LEONARDO TIMES

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

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An interview with the man who has done it all

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EDITORIAL

Dear reader,

We would like to welcome you back to our journal. Today we bring you an edition packed with interviews, opinions, and technical articles. But first, we would like to ask for your participation. The VSV is celebrating the 16th Lustrum this year, and every committee is developing a special project to celebrate. Part of our mission as a journal is to foster learning about all things aerospace, so our contribution will be the addition of a new aerospace library in our faculty. If you enjoy what we do and want to support our initiative, we would greatly appreciate the donation of aerospace engineering books to add to fill our bookshelves.

In this edition you can learn the story of the only Swiss astronaut, Claude Nicollier, and you can learn it first hand from the man himself. What is it like being in space? How did he feel about his firsts? And of course, what is the future of spaceflight? We will also take a peek into the future of lunar habitation with Space Oasis, a new Dream Team exploring how a future Moon base could look like, and how we could accomplish this with in-situ resource gathering. However, all of this will only be possible if we manage to leave our blue marble. Could Kessler syndrome put a hard stop into our dreams of space exploration?

Back in the atmosphere, learn how police officers go undercover on planes for all our safety. Has this been useful, or is it a waste of the officers' time? Despite recent incidents, aviation remains impressively safe. The main challenges faced by aviation currently are sustainability and structure. However, we soon may see innovative solutions to these issues. Schiphol is trailblazing the reduction of the climate impact of airports, by incorporating so-called "green zones", and Europe may be ever so close to unifying its airspace to improve air traffic management. We will also introduce BlueSky, a TU Delft-developed open source tool that might be key for the institutions contributing to such a project.

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

Yours truly,

Gerard Mendoza Ferrandis
Editor-in-Chief

James Josep Perry
Editing Director

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Last edition...

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

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

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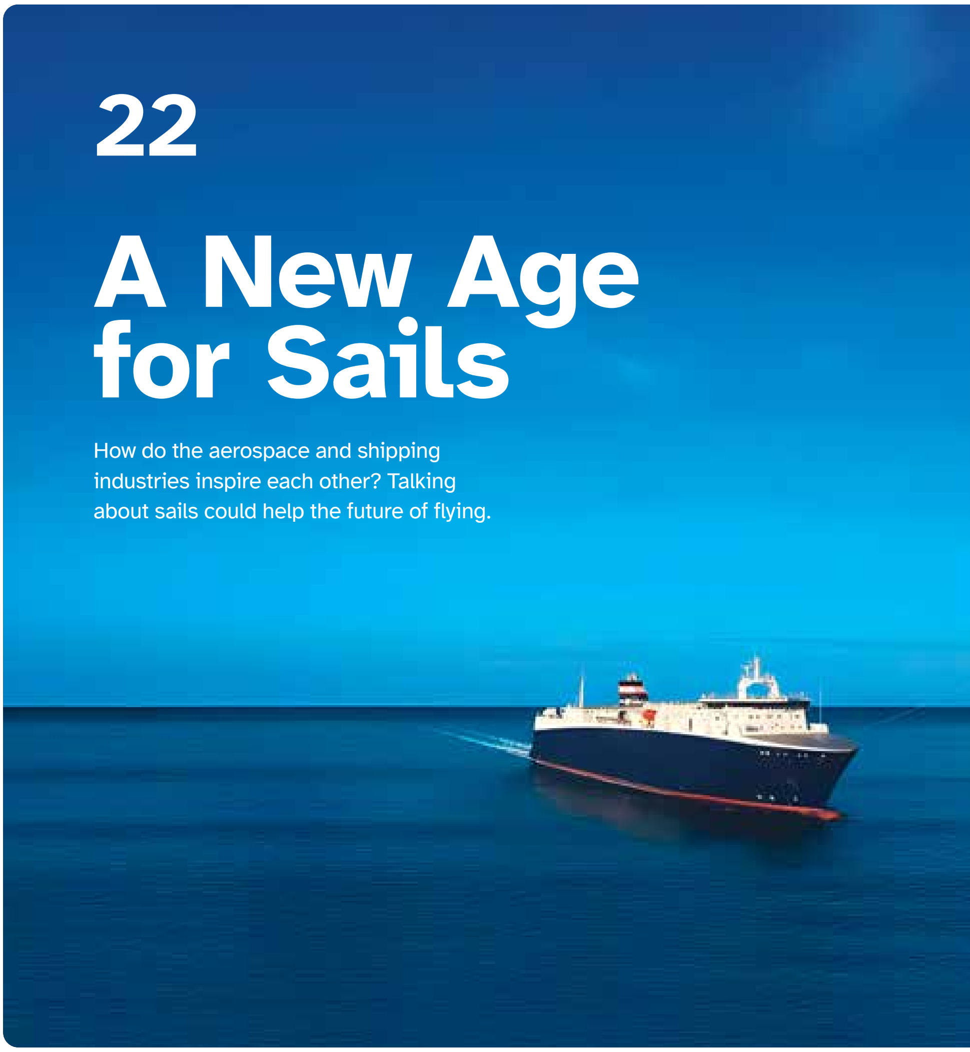
BlueSky

An open-source air traffic simulation tool driving global collaboration and innovation in the air traffic management sector.



A New Age for Sails

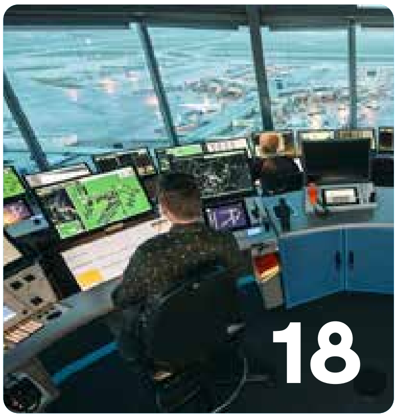
How do the aerospace and shipping industries inspire each other? Talking about sails could help the future of flying.

Skies Under Watch

The Federal Air Marshal Program has a storied past, evolving from its early origins to modern controversies. This article explores its history, impact, and the challenges threatening its future.

Is One Sky the Limit?

Despite years of reform, Europe's air traffic management continues to face delays and inefficiencies. Explore the challenges of integrating Europe's airspace and the ongoing push for a Single European Sky.



Drones in Combat

The advent, rise, and future of military UAVs

Colophon

Year 29, Number 2, Spring 2025

The 'Leonardo Times' is issued by the Society for Aerospace Engineering students, the VSV 'Leonardo da Vinci' at the Delft University of Technology. The magazine is circulated four times a year with a circulation of around 2500 copies per issue.

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The 'Leonardo Times' is distributed among all students, alumni and employees of the Aerospace Engineering faculty of Delft University of Technology. The views expressed do not necessarily represent the views of the Leonardo Times or the VSV 'Leonardo da Vinci'.

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ISSN (PRINT) : 2352-7021
ISSN (ONLINE): 2352-703X

Visit our website www.leonardotimes.com for more content.

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TURNING POINTS

In the next edition you, the reader, can be featured in the Leonardo Times! The idea is simple: we propose a topic, you write, and whichever submission shows the most thought, creativity and meaning gets published. In celebration of the 16th lustrum of the VSV 'Leonardo da Vinci', the prompt for this competition is as follows:

What if a major turning-point in the last 80 years of aerospace history had gone differently?

We want you to focus on the repercussions that a different outcome of a major event would have had in the world of air/space travel. But remember, the world of aerospace does not exist in a vacuum! While we don't want you to put excessive focus on non-aerospace topics, the industry has direct interaction with sociopolitics, the economy, and the environment for example. Be creative but describe realistic outcomes, grounded in reality.

Do not choose "an event happening at a different time" nor a "non-event that could have happened". Rather, we ask you to discuss a real moment in time, as if it had led to a different outcome.

Some example topics could be:

- Could we all be flying supersonic if the Concorde crash had not happened?
- What would have been the fate of international space laboratory research if the Apollo-Soyuz handshake had never happened?
- If the USSR had kept developing the Buran, could it have been the most used form of space travel?
- How would the airline industry look today if airlines had remained nationalised?

For your article, we expect the following.

- A minimum of 2,000 words. More words are not penalised, but encouraged if they are meaningful.
- In order to remain factual, cite your sources. It doesn't have to be pure imagination. If the scenario can be backed with real data and studies, even better!
- The Leonardo Times is written in American English, so keep this in mind.
- The article must be handed in as a Word or Google Document before 6th June 2024. Incorrect formats or late entries will not be accepted.
- Add as many figures as you want, but make sure you have permission to use them!
- Send the article to leotimes-vsv@stdent.tudelft.nl with the subject "A Different Future - [what your turning point is]"

Happy writing, and good luck!

A Message from the Board

Dear reader,

Spring has finally arrived! The days are getting longer, the sun is shining brighter, and with each passing week, the end of the academic year comes a little closer. This shift in seasons brings new energy and motivation to make the most of what's ahead. But before we dive into the exciting weeks to come, let's take a moment to look back.

We concluded the first semester with an unforgettable lustrum ski trip. Over 100 students headed to La Plagne for a week of skiing, snowboarding, and après-ski fun. The combination of mountain air, snowy slopes, and sunshine was the perfect reset before starting the third quarter.

That new quarter began with a major event: the annual aviation symposium. This year's theme, *From Vision to Flight*, focused on the future of aircraft design. It was a day full of inspiring talks, industry insights, and forward-thinking discussions.

Not long after, we set off again, this time for the Active Members Weekend in Brabant, where sunshine, games, and great company made for a wonderful weekend.

Meanwhile, the spring career weeks brought a range of companies to the faculty. During lunch lectures, we welcomed Parrot, Collins Aerospace, Dynaflow, and Ferrari, offering students a chance to connect with industry leaders. We closed off the week with an interview to inspire with Schiphol CEO Pieter van Oord.

Another lustrum highlight soon followed: the Gala. Held on the Scheveningen Pier, the setting sun over the sea created a magical backdrop for dinner and dancing, as we celebrated our lustrum year in style.

Afterwards, the board took a short but well-earned break. We flew the A321neo for the first time en route to Marrakech, where we enjoyed a week of sunshine, exploration, and relaxation — the perfect way to recharge before one of the most exciting times of the year.

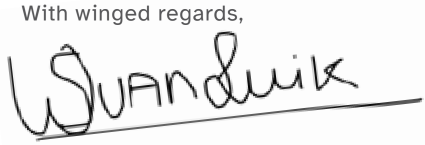
Because now, the time has come: lustrum month is here! We're starting strong with the lustrum night, followed by a clothing upgrade event featuring the lustrum logo. Ever dreamed of flying in a glider? Now's your chance, with our dedicated gliding day!

There's more in store: DeBaCoXL, a constellation evening, lasergaming in the Fellowship, tile painting, the Runway Run, and excursions to the Centrum voor Mens en Luchtvaart and ESA ESTEC. Finally, the month will be closed off with a spectacular surprise closing activity.

We warmly invite you to join us. Whether you're looking to try something new, reconnect, or just enjoy the moment , let's celebrate together and make this lustrum month truly unforgettable!

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

With winged regards,



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

Quarterly Highlights

Astronauts Come Home

US astronauts Butch Wilmore and Suni Williams have returned to Earth after nine months in space. They descended in the SpaceX Crew Dragon capsule “Freedom” after their Boeing Starliner spacecraft was returned safely but unmanned after its first flight.

Starliner suffered severe malfunctions with its reaction control thrusters and five Helium leaks, leading NASA to deem it unsafe for a manned crew. Wilmore and Williams remained on the ISS, joining the Expedition 71 and 72 crews to be productive in space until it was practical to return to Earth. Throughout their stay, an emergency return was always possible by a "lifeboat" Crew Dragon docked to the ISS.

Astronaut Nick Hague and cosmonaut Aleksandr Gorbunov, Crew 9, launched and docked with the ISS in September. The crew aboard this mission had been reduced from four to two in order to make room for the starliner astronauts on the return trip. The descent took 17 hours and was uneventful, splashing down on 18th March 2025. Despite their original eight-day mission, the Boeing Crew Flight Test astronauts were in space for a total of 286 days.

Open Fan Engines

At the 2025 Airbus Summit, the manufacturer announced a range of updates for its ZEROe hydrogen aircraft project. This included its intention to flight test a sustainable open fan engine under development by CFM, a joint venture between GE Aerospace and Safran Aircraft Engines. This will be done using an A380 test platform by the end of the decade.

The RISE program (Revolutionary Innovation for Sustainable Engines) aims for a 20% increase in fuel efficiency over traditional designs. It is envisioned as a successor to the CFM LEAP engine, which powers the A320neo and 737 MAX families. In addition to being SAF and hydrogen compatible, the engine makes use of an open fan design. Compared to current high-bypass turbofans, the lack of cowling increases efficiency and decreases noise pollution, while still being able to propel an aircraft at high speed.

The ZEROe aircraft, a project first launched in 2020, are designed to be powered by fuel cells supplied with liquid hydrogen. A ground test of the powertrain is planned for 2027. Although the flagship aircraft will be powered by propellers, there is exciting potential for the application of novel open fan engines in future.

A Hop Towards Space

On March 30, 2025, Isar Aerospace performed the first orbital rocket launch attempt from mainland Europe. The German aerospace company launched their Spectrum rocket from Andøya Spaceport in Norway. The attempt lasted for about a minute, as 20 seconds after launch an anomaly caused the rocket to lose control and plunge into the Norwegian Sea below.

Despite this, CEO Daniel Metzler considers this test flight a success. In Metzler's words: "We had a clean lift-off, 30 seconds of flight and even got to validate our flight termination system."

The Spectrum rocket is a two-stage launch vehicle designed with a payload capacity to Low Earth Orbit of 1000kg, powered by nine liquid propane-liquid oxygen engines. Its development started in the 2010s, and it wouldn't be until February 2025, when after a static fire test the rocket was deemed as ready to fly.

This launch marks a significant milestone for Europe's space endeavour, and proves a nice continuation from PLD Space's sub-orbital rocket launch in October 2023. Isar Aerospace plans to analyze the collected data to inform future missions, with their next one being planned for 2028.

Artemis Controversy

The Artemis program was initiated in 2019 with the objective of bringing humans back to the Moon by 2027. The long term goal of the program is to establish continued human presence on the Moon, and serve as a gateway for future Mars missions. In November 2022, the first uncrewed launch was performed as a step towards this goal.

A key element of Artemis is its commitment to diversity: NASA announced that the program would include the first woman and the first person of color to walk on the lunar surface. In April 2023, it was announced that NASA astronauts Christina Hammock Koch, Victor Glover, Reid Wiseman and Canadian Space Agency astronaut Jeremy Hansen would conform the crew for Artemis II. This marks a significant departure from the Apollo-era lunar missions, which included only white male astronauts.

However, on January 20th of this year, president Donald Trump issued a directive to eliminate all Diversity, Equity, and Inclusion (DEI) initiatives across all federal agencies, including NASA. This directive has raised concerns about the future of NASA's diversity pledges and whether the Artemis program will still fulfill its goal of representing a broader spectrum of humanity on the Moon.

SPACE

Claude Nicollier

An interview with the man who has done it all

James Perry, Editing Director

On a recent visit to the Faculty of Aerospace Engineering, Swiss astronaut Claude Nicollier took the time to answer some questions on his career, advice, and thoughts for the future.

Q: Could you briefly introduce yourself?
CN: I'm Claude Nicollier from Switzerland, I just turned 80 years of age last year so I'm no longer a young man – but I was in the past, like everyone! I was born in 1944 at the end of the last world war, which Switzerland was not really involved in. I had a happy childhood in Vevey, near Lausanne in the West, French-speaking part of Switzerland. Very early on I really had a passion for airplanes, for the sky. I looked at the planets, the moon and star clusters with a small telescope and I really liked aviation too, building model airplanes. I studied physics in Lausanne and astrophysics in Geneva, for me it was natural to go in the direction that corresponded to my passion for the sky. For aviation, I was happy that in Switzerland we have this militia system where every man has to serve in the armed forces. So, at 20 years of age you go to the "École de recrues" as they call it, so basic training. I was successful in reaching the status of squadron pilot in first the de Havilland Venom, then later the Hawker Hunter. In parallel, I was an astrophysicist for several years and an Air Force pilot once I had my degree and my license. As an Air Force pilot, I had 6 weeks of training a year, so every two months one week of training flying airplanes, and the rest was doing research in astrophysics. That was a happy combination of activities which corresponded to my passions.

I had a huge interest for space, when I was 25 years of age in 1969 we had Apollo 11, which was of course a huge inspiration for me, but the Americans and Soviets were the ones doing space. But a few years later, in 1975, we heard about the invitation by the US to Europe to participate in the next human space program, which was the space shuttle. There was a selection in 1977 which finished in 1978 with the selection of the first three European astronauts: Wubbo Ockels from the Netherlands, Ulf Merbold from Germany and myself. We were sent to Houston to train on the space shuttle and I did a lot of training for many years, in fact for 12 years as I had my first flight in 1992. That was the first group of ESA astronauts and there was zero priority for us in Houston. The Challenger flight delayed my flight from 1986 to '92, but afterwards, I had three more missions which were in 1993, '96 and '99, including two visits to Hubble in 1993 and '99. These were of course wonderful missions for me: I had been an astronomer, became an astronaut and now must go fix Hubble! These were dream missions for me, with a spacewalk on my last one in '99 to replace the main computer on Hubble and one of the fine guidance sensors. For me, this was a highlight of my career.

