team at Imec is working on just that, hoping to develop a process that will serve for all applications.

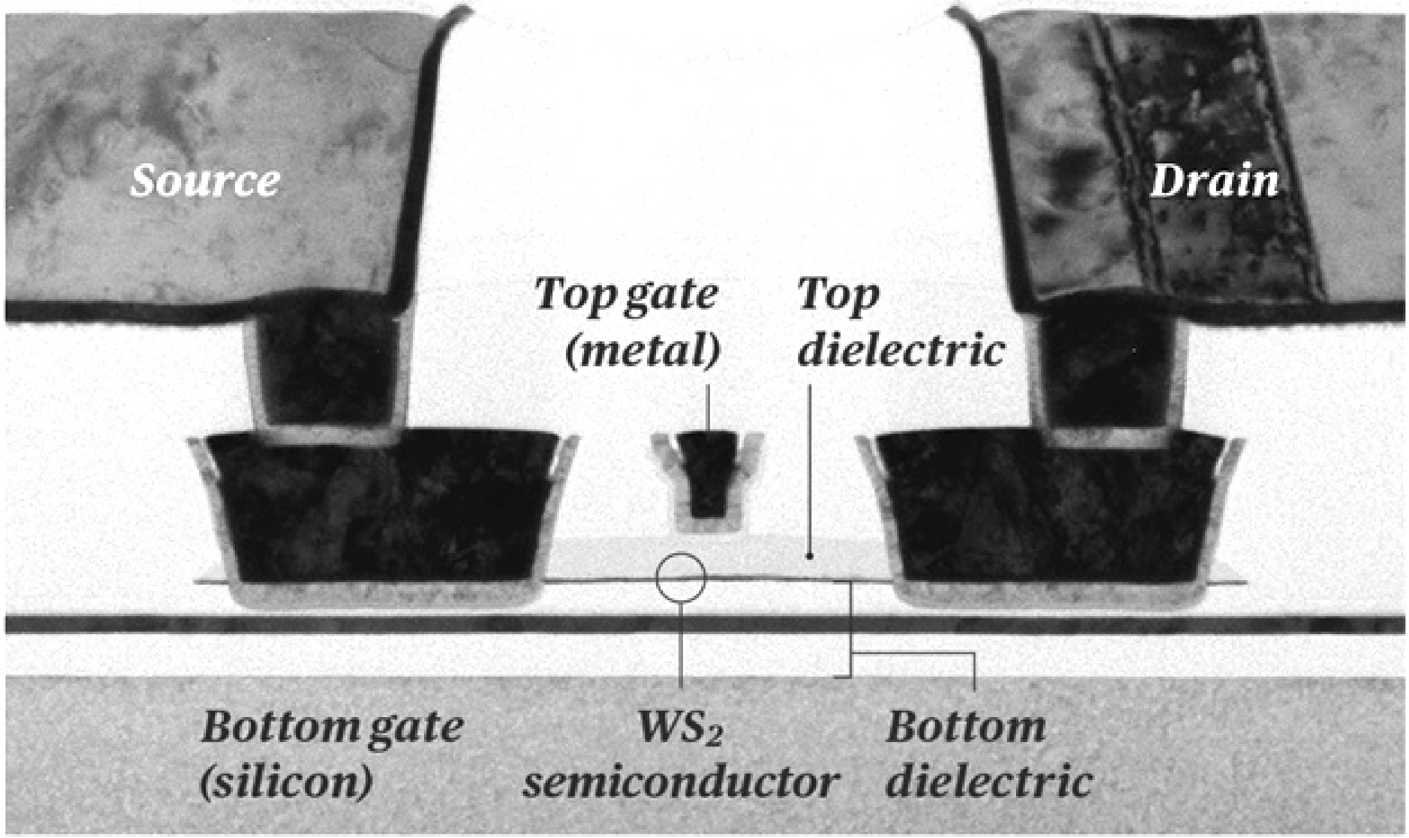
The first step is identifying the most promising 2D material and device architecture. We have therefore benchmarked a variety of 2D semiconductors and 2D FET architectures against an advanced silicon FinFET device.

