LEONARDO TIMES

JOURNAL OF THE SOCIETY OF AEROSPACE ENGINEERING STUDENTS 'LEONARDO DA VINCI'

The Ancient Quest For Flight

And why it took so long

A Dream of Mars

From Sumeria to SpaceX

PAGE 21

Trust Me, I'm AI

Learning to accept uncertainty

PAGE 30

Drones in Archeology

How LiDAR technology has transformed an entire field

PAGE 44

Year 29 | N° 1 | Winter 2025


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EDITORIAL

Dear reader,

As we welcome 2025, another Leonardo Times has arrived on your doorstep. The last year ended on a somber note, with a number of serious incidents which cost many lives. Aerospace engineers have a long history of learning from mistakes, so that they may never happen again. While working on this issue prior to these events, we noticed that a number of articles reference previous accidents in aviation and how they should be avoided in future. We are proud of our editors for taking this philosophy to heart in their articles, and we hope that this edition may help foster a culture of accepting past errors and making changes for the better.

We start with a discussion on sustainable aviation, considering both carbon offsetting and SAF. Both promise a quick solution to our climate woes, but both have their troubles. Reflections on the crashes of Pakistan International Airlines Flight 8303 and the 737-MAX invite the reader to ponder on the impact of human factors in and outside the cockpit. Could this be solved with AI? We shall also explore what role AI might play in aviation and if we can ever truly trust it.

Take a break from modern challenges with an ode to humanity's eternal longing for the heavens. We will explore early attempts at human flight and what we learnt from them, plus dreams of worlds beyond our own with a timeline of the red planet through human eyes. And the boundary between the two, the skies themselves. Recent initiatives have toyed with the idea of engineering the atmosphere in our favour - could it be possible, and is it something we would want?

You may notice our new look; we are proud to have improved the accessibility of the journal by switching to Atkinson Hyperlegible, an award-winning font created by the Braille Institute of America, among other early spring cleaning. The more attentive reader may also have noticed that you were expecting the fourth edition of 2024, and yet the first edition of 2025 was delivered. This is no mistake, we have updated our index system to better reflect the time of year when the issues are sent out. As such, there will be no "Year 28 No. 4", and we enter swiftly into the 29th year of our prized journal.

We hope you learn something, and we hope you enjoy.

Yours truly,

Gerard Mendoza Ferrandis
Editor-in-Chief

James Josep Perry
Editing Director

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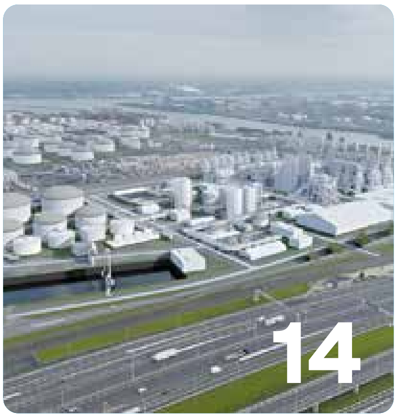
Last edition...

If you have remarks or opinions on this issue, please email us at: leotimes-vsv@student.tudelft.nl

We really want to make sure that all the Leonardo Times we send out get into the hands of people who are interested in reading them. So if for any reason you would like to remove your address from our mailing list, you can unsubscribe by using the form in the QR code. We're sorry to see you leave!

Contents



Is SAF the Future?

SAF promises to reduce aviation emissions, but many challenges complicate its widespread use. Explore SAF's potential, limitations, and future role in aviation.

24

Echoes of Mir

The decommissioning plan of the International Space Station follows closely in the footsteps of its predecessor.

Finding the Impossible

Among the mysteries of aviation, the tragedy of Malaysian Airlines Flight 370 is one of the greatest. Find out why it may not be for much longer!

Engineering the Atmosphere

Geoengineering offers hope and raises questions. Solar Radiation Modification seeks to cool Earth, but its risks, ethics, and global impact ignite debate on whether science should intervene at this scale.

Victims of a Broken System

Two Boeing 737 MAX crashes claimed 346 lives due to corporate negligence, flawed systems, and regulatory failure. This article explores the systemic injustice and bias within the global aviation industry.

Colophon

Year 29, Number 1, Winter 2025

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A Message from the Board

Dear reader,

As if in the blink of an eye, a fresh new year has arrived, bringing with it new opportunities to start afresh and make the most of what lies ahead. But before we look forward, let's take a moment to reflect on the remarkable events that have shaped the first months of this academic year.

We kicked off the year with a bang during the Career Weeks. These weeks featured nearly daily lunch lectures, showcasing a wide variety of companies such as Airbus, Pratt & Whitney, ASML, TWD, Transavia, and LVNL. It was truly inspiring to see so many students engage with these (aerospace) companies and explore potential career paths. The Career Weeks were closed off with the Alumnight, where recent graduates returned to share their experiences of transitioning from student life to working in the industry.

The highlight of the fall was our Extraordinary General Members' Assembly, a special event that only occurs once every 2.5 years. During this assembly, we welcomed two new Members of Honour in a spectacular ceremony held in the old municipal building in Delft's city centre. Their arrival was nothing short of memorable—they came in style, riding in a crash tender (an airport fire truck), accompanied by two police motorcycles. As they stepped out, the bells of the New Church played the VSV anthem, marking their entrance into the building. The ceremony, featuring speeches by Members of Honour Michiel van Dorst and Dean Henri Werij, celebrated their official installation and is something we look back on with pride.

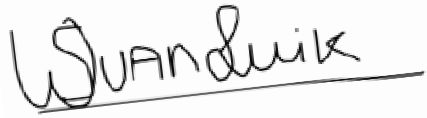
The week before the Christmas Holiday we hosted the annual Belgian Beer Drink. This year, the event was supersized (or XXL) as it doubled as the opening party of our lustrum celebration, selling out over 450 tickets. It was a fantastic evening of celebration, Belgian beer, and great music, setting the perfect tone for the festivities ahead.

After a well-deserved Christmas break, the board—and we hope all of you—are recharged and ready for the adventures that await in this special lustrum year! Exciting events lie ahead, including the lustrum ski trip, lustrum gala, and the lustrum month in May. Before then, we have other highlights to look forward to, such as our Interview to Inspire with André Steur, Commander of the Royal Netherlands Air Force, and our annual aviation symposium, themed 'From Vision to Flight.'

As we embark on this new year, we hope you're as excited as we are to create lasting memories, embrace new opportunities, and ignite the spirit of our lustrum celebration. For now, we invite you to take a moment to relax and enjoy this edition of our magazine.

On behalf of the 80th Board of
the VSV 'Leonardo da Vinci',

With winged regards,



Willemijn van Luik
President of the 80th Board of
the VSV 'Leonardo da Vinci'

Quarterly Highlights

Next Generation Stealth

At the end of last year, two as-yet-unseen stealth fighters took to the skies above Sichuan province, China. Prototypes of Chengdu and Shenyang aircraft manufacturers, the sixth-generation aircraft were likely undergoing flight testing. Their wing and inlet designs indicate that both fighters are supersonic, and highly resistant to radar detection.

The larger aircraft design has an unusual diamond configuration with three engines and a large payload bay. The design is approximately 23 m in length, with a wingspan of 20 m, roughly twice that of Lockheed Martin's F35. The control surfaces are also non-standard, with five blended-wing split elevons on each trailing edge. Military analysts presume that this Chengdu aircraft has been designated the J-36, although this has yet to be confirmed.

The Shenyang fighter is more conventional by design, though both aircraft are tailless. It sports a lambda wing design, with trailing edge extensions to improve aerodynamic performance. The criteria for a true sixth-generation fighter includes a host of cyber weapons, onboard AI control and variable-cycle engines. As more information is revealed, the extent to which this has been achieved will become clear.

Chang W. Lee

Up In Flames

Aviation is as safe as it gets. However, in the last days of 2024 there were a series of serious accidents. One of the most deadly was the crash of Jeju Air Flight 2216.

Jeju Air is South Korea's largest low cost carrier. They were operating Flight 2216 from Suvarnabhumi Airport in Thailand to Muan International Airport in South Korea. During approach, the plane declared an emergency after a bird strike event, which led to an aborted landing.

The pilots then attempted a second landing in the opposite direction. The aircraft landed on its belly, overshooting the runway threshold by 1.2 km. This shortened the remaining distance available to land, causing the aircraft to explode after colliding with the reinforced concrete base of the localiser antenna.

The crash is still under investigation, and many questions still remain. How was a non-frangible wall allowed to be placed in the Runway End Safety Area (RESA)? Did both engines stop working? Why did the landing gear not lower?

This accident comes at a very politically-unstable moment in South Korea, and has now become the deadliest in the country's history.

Millimeter Precision

ESA's Proba-3 "double satellite" has been launched by NewSpace India Limited (NSIL), on a mission to demonstrate precision formation flying. The PSLV-XI rocket launched from Satish Dhawan Space Centre in Sriharikota, India, on 5th December 2024. A technology demonstrator, the platform consists of two different spacecraft flying together, 150 m apart with a precision of just 1 mm, launched to a high elliptical Earth orbit with a perigee of just 600 km, climbing to an apogee of over 60,000 km each orbit.

In order to demonstrate the level of precision, the cuboid Occulter carries a 140 cm diameter disk to cast an 8 cm diameter shadow on the other satellite, the Coronagraph. This artificial eclipse will last for 6 hours per orbit, compared to just 10 minutes naturally, allowing instruments on the Coronagraph to make detailed study of the Sun's Coronal Mass Ejections (CMEs).

At 250 kg and 300 kg respectively, both class as "mini" satellites with sides one to two meters in length. Their mission has a nominal duration of two years, with both satellites solar powered. It has been under development since 2005, with an estimated total cost of €200 million.


ESA


NASA

Kissing the Sun

In 2018, NASA launched a mission to explore the Sun's corona: the Parker Solar Probe. It has already been collecting invaluable data for 6 years, including measurements of solar winds and their particles, among others.

The probe made its first major discovery in 2019, when researchers noticed that the Sun's corona had sudden and sharp reversals in the direction of the Sun's magnetic field, called switchbacks. This was a previously unknown phenomena.

The probe entered the Sun's corona for the first time in April 2021 after taking several gravitational assists from Venus to lower its heliocentric orbit. In December 2024, the Parker Solar Probe made its closest flyby of the Sun to date. It flew just 6.16 million kilometers above the Sun's visible surface. To the probe, the sun would have looked as big as holding a large beach ball at arm's length.

The data can not yet be downlinked, but has been informed to be safe. Scientists hope the data collected by the Parker Solar Probe will help them understand some big unknowns, like why the Sun's corona is hotter than the Sun itself, and what the mechanism driving solarwinds is.

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Who Pays for our Carbon?

The impact of European carbon offsetting on the world

James Perry, Editing Director

EasyJet

Have you ever paid to offset your carbon emissions? The magic monetary solution to pollution and climate change seems so easy to us as consumers. But how it works, if at all, is more complicated. Is it the best we can do?

In 2019, EasyJet became the first major airline to offset the carbon emissions from the fuel used for all its flights [1]. In 2022, this policy was quietly removed [2]. This means that for three years the airline paid to be carbon neutral. Overnight, easyJet became one of, if not the most, sustainable airline in the world, at least on paper. The airline became clean despite flying the same aircraft for the same duration, burning the same amount of fossil fuels, and emitting the same quantity of greenhouse gases. It's not as far-fetched as it sounds, the term was first used in the U.S. Clean Air Act of 1970 to permit increased pollution levels in some areas when reductions occurred in others [3]. Nobody invented carbon offsetting as we know it today; it emerged naturally over time. Increased pressure towards climate-friendly policies meant businesses and individuals alike searched for a simple, cheap method to improve their public image. Where there is demand, the market delivers, and so NGOs and private companies began to sell carbon credits. In principle, it doesn't matter where CO2 is emitted, just that the quantity released is reduced globally. So, to continue flying around Europe, airlines and customers can pay for schemes to reduce emissions by the same amount elsewhere in the world. Evaluating carbon offsets from the perspective of energy justice reveals a lot more to the story.

Energy Justice

Energy justice theory is a strategy for human-centered decision-making during the energy transition. It is a system that explains how we should fairly decarbonize the globe for all who live on it; more challenging than it may first appear. Energy justice is generally accepted to contain three key tenets [4]: distributional, recognition, and procedural justice.

Distributional justice refers to the physically unequal allocation of energy and environmental resources. This is clearly of great concern when emissions are offset in schemes abroad. One good case study of such a scheme is the implementation of biogas generators in countries such as Malawi. Located in southeast Africa, see Figure 1, Malawi has a financially poor economy heavily dependent on agriculture. To restate the implications and reduce the net

Figure 1: Malawi is a landlocked country with a population of over 21 million

emissions of the Netherlands, residents of countries such as Malawi are persuaded to change their lifestyles. They are encouraged to purchase discounted biogas generators [5], see Figure 2. These digesters produce cooking gas for a home to replace firewood, improving quality of life and reducing emissions. The waste product can then be used as fertilizer. Methane is a greenhouse gas, produced from cattle dung, which would eventually reach the atmosphere whether first captured and burned for cooking or not. If it is used for cooking, wood does not have to be burnt, reducing both direct emissions and the number of carbon-absorbing trees felled for this purpose.

But biogas generators are difficult to maintain and even more challenging to troubleshoot, and owners must commit time and money towards their upkeep, or else see them fall into disrepair and disuse. The convenient reduction of effective emissions in one country requires a huge change in the lifestyle of those in others. One people benefits more than another, with far less effort, because they can afford to make the problem move to a different country: out of sight and out of mind.

The People's Voice

This is closely tied to recognition justice, which calls for all stakeholders to be equally engaged and respected for their cultural identities. As soon as another country becomes involved, not only their government but also their residents become stakeholders who deserve to be heard. Kulugomba et al. [6] report that some of the barriers to biogas implementation are a reluctance to handle cattle dung and cultural perception of danger and health hazards. The proposed solution is increased educational campaigns, but this reflects a conviction that the biogas generators are objectively better. The organizations that install these generators would consider them a necessity to continue to receive funding from the Netherlands, but often unwanted by the homeowners receiving them.

We have not exhausted all options to reduce emissions domestically. The argument that such initiatives are vital for sustainability is only true if there are no alternatives. In aviation, sustainable aviation fuel (SAF) is a technology ready for implementation, see "Is SAF the future?" on page 14, but its cost compared to fossil fuels and lack of infrastructure means implementation is not yet widespread. On a day-to-day level, many people still drive when more climate-friendly options are available, such as cycling or public transport, because it's more convenient. Making these changes would have a far bigger impact on the global climate than offsetting projects, but they are harder to convince people to implement. The wants of Europeans are considered above the needs of the Malawians.

Money, Money, Money

However, foreign offsetting does support procedural justice, in particular the sub-tenet of cosmopolitan justice. Sovacool and Dworkin [7] define this as the application of distributive and procedural concepts globally, as a responsibility for high-emission nations to support poorer countries during the energy transition. This is part of the just transition, a need for changing energy habits to work to the benefit of all members of society with a global perspective [8]. The capitalist nature of carbon offsetting draws investment into green technologies, especially in countries where this may not have been the case otherwise. Energy-poor regions, as can be found within Malawi, rely on firewood for fuel – a labor-intensive energy source which encourages deforestation [5]. If biogas initiatives were to be successful in enabling a cultural shift to the exclusive use of biogas, this would be to the country's benefit at the expense of the wealthier Europeans.

However, Kulugomba et al. [6] also report a high proportion of failed projects and mixed fuels, which means the Europe-funded projects, often unwanted as mentioned previously, are also failing to deliver the change they promised. The climate impact of the materials for offsetting projects is often overlooked, as are the emissions involved in their installation. If and when biogas generators fall into disrepair, they are often left in place, littering the local environment. Such factors can be overlooked by the organizations selling carbon credits, as it would raise their prices to make them uncompetitive. A lack of transparency in the industry has ironically led to unsustainable practices; a kilogram of carbon sold is rarely a kilogram of carbon saved.

To Offset or not to Offset

Carbon offsetting relies on the assumption that removing greenhouse gases from the environment in one place is just as beneficial as cutting the emissions they are supposed to offset elsewhere. For example, forest credits are sold as an assurance that trees will be protected from deforestation. Often there are no more trees planted, rather trees currently removing carbon dioxide from our atmosphere will not be removed. This already tenuous premise is made completely worthless when wildfire or disease kills the trees anyway [9], a natural occurrence that climate change is making unnaturally common. These credits are bought from logging companies, a substitute for the lost income from not felling those trees. It is difficult to tell whether purchasing such credits ensured fewer trees were felled, or just moved logging operations elsewhere. Some of the funds are used to insure against such events, covering the costs of replanting trees. But, before even considering the emissions of a forest fire itself, these funds are often insufficient with the increasing

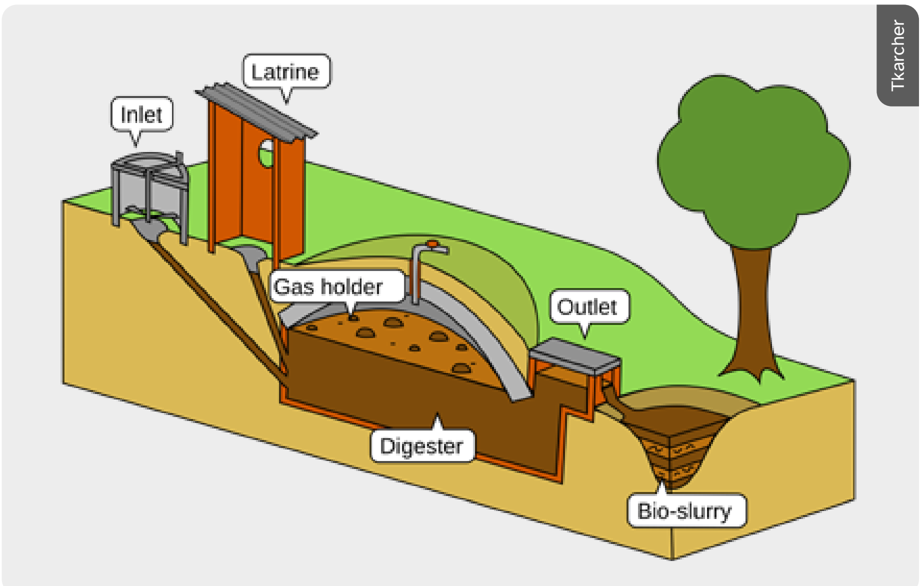
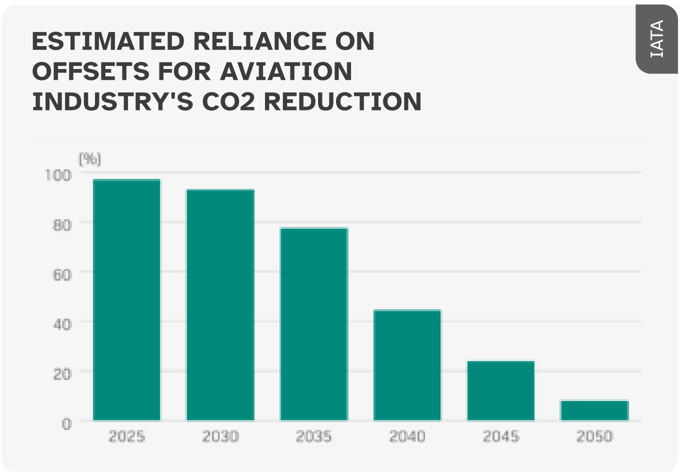


Figure 2: Diagram of a half-buried biogas generator, which takes cattle dung through the inlet and produces pressurized cooking gas at the pipe above the gas holder.