I stayed a little longer in Houston after my last flight, until 2005. There was a possibility of a 5th mission but it was abandoned after the Columbia accident in 2003. I came back to Europe, Germany for a year to work at the astronaut centre in Cologne, and then to Switzerland to teach at the École Polytechnique Fédérale de Lausanne (EPFL) – I got a position as a professor there. I taught from 2007 until last year, 15 years of teaching aerospace engineering at EPFL. I stopped teaching full-time last year, but I'm still asked for some lectures because

I have experience of human spaceflight, which nobody else in Switzerland has. We have another one coming up who was selected in 2022, the medical doctor Marco Sieber. So here I am, I'm doing outreach in the field of space and giving some lectures in Zürich and Lausanne, and that's my life.

Q: Most people your age would be retired, so why are you still doing all these things?
CN: It's a passion. I have always had a passion for space, a passion for astrophysics and for airplanes. And for me, as long as I'm physically and mentally able I will continue to share my experience, which is rather unique. You only get a little more than 600 out of 8 billion inhabitants of planet Earth who have been to space. It's a very unique thing and I feel the responsibility to share it. That's why I accepted to come here to Delft, this wonderful technical university, which is very highly ranked worldwide for its teaching and research. For me, there was no question that I would accept, and I accept many other requests of this kind. I go to schools and universities, and other groups ask me to talk about sometimes the technical or scientific aspect, sometimes the more human aspect of spaceflight. It's difficult, it's risky, it's expensive, so you need to manage the whole program such that you have a high likelihood of success. There are recipes for that which can be useful to managers and other groups of people. As long as I can share it I do, because I feel it's a responsibility.

Q: How did you reach such sought-after positions?
CN: I worked hard and I had passion, but at the same time there were several career paths open and I took them and sometimes by chance, it worked. I think this is the way life is. If you have only one field of interest then you go in that direction. I had several, and I made my way through these different opportunities to maximize the opportunity to be productive and useful, at the same time as taking pleasure.

Q: Most people decide they're going to go for aircraft or space, but you just did both!
CN: Yes, I picked both and since an early age I really had an interest in both disciplines. I had a curiosity about natural phenomena and flying an airplane was something I always wanted to do. I was privileged that I could do both at a pretty high level. Flying at a ground attack squadron in Switzerland – it's not that easy to handle a jet fighter if you fly low altitude in the mountains! Although it's fascinating, if you like flying it's wonderful. I was also an airline pilot with Swiss Air for a couple of years, before the selection of astronauts.

After the Challenger accident in 1986, I was an ESA astronaut but there were no shuttle flights for three years, so ESA sent me to Empire Test Pilot School in Boscombe Down, Great Britain. That was a wonderful chapter in my pilot education because test pilot school is really hard and you learn enormous amounts. Not only about flying different kinds of airplanes, from the Hawk to the BAC 1-11, which was an airliner, but also communicating the results of tests in a very rigorous manner. Whether it's verbal or written communication, it's extremely strict. For me, this was wonderful! Testing the handling characteristics, the performance, avionics, and the ability to accomplish the mission, whether that's military or civilian; that was a wonderful school.

Q: What is the hardest thing you ever had to do?
CN: The spacewalk I did, 8 hours and 10 minutes on the 23rd December 1999. Spacewalking is really hard. You need to be extremely focused: you are in an environment where you are extremely exposed and there's hardly any room for mistakes. In terms of the intensity of focus to do the right thing, that's one of the hardest things I ever had to do. Because you really want to be sure you do the right thing! To be extremely concentrated on a task for over eight hours is both mentally and physically difficult. It was hard, but it was successful.

Liftoff of STS-46, Nicollier's first mission to space

Q: You waited quite a long time to get to space for the first time. Did you ever get impatient?
CN: No, in fact it was kind of a pioneering time for European astronauts. We had no priority over there for quite a while. We could only train on the scientific experiments to be performed on the shuttle, as so-called "payload specialists". Then I was the first non-American mission specialist who had responsibility as far as the shuttle was concerned. At some point they let me do robotics, but no spacewalking training which only came later. So there were a lot of barriers. I can understand the Americans, they had just completed the extremely successful and difficult Apollo program. It was their pride, and suddenly three Europeans were landing there because of a decision at the level of headquarters of NASA and ESA. The management of NASA was a little hard on us, and it took quite a while to prove we could do the job like any American astronaut. I worked pretty hard over there, I didn't want to be considered the one who was taking it easy because he was only there because of decisions by headquarters. No, I worked pretty hard.

The Challenger accident also delayed my flight quite a bit. After that, the idea is al-

Nicollier operating the Space Shuttle's Canadarm to service the Hubble space telescope during his second flight, STS-61

A Swiss dual-seat Hawker Hunter, similar to those flown by Nicollier

ways to specialise in one area where you are one of the most experienced, and I was given the task of trying to understand the dynamic and electrodynamic properties of electrically conducting cables in space. I worked a lot in the simulator to figure out how we could deploy a satellite at the end of a conducting cable upwards or downwards – then you have the gravity gradient that gives an automatic tension on the tether. I worked on that quite a bit, together with another astronaut Franklin Chang-Diaz, a colleague of my class of astronauts of 1980, and Jeff Hoffman, who is now a professor of aerospace engineering at MIT the same as I am at EPFL. We were a small group of specialists who got two missions with tethered satellites, which was my first mission and then the repeat four years later. It was always this group of three: Franklin Chang-Diaz, Jeff Hoffman and myself. On the first Hubble mission, I worked pretty hard and I did well enough that I was asked to go back a second time. Hubble was another area where I had been an expert, together with others of course.

“There is nobody who can tell you how precious the earth is as well as an astronaut”

Prof. Henri Werij

I think that's a way to be successful. Select an area where you will become one of the experts, one of the masters, then people will come to you. That's a lesson for everyone.

Q: And when your missions did come, did you feel the pressure to perform?

CN: Yes, I would say the whole 25 years I spent over there in Houston was life under pressure. It's a competitive environment and you need to do everything you can to be successful on every mission. That means a lot of focus, concentration, doing all you can to get the things in your head that need to be in your head, and knowing how you find what you cannot have in your head. You must know the procedures and all the documentation so that you are never in a situation where you say “Oh my God, how am I going to do this?”. You need to be prepared. And that's pressure. I wouldn't say it was stress, but it was pressure. You try to avoid stress by being well-prepared, that's a general rule. Stress is something negative which makes you less likely to be successful. Whatever you do, if you are stressed you're not in the best shape to be successful. Pressure is okay, stress is to be avoided and you avoid stress by being well prepared.

Q: Do you think that flying helped you prepare for your work in space?

CN: I was a part-time fighter pilot in Switzerland but I was never a professional military pilot. Again, you had to do all you could to prepare your missions to be likely to be successful. We had no GPS at that time, and we had to attack simulated targets anywhere in Switzerland. Four airplanes, bad weather, a low ceiling, rain and you had about 20 minutes to get to the other side of Switzerland, with low altitude flying for the last stretch. Without GPS, you need to prepare the geography and you have to have this in your head because you cannot look at a map while you're flying at 800km/h close to the ground. So, that was a wonderful learning experience in the need for preparation.

Q: Unlike Hubble, the James Webb space is too far away to be serviced. Do you think that's problematic?

CN: I think we are happy that Hubble was serviceable because it needed it to be productive, especially with the optical problem we had initially. The second time I went, which was in 1999, we had gyroscope problems and the spacecraft was no longer able to point to celestial targets. Hubble was serviceable, and thank God it was because it needed it! James Webb is not serviceable and so far has not needed servicing because it works fine. But we can't make statistics on only two samples! I think in general serviceability is needed in the future, not necessarily by humans but by robots. If

Nicollier on his spacewalk to service Hubble during STS-103

The Hubble Space Telescope attached to the Space Shuttle Discovery during STS-103

Webb had gone to the L2 Lagrange point of the sun-earth system and would have had a problem, I think that NASA would have thought of a way to get there, maybe with the Crew Dragon capsule, and somehow do something. Because NASA wants to have success in the mission, and when there is a major problem, like was the case for Hubble, it is not easy to find a fix for that. I'm not only talking about the mission to install the optical correctors, but the design and building of the optical correctors was hard too. But NASA had this persistence, we wanted to have the Hubble working. If James Webb had not worked properly somehow I'm sure that NASA would have done something so that we could have serviced it although it was not designed for it.

I think serviceability is a big thing for the future. Not only for telescopes, but for satellites to extend their life with refueling and maybe exchange of some components. Space is expensive in general, the price of Webb was about $10 billion. You can imagine that if it arrived at L2 and didn't work that would not be acceptable. I think mainly robotic serviceability but humans as well. Beyond Hubble, we had another important human involvement in a scientific instrument, an alpha magnetic spectrometer (AMS) on the International Space Station. Luca Parmitano from Italy and an American, Drew Morgan, saved the AMS. The cooling system was not working; they planned spacewalks and they fixed it. So Hubble is not the only example where humans have significantly served science. Scientists have a classical criticism about human spaceflight because it costs a lot and draws a lot of resources from space agencies. But the AMS was not planned to be serviced and it was saved by human intervention, so that could happen with Webb.

Q: Do you think astronauts will have the same role in the future, or will increased automation do more and more?

CN: Human capability is somewhat limited because of the places we can go. Going to L2 is something we could have imagined, but it was not planned. Going beyond low earth orbit is already a big thing. We see with the Artemis program how difficult it is to go to the moon or Mars, which is Mr. Musk's dream, but also the plan of NASA. That's why I think we need to think about robotic servicing, because you can send robots for long-duration flights very far away. I think we need to continue human spaceflight capabilities, including not only working in labs, like the International Space Station, but also living in low earth orbit, maybe GEO, possibly beyond to the moon and Mars - but that's for the future!

Q: What was the best thing about being in space?

CN: If you believe in the value of human space exploration as I do, being part of it was a huge satisfaction and privilege. As an astronomer, I have a huge motivation to understand the physical processes of the universe and our origins. When you look at the faraway galaxies, you see the universe as it was a long time in the past, all the way to 13.7 billion years ago, when the Big Bang happened. So, being fascinated by the knowledge of physical processes of the universe, the formation of galaxies and the way the universe evolved, from the Big Bang all the way until now, and to have the opportunity to go into space and continue this knowledge with my work on Hubble. Of course, I did this together with others; my colleagues on the mission, but also all those who supported us from the ground in the flight control room, and the ones who designed the instruments that we installed on Hubble. For me that was a huge satisfaction to be part of the gathering of knowledge about the universe. That was exactly what I wanted to do with my life.

Q: Did you feel very detached from Earth and the rest of humanity?

CN: When you are in low earth orbit you still feel very close to humanity. You have communication nearly all the time, you have your colleagues, and you accomplish the mission according to a clear goal and a near obsession to be successful. I think people who go to the moon will feel a little detached but not completely, because the Earth will still be dominant in the sky. But

The BAC 1-11, similar to that which Nicollier learned to fly at Empire Test Pilots' School *where there will be a difference is for astronauts who will go beyond the moon to Mars, then the Earth will become a small blue dot in the sky together with a lot of stars and a few other planets.*

There's the huge activity of looking at the earth, and that fascinating view. When you work in low earth orbit, particularly on the Hubble and during a spacewalk, you don't spend too much time looking at the earth because you have your tasks. You must focus on what you are doing. But whenever there is an opportunity, especially at the end of the day when you have completed your specific operational tasks, you look at the earth and you look at the sky, which is beautiful. But you are close to the earth, and you feel connected with it.

Nicollier gave a presentation to the Faculty of Aerospace Engineering in a packed lecture theater

Q: What's your opinion on the progress for people with disabilities to go to space, such as the amputee John McFall?

CN: I think it's a great idea, the idea to be inclusive. This is a goal to broaden inclusivity. For many years it was only men, then it became women, Valentina Tereshkova was the first woman in space, by the Soviets in 1963. Twenty years later we had Sally Ride from the US and we had a few women astronauts at ESA, although not that many. That was a trend towards greater inclusivity, and that was very obvious. Like we do here on Earth, we are now trying to give people with disabilities, whether it's mental or physical, the ability to do as much as they can as humans. I think it's a great step for the ESA to try to bring astronauts with disabilities into space, of course with some limitations. I don't think McFall will be able to go spacewalking, but he will be able to do robotics and scientific experiments and be productive in space. I think this is wonderful. I am entirely for this and proud of ESA for doing that.

Q: Do you think there will always be barriers to overcome?

CN: I think we are only beginning, that was the first time we had an astronaut selected with a disability. The idea that a selected astronaut is a perfect person is not the case. I'm certainly not perfect... maybe Neil Armstrong was! You do need a certain level of capability to be above the line, so you can become an astronaut, and with a little bit of luck, you do. Now we open this possibility to people who have a clear limitation and will have limited access to some of the activities in space. I think, from an ethical point of view, to give the possibility for access to this very desired position is wonderful. You could have astronauts with disabilities who are tourists, but ESA hires astronauts to be productive in space and do work, and so will be the case for McFall – perhaps different work. There are a lot of activities where you are not required to use the lower part of your body a lot, you have to have your brain, arms and hands. For many activities in space, weightlessness is a condition which is better for people with disabilities in the lower part of their body because you don't have the weight of the body on the legs. 1g, 9.81m/s2, glueing you to the ground, the chair, the sofa or the bed. I think we are opening a new area here and it's wonderful, from an ethical point of view it's magnificent.

Nicollier and the faculty Dean in conversation about sustainable aviation

Q: Do you consider yourself an inspiration?

CN: I've been greatly inspired by many people, and I try to do the same, especially with young people. I go to schools quite often and I talk to the children. I think I can inspire them because I have been inspired myself. I have been able to do many unique and wonderful things. There are a few things which you need in your life. You need to have a passion, and a determination to follow a certain track and not get too distracted. Then you need to be lucky – I was lucky. You can't plan for luck, it either happens or it doesn't. Direct your life towards a certain goal that you pursue, such that you contribute and are a useful human being. You can be useful by being an artist, a scientist, an engineer, or an architect, or because you want to help people go through life in the best possible way. If you can be productive, do be, but you must follow a certain line and not be too distracted. Follow your dreams!

Leonardo Times would like to thank Claude Nicollier for taking the time for this interview and for sharing his passion for air and spaceflight with our faculty.

BlueSky

Trailblazing open data in aviation

Hidde Jansen, Freelance Journalist

Why would you buy or sell software commercially if you can get the data from public sources too and can make the tools available to the public? BlueSky, an open-source tool for creating air traffic simulations, came about some ten years ago in answer to this question.

This story of science was first published in June 2024 by the faculty of Aerospace Engineering, TU Delft. Published in Leonardo Times with consent from TU Delft.

BlueSky: Open Source Air Traffic Simulation

Since its creation ten years ago, BlueSky has grown into a community of users from around the world. It has also led to the development of an open-source tool for aircraft performance, OpenAP. Researchers Jacco Hoekstra, Joost Ellerbroek and Junzi Sun explain why you can achieve so much more by giving away software for free.

Looking down on airspace from above using radar, you see an enormous jumble of aircraft above land and sea alike. This jumble is underlaid by all kinds of algorithmic models for managing all of the traffic streams properly and safely. An important tool for creating these models is BlueSky, a simulator that allows you to create real-time simulations of air traffic, at lighting speed. Full Professor of Aerospace Engineering Jacco Hoekstra started developing this software tool over a decade ago. "By simulating air traffic with BlueSky, you can, for example, look at the future classification of airspace and airports and improve approach routes and procedures."

What Started Out as a Hobby

BlueSky evolved from a hobby project of Hoekstra's that he occupied himself with while recovering from a car accident. "I literally created the first version, called Traffic Manager, from my bed. NASA and a few universities were also involved in this. For Traffic Manager, we used only patented – thus closed – software and data. Later, a new, open version was created at TU Delft: BlueSky. You see, my view was that it would be much more interesting to make everything publicly available, so students and other scientists can access all of the data at any time."

The Added Value of Open Source

According to Hoekstra, making BlueSky open source has several advantages. "It makes research transparent and repeatable. What's more, you can compare different solutions, for example for airspace classification. This is considerably more difficult to do when researchers all work with different models, tools and variables. If everyone speaks a different language, no-one knows what the other is talking about. To ensure the greatest ease of use, all files in BlueSky are formatted in the same format. This eliminates the need for users to first transfer text or code to another file type."

Data from Public Sources

Another advantage of open data is that you are not dependent on commercial parties. Aircraft manufacturers and airlines charge money for the use of their data, says Assistant Professor Joost Ellerbroek. "Besides which, they don't always make all their data available. This makes it difficult to carry out research. For this reason, we only use public sources, such as airport websites or databases that are used for flight simulators. These are often open source and provide information on locations of flight beacons, airports, terminals and runways. Additionally, we get data from hobbyists working on data for flight simulators on PCs."

"The idea behind open source is that by giving away and sharing data you ultimately achieve much more. With BlueSky, that has certainly been the case. And that's something I'm extremely proud of."

– Jacco Hoekstra

Wikipedia for Air Traffic Management

Ellerbroek played an important part in the technical development of the platform. He explains how researchers use BlueSky. "They can import data for running simulations on their own computers. Besides this, users can add or modify information, such as adding new insights. In other words, BlueSky's website is a kind of Wikipedia. What's more, people can create issues themselves, to indicate that they have encountered something or found a bug, for example. Other users can then respond to the issue. So there's room for interaction. This makes BlueSky more than a software tool; it's a community as well."