Because researchers have the most experience with molybdenum disulfide (MoS2), experimental devices made using it have advanced furthest. Indeed, at the IEEE International Electron Device Meeting last December, Imec unveiled an MoS2 transistor with a channel just 30 nanometers across and source and drain contacts only 13 nm long. But after examining the possibilities, we've decided that MoS2 is not the answer. Instead, we concluded that among all the materials compatible with 300-mm silicon-wafer technology, tungsten disulfide (WS2) in the form of a stacked nanosheet device has the highest performance potential, meaning it can drive the most current. For less demanding, back-end-of-line applications, we also concluded that a FET architecture with a gate both below and above the semiconductor channel region works better than one with only a single gate.

We already knew one important thing about WS2 before we reached that conclusion: We can make a high-quality version of it on a 300-mm silicon wafer. We demonstrated that for the first time in 2018 by growing the material on a wafer using metal-organic chemical vapor deposition (MOCVD), a common process that grows crystals on a surface by means of a chemical reaction. The approach we took results in thickness control down to a single-molecule layer, or monolayer, over the full 300-mm wafer. The benefits of the MOCVD growth come, however, at the price of a high temperature—and recall that high temperatures are forbidden in back-end processes because they could damage the silicon devices below.

To get around this problem, we grow the WS2 on a separate wafer and then transfer it to the already partially fabricated silicon wafer. The Imec team developed a unique transfer process that allows a single layer of WS2—as thin as 0.7 nm—to be moved to a silicon target wafer with negligible degradation in the 2D material's electrical properties.

The process starts by growing the WS2 on an oxide-covered silicon wafer. That's then placed in contact with a specially prepared wafer. This wafer has a layer of material that melts away when illuminated by a laser. It also has a coating of adhesive. The adhesive side is pressed to the



WS2-covered wafer, and the 2D material peels away from the growth wafer and sticks to the adhesive. Then the adhesive wafer with its 2D cargo is flipped over onto the target silicon wafer, which in a real chipmaking effort would already have transistors and several layers of interconnect on it. Next, a laser is shone through the wafer to break the bulk of it away, leaving only the adhesive and the WS2 atop the target wafer. The adhesive is removed with chemicals and plasma. What's left is just the processed silicon with the WS2 attached to it, held in place by Van der Waals forces.

The process is complicated, but it works. There is, of course, room for improvement, most importantly in mitigating defects caused by unwanted particles on the wafer surface and in eliminating some defects that occur at the edges.

Once the 2D semiconductor has been deposited, building devices can begin. On that front there have been triumphs, but some major challenges remain.

Perhaps the most crucial issue to tackle is the creation of defects in the WS2. Imperfections profoundly degrade the performance of a 2D device. In ordinary silicon devices, charge can get caught in imperfections at the interface between the gate dielectric and the channel region. These can scatter electrons or holes near the interface as they try to move through the device, slowing things down. With 2D semiconductors the scattering problem is more pronounced because the interface is the channel.

2D Transistor: A two-gate device structure works best for devices meant to exist in the interconnect layers of a chip. The tungsten disulfide semiconductor is barely visible between the metal source and drain. Different dielectrics separate the semiconductor from the two gates.

Sulfur vacancies are the most common defects that affect device channel regions. Imec is investigating how different plasma treatments might make those vacancies less chemically reactive and therefore less prone to alter the transistor's behavior. We also need to prevent more defects from forming after we've grown the monolayer. WS2 and other 2D materials are known to age quickly and degrade further if already defective. Oxygen attacking a sulfur vacancy can cause more vacancies nearby, making the defect area grow larger and larger. But we've found that storing the samples in an inert environment makes a difference in preventing that spread.

Defects in the semiconductor aren't the only problems we've encountered trying to make 2D devices. Depositing insulating materials on top of the 2D surface to form the gate dielectric is a true challenge. WS2 and similar materials lack dangling bonds that would otherwise help fasten the dielectric to the surface.

Our team is currently exploring two routes that might help: One is atomic layer deposition (ALD) at a reduced growth temperature. In ALD, a gaseous molecule adsorbs to the semiconductor's exposed surface to form a single layer. Then a second gas is added, reacting with the adsorbed first one to leave an atomically precise layer of material, such as the dielectric hafnium dioxide. Doing this at a reduced temperature increases the ability of the gas molecules to stick to the surface of the WS2 even when no chemical bonds are available.