A large biogas reactor for a secondary school in Malawi installed by EcoGen



The International Air Transport Association predicts the required dependence on carbon offsets will decrease significantly with time

regularity of wildfires in a hotter, dryer climate. Remarkably, the insurance also covers recovery from logging if it takes place anyway – the very thing paying for the credits is meant to prevent.

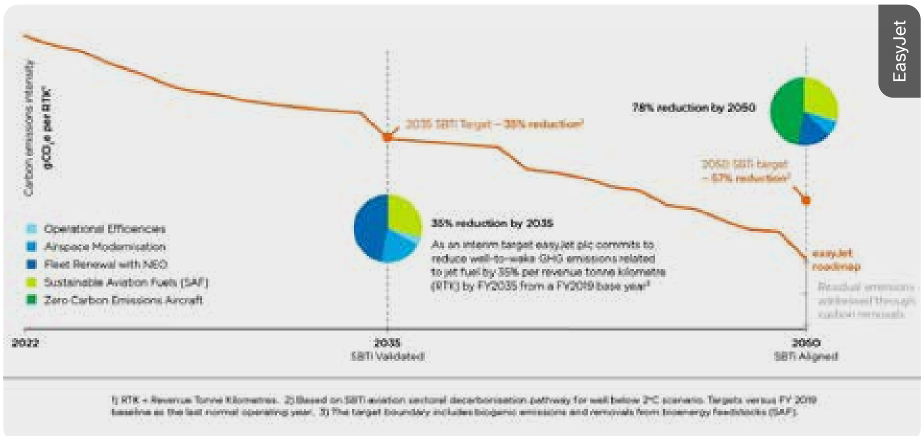
Consequently, some conditions must be met to make carbon offsetting worthwhile. There are certainly situations where this system works, despite the problematic examples given in this article. The first condition is that such credits are making a difference. Countries and organizations are under pressure to reach carbon neutrality; carbon offsetting provides an easy method of claiming to have done so without investing resources into worrying about how or if this is achieved. Returning to procedural justice, McCauley et al. [10] stress the importance of full information disclosure for government spending and subsidies. This enables a constructive exchange of information and assigns clear accountability. When the true impact on the environment is often debated or shrouded in corporate mystery, such accountability or assurances are nearly meaningless.

The second condition is that no dependency develops on the system. Carbon offsetting is currently a vital component of our plans to reach net zero, as this goal is not achievable within the time frame set out otherwise. Offsetting allows emission reduction where current technology does not yet allow. However, especially when offsetting may occur abroad, true global carbon neutrality cannot be achieved through offsetting. As long as greenhouse gases are emitted, preventative mechanisms or even carbon capture cannot truly compensate as if those emissions had never occurred in the first place. Therefore, despite its short-term benefits, offsetting should never be considered a true solution.

The Easy Way Out

We return to EasyJet and their offsetting policy which ceased in 2022. Such a decision seems strange as pressure to clean our emissions continues to increase. It's easy to assume the company didn't see their profits improve from what was marketed as a philanthropic endeavour – perhaps carbon credits were just too expensive. EasyJet says that they decided the money was better put to use elsewhere [2], investing in programs to help make aviation greener at its roots. Given the controversy over carbon credits, this is a sensible move. It gives rise instead to the question of whether it matters when carbon is emitted. Is it better to buy offsets now, or invest in lasting technologies for the future?

Many airlines still choose the former, such as British Airways and Delta, the latter of which spent $137 million in 2021 on carbon offsetting [11]. KLM allows the purchase of carbon offsets as an optional extra, leaving the choice to the consumer. For better or for worse, carbon credits are a part of aviation to stay. According to IATA [12], only 3% of decarbonizing efforts in 2025 will be achieved through SAF, and the remaining 97% through carbon offsetting. They expect this number will drop to 8% by 2050. Polluting aircraft will be around for decades, and carbon credits will be used to compensate. The outcome of these offsets must make a real and lasting difference to our planet, becoming more than just a buzzword for corporate advertising. Somebody always suffers the consequences of our emissions, but all too often the question is who, and do we even care?



EasyJet's updated sustainability roadmap sees a majority reduction in emissions, with the remaining 43% addressed through direct carbon capture technology as opposed to carbon offsetting.

In conclusion, carbon offsetting is a useful way to reduce emissions but does not do so in a sustainable manner. Europe prioritizes its carbon neutrality over the overall reduction in global emissions, in contrast with the tenets of energy justice. However, with a proper assurance that carbon offsetting makes a difference without dependency, and when projects abroad are carried out as promised with due cultural consideration, there remains a promising path forward. Carbon offsetting is a resource that, like so many others, is helpful now but will not last forever.

C&O

Is SAF the Future?

On the road to net-zero

Juan van Konijnenburg, Leonardo Times Editor

Rolls Royce

SAF has emerged as a popular solution for reducing aviation emissions. Produced from renewable sources like waste oils and captured carbon, SAF could cut emissions by up to 90%. However, challenges such as cost and feedstock availability call its effectiveness into question.

What is SAF?

Sustainable Aviation Fuel (SAF) refers to fossil-based jet fuel alternatives [1]. This means that, unlike conventional jet fuels, it is not synthesized from crude oil but from other sustainable sources. These sources, known as feedstocks, could range from cooking oil to municipal waste. Each feedstock has several possible production methods to create aviation fuel [1]. SAF's goal is to replace conventional jet fuels, such as Jet A-1 and Jet Am, with a lowered environmental impact and minimal performance loss.

Due to this definition, the list of potential aviation fuels classified as SAFs is broad. Almost any alternative fuel with reduced emissions compared to fossil fuels could be considered a SAF. These options fall largely into two main categories. 'Drop-in' SAFs are aviation fuels that can be used in the aviation industry with little change, blended with conventional fuels, while 'Non-drop-in' SAFs are fuels that require extensive changes to design and infrastructure, such as hydrogen [1][2]. As a result, Drop-in options are far more common, with seven production pathways already approved by the EU. By comparison, to date, there are no approved Non-drop-in SAFs.

Whilst these pathways have been approved, it does not mean they are ready for immediate use. In the European Aviation Environmental Report, the authors provided a so-called "Technical Readiness Level" from 1-9, where 9 is a mature and ready technology, while highlighting four key pathways [2].

First is Hydroprocessed Esters and Fatty Acids (HEFA), which achieves the highest score of 8-9. This pathway utilizes waste and residue fats such as cooking oils, and at the time of the report was the only commercially available SAF [2].

Another potential pathway is Alcohol-to-Jets (AtJ), sitting at a TRL of 7-8. As the name suggests, this pathway utilizes alcohols, such as those from fermented agricultural and forest residues. Unlike other SAFs, this pathway can include aromatics in the fuel. Reducing aromatics is beneficial for air quality, however, this is at the cost of airworthiness in parts of the engine, such as rubber seals. This makes it a good candidate for future 100% SAF blends [2].

Then there is Biomass Gasification + Fischer-Tropsch (Gas+FT), with another TRL of 7-8. This pathway creates biogases from the feedstocks, which are then processed through a Fischer-Tropsch reactor. These reactors use a mixture of carbon monoxide and hydrogen to produce liquid hydrocarbons such as methane, which are later processed into SAFs. It can use the same feedstocks as AtJ, and solid waste, making it a particularly sustainable option [2]. SAFs produced through gasification are known as 'synthetic' SAFs despite using biomatter as a feedstock.

Finally, there is Power-to-Liquid (PtL), which starts by producing hydrogen through electrolysis. The hydrogen and captured carbon dioxide are then synthesized into a synthetic gas before being processed into SAF through a Fischer-Tropsch reactor. Unlike the first three options, which are all some form of biofuel or take biomatter as feedstock, PtL only requires energy and captured CO2 to produce SAF [2]. In this way, it has the largest emission reduction potential and the smallest land use change. SAF created through PtL is classified as a synthetic SAF, but is also commonly referred to as eSAF [3].

The potential emissions reduction that each SAF is capable of is then estimated through the use of a Life Cycle Assessment (LCA). These LCAs are usually taken from Well-to-Wing, meaning from the recovery and/or extraction of the feedstock to the SAF production and finally the impact from the fuel used in an aircraft [2]. One such LCA was conducted for every CORSIA (ICAO Carbon Offsetting and Reduction Scheme for International Aviation) approved LCA pathway and feedstock, as shown in Figure 1 [2]. A more general LCA was also conducted by Twelve, a company specializing in "Carbon Transformation" [3]. Their LCA focused on the four primary pathways discussed here, as shown in Figure 2 [3]. It is clear from these results that SAF has immense emission reduction

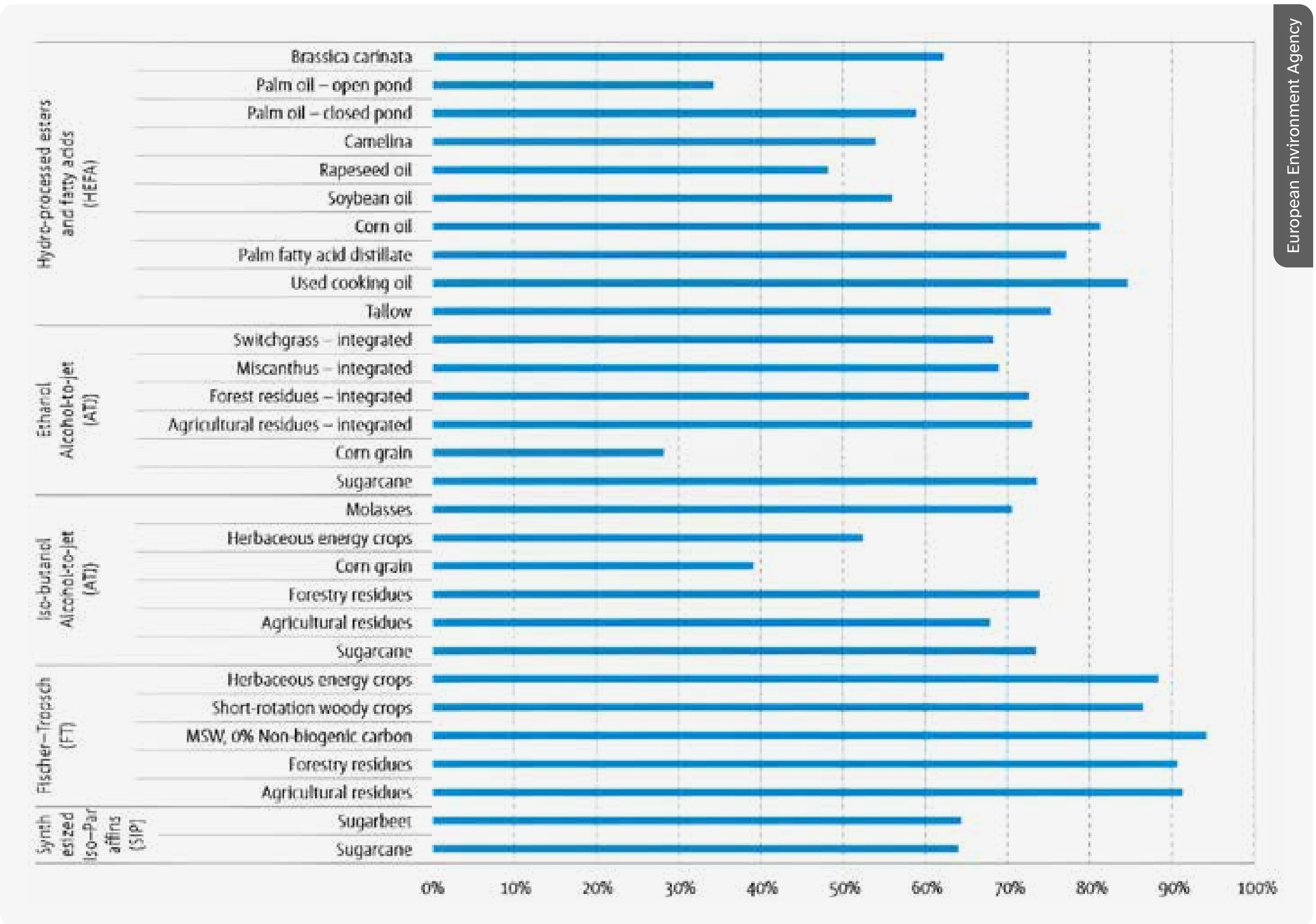


Figure 1: Emissions reduction of SAF compared to a fossil fuel (89 gCO2e/MJ)

potential, especially with Gas+FT and PtL, which perform exceptionally on both LCAs with up to a 90% reduction.

The Role of SAF in European Aviation

SAF has great emission reduction potential, with the advantage that Drop-in SAFs are easily integrated into the existing industry. So why isn't it being used? Well, it is! In the USA alone, the Department of Energy has revealed that SAF usage has steadily increased since 2021, with 24.5 million gallons used in 2023 [4]. Nevertheless, this remains a low percentage of the total market compared to conventional fuels.

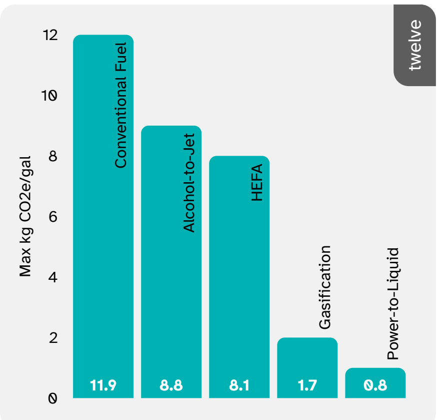


Figure 2: Lifecycle GHG emissions of different SAF Pathways

However, laws and regulations are pushing for SAF to take up a larger fuel market share in aviation, especially in Europe. In 2021, as part of their plan to reduce emissions by 55% by 2030, the EU announced the "Fit for 55" climate law [5]. This law makes the goal a legal obligation for all member states. As part of the Fit for 55 plan, the EU acknowledges the importance of reducing emissions in aviation, with 3-4% of all emissions in the EU originating from that industry [2]. To achieve this lofty goal, the EU implemented the ReFuel EU regulation. ReFuel EU, among other things, lays out a timeline for how much SAF should be used in EU airports, with 6% SAF use by 2030 and 70% (with 35% being synthetic) by 2050, as seen in Figure 3 [6].

In reaction to this policy, several countries are already implementing incentive programs to ramp up SAF production. In 2022, Norway introduced a SAF blending mandate of 0.5%, intending to increase it over time [2]. Sweden is following a similar path, with an end goal of 27% by 2030, going further than the ReFuel EU mandate by a fair margin [2]. The Netherlands has gone even further, aiming for a full fossil fuel replacement by 2050, with the intermediate step of 15% by 2030 [2]. This has led to several new announcements of SAF production facilities throughout the Netherlands.

Green and Sustainable Fuel in the Netherlands

In 2021, a startup called Synkero announced plans to build a new SAF factory in the port of Amsterdam by 2027 [7]. The facility would produce 50,000 tonnes of eSAF through the PtL production pathway, utilizing excess CO2 from industrial processes as the base feedstock. The jump towards immediately producing eSAF is part of Synkero's goal to produce "SAF in a circular way (that) fits seamlessly with (our) new four-year strategy to be a leader in the energy transition" [7]. However, Synkero isn't the only company aiming to produce large amounts of eSAF.

Advario, a leader in liquid storage logistics, and Power2X, a company specializing in producing 'clean and green molecules', have recently partnered to construct a state-of-the-art eSAF factory in the Port of Rotterdam [8]. The project aims to produce 250,000 tonnes of eSAF annually, which Power2X claims to be the equivalent of fueling 7000 flights from Amsterdam to New York annually —five times more than Synkero's proposed plant [8]. In their press release, Power2X stresses that the facility will be completely green, as it shall produce from entirely renewable sources, reinforcing that the methanol will be imported from "locations where renewable energy and green

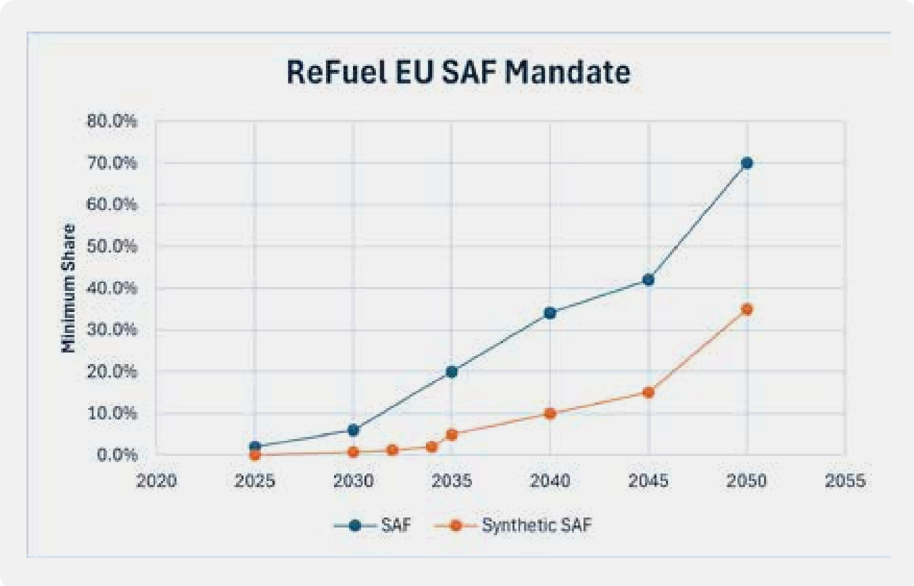


Figure 3: ReFuel EU's SAF mandate over time

hydrogen are available" [8]. This methanol will then be used as the source of aviation fuel with locally produced green hydrogen.

The construction of these facilities is naturally the result of the Fit for 55 plan and ReFuel EU. The facility, with a planned storage capacity of ~230 million liters, would then, according to Power2X, supply 40% of the synthetic SAF requirement by its completion in 2030 [8]. This ambitious plan would make the factory the largest of its kind.