"BlueSky is more than a software tool; it's a community as well."

– Joost Ellerbroek

Application in Air Traffic Control

In addition to researchers, commercial parties, such as aircraft manufacturers and air traffic organisations, also use BlueSky, says Hoekstra. "These parties often have their own programmes and user environments. But if you check under the bonnet, there is BlueSky's software there. We heard from researchers at Spanish air traffic control that BlueSky has by now become the standard research tool. Air Traffic Control the Netherlands (LVNL) is currently using the tool for prototyping the reclassification of our airspace. Increasing traffic and stricter rules on noise and emissions have made this necessary. BlueSky is an ideal tool for simulating this reclassification."

Drones in Urban Areas

Although BlueSky is overwhelmingly used for applications in conventional aviation, it also offers solutions for other types of aircraft. Ellerbroek: "In recent years, there has been enormous growth as far as smaller aircraft, such as drones, is concerned. As these aircraft too form, or will form, part of airspace, we have extended BlueSky to be able to create simulations of large numbers of drones in urban areas. Making this extension was quite challenging, as we wanted to keep the software the same as much as possible."

OpenAP, BlueSky's Spin-Off

In its 10-plus years of existence, the development of BlueSky has also led to the creation of OpenAP. Assistant Professor Junzi Sun, who started OpenAP as a PhD project in 2015, explains what exactly this open source tool is. "Whereas with BlueSky you can make simulations of air traffic, you can also use OpenAP separately to calculate aircraft performance. Say, for example, regarding fuel consumption or greenhouse gas emissions. Users can import a package consisting of data such as aircraft type, flight altitude and flight distance. The model then calculates performance."

Three Types of Data Packages

OpenAP is currently offered in three packages, says Sun. "The first consists of data for analysing the amount of greenhouse gases an aircraft emits on a given route. The second package very accurately shows emissions for each phase in flight. You can use this data to optimize the flight path to ensure minimum emissions. The third package lets you make a rough but quick estimate of how much fuel an aircraft consumes on a flight from a to b. This estimation isn't 100 percent accurate yet, but that isn't always necessary either."

TU Delft Frontrunner in Open Data

Like Hoekstra and Ellerbroek, Sun is a strong advocate of open data. "What is so nice about TU Delft is that the use of open source and open data is already the standard here. To develop an open-source tool or software, I don't need the approval of various committees first. In this respect TU Delft really is a frontrunner in the research community. The perfect situation would be if we no longer distinguished ourselves in this respect, but instead open source and data were standard practice everywhere." Hoekstra adds: "The idea behind open source is that by giving away and sharing data you ultimately achieve much more. With BlueSky, that has certainly been the case. And that's something I'm extremely proud of."

"What is so nice about TU Delft is that the use of open source and open data is already the standard here."

– Junzi Sun

Open Science at TU Delft

Open Science is an important way to spread TU Delft's mission to deliver Science to Society. With Open Science we wish to make scientific knowledge accessible, free of charge to all users and online. In this way new ideas spread faster and wider which in turn lead to new research. We support our researchers in doing all that is necessary to

BlueSky interface showing a simulation of air traffic over the Netherlands and surroundings.

BlueSky's logo references traditional Delft pottery, also known as Delft Blue.

C&O

Is one sky the limit?

The push for a Single European Sky

Juan van Konijnenburg, Leonardo Times Editor

For decades, air traffic across Europe has been plagued by inefficiencies, fragmentation and delays. While the vision for unified airspace, the Single European Sky was introduced to address these issues, achieving it has been far from smooth. From initial setbacks in the early 2000s to the recent SES II+ reforms, Europe continues the struggle to unify its skies.

The Limitations of Air Traffic Management

Around the turn of the century, European Air Traffic Management(ATM) suffered disorganization, inefficiencies, and delays. The summer of 1999 was a low point for air travel in the bloc. On the worst days that summer, up to 40% of all 26,000 flights handled across the continent were delayed [1]. The European Commission stated "In Europe today (2000), one flight in three is not on time. The average delay is 20 minutes, and this can stretch up to several hours at peak periods" [1]. An estimated €10 billion is lost by airlines annually due to these delays [1]. After the 1999's chaos, Eurocontrol, the European organization for aviation safety, promised to reduce delays by up to 50% across the bloc's airspace.

This did not happen. Delays persisted throughout 2000, with a 21% delay rate in the first quarter [2]. In the peak summer period, further mistakes and accidents led to even more delays. One such event was the failure of air traffic control computers at London Heathrow Airport leaving multiple flights delayed and canceled, and thousands of passengers stranded [3]. Throughout the early 2000s, these issues persisted with consistent delays across Europe [2]. But why is this such a big problem?

Europe's skies are a crisscrossed tangle of invisible divisions and borders. Flights in Europe are "zig-zagging between different blocks of airspace, increasing delays and fuel consumed" [4]. Attempting to help regulate and coordinate the traffic is Eurocontrol. However, in the early 2000s, this body had no authority over its members, and could not enforce decisions or properly coordinate air travel within the bloc [1]. The failings of the ATM system led to a growing call for reform, culminating in the establishment of a Single European Sky [5].

What is the Single European Sky?

The Single European Sky (SES) is a proposal by the EU to integrate the disparate ATM groups across the bloc, into a unified and efficient system [5]. Initially suggested in the wake of the chaotic summer of 1999, its objectives were to increase flight safety by a factor of 10, reduce ATM costs by 50%, increase airspace capacity three-fold, and later reduce the environmental impact of flights by 10% [5] [6]. Whilst SES is an EU proposal, it is also pan-European, allowing non-EU members such as Iceland, Norway, and the western Balkans, to join the initiative [5].

The initial regulations package passed in 2004, SES I, laid down a common framework for this proposal, discussing common requirements for air navigation services, standardization and organization of the airspace, and the interoperability of the current ATM network [7]. However, around 2007, the EU Commission found that SES I was not progressing towards its stated goals, specifically concerning flight efficiency and the 'defragmentation' of airspaces [7]. They also noted aviation's impact on the environment, a notably absent component of SES I. This led to a second round of regulations, known as SES II, passed in 2009. SES II built on the legal framework established by SES I in an attempt to improve on these issues, leading to the current state of the SES today [5].

The basic structure of the SES I & II is based on several key components [5]. The first of these is a "performance scheme", providing joint and standard goals for improving the efficiency of ATMs across several areas. The second is to create a "network manager" role, to centralize and coordinate ATM and radio communication. This role is currently filled by Eurocontrol, providing the much-needed authority. Third is the establishment of so-called "Functional Airspace Blocks" (FABs), aiming to redraw the borders of Europe's airspaces along highly traveled routes rather than national boundaries. The proposed implementation of these FABs is shown

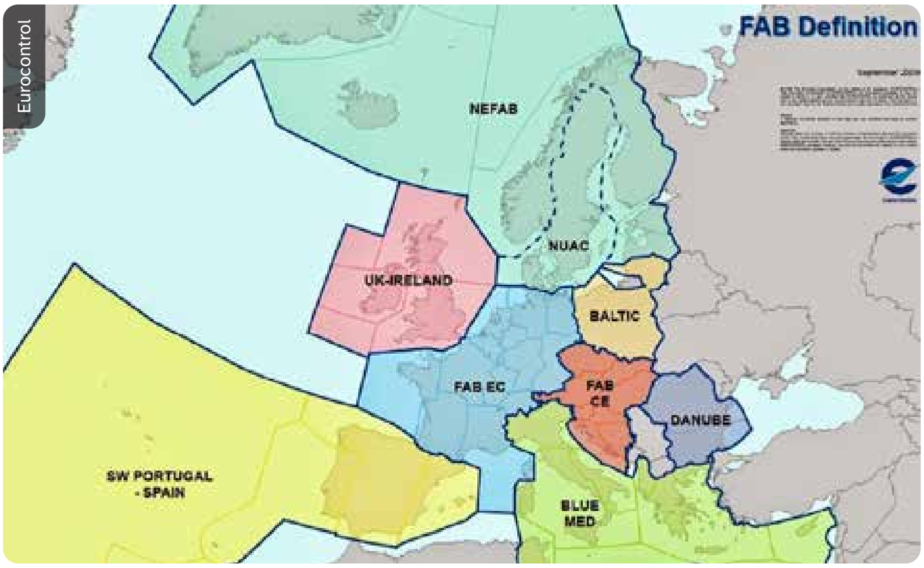


Figure 1: The proposed definition for Functional Airspace Blocks (FABs)

in Figure 1. Finally SESAR, a joint research initiative focused on ATM, would be used to create further innovation in ATM and lead to a more cohesive technological base. To provide oversight to implement these components, National Supervisory Authorities (NSAs) would have to be established or appointed by each member state [8]. The NSAs would then also be responsible for regulating and certifying local Air Navigation Service Providers (ANSPs), a service usually provided by a state's civil aviation administration. With this approach, the goals of SES would surely be reached, and air traffic delays are a thing of the past; Or so we thought...

Why Air Traffic in the EU is Still Not Fixed

Despite the implementation of SES across Europe, air traffic delays persist and worsen. Remember the talk of "zig-zagging" flights? In truth, that wasn't related to the 2000s, but said by the commissioner for transport in 2020 [4]! By 2012, the SES should have led to a 25% decrease in ATM costs, yet they remain high [9]. The year before, flights had a cumulative delay of 17.9 million minutes, the equivalent of 34 years of delay [9]. More recently, the summer of 2024 saw a substantial increase in delays and costs. Delays are now up 48% compared to pre-covid numbers [10]. Yet, this has come as air traffic has reduced by 2.6%. These delays have contributed to an estimated loss of €1.8 billion for airlines in the summer of 2024 alone. Causes for delays are largely weather-related, with delays being almost twice as common as in 2019 [10]. Whilst the weather is out of ATM control, with proper communication and organization, such delays could have been mitigated [10].

The performance has been so catastrophic, that Airlines for Europe (A4E), a trade group representing European airlines, has said that "Europe's airspace is failing" [10]. In 2023, A4E, together with IATA and other groups within the aviation industry, called out the failings of the SES, saying "None of these objectives have been fully realized", and asked for further EU reforms [4, 11]. The focus was to continue implementing a new regulation package for SES [11]. IATA has said that properly reforming and implementing SES could be immensely beneficial to the EU. Fulfilling the SES's original goals would result in a €245 billion increase in GDP for the EU, and one million more jobs annually from 2035 [6]. With such a great forecasted reward, what is the EU doing to achieve it?

Reform and Future of the SES

The EU has been taking steps towards further reform, with proposals starting around 2013. However, those proposals were tabled after disagreements between the UK and Spain over how to handle Gibraltar [12]. With Brexit, the proposal was free for discussion again and amended in September 2020 [5] [11]. The proposed changes, known collectively as SES II+, note the failings of the previous legislation and aim to improve them.

One such failing lies in the use of NSAs to regulate ANSPs. Due to a lack of a wider European perspective, these NSAs were largely ineffective at properly implementing the regulations. In some cases, the NSA and ANSP were joined under the same institution, which naturally led to conflicts of interest [8]. SES II+ seeks to provide a clearer role for the NSAs, and stricter requirements to ensure their institutional independence in finance and decision-making [13].

In addition to the NSAs, various other changes were proposed. Functional Airspace Blocks(FABs), were found to be slow to implement and, in general, largely ineffective [14]. As such, SES II+ removes them from the regulation but highlights that

Eurocontrol is an inter-governmental organization working on improving air traffic management, through the SES

member states finding the system working are free to continue. The performance scheme was also modified with the creation of a new Performance Review Board. This board would then be empowered to help implement new targets or incentives for improving efficiency or the environmental impact of flight [12]. These are just a few of the changes SES II+ has proposed.

Four years since their amendment and re-introduction, SES II+ has finally received some attention in the EU. On the 6th of March, the EU Council and the Parliament came to a provisional agreement on the proposal [12]. In September and October, both bodies worked on approving the text before it was finally officially signed and published on the 11th of November [12]. Whilst the regulation went into force on the 1st of December, full implementation within the industry will take some time. Nonetheless, it is a step in the right direction.

With SES II+ finally implemented, everything may appear fixed. But, as we have seen, even when legislation is introduced, it does not guarantee the delivery of what is promised. Chaotic delays in 1999 and the early 2000s led to the implementation of SES I, with the assurance that the situation would improve. However, the challenges endured and SES II was introduced. Despite these efforts, the situation deteriorated further with rampant delays throughout 2024, leading to the current fix. Whilst SES II+ does hold promise for improving the system, it is important to realise that nothing is guaranteed, and new issues can always arise. We will have to wait and see, with cautious optimism, how the Single European Sky develops.

Ever since its foundation, TNO has been active in the field of advanced optical instruments, and for over 50 years has been developing instruments for use in space, astronomy, scientific research and manufacturing industry. Examples of this work include the development of instruments for measuring the ozone layer (GOME and TROPOMI) and a space telescope (GAIA). The measuring instruments contribute to dealing with important social issues, spur on science and form the basis for industry and job opportunities in the Netherlands.

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Benjamin Brenny,
Optical Designer

'At TNO, you can truly immerse yourself in technology.' 'A great project I worked on was Sentinel 5, an ESA satellite that monitors air pollution. This pollution is detected by means of a telescope and spectrometers. Gases like CO_2, SO_2 and NO_x each absorb light in their own way. As a designer, I am involved in the beginning of a project.

Optical design deals with optimising and aligning lenses and mirrors, aided by specialized computer software. I also have a role in the performance analysis of the design, before and after it has been built. For example, what is the impact of minor manufacturing errors with respect to the model?'

I like the collaboration with industry, but above all the societal relevance. Take the satellite that measures air pollution or the medical instrument that detects eye diseases. Contributing to these instruments gives me great satisfaction. It's not without reason that I do so many different things, as I am still searching for what I like best – but that's allowed here!

Read more about space and scientific instrumentation at TNO:

TNO innovation for life

A New Age for Sails

How the aerospace sector inspires the shipping industry

Simon Caron, Leonardo Times Editor

The 1700s are back in style! Dear reader, have you ever looked at ships today and felt something was missing? Something big, white and triangular… That's right, sails are making a comeback in modern shipping vessels, but their form might be unexpected. These new sails are inspired by aerospace technology, where advanced materials and aerodynamics reshape wind-powered travel.

How does it Look Today?

The shipping industry transports 80% of the world's goods, which makes up 3% of global CO2 emissions, or roughly the same share as total aviation emissions [1]. Therefore, a sustainable transition in the sector would have a significant and enduring impact, particularly when considering other challenges associated with the global shipping industry, such as noise pollution, oil spills, and other environmental concerns, which will be further discussed in this article. This also comes with a deadline, as the International Maritime Organization (IMO) has set targets to reduce emissions to net-zero "around" 2050 [1].

Before the 20th century, wind power was a popular mode of propulsion for ships. It's how Magellan and his crew circumnavigated the world after all! And yet they fell out of style for the bigger, faster, and more reliable fuel-powered ships. While the transition to coal, then diesel and heavy fuel oil seemed inevitable, it was surprisingly more challenging than you might think.

Imagine yourself as a sailor in 1926's New York and you see this strange vessel docked into port, with a unique contraption, two immense cylinders, protruding out of this small ship, as if someone had put two giant, closed-off, chimneys on a tray. This was the Baden-Baden, a converted sailing ship, whose two masts were replaced by Flettner rotors. The rotors, named after their German inventor Anton Flettner, functioned like sails. These mechanisms proved highly efficient, enabling the ship to use less than half the fuel of a similarly sized oil-powered vessel to power the rotors. Additionally, they allowed the ship to sail closer to the wind than traditional canvas sails. The rotors were celebrated as a major technological breakthrough, even gaining praise from prominent figures like Albert Einstein. However, they were slightly ahead of their time and had large maintenance challenges. The killing blow came as cheap oil became more widely available, causing interest to fade quickly and Flettner's invention to become forgotten [1]. But that did not stop people from dreaming about a more sustainable way of shipping goods around the globe.

A Rotor Called a Sail

While a rigid sail concept was on hold, it was never truly abandoned. Although there were some experiments and prototypes in the 1980s, the technology only truly reemerged with the new millennium with some serious proposals for three main types of rigid sails. These are now finally being put to real use.

We've already introduced Flettner rotors; let's delve deeper into how they work.
They were invented in the early 1920s, making use of the Magnus effect, the same phenomenon responsible for the curved trajectory of a golf ball. When the ball spins, it encounters air resistance. As seen in Figure 1, the airflow moves in the same direction as the ball's spin, while on the other side, it moves in the opposite direction. This difference in airflow speeds creates a pressure differential: the air on the first side slows down, while the air on the other accelerates. This results in lower pressure on the left and higher pressure on the right. According to Newton's third law, this pressure difference then generates an equal and opposite force that propels the ball sideways, causing the well-known curve every golfer anticipates. For a ship subjected to high winds, the Magnus effect works in the opposite direction, creating a forward propelling force on the ship [2].