The other option is to enhance ALD by using a very thin oxidized layer, such as silicon oxide, to help nucleate the growth of the ALD layer. A very thin layer of silicon is deposited by a physical deposition method such as sputtering or evaporation; it's then oxidized before a regular ALD deposition of gate oxide is done. We've achieved particularly good results with evaporation.

A further challenge in making superior 2D devices is in choosing the right metals to use as source and drain contacts. Metals can alter the characteristics of the device, depending on their work function. That parameter, the minimum energy needed to extract an electron from the metal, can mean the difference between a contact that can easily inject electrons and one that can inject holes. So the Imec team has screened a variety of metals to put in contact with the WS2 nanosheet. We found that the highest on-current in an n-type device was obtained using a magnesium contact, but other metals such as nickel or tungsten work well. We'll be searching for a different metal for future p-type devices.

Despite these challenges, we've been able to estimate the upper limits of device performance, and we've mapped out what roads to follow to get there.

As a benchmark, the Imec team used dual-gated devices like those we described earlier. We built them with small, naturally exfoliated flakes of WS2, which have fewer defects than wafer-scale semiconductors. For these lab-scale devices, we were able to measure electron mobility values up to a few hundred square centimeters per volt-second, which nearly matches crystalline silicon and is close to the theoretically predicted maximum for the 2D material. Because this excellent mobility can be found in natural material, we are confident that it should also be possible to get there with materials synthesized on 300-mm wafers, which currently reach just a few square centimeters per volt-second.

For some of the main challenges ahead in 2D semiconductor development, our team has a clear view of the solutions. We know, for example, how to grow and transfer the material onto a 300-mm target wafer; we've got an idea of how to integrate the crucial gate dielectric; and we're on a path to boost the mobility of charge carriers in devices toward a level that could compare with silicon.

But, as we've laid out, there are still significant problems remaining. These will require an intensive engineering effort and an even better fundamental understanding of this new class of intriguing 2D materials. Solving these challenges will enable high-performance devices that are scaled down to atomic layers, but they might first bring new capabilities that need less demanding specifications even as we continue to scale down silicon.

Future of Rail transport in India

By Mahesh Mohan Mane
TE E&TC

The Indian government is undertaking several initiatives as to upgrading its aged railway infrastructure and enhance its quality of service.

Trains

1) India's first bullet train:

This next proposal has also caused some controversy as the final cost of the project is expected to amount to three times the size of India's annual health budget. However, there is no doubt that the infamous high-speed bullet train is expected to revolutionise passenger journeys in India by 2023. Reaching speeds of up to 350kmh – while not as impressive as developments China and Japan are working on, will still travel between Mumbai and Ahmedabad in just two hours. The line also involves some complex engineering as a 21km tunnel will need to be built under the sea.

2) Hyperloop (Mumbai–Pune hyperloop):-

Mumbai–Pune hyperloop is a proposed 1000 km/hr. Hyperloop system that will take 14 minutes compared to current 3 hours to commute between these two cities while carrying 10,000 commuters per hour (5,000 in each direction). The route is found feasible and can be made operational by 2026 as per the Detailed Project Report (DPR) submitted to "Pune Metropolitan Region Development Authority" (PMRDA) by "Virgin Hyperloop company" in January 2018. Commuters and cargo will travel in pods traveling in the near-vacuum tubes at the speed of 1,000 km/hr. DPR provided three feasible terminal end-points options in Mumbai, namely Dadar, Santacruz and the international airport. Currently, 300,000 people commute between these two cities daily in 110,000 vehicles (including 80,000 cars and 6,000 buses) as of Jan 2018.