The Challenges and Limits of SAF

Whilst SAF may appear as a silver bullet for the climate crisis in aviation, it's important to recognize its flaws. The biggest of these lies in the scale of feedstocks required by SAF production. Biofuels such as HEFA require vast amounts of cooking oils, fats, and plants. Their use is a great advantage, as they eliminate a source of waste and contribute to a more circular economy. However, with the size of the aviation industry, far more feedstocks will need to be acquired than is currently available [9]. For example, a study by Swanson and Smith in the US finds that if soybeans were used as the primary feedstock for SAF, soy farms would have to increase by 50% [10]. Meeting the US' target of 3 billion gallons of SAF by 2030 would require 8-11 million acres of corn or 35-50 million acres of soy [10]. The authors say "A rapid expansion of SAFs could reignite the food-versus-fuel debate". Furthermore, the land use change related to this expansion would have severe environmental impacts on ecology and biodiversity. Although SAF is a low-carbon alternative, it is not a perfectly sustainable option.

Biofuels may have some drawbacks to consider, but what about eSAFs? They do not rely on biological feedstocks, only needing CO2, hydrogen, and energy. But it's that last point where the issues lie. The energy transition is already leading to high demands for renewable power across all sectors. While the renewable sector is consistently growing, setting aside power for aviation fuel production is not a priority [9]. Additionally, if energy were obtained from fossil fuel sources, that would largely negate the emission-reduction benefits of SAF, which was the goal from the start. For eSAF to be sustainable and readily available, renewable energy production must grow even more.
Generally, the required supply of feedstocks and power for the necessary scale of SAF production is immense. Eurocontrol, the EU's air traffic network manager, estimates that to fulfill the SAF mandate by 2050, 870 TWh/yr would be required [11]. That is the equivalent of 73 nuclear power plants or 8157 wind turbines, solely used for SAF. In addition, the biofuels would require up to 787 Mt of biomatter, at a predicted cost of €1.2-2 trillion. To put that into perspective, using the values from Swanson's study, if the primary feedstock for SAF was from soybeans, 23-44 million hectares of land use would be needed to provide the necessary biomatter [10]. That's roughly equivalent to covering the entire land area of the UK (23 million hectares) to the entirety of Sweden (44 million hectares). Nevertheless, it's important to remember that using soy for SAF production is one of the least efficient production pathways available.

The lack of supply for these facilities is leading to increased costs of SAF. Currently, available HEFA fuels have up to 80% of their cost dependent on the feedstock being used, and SAFs are on average 2-3 times more expensive than conventional jet fuel. Furthermore, vast resources would be needed to provide the infrastructure required to produce SAF. For example, an estimated $1.3 trillion would be required to reach 25% of the US's goal by 2050 [12]. All in all, SAF is constrained by its supply of feedstocks and energy, which limits its ability to be cost-effective and sustainable.

SAF offers significant potential to reduce aviation's environmental impact through a diverse set of possible feedstocks and production pathways. eSAFs especially produced through the PtL pathway, are attractive options, with up to 90% emission reduction compared to fossil-based jet fuels. Increasingly more SAF facilities are beginning construction with EU mandates. However, it's essential to keep the limits of SAF in mind. The effect of the land use of Biofuels could have far-reaching ecological impacts and the energy and cost requirements are immense. SAF is not the solution for climate-neutral aviation, but it doesn't need to be. Multiple options and technologies must be employed together to make an effective transition to a sustainable society. In that regard, SAF will remain an important tool for the lofty goal of net zero by 2050.

Render of Advario and Power2X's planned eSAF factory

GENERAL

Cracks in the Cockpit

A case study in pilot oversight

Muhammad Arham Elahi, Leonardo Times Editor


Dawn

When passengers board a flight, they entrust their lives to the professionalism and expertise of the pilots in the cockpit. This trust is built on confidence that these trained individuals adhere strictly to procedures, meticulously follow safety protocols, and remain focused on ensuring a safe journey from takeoff to landing. When this trust is breached—through negligence, distraction, or procedural lapses—the consequences can be catastrophic. The tragedy of Pakistan International Airlines Flight 8303 starkly illustrates the fragility of this trust and highlights the devastating outcomes when human error undermines the principles of aviation safety.

Pakistan International Airlines (PIA) Flight 8303 was a scheduled domestic flight operating between Allama Iqbal International Airport in Lahore and Jinnah International Airport in Karachi, Pakistan. Karachi is one of the largest cities globally, with a population exceeding 17 million, though this figure is likely underreported. Due to the city's immense population density, Jinnah International Airport is located near residential areas. Residents in these neighborhoods often describe planes flying so close to rooftops that it feels as though they could touch them. At 13:05 on 22nd May 2020, the flight departed Lahore, piloted by Captain Sajjad Gul and First Officer Usman Azam for a 90-minute journey [1].

This flight occurred in the midst of the COVID-19 pandemic, during a time of strict lockdown measures in Pakistan. As one of the few flights still in operation, it carried heightened significance. Compounding the unusual circumstances, the flight took place during Ramadan, the Islamic holy month of fasting. Both pilots were fasting during the flight, a decision permitted under Islamic law but not required, as fasting can be postponed while traveling more than 80 km. Despite this religious flexibility, the pilots chose to continue their fast. While international aviation regulations prohibit pilots from fasting during duty due to its potential impact on concentration and decision-making, no such rule applied to this domestic flight. Additionally, the reduced workload caused by the pandemic meant that First Officer Azam had not flown for some time, though Captain Gul had logged 10.5 hours of flight time in the previous three days. Weather conditions were favorable, with clear visibility and wind levels well within acceptable operating ranges [1].

Captain Sajjad Gul, 58, was a veteran pilot with Pakistan International Airlines, having served the airline for over 24 years. Over the course of his career, he accumulated more than 17,000 flight hours, including nearly 5,000 hours on the Airbus A320. In 2019, his extensive experience earned him the title of standards inspector, a role that required him to ensure other pilots operating the A320 met safety and performance standards. However, his career began under contentious circumstances. In 1996, Captain Gul failed a psychological evaluation conducted during his pilot training. The evaluation described him as “bossy, dominant, overbearing, and resistant to authority, with below-average intelligence and a low tolerance for stress”. Based on these findings, the airline psychologists deemed him unfit for the role of pilot. Disagreeing with this assessment, Captain Gul sought second opinions from five independent psychiatrists, all of whom certified him as suitable to continue his training. After careful deliberation, the airline allowed him to proceed as a trainee pilot. First Officer Usman Azam, 33, had significantly less experience compared to Captain Gul, with only approximately 2,300 flight hours to his name [2].

Flight and Descent

The flight took off in routine fashion and leveled off at FL340. Everything appeared normal at first as the pilots engaged in casual small talk about the ongoing pandemic and how it was impacting their lives. Air Traffic Control (ATC) had cleared the crew for the Standard Arrival Route (STAR) Nawabshah 2A. This route included a holding pattern, allowing the aircraft to lose altitude gradually. However, given the low traffic conditions, ATC later cleared the crew for Nawabshah 1C. This was a shorter, more direct route that bypassed the holding pattern, and the crew immediately accepted this option [2].The first cracks in the crew's functionality emerged just prior to descent. The descent preparations were initiated much later than usual, and the distribution of workload between the pilot flying (First Officer Azam) and the pilot monitoring (Captain Gul) was not aligned with standard protocols. Typically, the pilot monitoring assumes the pilot flying role during the descent planning phase, while the pilot flying inputs the updated flight plan to the Flight Management Computer (FMC), and conducts a thorough briefing to double-check the parameters. On this flight, the first officer attempted to multitask by handling both roles simultaneously, without proper checks or effective communication [2].

A critical function of the FMC before descent is calculating the Top of Descent (ToD), the optimal point at which the aircraft should begin its descent toward the runway. The direct Nawabshah 1C approach eliminated the holding pattern present in Nawabshah 2A, requiring an earlier ToD. While reprogramming the FMC, the first officer altered the waypoints but neglected to remove the holding pattern, leading to a descent delayed by 23 nautical miles.This error went unnoticed due to the absence of an approach briefing and the crew's lack of communication. If the crew had identified this mistake earlier, they could have intercepted the correct descent profile by deploying airbrakes and adjusting their speed. As best practice, pilots conduct manual calculations to verify the FMC's accuracy, but this safeguard was not implemented during this flight [2].

Further compounding the situation, the crew preemptively switched radio frequencies after receiving clearance from ATC to descend to FL050, assuming an imminent handover to another controller. This action did not follow protocol, and the crew mistakenly input an incorrect frequency. Consequently, ATC could not contact the aircraft until they resorted to an emergency frequency. The pilots, preoccupied with irrelevant discussion during this critical phase of the flight, failed to notice the radio silence [2].

Approach and Crash

The crew continued their descent with a complete lack of relevant communication, omitting crucial callouts, confirmations, and checks. The first officer activated the ILS (Instrument Landing System) approach, which guides aircraft to descend on a 3-degree glide slope upon capturing a radio signal. As the flight passed twenty nautical miles from the runway, it was at double the altitude required for this stage of the flight plan. This situation, while serious, was still recoverable. The pilots could have let the aircraft fly the holding pattern to lose altitude safely, adding only five minutes to the flight time and ensuring a stable approach [2].

At this point, the tower controller noticed the aircraft's altitude was too high for a standard descent and asked the crew if the remaining track miles to the runway were sufficient. Captain Gul replied, "Affirm", and only then realized the gravity of their mistake. He instructed the first officer to remove the holding pattern from the flight plan but also directed him not to report the issue to ATC. Instead, the captain told the first officer to inform ATC that they were established on the ILS, despite the situation. The first officer, in an attempt to recover, deployed the speed brakes and initiated an aggressive descent far beyond recommended limits [2].

ATC repeatedly asked for confirmation that the descent was proceeding as expected. Each time, the captain assured them that everything was under control and declined ATC's offer to perform an orbit to lose altitude. The aircraft, now descending at an alarming rate of 7,500 feet per minute—nearly four times the normal rate—deployed its landing gear. Despite this, the captain insisted to ATC that they were comfortable and would make the landing safely. This dysfunctional cockpit setup was further evident as the first officer, the pilot flying, was also handling radio communications—contrary to protocol [2].

As the descent continued, the captain was recorded on the Cockpit Voice Recorder (CVR) saying, "He [ATC] will be surprised [at] what we have done". This comment ultimately reflected the captain's misplaced confidence and disregard for standard operating procedures. Post-crash analysis revealed the captain had a history of risky approaches involving high speeds, steep descents, and multiple Ground Proximity Warning System (GPWS) alerts during landings [2].

Eventually, ATC issued a direct instruction for the flight to abort its descent and turn left, but the crew once again declined, claiming they were established on the ILS. Unbeknownst to them, they had captured the 6-degree glide slope signal instead of the standard 3-degree angle. This error occurred because ILS signals can be falsely

Image captured moments before the crash (left) and the resulting explosion in a densely populated area (right)

Damage to the engines from scraping along the runway during the first landing attempt, with the Ram Air Turbine deployed for backup power captured at multiples of 3-degree, and the crew failed to perform manual backup calculations to verify the glide slope. As the aircraft descended below the 6-degree glide slope, the ILS system attempted to guide it rapidly toward the 3-degree slope thousands of feet below. Despite stern instructions from ATC to abort the descent, the crew insisted they were on track [2].

The aircraft's pitch reached an extreme -13 degrees, far outside normal operating limits. The pilots attempted to slow down by deploying flaps, increasing drag. However, this triggered overspeed warnings, as flaps are not designed for deployment at such speeds, which exceeded 230 knots. Multiple warnings blared in the cockpit, including GPWS alerts, which required an immediate pull-up maneuver. However, there were no callouts acknowledging the warnings or any actions to address them. The autopilot eventually disengaged due to the steep descent angle, further intensifying the chaos [2].

In a last-minute attempt to recover, the first officer pulled back on the control stick, retracting the landing gear and speed brakes, which slowed the descent significantly. At 1,000 feet, he suggested to the captain that they should perform an orbit to stabilize. However, Captain Gul dismissed this idea, insisting they proceed with the landing as ATC had just cleared them. Without any communication, the captain extended the flaps and took over as pilot flying, setting the stage for the tragic conclusion of the flight [2].

In standard operating procedure, at 1,000 feet above ground level all aircraft parameters must be stable and within acceptable limits, otherwise a go-around is mandatory. However, standard procedures had been disregarded throughout the flight, and the crew showed no intention of adhering to them now. As the aircraft's warning system detected their extremely low altitude with the landing gear retracted, a visual warning was triggered. However, due to the aircraft's excessive speed at this altitude, the system assumed the pilots were not attempting a landing and issued terrain warnings instead of calling attention to the landing gear. Consequently, the captain failed to notice the retracted gear and attempted to land [2].

During the attempted landing, the aircraft had multiple distinct touchdown points, grinding its engines against the concrete runway surface and producing intense sparks and vibrations. The captain's lack of situational awareness was further highlighted when he attempted to deploy reverse thrust and brake, unaware that these actions required the landing gear to be extended. Meanwhile, First Officer Azam kept pulling back on his control stick to lift the aircraft, while Captain Gul pushed his stick forward, resulting in conflicting inputs that canceled each other out—a phenomenon similar to what occurred during the Air France Flight 447 crash. The friction and damage during the botched landing attempt caused a fire warning to activate for Engine 2 [2].

Had the crew continued this landing attempt, they would likely have overshot the runway, potentially causing casualties. However, the proximity to emergency services might have mitigated the disaster. Instead, the captain finally heeded the first officer's suggestion and initiated a go-around. Miraculously, the aircraft managed to get airborne with only one functional engine, though both engines had sustained extensive damage. Engine 2 entered "autostart" mode, attempting to restart itself. The initial go-around seemed surprisingly smooth, with Engine 1 functioning normally and Engine 2 managing to restart and contribute thrust. Against all odds, it appeared as though the aircraft might recover [2].

Unfortunately, Engine 1 soon began to fail under the strain, and the crew noticed the fire warning for Engine 2. In response, they moved Engine 2 to idle, effectively shutting down the only engine providing thrust. Now gliding without power, the crew prepared for an emergency landing. When ATC asked if they would attempt another belly landing, the crew immediately replied, "Negative," and deployed the landing gear instead. This decision proved fatal, as the increased drag caused by the landing gear left the aircraft with insufficient glide distance to clear the densely populated Model Colony near the airport. The aircraft crashed into the neighborhood, killing 97 of the 99 people on board and injuring eight people on the ground, one of whom later succumbed to her injuries [2, 4, 5].

The subsequent investigation concluded the crash was primarily due to pilot error. On 25th June, 2020, it was revealed that 150 of the 434 pilots employed by PIA held fraudulent licenses. While the pilots on Flight 8303 were not among them, this discovery highlighted severe mismanagement within the airline. As a result, PIA faced operational bans in both the European Union and the United States. The EU ban was finally lifted in January 2025, while the US ban remains in effect [6].

The crash site in the densely populated Model Colony, which destroyed several houses, delayed emergency services, and caused injuries to eight people on the ground

The crash of PIA Flight 8303 serves as a tragic reminder of the critical importance of discipline, communication, and adherence to aviation protocols. While technical systems are designed to assist, they cannot compensate for lapses in human judgment or procedural violations. The sequence of errors—ranging from missed descent planning to ignored warnings—highlights the consequences of a dysfunctional cockpit. This disaster underscored the urgent need for enhanced pilot training, stronger oversight, and systemic reform in some airlines. As the aviation industry moves forward, lessons from such incidents must drive change to restore trust and prevent similar tragedies, ensuring safety remains the top priority.

SPACE

A Dream of Mars

From Sumeria to SpaceX

Alex Nedelcu, Leonardo Times Editor


20th Century Fox

The ancient Sumerians made the first recorded observations of Mars. Subsequent civilizations, from Egypt to China, studied the motion of the planet and ascribed meaning to its blood-red color. But how have our views of Mars evolved? And how are our perspectives going to change in the future?

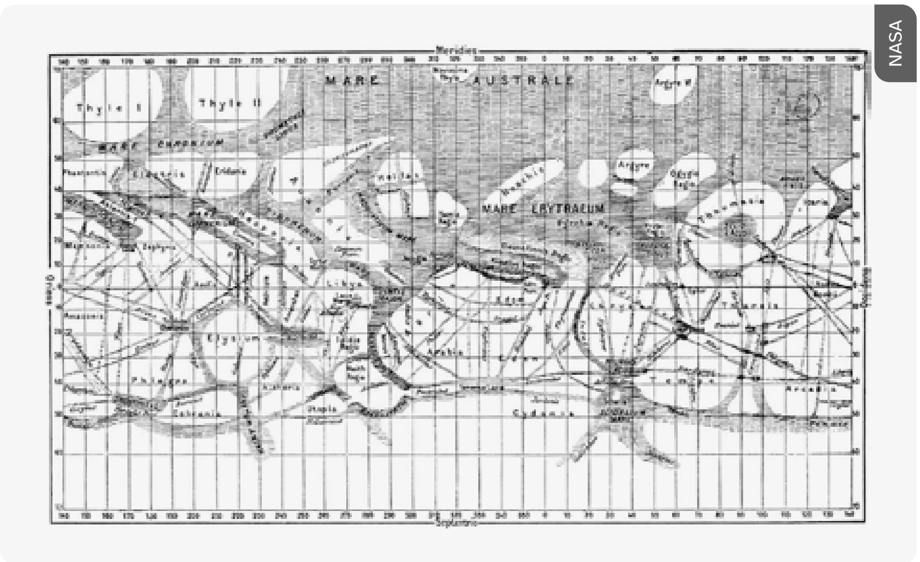
Mars has a radius equal to half the Earth's, a thin atmosphere dominated by carbon dioxide and an utterly inhospitable climate [1]. Once, it might have been capable of sustaining life, as proven by the traces of water in solid form that were found in 2018 in polar regions. Its surface, covered in iron oxide, is reminiscent of blood, which led to the ancient Romans calling it Mars after their god of war.

Mesopotamia, China, Rome

The civilizations in the fertile crescent, such as the Sumerians, Babylonians, and Assyrians, referred to Mars as Salbatanu, explained as 'constantly portending pestilence' [2]. Diviners and astrologers associated Mars with the god Nergal, mighty, vengeful, and bloody. Its radiance was directly proportional to the propensity of conflict, and a faded Mars was considered beneficial for the people. Interestingly, the correlation of Mars with Nergal took on political undertones, as historians argue that this 'false, malevolent star' would be associated with countries that were malevolent to the diviner and therefore to the king and the land. In general, the 'enemy star' was associated with the geopolitical enemies of the state, wherever they were located [2].

