LEONARDO TIMES

Journal of the Society of Aerospace Engineering Students 'Leonardo da Vinci'

ELYSIAN AIRCRAFT: SKIES REIMAGINED

CHALLENGING THE MYTHS OF BATTERY-POWERED AVIATION

Year 28 | N° 3 | Autumn 2024

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EDITORIAL

DEAR READER,

As my final year of the aerospace engineering bachelor faded away and summer was on the horizon, I received the honor of being offered the position of Editor-in-Chief of the Leonardo Times. The idea of continuing such an important legacy seemed daunting, but I was quick to accept the offer! The torch has now been handed over, and I will have the pleasure of working with James Perry, our new Editing Director. Time has shown the passion and dedication he has poured into this magazine, and is testament of the greatness that is to come in the next editions. I would like to thank the previous board, composed of Ruth, Arham, and Lisanne, for entrusting us with the management, and we only can hope to live up to their excellent work, commitment and quality.

And now, it is time to present to you the first edition of the Leonardo Times for the academic year 2024/2025, and dive into the fascinating articles that the edition holds.

Our journey begins in the 1900s, with the story of how aircraft were first designed and how, through stepping stones set by several pioneers, this process has evolved until where we are today. We will also take a look at the history of the Rotterdamsche Aeroclub (RAC), the oldest aeroclub in the Netherlands, as well as the history of the F16 as the Netherlands bids them farewell.

We will also discuss events that occurred fairly recently, such as the long-awaited launch of the Ariane 6 this last July, the unfortunate "overtime" that astronauts Sunita Williams and Barry Wilmore have been enduring since June.

This edition also comes charged (pun-intended) with debate about the future of aviation. We will provide our answer to the years-old question on the possibility of aviation decarbonisation, as well as dismantle several myths about the impossibility of electric-powered aviation.

Furthermore, two student projects are showcased. You will read about E-Racer, the winner of the faculty's Design Synthesis Exercise (DSE), and how their innovative and sustainable design came to be. Finally, we will present Elevate, a new Dream Team focused on participating in the GoAero eVTOL design competition.

We hope you find these articles interesting, inspiring, and thought-provoking. The whole team would like to thank you for making the Leonardo Times possible, thereby giving us the opportunity to share our passions with you.

Yours truly,

Gerard Mendoza Ferrandis
Editor-in-Chief,
Leonardo Times

Last edition...

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We want to make sure that all the mailed Leonardo Times reach 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, please unsubscribe by using the form in the QR code. We will be sorry to see you go!

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A new Dream Team at TU Delft has been established, with the aim to join the GoAero competition. The challenge is to design eVTOLs for emergency response.

The Pulitzer Trophy Races have been reinvented for the modern age. TU Delft's aerospace students designed a zero-emission aircraft, aiming to win the competition.

The Rotterdamsche Aeroclub is the oldest in the Netherlands - this interview explores an unlikely connection with the RAF's 617 Squadron, the Dambusters.

COLOPHON

Year 28, NUMBER 3, Autumn 2024

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IN MEMORIAM

Member of Honour Schröder

May 13 1931 - October 2 2024

It is with great sadness that we learned that one of our Members of Honour, Dhr. Schröder, has passed away.

He was the founder of the second Dutch airline, Martinair. For that, he was one of the biggest Dutch aviation pioneers and of great importance to our society and all its members.

For all of his efforts, he was installed as a Member of Honour of the VSV 'Leonardo da Vinci' in 2014.

A MESSAGE FROM THE BOARD

Dear reader,

With the beginning of the new academic year, the change of boards of the VSV 'Leonardo da Vinci' has taken place. That means that we, as 80th board, are officially inaugurated and have started our board year!

With fresh energy and an enthusiastic outlook, we are committed to making this year unforgettable. As always, we will focus on enriching the lives of all aerospace engineering students, supporting them educationally, socially, and career wise.

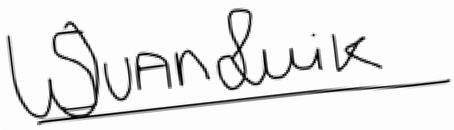
Yet, this year is not just any year; it is a lustrum year, marking the 16th lustrum, or 80th anniversary, of the VSV 'Leonardo da Vinci', which has been given the theme Ignite. To commemorate this milestone, a lot of special extra activities await. This includes the extraordinary GMA where we will install two new members of honour of the VSV 'Leonardo da Vinci', Arnaud de Jong and Arjan Meijer. Furthermore, we have a lot of exciting events planned for our members, including the lustrum opening Belgian beer drink, a lustrum ski trip, lustrum gala and the month-long lustrum celebration in May.

While much lies ahead, we also take a moment to reflect on the quarter that has flown by. We started the year with the annual Studytour in which 30 master students travelled to Singapore, Australia and New Zealand to visit a wide range of (aerospace) companies. For the first year students, we hosted the traditional Top Gun movie night and Fresh Prince of LR party. Our career pillar was highlighted by the career weeks with interesting lunch lectures from Airbus, Pratt&Whitney and Transavia, as well as the Alumnight, where we had alumni from all over the industry come back for a night to share their experiences of life after graduation. Lastly, the space department organised its first excursion, visiting Dawn Aerospace.

To conclude, a lot has already taken place in the first quarter of this year and a lot more is bound to happen in the months to come. We look forward to welcoming many of you at our upcoming events. For now, we invite you to take a moment to relax and enjoy this issue 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'

AN UNPRECEDENTED CATCH

We have become accustomed to the sight of rockets coming back down from space and landing safely for reuse. This is thanks to SpaceX, who have managed to land more than 350 rockets since their first landing in 2015. However, these landings now pale in comparison with the event the world witnessed the 13th of October of this year: the successful catch of the Super Heavy Booster.


SPACEX

SpaceX has been testing its Starship system since 2019. They started with "Starhopper", which was used as a testbed for what would later become the Starship Spacecraft. These would be later succeeded by static fires and high-altitude flights, and culminated with the integration tests where the Super Heavy Booster and the Starship Spacecraft were launched together.

Last October, during the fifth integration test, the team managed to perform a booster return-to-base maneuver, where it was caught in mid-air by the same launch tower that it was launched from. This was done using two arms (dubbed "chopsticks") at the top of the tower that closed on the booster as it descended.

The Super Heavy Booster had already been tested during reentry, performing soft simulated landings over water. However, this was the first attempt to use the actual tower to catch the booster.

F35 TAKES OVER

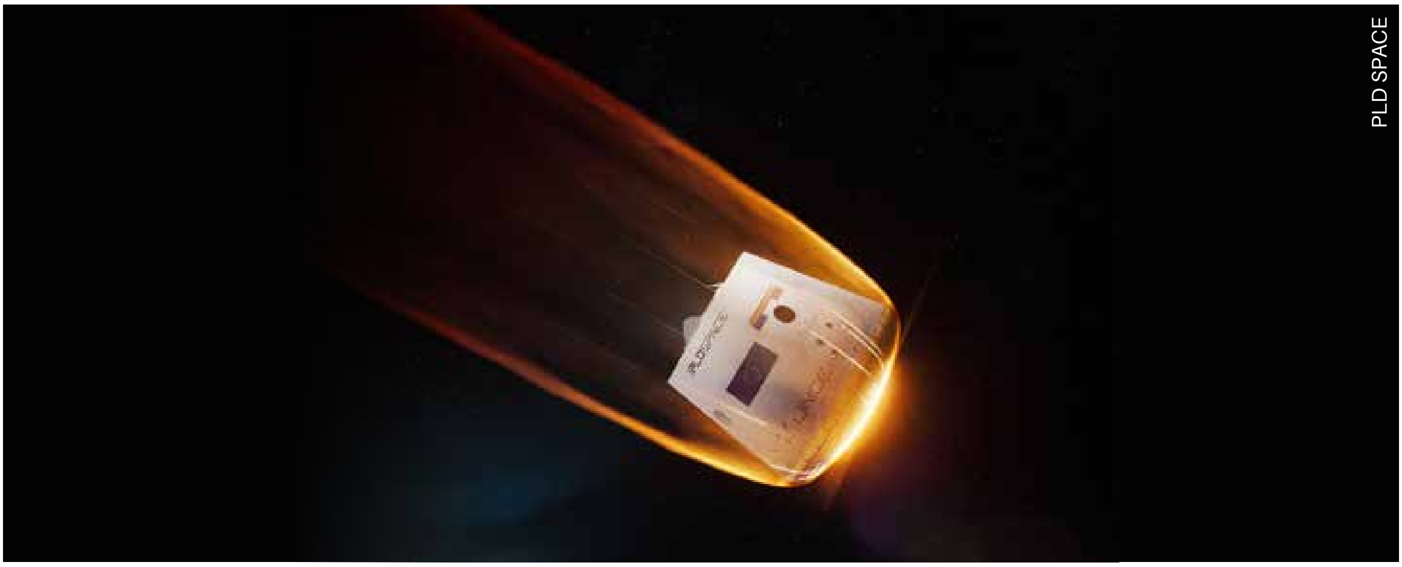
It's been more than a decade since the F-35's maiden flight at Fort Worth, Texas, in 2012. A year later, in December 2013, a Dutch pilot flew the F-35 for the first time. However, it wasn't until 2016 that the aircraft made its first appearance on Dutch soil for environmental testing. The Royal Netherlands Air Force (RNLAF) began receiving its F-35s in 2019, with Leeuwarden Air Base becoming the first to host the new fleet. By January 2024, the Netherlands had started deploying the F-35 for NATO air policing, taking responsibility for the Quick Reaction Alert (QRA). In May 2024, the F-35 officially took over the nuclear strike capability, known as the Dual Capable Aircraft (DCA) role.

The F-16, which had been the backbone of Dutch air power since 1979, has now been eclipsed by the F-35's advanced capabilities. Of the 213 F-16s originally purchased, just over 100 underwent the Mid-Life Update (MLU) in the early 2000s. The rest were either retired or sold, with some going to Chile and Jordan. By mid-2024, only 42 F-16s remained in the Dutch fleet. These final aircraft are now being used to train European fighter pilots, including Ukrainians, as the Netherlands prepares to send some to aid Ukraine's defense against Russia.

On 26 September, the RNLAF declared Full Operational Clearance (FOC) for its F-35A Lightning II fleet, officially retiring the F-16s on the same day. To mark the occasion, a "Farewell Falcon" ceremony was held at Volkel Air Base, where the last F-16s flew a commemorative sortie, signaling the end of the aircraft's four-decade service in the Netherlands.

MINISTERIE VAN DEFENSIE

PLD SPACE'S NEXT GENERATION PLANS



PLD SPACE

This October, Spanish private launch provider PLD Space has unveiled their new plans for a future generation of rockets.

Currently, PLD Space is the leader in European private access to space. In October of 2024, the company made their first successful flight test of Miura 1, becoming a trailblazer in the private sector both in Spain and in Europe.

With this flight, they sought to validate many technologies that they were later planning on using for Miura 5, their future orbital rocket planned to be launched at the end of 2025.

This is where many thought thestory ended. However, on the anniversary of Miura 1's successful test, PLD Space announced a whole new generation of rockets: Miura Next, Miura Next Heavy, and Miura Next Super Heavy. Miura Next will be two-stage and will have the capability to land. The Heavy variant would be similar to the Falcon Heavy, and the Super Heavy variant would have four side boosters.

These next generation plans were not the only announcement, as their plans to build the first private European return capsule "Lince" were also released. This capsule will be able to carry 5000 kg of cargo to the ISS, or up to 5 crew members, and would be launched using the Miura Next family. They plan to start testing the capsule by 2025.

BOEING EXECUTIVES IN PERIL

Democratic U.S. Senators Elizabeth Warren and Richard Blumenthal have expressed their disappointment with the Department of Justice (DOJ)'s plea deal with Boeing, finalized in July. The Senators emphasized their desire to hold the manufacturer accountable for ongoing safety issues with its aircraft. The plea deal, which followed Boeing's breach of a 2021 deferred prosecution agreement, involved Boeing admitting to conspiring to defraud the Federal Aviation Administration (FAA). As part of the agreement, Boeing will pay a fine of up to $487 million and invest heavily in compliance and safety programs. The company will also face three years of oversight from an independent entity.

US DEPARTMENT OF JUSTICE

However, both Senators believe these measures are insufficient and view the settlement as another example of corporate executives being shielded at the expense of public safety. Relatives of victims and their attorneys have similarly criticized the deal, calling it a "sweetheart" arrangement that fails to adequately address the tragic loss of life. Some lawyers have argued that Boeing received lenient treatment from the DOJ due to its status as a major government contractor.

In response to these concerns, U.S. District Judge Reed O'Connor has scheduled a federal hearing for October 11, where he will consider objections raised by the relatives of some of the 346 people killed in two Boeing 737 MAX crashes.

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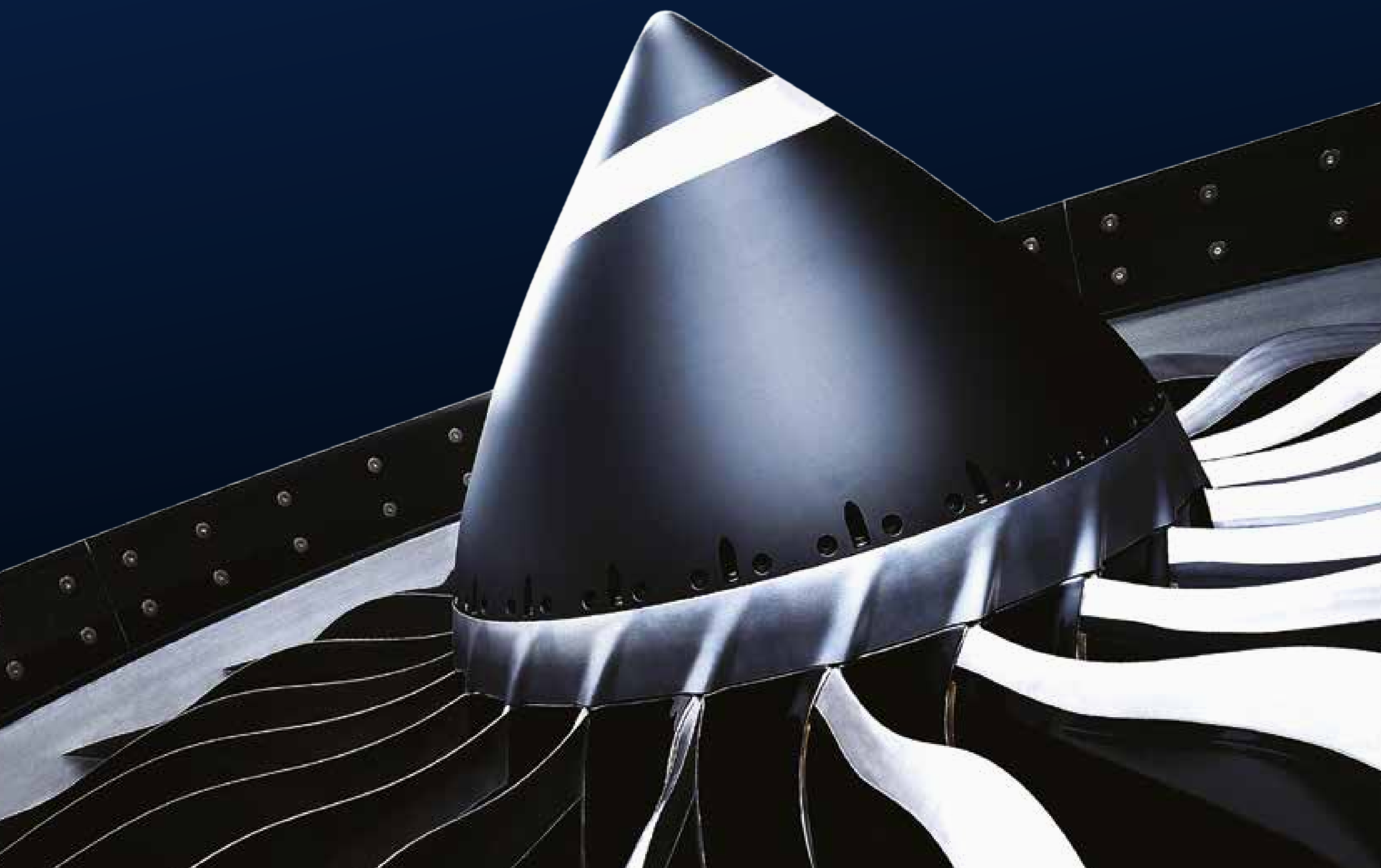


CAN AVIATION DECARBONIZE?

A detailed look at the most probable path forward

Alex Nedelcu and Miguel Castro Gracia, Leonardo Times Editors

MAGNIX

Quoting the International Air Transport Association, in 2024, "there was no let-up in the industry's determination to achieve net zero carbon emissions by 2050" [1]. But beyond the promotional material, is the aviation sector really on the way to decarbonizing in time to avoid the most dangerous climate scenarios? Or is the industry's continued growth fundamentally incompatible with sustainable transport?

Commercial aviation has increased more than eighty-fold since the 1960s, with a 3% average yearly growth rate. It has already contributed around 3.5% of the total anthropogenic global warming to date and now contributes around 5.9% of ongoing emissions. While global warming is generally considered a problem of carbon dioxide, aviation's CO_2 emissions have been found to only represent a third of its total contribution to global warming, with the non-CO_2 contribution flowing down from nitrogen oxide, water vapor, and contrails [2].

The Paris Agreement set a target to keep global warming below 2 degrees Celsius over pre-industrial levels. As such, aviation, like all other emitting sectors of human society, must decarbonize and reduce its impact on the Earth system. In this article, we apply a simple quantitative framework to evaluate the prospects of aviation decarbonizing in what we consider to be the most probable scenario.

1. METHODOLOGY

Studying the commercial aviation sector in detail is an enormous undertaking. Therefore, in order to quickly draw useful conclusions, our objective is to create a simple, intuitive framework for the climate impact of aviation. In transport ecology, the study of transport mode impacts is frequently pursued quantitatively through the Kaya identity, which allows for the impact to be divided into its component quantities [3]:

$$\text{Impact} = \text{Demand} \cdot \frac{\text{Vehicles}}{\text{Passengers}} \cdot \frac{\text{Energy Spent}}{\text{Distance Traveled}} \cdot \frac{\text{Total Emissions}}{\text{Energy Spent}}$$

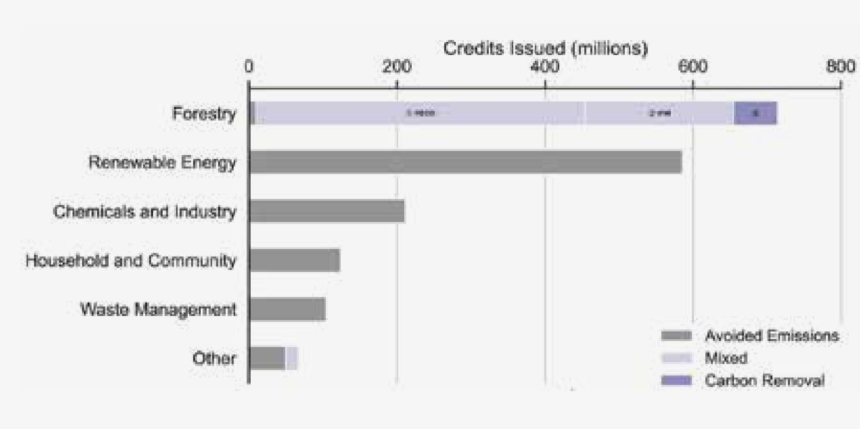
Where demand is measured in passengers-kilometer, vehicles/passenger represents the inverse of occupancy in passenger-kilometers per vehicle-kilometers, energy spent/distance traveled represents the inverse of energy efficiency (in km/kWh), and total emissions/energy spent represents the carbon intensity (in CO_2-equivalent/kWh). Because of the fundamental differences in demand, occupancy, and technological opportunities between long-haul and short-haul flights, we will investigate each separately, using a loose definition of short-haul flights as those under around 1500-2000 kilometers and long-haul flights as those above 2000-2500 kilometers.