3) High-speed Rail:

Feasibility studies for five high-speed rail corridors were conducted between 2009 and 2010. A "Diamond Quadrilateral" has been planned to connect Delhi, M umbai, Kolkata, and Chennai with a high-speed train network. The Indian government conducted joint surveys with a Japanese government team in 2014, finally approving a corridor between Mumbai and Ahmedabad. The new high-speed service will use a Japanese Shink ansen system and locomotives. India and Japan signed agreements for the project in December 2015; the Japanese government will fund 81% of the total cost with a soft loan fixed at a nominal interest rate. A special committee has recommended the trains be run on an elevated corridorto avoid the difficulties of acquiring land, building underpasses, and constructing protective fencing. Indian Railways will operate the corridor for a five-year period after its commissioning, and afterwards will be turned over to a private operator.Construction work of the corridor began in 2017 and will be completed by 2022.[7]

4) Semi-high-speed Rail:

A semi-high-speed rail network will be introduced for connecting important routes, including Delhi-Agra, Delhi-Kanpur, Chennai-Hyderabad, Nagpur-Secunderabad, and Mumbai-Goa. Initially, the trains will operate at a maximum speed of 160 km/h, which will be increased to 200 km/h after the rails are strengthened and fenced off. The Gatimaan Express began services on April 5, 2016, after safety clearances were obtained on its first route.

5) Mumbai Metro:

The Mumbai Metro has been one of the most talked about projects to impact the future of India's rails. Its construction could dramatically improve the most populous city in India. 88% of the city rely on public transport in their commute to work.

6) Maglev trains:

Maglev technology whilst not a new idea is yet to be used for commercial operation. The train uses electrically charged magnets which pull the train from the front and push it from behind. They are then controlled by alternating currents which propel the train forward. Hovering 10cm above the tracks, the maglev does not need to be fitted with wheels or traditional rolling stock technology. As a result, this design allows it to achieve speeds of up to 500 km/h.

Conversion to high-speed passenger and freight corridors: 2027 target of 10,000 km

IR will convert 10,000 km passenger and freight trunk routes in to High-speed rail corridors of India from 2017-2027, where half of the money will be spent on converting exiting routes into high-speed corridors by leap-frogging the technology and the rest will be used to develop the stations and electronic signaling at the cost of to enable automated running of trains at 5–6 minutes frequency. Dedicated freight corridors of 3,300 km length will also be completed thus freeing the dual use high demand trunk routes for running more high-speed passenger trains.

Rolling Stock:-

Modern locomotive factories

Indian Railways is now moving to manufacturing high-end aluminium self-propelled 160 km/hour indigenous Make in India coaches that require no locomotive and are 10% cheaper than the comparable imports. The first such self-propelled train, Train 18, was rolled out in October 2018. It is estimated to be 40% cheaper than foreign-built trains. By 2020 an even cheaper and lighter aluminum version is planned to follow.

Railway coach refurbishment

Railway coach refurbishment project aims for the refurbishment of 12 to 15 years old coaches at Carriage Rehabilitation Workshop in Bhopal to enhance passenger amenities and fire safety measures.

Bio-toilets in all trains: 2019 target

In 2014, IR and DRDO developed a bio-toilet to replace direct-discharge toilets, which are currently the primary type of toilet used in railway coaches. Upgrade of all trains to bio-toilet will be completed by the end of 2018-19.

The direct discharge of human waste from trains onto the tracks corrodes rails, costing IR tens of millions of rupees a year in rail-replacement work. Flushing a bio-toilet discharges human waste into an underfloor holding tank where anaerobic bacteria remove harmful pathogens and break the waste down into neutral water and methane, which can then be harmlessly discharged onto the tracks. IR plans to completely phase out direct-discharge toilets by 2020 or 2021.

Infrastructure:-

Stations

Station redevelopment

The 600 railway stations will be redeveloped by monetizing 2700 acres of spare railway land undertaken by Indian Railway Stations Development Corporation by converging it with the Atal Mission for Rejuvenation and Urban Transformation and Smart Cities Mission in collaboration with Ministry of Urban Development, Rail Land Development Authority and National Buildings Construction Corporation.

Power and fuel

Off-the-grid solar-powered trains: 1.13 gigawatt solar power target by March 2022

Off-the-grid solar powered trains by installing 1 gigawatt of solar and 130 megawatts of wind power between 2017-2022. India introduced world's first solar powered train in June 2017 as well as 50 coaches with rooftop solar farms.

Rooftop solar electricity

Rooftop solar electricity at stations to reduce long-term fuel cost and protect environment.

Traintop solar electricity

In 2017, first train with solar rooftop panels started. Increasingly more trains will be operated with renewal onboard solar electricity generation.