Flettner rotors offer significant advantages over traditional oil-powered ships, particularly in fuel efficiency and environmental impact. By utilizing the Magnus effect, these rotors harness wind power to reduce fuel consumption by up to 20-30%, leading to cost savings over time [3]. This reduction in fuel usage also directly lowers greenhouse gas emissions, making Flettner rotors one

The rotor ship Buckeau

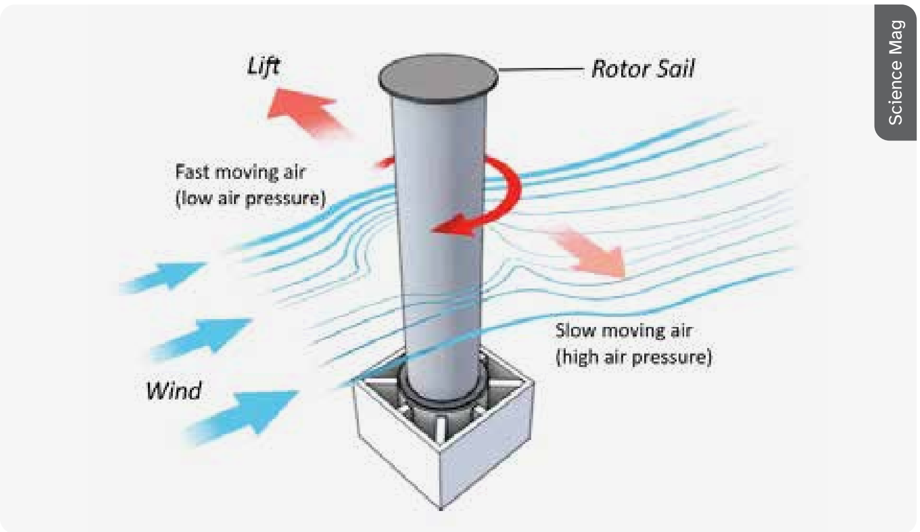


Figure 1: Magnus effect and schematic of the resulting lift and drag forces onboard a ship

of the most eco-friendly options in this fuel-intensive industry. Additionally, Flettner rotors offer operational flexibility as they can be adjusted to optimize performance based on wind conditions, allowing ships to rely more on wind propulsion and less on engine power. While the initial installation cost may be high, the long-term fuel savings make them economically beneficial, with typical payback periods ranging from three to ten years, according to the size of the ship or the desired share of wind power for the propulsion. Moreover, modern Flettner rotors are low maintenance, have fewer moving parts and provide a more reliable, cost-effective solution than traditional engines [3].

Wings on Ships!

Now, you might be wondering, "Where's the aerospace connection? This is starting to sound like a ship article!" Well, it's time to bring in the rigid wing sails, like the BAR Technologies' “WindWings”. These rigid sails resemble rectangular airplane wings installed perpendicular to the boat. Indeed, they use the same principle as aircraft to generate lift: their shape is aerodynamically optimized, resembling an airplane airfoil more than a traditional fabric sail. Each WindWing consists of multiple elements, like modern aircraft wings, allowing for better airflow control and lift generation. Some designs feature adjustable flaps, similar to those on an airplane, which can change angles to increase efficiency in different wind conditions.

As wind flows over the curved surface of the rigid sail, it moves faster over one side than the other, creating a pressure difference. This difference results in lift, which is directed slightly forward, helping propel the ship. Unlike traditional sails that rely purely on direct wind force, WindWings are designed to optimize both lift and drag, making them more efficient at converting wind energy into forward motion. Additionally, their rigid structure allows for better airflow control, reducing turbulence and maximizing propulsion. Because these sails generate significantly more lift per unit area than fabric sails, they can provide meaningful thrust even for heavy cargo ships. By adjusting their angle automatically based on wind conditions, WindWings ensure optimal performance while minimizing resistance, making them a practical and efficient solution for reducing fuel consumption in modern shipping[4].

The third most important type of rigid sail are "suction sails", see Figure 2. Developed by bound4blue, suction sails stand out from other rigid sails, such as WindWings, by actively manipulating airflow to enhance propulsion. Unlike WindWings, which function like vertical aircraft wings and passively generate aerodynamic lift, suction sails incorporate an advanced boundary-layer suction system. This technology, pioneered in the 1980s by Jacques-Yves Cousteau for his research vessel Alcyone, uses built-in fans to draw air through perforations in the sail's surface [3]. Suction sails can operate efficiently even in weaker winds by reducing turbulence and maintaining laminar flow. Bound4blue, a Spanish company founded in 2014 by aerospace engineers, has modernized this concept, installing its eSail system on ships like Ville de Bordeaux, a transport vessel used by Airbus. While suction sails require an external power source for the fans, they offer enhanced efficiency and adaptability, making them suitable for a wider range of ship designs. In contrast, WindWings and other rigid wing sails, though effective, are purely passive systems that depend on favorable wind conditions and require ample deck space. [3]

Despite these differences, both technologies contribute to reducing fuel consumption and emissions; their performance for these metrics is comparable to those of the Flettner rotors. Wind-assisted sails

Figure 2: Suction sail cut

offer significant benefits, reducing fuel consumption and emissions. One type is effective in strong winds, providing up to 30% fuel savings with minimal maintenance, making it easy to retrofit [3]. Suction sails, on the other hand, improve airflow, offering better efficiency in lighter or turbulent winds. This system is more complex but allows for adjustable performance. Both technologies help decarbonize the industry, reduce operating costs, and are scalable for existing and new ships, therefore pushing the maritime industry toward cleaner and more sustainable operations.

Playing with the Wind

While rigid sails are leading the charge in wind-assisted propulsion, other types of sails are also carving out their niche, each offering unique solutions for specific needs. Kite sails, such as the Seawing by Airseas, stand out as an innovative option. These massive parafoil kites can be launched and retracted automatically, cutting fuel consumption by up to 20%. Particularly useful for larger vessels with limited deck space, kite sails capture wind at higher altitudes, making them an efficient solution for reducing emissions on some of the largest cargo ships. However, they come with challenges: their reliance on strong, consistent winds and the complexity of their launch and retrieval systems can limit their effectiveness in certain conditions. In addition, managing kite sails requires careful coordination to avoid tangling or damage, making them more suited to specific routes or vessel types.

Soft wing sails are also gaining ground with their lightweight design and flexibility. Used on ships like the MS Tûranor PlanetSolar, a solar-powered vessel, these sails help boost energy efficiency and cut down emissions by optimizing wind power alongside solar energy. Even traditional fabric sails are making a comeback in certain corners of the industry. While not as advanced as modern rigid sails, these simpler sails offer an affordable and eco-friendly option for smaller ships or short-haul routes. Their design may be basic, but they still help cut fuel consumption and reduce emissions, making them a practical choice for many. Though these sails may not have the impact of cutting-edge technologies, they add to the growing trend of sustainable shipping. Together, these various sail technologies highlight the maritime industry's push for greener, more energy-efficient transport, showing that wind-assisted propulsion is taking many forms as the industry moves toward cleaner solutions. [3]

A Good Marriage Between Aerospace and Shipping?

Most importantly, it is interesting to see how comparable the aerospace and shipping industries can be when looking at their respective sustainable transitions. They have shared challenges in fossil fuel usage and contribute to global pollution on a similar scale. Moreover, both can 'suffer' from the longevity of the fleet, with planes and ships operating for decades. Regulatory lag is a common problem as well, just as the IMO rules take years to implement, aviation regulations (e.g., from ICAO, FAA, EASA) evolve slowly, delaying widespread adoption of new propulsion methods. Infrastructure also proves to be a cumbersome point of leverage, as ports will need to handle those new kinds of ships, just as airports will need to build the sustainable aviation fuel storage capacities necessary for the future, both requiring significant long-term planning and investment.

While this seems like a daunting task for both industries, mutual challenges also mean that collaboration and inspiration are possible. We have already seen how ships have looked to the skies for inspiration, but what about the aerospace industry looking down? Airbus and ArianeGroup, the two biggest players in the European aerospace industry, are both committed to significantly reducing their carbon footprint, including emissions from logistics and have invested in wind-assisted propulsion for transporting aerospace components. Airbus has partnered with companies to retrofit cargo ships with rigid sails, reducing fuel consumption on transatlantic routes. Meanwhile, ArianeGroup has backed the development of wind-powered vessels to transport Ariane 6 rocket parts from Europe to the launch site in Kourou, French Guiana. Specifically, the company has chosen the Canopée, a cargo ship equipped with Oceanwings sails developed by Ayro, to cut fuel consumption on this critical route. [5]

Artificial intelligence is playing an increasingly important role, as in every field nowadays. Here, it is used for optimizing rigid sails' angle of attack, drawing from aerospace advancements in autonomous flight and aerodynamics. AI-driven control systems adjust sail angles and positions in real-time, responding dynamically to wind conditions to maximize efficiency, much like how autopilot and fly-by-wire systems optimize aircraft performance. These systems rely on sensors, predictive algorithms, and machine learning, similar to those used in modern aircraft to adjust wing surfaces for optimal lift and drag reduction. Companies developing rigid sails are integrating AI to reduce human intervention and ensure maximum fuel savings, reinforcing the link between maritime and aerospace technological evolution. [6]

A Grand Transition

The global shipping industry is steadily embracing rigid sails as part of its ongoing transition toward sustainability, aiming to reduce its carbon footprint and mitigate the environmental impact. As awareness of the shipping sector's role in global greenhouse gas emissions grows, so does the recognition that wind-assisted propulsion offers a viable path toward greener operations. The technological advancements behind modern rigid sails, including wing sails and foils, have made them increasingly viable for integration into existing shipping fleets. These sails not only promise significant fuel savings but also contribute to lower emissions, positioning them as a practical solution in an industry under pressure to adopt cleaner technologies. Their potential to cut fuel consumption by up to 20% is a compelling reason for shipowners to consider retrofitting existing vessels or incorporating them into new designs. As the transition to more sustainable shipping practices gains momentum, rigid sails are being seen less as an experimental technology and more as a key component of the industry's future. [7]

Despite the promising environmental benefits, the path to the widespread adoption of rigid sails has challenges. High initial costs remain a significant barrier, with each sail priced between $1 million and $1.5 million and most vessels requiring multiple sails for optimal performance. The capital-intensive nature of these installations requires careful financial planning and, in many cases, the commitment to long-term investments. However, an increasing number of shipowners see the value in reducing operational costs over time and meeting stricter emission regulations has sparked a growing interest in wind-assisted propulsion. Even better, hybrid ships, which combine wind propulsion with traditional engine power, help facilitate this transition by offering a more flexible approach to reducing fuel consumption. These hybrid systems allow vessels to switch between wind and engine power depending on wind conditions, making them more adaptable and cost-efficient in the short term. This shift is driven by financial motivations and a broader commitment to sustainability, supported by international shipping regulations and environmental goals. The transition gains traction as the industry adjusts to the economic realities of adopting these technologies. More vessels across the major trade routes are expected to integrate rigid sails or hybrid systems, helping to further the maritime sector's role in global efforts to reduce emissions and promote environmental responsibility. [8]

A kite made by Airseas used as auxiliary aid for the engines

Sails are making a surprising return to the shipping industry as part of the push for more sustainable, wind-powered propulsion. Drawing inspiration from aerospace, modern rigid and suction sails, now enhanced with AI-driven systems, show significant promise in reducing emissions. These technologies offer considerable fuel savings and better operational efficiency, pushing the industry toward decarbonization. While high upfront costs and regulatory challenges remain, the long lifespan of ships means that a gradual, scalable shift to wind-assisted propulsion is increasingly viable. In this new age of sails, innovation and cross-industry collaboration drive the future of greener maritime transport. And who knows, next time you're flying across the Atlantic, you might look out the window and spot a sail-powered ship below, proving that the skies aren't the only place where aerospace is finding inspiration.

DC-3, 90 years old and still flying!

Simon Caron, Leonardo Times Editor

This year marks the 90th anniversary of an aircraft that has truly earned the title of "immortal" in aviation history - the Douglas DC-3. Originally built in 1935 to succeed the DC-2, this revolutionary plane transformed air travel and left an indelible mark on the industry.

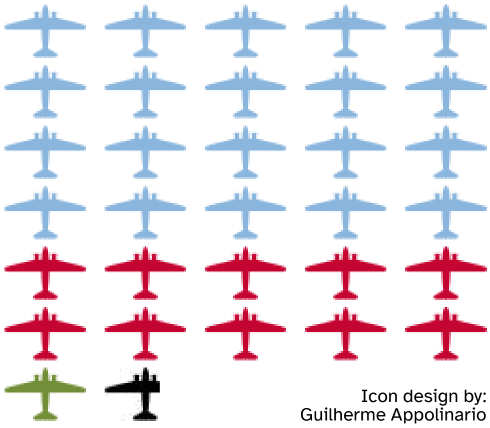
The DC-3s development was spurred by American Airlines' request for a larger, more comfortable aircraft with sleeping accommodations. Douglas Aircraft Company's engineers, led by chief engineer Arthur E. Raymond, ingeniously built upon the successful DC-2 design while reimagining its potential. They widened and rounded the fuselage to accommodate sleeper berths, increased engine power, and made numerous other improvements [1,3]. The result was a low-wing, twin-engine monoplane that could carry 21 to 32 passengers or 2,700 kg of cargo over a range of 2,400 km [1].

It became the first aircraft capable of turning a profit solely through passenger transportation, without relying on mail subsidies [2].

The DC-3s impact was immediate and profound. It was the first plane that could fly non-stop from New York to Chicago, completing the journey in just three hours and fifty-five minutes [3]. By 1939, a mere four years after its introduction, the DC-3 and its variants accounted for an astounding 90% of all airline flights worldwide [3].

This aircraft not only revolutionized commercial aviation but also proved invaluable during World War II, serving in various military roles. Its versatility, reliability, and robust design have allowed many DC-3s to remain operational even today, nearly nine decades after their first flight [1,4].

Towpilot



Icon design by: Guilherme Appolinario

More than two thirds of the DC3 where built for the American Military

The Soviet Union was allowed to built the DC3 under license, as the Lisunov-Li2

Around 600 planes were built for civil applications

Around 400 were built By Mitsubishi in Japan under license as the as the Nakajima L2D

= 500 DC-3s

Mauvries

Type	Airliner and transport aircraft
Manufacturer	Douglas Aircraft Company
First Flight	December 17, 1935
Introduction Date	1936 (American Airlines)
Production Period	1936–1942, 1950
Number Built	~13,000
Engine Options	Wright R-1820 Cyclone or Pratt & Whitney R-1830 Twin Wasp
Power Output	1,000–1,200 hp
Cruising Speed	333 km/h
Range	2,400 km
Passenger Capacity	21–32
Cargo Capacity	2,700 kg
Dimensions	Wingspan 29.0 m Length 19.6 m Height 5.16 m Wing Area 91.7 m²
Maximum Takeoff Weight	11,430 kg

MMK-Draw

Skies Under Watch

Exploring the history, role, and controversies of air marshals

Juan van Konijnenburg, Leonardo Times Editor

The history of air marshals is a long one. From the 1960s up until the present day, these officers have been a tool in preventing hijackings and terrorist attacks on flights, improving aviation security. But who are they, and are they as instrumental in this fight as they claim to be?

Who are the Air Marshals?

Walking down the aircraft aisle, you stow your bag before taking a seat. Sitting beside you is an unassuming man, calmly reading the in-flight magazine. As the seatbelt light turns off, you relax into your seat, taking out a book to pass the time. However, as you read, you don't notice the subtle glances around the plane, or the tense reaction to any loud, unfamiliar noise. As the plane prepares to land, the seatbelt light blinks back on. Entering the airport, as you make your way to the baggage hall, you spot the man walking towards the security office. He was a federal air marshal - an undercover agent responsible for protecting flights from potential attacks. While most travelers never notice them, these agents play a role in keeping the skies safe. But who are they?

Federal Air Marshals are officers within the US Transportation Security Administration (TSA). According to the TSA, their mission is to "protect commercial passenger flights by deterring and countering the risk of terrorist activity, aircraft piracy, and other crimes" [1]. Air marshals have a range of ground activities, such as running risk analyses, investigations, or even standing guard at the latest Super Bowl, but their primary task is to provide undercover in-flight security [2, 3]. The position is incredibly demanding, with long working hours and little or no backup during flights. Armed with firearms, these agents are given intense training and are subject to high qualification standards to reduce the risk of harming the aircraft or passengers. One study named them the top 1% of worldwide combat shooters [4]. Most flights only have one to two marshals on board, whilst riskier international flights may have up to four on a single flight [3]. But why did the air marshal service begin in the first place?

Evolution of the Sky Marshals

When commercial aviation began, security was not a big enough concern to warrant governmental regulation. However, by the 1960's the issue had grown larger. In 1961, President Kennedy began assigning these servicemen to important and risky flights [5]. The number of marshals remained relatively low until eight hijackings occurred in January 1969. Soon after, on September 11th, 1970, President Nixon unveiled plans for a program to help protect flights from further hijackings. This force would be responsible for screening passengers before boarding and joining flights whilst undercover, contributing towards tougher anti-piracy actions in retaliation to the recent hijackings [5]. 1,784 men and women were trained and ready for policing aviation [6]. Officially named 'Customs Security Officers' (CSOs), they were informally referred to as "Sky Marshals" [6].

That same year, two engineers demonstrated their new invention to FAA officials; a low-dose x-ray machine to improve the screening of passengers at the airports [7]. The demonstration was incredibly successful, and in February of 1972, the FAA mandated that all airports were to use these machines to screen all passengers before boarding [7]. This advancement led to less of a need for the sky marshal program. As a result, many CSOs moved on to other positions, such as Customs Officers, Law Enforcement, or even some top leadership positions [6]. Nevertheless, hijackings and bombings continued in the following decades, whilst solutions mainly focused on operational and design changes.