Though we aim to reach quantitative conclusions by separating the component quantities, it is unlikely that complete and certain data is available for all existing (and especially prospective) sections. Many predictions, including future macroeconomic growth and technological development, are bristling with uncertainty. In this context, we realize that such a back-of-the-envelope estimation is inherently subjective and driven by the author's biases. However, we believe it can still provide a qualitative framework for thinking seriously about the feasibility of decreasing aviation's environmental impact.

Though scenario analysis could be in some cases exploratory [4], and investigate possible futures (for example, looking at possible pathways toward decarbonization based on how the technological, social, and economic environment would develop), our objective is to take a predictive look at the future. This means accounting for current material conditions in and around the aviation sector to extrapolate the most probable scenario out of the possible pathways forward to the best of our ability. This approach contrasts with a comprehensive paper by Bergero et al. [5], which studies many possible pathways toward decarbonization with a similar framework. With these caveats out of the way, the first (and least optimistic) quantity to be studied is future demand for commercial aviation.

2. DEMAND

In the industry, demand is represented in "Revenue Passengers-Kilometer", meaning the total number of paying passengers multiplied by the kilometers they travel. The 2019 RPK value of 8.4 trillion is typically used as a reference, which is on the way to being met once again in 2024 after the disruption caused by the COVID-19 pandemic. The International Air Transport Association, in its 2024 annual report [1], predicts an average annual growth rate of 3.8% until 2043, while Bain & Company estimates an overall increase in RPK of 36% by 2030 compared to 2019 numbers [6], resulting in a total RPK of 11.4 trillion. Eurocontrol estimates that long-haul flights cover around 40% of the total RPK [7], so a 60-40 division of demand between long-haul and short-haul sounds reasonable, resulting in 3.4 trillion RPK for short-haul and 5 trillion RPK for long-haul flights for 2019. This means that, even though there are fewer long-haul flights, their greater length means that emissions are more or less balanced between the two.



CULLENWARD ET AL

Most offsets avoid emissions, rather than actually remove carbon.

Whether led by general macroeconomic growth, increases in spending power, or higher competition by low-cost carriers, any kind of increase in demand will result in a proportional impact increase. According to our simple framework, IATA's estimate of 3.8% growth, approximately in agreement with historical figures for growth, would result in an almost tripled demand by 2050. Of course, a constant growth rate is simply an extrapolation of current trends and excludes uncertainties related to the destabilization of the climate system, geopolitical and policy events, or flash technological breakthroughs. However, all scenarios seem to point toward continuous growth. Whether this growth will (or even can) be curtailed is a topic we keep for later.

3. OCCUPANCY

The vehicle-kilometers per passenger-kilometers value is the inverse of the occupancy, given by the number of passengers per vehicle. To obtain a first-order estimate, we can multiply the average number of passengers by the passenger load factor for the flight. According to ICAO data [8], for short-haul flights, the average aircraft can house 160 passengers (148 for the Boeing 737, 165 for the Airbus A320 etc.), with a passenger load factor of around 0.8. In contrast, long-haul flights can carry around 305 passengers (370 for the Boeing 777, 287 for the Airbus A330 etc.) with a passenger load factor of around 0.82. This means we currently see values of 0.0078 vehicle-kilometers per passenger-kilometers for short-haul flights and 0.004 for long-haul flights. Strictly from the occupancy perspective, a long-haul flight is more sustainable, since it can carry almost double the passengers.

The passenger load factor is the ratio between the revenue passenger kilometers and the available seat kilometers (ASK), with the latter representing the overall supply of seats in commercial aviation. Increasing this 'efficiency' beyond 0.8-0.82 would require significantly more advanced passenger traffic forecasting and flight and route planning, which is the subject of much research in the machine learning field [9]. However, the ideal value of 1 remains elusive, as long as there is one unsold seat on a flight.

4. ENERGY EFFICIENCY

Zheng and Rutherford find that, since 1970, the fuel burn of aircraft has decreased at a rate of about 1% a year due to the introduction of highly efficient aerodynamic shapes and high-bypass turbofan engines [10]. Their analysis shows that every subsequent aircraft model introduced results in a certain increase in energy efficiency, with the latest being the Airbus A320neo and the Boeing 737 MAX. These incremental improvements lead to the ICAO industry goals being represented by a yearly increase of 2% in energy efficiency [11]. Though Bergero et al. mentions other possible improvements, such as open-rotor power plants, blended wing body aircraft, and other novel architectures resulting in higher possible energy intensity gains [5], we posit that the introduction of these solutions would require serious delays in engineering, certification, and rollout. As such, we believe the ICAO 2% energy efficiency target represents the upper limit of plausibility.

Incremental gains in energy efficiency appear with the rollout of new aircraft models from original equipment manufacturers, resulting in staggered increases as the new models are released and slowly replace the existing aircraft fleet. Achieving a result between the 1% business-as-usual figure and the ICAO 2% figure would decrease from the current energy efficiency of 3.5kWh/km to between 2.7 and 2.1kWh/km by 2050. To represent increased ambition to reduce the energy intensity of aircraft, we believe it probable that a yearly increase of 1.5% efficiency will be met, while not necessarily meeting the ICAO goals - resulting in a final expected value of 2.35kWh/km, or a decrease of about 33% in energy intensity.

These figures do not account for any possible revolutionary improvements, such as the integration of either hydrogen or electricity as energy carriers (discussed in further detail below), which might require the implementation of different, less efficient architectures to account for lower energy density or specialized storage requirements.

5. CARBON INTENSITY

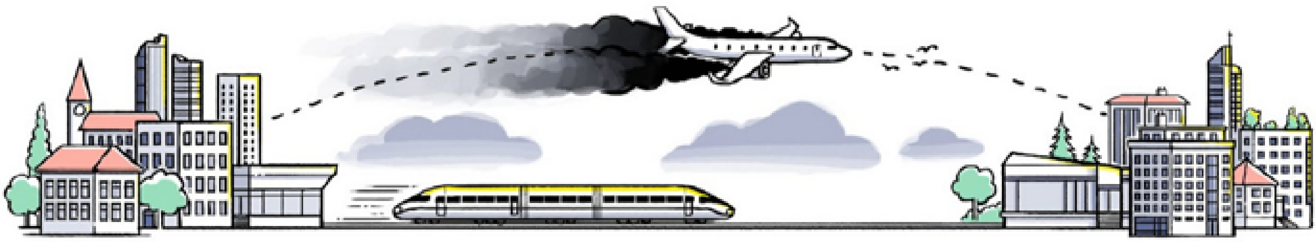
Currently, the energy density, vast existing infrastructure, and low cost of kerosene make it an ideal jet fuel. However, regardless of the fuel's source (fossil, biomass, or synthetic), its combustion inevitably produces CO2 emissions and other particulates that influence global warming. The carbon intensity of jet fuel has remained constant at around 0.265 kilograms of CO2 per kWh [5]. Comparatively, sustainable aviation fuels (SAF), hydrogen, and batteries are touted as lower-carbon alternatives. Sustainable aviation fuels are a topic of great controversy, as the industry, policymakers, and researchers do not agree on their actual decrease in emissions. IATA data shows that only around 0.2% of used fuels are currently biofuels [1], with growth limited by economic conditions, the trade-off between energy crops and food crops, and the inherent limitation of waste-based biofuels. As such, we do not consider that it is possible to provide a reasonable quantitative estimate for the evolution of sustainable aviation fuels, and, together with other non-technological improvements such as offsets and direct air capture, we leave it for further discussion.

A Safran open rotor demonstrator

Battery-powered aircraft emissions can usually be assumed to be represented by those of the grid that supports them, so a grid with strong support from solar, wind, hydropower, and nuclear electricity generation should theoretically be able to provide sufficient power for running a strong battery-electric aviation subsector. Therefore, for our analysis we will estimate that battery-electric aircraft by 2050 will be carbon-neutral while noting concerns about embodied emissions and the grid energy mix.

However, the viability of battery-powered aircraft is greatly affected by energy density. Battery-powered aircraft suffer from having almost an order of magnitude lower energy density by mass when compared to jet fuel (from 144 kWh/kg to 11 kWh/kg), which makes the concept of long-range battery-powered aircraft impossible with current technologies. This leaves the electric powerplant relegated to a relatively smaller (albeit still important) niche in very short-range flights, with designs currently in commercial production reaching up to 250 km [14].

Hydrogen combustion, on the other hand, causes significantly lower emissions than ker-



STAY GROUNDED

Modal shift could represent a solution to increasing demand for travel.

osene, and recent research has found that long-haul hydrogen aircraft designs could be more efficient than their kerosene counterparts in terms of energy consumption [12]. However, this does not consider the fuel production itself: the production and liquefaction of hydrogen is currently an energy-intensive industrial process relying on feedstocks of methane. With emissions of 2 kg of CO2 per kilogram of hydrogen, and 33.33kWh per kilogram of hydrogen, the emissions of hydrogen come out to be 0.06 kgCO2/kWh [13] 23% that of kerosene. Additionally, hydrogen aircraft are affected by poor volumetric energy density, resulting in hydrogen aircraft generally having a much higher operating empty weight (OEW) than their kerosene-fueled counterparts. Companies like Airbus are already working on designs that could accommodate this, but these designs only prove more viable for larger, long-range aircraft. It seems a promising technology for the long-haul market, but the question remains when adoption will commence, especially given the (rightfully) thorough certification process for aircraft.

The discussion of battery-electric and hydrogen aircraft presented above leads to the conclusion that very short-haul flights (up to 500 km) are the only ones that could be decarbonized impactfully in the following five to ten years. Battery chemistry and design improvements can extend the range of battery aircraft, expanding its share of the short-haul market (500-1500 km). It is unsure whether technology can cover ranges longer than that in a reasonable timeline. Hydrogen aircraft could be viable for long-range flights, but only technological demonstrators at a subsystem level are currently in development, so a timeline for implementation is uncertain.

Already in 2024, operators have signed orders for battery-powered aircraft for very short-haul flights (up to 500 km), representing 30% of all flights - barely 4.3% of the sector emissions [7]. In contrast, short-haul flights above 500 km account for 20.5% of the total emissions, while long-haul flights account for 75.1%.

As a benchmark for 2050, Eurocontrol's Aviation Outlook estimates an adoption rate of "revolutionary technologies", including battery-electric, hydrogen, and hybrid aircraft, of around 8% [15]. For short-haul flights, this adoption rate would result in a reduction of 8% of emissions, since we assume battery-powered aircraft to be non-emitting. Of course, this also assumes that the battery improvements discussed above allow significant range increases beyond 500 km. For long-haul flights, assuming hydrogen is still produced through SMR, this would result in 8% of flights reducing their emissions by 75% - a total emissions reduction of 6%. Overall, total emissions reductions would hover around 6.5%, resulting in a carbon intensity of 0.248 kilograms of CO2 per kWh - far from the considerable reductions required to reach net zero.

6. DISCUSSION

In this article, we studied only the effect of aviation on global warming through carbon dioxide emissions, without including non-CO2 effects, which have an important impact. Additionally, we limited our modeling of the impact on the Earth system to global warming. Rockstrom et al.'s planetary boundaries framework adds other coordinates to the discussion, such as eutrophication, land use, and material use [16]. Currently, aviation is highly carbon intensive but does not majorly impact other planetary boundaries. However, as discussed below, developments in the sector could result in outsized impacts.

When discussing demand, we relied partially on IATA's 2024 report. In this report, the Association proudly claims the industry's determination to achieve net zero carbon emissions by 2050, while presenting a growth rate that would result in a tripling of overall demand, and boasting of their fight against any measures that would constrain demand. However, our back-of-the-envelope calculation shows that, short of a miracle, the only way to decrease the impact of aviation effectively is to reduce demand, or at least curtail its growth. Our results are in agreement with those found by Eurocontrol, whose Aviation Outlook for 2050 shows that only a reduction of 27% in carbon emissions would be possible without the use of SAF and offsets or carbon pricing, even in the most favorable scenario for technological evolution and revolution [15].

The IATA also estimates that 65% of carbon mitigation needed will come from sustainable aviation fuels, which, as seen above, currently represent only 0.2% of total fuel used. This means that an enormous increase in SAF is required, which means a corresponding increase in the growth of crops to produce this SAF. The future decreases in emissions depend entirely on the development of SAF infrastructure, including energy crops, which compete with agricultural crops and can induce deforestation and further emissions due to land use change and intensive fertilizer use.

The other two aspects of the trifecta of IATA solutions to close the emissions gap are represented by offsets and direct air capture. Offsets would determine the development of net environmental carbon sinks to compensate for the emissions caused by aviation and are found by Joseph Romm to be "unscalable, unjust, and unfixable" [17]. This is because current offsets are typically either not real (fraud), not additional (carbon reductions would have occurred without the revenues from the offsetting sale), or over-credited. Direct air capture is also considered necessary to complement SAF, but it is incredibly energy-inefficient, resource-intensive, and unproven at scale [18]. This does not mean that negative emissions technology should not be developed, but rather that it seems unsound to continue emitting while hinging on the possibility of a later drawdown.

Currently, hydrogen production is overwhelmingly dominated by so-called "grey hydrogen", produced by Steam Methane Reforming (SRM). The emissions associated with SMR are even worse than electricity production with natural gas, and the production cost of "green hydrogen" (produced by electrolysis with green electricity sources) is still high, as the technology is not mature at a large scale. There remains a great barrier to entry in the form of a high infrastructure cost. However, as oil extraction is expected to become more difficult and costly [19], hydrogen production with low-cost green electricity may become more economically viable.

Critically, our simple framework does not model cost in any way. Historically, all efficiency improvements have led to increased travel not decreased emissions because airlines are encouraged to increase profits, with the optimum point being wherever maximum revenue can be extracted. This, once again, leads to the conclusion that demand must be curtailed through policy instruments.

Offsets have been found to often greenwash aviation, rather than compensate for its impacts.

So how can demand be limited? Typical policy instruments such as carbon pricing, beyond being practically impossible to coordinate at a global level, naturally result in increased ticket costs, creating distributional inequalities. Seeing as 1% of the world population has caused 50% of aviation CO2 emissions [20], measures such as frequent flier levies and air miles levies [21], as well as stopping current tax exemptions, may be necessary to decrease aviation demand while raising funds for decarbonization and climate mitigation. However, these frequent fliers represent affluent and powerful parts of the world, and it remains unlikely for such a 'self-tax' to be dictated by the Global North.

More positively, modal shift could represent a solution for short-range flights. High-speed rail can represent a clean and comparable solution (for example, Amsterdam to Paris in a Eurostar vs. a KLM Cityhopper), but requires significant infrastructure investments. The COVID-19 pandemic brought online work to unprecedented prominence, and there is no reason why organizations cannot change their travel policies for work-related reasons, such as meetings and conferences. Increased visibility of the climate impact and decarbonization struggles of aviation may lead to further behavior change, which, combined with responsible, coordinated policy instruments, could lead to significant decreases in air travel and subsequent reductions in emissions.

In short, our excursion into the realm of decarbonization should make one thing clear: decarbonizing aviation, though possible, represents a wicked problem with contradicting incentives for the many stakeholders involved. Airlines and original equipment manufacturers are likely to welcome growth in demand, as their profitability rises with every flight and aircraft sold respectively. However, unlike other sectors, such as energy and transport, it seems that short of vigorous global public intervention, aviation is barreling toward a greater and greater impact on our climate.

CONCLUSION

As members of the aerospace engineering community, we believe we should not be complacent with the idea that, eventually, aviation will decarbonize. A significant system change of this magnitude requires all hands on deck and, though our main contribution will be in the realm of technological development, even our simple framework shows that it is insufficient. Only if we add our strength to the chorus of voices critical of our current path, and speak up about the necessity of systemic change, can we truly make aviation decarbonize.

ELYSIAN AIRCRAFT: SKIES REIMAGINED

Challenging the Myths of Battery-Powered Aviation

Shourya Bhandari, Leonardo Times Editor

FPP

The Elysian E9X

The E9X designed by Elysian Aircraft promises to be a more sustainable approach to reducing CO2 emissions produced in commercial aviation by providing a battery-electric alternative to more than 50% of scheduled commercial flights [1]. Promising to lower operational costs for airlines while also being the most efficient path to zero-emission travel compared to other fuel sources, this new aircraft could be the innovation needed to meet the EU's net-zero carbon emission goal by 2050 [2].

The Elysian project commenced in 2021 and became a private venture in 2023. Their initial efforts were condensed into a series of ground-breaking papers released to the public at the 2024 AIAA SciTech Forum [3, 4]. Previous assumptions about larger battery-electric aircraft were meticulously dismantled, cementing the small company's place among aviation giants.

THE PERTINENT PARAMETERS

Aircraft designers develop aircraft concepts of various sizes based on several key top-level requirements. Data from previous aircraft is used to make informed decisions for new designs. However, making sense of the interdependencies between these old concepts from just raw values of mass and dimensions is impractical. For this reason, designers prefer working with mass fractions to encapsulate the trends between aircraft of various sizes. The energy mass fraction, for example, expresses the ratio of the mass of the fuel source to the maximum take-off mass of the aircraft. The operational empty mass fraction captures the ratio between the structural mass of the aircraft and the maximum mass, and a similar inference can be made for the payload mass fraction. These fractions are extremely useful in the evaluation of new concepts.

DEBUNKING MYTHS

Several research articles published in aeronautical journals discarded the feasibility of battery-electric aircraft for several reasons. One research article by Epstein and O'Flarity commented that the required shaft power and energy at take-off were too demanding for battery technology [5]. Another article by Viswanathan et al. commented that a fundamental reassessment of battery chemistry would be needed considering the gravimetric density of current batteries [6]. However, in the paper entitled, "A New Perspective on Battery-Electric Aviation, Part I: Reassessment of Achievable Range", Elysian and its research partners at TU Delft re-evaluated these assumptions and performed a first estimate for range calculation [3].

MYTH 1
High energy mass fraction is unachievable

Research has suggested a causal correlation between the empty mass fraction and aircraft size, see Figure 1. Even though larger aircraft show a lower empty mass fraction of nearly 50% due to the positive scaling effects, battery technology is still considered too heavy to accommodate the energy mass fraction within the remaining total. The conclusion was that either the payload fraction must be sacrificed or exotic materials are needed to reduce the empty mass fraction, to provide enough capacity for the batteries [3].