Services:-

Wi-fi-enabled trains and stations

Progressively CCTV cameras and wifi will be installed on all trains and stations. In September 2015, the IR and Google announced a joint initiative intent on delivering high-speed wi-fi access across 400 major railway stations. To the 36 Stations are made "ECO-SMART" under Government project.

Tickets

Select passengers with confirmed tickets will now be allowed to transfer tickets to someone else. Indian Railway Catering and Tourism Corporation (IRCTC) is now offering a pay-on-delivery option for train tickets on its website and app, where the customers can book their tickets and pay on delivery.

Escalators

Progressively escalators will be installed on all stations with a footfall of more than 25,000 per day.

Station upgrades

In days,600 stations will be upgraded, including 400 to be redeveloped, progressively to enhance services, safety and security.

Intelligent Transportation Systems (ITS)

Mahesh Mohan Mane
TE E&TC

Introduction:

Intelligent Transportation Systems (ITS) is the application of computer, electronics, and communication technologies and management strategies in an integrated manner to provide traveler information to increase the safety and efficiency of the road transportation systems. This system is based on Internet of Things (IoT) which easy to connectivity, exchanging data to the device .These systems involve vehicles, drivers, passengers, road operators, and managers all interacting with each other and the environment, and linking with the complex infrastructure systems to improve the safety and capacity of road systems.

Intelligent Transportation Systems (ITS) combine many different types of information and communications technology to create a network of systems that help manage traffic, protect roads and more. As more and more parts of our transportation network become networked, ITS will change the way drivers, businesses and governments deal with road transport. These advanced systems can help improve transportation in several ways.It uses number of electronics, wireless and communication technologies to provide consumers an access to a smarter, safer, and faster way to travelling.

ITS architecture:

The ITS architecture should be common and of specified standards throughout the state or region so that it can address solution to several problems while interacting with various agencies.

1. Interoperability - The ITS architecture should be such that the information collected, function implemented or any equipment installed be interoperable by various agencies in different state and regions.

2. Capable of sharing and exchanging information - The information by traffic operations may be useful to the emergency services.

3. Resource sharing - regional communication towers constructed by various private agencies are required to be shared by ITS operations.

Application areas of Intelligent Transport System:

The entire application of ITS is based on data collection, analysis and using the results of the analysis in the operations, control and research concepts for traffic management where location plays an important role.

Here sensors, information processors, communication systems, roadside messages, GPS updates and automated traffic prioritization signals play an imperative role in the application of:

1. Advanced Traffic Management System
2. Advanced Traveler Information System

3. Advanced Vehicle Control system

4. Advanced Public Transportation System

5. Advanced Rural Transportation Systems

6. Advanced Commercial Vehicles Operations system.

ITS Works:

Traffic Management Centre (TMC) is the vital unit of ITS. It is mainly a technical system administered by the transportation authority. Here all data is collected and analyzed for further operations and control management of the traffic in real time or information about local transportation vehicle.

Well-organized and proficient operations of Traffic Management Centre depends on automatized datacollection with precise location information than analysis of that data to generate accurate information and then transmitting it back to travelers. Let's understand the entire process in a more detailed way.

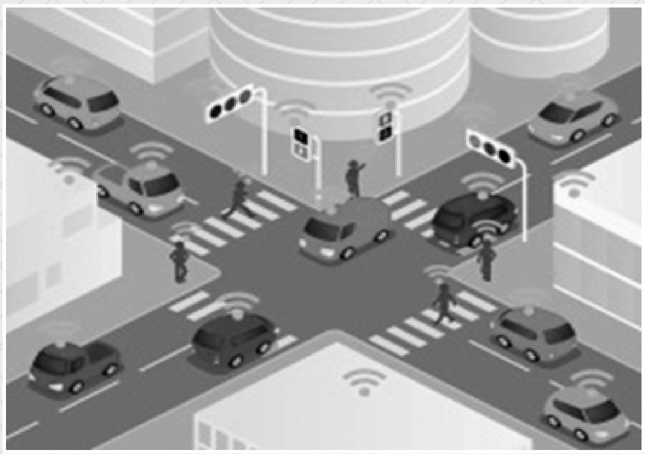
Data collection: Strategic planning needs precise, extensive and prompt data collection with real-time observation. So the data here is collected via varied hardware devices that lay the base of further ITS functions. These devices are Automatic Vehicle Identifiers, GPS based automatic vehicle locators, sensors, camera etc. The hardware mainly records the data like traffic count, surveillance, travel speed and travel time, location, vehicle weight, delays etc. These hardware devices are connected to the servers generally located at data collection centre which stores large amounts of data for further analysis.