This, of course, all changed after the events of 9/11. The horrific attacks led to an immediate refocus on improving security within aviation. Until then, in the event of any other hijacking or attack, new legislation was primarily focused on preventing the same attack from reoccurring. However, the response to 9/11 in the Aviation and Transportation Security Act (ATSA) of 2001 implemented a wide range of sweeping reforms to aviation security [5]. One such reform was the reinvigoration of the sky marshals, leading to a rebranding under the new name of the Federal Air Marshal Program [6]. On the day of the attack, only 33 air marshals were still in service [5]. In the aftermath, 125 former CSOs were temporarily reassigned and immediate action was taken to recruit more [6]. Just as the sky marshals were introduced in 1970, so were they given a new chance as air marshals in 2001.

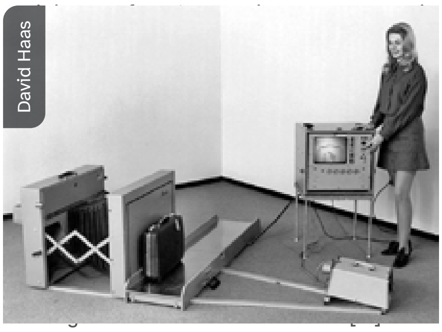
The attack on 9/11 lead to a revitalization of the Federal Air Marshal program

In-Flight Security Outside the US

Undercover law enforcement on flights is not only an American idea. Several European countries, such as Germany, Switzerland, and Spain, simply assign plainclothes officers to several flights as a security measure [8]. This has caused controversy, for example, in Germany, where the airline Lufthansa sued the government for revenue lost from providing business class seats to the officers. Australia started their air marshal program, known as Air Security Officers, shortly after 9/11, whilst the UK took a year to begin its air marshal program [8]. Although the majority of these programs started in response to the 9/11 attacks, a few began after other incidents. The Austrian Einsatzkommando Cobra anti-terrorism unit, which provides air marshals to Austrian flights, was founded following the attack at the Munich Olympics in 1972 [8]. India began introducing their officers on flights following the hijacking of Indian Airlines flight 814 in 1993 [8]. However, whilst all these other programs exist, none are as large as the Federal Air Marshals from the United States.

Current Controversies

The exact number of marshals currently in service in the US is unknown, but estimated to be around 5,000 [5]. Naturally, this is not enough to police every flight; every day, 44,000 commercial flights occur across the US [3]. Air marshals can only participate in approximately 5% of all those flights. However, some air marshals have come forward, stating that this figure is unachievable and is most likely far lower [9]. This quantity of flights is already extremely hard for the small group of air marshals. On call at all times, with shifts of up to 20 hours, the program is incredibly overworked [10]. The original surge of members following 9/11 has largely retired, and the remaining marshals are leaving the program at an alarming rate,



Demonstration of one of the original "Saferay" low-dose X-ray system

Surprisingly, being strained, undermanned, and overworked is the least of the agency's issues, as mismanagement runs far deeper into the core of the program. In 2009, Tennessee Congressman John J. Duncan called the air marshal program the "most needless, useless agency in the entire federal government" [12]. He went on to claim that up until that point, the agency had only made an average of 4.2 arrests a year since 2001 and, as such, is spending approximately $200 million per arrest [12]. On top of that, Duncan claimed that according to a 2008 study, more air marshals have been arrested than have made arrests. The study found that more than 36 air marshals had been charged, with cases ranging from bribery to smuggling explosives from Afghanistan [13]. One agent even forgot his firearm in the aircraft's bathroom [13]. These incidents have continued to persist, with one agent not properly identifying himself to the cabin crew and being arrested after showing his pistol to a stewardess [14]. In 2023, an air marshal was arrested on charges of domestic abuse [15]. Whilst many of these events could be blamed on the TSA's management, the lack of meaningful arrests indicates a deeper issue. Whether the new Union can reform the agency to be more successful and effective will have to be seen.

Other countries have on-flight security, such as the Air Security Officers in Australia

From their origins as Sky Marshals to their resurgence in 2001, these agents have continued to evolve alongside the threats to commercial aviation. The program's effectiveness is questionable as it faces serious challenges; convicted officers, low arrest rates, high costs, and a significant manpower shortage all make the future of the agency uncertain. Whether the new Air Marshal Union's push for reform and restructuring will lead to any success or be dropped to the side by the current administration remains to be seen.

Mining the Moon

A new era of lunar resource utilization

Aitor Bilbao Pardo and Jan Franquesa Monés, Space Oasis I Space Design Engineers

Space Oasis Delft

Space exploration is becoming increasingly popular, but a big question remains: When will humanity have an autonomous and self-sustained interplanetary society? At Space Oasis I, a student team focused on developing a feasibility study and designing the foundations for colonizing Earth's nearest astronomical body, the Moon. Thus, the following article studies how in-situ resource utilization can be implemented in lunar colonization.

Humanity's renewed interest in lunar exploration has sparked a deep investigation into In-Situ Resource Utilization (ISRU), extracting usable materials directly from the Moon's surface, which is critical to achieve an independent and self-sustained colonization. In our work as space design engineers, we have delved into these innovative methods, especially those focusing on how to turn lunar regolith into life-supporting oxygen, structural metals, and other essential compounds.

Lunar ISRU Processes

The processes used in lunar ISRU can be visualized as a series of interconnected steps. As shown in Figure 1, one can extract valuable resources from the Moon using several techniques, each with its own advantages and challenges. The diagram outlines multiple methods, including:

- **Electrolytic Reduction:** Using molten regolith electrolysis (MRE), lunar soil is melted at temperatures around 1600 °C, and an electrical current is applied to separate oxygen from metal oxides.
- **Thermal Extraction:** This method employs high temperatures to extract water from icy regolith and thermally decompose minerals.
- **Hydrogen Reduction:** Particularly effective in ilmenite-rich areas, this technique reacts hydrogen with lunar minerals to produce water, which is then electrolyzed to yield oxygen.
- **Carbothermal Reduction:** Here, methane is used at high temperatures to strip oxygen from regolith, producing CO/CO_2 in a closed-loop reaction that ultimately releases oxygen.
- Vacuum Thermal Decomposition: By heating regolith in the natural vacuum of the Moon, oxygen is released while metals condense on cooler surfaces.

The journey from lunar dust to usable oxygen and metals is filled with promise and challenges. The ISRU processes discussed, from molten regolith electrolysis and hydrogen reduction to carbothermal and vacuum thermal decomposition, illustrate the technical ingenuity required to turn the Moon's resources into life-sustaining materials. While the energy costs range from 24 to 90 kWh per kilogram of oxygen, these processes offer a self-sustaining alternative to Earth-based supply lines.

In parallel, the exploration of alternatives such as lunar polar ice extraction, asteroid mining, and even selective resource transport from Earth provides additional pathways to support human expansion into space. The combined efforts in these areas hint at a future where lunar bases become self-reliant, manufacturing everything from propellant to structural components from local materials.

Each material can serve multiple functions. For example, iron not only contributes to structural elements (both tensile and compressive) but also plays a role in magnetic shielding and electrical conduction when processed into alloys like FerNiCo. Similarly, silicon is versatile in its use, from forming optical structures to serving as a high-quality electrical insulator in electronics.

Energy Demands: The Price of Extraction

A recurring challenge across these ISRU methods is the substantial energy required to free these materials from the lunar soil, as the relative amount of valuable materials that can be extracted from a handful of regolith is extremely low, and hence, a huge amount of this lunar powder is needed to make the process efficient and valuable enough. Consider the following insights from recent research.

- **Molten Regolith Electrolysis (MRE):** Operating at temperatures of around 1600 °C, MRE requires roughly 50 kWh of energy per kilogram of oxygen produced. While this method can recover nearly 95% of the oxygen in the regolith, it demands a continuous, robust power supply—likely through nuclear reactors or large solar arrays.
- **Hydrogen Reduction:** By reacting hydrogen with ilmenite (an iron-titanium oxide common in lunar basalts) at 900–1000 °C, it uses around 24 kWh per kilogram of oxygen. Although more energy efficient than MRE, it is limited by the available concentration of ilmenite in the regolith.
- **Carbothermal Reduction:** This method employs methane to strip oxygen from regolith oxides at high temperatures (exceeding 1600 °C). Using solar thermal energy to preheat the regolith can reduce the overall electrical energy requirement. In practice, about 75–90 kWh per kilogram of oxygen is needed, though a large fraction of this energy is delivered as heat via solar concentrators.
- **Vacuum Thermal Decomposition:** Also known as vacuum pyrolysis, this approach directly heats the regolith in the lunar vacuum to around 2000–2500 °C. Laboratory tests have shown yields of up to 0.2 grams of oxygen per gram of regolith, but the extreme temperatures challenge material limits and system design. Energy estimates for this process fall within 30–50 kWh per kilogram of oxygen when optimized.

The high energy demands stem not only from the need to reach extreme tempera-

MATERIAL (ISRU)	FUNCTIONALITY
Iron	• Tensile Structure (Wrought) • Compressive Structure (Cast) • Elastic structure (Steel springs or flexures) Magnetic Material (Cobalt-ferrite; Silicon steel) Thermal Conduction (FerNiCo) • Electrical Conduction (FerNiCo) Electrical Insulation (Silicon Steel) • Active electronic devices [vacuum tubes] (FerNiCo)
Aluminium	• Tensile Structure • Compressive Structure Hard Structure (Alumina) • High thermal tolerance (Alumina) Electrical conduction • Electrical Insulation ($Al2O3$ ceramic) Magnetic Material (AlNiCo) • Sensory Transduction • Optical Structure
Regolith	• Compressive Structure • Magnetic Shield • Thermal Storage
Nickel	• Thermal Conduction • Electrical Conduction • Active electronic devices [vacuum tubes] Magnetic Shield (Permalloy) • Optical Structure
Silicon	• Elastic Structure (Silicone elastomers) • Thermal Insulation (Fused silica glass; SiO2 ceramic) • Electrical Insulation (Fused silica glass; SiO2 ceramic; Silicone plastics) Active electronic devices [vacuum tubes] (Fused silica glass) • Optical Structure (Fused silica glass) Lubricants (Silicone oils) • Adhesive (Silicone elastomer/gel/cement)
Titanium	• Tensile Structure • Compressive Structure High thermal tolerance • Electrical conduction
Magnesium	• Tensile Structure • Compressive Structure Thermal Conduction • Electrical conduction
Tungsten	• High thermal tolerance • Active electronic devices [vacuum tubes]
Water	• Life Support (Water; Oxygen) • Fuel (Hydrogen; Oxygen) • Energy production and storage (Water, Oxygen, Hydrogen)
Others	• Quicklime - Active electronic devices [vacuum tubes] Quartz; Selenium - Sensory transduction

Table 1: Potential in-situ materials and properties

tures but also from maintaining those conditions over extended periods and handling the byproducts, such as metal alloys or slag. Every system, regardless of its method, requires a comprehensive infrastructure: high-temperature reactors, solar concentrators or nuclear power, and efficient heat management systems. It is clear that while ISRU can provide a sustainable path forward, it is not an easy or cheap process in terms of energy.

Beyond Regolith: Alternative Resource Strategies

Given the energy intensity of lunar ISRU processes, it is natural to ask whether alternatives might prove more efficient or practical in the long run.

One promising alternative is to mine the water ice found in permanently shadowed craters near the lunar poles. Extracting and melting this ice to produce water and subsequently oxygen through electrolysis requires significantly less energy (approximately 4–5 kWh per kilogram of oxygen) compared to processing regolith. However, this method is geographically limited and might require transporting the extracted water to other parts of the lunar surface.

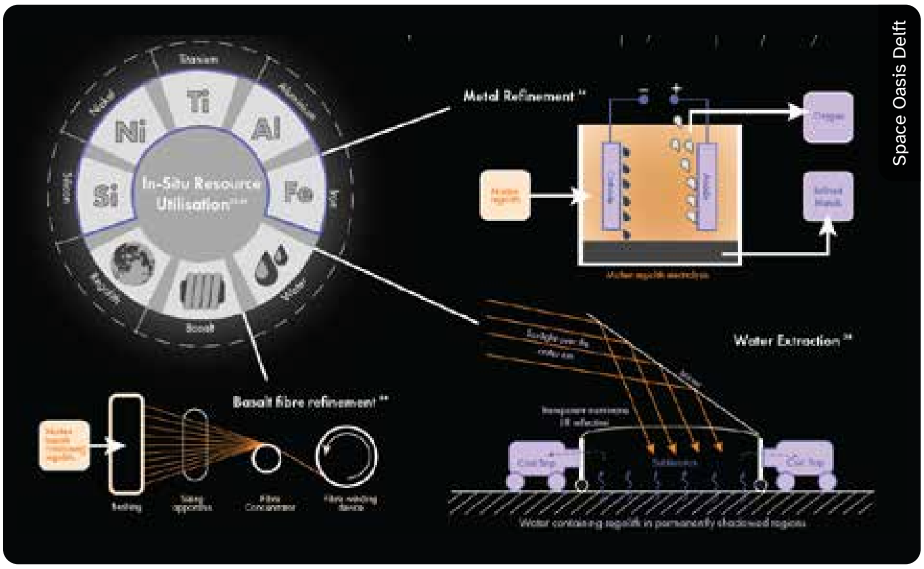
Looking farther afield, near-Earth asteroids (NEAs) and comets have captured the imagination of researchers as potential sources of water and metals. Many NEAs contain hydrated minerals, and comets are massive icebergs rich in water and carbon compounds. Due to their low gravity, the energy required to extract materials from these bodies is much less than needed to overcome the Moon's gravitational well. The trade-off here is transportation; solar-electric propulsion could gradually ferry resources back to lunar orbit, but this approach still requires significant infrastructure development [2].

Historically, our space programs have relied on transporting resources from Earth. However, launching materials from Earth is energetically expensive. To place even a kilogram of oxygen into lunar orbit, rockets must overcome Earth's deep gravitational well, demanding hundreds of kilowatt-hours per kilogram when inefficiencies are considered. While Earth-based supply lines are viable for early missions, they become less practical as the scale of lunar operations grows. In contrast, once a robust ISRU system is established, the energy cost per kilogram of oxygen produced on the Moon is far lower, making local production a more sustainable long-term solution.

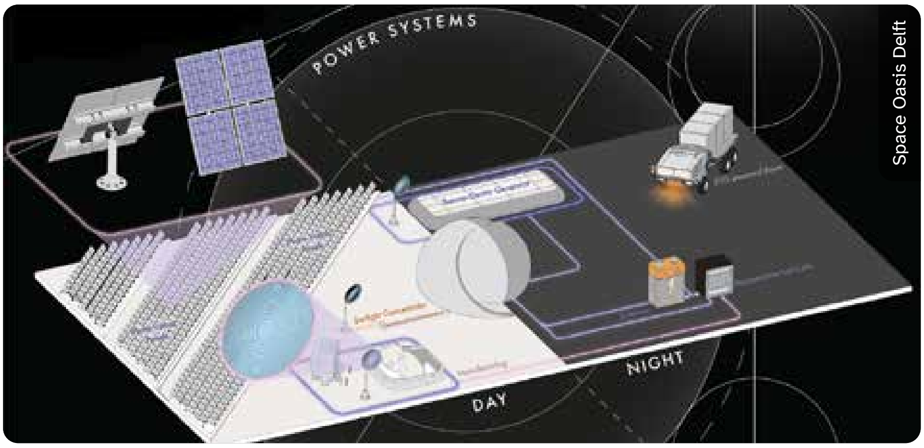
A Vision for Sustainable Lunar Operations

Imagine a future lunar base where several ISRU processes operate in parallel. A large solar concentrator could provide thermal energy to a carbothermal reduction plant while a separate unit runs molten regolith electrolysis. Hydrogen reduction systems might be deployed in ilmenite-rich regions to complement the oxygen produced by other methods. Meanwhile, material extracted, such as iron, aluminum, silicon, and titanium, would be refined into structural components, magnetic shields, and electronic devices (as outlined in Table 1). Such a diversified approach not only optimizes resource extraction based on local conditions but also creates a flexible manufacturing infrastructure capable of supporting both life and further exploration.

The key challenge remains the energy input. Each process, from MRE to vacuum pyrolysis, competes for a share of the available power. However, by integrating solar thermal energy and possibly nuclear sources, the energy demands can be met more sustainably. Hybrid approaches that use solar energy to preheat regolith or drive chemical reactions significantly reduce the need for electrical power, a critical advantage on a resource-constrained lunar surface.



Overview of resource refinement and extraction methods from reglolith



Space Oasis I self-sustained power management concept for a single base

The journey from lunar dust to usable oxygen and metals is filled with promise and challenges. The ISRU processes discussed, from molten regolith electrolysis and hydrogen reduction to carbothermal and vacuum thermal decomposition, illustrate the technical ingenuity required to turn the Moon's resources into life-sustaining materials. While the energy costs range from 24 to 90 kWh per kilogram of oxygen, these processes offer a self-sustaining alternative to Earth-based supply lines.

In parallel, the exploration of alternatives such as lunar polar ice extraction, asteroid mining, and even selective resource transport from Earth provides additional pathways to support human expansion into space. The combined efforts in these areas hint at a future where lunar bases become self-reliant, manufacturing everything from propellant to structural components from local materials.