Two thousand years later, the Romans also ascribed Mars' red hue to their god of war, second in importance to Jupiter. Under the emperor Augustus, Mars became Mars Ultor ("the Avenger"), his personal guardian as he avenged the murder of his uncle, Julius Caesar [3]. A prominent myth also links Mars to Rome's founding, with the god said to have fathered legendary founders Romulus and Remus. Beyond fables, Mars was the protector of Rome's proud military tradition and was worshipped by the legions [3]. Under his auspices, sacrificial blood flowed from the Field of Mars, and warriors died a glorious death on the battlefield.

Further east, under the reign of the Qin, Han, and Tang dynasties in ancient China, astronomical observations were used to predict the future. Astronomers had



NASA

Schiaparelli’s initial sketches of the Mars canals

Jean-Pol Grandmont

Mars, Roman god of war

assigned a certain subject to each constellation, and each planet corresponded to a certain element in the “Wuxing” (Five Phases) system that connected the elements of Fire, Water, Wood, Metal, and Earth [4]. Mars represented fire and was known as the fire star, characterized by conflict and fighting. In his paper on the role of astronomy in ancient Chinese society and culture, Xiaochun Sun writes that comprehensive treaties were composed to explain every possible interaction between the heavenly bodies [4]. Specifically, if Mars entered the constellation Scorpius, assigned to the Chinese Imperial Court, ill tidings were foretold for the harmony of the imperial family.

al-Qabisi and Kepler

But this wasn’t Mars’ only connection to faith and religion. The doctrine of planetary dignities, an astrological theory developed by 10th-century scholar al-Qabisi, was used to determine the strength and nature of the influence of each planet on a new child’s birth based on their location in the zodiac at birth [5]. The astrologer divided the degrees of each sign into masculine and feminine groupings, with Mars representing “tyranny, bloodshed, conquering, highway-robbery, wrongful seizure, the leadership of armies, haste, inconstancy, smallness of shame, journeys, absence”. Furthermore, in the Middle Ages, Europeans organized their lives based on the position of the heavenly bodies, with this influence shown even in the language for the days of the week: Tuesday is Mars-day (or “Mardi, “Martes”, and “Martedi” in French, Spanish, and Italian respectively) [6].

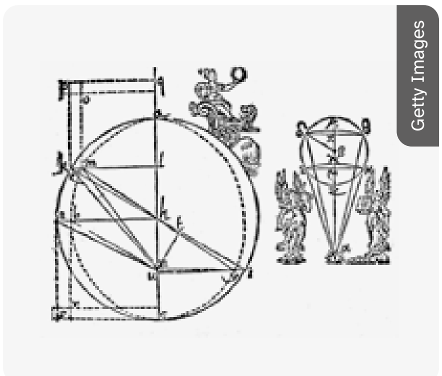
> *“If we can conquer space, we can conquer childhood hunger.”*
>
> **- Buzz Aldrin**

Late Roman philosopher Boethius built on the work of Plato and Aristotle to describe three categories of music, the critical one was that of the universe, with the mathematical relationships that drive it manifesting in musical qualities and tones. It was in the pursuit of this concept of “musica universalis” that Johannes Kepler discovered the third law of planetary motion in 1618. The astronomer aimed to reconcile the emerging vision of a Sun-centered planetary system with Pythagoras’ concept of “Armonia”, universal harmony [7]. Though Kepler was distraught that Mars’ orbit did not represent a circle, the archetypal symbol of perfection, the resulting elliptical orbit revealed a more subtle form of harmony. He found that the ratio between the maximum and minimum angular speeds of each planet approximated musical intervals, with Mars taking up the role of tenor in Kepler’s celestial choir. The ratios of the maximum and minimum speeds of planets on neighboring orbits yielded a complete scale - with one exception: Mars and Jupiter, which created an inharmonic ratio of 18 to 19 [7].

Aliens on Mars?

After it was proven that the Moon could not sustain life, the focus shifted towards Mars. In 1877, Italian astronomer Giovanni Schiaparelli charted the surface of Mars using a primitive refractor telescope. A mistranslation of his observations (“canali” - grooves) resulted in increased interest from the public speculating that intelligent life had dug canals into the surface [8]. Throughout the first half of the 20th century, artists created stories and images of the Martian landscape based on these observations, with H.G. Wells’ “War of the Worlds” novel being most representative of this time of excitement [9]. With near-infrared spectroscopy, Dutch astronomer Gerard Kuiper proved that the Martian atmosphere was primarily composed of carbon dioxide in 1947 [8]. Though the inhospitable climate was used as proof that no sentient life close to what exists on Earth would exist, the planet’s mythologized reputation (and a new geopolitical competition) transformed it into an inspiration for exploration and discovery [9].

Space exploration served as a dramatic arena for Cold War competition, with the capitalist United States and the communist Soviet Union racing towards the stars. From Sputnik to Challenger, the two superpowers constantly tried to one-up each other, with achievements in space



Getty Images

Kepler’s illustration of Mars’ elliptical orbit exploration being seen as sources of national prestige. Several orbiters were dispatched to Mars by both countries, with the USSR's Mars 1 successfully attaining a payload-less flyby in 1962 and the US's Mariner 4 famously taking pictures of the Martian surface in 1964 [10].

Though both the Soviets and the Americans attempted multiple launches of orbiters and landers towards Mars, only the American Mariner 9 orbiter and Viking lander succeeded in 1971 and 1975 respectively [10]. Each superpower independently planned crewed missions to Mars, but funding for NASA and the Soviet - and then Russian - design bureaus slowly decreased after the collapse of the Soviet Union. As Fukuyama's so-called end of history dawned, the dream of Mars became a unipolar fantasy.

After the end of the Cold War, NASA's Mars programme continued with the Pathfinder lander (1996), the Global Surveyor orbiter (1996), the Odyssey orbiter (2001) and the more recent Mars Exploration Rovers [10]. In the new millennium, Mars became the target of true international exploration, with European and Indian spacecraft successfully reaching Mars.

The Mariner 9 orbiter

Red Mars, Blue Mars

And what about the future? It is impossible to talk about Mars without mentioning the elephant in the room. Elon Musk's SpaceX stated their intention to deliver a crewed mission to Mars, working within NASA's Artemis program. However, the claims made by Musk over the past decade have only materialized on a few (but veritable) occasions. For example, in 2018, he stated that SpaceX could help build a base on Mars by 2028 [11], but, even with the recent successes in Starship launches, they seem far from capable of reliably transporting everything required for a "Mars Base Alpha". As Matthew Shindell writes in his recent book "For the Love of Mars", in prominent political figures' rhetoric, a trip to Mars always appears to be just a few decades away, allowing present policies to be justified indefinitely [12].

It is undoubtedly true that pushing for space exploration would spur a new age of innovation, triggering developments in propulsion, robotics and automation, structural design, and materials science, but also health and safety, governance, and nuclear engineering. Furthermore, so-called "techno-optimists" argue that the dream of Mars provides a compelling vision for the future, which could help bridge our petty divisions here on Earth [13]. Quoting Buzz Aldrin, "If we can conquer space, we can conquer childhood hunger." Perhaps Mars will be the fulcrum of this vision.

But the future might not be all milk and honey. In a geopolitical climate once again taking the shape of a bipolar world, the two superpowers, the United States and the People's Republic of China, may seek to further their security competition through a new space race, potentially to Mars. A second Cold War could sink resources into both military pursuits and spacefaring capabilities, some of which might be repurposed in deadly directions. In any case, vicious competition might be the last thing we need to succeed on Mars and to solve the many crises humanity faces.

A render of the proposed Mars Base Alpha

From ancient history to the present, Mars has had the potential to unite humanity and tear us apart. Its blood-red surface inspired wars spurred technological innovation and served as a location for the Opportunity rover's heart-rending shutdown. Will the dream of Mars take precedence to solving the problems we already face, and doom us to an increasingly perilous journey on Earth? Will security competition intensify to new heights? Or will we find the sense and reason to collaborate? We will find out soon enough.

SPACE

Echoes of Mir

The ISS's inevitable fate

Vince Lukácsi, Editor

NASA

After more than two decades, The International Space Station (ISS) is due to retire within six years. Although it may seem distant, the complexities of decommissioning the largest human-made space station are a growing concern within the space industry. As plans are drafted for the future of space exploration, solutions to bring the ISS back to Earth are sought from the past.

Operation Choice

The ISS approaches the end of its mission. Although it remains fully operational, various critical components are getting close to their design life due to dynamic loadings, such as from docking, and thermal cycles [1]. To ensure a safe environment for the crew members, NASA decided to retire the ISS in 2030. Various plans regarding the decommissioning operation have been drafted with different budgets, sustainability policies and degrees of complexities. One of the options considered by NASA was to disassemble the ISS in space and return the individual components piece by piece. Although this would have allowed scientists to study those components for technical analysis, and the ISS would have been "preserved", the projected financial and technical difficulties of such an operation were colossal. The space station was simply not built to be disassembled easily, and it would have required at least the same effort required to build it [1]. The tedious operation, including possible delays, also caused concerns about whether or not the ISS could be disassembled before its natural orbit decay would become too important. Another solution considered was to raise the ISS to a higher orbit, which, in return, would have reduced the accessibility of the space station and simply delayed the problem. Amongst these various plans, NASA decided to opt for a method that has already been proven effective in the past, namely for de-orbiting Mir.

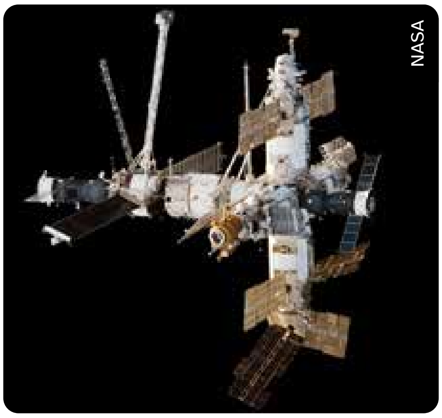
The ISS Predecessor

It is key to first have a look at the context surrounding this event to grasp how the decommissioning of Mir occurred. Mir was the first ever Modular Space Station to exist. Its name can be translated from Russian to "peace", and it was operated by the Soviet Union, and later by the Russian Federation, from 1986 to 2001.

Unlike any other single-module satellite at that time, Mir consisted of independently launched vehicles docked together in low Earth orbit. Over ten years, six different modules were attached to the core of the space station, making it the heaviest spacecraft of its time. This pivotal achievement set up a new horizon for scientific experiments. It provided a laboratory platform in a constant state of microgravity for crew members to research in numerous scientific fields and to study the effects of prolonged time in space on the human body. Mir was particularly useful in establishing the importance of space stations, and its relevance in the space industry strongly impacted the direction in which it was evolving.

Mir's large structure allowed it to house 3 permanent crew members and was continuously inhabited for 3644 days [2]. Throughout its mission, it housed 105 cosmonauts and astronauts, from 13 different countries, even including the USA [3]. Although the Cold War was not completely over, political tensions were easing. The last years were marked by a new international cooperation in space research, ending the lengthy Space Race. The Shuttle-Mir program, involving American astronauts visiting the Mir, was one of the first instances of such collaboration and is "also known as Phase 1 of the International Space Station Program" [4].

Shuttle-Mir astronauts



Mir Space Station

Mir breaking up during re-entry

It became clear that, as the millennium was approaching, several systems of the Mir were becoming outdated and it was getting close to its final phases. With a larger space station in vision and the start of a new era of international collaboration, the funds were cut off. After this decision, several commercial missions were still made, with an optimistic view of Mir's future. However, Roscosmos, the State corporation for space activities, forbade any further missions after the Soyuz TM-30, the last human space flight to Mir. The decision to decommission, although difficult after more than 15 years of operation, was made.

Lessons From the Past

Decommissioning such an imposing structure was more difficult than initially expected. The scale of Mir was incomparable to any other satellite previously retired. The engineers faced a huge challenge with an impressive mass of around 140 tons [3], flying at speeds close to eight kilometers per second [5]. Additionally, the disasters of the Skylab were still vivid in the minds of many.

Skylab was the first space station operated by NASA between 1973 and 1974 [6]. After its last human mission, the power on the station was turned off and it continued to wander in low-Earth orbit for several years. NASA scientists had predicted that it would remain in orbit until March 1983 [7], leaving nine years to prepare a decommissioning plan. However, due to an unexpected increase in solar cycles, the orbit of Skylab turned out to decay at a much faster rate. As the atmospheric density increased, the satellite experienced significant levels of drag at higher altitudes, and "revised estimates projected Skylab's reentry occurring as early as mid-1979" [7], or four years earlier than planned. This left little time to plan the Skylab's decommissioning and the fear of an uncontrolled reentry over populated areas raised worldwide concern. Even the tiniest space debris, travelling at supersonic speeds, would cause significant, deadly damage. Through the little control it had over Skylab, NASA tried to extend the orbital life to allow the space shuttle to save the satellite, but further delays in the schedule made the rescue mission impossible.

Skylab

On July 11, 1979, Skylab made its reentry into the atmosphere. As it flew above South East Africa, drag caused the breakdown of components over the Indian Ocean and the western part of Australia. Although some parts crashed on land, no one was injured and the damages were limited. However, this incident raised significant awareness about the importance of controlled reentry. Debris falling over a populated area could have had disastrous effects. 22 years later, it was Mir's turn to return to Earth.

Final Operations

The de-orbiting occurred in three stages. On January 27, 2001, Progress MI-5 docked to Mir to provide the necessary thrust force to lower the orbit in a controlled fashion [8]. It initially fired eight control thrusters for 22 minutes bringing down the altitude from 219 km to 188 km. One orbit later, the same thrusters were activated for another 24 minutes to further decrease Mir's height to only 158 km. The third and final stage took a matter of minutes. As the main thruster of the module was fired, Mir re-entered Earth's atmosphere watched by Leonid A. Gorshkov, its designer, whose creation fell to pieces in the sky. He and five other cosmonauts, who had all been housed by the space station, were on the Island of Fiji at the time. The lighter parts disintegrated under the scorching heat, reaching 1500°C [9]. The heavier components turned into plasma, seen from Earth as glowing meteorites. Finally, all debris landed in the Pacific Ocean some thousands of kilometers away from the southeast coast of Australia.

After the flawless execution of the decommissioning, the relief felt after the stressful moments of the operation was mixed with strong emotions. For many, Mir was more than a space station. It symbolized the fruit of years of hard work by engineers who had dedicated their lives to this project. Throughout its 15 years, Mir broke countless records and displayed impressive achievements. It traveled an impressive 2.2 billion miles [8]. To put it into perspective, that distance exceeds 23 times the Earth-to-Sun distance. It was also home to Valeri Polyakov, a Russian cosmonaut, who still holds the record for the longest time spent in space in one go. He remained on board for 437 days [10]. Mir proved to the world that space stations were the future of the space industry. It had permitted for 15 years the conduction of countless research projects in all fields, leading to significant progress in medicine and meteorology. Finally, its de-orbiting provided important insights and guidance for today's engineers. The lessons learned on the controlled re-entry of such an imposing structure will be key to ensuring a safe return of the ISS.

Amongst the numerous ways to decommission the ISS, NASA decided on a controlled re-entry, based on previous successes and mistakes. This option is safe and relatively cheap compared to an uncontrolled re-entry, a disassembly or an orbit increase. The exemplary work done by Russian engineers in 2001 played a significant role in shaping engineers' decision to pursue a similar approach to retiring the ISS in six years.

The Ancient Quest for Flight

And why it took so long

Gerard Mendoza Ferrandis, Editor-in-Chief

"The Fall of Icarus" painting by Jacob Peter Gowy depicting the legendary story

The Wright Brothers will go down in history as being part of the few who truly revolutionised the world by being the first to achieve sustained heavier-than-air flight. However, we must remember that many before them also attempted similar feats. Why didn't they succeed? And could their inventions be making a comeback?

Imitating Nature

Since the beginning of the human dream to fly, engineers have turned to nature for inspiration. Many stories and legends mention this imitation of nature as a method to achieve flight. The oldest and most popular story is the myth of Icarus. As the legend goes, Icarus and his father Daedalus were trapped in the Minotaur's labyrinth. Daedalus crafted some wings using string, feathers, and wax, and they used them to flee from the labyrinth. However, Icarus flew too close to the Sun, the wax melted and he fell to his death.

One of the oldest written records of such attempts, where crafted wings were used to attempt flight, was that of Yuan Huangtou. Yuan was the Prince of Anding, in the dynasty of Eastern Wei, a Chinese imperial dynasty in today's north-eastern China. Kites had already been invented in Eastern Asia, and although their mechanics were not fully understood, some were used for military applications [1]. Yuan was taken prisoner and, along with other prisoners, was used to conduct experiments on flight using a kite-like machine. In 559 AD he was the first prisoner to survive the use of the machine [2].

In 875 AD, a similar feat was accomplished by Abbas ibn Firnas in Córdoba, Al-Andalus, and in the 11th century by monk Eilmer of Malmesbury in Wiltshire, England. These two pioneers strapped two wings to their arms and feet and threw themselves from a tower. They both managed to land after a short glide, with some injuries. Interestingly, they both agreed that their lack

E.P. Frost's engine-powered ornithopter, which managed to make a brief hop

of control, especially during landing, was probably due to a lack of tail [3]!

We can observe from this early "Icarian" phase of flight history that, while these people glided down to Earth, they did so uncontrollably and did not manage to sustain flight. Why is this? The answer is that when these imitations of bird wings were designed, there was not much thought into why birds could fly in the first place. It is inevitable that if you attempt to replicate the wings of a bird and do it well, the minimum that will happen is that you will be able to glide. Correct shape and aerodynamics will be in your favor. However, sustaining flight is a whole different ball game. Birds have very strong muscles in relation to their size and weight. For birds, flight muscles account for 15-25% of their body weight [4], while for humans our upper-body muscles, the ones we would use to pump the crafted wings, only account for 11-18% of our weight on average [5]. We can see with a quick rough estimation why this is important. If we assume a bird and a human were trying to hover, then the thrust produced by them flapping their wings would have to counter their weights ($T = W = m*g$). The average weight of a human is 79 kg [5], while that of a bird (like a falcon for example) is 1.1 kg [6]. Then $T_{human}/T_{bird} = 79/1.1 \approx 72$. This means humans must provide 72 times more thrust by flapping their wings. To achieve flapping flight, humans would need to have pectoral muscles twice the size of a professional bodybuilder, readjust their anatomy so the muscles have more leverage, and have lighter bones [7].