However, analyses by Obert and Torenbeek led to a different conclusion; the empty mass fraction was almost independent of aircraft size and more dependent on the range [7, 8]. Their analyses implied that larger aircraft do not have lower empty mass fractions due to the combination of lightweight structure and positive-scale effects, but rather have higher energy mass fractions due to their range requirements.

The trends uncovered by Elysian in their derivations supported this observation. Interestingly, the relationships between different mass fractions and the energy mass fraction held across all narrowbody aircraft, regardless of size, and did not suggest a causal link between empty mass and aircraft dimensions as initially believed.

The consequence of this myth was the reassessment of reference aircraft for battery-electric technology. Unlike traditional short-range turboprops, which are efficient for their missions, battery-electric aircraft inherently have a higher energy mass fraction due to their heavier energy carriers and resemble first-generation jet models more than current fossil-fuel planes [3]. In other words, trying to replicate turboprops for battery-electric aircraft, as many were doing in the aerospace field, was inherently incorrect. The researchers concluded that a more appropriate reference for short-range battery-electric aircraft would be a 70-100-seat single-aisle fossil-fuel aircraft with an empty mass fraction below 45% [3].

MYTH 2
Required aerodynamic performance is unattainable with current technology

Aerodynamic efficiency measures how much lift an aircraft can produce with drag as the price to pay; it contributes significantly to energy efficiency, which is particularly important for battery-electric aircraft considering the battery weight that has to be carried from origin to destination. To compensate for these heavier batteries, the aerodynamic efficiency of battery-electric aircraft would need to be much higher. However, such increases are believed to be attainable only by using technologies with a low Technology Readiness Level (TRL).

Over the years, the maximum aircraft aerodynamic efficiency has ranged between 14-18, see Figure 2. This efficiency inversely relates to the ratio of wetted area to wing reference area based on an estimate by Raymer [9]. The wetted area is the total surface area in contact with the external airflow, whereas the wing reference area is simply the planform area of the wings.

Elysian realized that for battery-electric aircraft to possess reasonable range capabilities - these planes must have high energy mass fractions, which results in a higher maximum aircraft mass, and bigger wings to lift the weight. The researchers justified the larger wings by stating that as the battery gravimetric density is almost twice that of current jet fuel, they can be stored within the wings to provide significant aerodynamic bending relief [3].

The researchers remarked that due to a larger wing, the aircraft would also require larger horizontal and vertical tail areas; however, these tail areas grow slower than the increase in wing area [3]. Moreover, the fuselage is very small relative to the resulting wing size. Therefore, the ratio of wetted area to wing-reference area reduces, increasing the aerodynamic efficiency by up to three points - significantly higher than previously assumed. Note that this increase is a direct consequence of the wing sizing for a battery-electric aircraft and has nothing to do with new aerodynamic technologies, disproving the myth.

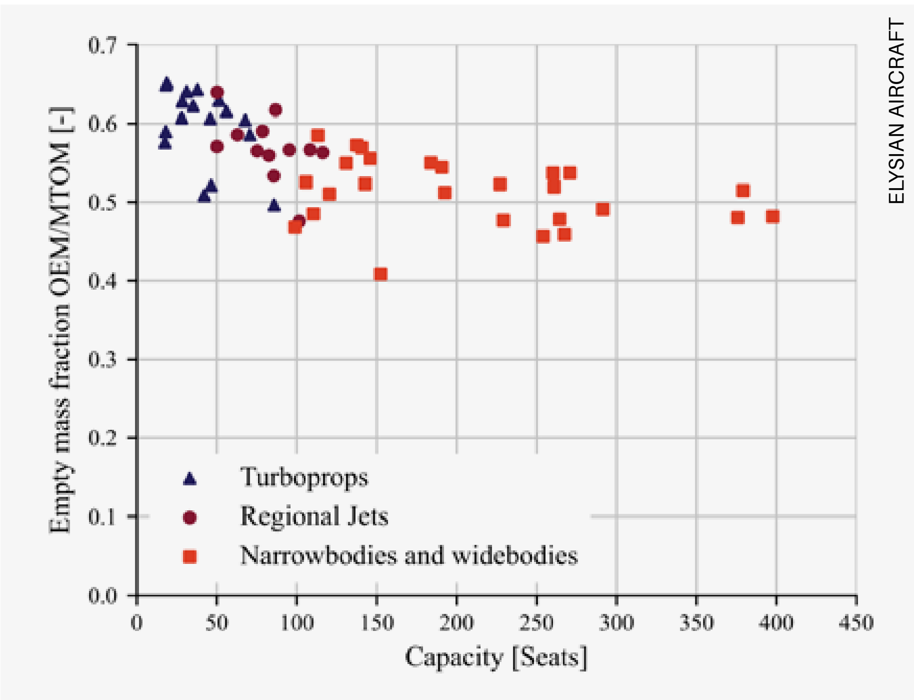


Figure 1: Correlation between empty mass fraction and aircraft size

To account for the fact that the aerodynamic and propulsion characteristics of this aircraft type are so closely intertwined, the researchers introduced a new parameter into the research field, dubbed the Electric Range Factor (ERF) [3]. The ERF is simply a product of aerodynamic efficiency and the energy mass fraction, which proves extremely useful when determining the range for battery-electric aircraft and their parametric design.

MYTH 3
Reserve requirements result in a practical range close to zero

EASA regulations require a specific amount of reserve fuel for emergencies and diversions [10]. Given that these reserves vary based on several operational factors and aircraft types, establishing a universal design requirement is challenging.

In practice, reserves are rarely used for diversions to alternate airports and final reserve usage is uncommon. In the spirit of saving weight, the researchers propose carrying reserve energy through a turbine-generator system running on Sustainable Aviation Fuel (SAF) rather than using batteries [3]. The researchers also note that even with a dual system, that could be required for redundancy and certification, the total mass would still be lighter than a battery system. Thus, the researchers assert that reserve requirements do not drastically limit operational range.

MYTH 4
Battery-electric aircraft negatively scale with aircraft size

Several experts argue that battery-electric propulsion is only viable for small-scale aircraft, not larger transport aircraft, citing economic and technical reasons [11, 12]. The economic argument is that battery-electric aircraft can only serve low-range routes and, as a result, serve a small market. However, the researchers at Elysian argue otherwise in their paper, where range isn't a limitation.

From a technical viewpoint, the researchers point to several arguments that counter the negative scale effects, where negative scaling refers to a decrease in aircraft performance due to an increase in size. Analysis by Torenbeek and Obert indicates that larger aircraft benefit from lower pilot and avionics mass fractions, thereby giving more capacity for other critical aircraft systems [7, 8]. Also, larger aircraft allow for greater battery storage capacity in the wing, offering structural and aerodynamic advantages.

The authors acknowledge that certain negative-scale factors do exist in terms of electric propulsors and their power-to-mass ratios. However, given that two motors and smaller propellers can offer better efficiency than a larger motor-propeller system, the authors

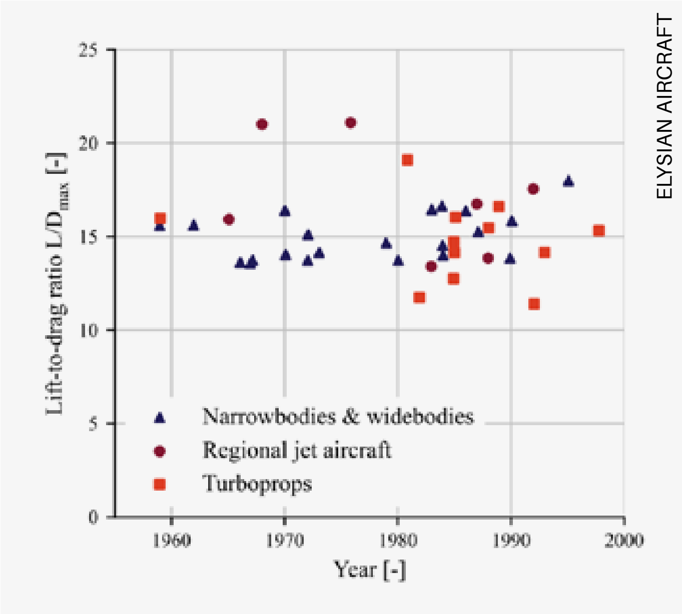


Figure 2: Maximum aerodynamic efficiency of various aircraft

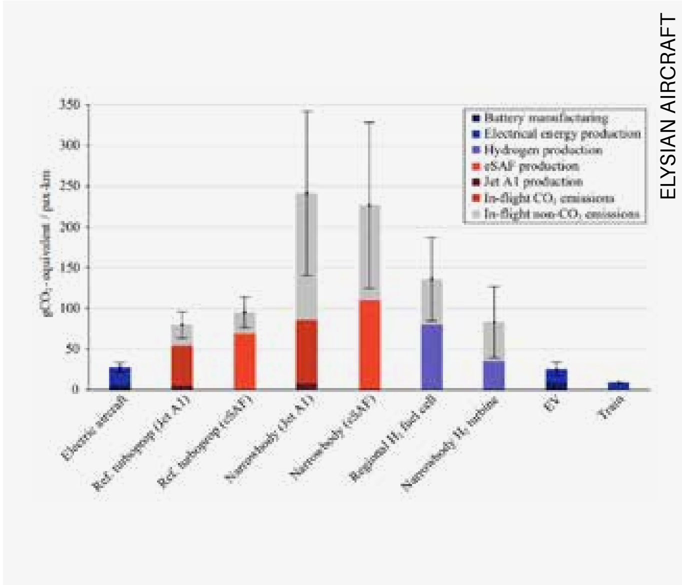


Figure 7: Equivalent CO2 emissions per passenger-kilometer for various aircraft propulsion concepts

point to a distributed propulsion configuration to counter this effect [3] and show that larger electric aircraft are practical.

A REVISED RANGE ESTIMATE

The researchers performed Class-II mass and aerodynamic estimates to assess feasible ERF values on twelve parametric aircraft designs on passenger numbers between 40-120 and ERF values between 6-12. Their results concluded that a feasible maximum cruise range could reach values above 1000 km. Based on these estimates, passengers could fly from Amsterdam to Prague, New York to Toronto, or Los Angeles to San Francisco - with zero emissions [1]. Battery-electric aviation thus provides great opportunities to convert popular routes to green routes.

DESIGNING THE E9X

Motivated by their findings, Elysian went on to perform a conceptual design of a battery-electric aircraft and validate the findings of their first paper - extensively covered in the second paper, "A New Perspective on Battery-Electric Aviation, Part II: Conceptual Design of a 90-Seater" [4].

Most of the design choices in the E9X are related to minimizing the empty mass fraction of the aircraft. A unique feature of the design was the irregular proportions compared to existing narrowbodies such as the A320. The fuselage of the E9X is significantly smaller as it carries almost half the passengers. However, the wing is considerably larger as a function of the aerodynamics of such an aircraft (figure 3).

For the wing design, several configurational choices were made for weight reduction. Batteries are stored in the wings, relieving the aerodynamic bending loads and facilitating a lighter structure. However, battery integration and packaging for replacement and inspection are challenges that would have to be addressed [4]. Safety mechanisms for battery failure are another area needing consideration. In terms of positioning, a low-wing configuration was chosen for a shorter and hence lighter main landing gear.

The aspect ratio of an aircraft represents the ratio of the wingspan to the wing chord. A higher aspect ratio for an aircraft weakens tip vortices, reducing drag and increasing aerodynamic efficiency. However, for the E9X, a modest aspect ratio was chosen to provide more wing volume for powertrain components and diminish aeroelastic effects [4]. Despite the modesty, the wingspan exceeds the gate-span limits, and the researchers propose a folding wing-tips solution similar to the Boeing 777X (figure 4). Another distinctive design element is storing the main landing gear within the wing itself, primarily due to the smaller fuselage.

The E9X also has eight propellers covering the entirety of the wing span utilizing a direct-drive arrangement for simplicity, see Figure 5. The aircraft has a particularly low disk loading compared to typical turboprop aircraft (377N/m2 compared to 500-800N/m2) that ensures a high propeller efficiency in cruise and especially during take-off, which is important for motor power and sizing.

ENVIRONMENTAL IMPACT

The primary purpose of Elysian's project is to provide a superior sustainable option compared to other current and promising future propulsion technologies, which in-

Figure 3: Top view comparison of A320 and E9X

Figure 4: 777X Folding Wingtips

Figure 5: Propellers distributed over wing-span

clude liquid hydrogen and eSAF [4]. To fairly evaluate these technologies for environmental impact, well-to-tank (grid) and tank-to-wake (vehicle) energy consumption per passenger-kilometer are evaluated for all propulsion technologies.

In terms of tank-to-wake, the researchers evaluate energy consumption per passenger-kilometer for various transport modes over an 800 km range, a conservative mission range for a 1st generation electric aircraft designed to carry 90 passengers [4]. This analysis includes comparisons with a next-gen turboprop, an A320neo-like narrowbody, and hydrogen-fuel concepts. And also ground transportation options like electric cars and trains. The findings shown in Figure 6 reveal that the battery-electric aircraft (167 Wh/pax-km) and the conventional turboprop (187 Wh/pax-km) are nearly comparable in energy consumption. Despite being over twice as heavy, the electric aircraft benefits from higher efficiency, contributing to its competitive energy profile.

Efficiency from the grid to the propulsor system plays a crucial role in assessing these pathways. For instance, it takes about 1.3 kWh of grid energy to produce 1 kWh of usable power for battery-electric aircraft, whereas hydrogen turbine and fuel cell options require approximately 4 kWh, and eSAF demands 5-9 kWh. This shows that, for a given weight, battery-electric systems are roughly three to six times more efficient than hydrogen or eSAF options [4]. This efficiency is particularly important when examining grid energy use—an indicator of life-cycle emissions. Battery-electric aircraft still demonstrate impressive efficiency, requiring approximately 70-80% less grid energy than eSAF aircraft and 40-75% less than hydrogen counterparts. The electric aircraft's energy consumption aligns closely with ground-based electric vehicles and is about twice that of trains per passenger-kilometer [4].

Elysian also compares the CO2-equivalent emissions per passenger-kilometer of different transport modes, highlighting the environmental impact of future aircraft technologies. The report considers emissions from in-flight CO2 and non-CO2 effects, energy production, and battery manufacturing but excludes vehicle and infrastructure manufacturing [4]. Non-CO2 effects include contrail formation and NOx production [13]. It shows that battery-electric aircraft, powered by a future grid mix with high renewables equating to 114gCO2/kWh (Europe's 2030 target) [14], are significantly cleaner than hydrogen or kerosene-powered planes for short missions (figure 7).

SAF offers short-term emission reductions due to its ease of implementation. However, its long-term viability hinges on a fully renewable energy grid, as other energy sources would have been developed and inherently have lesser emissions, as shown in Figure 8. Current SAF technologies like biofuels are limited in scalability, and synthetic fuels require abundant green energy and are inadequate long-term solutions. Hydrogen aircraft, although promising, currently have higher CO2-equivalent emisions due to heavier airframes, as well as, higher non-CO2 effects, when compared to electric aircraft [4].

Battery-electric aircraft are found to have a similar environmental impact as electric cars and trains on a per-passenger basis. This suggests that, if feasible, short-haul flights should prioritize electric propulsion over fuel-based alternatives, as it presents a clear advantage in reducing emissions [4]. The analysis also highlights that while electric aircraft could make short-haul flight bans, like those in France, unnecessary, hydrogen and eSAF are better suited for longer-range missions where batteries fall short.

THE FUTURE

Elysian has bold ambitions to launch its E9X variant by 2033, introducing itself as a game-changer for the aviation industry. The company plans to finish the final stages of conceptual design by 2025, after which they plan on moving to preliminary design, system testing and aircraft certification. With the support of several industry partners such as NLR, Fokker, and DLR as well as an experienced and accomplished supervisory board, Elysian looks to grow strong in the years to come.

CONCLUSION

This article provided a look back into the origins of Elysian, a company still in its juvenile stage. Several myths about battery-electric aircraft were debunked by their researchers, and the E9X was developed as a proof-of-concept. Elysian's aircraft offers a significant opportunity to achieve net-zero carbon emission targets by serving several air-travel routes within the EU and North America. For students, engineers, and executives who deal with vast amounts of data, research and engineering processes on an almost daily basis, Elysian offers a stark reminder that we must be critical yet open-minded to the possibilities and opportunities for future technologies presented to us; "Correlation does not imply causation", and to truly make a change, we must innovate and not replicate.

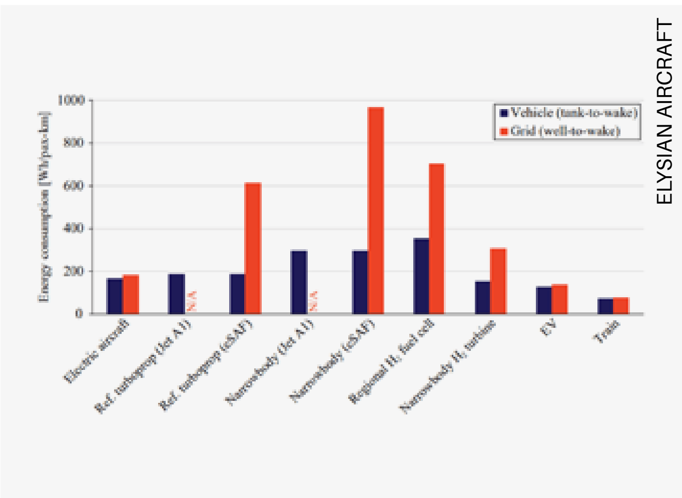


Figure 6: Vehicle and grid energy consumption per passenger kilometer for various transportation

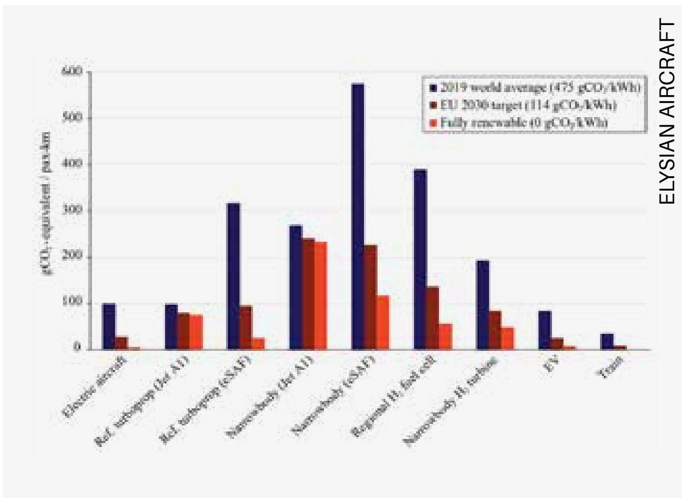


Figure 8: Equivalent CO2 emissions for various grid cleanliness scenarios


Als meisje worden wat je wil
Wij zijn enorm trots op onze vrouwen in de cabine, de cockpit en de rest van de organisatie.
transavia

ARIANE 6, A LONG-AWAITED LAUNCH

An overview of the Ariane 6 launch last July, including its struggles and successes

Simon Caron, Leonardo Times Editor

Ariane 6 finally launched on the 9th of July 2024! It was a long, overdue event awaited by all, from amateur rocket lovers to the European rocketry industry. In short, it was successful as it proved that the newest European launcher could safely deliver its payload in space, but not without challenges.