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GENERAL

Drones in Combat

How drones shaped warfare and became integral to combat

Chaitanya Dongre, Leonardo Times Editor

General Atomics

The constantly changing global dynamic that heavily affects the combat requirements of big military powers, coupled with the range of applications and versatility offered by drones and AI, suggests a revolution might be underway. But is it all too new?

History

Unmanned Aerial Vehicles (UAVs), or drones, have been around for decades. They are a part of the common household vocabulary and are popular for aerial photography, precision farming, monitoring of infrastructure, and even cargo delivery [1]. The first idea of an "unmanned aerial vehicle" goes back to the 19th century. In 1849, the Austrian army attempted an air raid on Venice by deploying a fleet of hot air balloons filled with explosives. Although ambitious, the winds did not favor the Austrians and they failed to do much damage [2].

Following the advent of powered flight, this idea resurfaced. What was lacking in the Austrian plan had become feasible: the ability to control the movements remotely using radio waves. Distance had less influence on the operational limits of engineered tools. Elmer Sperry, an American inventor, found interest in a radio-controlled aircraft and developed an automatic gyrostabiliser in 1913. This allowed him to fly a Curtiss Flying Boat on a straight-level flight without any onboard pilot input. In 1914, he demonstrated his invention at the Aéro-Club de France's safety competition and won the first prize of 50,000 Francs. This was a breakthrough in pilotless planes driven by radio guidance systems. It picked up speed later in World War I, with Britain developing the 'Aerial Target' - a small aircraft meant to defend against Zeppelins and serve as a flying bomb [3]. The Americans soon designed their first version of a UAV, the 'Kettering Bug' - an aerial torpedo designed to strike targets up to 75 miles in enemy territory. It used a gyroscopic stabiliser and had a barometer-based altitude control made using piano bellows and cranks. This aircraft is considered a forerunner of what later came to be the cruise missile.

Both aircraft showed promising test results but were not used during the War. During testing, the Kettering veered off course and nearly crashed into observers, which did not further its cause. Similarly, the Aerial Target showed minimal control capability. However, after the War, research and testing of drones continued, and their production was in full swing halfway into World War II [4]. The first mass-produced drone was the Radioplane OQ-2A, based on designs of the movie actor Reginald Denny, a hobbyist who decided to try to make his model aircraft radio-controlled. The OQ-2A was launched using a catapult, with a controller flying it through a control box on the ground. It used a 24-foot (7.31m) diameter parachute for recovery [5]. Similarly, during World War II, the United States military made use of innovative drone strikes using old aircraft. They repurposed the B-17 Flying Fortress and the B-24 Liberators into massive flying bombs carrying 20,000 pounds (9072 kg) of explosives. These had previously been flown by human pilots who bailed out with a parachute. It represented an early experimentation with remote-controlled weaponry, decades before the new-age drone technology [4].

Cold War Era

After the end of World War II, unmanned Grumman Hellcats and B-17s were used to gather critical data during Operation Crossroads nuclear tests at Bikini Atoll in 1946. These repurposed aircraft gathered data from radioactive environments that were too dangerous for humans. The Cold War saw the most significant advancements in drone technology. Drones became increasingly autonomous due to advancements in guidance systems and onboard processing. They were primarily used for surveillance and intelligence gathering. The Ryan Firebee was originally a target drone, i.e., a "drone used for the development and testing of military systems, training military crews on threat identification, destruction tests of both anti-aircraft systems and piloted combat aircraft" (UAV Navigation, [6]). It was later adapted for reconnaissance missions [6]. One of the first jet-propelled drones, and its variant the AQM-34 Ryan Firebee, equipped with cameras and sensors, was extensively used by the United States Air Force for surveillance over China and Vietnam, flying thousands of missions. Another iteration of this aircraft, the BQM-34, could fly as fast as Mach 0.97 and at altitudes ranging from 10 to 60,000 feet (3.05 to 18288 m) above sea level. It had a remarkable range of 600 miles (965 km) and an endurance of 75 minutes [7]. This was one of the first promising combat UAVs, capable of carrying missiles and bombs.

The Soviets developed the TU-123 in the 70s, which was a part of their attempt to make long-range cruise missiles for nuclear delivery. Although they never fielded these large cruise missiles, they did create a drone based on these concepts. The TU-123 was a supersonic, long-range reconnaissance drone designed to conduct photo and electronic intelligence missions up to 3,000 km deep into enemy territory. It carried advanced cameras and electronic reconnaissance stored in its nose, which could be recovered via a parachute. However promising, this design was not feasible for long due to its non-reusability [8]. Besides these two major powers, another nation recognised the importance and potential of drones - Israel. In a region marked with frequent conflicts and security challenges, Israeli Aerospace Industries (IAI) developed its first promising UAV - the Scout. It was a piston-engined, lightweight, tactical drone designed for battlefield surveillance. It transmitted real-time, 360-degree surveillance data. It gained prominence during the 1982 Lebanon War. Its fiberglass wing emitted an extremely low radar signature, making it almost impossible to shoot down [9].

The Scout's success impressed the United States. They subsequently initiated the Pioneer UAV program, to procure UAVs to provide imagery intelligence for naval gunfire support and tactical commanders. The Pioneer initially faced issues relating to recovery difficulties aboard ships and electromagnetic interference, which led to crashes. To fix these problems, an R&D effort was undertaken with additional monetary support. The Pioneer supported major U.S. military operations during the Persian Gulf War and in Haiti, Bosnia, and Somalia. It was instrumental due to its effectiveness in target acquisition, naval gunfire support, and battlefield management [10]. In the late 20th century, Israel continued the innovation of its drone technology, focusing on improving endurance, payload, and sensor capacities. This laid the groundwork for the future generations of Israeli UAVs, which are considered one of the best in the world today. Other NATO countries, such as Canada, the United Kingdom, and West Germany, developed their drone technology in collaboration. They fielded the Canadair CL-89, which was used by NATO forces for tactical reconnaissance missions [11].

After the Cold War

After the Cold War and other conflicts around the same period, drone technology advanced significantly. The United States added the RQ-1B, one of the most iconic drones of the post-Cold War era, developed by General Atomics. The 'R' signified the US Department of Defense's designation of the aircraft as reconnaissance, and the 'Q' stands for a remotely piloted aircraft system. '1' indicates it was the first of the series of remotely piloted aircraft systems. Later, it was equipped with a multi-spectral targeting system and the AGM-114 Hellfire missiles, giving it the name MQ-1B, where 'M' stands for multirole. The wide-range sensors, a multi-mode communications suite, and precision weapons enabled strikes, coordination, and reconnaissance (SCAR) against high-stakes time-sensitive targets. It constituted the Predator system, which consisted of four aircraft and a satellite link, operated by a pilot and crew. The Predator offered capabilities of being deployed globally, utilizing remote split operations to streamline command and control, reducing required personnel at the conflict zone, thereby furthering their safety [12].

Various new nations also came into the fold, including Turkey. They had previously made use of the CL-89 but were eager to come up with indigenous drones. The Turkish introduced the Bayraktar Mini UAV, investing heavily in built infrastructure and expertise. It became operational in the mid-2000s

Inna Varenytsia, REUTERS

Ukrainian serviceman launches a kamikaze FPV drone at the frontline and was used for tactical reconnaissance and surveillance missions. This advanced drone used carbon fiber and Kevlar composite, having a maximum takeoff weight (MTOW) of just 5.8 kilograms, which was an impressive accomplishment for that time. The success of the Bayraktar Mini UAV laid the groundwork for more advanced systems like the Bayraktar TB2, which gained international recognition for its effectiveness in various military operations in Syria and Libya, amongst other fronts. Turkey is now one of the leading nations in drone technology and supplies drones to several nations, including Qatar, Ukraine, and Poland [13]. Another notable drone of this era was the BAE Systems Phoenix, developed in the UK by BAE Systems and used by the British Army for artillery spotting and reconnaissance. It was deployed in the Kosovo War and Iraq, providing intelligence and targets [14].

Present Day

Modern combat drones have become integral to military operations worldwide. The MQ-9A Reaper, for example, has an endurance of over 27 hours and can be deployed using a bigger aircraft such as the C-130. The ability to self-deploy or be transported makes drones readily available for long periods, giving them a huge advantage over manned fighter jets [15]. In 2019, the cost to train a single fighter pilot was around USD 5 to 11 million, with bomber pilots requiring a high investment of around USD 7-10 million [16]. This is in addition to the known expensive costs of acquiring these fighter jets.

In contrast, drones can be acquired at a much lower cost and their operators require much lower investment [19]. Jet fighters still maintain superiority in speed, payload capacity, and air-to-air combat. However, the increased capabilities and range of operations that drones provide have enhanced the effectiveness of military strategies. Drones provide continuous coverage over areas of interest, collecting data and imagery to inform decisions. These decisions include precision strikes, which are also performed using drones. The surgical accuracy has on many occasions proved substantial in minimizing collateral damage. They also help in providing support to ground troops. Multirole drones can be deployed to increase situational awareness for troops on the battlefield using their cameras and can act as air support simultaneously. They can operate in almost any environment, with their size offering a ton of agility and endurance. Bigger drones deliver support in the form of supplies or other equipment. Last but not least, they can be used for electronic warfare to disrupt communication lines and radar systems.

The Ukraine-Russia War showcases the new age of drone warfare - a technological chess match where advancements by each side prompt countermeasures from the other. They also show how drones are effective in both offensive and defensive strategies [17]. Since the War started, Ukraine has rapidly developed a large-scale first-person view (FPV) drone program. These drones transmit real-time video feeds to operators with screens or wearing VR goggles. A big advantage of FPV drones is that, unlike traditional drones that are controlled from a third-person perspective, these provide operators with an immersive cockpit view, whilst at the same time being extremely cheap. They are being built not only by the army and other defense personnel but also by volunteer citizens who are eager to participate in defending their country. According to some Ukrainian soldiers, FPV drones have emerged as crucial alternatives to Western artillery rounds and precision weapons. Their capacity to deliver larger explosive payloads with high accuracy has even made them preferred weapons against tanks in certain units. Operators can target specific vulnerabilities such as engines and tracks with surgical precision, maximizing effectiveness despite limited resources. They do not come without limitations, as they can be easily neutralised by electronic warfare. To overcome this, they have resorted to using analog signals to resist the jamming of the feed to their screens [18]. This Ukrainian experience with FPV drones showcases how asymmetric capabilities can challenge conventional military advantages. It suggests that future conflicts will likely see increased use of low-cost, adaptable unmanned systems alongside traditional military platforms.

Today, many military organisations have taken to developing drone technology. The United States recently classified two prototypes - the General Atomics YFQ-42A and the YFQ-44A by Anduril Industries - as the first uncrewed aircraft to receive a fighter designation [19]. The country currently operates the MQ-9, an intelligence collection unit that uses a satellite link and a ground control station. It features a Multi-Spectral Targeting System with infrared, color/monochrome cameras, laser designator, and synthetic aperture radar, allowing for precision targeting with up to eight Hellfire missiles or laser-guided munitions. It is designed to be contained and transported via the Lockheed C-130 Hercules. The Reaper employs "remote split operations," where local crews handle takeoff and landing at forward locations, while mission control occurs from the mainland United States via satellite links [20]. Other state-of-the-art drones include the Heron TP developed by IAI and the CH-4 developed by China. Many other nations have funded projects to develop their drones - the Ghatak and Rustom Medium Altitude Long Endurance (MALE) drones made by India, the EADS Barracuda MALE developed by Germany and Spain, and the Dassault nEUROn developed by several European Nations led by France. There is also the use and development of Unmanned Underwater Vehicles (UUVs), also called undersea drones, to monitor and gather intelligence in seas and oceans. These can reach depths that are inaccessible to traditional submersibles and can conduct anti-submarine and other sea vessel warfare. Still largely in development, Northrop Grumman's Manta Ray aims to operate in long-duration, long-range missions in ocean environments [21]. Another promising undersea drone is Anduril Industries' Dive-LD, which is claimed to be able to autonomously conduct surveillance and reconnaissance, mine counter-warfare, anti-submarine warfare, and seafloor map-

Inna Varenytsia, REUTERS

Ukrainian servicemen operate a first-person view (FPV) drone

Manta Ray - Northrop Grumman's undersea drone

ping missions for up to 10 days at sea and operate in depths of up to 6000 metres [22].

Ethical Disconnect

The widespread usage of drones sparks many ethical concerns. While they offer advantages on the battlefield, they are extremely lethal. The idea that a UAV operator sitting thousands of miles away can cause casualties and other kinds of mayhem to a large number of people and proceed to return home as if it were just a normal day is scary. Operating the drone from a bunker on a different continent may provide support and convenience to the soldiers on the battlefield and reduce harm to the operator. However, it diminishes human lives by being targeted to mere data points. While it may feel like operating a sci-fi machine using a VR headset, much like a video game, the lack of situational awareness removes the touch of reality. Many drone strikes have been known to cause harm to civilians, raising questions about the credibility of the nations employing them [23]. A very recent and ongoing example of this is in Gaza, where countless civilian lives have been harmed due to drone strikes [24]. The Bureau of Investigative Journalism has tracked down drone strikes and other covert operations in Pakistan, Afghanistan, Yemen, and Somalia. There must be more independent bodies to provide comprehensive reporting on civilian deaths due to drone strikes, as it helps to build up to greater transparency and makes note of the information needed to hold organisations accountable [25].

Although designed to be precise, it is a person controlling the drone and calling the shots in the end. Hence, evaluating their effectiveness in combat is difficult, as there needs to be a strong humanitarian and legal precedent as to what can be classified as "successful". Like any other military tool, they can be hugely misused to act in the interests of a handful. Their classified nature also presents concerns. A faction or a nation can penetrate deep into other territories without a proper declaration of intent or fielding soldiers. This secrecy can cause instability in regions that are otherwise peaceful with far too much ease and also violate the sovereignty of nations. Some arguments against them are also that drone strikes circumvent legal processes by executing targets without trials, which goes against democratic principles [23]. In recent years, the Parliamentary Assembly of the Council of Europe has raised the issue with its member states to adhere to strict legal and ethical standards regarding drone warfare. The key points raised include establishing transparent authorization procedures with judicial oversight and independent post-strike evaluation and publishing targeting criteria, procedures, and investigation results for transparency. Lastly, they also call for prohibiting automated targeting based on mass surveillance data and prohibiting "double-tap strikes" that deliberately target first responders and medical personnel in the name of engaging enemy combatants for a second time [26].

Future

In 2021, the global drone industry was worth approximately $27.4 billion. While this represents all drones, commercial and military, the growing nature of this industry attracts more investments, leading to a higher innovation ceiling. North America currently leads the market, but China is experiencing the fastest growth, thanks to its government's substantial investments in civil and military applications [27]. Future drones will increasingly incorporate advanced Artificial Intelligence and may operate fully autonomously. There is also a lot of focus on advanced radar-absorbing materials and thermal signature reduction to make them more stealthy. A new type of technology called a 'drone swarm' is being developed where dozens or hundreds of drones operate in a coordinated system. These will be immensely difficult to deal with from a combat standpoint and will work to complete complex tasks with greater efficiency and redundancy. The United States Defense Advanced Research Projects Agency (DARPA) is working on Offensive Swarm-Enabled Tactics (OFFSET), which aims to equip small infantry units with swarms of up to 250 unmanned aircraft and ground systems. The key components include an advanced human-swarm interface utilizing augmented or virtual reality and intuitive control methods to enable operators to direct hundreds of platforms simultaneously [28]. In Europe, Airbus Defence is working on the Future Combat Air system (FCAS) - aimed at increasing Europe's security independence. Its integrated multi-platform approach will operate new-gen fighter jets alongside drones. By 2040, it is planned to integrate enhanced platforms such as the Eurofighter and Dassault Rafale, using AI, big data, cryptography, and human-machine interaction [29].

Furthermore, several nations are researching high-speed drone platforms that can travel at Mach 5+ for rapid response missions [30]. All this can be considered a small glimpse into the future of military drone technology. However, note that there is a dire need to balance these security needs with ethical considerations and legal obligations.

The ever-expanding defense industry and advancements in aviation have made drones an essential component of combat strategy. Initially a secret from the public, they were used for reconnaissance and surveillance during the Cold War. Today, drones are well-known combat machines that serve various military functions. This technology continues to advance globally, with numerous nations developing increasingly autonomous systems that transform modern combat operations. Although there are many regulatory and ethical concerns, it will be interesting to follow the industry transformation during the next few years.

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June 19

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Space Debris

The risks and solutions associated with hypersonic junk

Vince Lukacsi, Leonardo Times Editor

The rapid expansion of the space industry has generated a significant amount of space debris in Low Earth Orbit (LEO). Unless the industry changes its approach, the dangers of these fast-moving projectiles pose important safety issues and may burden space exploration in the coming years.

Space Pollution

In 1957, the Soviet Union launched the first satellite, Sputnik 1, into LEO. This event marked the beginning of a long and successful chapter in human history, namely, space exploration. It would also be the start of what is known today as space pollution. Space pollution is a broad term encompassing numerous components. However, one element in particular has caused concern in the space industry - the presence of space debris. This debris has caught the attention of many due to the threats it poses to the safety of space missions, its rapid and largely uncontrolled growth, and, most importantly, the difficulties of removing it. The increased attention towards the issues related to space debris has prompted numerous researchers to publish papers on this topic and even led to the creation of the movie "Gravity" in 2013.