> *"Every failed attempt at powered aviation taught us something we could later use to improve the designs."*

Studying Nature

Leonardo da Vinci provided the first documented detailed study of flight. In 1490, he drafted ideas for an ornithopter. However, he ascertained that mechanical advantage would be needed, so his ornithopter was actuated by pedaling a crank to make the wings flap. The main idea was to use the legs and the mechanical advantage of the pedals to increase the energy output given the limited muscle proportion of the human upper body. He later discovered that the power output was insufficient regardless [8]. In 1655, polymath and inventor Robert Hooke found that the human body did not have the strength to power artificial wings [9] and, in 1809, Sir George Cayley finally killed the ornithopter after publishing his work "On Aerial Navigation". He decomposed the forces of flight into the four we know today: lift, weight, thrust, and drag [10].

This decomposition explained why ornithopters never worked. They attempted to compensate for weight and drag with only one force: the resultant of pumping the wings. This meant the artificial wings had to provide thrust and lift, which needed much power. Understanding the forces of flight led to a big paradigm shift. It meant that the wing could be fixed and compensate for the weight, and the thrust could be provided by an external means, like an engine. However, this would not stop many inventors, like Edward Purkis Frost, who still tried to make an ornithopter fly, but this time using an engine to provide enough pumping power [11].

Going Vertical

Lighter-than-air flight had been around for much longer. The Montgolfier brothers performed the first manned balloon flight in 1783. However, it would take longer for the first heavier-than-air attempts at vertical flight. This was understandable, as few of nature's counterparts fly using helicopter-like mechanics. The closest thing we have are samaras, the seeds of some trees that spin when falling. Maybe inspired by these, the ancient Chinese invented a toy they called the "flying top". It was a winged top that when spun would take off vertically and slowly fall back down [12].

It wasn't until Leonardo da Vinci's time that the first concept of a vertical flying machine was presented: the aerial screw. His concept consisted of a screw that would be spun by a crew of four men. The idea was that the screw would take off by compressing air downwards, in a similar fashion to how a water screw works [13].

Eilmer of Malmesbury depicted with his wings before the jump

The "Crimson Spin", University of Maryland's aerial screw drone

Sketch of Leonardo da Vinci's aerial screw in one of his notebooks

However, da Vinci's screw would not have worked for the same reason that ornithopters didn't: it was too heavy [13]. Furthermore, despite air and water both being fluid, they have very different properties. The main difference is that gas tends to fill all volume. As the helix was not bounded, the air would have never followed the "compression path", scattering instead.

The Renaissance of Forgotten Designs?

We must not undermine the works of these pioneers. Their attempts and concepts may look absurd in retrospect, but they did not have the theoretical understanding we do now. Every failed attempt at powered aviation taught us something we could later use to improve the designs. It is widely known that the Wright Brothers read Octave Chanute's 1893 book, "Progress in Flying Machines" to attain their first flight in Flyer 1. This book was a compendium of all of these attempts and the lessons learned, among many other things.

Today, we have been slowly recovering many of these failed concepts and designs. Now that we understand why they did not work, we can revise the designs, which may lead to surprising use cases that we had not thought of before.

One of the sketches from Leonardo da Vinci's study of ornithopters

The Wingsuit

Many will have seen videos of the viral stunts performed by BASE jumpers and skydivers. These jumpers use what we now call a wingsuit. If Yuan Huangtou, Abbas ibn Firnas, and Eilmer of Malmesbury had seen these "wingsuits", they would have found them quite familiar. The wingsuit is a clear descendant of the techniques they used in their flight attempts. Instead of being made of wood, feathers, and cloth, attached to the arms and feet, these new wingsuits are typically a one-piece synthetic suit.

The wingsuit was created in 1930 to enable skydivers to reach further distances, although the first commercially available wingsuit was only released in 1999 [14].

Ornithopter Drones

The ornithopter has made a comeback thanks to the rapidly developing world of drones. The most common type of drone is the rotary-wing type, with the quad-copter usually being used to depict drones as a whole. However, in the last few decades flapping-wing drones have made an appearance. TU Delft, for example, started developing DelFly in 2005, a micro-UAV that could sustain flight by flapping its tiny wings [15]. In 2024, China's Northwestern Polytechnical University developed the biggest ornithopter drone to date [16]. Ornithopter drones offer several advantages: being cheaper, safer, able to interact non-destructively with surfaces, and are also more agile. However, the transmission system is much more complex and carries significant weight penalties [17].

Aerial Screw Drone

The ornithopter is not the only one of da Vinci's machine making a comeback in the world of drones. There is also the 2022 University of Maryland's "aerial screw quadcopter". That same year, it took off for the first time in the Transformative Vertical Flight conference. They managed to achieve such a feat by making the drone very light. Although the drone is not as stable as its rotating wing counterpart, it produces significantly less downwash and is quieter [18].

Aerial Screw VTOL

Finally, in 2020, a TU Delft team also made a conceptual design that awarded them the first prize in the Vertical Flight Society Student Design Competition, which was also based on Da Vinci's aerial screw. Their design "SolidarityOne" is a motorcycle-looking VTOL that achieves take-off using ducted aerial screws. The design was electric, quieter and less disruptive, making it ideal for urban mobility [19].

Humans learned how to fly the hard way: by trial and error. Many first attempts were fundamentally flawed, due to the use of heavy materials, and thinking we were as strong as birds. However, as technology has progressed and our understanding of flight has advanced, we have managed to revive these designs by replacing human power, wood and steel with powerful engines and lightweight, strong, innovative materials. This has allowed some of these flailed designs to slowly but surely make a comeback; some are back already without us even noticing.

New ideas taking flight

As pioneers of the aviation community
We set out new courses to accelerate innovation

We are innovators
We are curious and courageous
We are eager to sustainably connect your world

We explore the future while improving the present
We embrace experimentation to solve complex challenges
We put problems and people at the core of our process
We unlock superpowers through data and technology

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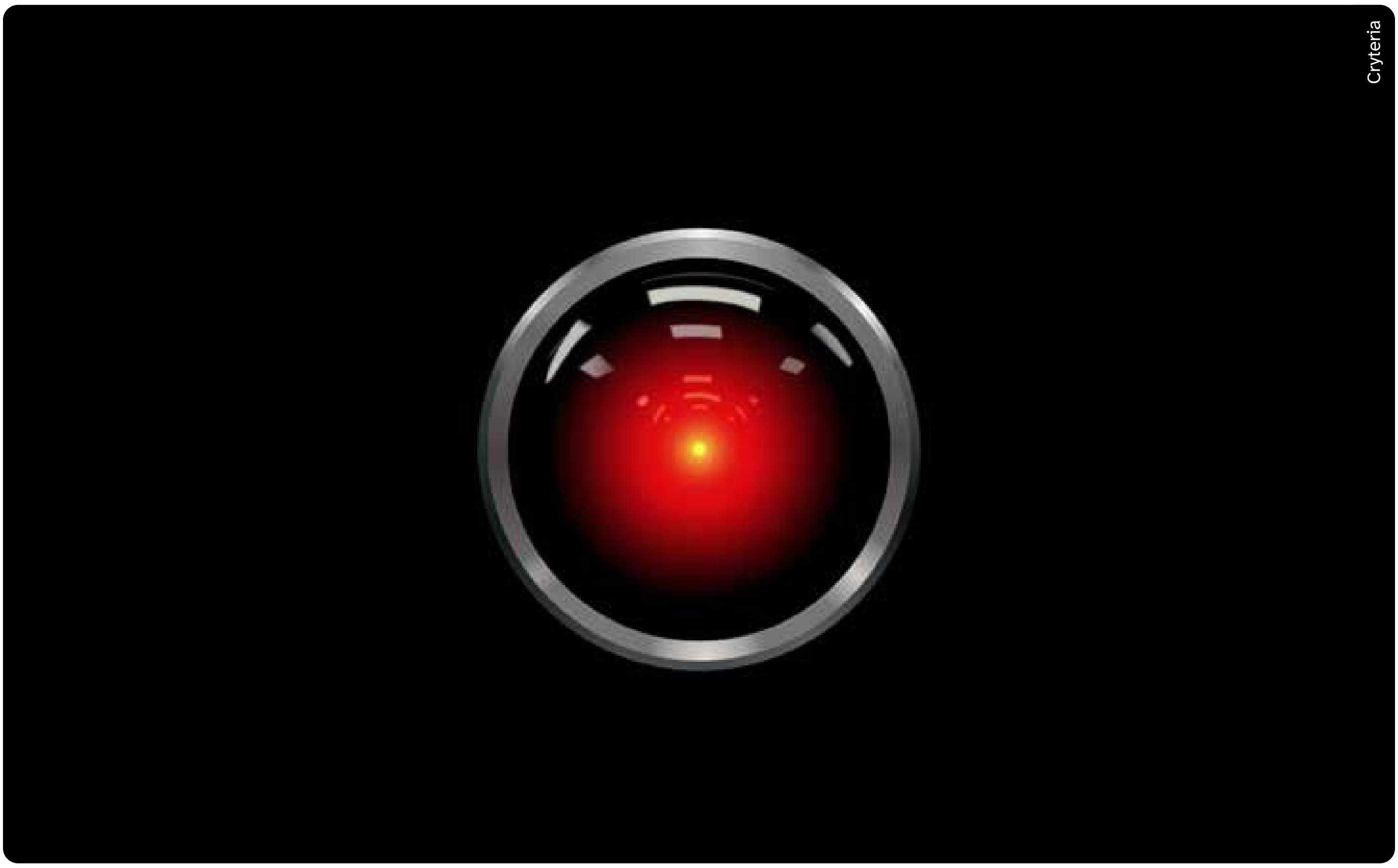
Trust me, I'm AI

Why we must learn how to accept uncertainty

James Perry, Editing Director



Cryteria

Artificial intelligence is creeping into all walks of life as its potential uses are explored. Despite the many advantages such technology could bring, adoption into commercial aviation has been slower than elsewhere. We explore the reasons why, and how this can change.

In 2022, OpenAI released the first public version of ChatGPT [1]. The name easily rolls off the tongue nowadays, and few readers would not be familiar with it. Casting one's mind back two years shows how much the world has changed in such a short amount of time. Two years ago, there was no way to put something on paper except by writing it yourself. There was no way to solve a bug in your code except by searching Stack Overflow and hoping somebody else had already solved the problem for you. And there was no doubt about the uniqueness of the creativity of mankind. A computer could never be an artist, at least not until 2022.

Daily life feels the same. The conveniences of AI for students are generally met with higher expectations, just as calculus is still as challenging since the advent of calculators. More websites have AI chatbots, autocomplete is better, and there has been an increase in faked hyper-realistic videos online – but despite AI, you probably still have to wake up early for your commute! Below the surface, however, the uptake of AI has been stark. 2023 saw a near-doubling in the prevalence of words such as "commendable", "intricate" and "meticulous" in scientific publications, all of which are more commonly used by generative AI than human authors. A University College London study [2] estimated over 1% of papers were at least partially written by AI that year, despite nearer to 0.1% disclosing it. Taking a probabilistic approach, researchers at Stanford University [3] found numbers much higher, up to 17.5% in computer science. Some papers even have phrases like "as an AI language model" left in! Other than that, however, the wide range of estimates shows how hard it is to tell when exactly AI has or hasn't been used. The point is that AI use is widespread in academia and beyond. When it is impossible to detect whether an action is human or machine-driven, it is futile to argue the world has not fundamentally changed.

The Rise of Automation

Humans are troublesome. Almost since the dawn of powered flight, automation has been creeping into aviation to help overcome human limitations, the one element of

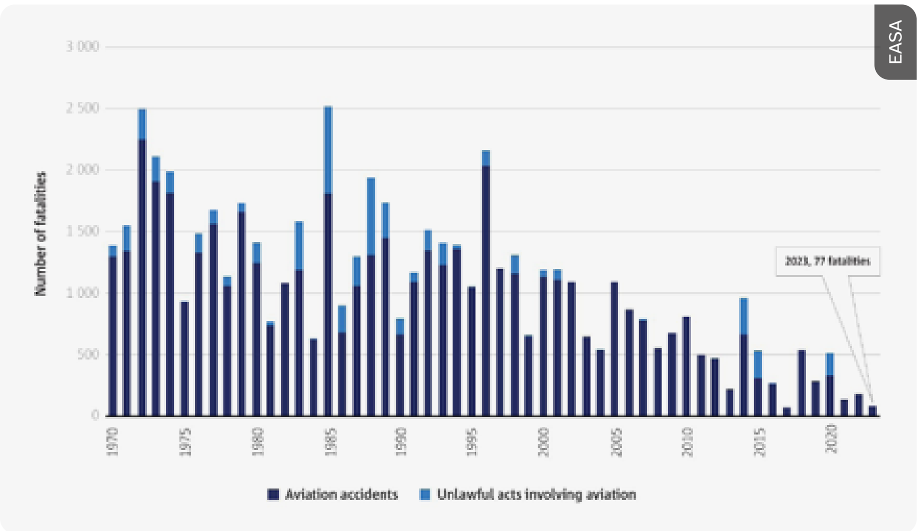


Figure 1: The number of fatalities worldwide in commercial and cargo aviation has decreased significantly in the past forty years

an aircraft that we cannot design. Especially in emergencies, pilots face a high workload in a stressful environment. Automation can help to relieve that workload, allowing pilots to focus on making safe decisions. It is difficult, however, to find examples of when computers have saved lives – an aircraft proceeding without an accident isn't newsworthy.

However, over the last few decades, automation has heavily contributed to the incredible improvement in aviation safety, as shown by Figure 1. In 2023, there were 77 fatalities in commercial and cargo operations worldwide, none of which involved airliners, down from a peak of over 2,500 in 1980 [4]! Compared to the nearly 4.5 billion passenger journeys [5], that's a 1 in 1.7x10-18 chance. This means last year you were 80 times more likely to be struck by lightning than to die when you flew [6]. Only 4% of serious incidents over the last 5 years were caused by system or component failure, avionics-based or otherwise [4]. Automation has led to many tragic accidents, including the infamous MCAS system onboard Lion Air Flight 610 and Ethiopian Airlines Flight 302, which the Leonardo Times has already discussed to a great extent. Such accidents are so noteworthy because the reliability of aircraft systems is usually so high, making it shocking when things go wrong.

By contrast, flight crew error was the most common cause of fatal accidents over the last five years [4]. This was often caused by confusion or mismanagement of challenging circumstances, such as thunderstorms or minor technical failures, ultimately leading to loss of control. One benefit of automation is that it does not get tired or confused. A computer system can process more information than a human, faster, considerably longer, and with almost perfect accuracy. The quantity of data generated by aircraft continues to increase. The average commercial aircraft produces 20 terabytes of data from sensors in each engine alone [7]! The human mind can consciously process the equivalent of 120 bits of data per second [8], so it would take 400 people ten years to sift through all the information just one engine produces in an hour. That's before considering all the other aircraft systems, from hydraulics to electrical power, pneumatics to air conditioning. Modern aircraft cannot be flown by humans alone; we need computers.

TU Delft's Center for Excellence in AI for Structures is investigating the potential to use data from acoustic waves for composite structural health monitoring [9]. This involves attaching piezoelectric transducers to an aircraft's structure, allowing the signals to be interpreted and the health of the structure determined. This has great potential to reduce preventative maintenance, as components can be replaced based on their actual state, which saves money and is better for the environment. Imagine the sheer quantity of data an aircraft would produce when the entire structure is monitored!

Up until now, automation has always been a tool for human pilots. It has already made the positions of radio operators, navigators, and most recently flight engineers, redundant. Pilots can get the information they need at the push of a button, which once required an extra crew member. EASA classifies AI applications into three categories [10]: Level 1 – assistance to a human; Level 2 – human-AI teaming; and Level 3 – advanced automation, either overridable or not. The latter would permit Single-Pilot Operations, which EASA is slowly pursuing in the face of several safety concerns. Whether this stage is reached or not, AI can greatly improve current autopilots, allowing them to cope with far more challenging situations than traditional control systems can [11].

Anything above level 2 automation requires a different approach to the current automated systems. The computer is no longer a tool, but a flight crew member capable of making its own decisions, which may disagree with the human pilots, for better or worse. The computer acts independently, under human supervision, in the interest of the safety of the aircraft. This is a huge change in how we use automation – it's like letting ChatGPT reply to all your emails and just checking them periodically. Probably a bad idea at the moment, but it could save so much time for more important things. The software requires slight improvement – so what's the barrier?

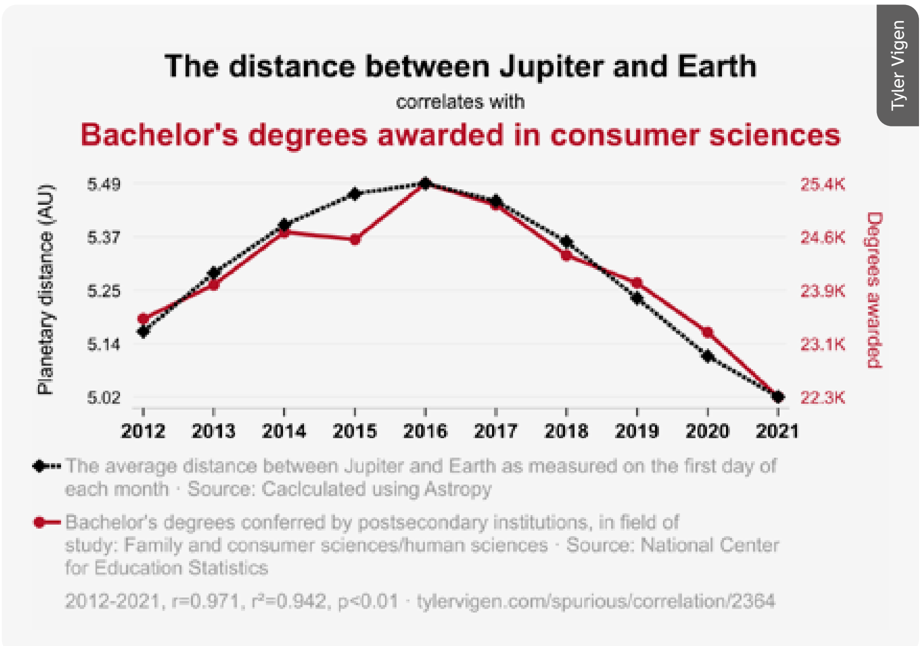


Figure 2: One of thousands of obviously spurious correlations available online, backed up by an AI-generated research paper

An AI-generated painting of Delft, with the prompt to draw "an artistic painting of modern day Delft in the style of Vermeer, with visible brushstrokes"

Engineering is Hard

The impressive safety record of commercial aviation is only maintained by strict safety regulations, which include certification requirements for all new technologies. Usually, this is a fairly straightforward matter – simply determine what system performance is safe and ensure by testing that this safe behaviour is maintained throughout the aircraft's lifespan. More bureaucratically, manufacturers must demonstrate compliance with the legislature through specified acceptable means. This is most publicly visible in destructive structural testing; videos of aircraft wings being bent until failure can be easily found online. The testing process is rigorous, from full-system flight tests down to individual components. Everything is tested and has a standard to meet to pass the test and be certified as safe to fly.