A GREAT PREDECESSOR

Before Ariane 6 there was, of course, Ariane 5. From its first launch in 1996 until its final mission in 2023, it was once the most frequently launched rocket on Earth. It put some noticeable payloads in orbit such as the Rosetta mission, Galileo navigation satellites or the James Webb Space Telescope. However, it was getting too old and in its quarter of a century lifetime, technology changed significantly. Philippe Baptiste, president of France's National Center for Space Studies, said the delays in the Ariane 6 program were partly due to a loss of technical expertise, as the long gap between the development of Ariane 5 in 1988 and Ariane 6 in 2014 caused key knowledge to be lost.

"Ariane 5 was a very good launcher, and we kept it too long," Baptiste said. Once a leading rocket, it has recently been surpassed by SpaceX's Falcon 9, which offers similar performance at a lower cost [1].

Even more concerning, the decommissioning of Ariane 5 occurred around the same time the brand-new Vega C rocket, supposedly at the forefront of small launchers for ESA, failed its second launch ever, destroying its payload and leaving Europe utterly rocketless. To add to the problem, the Ukraine war broke out the same year, leaving the use of the Soyuz launcher out of the question. This left ESA no choice but to turn to SpaceX for its bigger payloads. Still, this did not happen without a strong backlash from the European space sector seeing an interference from a foreign company into Europe's technical sovereignty [2].

Hence, the pressure was on to make a new flagship launcher for the European Union. After ten long years of design, setbacks, pandemic and other delays, on the 9th of July 2024, ArianeGroup finally showed Europeans' capabilities to the world. The question is, what exactly was inside that metal giant that departed from Kourou that sunny summer evening?

ALL IS GOOD UNTIL...

First, a little data dump is needed; Ariane 6 will come in two variants based on the performance required: Ariane 62, as seen on the left of Figure 1, equipped with two boosters, and Ariane 64, on the right in Figure 1, featuring four boosters. The 62 model can launch payloads up to approximately 4.5 tons into geostationary transfer orbit and 10.3 tons into low Earth orbit. The 64 configuration, on the other hand, can launch payloads of around 11.5 tons into geostationary transfer orbit and 21.6 tons into low Earth orbit. At 60 meters tall it weighs around 900 tons at full payload, or about as high and heavy as the leaning tower of Pisa filled with nine blue whales.

Figure 1: Ariane 62 and 64 components

Ariane 6 features three stages, consisting of two or four boosters, alongside a main and upper stage, known collectively as the central core. The main stage utilizes the Vulcain 2.1 engine (a liquid-fuel engine upgraded from Ariane 5's Vulcain 2) and P120C solid rocket boosters for initial thrust. The upper stage, powered by the re-ignitable Vinci engine and fueled by cryogenic liquid oxygen and hydrogen, allows multiple burns to

A Rafale maneuvering as Ariane 6 powers through the sky

reach various orbits and includes a final burn for deorbiting. Its fairing, made from a carbon fiber-polymer composite, is available in 20-meter or 14-meter sizes. It protects satellites from the heat, sound, and aerodynamic forces during the ascent [3]. The rocket is the result of more than a hundred companies working together from 13 European countries, led by ArianeGroup.

Ariane 6 launched successfully from Europe's Spaceport in French Guiana at 19:00 UTC after a brief delay caused by a technical issue. The rocket's early stages performed smoothly, with the boosters and main engine working as planned, and the upper stage completing a key burn to place the vehicle in orbit. However, the mission encountered an issue during the final phase, when the Auxiliary Propulsion Unit (APU) failed to fire up the Vinci engine for a third and final burn. This burn was meant to guide the rocket's upper stage back into Earth's atmosphere for a controlled reentry, but the malfunction left the stage stuck in orbit.

The incident highlights the ongoing challenges in the space sector, reinforcing the need for rigorous testing and contingency planning as Europe seeks to reestablish its foothold in space exploration. Despite this setback, Arianespace CEO Stéphane Israël reassured that the problem "would have no consequences on the next launches." While the mission completed many objectives, the failure has raised concerns, especially considering ESA's commitment to reducing space debris [4].

THE PAYLOAD

The launch carried 18 missions from three types of organizations: commercial companies, space agencies, and universities. Passengers ranged from established players like NASA to high school students from Sint-Pieterscollege in Belgium. While most payloads were CubeSats deployed via two deployers, four experiments remained fixed to the rocket body for the flight duration and returned to Earth. One of the experiments, YPSat, stayed attached to Ariane 6's upper stage, recording the mission before being released into space. Overall, ESA's decision to launch real satellites aboard Ariane 6, rather than using dummy payloads, was bold, as few rockets of this size take such risks on their inaugural flights [5].

Two particularly noteworthy missions were NASA's CURIE mission and the YPSat, each contributing to the goal of the launch. The CubeSat Radio Interferometry Experiment or CURIE is a dual spacecraft, launched as a 2x3U CubeSat, designed to use radio "interferometry" to study radio burst emissions from solar eruptions, such as flares and coronal mass ejections in the inner heliosphere. It is crucial because these events' influence can be felt on Earth as they drive space weather by increasing auroral activity and geomagnetic effects [6].

The YPSat, or ESA's young professional satellite, is integral to the Ariane 6 mission, focusing on testing advanced satellite technologies. Its key aim is to validate miniaturized systems for onboard data processing and enhance communication capabilities. By doing so, YPSat will contribute valuable insights that can shape ESA's future satellite deployment strategies. This mission is a step forward to improve efficiency and functionality for upcoming space endeavors. As the name suggests, it was designed by a team of about 30 young employees from different departments throughout ESA, who dedicated a large amount of their downtime to this project [7].

A SUSTAINABLE ROCKET?

Can a launcher ever be environmentally friendly? ESA thinks so. With Ariane 6, the organization has adopted sustainable design methods from the initial development phase and throughout the rocket's lifecycle. This commitment manifests in several key areas.

Ariane 6's journey toward sustainability began with a comprehensive Life Cycle Assessment, designed to uncover ways to enhance its products and processes for reduced environmental impact. The assessment evaluated several potential issues, from greenhouse gas emissions to soil contamination, though results will only be clear post-launch. Moreover, the program conducted an in-depth analysis of CO_2 emissions over the production and transport to Kourou. It also looked at strategies to minimize waste through helium or hydrogen production.

A custom hybrid wind-powered cargo ship was built to transport the different elements from European countries to French Guiana. The ground segment was also carefully chosen, as its location avoids as many protected species as possible. It is also full of sensors that monitor energy consumption at all times. While it was not in place for this first launch, ESA also committed to enable clean production of its launcher hydrogen and liquid oxygen fuel. Finally, thanks to the re-ignitable Vinci engine and careful mission planning, the Ariane 6 upper stage can stop and restart multiple times. It can perform a final burn to deorbit and burn up in Earth's atmosphere or shift to a graveyard orbit, reducing the risk of collisions with active satellites and debris. This supports ESA's Zero Debris approach for 2030 [8].

However, what good can a Life Cycle Assessment do if the rocket is expendable? Ariane 6 has faced criticism for its higher-than-expected launch costs and lack of reusability. Originally approved in 2012 as a cost-effective update to Ariane 5, it struggled against SpaceX's advancements in reusable rocket technology. While ESA officials argue that access to space independent of foreign entities is crucial, especially after losing the Soyuz options, the rocket's planned fewer launches make its reusability less viable. To support the project, ESA member states have agreed to subsidize it up to €340 million annually until 2031 in exchange for discounted launches [9].

CONCLUSION

To sum up, Ariane 6 represents a fresh chapter for Europe in space exploration by putting an innovative design with sustainability goals. While it faces challenges, especially with launch costs and competition from reusable rockets, it represents a commitment to regaining autonomy in space access, especially since it already has 30 launches in the books. The upcoming missions will be critical in proving Ariane 6's worth and ensuring it fulfills its promise. As Europe navigates this new era, it will be interesting to see how this rocket evolves and adapts to the ever-changing landscape of space technology.

TEAM ELEVATE JOINS GOAERO

The new TU Delft Dream Team Participating in the Emergency Response eVTOL Competition

Juan van Konijnenburg, Leonardo Times Editor

Founder of GoFly and GoAero, Gwen Lighter (Left) at the GoFly fly-off event

The aerospace industry is pushing towards innovative electric Vertical Take-off and Landing vehicles (eVTOLs). Competitions such as GoFly and GoAero inspire further development into these vehicles. One such inspiration can be found in TU Delft's newest Dream Team, "Elevate". In this interview, Team Elevate discusses their journey, design goals, and the future of electric aircraft.

SPONSORING INNOVATION IN EVTOLS

In recent years, the aerospace industry has been working towards achieving net-zero emissions by 2050 [1]. Progress has been made to improve aircraft efficiency and investigate alternative fuels. One area of investigation is personal eVTOLs, which have been particularly promoted by the GoFly competition. Begun in 2017, the competition aimed to inspire innovation in developing eVTOLs for personal use by offering large cash prizes for the best designs [2]. Sponsored by a range of aerospace companies, such as Boeing, a fly-off was held in February 2020 with 21 teams participating and a $1 million prize.

The GoAero Challenge, a successor to this event, was announced in early 2024, with a total prize of $2 million [3]. The aim is to develop an eVTOL for search and rescue missions conducted in three main stages: a digital submission of the vehicle design with ten cash prizes of $10,000, followed by the development of a full or sub-scale eVTOL with eight prizes of $40,000. The final stage is a fly-off, with a total prize of $1.7 million in five separate categories. The goal is to pit teams against each other to "out-innovate" the rest and ultimately develop a feasible design for an emergency response eVTOL [3]. The GoFly competition resulted in several successful designs and GoAero seems well-prepared to usher in a new wave of eVTOLs into the world.

DREAMS MADE OF TEAMS

TU Delft is famous for its student teams, student-driven organizations focused on a specific engineering project. The first team was founded in 1999, many more followed in the subsequent years [4]. There are now 19 student teams tackling projects ranging from hydrogen vehicles to space architecture. Seven are the so-called 'Dream Teams', given special access to the 'Dream Hall' on TU Delft's campus. The university fully supports these Dream Teams to accomplish their goals, providing the necessary resources and machines. There is now a new addition to this special group, Team Elevate, founded recently to participate in the GoAero competition and design an emergency response eVTOL. A special interview was conducted with two team members, to discover how one starts a new team and what Elevate is all about. These are chief engineer Valter Somlai, and propulsion engineer Swayam Kuckreja.

WHO IS TEAM ELEVATE?

Note: This interview has been edited for length and clarity.

Q: How did Team Elevate start, and why did you decide to join the GoAero competition?

VS: One day, a friend and I discussed how you keep hearing about eVTOLs, electric aircraft, and urban air mobility in aerospace engineering. But in Delft, there's a rocketry team (DARE), and a hydrogen team (AeroDelft), but where's the electric aircraft team? So we decided to give it a try, asked a few close friends, such as Swayam, and came up with the first six members. We spoke to several professors who guided us in the right direction. One of the professors, Fulvio Scarano, suggested the GoAero competition since it has gone through a few iterations and works quite well. And so that's how we formed the Dream Team.

SK: To give a rough timeline, we sent the first emails around in November last year. From there, the small team of six worked on creating an initial design for a few months. After those months, we realized we would need more people and had to scale up the project. So, that's why we decided to apply to become a Dream Team.

Q: How was the process of starting a Dream Team?

VS: It can be quite bureaucratic, but it wasn't that bad. Firstly, we had a pitch meeting with the Dream Hall committee, in which we essentially gave a presentation arguing why we should be a Dream Team. Since we already had a design, it wasn't that difficult. However, after we had set up in the Dream Hall, getting permission for the team to access all the machinery was bureaucratic. We also got approval quite late in August, which made recruitment for the team difficult, as the Dream Hall requires 60% full-time members.

The Dream Hall at TU Delft, where all Dream Teams are based

If we could do it again, we would've aimed to have approval around Q3, such that there is still time and interest in recruitment for a Dream Team.

SK: For the approval process, it's quite straightforward as Valter said. You reach out to the Dream Hall and tell them "Hey we have this idea for a new project that we want to discuss with you". You then schedule the meeting and give your presentation to the committee, the decision-makers behind the Dream Hall. You talk about your plans, how you're going to achieve them, and why you should be trusted with the resources and space of the Dream Hall. Then, they either approve your case or not. After that, there are a lot of guidelines to follow, like the full-time requirement or these reports about the project that need to be submitted every few months.

Q: What are your long-term goals with Elevate?

VS: The GoAero competition lasts for three years (up until February 2027), the first major goal being a working third-scale model by June. The coming two years are then just assembling the full-scale aircraft. Next year's team will do this, as the Dream Team is renewed annually. After GoAero, we want to pursue another eVTOL-centered competition. Previously, Go Fly had more events after the flyoff, so hopefully, GoAero has a similar plan. Regardless, the team will focus on developing an electric aircraft as an aerospace Dream Team.

Q: You've mentioned there are many concepts for eVTOL aircraft. What makes your approach stand out?

SK: A few things make our design unique. The first is that the competition enforces strict requirements for the whole vehicle to fit in a truck for transportation. So, it is designed to fold up, such as the propeller booms; they're designed to hinge and fold. The second is the design is fully autonomous, able to navigate from point A to point B. Thirdly, there aren't any solutions for medical or rescue drones. So, that in and of itself is a unique aspect of the design.

VS: While there are many eVTOL companies, they mainly focus on transportation and do not seem to consider rescue. For example, this summer I was in a rural area where someone suffered from a heart attack. The ambulances were too far away and couldn't get there in time, so the patient passed away. So, in that case, an eVTOL would have been able to get there faster due to its lightweight design and capability to land easier than a

GoAero competition will center around eVTOL design for emergency response

Japanese team teTra, winners of one of the prizes in the GoFly competition

helicopter. It would also be easier to deploy in these regions, as it wouldn't be as expensive as a helicopter, and trained pilots would not be needed.

Q: What do you find most exciting about this project?

VS: For me, leading a long-term project and assembling a final product is the most exciting since we don't cover this in our bachelor's. There aren't many practical assignments, so having the chance to go through the design process and make the aircraft is quite exciting. Also, learning more about rotorcraft, helicopters, and eVTOLs is exciting, as the focus in the bachelor's is more on fixed-wing aircraft. The opportunity to contact and collaborate with companies is also fun, not only in the assembly connections aspect but also in gaining that extra knowledge and experience.

SK: On my end, like Valter, I enjoy going through the engineering process, where you have this wild idea; "Ok, we have to do this competition", and pursuing it, designing, and making the final product. Going from bare-bone requirements, performing weight estimations, and doing all those steps. The process of making something from nothing is super fun for me, and I've learnt a lot. And, adding to Valter's point, something I learnt from this project is how far you can get by asking for help. You'd be surprised how many people are open to talking and how many companies are genuinely interested in helping you. It's great to see.

Q: What do you expect to be the main challenges going forward? How are you planning on overcoming those challenges?

VS: The biggest challenge is finishing the design by mid-October. With the team growing in size from 6 to 20 members over the summer, we fell back on our work to onboard the new team. Of course, the team is bigger now, but it remains a challenge to achieve a substantial, detailed design by October. Building the third scale itself is not a big issue, as it's more similar to a large drone, so there are enough parts on the market. The next big challenge is the full-scale aircraft, especially the batteries, one of the biggest challenges with electric vehicles. However, we know the last team (for the GoFly competition) made their own batteries, so we can use their knowledge. We've also been in contact with a battery company so we may outsource.

SK: The biggest challenge now, as Valter said, is the upcoming deadline. The first design report must detail the entire design and is due by December 13th. We've set a preliminary deadline to complete the initial design by mid-October to leave time for writing the report. I would also say that communication is a big challenge when working on engineering projects like this. Making sure everyone is on the same page, and there are no misunderstandings so that time isn't spent on something that will have to be changed again. It's not an issue yet, but it's something we're focusing on.

Q: The team is still quite young, with 20 members so far. Are you aiming to recruit more members, and if so how?

VS: For the moment, we're not looking to expand the team that we have until we finish the design report. With the upcoming deadline and short time frame, we can't afford to expand yet and spend time onboarding. Communication would also become harder with a larger team. When work on the third-scale model starts, we will probably look into expanding, and most definitely, for the full-scale work. So, there hasn't been much focus yet on the exposure and branding side of the team. But, we will start around December through to February, when other Dream Teams recruit for their next year too.

SK: We will follow a similar procedure to other Dream Teams since it's tried and proven. So, a semester-by-semester recruitment plan. Recruitment will open around August-September, followed by a second round in December-February. We will search for people with manufacturing experience to help with the third-scale model.

Q: How do you feel about the future of electric aircraft in the industry?

SK: As Valter said earlier, the biggest unexplored market in the aviation sector is rescue and aid. So, we think an eVTOL aircraft like this would be perfect for fire rescue or medical emergencies. I would say eVTOL has a bright future in rescue, which is why we're working on it.

VS: The requirements for the aircraft imposed by GoAero do not enforce hard limits on the electrical system compared to what's on the market already. And our range isn't too long, so it's not too constricting for us. But I would say that for commercial aircraft, unless there's substantial improvement in the capacity of the batteries, it's quite a challenge. We were looking into solid-state batteries which do show promise for future aircraft, with a much higher capacity density. But, they're still not tested to show full reliability. For aircraft that aren't too large, electric propulsion is a real option, as a combustion engine is quite complex and heavy. For larger aircraft, that becomes a bigger issue, unless we improve the manufacturing process of batteries.

ELEVATE

SPECIAL THANKS

Leonardo Times would like to thank Valter Somlaiand and Swayam Kuckreja for taking the time to conduct this interview. Since the interview, Elevate's design is nearing completion, and with help from the Von Karman Institute, they have begun simulation of their mission profiles. We wish them all the best in the GoAero competition and hope this interview inspires more students to fulfill their dreams by starting their own dream teams.

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"As a strategy expert, I focus daily on changes within LVNL, carefully assessing the impact on people, machinery, and procedures. In collaboration with partners such as Schiphol, the Ministry of Infrastructure and Water Management, and airlines, we analyze long-term trends in aviation. Sustainability is currently one of the primary themes we address. We explore ways to make aviation more efficient and opportunities to reduce CO_2 emissions."

STRATEGY EXPERT JEANETTE

"I work as an air traffic controller both at the control tower of Schiphol Airport and at the Air Traffic Control Radar Room located in Schiphol East. The job comes with pressure, but we are trained to work under these challenging circumstances. I also coach the new air traffic controllers during their training. It's fun and also adds an extra dimension to my work. In a few years from we'll be moving to the new radar room across the street in the Polaris building. I'm really looking forward to working in this new workspace with our new radar system. I really do have the best job!"

AIR TRAFFIC CONTROLLER MARTIJN

PIONEERS OF AIRCRAFT DESIGN

From the Wright Brothers to Torenbeek

Gerard Mendoza Ferrandis, Editor-in-Chief, and Ruth Euniki Vraka, Leonardo Times Editor

FPP

Portrait of Sir George Cayley, "the father of aviation"

Aircraft design is a fairly new field of study. Today, we can just pick any of the hundreds of books published on the topic and start designing. However, for the first hundred years of aircraft design, life was not so easy. These works had to start with someone, and that someone was Dutch.