Origins of Space Debris

Space debris comes in various shapes and sizes, largely defined as "(...) all non-functional, artificial objects, including fragments and elements thereof, in Earth orbit or re-entering into Earth's atmosphere (...)" [1]. Another way to refer to them is simply as "space junk". They can range from abandoned satellites and rocket stages to paint fragments and fuel particles. Their origins, however, can be associated with three main sources: mission-related operations, accidents, and intentional creation [2].

At the start of the space age, especially during the Cold War, focus on performance left little to no attention to space debris. In other words, "nations prioritizing short-term advantages over long-term shared goals" [3]. As such, engineers overlooked the issues related to the creation of debris. For instance, early designs for the explosive mechanism responsible for detaching the upper stage of the rocket from the spacecraft show no initiatives to limit the number of fragments created by the operation [4]. This carelessness resulted in mission-related debris forming around 11% of all catalogued debris. Catalogued debris is a specific type of debris that is monitored by the Space Surveillance Network (SSN) [5]. Recently, however, as sustainable engineering became the norm, several guidelines were implemented by entities such as the European Space Agency (ESA) to mitigate the production of debris. Their "Zero Debris Approach" imposes stricter requirements on the design of components that would be likely to create debris [6].

The second major source of space junk is from accidents and unintentional collisions. In total, "there have been four confirmed collisions between catalogued objects", the most notable one being the collision between Iridium 33 and Cosmos 2251 [7]. In 2009, the two satellites collided at a hypervelocity of 770km over northern Siberia [8]. This accident shattered both satellites into pieces and sky-rocketed the debris into LEO. Although it is difficult to estimate the number of fragments produced by the collision, more than 1600 additional objects were added to the catalogue of the U.S. tracking system [9]. However, this statistic does not take smaller debris into account, which is equally dangerous. This collision could have been avoided as, although the Russian satellite was no longer operational, Iridium was still capable of manoeuvring.

Finally, the last contributor to space debris is deliberate human action. Anti-satellite weapons (ASAT) are ballistic missiles aimed at destroying satellites. The reason behind the development of such technology stems from political motives. These missiles were first designed during the space race between the US and the Soviet Union [10]. As both sides saw the potential of satellites for military and spying purposes, they also started to develop solutions to prevent the other side from using them, which led to the creation of ASATs. To test this new technology, ASATs were employed to destroy old non-operating satellites, which inevitably led to the creation of a large amount of space debris. A famous instance of such destruction was in 2007 when China launched a ballistic missile aimed at the obsolete Fengyun 1. The cloud of debris quickly spread across LEO, causing a peak in the number of monitored debris and resulting in an approximate increase of 30% in the total population [11].

Prediction Models

In the past decades, the amount of space debris has grown exponentially. Numerous predictions and speculations regarding space junk and its effects have been made. The most famous theory was formulated in 1978 by an American astrophysicist, Donald J. Kessler, and would later be referred to as "The Kessler Syndrome" [12]. The model follows what is known as the "snowball effect", where an initially harmless situation grows into a dangerous and uncontrolled scenario. He argued that the number of space debris would one day reach a number where the probability of collision between satellites and debris would be so high that it would inevitably lead to the creation of even more junk. Wall describes this theory as "a cascade of orbital debris that could potentially hinder humanity's space ambitions and activities down the road" [12]. Several studies have been conducted, such as the one by the American Astronautical Society, which used different models to predict the growth of space debris. Their findings concluded that "we are now entering a time when the orbital debris environment will increasingly be controlled by random collisions" [13].

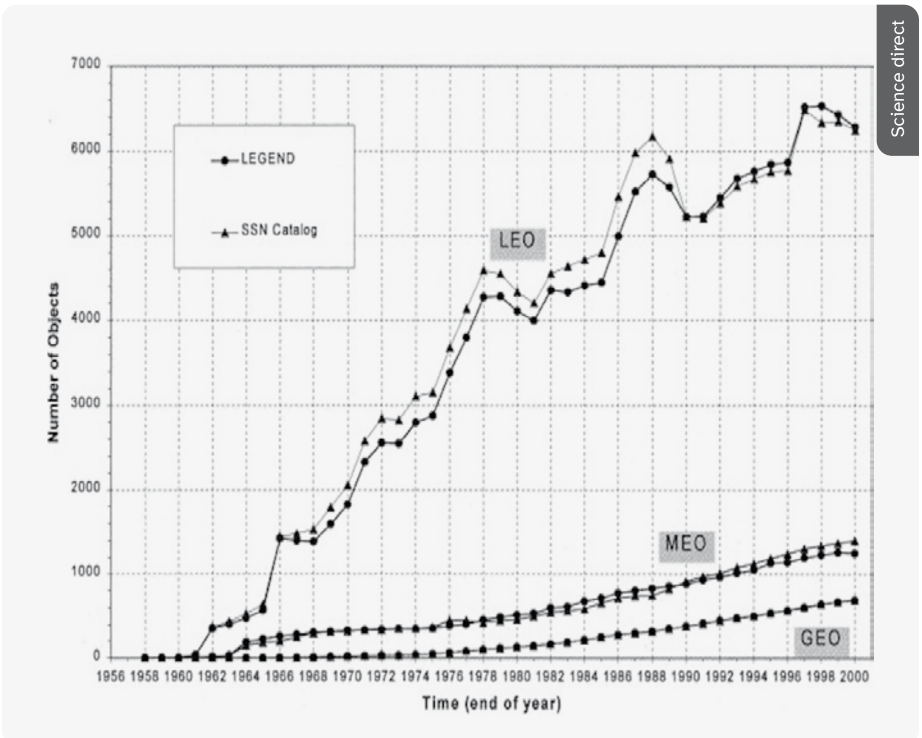
A famous tool to predict the future number of debris over 10cm is the "NASA LEGEND", one of the most complex models as of today. Figure 1 from Liou et al shows how accurate the model is for the number of catalogued objects by the SSN [14]. This very same model has been used to predict future estimates, taking into account different scenarios. Figure 2 from Liou illustrates the worst-case scenario, in which no mitigations are made [15]. Here, the effects of the Kessler syndrome become apparent, shown by the exponential increase in large space debris after 2050.

The Problem with Space Debris

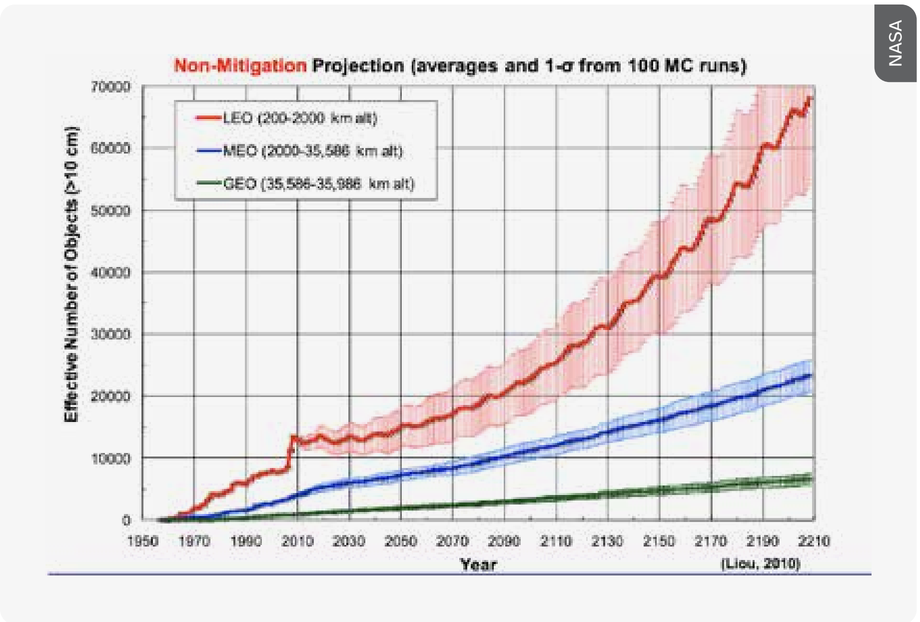
The origins and predictions regarding space debris have been mentioned so far, but why do they raise such concern amongst scientists and engineers? After all, the majority of space debris does not exceed more than a few millimetres in size, such as paint fragments, whilst the larger ones are monitored, meaning that their paths can be predicted and collisions avoided. However, the potential damage caused by even the smallest debris is incredible, as it orbits around the Earth at extreme velocities, 10 to 20 times faster than a bullet [16]. This causes it to have extremely high kinetic energy, which, in case of an impact, can have disastrous consequences.

Damage caused by a tiny debris

The main worry stems from the threat it poses to future satellites, especially in LEO. With mega-constellation initiatives, such as Starlink, projecting to place more than 40 thousand satellites in LEO, the probability of interference with space debris becomes troubling [17]. If the events touched upon by the Kessler Syndrome were to happen, this could potentially make the LEO unusable. "Important space applications could be lost, such as weather forecasting, climate monitoring, earth sciences and space-based communications" [11]. The rate at which space debris is produced is still much larger than the rate of removal. Nevertheless, growing awareness has led to several solutions and plans being drafted to decrease the amount of debris in LEO.



Modelling of the NASA LEGEND for the past years



Predictions for worst case from NASA LEGEND

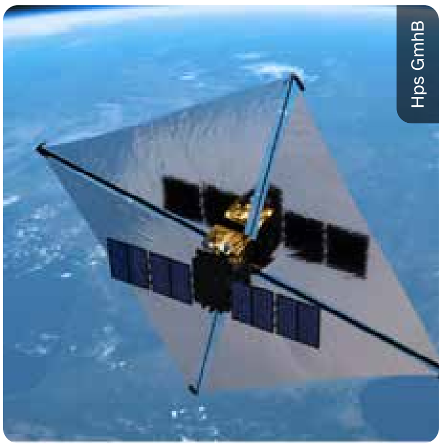
An F-15 releasing an ASAT during testing

Solutions

There are two methods to decrease the amount of space debris: remove existing debris from space and prevent the creation of new ones. By implementing these two solutions, the growth of space junk would slow down significantly and eventually start decreasing. This could in turn induce a reverse Kessler Syndrome, where less debris would reduce the probability of collision between debris and existing satellites.

As previously mentioned, ESA has been implementing policies, namely through their “Zero Debris approach”, that aim to meet this goal. One requirement their program includes is the guarantee of disposal [6]. This ensures that, at the end of its mission life, the given satellite can perform a controlled atmospheric reentry or increase its altitude to a “graveyard orbit”, typically for geostationary satellites. This avoids leaving non-operational satellites, such as the Cosmos, at orbits with high satellite densities and prevents unnecessary collision.

A strong example to consider, which has implemented various techniques to limit the amount of debris produced, is the ISS. Given its importance in research, the ISS is equipped with multiple systems that protect it from both small and large debris. For instance, in case the probability of a collision with a tracked object exceeds 1 in 10000, the ISS can perform a “Debris Avoidance Maneuver” [18]. This involves the ISS firing its thrusters to change its initial path and thus reduce the chance of an impact. Although this method works for larger debris, it would be too costly and unsustainable to utilize this solution for all types, given that estimates show that there are more than 130 million objects between 1mm and 1cm in LEO [7]! To protect itself from this smaller debris, the ISS is equipped with Whipple shields, which are multi-layer protection barriers that can absorb the energy produced at impact [18].



Drag Augmented Sail

While these methods prevent the creation of new debris, they still do not bring a solution to cleaning up LEO from already existing junk. The issue stems from the fact that, given the low drag levels at the altitudes at which debris orbit, the rate they naturally degrade is minimal. Therefore, there is an imperative need for solutions that could actively remove and clean areas of high junk densities, which has led to numerous incentives and international collaborations. However, the Council explains that, unfortunately, as of today, there exists no such method that could be used at a large scale for such a project and that “any foreseeable schemes look very costly” [19]. One of the most promising projects, nevertheless, is the “Drag Augmented Sail” (DAS). As Vaseeq & Ntantis describes it, this method involves deploying a large sail on the satellite at the end of its life, increasing its surface area-mass ratio [3]. This would accelerate the process of its natural decay through an increase in drag and would lead to the satellite burning up in the atmosphere, eliminating the potential threat they could be in LEO. The main concern with this project remains the material required for the sail, as it must be both lightweight and resistant enough. Another potential solution is the “Laser Debris Removal” which can be described as “The LDR concept uses a beam of closely directed laser energy projected from the ground to modify the trajectory of debris objects in low earth orbits” [20]. It also describes how this concept has been approved “within the framework of the CLEANSPACE project”, which is already a great achievement. However, similarly to the DAS and to any other method not discussed here, the main problem remains the lack of technology that is needed to bring these ambitious projects to reality.

Space debris is a real threat to the future of the space industry and space exploration. The consequences of uncontrolled growth in the population of junk and the Kessler syndrome could very well have irreversible effects on satellites in LEO, which would affect our everyday lives. Luckily, with the growing awareness regarding this issue, numerous policies are being implemented to control the situation. While these can slow down the growth of junk, plans for long-term sustainable solutions are currently being explored to put an end to this threat.

C&O

Green Airports

Reducing airport emissions to support sustainable future

Alfonso de Rato Pueyo and Siddharth Bhowmik, GreenTeamAE


MVRDV

Airports are an essential part of air travel and they must focus on sustainability if the industry is to achieve climate neutrality. This article explores the key factors contributing to airports' environmental footprint and examines the various options for improvement.

The Environmental Footprint of Airports

Although universal agreement remains elusive, there is more consensus than ever on the need for the aviation industry to strive for climate neutrality, with agreements in place to achieve this goal by 2050 [1]. Efforts have primarily focused on improving aircraft technology, emphasising a fundamental change in how aircraft are powered—notably through hydrogen or electric batteries. However, the common denominator for all these new technologies is the continuing necessity of airports for their operation. An airport's environmental footprint can be divided into three broad scopes, following the widely recognized Greenhouse Gas (GHG) Protocol framework [2]: scope 1, scope 2, and scope 3 emissions.

Scope 1, or direct emissions, stem from airport-owned or controlled operations. These include aircraft ground operations, the airport-owned vehicle fleet (such as shuttle buses, airplane tractors, and tankers), and any on-site energy generation, such as heating systems or emergency generators. Indirect emissions are divided into scopes 2 and 3. Scope 2 refers to the emissions from the generation of purchased electricity, heating, and cooling consumed by the airport. On the other hand, scope 3 includes all indirect emissions not included in scope 2. For an airport, this mainly consists of aircraft emissions during taxi and all flight phases for departing aircraft, although the definition can vary. Passenger and employee transportation, airport waste disposal, and fuel supply chain emissions also fall within this scope. Unsurprisingly, Scope 3 emissions constitute the majority of an airport's footprint. While they account for over 70% of emissions in many businesses [3], this percentage is even higher for airports.

Tackling Scope 1 Emissions

Since they depend directly on an airport's operations, scope 1 emissions are arguably the easiest to approach. However, they still require careful consideration, especially


Schiphol Airport

Figure 1: Electric bus in use at Schiphol Airport

Figure 2: PCA unit in use at Munich Airport

if the objective is to reduce emissions to near-zero levels.

One of the improvements made in airports worldwide is the renewal of ground support equipment by purchasing electric alternatives. Ground support equipment includes fuel trucks, people movers, belt loaders, etc. These electric alternatives directly help to reduce scope 1 emissions and result in a healthier working environment for airport personnel. AENA SME, S.A., the world's leading company in airport infrastructure management by passenger volume, has set a target to electrify 26% of its fleet by 2026, highlighting ongoing changes [4]. Here in the Netherlands, Schiphol airport is also electrifying its fleet and uses HVO 100 fuel in the remaining fuel-powered vehicles. This biofuel reportedly emits 98% less net CO2 than the previously used diesel [5].

Another measure to reduce airport scope 1 emissions lies in how electricity is provided to parked aircraft. While most aircraft can use "shore power"—meaning they connect to the airport's grid—this is only possible when parked at a gate and not typically the case for cargo aircraft. In these cases, a fuel-powered Ground Power Unit (GPU) usually provides electricity to the plane, but battery-powered counterparts, e-GPUs, are replacing these generators, once more reducing emissions [6]. f Preconditioned Air Units (PCAs) to maintain comfortable cabin temperatures while docked are replacing fuel-burning Auxiliary Power Units (APUs). PCAs provide aircraft with fresh conditioned air at appropriate temperatures and humidity while the aircraft is at the gate. The use of such a system at Munich Airport is shown in Figure 2.