AI systems must be tested similarly if integrated into aircraft. They must be demonstrated to work exceptionally safely under all conditions the aircraft will encounter, potentially facing increased scrutiny in light of public scepticism. But AI is notoriously difficult to test. Software is usually tested through white-box testing, verifying all paths through the program work as intended, and black-box testing, verifying only that the correct inputs lead to the correct outputs. Black-box testing is the only method for traditional neural networks, [12]. The network learns patterns in data and, while we can inspect the nodes and weights, we usually don't understand exactly how an AI system reaches the answers it does. All that can be seen is the correct answer being generated for the input given. This is not good enough! AI in aircraft systems will not be faced with a finite number of discrete, testable scenarios, but rather a huge influx of continuous data from a range of sometimes erroneous sources. It is impossible to exhaustively test the response to every condition that the AI might face, especially if it is allowed to continue learning while in use. It may work once, but how can we be certain it will work every time? Safety standards will not budge for the sake of convenience.

There is also the question of accountability, which has been raised many times for self-driving cars. When a self-driving vehicle crashes, who is to blame? The manufacturer or the human supervisor? And, if the responsibility is shared, to what extent? How advanced does AI have to be before the software itself is blamed, just as if it were human? Attributing responsibility is important for the justice system but also before accidents even occur. Clear accountability ensures people know what they are responsible for and act accordingly. Where the blame can't be traced, there is always the option not to care, not to do anything about a problem.

Once the manufacturer has developed an AI system, its use case must also be considered. Just because it looks good on paper does not mean it will see success in the real world. Pilots need to be comfortable supervising and operating an AI system. They must understand its decision-making process and challenge or override it if necessary. They should not rely on it without alternatives and should be able to troubleshoot the system like any other in the event of a malfunction. How do you figure out what's gone wrong with an abstract network of mathematical weights?

Communication Matters

It is also dangerous for pilots to be overly cautious. An example of this is Air France Flight 447, which in 2009 crashed into the Atlantic Ocean en route from Rio de Janeiro to Paris, sadly killing all 228 on board [13]. Pitot tube icing caused the flight computer to receive inconsistent inputs, which caused it to disengage the autopilot and flight envelope protection, reverting manual control to the pilot flying, First Officer Pierre-Cédric Bonin. The avionics functioned as intended, the pilots simply needed to fly the aircraft manually. However, the pilots were not used to flying manually at altitude, where handling characteristics are quite different from nearer to the ground, and the A330 entered a pilot-induced oscillation. Although this was recovered from, Bonin had also unintentionally begun to pitch the aircraft up and it started to stall. None of the three pilots acknowledged the stall, which was indicated to them as designed by stall warnings and buffeting. The computer trusted them with control, so they thought they knew best.

One can argue that the concept of human error is only a myth. Maybe there is no such thing, but rather the failure of a complete system which includes humans in the loop. Of course people will make mistakes, it's in our nature, so systems and procedures must be designed to prevent our failings from leading to such consequences. While the flight computer in this example behaved as programmed, how it was programmed was not suited for this situation. The aircraft was fully stalled for three and a half minutes, which should have been ample time for three experienced flight crew to recover, or at the very least decrease the angle of attack below the 35° at which it remained. They did not do this, because the computer considered its airspeed indications unreliable at such high angles of attack and temporarily deactivated the stall warning. This meant that the stall warning resumed when the angle of attack reduced, so the pilots were afraid to do so. The system designers didn't consider a situation where the aircraft could be at such a high attitude and the pilots did not notice that they were stalled, so the computer did not communicate this information to the pilots in control [13].

F-GZCP two years prior to its involvement in the crash of Air France Flight 447

This story highlights the vital importance of accurate and efficient human-machine interaction, but also trust. Bonin did not trust the computer from the moment of the icing, despite its otherwise normal function. If an automated system is untrusted and so ignored or even overridden, the resulting situation can be even less safe. The whole system must be assessed, both human pilots and automated systems together. The safest outcome does not rely on perfecting either element individually, but rather on the system as a whole and the cooperation between these two players.

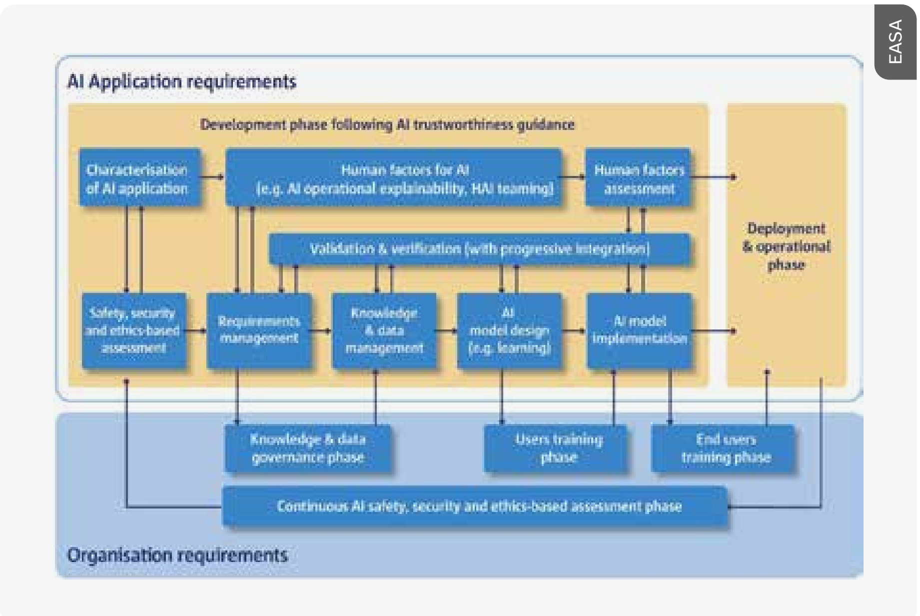
Source: Trust Me

So, how do we avoid the advent of AI systems leading to such accidents, whether through genuine fault or miscommunication? XAI stands for "eXplainable Artificial Intelligence", and refers to any AI systems which explain how they reached an output. This is vital for improving trust in AI systems and installs confidence and power in humans to enable them to tell whether a mistake has been made. This may be interactive such that humans submit a text-based query and receive a written explanation, but could also be graphical displays or plots showing the model mapping from input to output, or confidence that the output is correct.

Often, a grey-box method is proposed, where the inner workings of a model can be partially understood while retaining the high performance that pure white-box systems fail to achieve. In addition to model interpretability and post-hoc explainability, XAI should justify the data being used as input. A model may be sound based on an existing correlation, passing all the grey-box tests, but if the correlation does not make real-world sense then it is foolish to trust it. Tyler Vigen has a website of spurious correlations, one such example being how the distance between Jupiter and Earth correlates with bachelor's degrees awarded in consumer science, see Figure 2 [14]. The website also includes a five-page AI-generated paper explaining a farcical study and leading to these results! It's all nonsense, but if you couldn't tell, how could you know whether to believe it? A written excuse is insufficient by itself, only full consideration of the input data and model process provides a proper explanation.

Even in this context, the complete system should not be ignored. Interpreting the XAI results is yet another potential for misunderstandings, and well-placed trust can only be achieved with a total understanding of the system's abilities, limitations and methods. Sutthithatip et al. [12] even suggest a need for dedicated training and certification for XAI users in aerospace; the risk of misuse and mistrust is of such great concern. XAI is surely the way forward, but there is so much variance within the field it is hard to tell which safest, most effective solution will emerge. Previously, aviation has learned from tragic accidents, but with standards so high we cannot afford anything but to get AI right the first time.

The three levels of automation described by EASA are a subset of the complete possibilities of human-supervised automation, the most extreme of which is that the "computer does the whole job, if it decides it should be done, and informs human, if it decides human should be told" [15]. It becomes clear that trust will eventually go both ways, depending on whether the computer believes the human can improve the situation. This conjures memories of the science-fiction novel "2001: A Space Odyssey", in which the computer HAL kills the crew to protect its mission. But, consider the implications when an AI's objective is to preserve life instead. As Air France Flight 447 has shown, humans don't always know best. If it is probabilistically the safest option not to involve humans in decision-making, it is difficult to argue why we should be.



EASA's life cycle process for AI-based systems for use in aviation, highlighted to have a much wider scope than traditional systems

Despite rapid progress in the last few years, AI still faces major hurdles before it can enter safe use in commercial aviation. It is challenging to build trust in a system you don't understand, which is why XAI is vital to this transition. It is common for articles such as this to ask whether you would put your life in the hands of a computer, but consider that they would only ever be certified to the highest standards of provable safety. Perhaps the harder question is: why do you trust your life in the hands of humans?

GENERAL

Engineering the Atmosphere

Cooling the planet, but at what cost?

Ruth Euniki Vraka, Leonardo Times Editor


Robert Markowitz / NASA-JSC

A modified bomber plane that carries instruments to count and analyze natural particles in the atmosphere, as part of a campaign to understand how reflective particles affect the Earth's climate

Everyone loves a beautiful sunset. What if there was a way to make them even prettier? According to US-based startup "Making Sunsets", this could be a byproduct of their main goal of "cooling the Earth" by releasing aerosols into the stratosphere [1]. Though it may sound tempting, the science behind the technology is a largely controversial topic in geoengineering. It has instigated conversations and research on an international scale.

What is Geoengineering?

The Earth's climate steadily inches closer and closer to a point of no return. Points of no return (PNRs) can be defined in various ways using different statistical methods and taking different factors into account. However, it is widely accepted that these points lay in the 2030s-2040s if the current climate trends continue [2]. Calls for immediate action have been made, and steps are being taken by many different parties to correct the damage we have inflicted on our planet. Among the potential solutions and technologies to combat the phenomenon of global warming is geoengineering. According to the Center for International Environmental Law (CIEL), "geoengineering refers to large or planetary-scale interventions in the Earth's atmosphere, oceans, and soils to counteract only some of the effects of climate change" [3]. [Note for Ralf: would it be possible to add the definition in a little box or something that makes it stand out?] The specific methods vary from the injection of chemicals into the atmosphere to reflect the sunlight, to the manual removal of carbon dioxide from the atmosphere, also known as carbon capture. They all have one thing in common: they do not focus on solving the root cause of the problem. The reason they gain attention is because they could potentially act as an emergency solution that buys humanity more time to solve the root cause.

SRM: Solar Radiation Modification (or Perhaps Slightly Risky Meddling)

One of the current prevalent geoengineering methods is Solar Radiation Modification (SRM). The technologies related to SRM (see Figure 1) aim to increase the re-

Front page of Make Sunsets website

flection of the Sun's radiation in the atmosphere, effectively controlling the amount that reaches Earth. In this way, Earth's temperature increase can be partially controlled. One of the ways that SRM can be implemented is with Stratospheric Aerosol Injection (SAI). Aerosols are microscopic liquid or solid particles that exist in a gas. In the context of geoengineering, this gas is the atmosphere. Examples of natural aerosols are desert dust, wildfire smoke, and sea spray, while anthropogenic aerosols are mainly caused by the combustion of fossil fuels. Aerosols play a direct role in Earth's climate and can have a warming or cooling effect depending on the type and color, but current research suggests that they have a total negative effect on the amount of radiation entering the atmosphere [4,5].

It is also very interesting to note that reduced fossil-fueled travel during the COVID-19 pandemic led to a decline in anthropogenic aerosols, which has been correlated to a slight warming of 0.1-0.3 degrees Celsius in certain areas [4]. Overall, according to a report by the Intergovernmental Panel on Climate Change (IPCC) in 2021, aerosol air pollution is responsible for keeping the Earth at approximately 0.4 degrees Celsius cooler than if it didn't exist. For scale, the effect of greenhouse gas emissions has been estimated to cause 1.5 degrees Celsius of warming [4]. However, there is still a large gap in our understanding of the full effect and role of aerosols. The processes in the Earth's natural ecosystem are intricate and interrelated, and slight changes can cause disruptions in natural patterns. One such process for which there are still uncertainties is the effect of aerosols (e.g. sulfate aerosols) on cloud formations [5]. Such knowledge gaps are also part of the reason why scientists and climate experts are still hesitant to conclude potential ways in which SAI could be used to combat climate change.

The Irony of SRM

A study published in March of 2024 by the European Geosciences Union also raises concerns regarding the effect of SRM technologies on renewable energy sources. The paper highlights that in current simulations SRM and other mitigation strategies are considered additively, without any physical interdependencies. However, an analysis of the coupling between SRM and renewable energy capacity points to the conclusion that SRM can increase the difficulty of decarbonization by reducing the production potential of photovoltaic and concentrated solar power. In other words, "failing to decarbonize early enough, which would render SRM unnecessary, makes it even more challenging to decarbonize later when SRM is implemented" [2].

The irony of SRM is evident: the motivation behind its implementation would be to buy us more time, but simultaneously it would be lengthening the timeline of decarbonization with the use of renewable energy sources. This raises a series of questions, many of which apply to other geoengineering methods as well:

By implementing SRM, do we assume that in the "time bought", technology regarding alternative energy sources (such as nuclear) will have advanced enough that the reduction in solar renewable energy sources would not considered a problem? And who is responsible for making this call?

Who defines the threshold after which the implementation of such "emergency procedures" is considered necessary, and resources are allocated to a "quick fix" over a long-term solution? What happens if we make our climate dependent on SRM and have to continue using it forever to avoid "termination shock"?

If implemented at a large scale, which would be required to reach results, SRM has global-scale effects and is not contained geographically. Should SRM implementations be regulated at an international level? Is this realistically possible? Could SRM create or exacerbate international power imbalances? For example, who will control the Earth's thermostat?

Due to the global effect of SRM, and if its implementation actively delays the path to decarbonization, there is an ethical and moral responsibility of informed consent from Earth's population. How can informed consent be organized in this case? Can the decisions be trusted in the hands of the world's leaders? Are underrepresented and indigenous communities involved in the design and decision process? If SRM is implemented and causes harm due to unforeseen consequences, who is held accountable?

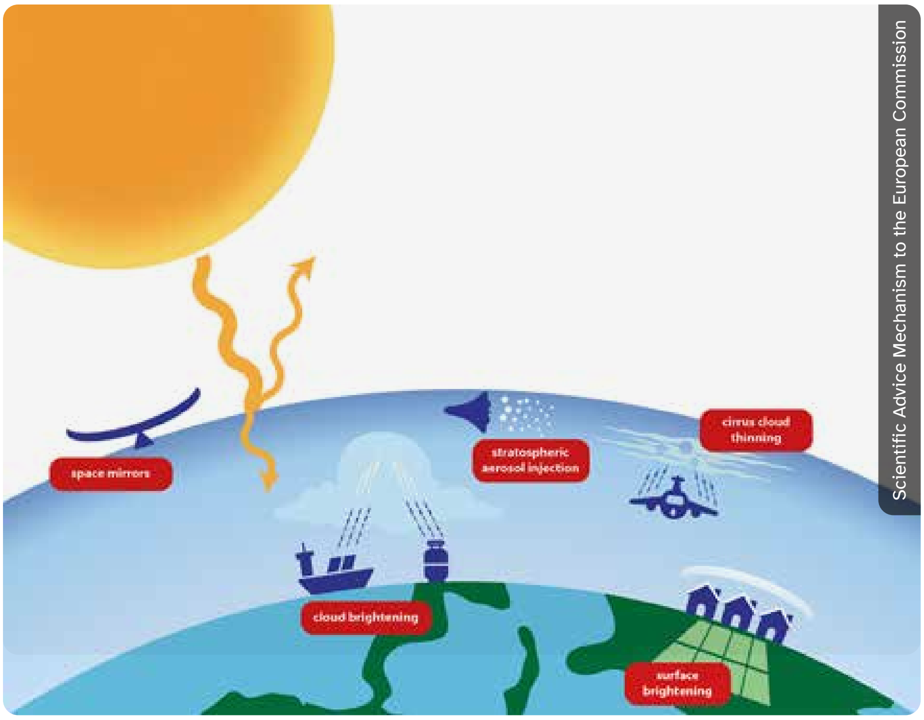


Figure 1: Different types of Solar Radiation Modification technologies

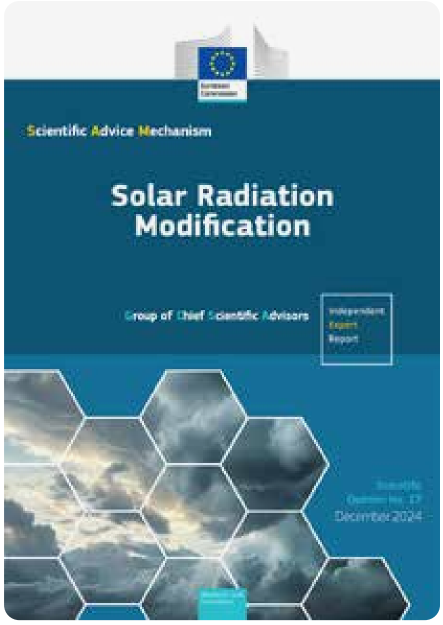


Figure 2: Advice on Solar Radiation Modification from the European Commission's Group of Chief Scientific Advisors

The Stance of the European Union

The global effect of SRM and potentially other geoengineering technologies is evident. Naturally, this controversial topic has led to discussions within political and scientific bodies around the world, including the European Union (EU). Already in June of 2023, the European Commission and EU External Action Service expressed their skepticism of geoengineering being the solution to climate change, given the current scientific knowledge. According to their released document, "these technologies introduce new risks to people and ecosystems, while they could also increase power imbalances between nations, spark conflicts and raise a myriad of ethical, legal, governance and political issues" [6]. In November of 2023, the European Parliament passed a resolution calling "on the Commission and the Member States to initiate a non-use agreement at international level, following the precautionary principle and in the absence of evidence of its safety and a full global consensus on its acceptability", also noting that "a UN resolution on global governance has been blocked" [7, text 92].

Most recently, on the 9th of December 2024, the Scientific Advice Mechanism (SAM) to the European Commission delivered advice responding to a request made in August of 2023 regarding the question: "How to address the risks and opportunities associated with research on Solar Radiation Modification and with its potential deployment? What are the options for a governance system for research and potential deployment taking into account different SRM technologies and their scale?" [8]. The response (see cover in Figure 2), formulated by the Group of Chief Scientific Advisors and the European Group on Ethics in Science and New Technologies, recommends a conservative approach to SRM technologies. They highlight, among others, the necessity of inclusive public deliberations, alignment with fundamental rights and values, and negotiations for a global governance system for global SRM technology deployment [9]. Two open webinars have already been scheduled for February 2025 to discuss SRM and its societal impact [10], as well as what Europe's strategy should be [11].