BEFORE TORENBEEK

What differentiates a car from an aircraft? The answer is clear: the wing. Thus, we can explore the history of aircraft design by following the history of aerodynamics.

The earliest attempts to design a flying machine attempted to imitate nature. Many machines were designed to mimic birds' flapping wings (ornithopters), through trial and error. The issue with these attempts was that birds fly because they have strong muscles to pump their wings in relation to their size and weight [5].

Sir George Cayley was the first to identify that flight deals with four forces – lift, drag, weight, and thrust. Contrary to the public belief, he stated in his thesis "On Aerial Navigation" in 1809, that thrust and lift didn't have to come from the same source as intended with the ornithopters. Instead, he determined that thrust should come from a propulsive system, equal to the drag, and that lift should come from a wing, equal to the weight. It is why George Caley is often referred to as "the Father of Aviation" [6].

Sir Isaac Newton had already defined an equation for the force of drag of a flat plate given a certain angle to the air. It was a function of the square of the airspeed, the air density, and the surface area. After the decomposition of the forces of flight by George Cayley, people started to figure out that the forces of drag and lift had to be obtained from the transfer of momentum from the air to the plate, leading to an aerodynamic force. This resulted in the first equations used to size aircraft: the lift and drag equations. These equations were meant to model what fraction of the force was used for lift and what fraction for drag [7, 8]. Then both equations were linearly proportional to the wing surface area "S", and the flight speed squared "V^2". The slope of this proportionality was the Smeaton Pressure Coefficient (k) multiplied by the lift and drag coefficients, respectively. This Smeaton coefficient, named after John Smeaton for being the first to publish a value, measured the drag on a one-square-foot flat plate moving at one mile per hour [7]. The lift and drag coefficients were just the "ratio of the lift (or drag) of the object to the drag of a flat plate of the same area" [7]. These equations were the first analytical ways to obtain the wing size of an aircraft and were used to design the first kites and gliders that carried humans. All of this aircraft design progress and flight theory was collected by Octave Chanute in his 1893 book titled "Progress in Flying Machines". The Wright Brothers would later use this book in their design process.

When using the values of Smeaton Coefficients published by other pioneers such as Otto Lilienthal, with values ranging between 0.005 and 0.0027, the Wright brothers did not obtain the performance predicted by the lift and drag equations with their wing [8]. In 1901, the brothers built their own wind tunnel and performed experiments to measure the Smeaton Coefficient more accurately. They obtained 0.0033 [8]. Today's accepted value under the same conditions tested by the brothers is 0.00326, showing their measurements were an amazing feat that explains why they were the first to accomplish the first powered heavier-than-air flight.

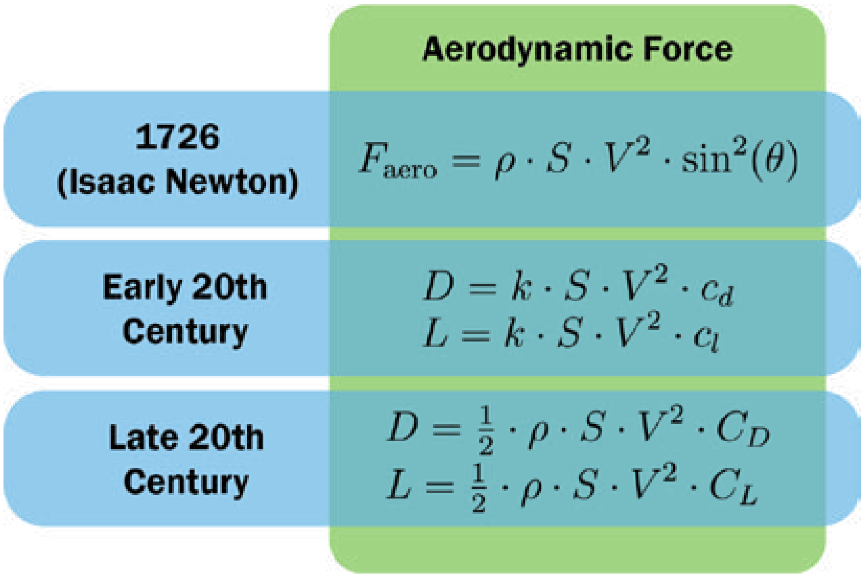
After the Wright Brothers disproved and corrected some theories for aerodynamics, the world of aircraft design was about to explode. Many scientists and researchers started to write on the theory of aerodynamics and aircraft flight performance and design, each publishing independent reports and papers. One of the most influential institutions was the USA's National Advisory Committee for Aeronautics (NACA). Founded in 1915 for the promotion of aeronautical research, they performed several experiments and developed theories that are now standard in the world of aircraft design, such as the NACA airfoil and thin-airfoil theory. In fact, Orville Wright was a board member, appointed in 1920.

However, despite the mature state of these theories, there was no immediate source which compiled all this knowledge for future aircraft design reference. This was until the birth of one man in a small country about to be consumed by one of humanity's biggest wars.

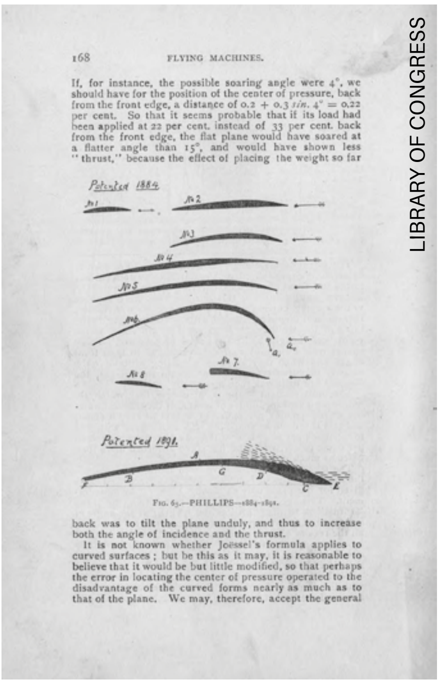
THE BIRTH OF CHANGE

Egbert Torenbeek was born in March of 1939 in the Netherlands. This year might be familiar to many as the beginning of the second world war. In 1940, the Germans invaded the Netherlands in a battle lasting just one week. In 1945, Torenbeek was 6 years old when he saw British bombers flying over into the European theater. This sight is what sparked Torenbeek's love for aviation. Ever since his secondary education, he wanted to become an aerospace engineer [1]. His dream was realized in 1956 when he got into TU Delft; back then TH Delft (Technische Hogeschool Delft). After graduating in 1961, Torenbeek went to the College of Aeronautics in Cranfield, England, to study a course on guided missiles [1, 4]. After performing his military service from 1962 to 1963, Torenbeek returned to TU Delft and worked under the supervision of aircraft design professor Hans Wittenberg as a research assistant, later making his way up to principal associate. In 1977 he took a sabbatical and started working for Lockheed in Georgia, USA, as a consultant in the Advanced Systems Department. During one of the laboratory courses he had been supervising with Professor Wittenberg, he realized there was no book for aircraft design [1]. Thus, during this sabbatical, he started writing the book in his own time at night. He recalls that the most challenging task was to gather all the data on pre-war aircraft, but also more recent aircraft at the time, such as the DC-8, the Boeing 707, or the Concorde [1]. In 1980, Torenbeek became a full professor of Aircraft design at TU Delft [4]. Eventually, his colleague Hans Wittenberg suggested he do a doctorate based on the work he had been doing during his sabbatical. This was a complete paradigm shift, as usually doctorate works were research-centered, and not methodology-centered. This would lay the groundwork for future doctorates in aerospace engineering [1].

Torenbeek published his famous book "Synthesis of Subsonic Airplane Design" in 1982 after 5 years of work. It was typewritten, and most illustrations were drawn by hand. A testament to the quality of the production, his fully manual work contained zero typographical errors [1]! He might not have been able to grasp it at the time, but aircraft design was about to change forever thanks to his work. Despite the aircraft design methodology shifting to computer-aided design (CAD) in the 1980s, his work would become the standard for students, researchers and designers at the time [1]. His book would be translated into several languages, originally published in English, and managed to reach a global scope.



History of aerodynamic force equations



168 FLYING MACHINES.

If, for instance, the possible soaring angle were 4°, we should have for the position of the center of pressure, back from the front edge, a distance of 0.2 + 0.3 *sin.* 4° = 0.22 per cent. So that it seems probable that if its load had been applied at 22 per cent. instead of 33 per cent. back from the front edge, the flat plane would have soared at a flatter angle than 15°, and would have shown less "thrust," because the effect of placing the weight so far

FIG. 65.—PHILLIPS—1884-1891.

back was to tilt the plane unduly, and thus to increase both the angle of incidence and the thrust.

It is not known whether Joëssel's formula applies to curved surfaces; but be this as it may, it is reasonable to believe that it would be but little modified, so that perhaps the error in locating the center of pressure operated to the disadvantage of the curved forms nearly as much as to that of the plane. We may, therefore, accept the general

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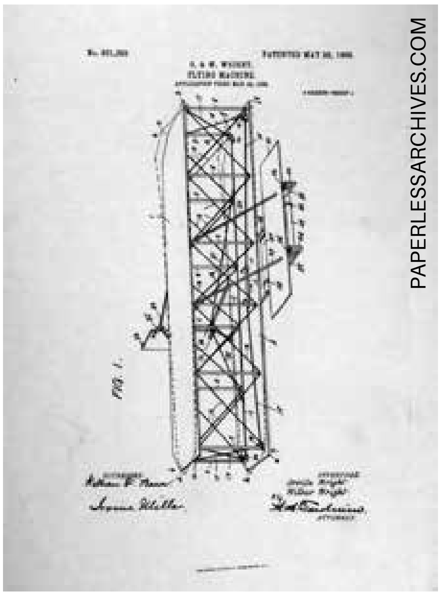
Page 168 of Octave Chanute's 1894 "Progress in Flying Machines" book shows different types of airfoils



Patent of Orville and Wilbur Wright's "Flying Machine"

Egbert Torenbeek receiving the Ludwig-Prandtl-Ring

After publishing the now-nicknamed "Torenbook", Torenbeek continued researching and teaching. In 1996, he became the vice-rector of TU Delft and also led the development of the EXTRA-400, the first 100% synthetically-designed aircraft [1]. In 1998, Torenbeek, alongside Jan Roskam, started the "Aircraft Design" journal published by Elvesier. He would later retire in 2000. This same year, he would be awarded the Honorary Doctorate by the Moscow Aviation Institute (MIA), and the Aircraft Design Award by the AIAA [1]. His "retirement" consisted of writing more and coming to the faculty twice a week [2]. In 2009 he published "Flight Physics", which he wrote based on his and Wittenberg's lectures. Originally in Dutch, the book was translated into English before publishing when it was brought to his attention that there were plans to impart the aeronautical curriculum in English at TU Delft [2].

In 2013, his golden wedding anniversary, Torenbeek published "Advanced Aircraft Design". This book also transcended into the core of all aircraft design courses and research. A year later, after the shooting down of Malaysian Airlines Flight 17, in which two TU Delft students were unfortunately killed, Torenbeek returned his honorary doctorate to the MIA as a message of disapproval of President Vladimir Putin. He wrote: "Cancelling my honorary doctorate is the only way for me to make it clear that the president you serve is an unguided missile" [3]. His main message was to the scientific and academic community, stating that they "should set a good example of ethical conduct to society and to students in particular" [3]. His message resonated among the aeronautical community and made many colleagues reconsider attending the International Council of Aeronautical Sciences (ICAS) in Saint Petersburg [3]. Some years later, in 2016, Torenbeek received the 58th Ludwig-Prandtl Ring awarded by the German Aerospace Society (DGLR) for his "outstanding contribution to the field of aerospace engineering" [1][4]. His final publication came to fruition in 2020 entitled "Essentials of Supersonic Commercial Aircraft Conceptual Design". Sadly, Torenbeek passed away last August at the age of 85, but his legacy lives on.

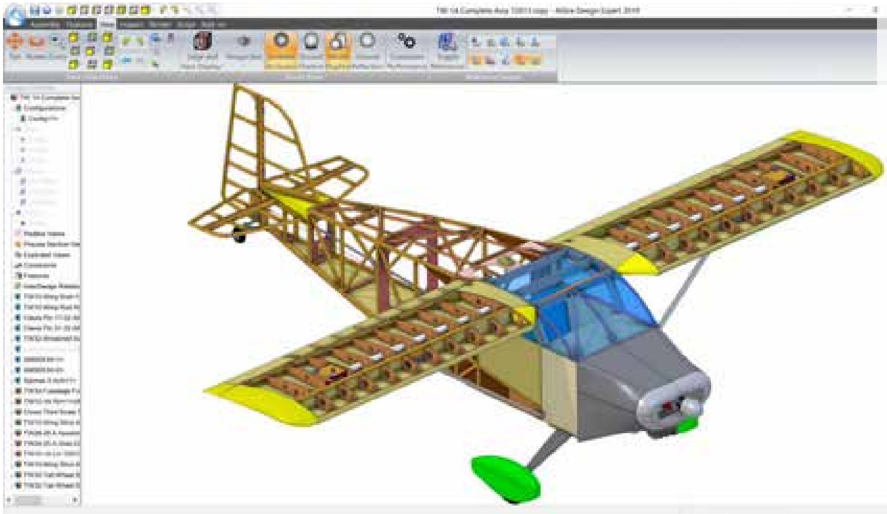
In several interviews, Torenbeek stated that his main inspiration came from Spinoza, Darwin, and Einstein. From the latter, he outlined the quote that inspired him to create the Torenbook: "If you have insufficient knowledge about a subject, you should write a book about it". What were his 3 mottos in life? Always pursue the sublime, adapt to your environment, and try to explain what you cannot understand. These were the key drivers in his more than 1700 pages of works, and are a tenet of his passion for learning, teaching, and striving for excellence [1].

BUILDING ON TORENBEEK: JAN ROSKAM

The pioneering work of Torenbeek inspired many other authors to expand and increase the existing written knowledge and expertise in aircraft design. Their books are used globally in aerospace engineering education and are relied upon by professionals in the industry. Whether focusing on conceptual design, aerodynamics, or flight dynamics, these authors have provided the foundational knowledge that continues to drive modern aerospace engineering.

One of the authors who stands out with his extensive work and large volume of publications is Jan Roskam. He was born in 1930 in the Hague, where he completed his early education. In 1954 he continued his studies at the Delft University of Technology (then TH Delft), obtaining a Master's degree in Aeronautical Engineering. After graduating, he kickstarted his professional career as an Assistant Chief Designer at Aviolanda Aircraft Company, where he worked on military aircraft projects. During this time, he also fulfilled his military obligations as a Second Lieutenant in the Royal Netherlands Air

Force, while continuing his design work. In 1956, Roskam moved to the United States and began working for two years at Cessna Aircraft Company in Wichita, Kansas, and then another nine years for The Boeing Company in Wichita and Seattle [9].
During this period he also earned his Ph.D. in Aeronautics from the University of Washington while teaching at the University of Wichita and Seattle University. In 1967, Roskam joined the University of Kansas as an Associate Professor of Aerospace Engineering, being promoted to full professor in 1972, and becoming Ackers Distinguished Professor of Aerospace Engineering in 1974. He chaired the Aerospace Engineering department from 1972 to 1976 and established the KU Flight Research Laboratory in 1968, where he served as Director until 1984 [9].


ALIBRE

Example of an aircraft modeled using CAD

During his career, Roskam consulted for many companies and organizations, including NASA, the USAF, and DARPA. From his consulting experience, Roskam founded the Roskam Aviation and Engineering Corporation (RAEC) in 1971. During this period, He published his famous eight-volume series on airplane design. The influence that the Torenbook had on his series is very evident. There are many methods cited in these books developed by Torenbeek. However, the Roskam series had each topic divided into a different book. His series also expanded beyond aircraft design and performance, including subjects such as cost estimation techniques.

In 1991, he founded the Design Analysis and Research Corporation (DARcorporation) which became a prominent player in aircraft design consulting and software development under his leadership until his retirement in 2006 [9]. He was a Fellow of the American Institute of Aeronautics and Astronautics (AIAA), the Society of Automotive Engineers (SAE), and the Royal Aeronautical Society of England (RAeS). He received numerous awards throughout his career, including the AIAA Aircraft Design Award in 2007 and the KU Chancellor's Career Teaching Award in 2003. Roskam continued teaching full-time until 2003, by which time he had already taught more than 160 short courses to thousands of engineers, engine ering managers, and pilots. In 2011, he taught his final short course on Aircraft Preliminary Design in Seattle, Washington [10, 11].

Dr. Roskam has authored 16 textbooks on aeronautical engineering, being used by over 50 universities, and has contributed to over 150 technical papers and reports, making him one of the most influential figures in the field [10].

He concluded his writing career with two reflection books. "Roskam's Airplane War Stories: An Account of the Professional Life and Work of Dr. Jan Roskam, Airplane Designer and Teacher" (2002) is a professional autobiography that recounts and illustrates stories of various aircraft programs [12]. The book "Lessons Learned in Aircraft Design" (2007) provides key insights from post-1945 airplane design, focusing on improving safety by analyzing accidents and incidents [13].

THE FUTURE OF AIRCRAFT DESIGN

The work of Torenbeek, and later Roskam, inspired many other authors to publish similar works. Some of the most famous ones are Daniel Raymer's "Aircraft Design: A Conceptual Approach", John Anderson's "Aircraft Performance & Design", and more recently, Thomas Corke's "Design of Aircraft".

However, since Torenbeek's time, computer-aided design (CAD) has replaced the pen-and-paper approach used in the early days. At first, CAD was based on the methodologies presented in the books, similar to a digitized and interactive version of the books. Today, techniques such as computational fluid dynamics (CFD) and finite-element method (FEM) have replaced, and to a certain extent, made all of the presented techniques in these books redundant. Aircraft are now designed by approximating and simulating the fluid and material mechanics governing aerodynamics and structural design. The software can range from first-order estimations on parts of the aircraft, such as the airfoil, wing, or empennage, to full more accurate estimations of complete aircraft in several dynamic environments.

CONCLUSION

The world of aeronautics is less than 200 years old. Aircraft design was started through trial and error by early pioneers. Aviation grew exponentially thanks to the contributions of figures such as Cauley, Chanute, and the Wright Brothers. However, modern aircraft design would not be the same without the groundbreaking work of Egbert Torenbeek. He managed to kickstart a second revolution in aircraft design, inspiring many other authors to build on his work and contribute to the field, ultimately leading to the creation of the CAD methods for aircraft design that we use today.

E-RACER: THE FUTURE OF AIR RACES

The Design of a Zero-Emission Aircraft for the Pulitzer Air Race

Gerard Mendoza Ferrandis, Editor-in-Chief, and Juan van Konijnenburg, Leonardo Times Editor

Artistic rendition of the final design for E-Racer

In 2022, the historic Pulitzer trophy races were revived, focusing on developing zero-emission aircraft. Inspired by the competition, a group of aerospace engineering students from TU Delft were tasked with designing an aircraft that would win the race. This article begins by discussing the history of the Pulitzer races before delving into an interview with the students about their design process.