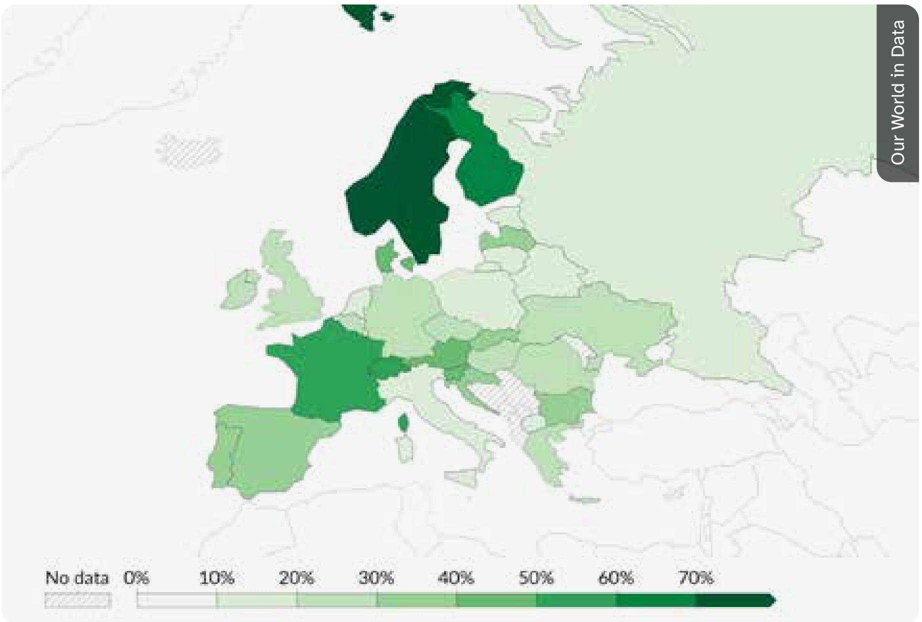


Figure 3: Share of primary energy consumption from low-carbon sources (nuclear + renewable)

Tackling Scope 2 Emissions

Scope 2 emissions present different challenges. Airports can source electricity differently but are dependent on their location. The availability of renewable energy sources such as wind, solar, or hydroelectric power varies significantly by region, influencing how easily an airport can transition away from fossil-fuel-sourced electricity.

Airports in areas with strong renewable energy infrastructure may have direct access to green power through local grids or power purchase agreements, while those in fossil-fuel-dominated regions may struggle to secure sufficient low-carbon electricity. Figure 3 shows how even in Europe there is significant variability in the fraction of energy generated using renewable sources. Stockholm's Arlanda Airport can rely on Sweden's grid to have relatively low scope 2 emissions, while Schiphol has to purposefully source energy by partnering with energy providers to currently achieve 100% renewable energy [7]. The options are even more limited for airports without reliable renewable energy sources. One notable example of reducing scope 2 emissions is the Cochin International Airport in India, which was the world's first fully solar-powered airport after the inauguration of a dedicated solar power plant [8]. It highlights that the availability of natural resources substantially increases the airport's possibilities to reduce scope 2 emissions. Cochin was awarded the coveted Champion of the Earth award in 2018, the highest environmental honour given by the United Nations [9].

Tackling Scope 3 Emissions

It is clear that many measures can be, and indeed have been, taken to reduce scope 1 and 2 emissions. The effect of such measures is evident in the evolution of these emissions for Schiphol Airport. The use of renewable energy effectively removed scope 2 emissions after 2018, and since 2022, carbon removal means net CO2 emissions from both scopes are zero. However, it is important to note that CO2 emissions are not the only relevant factor in this discussion, with other pollutants like nitrous oxides (NOX) or methane (CH4) emissions critical yet not directly considered. What about scope 3? This category includes nearly everything not covered by the previous two, ranging from fuel use in departing flights to emissions from passenger commutes to the airport.

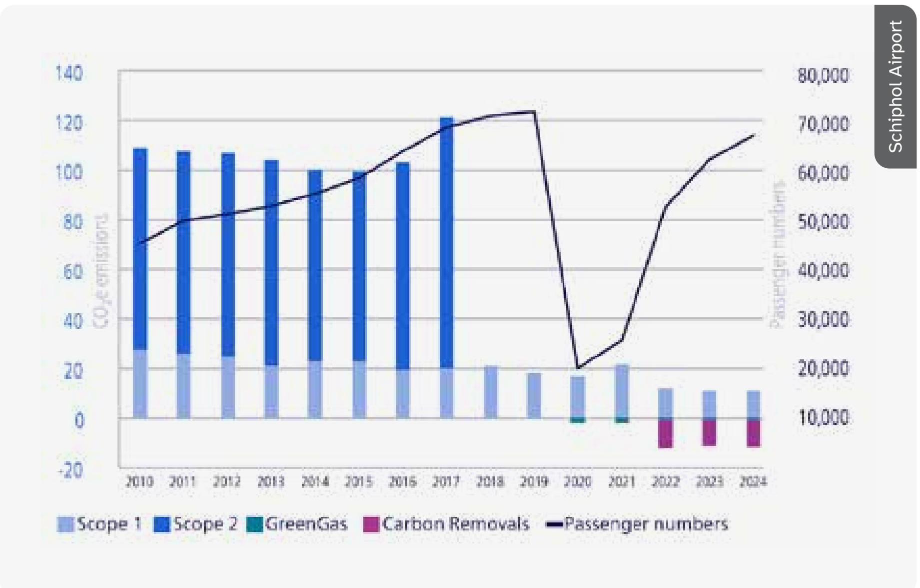


Figure 4: Scope 1 and 2 CO2e emissions and passenger evolution for Schiphol Airport (x1000).

According to Deloitte, scope 3 contributes to 70% of the total carbon footprint of most businesses. For airports this number is usually even higher with aircraft fuel burn greatly driving emissions [3]. Scope 3 emissions are the largest contributor to an airport's climate impact, for reference they composed almost 90% of London's Heathrow Airport emissions in 2023 [14]. These emissions primarily stem from fuel burned by departing aircraft, making it imperative that the aviation industry and academia continue to research innovative aircraft technologies. As can be seen in Figure 6, similar to previously presented Figure 4, Schiphol airport has seen an increase in fuel usage closely following the increase in air traffic movements (ATMs); for this correlation to weaken aircraft need to evolve. Mitigation options include the use of Sustainable Aviation Fuel (SAF) in current aircraft and the development of new technologies, such as battery-powered or hydrogen-powered aircraft.

While the use of SAF is presented to have the capability to reduce CO2 emissions by 80% [10], ICAO also highlights that this alone is not enough. Improved technology, increased aircraft efficiency, and operational improvements at the airport are also necessary to tackle scope 3 emissions [11]. However, the infrastructure surrounding SAF needs careful assessment. All steps must be sustainable, including the feedstock, conversion of feedstock into SAF, blending with conventional jet fuel and transportation to airports. This chain must also supply the entire world with fuel. While some European airports in countries like France, Germany, or Sweden have developed value chains for SAF [12], concerns about large-scale viability persist, as noted in previous editions of this publication.

The commute to the airport for passengers also contributes to scope 3 emissions.

Figure 6: Jet A-1 fuel usage outbound flights per ATM (x1000)

Schiphol and other airports in the Netherlands score very highly due to the direct access to public railway stations. However, this is not always the case, as many airports suffer from limited public transport access, hindering both travel convenience and efforts to curb scope 3 emissions. Addressing these emissions is challenging, as they encompass a broad range of indirect emissions that contribute significantly to an organization's overall carbon footprint. Accurately tracking them is a Herculean task, and implementing effective mitigation strategies presents an even greater challenge.

The Future

In the EU, airports must declare their Scope 1 and Scope 2 CO2 emissions, while attention to Scope 3 remains voluntary. Some US states, such as California and Massachusetts, have introduced initiatives to reduce airport emissions, with no country-wide normative present.

Collaboration and agreement are key factors in addressing this issue. Isolated operations have a lower chance of having an impact, as they are often not aligned with other stakeholders. Schiphol Airport's recent steps to cut flights have demonstrated that it is a tough challenge to address. Organizations like the IATA, ICAO and UN have advocated for more collaborative efforts between airports and various stakeholders to minimize emissions. This also serves as a precursor to achieving net zero emissions in aviation by 2050.

Finally, management and operational policies like flight path optimization and single-engine taxiing should be encouraged to reduce fuel burn. Strengthened environmental policies and global cooperation help in this matter, with more experienced airports having the chance to share their experiences with emission reduction measures. The biggest challenge for airports in the next decades will be to curtail their emissions while adapting to an ever-changing aircraft fleet.

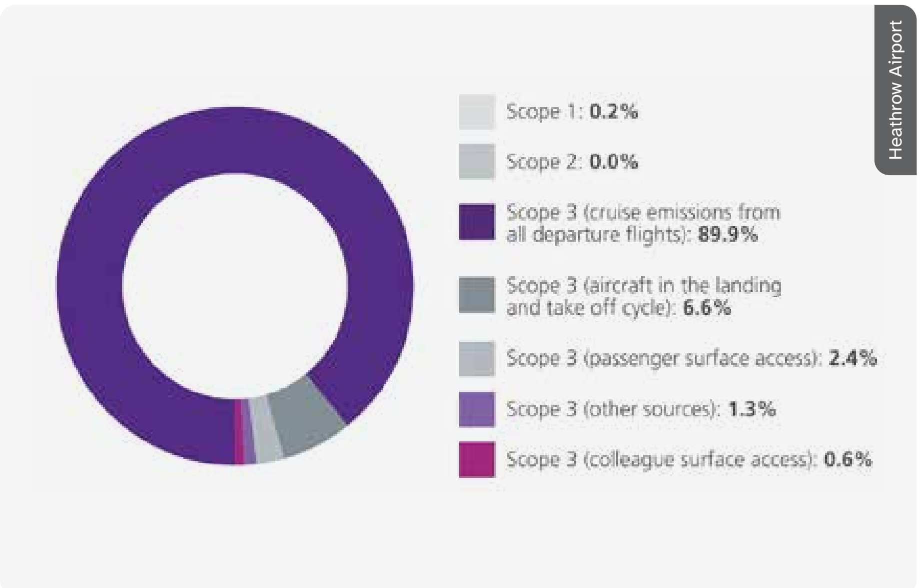


Figure 5: Heathrow airport emission breakdown by scopes for 2023

This article has examined how airports are reducing their environmental impact, analysing the three classified emission scopes and illustrating how airports like Schiphol are faring in their goals. The progress made in reducing scope 1 and 2 emissions is encouraging, but it is important to stay aware of the big picture: developing new aircraft technologies is essential. However, airports must emit as little as possible, while adapting to operating the aircraft of the future.

Longing for Adventure

The challenge of interest when things get boring - an opinion

James Perry, Editing Director

Aerospace isn't as cool as it once was. The ongoing green transition is vital but exciting to very few, while space "exploration" today rarely involves going anywhere new. More dialogue is the first step to patching a gaping vulnerability.

Born too late to explore the world, too early to explore the stars. People of all generations today would share this sentiment; since the moon landings nearly sixty years ago, we haven't really gone anywhere new. Tales of explorers and adventurers fill our childhood bookshelves, but as we grow up we are slowly faced with the daunting reality that all the exploring is pretty much done. The planets seem far out of reach, while Earth lies easily at our fingertips. Too easily.

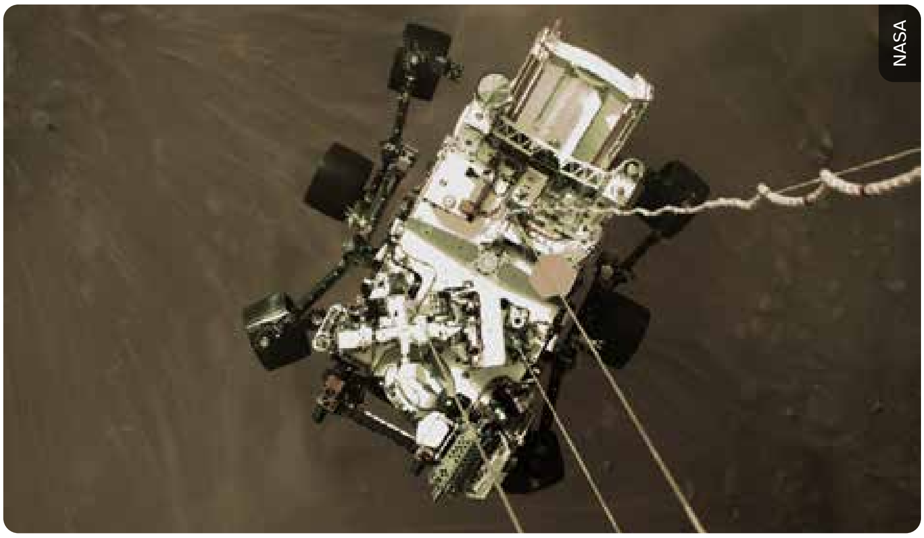
Since the days of early aviation pioneers, the spirit of adventure has driven us. Days after the first manned hot air balloon flight, US President Benjamin Franklin was asked what the point was. He famously replied, "What use is a newborn baby?". The benefits and drawbacks of aviation were not fully understood until after we already had it. Travelling is easier, the economy is boosted, and life-saving treatment can be given to those who need it. But when the Wright brothers made their first flight at Kitty Hawk, they had no idea what it would lead to. They simply did it because they believed they could, they wanted to, and they hoped it would change the world. The motivation required for their years of work cannot have come from that alone. There was something inside them, and all pioneers of that time, who wanted to be the first to do what nobody had done before: to taste flight, sustained and controlled, just as birds do. To understand what it is like to be truly free and see the world from above, views never seen before. They were driven to take that first step into the dangerous, yet exciting, unknown.

Space travel cannot be viewed so romantically. The backdrop of war and the ongoing arms race meant that from the first man in space to the first on the Moon, astronauts were all military pilots serving their country in a display of power against other nations. Since then, we have seen a drastic shift. To be an astronaut is a highly sought-after position, with application success rates of four thousand to one. Motivations vary, but many of these would-be astronauts want to do something new, to experience the things which so few have experienced, and the adrenaline which comes with it. The increasing number of private space flights is proof of this. Passengers on Blue Origin's New Glenn or Virgin Galactic's SpaceShipOne rarely conduct science or technical demonstrations. They are just there for the adventure, the excitement worth millions of dollars.

Famously, young men scrambled to sign up to fight in the First World War, afraid it would be over by Christmas and they would miss all the action. In the Second World War, 6,700 applications were received by the UK's Royal Air Force from US citizens before their own country even joined the war. Again motivations varied, of course the repeal of fascism, but for many of these pilots, it was also a lust for adventure that drove them to cross the ocean to fight in somebody else's war. Many were killed. Today, the war in Ukraine still attracts many overseas patriots to leave their lives behind for a good cause. They are also after the adventure. War is a falsely romanticised adventure, but it is an example of where such promise influences people of all genders, in their masses, to give up the lives they once knew for the promise of something different.

Aviation is no longer the promise of an adventurous new life it once was. It's safe, regulated, scheduled, and rarely takes you anywhere new. Flying is just a part of life for billions of people, which means the industry does not attract young people as it once did. There are shortages of pilots and air traffic controllers worldwide, a problem which appears quite intractable. Pioneers of aviation were regarded as international heroes, the Golden Age which followed left footprints of jet-age glamour. And now? Flying is safe,

Buzz Aldrin descends to the lunar surface



The Perseverance rover landing on Mars

and affordable, and the airplanes all look the same. It's boring.

Space travel is years away from this problem, but surely one day it must come too. The hype for Artemis is losing steam before the program has even begun, while the innovations of SpaceX are becoming the norm. Although the largest lecture hall in the faculty was packed full to watch the first flight of Starship - you could feel the roar of excitement at its success - by the third or fourth there were only ten of us watching. When things become common, they become uninteresting, no matter how spectacular or impressive. So how long will it be before the adventure of spaceflight fades, and with it the money? Before a lack of interest bleeds the industry dry? It may be imminent, it may be years away, but it will undoubtedly come, just as it did for aviation.

Most major space companies now know that their public support and funding depend on the excitement of adventure among the stars. Hence the increased number of onboard cameras, live-streamed launches, and the first videos of a rover landing on the surface of Mars. Boom Supersonic similarly live-streamed the first supersonic flight of their XB-1 test aircraft, hosted by chief Concorde pilot Mike Bannister. The importance is recognised, and with high viewership these live-streams seem to provide the excitement intended. But is it enough?

To truly appeal to the longing for adventure, we must openly recognise the importance of this driving factor. Job descriptions for airline passengers tempt recruits with an image of pride, delivering passengers to their destination safely. But most pilots would highlight the best part of their job as the incredible sunsets or layovers in exciting new cultures. Most astronauts speak of the famous view of planet Earth, the blue marble, as the best part of their experience. Why are we reluctant to admit that some jobs can be fun, as well as beneficial? Why do we search out employees who will be interested, or content, rather than excited about what they will be doing? It is often critical that roles in aviation are performed correctly to ensure safety is maintained, but boredom is as big a killer as distraction.

When we hear about careers in aerospace from those who have lived them and they are not enthusiastic, our hearts sink. Why would we subject ourselves to a career of meticulous attention to detail and commitment when higher-paying alternatives are available? Aerospace relies on motivating its future engineers and pilots through passion where adventure once stood, a passion which is often sucked out of students by years of equations and exams. If it is no longer possible to go to new places and see new things, we need to find a way to better enjoy the things that we have. We need more airshows, more innovation, and new opportunities! When it feels like the world begins to stand still, people start to lose hope and, with time, it does. Since 1903, aircraft have allowed adventurers to reach inaccessible locations easily. Today, rockets do the same, but progress is slow. Adventure is fading away, and a replacement is urgently needed.

There is such incredible technology today to make leaps and bounds, but aviation never goes anywhere quickly. It is surely a rare priority to consider how to motivate young children to get excited when they get on a plane to go on holiday or see a rocket launch on TV. But that's where it starts for so many, an obsession with flying machines and men on the moon. A dream to boldly go where no one has gone before. That's where it begins and, all too often, where it ends.

The XB-1 test aircraft during its first supersonic flight

A world without adventure is difficult to sustain, so we must do our best to find other ways to generate excitement about aerospace pastimes, studies and careers. This starts with acknowledging the influence of excitement on the decisions people make at all stages of life and doing all we can to motivate that excitement accordingly. It is not the only problem we face, but it is nevertheless, one requiring care, attention and change.

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