> *"This is about acting in an emergency. Nobody asked me whether I wanted to have runaway climate change. And, you know, we shouldn't have to ask permission to try to fix it."*

Are We All in This Together?

The EU's approach to non-use is backed by the Center for International Environmental Law (CIEL), as well as African and Pacific states. This trend is also visible in the Global South countries. The CIEL Geoengineering Campaign Manager Mary Church also points out that "there is nothing in the history of humanity to suggest that we could fairly and responsibly govern an undertaking like geoengineering that would need to be sustained over hundreds of years" [3].

However, a polar opposite approach is being adopted by several ambitious entrepreneurs in the United States. "Make Sunsets" has begun independently implementing Stratospheric Aerosol Injection (SA) by releasing sulfate aerosols in large balloons 20 km above the Earth's surface. They released two prototype SO2 balloons from Baja California in Mexico in early 2023, shortly after which Mexico announced its intention to ban SRM technologies in the country. The startup has released more than 53 kilograms of sulfur dioxide into the stratosphere since February 2023, which according to one of the founders is the equivalent of planting 2.5 million trees [12]. According to their calculations, the reflective clouds remain in the atmosphere for about a year. And their slogan? "An effective solution to buy time for other efforts to take hold" [1]. However, the effectiveness, long-term impact, and ethical standing can be questioned based on the resources presented even only in this article.

The company was founded by Luke Iseman and Andrew Song (in Figure 3), two individuals with a non-scientific background and a very bold approach to the field of geoengineering. Luke Iseman stated in an interview: “This is about acting in an emergency. Nobody asked me whether I wanted to have runaway climate change. And, you know, we shouldn’t have to ask permission to try to fix it.” [13]. The company’s business model is also unique and includes selling “cooling credits” to the general public. Cooling Credits can also be purchased on a subscription base, for just $1 each, and one Cooling Credit offsets one ton of CO_2 warming for a year, according to the company’s website. As of December 2024, Making Sunsets has launched 120 balloons and delivered 90,820 Cooling Credits. It is also important to note that their activities are fully legal and approved by the FAA, and fall under the Weather Modification Act of 1976 [14].

So, What’s Next?

Making Sunsets, and the contrast of their approach to the one adopted by the European Union and many other governing bodies is a clear example of why there is a need for a unified international strategy on the research and implementation of SRM technologies. Many of the concerns and questions mentioned in this article seem to have been disregarded, including concerns regarding unforeseen long-term effects, the existing knowledge gaps, the lack of public informed consent, and the risk of creating an SRM-dependent climate.

Academics and scientists call for responsible actions to be taken. This call has also been voiced and supported by academics at the Delft University of Technology. Several TU Delft academics have signed an open letter calling for an international non-use agreement on solar geoengineering [15], as well as an open letter regarding research on reflecting sunlight to reduce climate change [16], and a call for balanced research on SRM technologies [17].

The latter, published in the Oxford Open Climate Change, highlights three main concerns:

1. It is uncertain whether technologies to remove CO_2 from the atmosphere will be ready in time to meet the targets of the Paris Agreement (limiting warming to 1.5 degrees Celsius).
2. The sensitivity of the climate to greenhouse gases may be stronger than expected, leading to higher warming rates.
3. Limiting global warming to the targets of the Paris Agreement may not be enough to sustain and preserve Earth’s ecosystems.

Taking into account a list of ethical concerns, the call concludes that “if a choice on the use of SRM has to be made, ignorance increases the risk of inadequate decisions. We believe that society has a moral obligation to engage in SRM research— and to set up this process in such a way as to minimize potential risks stemming from the research itself. We therefore call for international, inclusive, transparent, reflective, and comprehensive research efforts to enable a balanced assessment of SRM” [17].

Figure 3: Founders of Make Sunsets

> *“If a choice on the use of SRM has to be made, ignorance increases the risk of inadequate decisions.”*

The climate crisis is at an all-time high, and efforts are being made on all fronts to mitigate the effects. Geoengineering represents both a challenge and an opportunity to address the urgent need for action. If implemented at a large scale, it is crucial to ensure that it is based on a complete and robust scientific knowledge and research base, as well as an informed population that is correctly represented in the decision process.

Finding the Impossible

Solving MH370's disappearance through detection technology

Gerard Mendoza Ferrandis, Editor-in-Chief

Malaysian Airlines Flight 370 has become synonymous with “something we know nothing about” or “something we can never find”. However, being unable to find something does not mean that its location is completely unknown. Ever since its disappearance in 2014, thanks to several detection technologies, we have had a rough idea of the aircraft’s location.

Malaysian Airlines Flight 370 (MH370)

On 8th March 2014, one of the greatest mysteries in aviation history took off from Kuala Lumpur International Airport en route to Beijing Capital International Airport. More than ten years after its disappearance, how and why this plane ended up in the Indian Ocean is still unknown. As of the writing of this article, MH370 has not been found. This has also led to much speculation about what happened to the plane. However, this article will not deal with such theories, nor will it attempt to find a reason why MH370 never made it to its destination. Instead, this article aims to challenge the public notion that MH370 “disappeared”.

Good Night. Malaysian Three Seven Zero.

In World War II, with the increase of aircraft use in warfare, a method was needed to identify from the ground which aircraft were on your side and which were enemy aircraft. The issue was solved by equipping aircraft with transponders. This was called “friend-or-foe identification” [1]. The system consisted of two parts: the on-board transponder, and a ground-based interrogator. Troops would point the interrogator towards an aircraft, which, in turn, would then prompt the onboard transponder to reply with a coded signal. This code would later determine if the aircraft was friend or foe [2].

This system later evolved into what we now call secondary surveillance radar. The principle is similar. A radar antenna constantly interrogates all aircraft in range using the 1030 MHz band, and aircraft transponders automatically send a reply containing information about the flight at 1090 MHz. The amount of information depends on the transponder mode [3]. Most aircraft today, like MH370’s Boeing 777 [4], are equipped with Mode S transponders. These transponders usually have ADS-B functionality, which means that as long as the transponder is on, the aircraft will transmit its altitude, position, and flight code, among others. This means that the aircraft was visible to any secondary surveillance radar.

From its take-off at 16:40 UTC until reaching waypoint IGARI at 17:19 UTC, MH370 was tracked using this secondary surveillance information. Waypoint IGARI is located at the border between the Singapore Flight Information Region (FIR) and Ho Chi Minh FIR. This was the waypoint where the final transmission of MH370 was received: “Good night. Malaysian three-seven-zero”. The aircraft was present on the radar displays of Kuala Lumpur, Bangkok Ho Chi Minh FIRs for ten minutes before it vanished from secondary radar. Three minutes after reaching IGARI, the trace of MH370 was lost [4].

Investigators are unsure what caused MH370 to disappear from secondary radar. What is known for certain is that the Boeing 777 has two transponders [4]. If the flight did not appear in any secondary radar, either one of the transponders ceased working and the pilots did not switch to the standby transponder, or both transponders failed.

Now that the transponders have ceased to send the aircraft position, how can we keep track of it? How can we see in the dark, like a bat?

Physics is Inescapable

What do bats, belugas, and even you screaming at a mountain, have in common? Echos. Who hasn’t yelled into a cave or a big empty room and heard their voice come back to greet them? This principle forms the basis of echolocation. Many animals, including bats and belugas, send acoustic waves into their environment and measure the characteristics of the responding wave. Through the time delay and changes in frequency and amplitude, these animals can probe their environment to detect objects and targets [5].

As the name implies, secondary radar was used with primary radar, which stands for “Radio Detection And Ranging”. As primary radar relies on the laws of physics for its detections, it does not require compliance by the tracked target; it uses echolocation. A radar antenna sends a radio signal and waits for its reflection to come back. The time delay and direction allow the system to estimate the position of enemies without requiring them to carry an active transponder [6].

Several civilian radar stations within the Kuala Lumpur FIR were equipped with such radars. Even though secondary radar could not track MH370, radar stations at Butterworth and Kota Bharu (Malaysia) could detect some reflections. These reflections were not continuous. The first two detections were performed by Kota Bharu Radar from 17:30 to 17:37 UTC and from 17:39 to 17:44 UTC. The next four detections were performed by Butterworth Radar in short intervals from 17:47 to 18:01 UTC [4]. These detections were corroborated to have been from MH370 by analysing the bearing and speed. They seemed to belong to the same aircraft. This was later confirmed when Malaysian military radar data was made available. Even though civil primary radar lost contact with MH370 at 18:01, military radar provided a primary radar track until 18:22 [4].

This was the first new piece in the flightpath puzzle of MH370. Until the 10th of March, only the secondary radar data was known, so it was believed that the aircraft might have continued following the filed flight plan towards Beijing. However, this military primary radar data showed the aircraft turning back almost immediately after waypoint IGARI and heading back over the Malay Peninsula [4]. The aircraft is then seen turning around the Island of Penang and heading northwest. There is a small window from 18:03 to 18:15 where the radar return disappears, but the heading is being maintained [4].

The cause for this "radar silence" is cited in the report as being caused due to limitations in radar range and availability. Primary radar is limited in how far it can detect aircraft, with the maximum range depending on many factors, like radar resolution, line-of-sight, tower and aircraft height, and power sensitivity, among others. Eventually, the radar return loses enough power over a long distance and returns cannot be registered against background noise. This point was reached by MH370 at 18:22, situating the last known radar location of the missing plane just about to enter the sky above the Andaman Sea [4]. This was also the final radar detection overall, which could mean that the aircraft crashed here or headed towards the Indian Ocean, where no radar was present.

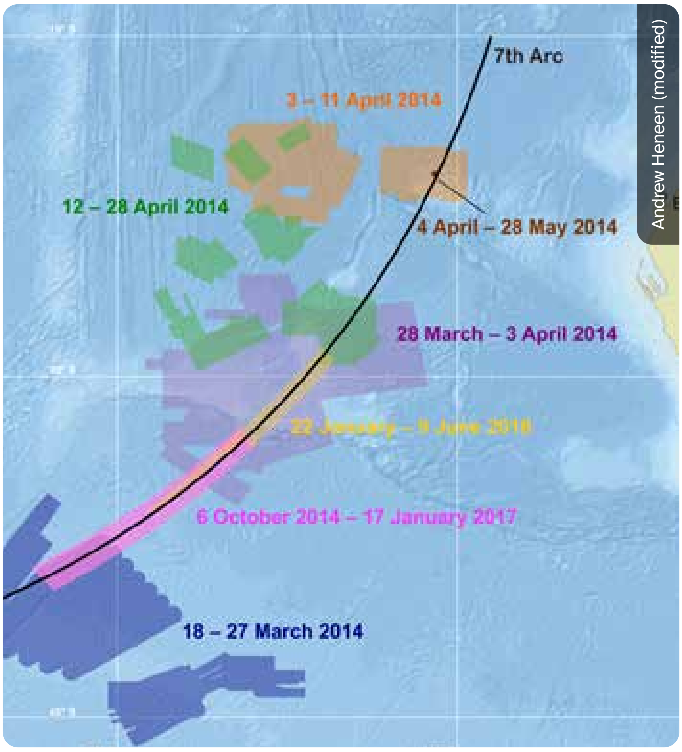
However, it is known that the second option is what happened. But how? As mentioned, there is no radar, so how can it be determined if the aircraft was still flying? The answer here is to shift our perspective.

Looking from Above

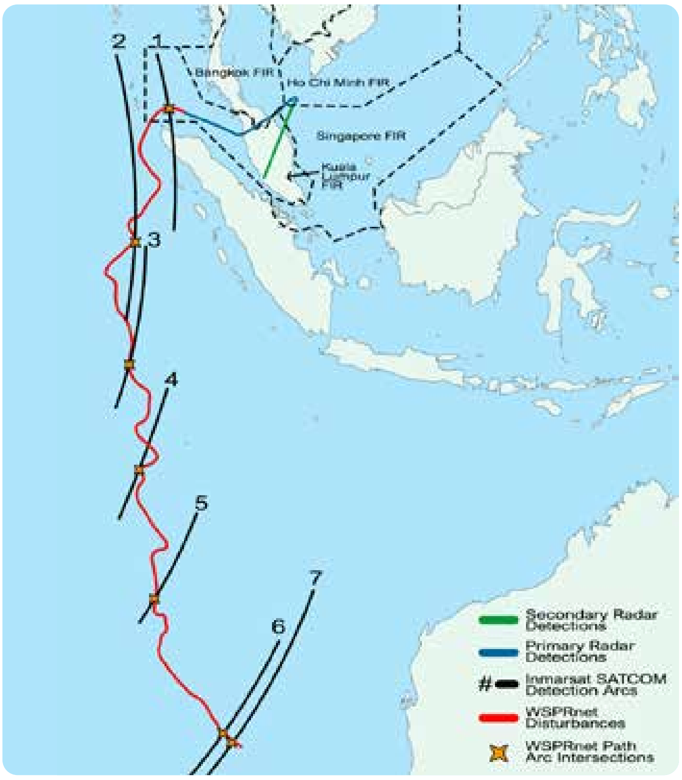
When aircraft fly, they cannot only rely on direct ground communication, as there might be no line-of-sight with radio antennas. Thus, almost all aircraft in service also have satellite-based communications, or SATCOM. Pilots can use the Aircraft Communications Addressing and Reporting System (ACARS) through SATCOM to send and receive commands to and from the ground. This system is also used automatically by the aircraft to send occasional reports. In the case of MH370, the satellite constellation used for such tasks was the Inmarsat Constellation [4].

The first satellite interaction with MH370 that occurred using SATCOM was an automatic ACARS report at 17:07. This connection is important as the next planned automatic ACARS was not received, so it is known that somewhere in this period SATCOM was lost [4]. However, the SATCOM system sent a new log-on request at 18:25 UTC to Inmarsat, re-establishing the connection. Thus, there were only three minutes of detection blackout from the last primary radar return and the following SATCOM connection. This connection is usually referred to as "the first handshake". In this context, "handshake" refers to the automated signals sent between the ground station, the satellite, and the aircraft to check that the terminal is online. These are usually automatically sent after no signal has been received for an hour. Five other handshakes occurred from 18:25 to 00:11 UTC (March 8) [4]. This shows that the SATCOM system was still online. At 00:19 the last seventh handshake was performed, and the aircraft did not reply to the eighth handshake at 01:15 UTC. Thus it can be concluded that the aircraft crashed somewhere in this period. This would also coincide with the maximum endurance from the fuel that MH370 had onboard.

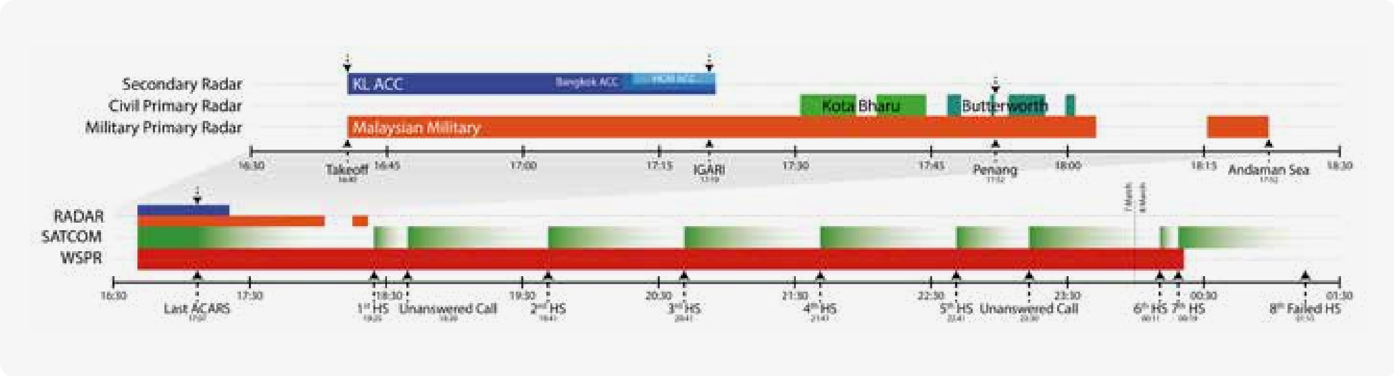
These handshakes are very interesting, but what do they tell us? First, they show the vital information that the aircraft used all of its fuel. Secondly, these handshakes provide much more information than meets the eye. The handshake was a two-way process, so



Map showing all of the areas that have been searched at and around the infamous 7th arc



Map showing all of the pieces of the flightpath puzzle together



Timeline of all MH370 detections showing when the aircraft was detected with each method

similarly to the primary data, the time delay and Doppler can be used to determine the position and speed of the aircraft. The Inmarsat satellite that received all handshakes is a geostationary satellite situated above the Indian Ocean. It is also known that the handshakes were carried out at the ground station in Perth, Australia [4]. Using this information, the "arcs" on which the aircraft would have lied when the handshakes occurred can be determined. The reader may have heard about the search occurring "along the 7th arc" - this is why.

At the time, this discovery was groundbreaking. Even though it could not pinpoint the location of MH370, it was now known that it must have crashed somewhere close to the 7th arc. Several experts analyzed the available data and a search area was proposed. However, the aircraft was not found. This is understandable as the initial proposed search area spanned 31.5 million hectares. Despite several search attempts, no wreckage was found, with the last search called off in June 2018. The only tangible evidence there is of the fate of MH370 is the debris from the aircraft that has been recovered off the east coast of Africa [4].

This is where many thought hope was lost to find the wreck. However, a last attempt at finding out about the last moments of MH370 was made in 2021 with the groundbreaking paper "Geocaching in the Ionosphere" by Dr. Robert Westphal [6].

Whispers from the Skies

There are many unique hobbies around the world, but a specific one may have provided the missing link in MH370's fate: amateur radio. There are more than 3 million amateur radio operators worldwide [7]. Since 2008, an open-source protocol for weak-signal radio communication, called Weak Signal Propagation Reporter (WSPR), has been used by many in the field of amateur radio. This protocol also maintains records of all of the information regarding these communications between radio operators [8].