THE PULITZER RACE

In the early 1920's, the aviation industry was small but rapidly growing. World War 1 showed the importance of aircraft, and with that importance came a need to invest more heavily in developing newer, faster planes. This need culminated in the Pulitzer Trophy Races in 1920. The race was established as a motivator for innovation and improvement of aircraft designs, specifically in terms of speed [2]. It was largely sponsored by the US Army and Navy, and publisher Ralph Pulitzer, after whom the contest was named [1].

Despite being hosted by the US military, the race was open to all contestants [2]. Rather than a formal research event, it presented an exciting platform for new developments in aviation showcased to the public. Multiple races were held at this event, and the headline was, of course, the Race for the Pulitzer Trophy: a four-lap race around a closed fifty-kilometer course, of which the winner earned a cash prize, and the trophy itself, see Figure 1 [3].

The success of the race led to its growth in later years, eventually moving south to Cleveland in 1930 [1]. The range of air events also expanded to include glider demonstrations, airship flights, parachute drops, and more races, such as the trans-continental Bendix Trophy Race [1]. These events were extremely popular in the US, attracting crowds of up to 140,000 [3], and creating great leaps in aircraft performance, leading to Cleveland gaining the nickname "The air laboratory of the world" [4]. However, following an accident in the 1949 race that led to the demise of three people, these events stopped. Fifteen years later, a revival of the Cleveland Air Show was attempted [4]. However, aerospace technology had progressed too far; Jets were too fast for the spectators to follow. The military was no longer interested in these races, preferring to conduct research at secure facilities. And with that, the long line of air races ended.

THE NEXT GENERATION OF RACES

That is, until December of 2022 when a revival of the Pulitzer Trophy Races was announced [5]. This iteration, re-named the "Pulitzer Electric Air Race", draws on the history of the Pulitzer races as drivers of innovation, with a clear focus on tackling zero-emission flight [6]. The race is planned to start in Omaha, Nebraska and end near Kitty Hawk, North Carolina where the Wright brothers worked on their designs [6]. Participants should complete this route in as short a time as possible, with a four-day limit set for the race [5]. The winner would gain a coveted Pulitzer Trophy [6], but the race is yet to take place.

The aircraft must use either electric batteries, hydrogen fuel cells, or solar panels as power sources. Whilst zero emissions is a strict requirement, all aircraft types were welcome to participate. This includes conventional planes, helicopters, eVTOLs, and any innovative electric design [5]. The scope of the race, spanning a length of 1000 nautical miles, was chosen to emphasize the importance of range and endurance for electric aviation. With such an illustrious history, the event promises to herald a new leap in electric aircraft development.

A DSE TO RULE THEM ALL

The Design Synthesis Exercise (DSE) is the project that aerospace engineering bachelor students at TU Delft must complete to obtain their diploma. Students work on a design in groups of ten for ten weeks either in aeronautics, astronautics, or wind energy. During this process, students go through most of the design process, starting from establishing requirements and ending with a final conceptual design of the system. These systems range from mine-sweeping drones to next-generation lunar landers, renewable energy aircraft, and planetary probes [7].

In 2024, Professor Alexander in 't Veld from the faculty of Aerospace Engineering had an idea. What if one of the DSE projects was targeted to win one of this new generation of races? This was the main idea behind the 2024 Summer DSE Winner: E-Racer. Their design consisted of a single-seat hydrogen-powered Prandtl-wing design. With this configuration, the team proposed an aircraft with a high winning chance, potentially able to complete the race in under 3.5 hours at an average speed of 536 km/h, and no intermediate stops [8].

We interviewed two of the team members involved in the E-Racer design to understand the intricacies of the design process that led to their winning design. These were Roeland Oosterveld, the team leader, and Jorge Gasch Chanfreut, the project manager.

Russel L. Maughan, winner of the 1922 Pulitzer Trophy Race

E-RACER: THE DESIGN PROCESS

Note: This interview has been edited for length and clarity.

Q: What was the objective of your DSE?
JGC: The goal was to participate in the Pulitzer Electric Aircraft Air Races, a 1000 nautical miles race. The only condition was to fly from Omaha, in Nebraska, to Manteo, in North Carolina, using zero-emission propulsion. The winner was the aircraft that finished the race in the least amount of time. But you could make stops and that ground time didn't count. You had four days to complete the race.

Q: I guess you had a lot of constraints in the design. So what would you say were your killer constraints or the toughest ones to deal with during the design phase?
RO: We had very few top-level requirements. It was only the race rules. And then we had just a budget, which proved to be the most difficult in the end. We had to negotiate with our client to increase the budget because our initial design needed more money to realize the required performance. And then the main influence on design was the race rules such as the zero-emission energy source and electric propulsion.
JGC: But apart from that, it was very free. It was both a blessing and a curse that we had no constraints. We had to grind it out and start constraining stuff so it was easier for us when it came to design.

Q: In this case, you were under-constrained, so you put yourself under more constraints. How come your two finalists were the conventional configuration and the Prandtl wing configuration?
RO: We had three main pillars of technologies we were looking into. So we looked into the different types of energy sources and then it was electricity via batteries (with or without solar panels) or hydrogen (gaseous or liquid). So we looked mainly into those, then we had the propulsion units, which turned out to be less important, and finally the configuration. We looked into flying wings, blended wing bodies, the Prandtl plane, and the conventional configuration. We then made combinations between those that made sense. And we soon found out that using batteries underperformed hydrogen for all configurations. Also, for our size, a flying wing or a blended wing body could not store the volume of hydrogen we needed. So then we had two options, the Prandtl wing and the conventional hydrogen-electric aircraft.
JGC: We also did market research to find constraints and see who our competitors could be. And so we found the Sirius Business Jet - already very fast using zero-emissions propulsion. So we took that and said, okay, we need to be faster. That really helped us when we selected those final two.

Figure 1: One of the original Pulitzer Trophies, from ~1920-25

RO: I think that helped us in the design process. Our timespan was until 2030, so we could rely on technological improvements, which in the end we didn't use much. It was mainly for the battery analysis of the electric aircraft that we used some values that were expected quantities of battery efficiencies and capacities.

Q: The final design was a Prandtl wing aircraft with a hybrid of batteries and hydrogen. Why would you not choose, for example, hydrogen combustion or full battery power?
RO: That was part of the race rules. You had to have electric propulsion. So we had no choice of a hydrogen turbine engine, for example. There were options other than the electric propeller, but it turned out to be very efficient and not too complex either. Batteries alone were still too heavy to provide enough energy, so you could never make it in one go, making the flight slower on average. Also, instead of sizing the full fuel cell for maximum power, we sized the fuel cell for cruise conditions with a small margin and added an additional battery to provide an energy boost during climb.

Q: I also wanted you to briefly mention some other innovations incorporated, like the heat exchanger on the lower wing and batteries on the upper wing. Can you talk about your thoughts on this design process and how they optimized the design?
JGC: The batteries are at the back in the upper wing because we wanted them to be as close as possible to the propellers. So the

The E-Racer team holding their certificates and the DSE trophy

best way was to put them there, and it was safer not to have them in the same compartment as the hydrogen equipment.

RO: And then, we needed to cool the fuel cells and a lot of other components like the batteries and some regulators and compressors. So we looked into how we could supply that cooling. Some type of ram inlet with airflow through the fuselage? Or do we want to do something else? And then we found that we could do heat exchangers inside the wing. It's still quite a novel concept. It can affect your boundary layer, but we found that if we located it on the lower side in the aft of the wing, where you already have a turbulent boundary layer, it should not diminish the wing efficiency. But yes, you needed to test it to see how it affects the aerodynamics of your wing.

Q: So this design was realized for the electric Pulitzer competition. However, can you brief us on what happened to the competition?

JGC: It was first supposed to happen in 2023, but was postponed to May 2024. Then, there was no announcement. They just removed all the information from the internet. We figured it might be a lack of participants. We still assumed with our client, the NLR, that it would happen yearly from May 2024, and that we would participate in 2028.

Q: If the competition were to happen and your design was to move into further design phases, how positive would you be that it would win the race?

RO: Yeah, it's hard to say. During later design stages, you might lose some performance and need to change things. Winning is always hard because competitors, in essence, could do the same as you.

JGC: But we don't know, because few participants appear online. This research happens in silence, so it's hard to compare ourselves with other projects. I think we'd have a pretty good chance. We're pretty confident in our design.

RO: Yeah, I think the only real stuff that might create some uncertainties is the structure, which was hard to analyze in detail. It could weigh much more. Our aerodynamics can also be improved with CFD instead of the vortex-lattice methods we used for analysis. Also, the interaction between the rotor and the wings and the specific interactions of the Prandtl wing were not analyzed.

Q: My final question is, why did you put this DSE topic as your first option over the rest? What was the most attractive part of such a DSE topic?

JGC: I chose this project mainly because of Alexander in 't Veld, the tutor. I know how he teaches and like his interaction with students. Also, this DSE was destined towards race, right? However, during the process, you can invent new technologies, like F1. I really like the idea of participating in a race and making a fast, cool aircraft that produces technological advancements.

RO: Yeah, when I looked at the other topics, I liked that this would be a full design of a new aircraft, which was one of the only ones. I'm also doing flight performance right now, so that's basically what I was interested in, not designing something detailed or making something better, but designing the full aircraft. And I also like the racing aspect that gives you, that you focus while designing that aircraft on the high-performance aspect. I also like Alexander as a tutor. I had three options I liked the most, and I put this one on one as my first choice because of him.

JGC: I'm glad I chose this DSE. The group had good chemistry and we bonded well with each other because it was everyone's first option. I think that that set us apart from some of the other groups where maybe some people were not that interested. And everyone had different expertise, like project management, Photoshop, or CATIA.

RO: Yeah I think that is what made us win. We were all strong on the basics, and a lot of us had different specific expertise. We made good use of that.

SPECIAL THANKS

Leonardo Times would like to thank Roeland Oosterveld and Jorge Gasch Chanfreut for taking the time to conduct this interview. We hope this insightful view into the design process is inspiring for engineering students in their future endeavors.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SPACE ODYSSEY

The story of two astronauts stranded in space

Vince Lukácsi, Leonardo Times Editor

SPACE

NASA

Somewhere hundreds of kilometers above Earth, two astronauts' missions turned into a 21st-century odyssey when they could not safely return to Earth. They remain stuck on board the ISS, with no immediate way home.

A SHORT TIMELINE

In 2014, NASA signed two contracts with Boeing and SpaceX as a part of the Commercial Crew Program, aiming to create a safe and cost-effective transport between the United States and the International Space Station (ISS). After the retirement of the Space Shuttle, NASA chose to task the private sector to develop a new generation of spacecraft capable of performing crew rotations [1]. They assigned this duty to multiple independent companies according to their "dissimilar redundancy" philosophy. It consists of working on different systems with the same purpose yet sharing no critical path [2]. Boeing proposed the Starliner, while SpaceX brought forth the Crew Dragon. It was not before the 19th of May 2022 that the first successful (uncrewed) launch of the Starliner occurred. After launch by a ULA Atlas rocket, the capsule docked at the ISS for four days before returning safely. Following this achievement, the astronauts were chosen for the first crewed mission to reach the space station, and the date was set for the 6th of May 2024. Unfortunately, on launch day, a problem with the oxygen valve on the Atlas launch vehicle was detected, which canceled the event [3]. Greater problems were yet to come. After a second aborted launch a few days later, the third and final date was set.

THE DAY OF THE LAUNCH

On the 5th of June, American astronauts Sunita Williams and Barry Wilmore launched from Cape Canaveral, Florida, on board the Boeing Starliner. At 10:52am ET, the Atlas V lifted off, and the journey officially began. After 25 hours of flight, they arrived safely at the ISS and joined six other members. Their expected return to Earth was planned eight days later. The first problems were encountered before they reached the Space Station. Approaching the ISS, five of the 28 control thrusters malfunctioned. Eventually, four were recovered, and docking was successful, one hour later than planned [4]. NASA performed tests to investigate the source of the problem. Amongst various possibilities, the most likely cause of the incident was a piece of Teflon seal blocking the propellant flow in the broken thruster. As the thrusters were overheating, it reached the fluid system and clogged it. Precious helium leaks were also detected. These were apparent before the launch, but their magnitude was categorized as negligible [4]. After the launch, however, the rate became significant. Following these events, NASA announced that the astronauts would not return on the initial date. They wanted to keep the Starliner docked on the ISS to investigate the problem before the faulty module burned up during re-entry and the information on the source of the issues was destroyed. After further delaying the return date, NASA finally announced that the risk to bring back the astronauts with the Starliner was too high and that it would return uncrewed. Indeed, in early September, the empty Starliner landed successfully in New Mexico. As for Williams and Wilmore, they would have to wait until the beginning of 2025 to return with SpaceX's Crew Dragon [5].

PUBLIC AND PROFESSIONAL OPINION

The media quickly picked up on this incident, and polar opinions emerged on the urgency of the situation. Many were concerned about the safety of the astronauts and started questioning the decisions made to permit the launch of the Starliner despite the known leaks of helium. According to Dr Adam Baker, head of the British company Rocket Engineering, "There is a risk of trying to get things too perfect and ending up taking too long and it being too expensive and as a result, public and political support disappears" [6]. He argued that new technology comes with new risks but that more care should have been taken considering the degree of the leaks. Dr Simeon Barber, a space scientist at the Open University in the UK, said these issues should have been identified during the tests and resolved before the crewed flight [6]. Although many media

Barry Wilmore and Sunita Williams

companies have framed the astronauts' situation as undesirable, Chris Hadfield stated, “Astronauts consider themselves ‘stranded’ on Earth, so this is a huge gift.” [7]. Hadfield noted that astronauts train their whole lives to be in space, including for similar situations, and that spending some extra time there is an honor.

HAS THIS EVER OCCURRED BEFORE?

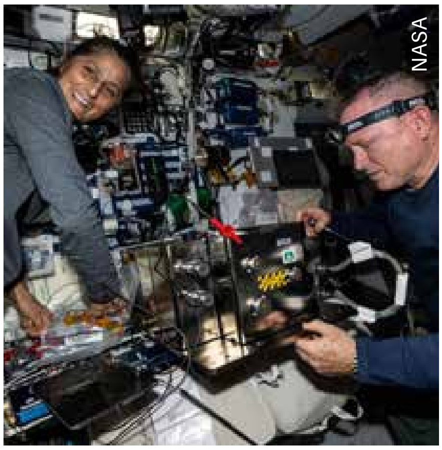
The answer might be surprising, but yes, quite a few times. In 2022, Frank Rubio and two other Russian astronauts reached the ISS with a Soyuz capsule. While the spacecraft was docked, it was struck by fast-traveling space dust, which caused several technical issues. It resulted in a total mission length of 371 days instead of the originally planned 180. Apart from technical difficulties, other factors have caused astronauts to be stranded in space, although more rarely. One such instance was due to political reasons. In 1991, Sergei Krikalev, a Russian cosmonaut, was on the Mir space station. His mission had been organized and financed by the Soviet Union. However, during his time in space, the collapse of his country made it impossible for him to return as scheduled, and he was asked to stay in Space for an additional 150 days [7]. Williams and Wilmore are not the first and almost certainly not the last astronauts to have their flight home delayed. Extensions of mission time are quite common and cause few problems, provided that the astronauts don’t stay in space too long. The limit on how much a person can endure in space is currently unknown, but an overview of the main health problems that can arise will be touched upon in the next section.

CONSEQUENCES OF THE ISS

Fortunately, the International Space Station can easily accommodate the two American astronauts for this extended period. This engineering marvel, weighing around 400 tons, is one of the most sophisticated creations by humans and has been the home to at least three astronauts uninterrupted since November 2000 [8]. It typically holds a crew of six, but during handovers, it is common for the number of people on board to increase, with a record of 13. Sunita Williams and Barry Wilmore are not at leisure on board, as they help with daily tasks, maintenance, and conducting research experiments. One concern that soon arose after the news of the delay was the potential consequences to their health due to the longer time spent in space. Valeri Polyakov, a Russian astronaut, holds this record and remained there for 437 consecutive days [7]. Spending that much or more time there can result in serious consequences. Radiation can lead to cancer, central nervous system effects, and degenerative diseases. Astronauts experience the equivalent of a year’s radiation in only a week [9]! The lack of gravity seriously affects weight-bearing bones, which can lose up to 1.5% of their density per month [10]. Luckily, the eight months they will spend on board is only slightly longer than the average six-month mission. Therefore, this hostile environment should not affect the astronauts much more than it would during a routine rotation. Finally, the mental health of the astronauts is also a concern, especially in the case of Williams and Wilmore as they were not expecting such a scenario. They both admitted that it was difficult for them to see their spaceship leave without them. Fortunately, they are both experienced, having each been on the ISS twice before this mission, and know how to deal with these challenges.

The Mir space station

Sergei Krikalev onboard the Mir space station



Daily tasks on board the ISS

SPECIAL THANKS

Sunita Williams and Barry Wilmore are safe and plan to return in February 2025. Their resilience testifies to the years of training and hard work preparing for this mission. Despite the dangers, they embraced the unknown and their contribution to the commercial space program has been vital. They displayed an exemplary attitude when their mission deviated from the original plan, serving as role models for future generations who too want to explore the mysteries of the Universe.

MISSING MAN

The unlikely history of the Rotterdamsche Aeroclub and the Dambusters squadron

James Perry, Editing Director

ROTTERDAMSCHE AEROCLUB

Michiel Munting is a contract manager at the faculty of Aerospace Engineering and the secretary of the Rotterdamsche Aeroclub. During a recent visit to the club, this editor noticed the crest of 617 Squadron on the wall, the Dambusters, which gave rise to this story.

Note: This interview has been edited for length and clarity.

Q: Could you please briefly introduce yourself?

MM: I am a lawyer by training and practiced law as a lawyer a long time ago. I worked in the banking industry for a bit and was involved in railway finance. Since December last year, I've been a contract manager for TU Delft. We are mostly legal people responsible for checking whether the agreements that the university enters into are in the best interests of the university, and to a large extent it means we look at Intellectual Property, how easily we can publish, etc. So my contracts will usually either be EU contracts, consortium contracts, or contracts with companies.

In 2012 I started taking flying lessons at the Rotterdamsche Aeroclub (RAC), and in 2015 got my Private Pilot's License (PPL). Since 2012, I've been a member of the Rotterdamsche Aeroclub, the oldest aeroclub in the Netherlands. Like most clubs, there's a small backbone of people who do something, so I got involved and currently have one or two functions. I previously had another function, without a title, but now I've moved on to be the club secretary.

Q: Can you tell us a bit about the history of the RAC?

MM: Yes, it's quite interesting! It was established in 1926, so we're getting close to our 100th anniversary. We've been responsible for quite a lot of Dutch aviation history. The Nationale Luchtvaartschool (NLS) is derived from the RAC, as well as several other aeroclubs. The RAC was founded in the interbellum by Rotterdam industrials and it's funny to see that the city of Rotterdam and its residents had a view on aviation being a mode of transportation of the future, before Amsterdam. So, the RAC started at Waalhaven, which is in the southern part of the city. It is now partly a port and partly filled in. But it was originally a big field, the first commercial airfield in the Netherlands. People from abroad came to Waalhaven to see how they did things! There were connections from Waalhaven to London, to Paris, and places in Zeeland. Haamstede used to have an airfield, and KLM flew there as well. So before Schiphol became an item or an issue, Waalhaven was already well known. Then around 1936, just pre-war, the RAC was moved to Ypenburg, near the Hague. That is where the Haagse Aeroclub joined the RAC. In 1967, the RAC moved to Zestienhoven, now Rotterdam (the Hague) airport.