Data Transmission: Rapid and real-time information communication is the Key to proficiency in ITS implementation so this aspect of ITS consists of the transmission of collected data from the field to TMC and then sending back that analyzed information from TMC to travelers. Traffic-related announcements are communicated to the travelers through internet, SMS or onboard units of Vehicle. Other methods of communications are dedicated short-range communications (DSRC) using radio and Continuous Air Interface Long and Medium Range (CAILM) using cellular connectivity and infra-red links.

Data Analysis: The data that has been collected and received at TMC is processed further in various steps. These steps are error rectification, data cleaning, data synthesis, and adaptive logical analysis. Inconsistencies in data are identified with specialized software and rectified. After that data is further altered and pooled for analysis. This mended collective data is analyzed further to predict traffic scenario which is available to deliver appropriate information to users.

Traveler Information: Travel Advisory Systems (TAS) is used to inform transportation updates to the traveling user. The system delivers real-time information like travel time, travel speed, delay, accidents on roads, change in route, diversions, work zone conditions etc. This information is delivered by a wide range of electronic devices like variable message signs, highway advisory radio, internet, SMS, automated cell.

With urbanization expanding with speedy stride, number of vehicles on road is also increasing. Combination of both in return puts enormous pressure on cities to maintain a better traffic system so that the city keeps on moving without any hassle. For the purpose application of Intelligent Transport System is the only solution. ITS is a win-win situation for both citizens and city administrators where it provides safety and comfort to citizens and easy maintenance and surveillance to city administrators.



ITS:

With the conception of smart city transmitting cities into digital societies, making the life of its citizens easy in every face, Intelligent Transport System becomes the indispensable component among all. In any city mobility is a key concern; be it going to school, college and office or for any other purpose citizens use transport system to travel within the city. Leveraging citizens with an Intelligent Transport System can save their time and make the city even smarter. Intelligent Transport System (ITS) aims to achieve traffic efficiency by minimizing traffic problems. It enriches users with prior information about traffic, local convenience real-time running information, seat availability etc. which reduces travel time of commuters as well as enhances their safety and comfort.

The application of ITS is widely accepted and used in many countries today. The use is not just limited to traffic congestion control and information, but also for road safety and efficient infrastructure usage. Because of its endless possibilities, ITS has now become a multidisciplinary conjunctive field of work and thus many organizations around the world have developed solutions for providing ITS applications to meet the need.

One such example is the city of Glasgow. In the city, Intelligent Transport System gives regular information to the daily commuters about public buses, timings, seat availability, the current location of the bus, time taken to reach a particular destination, next location of the bus and the density of passengers inside the bus.

Example:geographic information system(GIS) and Data Manager, Glasgow City Council explains, bus operators in the city have the sensors in their buses. So, if the bus is going to be early to the next bus stop the bus is temporarily and very slightly is slowed down at the red light little longer than it should be to make sure the bus is on time and do not ahead of the schedule. The system has been designed so smartly that passengers and even drivers are unaware of the delay as they are very little delays.

Commercial Vehicle operations:

The aim is to improve the efficiency and safety of commercial vehicle operations. This involves following services:

1. CV electronic clearance
2. Automated road side safety inspection
3. On-board safety monitoring administrative process
4. Hazardous material incident response
5. Freight Mobility.

Important Technologies in ITS:

Internet of Things (IoT) is poised to disrupt almost every sector and transportation is one of them. By generating an ITS, it can help optimize logistics and fleet management, tracking and monitoring of goods and services, traffic management, driver assistance, etc.

* Advanced Tracking System
* Advanced Sensing Technologies
* Advanced Video Vehicle Detection
* Advanced Traffic Light System
* Emergency E-Call Vehicle Service.