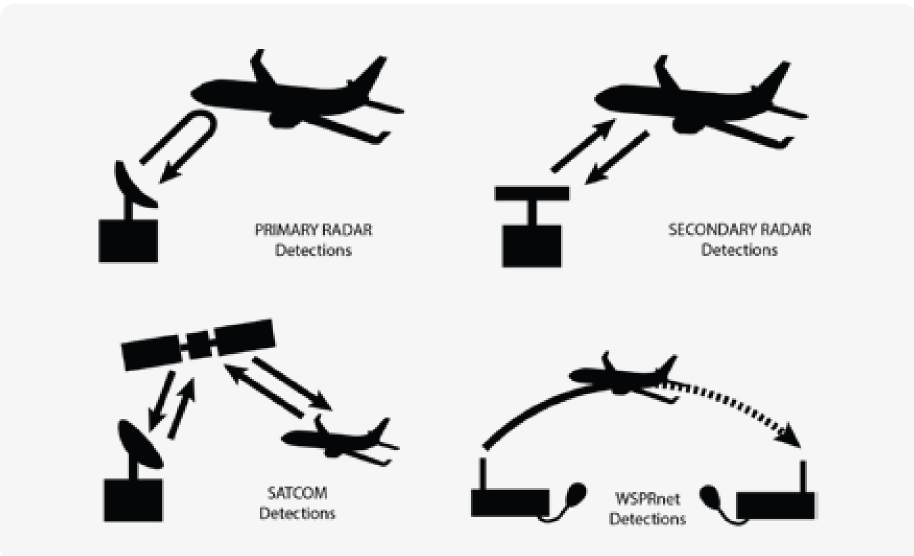
Dr. Robert Westphal proposed using this database to track MH370. His idea was to analyze the disturbances in connections between radio operators whose radiowaves crossed the Indian Ocean at the time of MH370's disappearance. When an aircraft flies through the part of the atmosphere where the radio waves are propagated, it creates a disturbance. We can imagine these connections as tripwires activated by the aircraft, and the activation is an anomaly in the signal [6].

This idea was later picked up by aerospace engineer Richard Godfrey, Dr. Hannes Coetzee and Prof. Simon Maskell. Since 2021, their flightpath prediction has been improving and the technology has been validated in several case studies with other known aircraft. In 2023 they released their final prediction, placing MH370 at about 29.128°S 99.934°E [9]. This paper is still under review. However, the route proposed in the paper agrees with the previous primary radar, secondary radar and SATCOM handshake data.

What Now?

The Malaysian Government announced the activation of a new search on the 10th anniversary of the disappearance of MH370. A proposal from Ocean Infinity, a private business previously involved in the search was submitted and accepted by the government under a "no find, no fee" policy [10].

If the aircraft is found, will all the costs be worth it? Yes. Because finding out what happened to MH370 means we can make aviation safer, and because 239 families deserve closure. Will the black box be readable after more than ten years submerged? Will any bodies be found and returned to their families? Will we even recover most of the plane or just pieces? We do not know, but that doesn't mean we will not try.



Simplified view of how the detection methods work

MH370 has not disappeared. We know what path it took, and we might now even know where it is. This is possible thanks to years of technological development, from primary and secondary radar in the mid-20th century to satellite communication networks in the late 20th century, and newer approaches like WSPRnet analysis from as recent as 2019. Inevitably, the aircraft will eventually be found, and by not giving up on the search, we are keeping the flame of MH370 alive.

GENERAL

Victims of a Broken System

The 737 MAX crashes and global aviation injustice

Calvin Grootenboer and Timo Burggraaf, Aerospace Diversity Department

Flower petals being distributed in memoriam of the victims of the Lion Air crash

Two Boeing 737 MAX crashes claimed 346 lives due to corporate negligence, flawed systems, and regulatory failures. This article explores the systemic injustice and bias within the global aviation industry. First by examining how such a flawed system ever came to be certified, before diving into the root causes embedded deep within our culture.

On Monday 29th October 2018, Lion Air Flight 610 took off from Jakarta, Indonesia. Only twelve minutes after take-off, the aeroplane crashed and all 189 lives on board were tragically lost. Almost five months later, on Sunday 10th March 2019, Ethiopian Airlines Flight 302 took off from Addis Ababa, Ethiopia. This time, it only took 6 minutes before the aeroplane went down, killing all 157 people on board [1]. A total of 346 people—mothers and fathers, daughters and sons, friends and loved ones—died in the crashes of the Boeing 737 MAX. The actions leading up to the crashes, the slow reaction to the first, and the results of the lawsuit against Boeing show how the current system is unfair and desperately needs change.

Boeing was criminally charged almost three years after the first crash [2]. In their rush to compete with the Airbus A320neo, Boeing created a plane with a design flaw: larger engines meant to make the aeroplane more efficient also caused it to pitch up. To combat the problem, and to make the aircraft handle more like previous versions of the 737, the Maneuvering Characteristics Augmentation System (MCAS) was implemented. The MCAS would engage the horizontal stabiliser in the nose-down direction when certain conditions were met. However, only a single angle-of-attack sensor measured these conditions. Furthermore, the actions of the MCAS could not be overridden by the pilots' input, only shutting down the MCAS could regain full pitch control. [3].

Thus if the angle-of-attack sensor gave false readings, which was the case for both the Lion Air and Ethiopian Airlines

Aftermath of the Ethiopian Airlines crash

flights, the pilots would have to know that the MCAS is responsible for the nose-down trim on their plane. They could then shut down this system and regain control of the aircraft. However, the crew of neither flight knew about this system. Worse still, none of the pilots flying the 737 Max knew about it. The Federal Aviation Authority (FAA) deemed that the plane was similar enough to previous versions of the 737 that no extensive retraining was needed, so there was no mention of the MCAS in the briefings for the new aircraft [1]. The single point of failure in the lone angle-of-attack sensor in combination with the lack of knowledge about the existence, let alone workings, of MCAS was a recipe for disaster. How was this allowed to happen?

One of the things that kicked off this chain of events was the sale of the Airbus A320neo to American Airlines. The “new engine option” of the A320 which, as its name implies, is an updated version of the A320 with a focus on efficiency. In the wake of rising fuel prices in 2008, this was very attractive to airlines when it was released in 2012. With its competitive edge over the other options in the market, Airbus was able to convince American Airlines, a traditional Boeing-only customer and currently the largest airline in the world, to add the A320neo to its fleet. With Airbus’s foot in the door of one of Boeing's largest customers, Boeing needed to decide how to proceed fast. They could continue with their original plan of designing an all-new plane to be ready by the end of the decade, with all the added costs of R&D and setting up new production lines. As an alternative, they could do what Airbus did, take their 737 and give it an engine upgrade, minimising the cost of the new plane and getting it to market quicker. In a quest to defend their market share, they chose the option that would give them a competitive aircraft quickly [4]. Unfortunately, Boeing not only rushed the design and certification of the plane but also lied to and hid the facts from the relevant authorities.

The certification of the 737 Max was done by the FAA, which was then adopted worldwide due to the mutual recognition of airworthiness certifications [5]. In this process, Boeing had significant power over the certification, as parts of the process were delegated to Boeing itself. Throughout, Boeing deliberately hid information from the FAA, with one Boeing employee saying in internal communication, “I still haven't been forgiven by God for the covering up I did last year", just before the first crash [7]. One example of this is the limit of how much the MCAS could change the angle of the horizontal stabiliser. This was reported to be 0.6 degrees but later turned out to be 2.5 degrees, completely changing the safety considerations [6]. Furthermore, the parts of the aircraft that the FAA was certifying were being rushed. Interference from managers at the FAA pushed the engineers to meet strict deadlines. There was a constant change in what was going to be certified by the FAA and what Boeing was allowed to do themselves. When deadlines could not be met by engineers, the managers would sometimes still sign off on the unfinished documents [6].

This process demonstrates how Boeing was able to get approval for minimal training in the transition from older versions of the 737 to the MAX. After the first crash, Boeing revealed the existence of MCAS and what to do if it triggered erroneously. Nonetheless, in the same statement, they also reminded pilots about the standard checklist procedure for unwanted horizontal stabilizer movement [6], indirectly blaming the pilots of Lion Air for the crash. However, the behaviour caused by MCAS does not align with the behaviour covered in the checklist and thus would not have been the obvious step to take [6].

Some details in this article come from investigations by journalists during the debacle, and others have come to light during court proceedings. It is these court proceedings, and especially the verdict that was reached, that highlight the injustices present in the system that led to the crashes. In January 2021, Boeing was convicted of “Conspiracy to defraud the United States” by the Department of

Family of the victims on their way to the courtroom

Former Boeing company CEO during the court hearings

Justice (DoJ) [2]. They were not charged with the deaths of the 346 victims of the two crashes, nor with putting thousands of other people in danger whilst they knew their plane had issues. They were not even convicted of criminal neglect for the way they rushed the certification of the aircraft to get to market quicker, or how they kept crucial information away from pilots such that they could avoid re-training.

> *“The assumption that pilots trained in Western countries are somehow superior reflects deeply rooted biases.”*

The victims' families were not totally forgotten in the settlement. From the $2.5 billion fine, $500 million was set aside for a fund to help the families and relatives of the victims. In the same year, Boeing had $100 billion in revenue, and $12 billion in profit [2], and paid some $5 billion in dividends to its shareholders. The amount paid to the fund is a fraction of what the families requested [2], not to mention the lack of any conviction against Boeing or the responsible individuals inside the company for the deaths that occurred.

There is a clear imbalance of power in the global system related to this crash. An American aircraft manufacturer had its plane certified under false pretenses by the American authorities, was sued by the American Department of Justice, and convicted in American courts. In theory, this set-up of authority could be fair and just for all, not only for Americans but citizens of other countries as well. However, as has been practically demonstrated, this is not the case. The fact that the plane made it through certification is not where the imbalance of power starts. With the current international system of mutual recognition of airworthiness certificates, this issue is mutual. However, action should have been taken the moment the first plane went down. Boeing did notify the world about the MCAS, which did not prevent the second crash, but also criticised the pilots. As per an article in The Air Current, senior US officials said, “If it was Southwest Airlines and American Airlines and not Lion Air and Ethiopian Airlines five months apart, the 737 Max fleet would have been grounded by Sunday evening” [4]. The FAA could have grounded the plane after the reports from the first crash, but they did not. Even after the second crash, the FAA reiterated the safety of the 737 Max. Only after China and Indonesia grounded the aircraft, and the rest of the world not long after, did the FAA ground the plane in the US [8]. This delay reflects skepticism of the ability of the pilots of the flights, “Pilots trained in the United States would have successfully been able to handle [the emergencies]”, said Rep. Sam Graves of Missouri in a US House hearing on the 737 MAX [9].

The aviation industry is not immune to the broader issues of Western bias that persist in global systems. The assumption that pilots trained in Western countries are somehow superior reflects deeply rooted biases. These attitudes were evident in the aftermath of the 737 Max crashes. Western media and officials subtly, and sometimes overtly, cast doubt on the competency of the pilots from Lion Air and Ethiopian Airlines, despite the latter airline having safety records comparable to most modern carriers. The narrative implied that such accidents would not have occurred with Western airlines, even though investigations revealed that the crashes were due to design flaws and a lack of adequate training information provided by Boeing. This bias extends beyond individual crashes to how regulatory bodies and manufacturers view airlines from non-Western countries. There is a tendency to impose stricter standards on these airlines and question their capabilities, while Western airlines benefit from a presumption of competence. Such double standards perpetuate the idea that Western expertise is the benchmark, which is dangerous for air travel across the world. Addressing these issues requires not only regulatory reform, but also a cultural shift within the industry to recognize and value the professionalism and expertise of aviation professionals from all countries. When the court hearing finally took place, no justice was served for the victims and their families. Perhaps worst of all, once the verdict was delivered to Boeing, the DoJ said in a statement, “This resolution protects the American public” [10].

It is still unclear how the international system should change to prevent regulatory failures and corporate greed from ruining lives worldwide. However, the first step toward resolution is acknowledging the problem. Only by addressing these systemic flaws and inherent biases can we honor the 346 victims and ensure such tragedies never happen again.

GENERAL

Drones and Archeology

How drones and LiDAR technology have changed an entire field in just one decade

Simon Caron, Leonardo Times Editor

When was the last time you made a groundbreaking archaeological discovery from your computer? When it comes to ancient civilisations, Indiana Jones stealing a golden figure in a secluded temple might come to mind, or some magnifying-glass-wielding scientist in a desert, dusting off a vase with a tiny brush. However, like every aspect of our world in the past two decades, archaeology has modernized itself drastically and, with the help of LiDAR images and drones, discoveries can be made from the comfort of your home.

The Lost City of Valeriana

It begins with the story of a bored student, browsing page 16 of Google for his doctorate research. That is what Luke Auld-Thomas, a PhD student at Tulane University in the US, was doing when he came across a 2013 UAV environmental LiDAR survey from Campeche, a southern state of Mexico. He realized it might hold more than just endless mappings of thick jungles. When he applied archaeological data processing techniques, this student uncovered evidence of a vast ancient city that likely supported a population of 30,000 to 50,000 people at its peak between 750 and 850 AD, more than the current population of the region it lies in. The remains were really "hiding in plain sight", as they are only 15 minutes by foot from the main road. It has been named "the lost city of Valeriana" due to its proximity to the Laguna la Valeriana lake [1-3].

The local population thought that there might have been some sort of ruins in the forest, but no formal discovery was ever made due to the dense vegetation under the jungle canopy making it arduous to complete any field work. That is until LiDAR technology was introduced in land surveys and in archaeological research. And it is diabolically efficient: such flying robots can cover in a decade 10 times the area that previously took archaeologists a century of work [2].

On the other side of the Atlantic Ocean, drones are also revolutionizing archaeology in Scotland's remote Canna and Sanday Islands. Over a five-day survey, researchers used UAVs to capture ultra-detailed images of the terrain, creating 3D maps that unveiled layers of history hidden beneath the surface. Among the discoveries were traces of Bronze Age agricultural systems and ancient settlements long obscured by time. These drones didn't just save weeks of manual labor, they revealed details invisible to the naked eye, proving how accessible and transformative this technology can be for exploring challenging environments [4].

New Tools for an Old Discipline

One of the most transformative tools in archaeology today is LiDAR (Light Detection and Ranging), which has enabled some of the biggest discoveries in the field. LiDAR works by emitting rapid pulses of laser light at the ground and measuring the time it takes for the light to bounce back. This data is then processed to create a high-resolution 3D map of the surface, capturing features like vegetation, terrain, or built structures, as seen in figure 1. When mounted on drones or aircraft, LiDAR systems can penetrate dense vegetation and detect subtle elevation changes, revealing archaeological sites or features hidden from any human [5,6].

Archaeologists have always tried to use any tools available to explore complicated ancient sites. Think about the Nazca lines and huge landscape drawings made by the Nazca people in the southern Peru desert. They were studied properly for the first time in 1939 by flying over them and using clever techniques of aerial photography, something quite new at that time [7]. However, the leap taken by combining drones with LiDAR technology is even more significant. Archaeology, of course, is not the only one

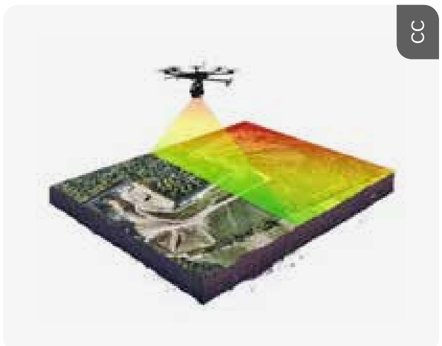


Figure 1: LiDAR drone survey

to have been impacted by those new technologies. Since UAVs have been commercialized for the broader public, they have revolutionized multiple fields of work, from videography to search and rescue or agriculture [8].

Drones are also remarkable at cutting costs and increasing efficiency as they replace labor-intensive ground surveys with faster, safer, and more precise methods. They are also a lightweight solution, making them accessible for smaller teams and projects. All of this helps a movement towards the democratization of archaeology since groundbreaking discoveries do not necessarily need major operations with big funding anymore [9,10].

Furthermore, LiDAR images also provide valuable data from other types of inaccessible terrain, like conflict zones, where scientists can research endangered monuments where it would not be possible to be there physically. One notable example of drones used in a conflict zone for archaeological purposes is the documentation and monitoring of Syria's ancient city of Palmyra during the civil war. Organizations like the Getty Conservation Institute employed drones to capture high-resolution images of the site, generating 3D models to assess damage caused by the conflict and plan for conservation. This method allowed experts to evaluate conditions remotely and safeguard crucial data about the site's historical significance, despite the country's instability [11,12].

The processed images are analyzed by professionals offsite and provide insight into otherwise inaccessible or "too big to research" regions. The use of LiDAR-equipped drones in archaeology has transformed the field, yet it comes with an unexpected challenge: the sheer volume of data produced. Surveys often yield billions of data points, requiring advanced software and expertise to interpret. Researchers note that this influx of information is both a blessing and a hurdle: "You can uncover a hundred years' worth of discoveries in a single flight, but you might need a decade to analyze it all." [10]

Point cloud from an archaeological project

Detail of Valeriana site

A Glimpse Into the Future of Studying the Past

One such solution for the huge amount of data points that high-resolution LiDAR images generate is Artificial Intelligence (AI) for data processing. Tools like pattern recognition algorithms can identify potential archaeological sites from vast terrain models, saving researchers months of manual analysis. For instance, AI can detect subtle anomalies in LiDAR point clouds, which could indicate human-made structures hidden beneath vegetation. Artificial intelligence is sometimes described as a "bonus set of glasses" that enables researchers to analyze vast datasets. Unlike humans, AI doesn't experience fatigue, allowing it to process massive amounts of data gathered through traditional fieldwork or surveillance programs. "That's the real revolution of AI and machine learning. It allows us to process all that data we already have," said Gauthier, who works as an assistant curator for artificial intelligence at the Florida Museum of Natural History. [5,8]

AI is also used for predictive modeling, enhancing the efficiency of archaeological exploration by analyzing satellite imagery alongside historical, environmental, and geographical data. This allows AI to identify regions likely to contain undiscovered sites, especially in vast or inaccessible areas like dense forests or remote deserts. AI can pinpoint subtle changes in landscape features that suggest human activity, such as anomalies in tree cover or soil composition, visible in satellite images but often overlooked by the human eye. This method, combined with traditional survey techniques, helps archaeologists narrow down where to focus their efforts, saving significant time and resources. Additionally, AI helps to create detailed 3D models of archaeological sites from scattered satellite or drone images, enabling more accurate reconstructions and providing a clearer understanding of past civilizations. This growing reliance on AI and satellite or aerial imagery is not only reshaping how archaeologists uncover the past but also providing crucial insights into how we might adapt to the challenges of our rapidly changing world [5].

In conclusion, the fusion of UAVs, AI, and LiDAR is revolutionizing archaeology, bringing a new level of excitement and efficiency to the field. These cutting-edge technologies are unlocking hidden civilizations, such as those beneath Mexico's jungle-dense canopy, and helping protect precious sites from conflict or development. With AI's ability to process vast datasets, archaeologists can quickly uncover patterns and anomalies that were previously invisible, while drones and satellite imagery provide crystal-clear, high-resolution views of landscapes. As these tools continue to evolve, they offer new ways of understanding the past and new possibilities for preserving our cultural heritage in a rapidly changing world.

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Drones in Archeology

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