Q: Do you know anything about what the RAC did during the Second World War?

MM: No, not a lot. Ypenburg was attacked by German paratroopers at the beginning of the war. Their task was to go and grab the Queen. They failed, but a lot of RAC archives were destroyed. There's an abundance of information on the RAC before the war. We're currently writing a book on 100 years of RAC history, so that period will be covered too. Because we Dutch are not very good at recording our history! Hence, we thought it was important to write this book, partly an interesting story for members of the RAC, but also beyond that as it contains a lot of Dutch aviation history.

Q: Who is Guy Gibson, and what were the Dambusters?

MM: Guy Gibson was a well-known British Squadron Leader in the war and in com-

mand of Operation Chastise, which was the bombing of the Ruhr dams. The idea was that, by destroying the dams, you would hit a large part of German industry because, as today, the Ruhr area was a major industrial hub. It was no easy feat because there were torpedo nets in the lake before the dam, and therefore you couldn't attack the dams with torpedoes. So, Barnes Wallis developed the bouncing bomb, a container that spins at a large speed. It's like that game everybody plays at the lake when you try to get the rocks as far as possible by skimming the surface. That's the idea that Wallis had. To be successful in an attack, the aircraft had to fly rather low. The RAF chose 617 Squadron, where Guy Gibson was the Squadron Leader, to action these attacks. In May 1943, Operation Chastise destroyed three dams, so the raid was successful. Guy Gibson was awarded the Victoria Cross.

He was a relatively stubborn man because afterwards, for morale purposes, the Air Force leaders were rather reluctant to let Guy Gibson fly. But Guy Gibson was having none of that, and he desperately wanted to fly. At some point, he became a pathfinder, going ahead of the bombing raids to mark the targets from de Havilland Mosquito aircraft. This is what happened in September 1944 when he was with his navigator, Jim Warwick. The story goes that after the raid in Germany, which was marked successful, they hooked up behind a Lancaster bomber whilst flying over the Netherlands. The Lancaster mistook the Mosquito for a German Junker! Given the circumstances, this was not strange. The Junker was also a twin-engine aircraft and looked relatively similar. Guy Gibson and Jim Warwick were shot down by blue on blue, 19th September 1944, and their Mosquito crashed in the vicinity of Steenbergen, in Brabant, and that is where they are buried.

One of the RAC's Diamond aircraft used in the flypasts

Q: What does this have to do with the RAC?

MM: The story is that, after the war, that grave was quite neglected. Then there was a Dutchman, Jan van der Driesschen whose father had fought in Rotterdam in May 1940. He fought at the bridges and gave the Germans a hard time. So much so that they decided to bomb Rotterdam, because otherwise it would have taken too long – and that is what forced the Netherlands to surrender on 14th May 1940. Jan van der Driesschen saw the graves of Gibson and Warwick in a deplorable state and thought it disgraceful. He started a whole campaign, writing to the Commonwealth War Graves Commission and the municipality of Steenbergen. In other words, he adopted the grave and, I think since the beginning of the '70s, he had contacts with the Rotterdamsche Aeroclub.

Since then, on 4th May, our remembrance day, at 20:02 precisely, we fly a missing man formation over the graves of Guy Gibson and Jim Warwick in Steenbergen, weather-dependent. Then we fly back to Rotterdam and fly over the Irenebrug in the east of the city, where there is a monument to resistance members executed by the Germans. We end in Zoetermeer to the north of the city where there is the grave of an American gunner, John McCormick. He was downed after a bombing raid and hidden at a hunting lodge, but towards the end of the war, something went horribly wrong. He ended up in a firefight with the Germans and did not survive. So lastly, on 4th May, we fly a missing man formation over his monument in the park in Zoetermeer, and we've done that for quite some time. The older people within the formation group have had contact with 617 Squadron and RAF veteran groups. The mayors of Steenbergen and Zoetermeer have told us that our efforts are appreciated. I think in Zoetermeer the American military attache is usually present as well. On 19th

Michiel Munting (right) is a private pilot and secretary of the Rotterdamsche Aeroclub

The Missing Man Formation, named for the missing aircraft which commemorates the fallen

Michiel Munting (rightmost) is a private pilot and secretary of the RAC

The graves of Guy Gibson and Jim Warwick in Steenbergen.

September this year, it was of course the 80th anniversary of Guy Gibson's death, so we were invited to Steenbergen and there was a good turn out. There were representatives of 617 Squadron and the Royal British Legion.

Q: Can you tell us more about Jan van der Driesschen?

MM: His father, apart from being a marine in May 1940, helped Allied airmen escape during the war. I once visited van der Driesschen's home, and saw letters from a British Air Marshall, and an American, thanking him for his efforts during the war. It was a family who always, in one way or another, was in touch with and connected to what happened in the Second World War. Jan van der Driesschen lived in Rotterdam. He also wrote a book about Operation Chastise, "We will remember them." I don't know who his original contact in the RAC was... Jan van der Driesschen himself passed away quite recently. He was quite old.

Q: What will happen to the graves now?

MM: They are well cared for now. The last commemoration at the graves was quite interesting because a Lancaster came over from the UK, that flew over the graves on 19th September. The graves now actually look very nice, I'm quite sure they are being taken care of by the Commonwealth War Graves Commission. In the '50s, I think there were many places where people were buried, so it took some time to get everything sorted.

Q: Do you think that this might have to change in the future?

MM: No, I don't think it will change. I think it's a great idea and it's been in the Dutch news a fair bit. We have a huge American cemetery in Margraten in Limburg, where graves were adopted by local children. Of course, they are not local children anymore, so the graves have basically been adopted by families. They usually contact the family of the grave that they represent, and I don't think that these things will change very quickly.

Q: Who decides who flies the formation?

MM: It's an interesting question, it's a sort of natural selection. Anyone who wants to join can. We had a time when the fleet was four identical Piper aircraft. At the moment, we have one Piper and two Diamonds. We recently purchased a third Diamond, so the next one may have four aircraft again, and we'll have the Piper and three Diamonds. It's a humbling experience.

Q: Are there any other memorials you would like to fly by and pay respects to, but it isn't allowed?

MM: It's interesting how people react. It's a very nice thing to do. We had a very short time when we did a fly-by in Rotterdam on 12th May because a Short Stirling went down in war, and it took forever to erect a monument. For a couple of years, we did a missing man on 12th May, which was the day that the Short Stirling went down, but I think the local municipality or the people responsible there weren't sure how they wanted to continue that. But we usually get a positive reaction from the people wherever we go.

Rotterdam is home to the Dutch marines, who have a link with the city because they prevented the Germans from crossing the river in May 1940. The training barracks of the Marine Corps are in Rotterdam. Their birthday is 10th December, and we applied for a missing man formation then as they commemorate their fallen on that day. We received a very formal reply from a navy officer in Den Helder, saying, "No no, we only want military personnel to carry out a missing man, that's very important for us". But I spoke to the commander of the van Ghent barracks, and there is this will to have a relationship between the city and the Marines. So it is possible that soon we will do the flypast as next year is also the 365th anniversary of the Marine Corps.

Q: Going back to the RAC, how can someone get involved?

MM: We have a flying school, so people who want to get their license can apply and get to fly with the RAC. I think in the past, if an aerospace student did their Bachelor's in one go, they got several lying lessons with the RAC! Times are not that nice anymore, but we hope to slowly succeed in at least getting the aerospace students who either have a PPL or are interested to get a PPL to become members. One of our flight instructors is Egyptian, a TU student in his Masters phase. So we're trying to get more people interested and see whether they can stick around at the RAC.

For non-members, we try to accommodate student activities in a nice aircraft-type environment. I've been in touch with the new board of VSV 'Leonardo da Vinci' and Lambach Aircraft, to see if there are activities that we can host during the coming year. In general, we want to try to make people aware that we are there! For the RAC, it is really important that we get a new generation of younger members.

SPECIAL THANKS
Leonardo Times would like to thank the Rotterdamsche Aeroclub and Michiel Munting for taking the time to conduct this interview.

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FAREWELL FIGHTING FALCON

A reflection on the F16's legacy in the Royal Netherlands Air Force

Calving Grootenboer, Leonardo Times Editor

FPP

US AIR FORCE

Over 45 years after its introduction to the Royal Netherlands Air Force, the F-16 Fighting Falcon is being retired. As a final goodbye, the aircraft flew in a formation of eight over the country on the 27th of October. But what did its service life look like, and what comes next?

EARLY YEARS: THE COLD WAR

The F-16 was introduced to the Royal Netherlands Air Force while the Cold War still raged on [1]. In 1979 alone, the People's Republic of China invaded the Socialist Republic of Vietnam, the Iranian revolution started in which its monarchy was overthrown leading to modern-day Iran, and the Soviet Union invaded Afghanistan. Despite these tensions and the Cold War continuing for more than a decade after its introduction, the F-16 never saw combat action in this period.

Instead, the F-16's primary task was to protect Dutch airspace [2]. Two aircraft were always in a state of Quick Reaction Alert (QRA), ready to intercept any aircraft that came close to or entered the airspace. This responsibility later expanded to the whole airspace of the Netherlands, Belgium, and Luxembourg, monitored by the Dutch and Belgian air forces since 2016. As part of their QRA duties, F-16s would sortie against military aircraft from the Warsaw Pact, which came to probe the air defenses of NATO countries. More recently, such actions were undertaken by Russia, which most recently had Tu-95 strategic bombers violate NATO airspace in August of 2023 [3].

AFTER THE FALL: MISSION OPERATIONS

Almost immediately after the fall of the Soviet Union and the end of the Cold War, Dutch F-16 were involved in their first combat operations [4]. During the Yugoslav wars, which started in 1991, they participated in Operation Deny Flight to enforce the no-fly zone over modern-day Bosnia and Herzegovina. The no-fly zone was mandated by United Nations Security Council Resolution 781 [5]. With Resolution 816 [6], the UN authorized its member states to enforce the no-fly zone by all means necessary.

However, the situation on the ground kept deteriorating for civilians due to the war crimes of the Republika Srpska. This reached a boiling point for the UN with the 2nd Markale marketplace massacre, where forces of the Republika Srpska bombed the central marketplace of Sarajevo, leading to 43 civilian deaths [7]. In light of these events, UN Secretary-General Boutros Boutros-Ghali requested NATO to prepare to conduct airstrikes in Bosnia [8]. These subsequent strikes became part of Operation Deliberate Force [9], during which NATO aircraft gave active ground support to United Nations peacekeeping troops and enforced safe zones for civilians. The scope of these operations expanded after the Srebrenica genocide, where after the capture of the town by Srpska forces, over 8000 civilians were murdered [10].

On the 28th of February 1994, four United States F-16s intercepted six jet aircraft from the Republika Srpska, shooting down four of them. It not only marked the first combat engagement of any F-16, but NATO as a whole [11]. Dutch F-16s engaged in combat operations like these but also had other duties,

AP NEWS

Dutch Prime Minister Rutte and Ukrainian President Zelensky visit Dutch F-16s in Eindhoven

MINISTERIE VAN DEFENSIE

A Dutch F-16 in the sky above Afghanistan

such as four F-16s equipped with special cameras to confirm the withdrawal of heavy weapons or troop formations as per international agreements. Both Operations Deny Flight and Deliberate Force ended in 1995 with the Dayton Accords [12, a diplomatic settlement between all parties involved.

Unfortunately, peace was not to last in the Balkans, as ethnic tensions erupted in modern-day Kosovo in 1998. Yugoslavia, then named the Federal Republic of Yugoslavia, was a shell of its former self after the independence of several of its member states. What was left was politically dominated by Serbians, whilst the region of Kosovo, an autonomous region of Serbia during the Yugoslav years, was majority Albanian. Serbian president Slobodan Milošević reformed the structure of what was left of the country, which revoked the privileges the Kosovar people had to rule over themselves. These actions escalated into open hostilities between a newly formed Kosovo Liberation Army (KLA) and the Federal Republic of Yugoslavia [13].

When an attempt to quell the violence, the Rambouillet Agreement, failed, and the reports of war crimes perpetrated against the Kosovar Albanians kept mounting, NATO decided to launch Operation Allied Force [14]. The Dutch government agreed to participate in Operation Allied Force and, among others, sent 16 F-16s in March 1999 [15]. This force carried out several tasks, like the escort of bombers, performing ground strikes, and taking pictures to confirm intelligence and asses struck targets.

MINISTERIE VAN DEFENSIE

A Dutch F-16 about to land after depletion of its loadout

By June 1999 [16], a peace agreement was reached after less than four months of the NATO operation. As per UN resolution 1244 [17], a NATO peacekeeping force would ensure the safety of the civilians in Kosovo and prevent the outbreak of renewed hostilities. Action came once again when the United States government invoked Article 5 of NATO after the attacks of September 11th, 2001. Operation Enduring Freedom was launched on October 7th, 2001 and aimed to overthrow the Taliban regime and eliminate Al-Qaeda from Afghanistan [18].

However, F-16s were deployed only after the establishment of the International Security Assistance Force (ISAF) [19]. ISAF was established by UN Resolution 1386 [20] to maintain security around Kabul and assist the Afghan Transitional Authority where needed. F-16s were sent to support the ground troops of the ISAF, which contained Dutch personnel. Dutch aircraft were sent out on reconnaissance missions and as close air support for troops. Furthermore, the jets were now also tasked with flying sorties for Operation Enduring Freedom, which the Dutch government had not permitted before.

Activity started to wind down with the start of Operation Resolute Support, which aimed to train and assist the Afghan security forces. On August 30, 2021, Operation Resolute Support officially ended as NATO forces withdrew from Afghanistan [19]. When this gradual withdrawal ended, a rapid resurgence of the Taliban occurred, which resulted in the collapse of the Afghan government in mid-August 2021 and the return of Taliban control over Kabul.

During this time, the Royal Netherlands Air Force also partook in Operation Unified Protector [21]. Due to violence against the civilian population by the regime of Muammar Gaddafi during the Libyan civil war in 2011, the UN passed Resolution 1973, authorizing the use of force to protect civilians.

Dutch F-16s enforced the no-fly zone over Libya as part of the NATO operation. In addition to this, they carried out strikes against Gaddafi's military infrastructure to degrade his capabilities and support the National Transitional Council (NTC), which was fighting for the liberation of Libya. The NTC won the civil war after 8 months of fighting and allowed for the peaceful transition of power to a democratically elected government. The formed coalition government did not last long, and another civil war broke out in 2014, which lasted six years.

Operation Inherent Resolve was launched in 2014 to combat the rise of ISIS (Islamic State of Iraq and Syria) and stabilize the region through coordinated military efforts. The Netherlands played a significant role in this operation by deploying F-16s to conduct airstrikes against ISIS targets in Iraq and Syria [22]. The Dutch government's involvement aimed to support local ground forces, including the Iraqi Security Forces and the Syrian Democratic Forces, in their fight against the terrorist organization.

Dutch F-16s were tasked with various missions, including precision airstrikes, reconnaissance, and intelligence-gathering operations. They provided critical support in targeting ISIS infrastructure, command centers, and supply routes, which contributed to the overall degradation of the group's capabilities.

CONCLUSION

After more than 45 years of service, the F-35 will replace the F-16 in the Royal Netherlands Air Force. But this will not be the last time the Dutch Falcons will fly, as a significant amount will have a second life to support Ukraine. 18 F-16s will go to training facilities in Romania to teach Ukrainian pilots how to fly them [24]. Another 24 will directly go to the Ukrainian armed forces. This last chapter for jets will prove to be their most challenging yet, as they will be operating in a heavily contested airspace for the first time in service life.

REDUNDANCY

From plan A to Z – an opinion

James Perry, Editing Director

MICHAEL GAT

The lessons we learn in our everyday lives shine light on our responsibility as engineers. The only way we can make space travel as safe as riding a bike is by making it as foolproof as the pedals, as redundant as the brakes and as simple as the steering.

To be redundant comes with negative connotations. At best, a redundant part in a mechanism adds to the weight – at worst, it can be detrimental to the function. Redundant components should be removed, just as a person made redundant is out of a job. Day to day, we avoid redundancy as much as possible – students tend to have one desk with one chair, one lamp and one bed. We buy two wheels for our bikes and no more, because it's cheaper that way. There are incentives to surround ourselves only with things which we use regularly and, when things go wrong and we drop a plate, we find ourselves hopelessly searching the back of the cupboard or making a late-night trip to IKEA to find a replacement. It may be inconvenient at that moment, but we get by fine in the end. There is no real reason that we need to do things any differently.

As humans we are cautiously optimistic about our prospects and can usually expect our day to go more or less as planned. But as engineers, or engineers to be, it's not enough to simply react. As a recovery engineer at the student team Delft Aerospace Rocket Engineering, I have seen my fair share of first-year rockets go up very fast and come down just as quickly! My own rocket descended quickly after half the parachute lines ripped off, but the rest held strong and the rocket was mostly unharmed. When half a year's work is beginning to fall from a kilometer in height, there's nothing you can do any more except hope the job you already did was good enough. Engineering is problem solving of the highest order. It is staring a challenge in the face and overcoming it with the power of teamwork and safety factors. Already redundancy begins to creep in. Solving projects collaboratively is far more effective than alone, as a team of engineers is more than the sum of its parts. Group work allows us to support and challenge each other, to spot mistakes and fix them before they become a problem. Similarly, we apply safety factors to everything we do, with an optimistically cautious approach of "but what if" and "just in case". Because then we know that, despite our best efforts, if something unexpected occurs everything will still be okay. Lives may genuinely depend on it. So, we have a responsibility, and our entire work ethic is centered around making the best decisions to uphold the trust placed in us.

It is for this reason that the apparent lack of redundancy in daily life is completely unacceptable in engineering. The first transatlantic airline services operated flying boats, so in the event of an emergency the airplanes could simply land. This of course did not mean the engineers put any less effort into making a plane which could fly, but it meant if all else failed there was always a backup. Even then, the flying boats were equipped with life rafts. If a plate breaks you can always buy another one. Where do you buy another engine in the middle of the ocean? There's no hard shoulder to pull over on.

One of the most intriguing aircraft designs is the Junkers G38 from 1929, which featured wings so thick you could crawl through them to reach the engines and carry out repairs mid-flight. This was like airships of the time, which also provided in-flight access to the engines for repairs during their days-long journeys. In an incredible presentation at the American Astronautical Society, flight test engineer Destin Sandlin makes a case for simple design. He points out that in the Apollo Operations Handbook, one of the contingencies for a failed separation of the descent module is to "Exit cabin, descend ladder to last rung… remove the cable". In other words, go outside and fix it! You can find the full presentation on his YouTube channel "Smarter Every Day", which I highly recommend.

Many claim that this approach to systems design is what made the moon landings a success. There is a certain brilliance to simplifying a mission-critical problem to the point where it can be fixed nearly as easily as putting the chain back on a bike. Except on the moon. Modern space capsules are full of touchscreens, which do provide advantages in intuitive and flexible displays. But could you run the spacecraft on a 12 Amp supply, just as the crew of Apollo 13 did? Could an astronaut regain control of a rotation-per-second spin, just as Niel Armstrong did on his first flight, Gemini VIII? There is a trend towards eliminating human control altogether, on the basis that we can build robust and reliable, well tested computer systems which can handle emergencies as well as any human. If we throw enough technology at it, the problem is solved.

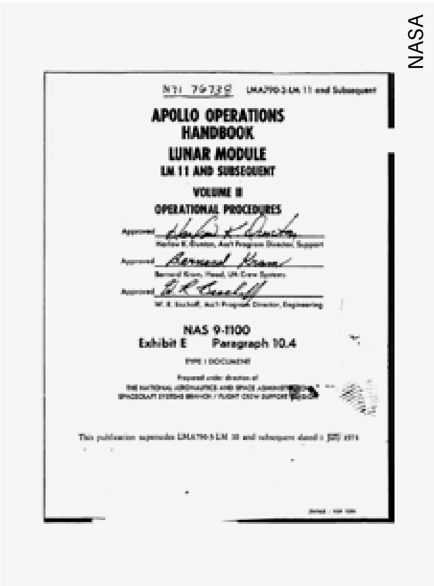
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Exhibit E Paragraph 10.4

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I do not believe this is true. From a technical perspective, I do believe we can develop such systems. From a philosophical one, or perhaps just more cautiously, I also believe that lack of redundancy is a bad idea. True redundancy is not just a backup system, it's a planned checklist of options which should be near impossible to exhaust. This means it should never stop at the software. It's life jackets on the life raft of a flying boat, it's going outside to cut the cable yourself. It should exhaust every possible option, all the way down to the human crew. If the system doesn't work, and nothing you can do on the control panel will fix it, you should be able to unscrew a panel and fix it yourself. Imagine trying to put the chain back on a bicycle while keeping your hands on the handlebars. There has to be the flexibility to improvise, to go and fix the problems which nobody saw coming. Because by their very nature, there will always be more.

Our everyday life is in fact full of redundancies. Going to buy another plate when you break one is a backup plan you have had since you got the first plate, even if it was never written down. It is not an immediate solution, but it is a solution nonetheless. And if the shop was closed, you could borrow a plate from a friend, or even improvise and eat off the back of a saucepan lid! The point is, there will never come a point where there is nothing more you can do. It is easy to mistake the lack of a quick solution, like we find in aerospace applications, for no solution at all. It therefore seems wrong to permit our astronauts' lives to rest on fewer backups than our dinner plans, yet solving this imbalance is incredibly hard to do.


NASA APOLLO ARCHIVE

Every safety system which is added brings additional complexity, which becomes harder to understand if it goes wrong itself – take Boeing's 737 MCAS as an oversimplified example from the world of aviation. There is no easy solution or obvious balance to strike. But I truly believe that we should never stop trying, we should never forget this fundamental necessity among the complexity of the new technology we develop. When human life depends on it we should indeed be cautious to the extreme, but we should also be optimistic of our successes and proud of what we achieve. We plan for the worst, hope for the best – and stick a safety factor on top.

CONCLUSION

Expect the unexpected! There are always factors beyond your control, so the consequences must be mitigated through layer after layer of redundancy. Human error can just as easily occur at the drawing board as on the launchpad, and it is a responsibility of the good engineer to acknowledge the limitations of themselves and their system. No failure should come as a surprise, else improvisation is the high price to pay, but every failure should be avoided before it occurs. That said, the part designed never to be changed will be the first to break.

REFERENCES

CAN AVIATION DECARBONISE?

[1] Annual Review 2024. (2024) International Air Transport Association. iata.org.
[2] Lee, D.S., Fahey, D.W., Skowron, A., Burkhardt, U., Chen, Q., Doherty, S.J. et al. (2020). The Contribution of Global Aviation to Anthropogenic Climate Forcing for 2000 to 2018. Atmospheric Environment 244 (September), 117834. doi.org/10.1016/j.atmosenv.2020.117834.
[3] Bigo, A. (2020). Transport Facing the Challenge of Energy Transition Explorations: Between the Past and the Future, Technology and Sufficiency, Acceleration and Slowdown. PhD Thesis, Institut Polytechnique de Paris.
[4] Börjeson, L., Höjer, M., Dreborg, K., Ekvall, T., and Finnveden, G., (2006). Scenario Types and Techniques: Towards a User's Guide. Futures 38 (7), 723–39. doi.org/10.1016/j.futures.2005.12.002.
[5] Bergero, C., Gosnell, G., Gielen, D. et al. (2023). Pathways to net-zero emissions from aviation. Nat Sustain 6, 404–414. doi.org/10.1038/s41893-022-01046-9
[6] Air Travel Forecast to 2030: The Recovery and the Carbon Challenge. (2024). Bain. bain.com.
[7] EUROCONTROL Data Snapshot. (2021). Eurocontrol. eurocontrol.int.
[8] Calculation Principles - Flight Emissions Calculator. (n.d.). myclimate.org.
[9] Ehsani, S., Sergeeva, E., Murdy, W., and Fox., B. (2024). Predicting the Skies: A Novel Model for Flight-Level Passenger Traffic Forecasting. arXiv. Org. January 7, 2024. arxiv.org/abs/2401.03397.
[10] Zheng, X. S. & Rutherford, D. (2020) Fuel Burn of New Commercial Jet Aircraft: 1960 to 2019. ICCT theicct.org/sites/default/files/publications/Aircraft-fuel-burn-trends-sept2020.pdf.
[11] Resolution A40-18: Consolidated Statement of Continuing ICAO Policies and Practices Related to Environmental Protection–Climate Change. (ICAO, 2019).
[12] Aba, M. M., Sauer, I. L., & Amado, N. B. (2024). Comparative review of hydrogen and electricity as energy carriers for the energy transition. International Journal of Hydrogen Energy, 57, 660–678. doi.org/10.1016/j.ijhydene.2024.01.034.
[13] Hydrogen fact sheet. (n.d.). H2Data h2data.de.
[14] Warwick, G. (2020, October 28). The Week in Technology. Aviation Week Network. aviationweek.com.
[15] Aviation Outlook 2050: air traffic forecast shows aviation pathway to net zero CO_2 emissions. (2022, June 17). Eurocontrol. eurocontrol.int.
[16] Rockström, J., Steffen, W., Noone, K. et al. (2009). A safe operating space for humanity. Nature 461, 472–475. doi.org/10.1038/461472a.
[17] Hanley, S. (2023). "Carbon Offsets Are Unscalable, Unjust, & Unfixable — Joe Romm." CleanTechnica. cleantechnica.com.
[18] Chatterjee, S., Huang, KW. (2020). Unrealistic energy and materials requirement for direct air capture in deep mitigation pathways. Nat Commun 11, 3287. doi.org/10.1038/s41467-020-17203-7.
[19] Misra, S. (2023, March 20). Plummeting "Energy Return on investment" of oil and the impact on global energy landscape. JPT. jpt.spe.org
[20] Gössling, S., Humpe, A.. (2020). The Global Scale, Distribution and Growth of Aviation: Implications for Climate Change. Global Environmental Change 65 (November): 102194. doi.org/10.1016/j.gloenvcha.2020.102194.
[21] Committee on Climate Change. (2019). Behaviour Change, Public Engagement and Net Zero (Imperial College London) Climate Change Committee. theccc.org.uk.
[22] EUROCONTROL Aviation Outlook 2050. (2022, April 13). Eurocontrol. eurocontrol.int

ELYSIAN AIRCRAFT: SKIES REIMAGINED

[1] Elysian Aircraft (2024, October 12). Elysian Aircraft elysianaircraft.com
[2] A route to net zero European aviation. (2024, October 12) Destination 2050. destination2050.eu
[3] Wolleswinkel, R. E., de Vries, R., Hoogreef, M. F. M., & Vos, R. (2024). A New Perspective on BatteryElectric Aviation, Part I: Reassessment of Achievable Range. In Proceedings of the AIAA SciTech 2024 Forum Article AIAA 2024-1489 (AIAA SciTech Forum and Exposition, 2024). American Institute of Aeronautics and Astronautics. https://doi.org/10.2514/6.2024-1489
[4] de Vries, R., Wolleswinkel, R. E., Hoogreef, M. F. M., & Vos, R. (2024). A New Perspective on BatteryElectric Aviation, Part II: Conceptual Design of a 90-Seater. In Proceedings of the AIAA SciTech 2024 Forum Article AIAA 2024-1490 (AIAA SciTech Forum and Exposition, 2024). American Institute of Aeronautics and Astronautics. https://doi.org/10.2514/6.2024-1490
[5] Epstein, A. H., & O'Flarity, S. M. (2019). Considerations for Reducing Aviation's CO2 with Aircraft Electric Propulsion. Journal of Propulsion and Power, 35(3), 572–582. https://doi.org/10.2514/1.b37015
[6] Viswanathan, V., Epstein, A. H., Chiang, Y. M., Takeuchi, E., Bradley, M., Langford, J., & Winter, M. (2022). The challenges and opportunities of battery-powered flight. Nature, 601(7894), 519–525. https://doi.org/10.1038/s41586-021-04139-1
[7] Obert, E. (2009). Aerodynamic design of transport aircraft. IOS Press.
[8] Torenbeek, E. (2013). Advanced Aircraft Design - Conceptual Design, Analysis and Optimization of Subsonic Civil Airplanes. John Wiley & Sons.
[9] Raymer, D. (2018). Aircraft Design: A Conceptual Approach, Sixth edition. https://doi.org/10.2514/4.104909
[10] de Moor, S. (2024, October 12). Navigating and Understanding EASA's Latest Fuel/Energy Scheme Requirements. Honeywell. aerospace.honeywell.com
[11] Webber, H., & Job, S. (2021). Realizing Zero-Carbon Emission Flight. Aerospace Technology Institute report. ati.org.uk
[12] Waypoint 2050 – Balancing growth in connectivity with a comprehensive global air transport response to the climate emergency: a vision of net-zero aviation by mid-century. (2021). Air Transport Action Group. atag.org
[13] Non-CO2 Emissions - Contrails. (2024, October 12). American Institute of Aeronautics and Astronautics iata.org
[14] Greenhouse gas emission intensity of electricity generation in Europe. (2024, October 12). European Environment Agency. eea.europa.eu

ARIANE 6, A LONG-AWAITED LAUNCH

[1] The New York Times. (2024, July 9). Europe's Ariane 6 rocket launches after years of delays. nytimes.com
[2] Horner, R. (2024, July 10). Europe sees Ariane 6 launch as an end to its launcher crisis. SpaceNews. spacenews.com
[3] European Space Agency. (2024). Ariane 6 overview. European Space Agency. esa.int
[4] Miller, M. (2024, July 10). Ariane 6 performs flawlessly on long-awaited first flight. SpaceNews. spacenews.com
[5] European Space Agency. (2024, March 03). Flying first on Ariane 6. esa.int
[6] European Space Agency. (2024, April 2). Ariane 6 launches NASA's radio detective CURIE. esa.int
[7] European Space Agency. (2022, December 24). About YPSat. esa.int
[8] European Space Agency. (2024, May 15). Ariane 6: designed with sustainability in mind. esa.int
[9] Davenport, J. (2024, July 3). Europe's Ariane 6 rocket set for maiden voyage amid stiff competition. Space Explored. spaceexplored.com

TEAM ELEVATE JOINS GOAERO

[1] Our commitment to fly net zero by 2050. (n.d.). International Air Transport Association. iata.org
[2] Swartz, K. (2020, April 29). GoFly Inspires Innovation. Electric VTOL News. evtol.news
[3] Swartz, K. (2024, February 12). GoAERO

Launches $2M+ VTOL Challenge. Electric VTOL News. evtol.news
[4] History. (n.d.). TU Delft Dream Hall. tudelft.nl

PIONEERS OF AIRCRAFT DESIGN

[1] de Vries, M. (2015, December). Nine pioneers' stories. Aerospace Engineering Faculty of Delft University of Technology. filelist.tudelft.nl
[2] Redactie. (2014, January 26). Egbert Torenbeek. TU Delta. Retrieved May 19, 2024, from delta.tudelft.nl
[3] Tersteeg, W. (2016, March 4). Professor returns honorary doctorate to Putin after MH17. AD. Retrieved May 19, 2024, from ad.nl
[4] German Society for Aeronautics and Astronautics. (2016, September 14). Prof. Egbert Torenbeek erhält den 58. Ludwig-Prandtl-Ring. DGLR. Archived March 9, 2019, from dglr.de
[5] Let's Talk Science. (2021, December 15). A history of how humans learned to fly. Retrieved May 20, 2024, from letstalkscience.ca
[6] Rumerman, J. (2008). Sir George Cayley - Making Aviation Practical. US Centennial of Flight Commission. Archived September 20, 2008, from centennialofflight.gov
[7] NASA. (2002, September 30). Smeaton Pressure Coefficient. Retrieved May 20, 2024, from grc.nasa.gov
[8] NASA. (2002, September 30). Lift Equation of the 1900's. Retrieved May 20, 2024, from grc.nasa.gov
[9] Dr. Jan Roskam – Warren McElwain Mortuary. (2022, October 3). Warren McElwain Mortuary. Retrieved October 4, 2024, from warrenmcelwain.com
[10] Dr. Jan Roskam. (1997, May 3). DARcorporation. Retrieved October 4, 2024, from darcorp.com
[11] The University of Kansas. (2024). The Dr. Jan Roskam Faculty Opportunity Fund. Retrieved October 4, 2024, from ae.ku.edu
[12] Roskam, J. (2002). Roskam's Airplane War Stories. DARcorporation.
[13] Roskam, J. (2007). Lessons Learned in Aircraft Design. DARcorporation.

E-RACER: THE FUTURE OF AIR RACES

[1] Wikipedia. (2024, January 4). National Air Races. Retrieved September 21, 2024, from en.wikipedia.org
[2] Hankin, H. R. (1959, September). The Pulitzer Races, 1920-1925. U.S. Naval Institute. Vol. 85/9/679. usni.org
[3] Roach, E. (2024, June). The Pulitzer Trophy and National Air Races at Wilbur Wright Field. U.S. National Park Service. Retrieved September 21, 2024, from nps.gov
[4] Guerrieri, V. (1 C.E., January 1). The rise and fall of the Cleveland Air races. Ohio Magazine. Retrieved October 21, 2024, from ohiomagazine.com
[5] Weitering, H. (2023, February 6). Pulitzer Electric Aircraft Race Postponed Indefinitely. Aviation International News. Retrieved October 21, 2024, from ainonline.com
[6] Pilot Magazine. (2023, January 25). Pulitzer Air Race revived for e-aircraft. Retrieved September 21, 2024, from pilotweb.aero
[7] TU Delft. (2024, June 28) Symposium Design/Synthesis exercise. Technical University of Delft. Retrieved October 10, 2024, from tudelft.nl
[8] Oosterveld, R.H., et. al. (2024, June 25) E-Racer - Final Report. Technical University of Delft. Retrieved from repository.tudelft.nl
[9] Smithsonian National Air and Space Museum. (n.d.). Pulitzer Trophy. Retrieved October 21, 2024, from airandspace.si.edu
[10] Swopes, B.R. (2025, October 14). Pulitzer Trophy. This Day in Aviation. Retrieved October 21, 2024, from thisdayinaviation.com

SPACE ODYSSEY

[1] Commercial Crew Program - Essentials - NASA. (2023, July 26) nasa.gov
[2] Jones, H. (2015). Diverse Redundant Systems for Reliable Space Life Support. ntrs.nasa.gov
[3] Mesa, J. (2024, July 18). Boeing Starliner Timeline: Launch Delays, System Failures and Milestones. Newsweek; Newsweek. newsweek.com
[4] Chow, D., & Carman, J. (2024, August 20). What went wrong with Boeing's Starliner spaceship that left two astronauts in space? NBC News. nbcnews.com
[5] NASA will bring stranded astronauts back on SpaceX — not Boeing's Starliner. (2024, August 24). NPR. npr.org
[6] Pallab Gosh (2024, June 26), "Why are the Boeing Starliner astronauts still in Space?" bbc.com
[7] Tom Metcalfe (2024, August 30) "Astronauts getting stuck in Space is more common than you think" nationalgeographic.com
[8] NASA. (2023, September 27). International Space Station Facts and Figures - NASA. Nasa. nasa.gov
[9] Radiation and life. (2007, October 26). ESA esa.int
[10] "The human body in Space" (2021, February 02) NASA nasa.gov

FAREWELL FIGHTING FALCON

[1] Ministerie van Defensie. (2024, September 27). F-16 uit militaire inventaris gehaald. defensie.nl
[2] Ministerie van Defensie. (2024, February 6). Infographic QRA. defensie.nl
[3] Ministerie van Defensie. (2023, August 14). F-16 jachtvliegtuigen ingezet voor naderende Russische bommenwerpers. defensie.nl
[4] Nederlands Instituut voor Militaire Historie. (n.d.). Inzet luchtwapen boven Bosnië, Kroatië en Kosovo: Nederlands aandeel. nimh.nl
[5] U.S. Department of State. (n.d.). November 1995: The Dayton Accords. diplomacy.state.gov
[6] NATO. (1999, March 26). Statement by the Secretary General on Operation Allied Force. nato.int
[7] Ministerie van Defensie. (n.d.). Dutch contribution to Operation Allied Force (1999). english.defensie.nl
[8] United Nations Security Council. (1992). Resolution 781 (Prohibition of military flights in airspace of Bosnia and Herzegovina) [S/RES/781]. undocs.org
[9] United Nations Security Council. (1993). Resolution 816 (Enforcement of no-fly zone over Bosnia and Herzegovina) [S/RES/816].undocs.org
[10] NATO. (1999, June 10). Statement on the suspension of air operations in Yugoslavia. nato.int
[11] Michel III, C. W. (2006). The end of a war: A study on military strategy in Operation Deliberate Force. Auburn University. etd.auburn.edu
[12] Owen, R. C. (Ed.). (2000). Deliberate force: A case study in effective air campaigning. Air University Press.
[13] Ministerie van Defensie. (n.d.). Dutch contribution to Operation Allied Force (1999). english.defensie.nl
[14] NATO. (1999, March 26). Statement by the Secretary General on Operation Allied Force. nato.int
[15] The New York Times. (1999, June 4). The Kosovo peace plan. web.archive.org
[16] United Nations Security Council. (1999). Resolution 1244 (On the situation relating to Kosovo) [S/RES/1244]. undocs.org
[17] Nederlands Instituut voor Militaire Historie. (n.d.). Nederlands aandeel in Operatie Enduring Freedom in Afghanistan. nimh.nl
[18] United Nations Security Council. (2001). Resolution 1386 (On the situation in Afghanistan) [S/RES/1386]. undocs.org
[19] Nederlands Instituut voor Militaire Historie. (n.d.). Nederlands aandeel in Operatie Unified Protector in Libië. nimh.nl/themas
[20] Ministerie van Defensie. (2023, March 30). Database Nederlandse luchtaanvallen tijdens Operation Inherent Resolve. defensie.nl
[21] Ministerie van Defensie. (2024, September 13). Toekomstige Oekraïense F-16-vliegers in Roemenië begonnen aan hun opleiding. defensie.nl

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