LEONARDO TIMES

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

JWST

Remote Education
The final installment
Page 12

Airbus vs Boeing
A disputed history
Page 26

Leolabs
Tracking space debris
Page 28

Year 26 | N° 3 | Autumn 2021

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A WORD OF WELCOME

Dear reader,

Every year, the end of Summer and the start of the new academic year mark the transition to a new Editor in Chief. So let's start with an introduction! My name is Ties Rozema, I'm 22 years of age and I am excited to be Leonardo Times' brand new Editor in Chief. I have been part of the editorial team as an editor since 2020 and I am thrilled to take on the responsibilities that come with being Editor in Chief. I am a first-year MSc student in the faculty's Space Flight track and two of my hobbies are writing and journalism. For this reason, when Ranjan Gaur offered me to become his successor in late May of this year, my answer was a resounding "yes!" In short, my role includes all of the managerial and organizational tasks that come with writing and publishing this magazine. Rest assured that I will not stop writing articles in my new role, so you can be on the lookout for my name at the top of many articles to come! I look forward to writing and publishing new editions this year and I am excited to engage and spark a dialogue with you, the reader, about all the interesting content Leonardo Times has to offer.

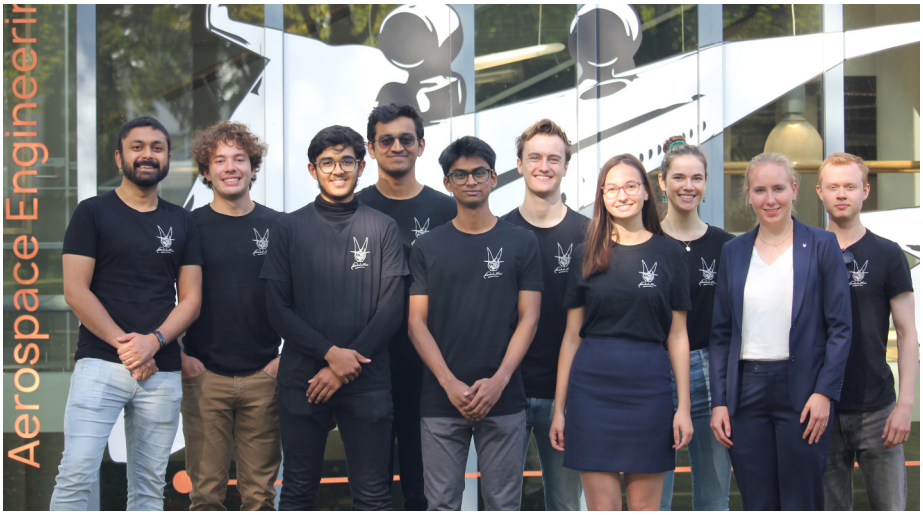
I am also glad to be joined by Roosa Joensuu, a second-year Aerospace Structures & Materials student, who will fulfill the role of Final Editor. In short, Roosa's role as Final Editor includes all the final stylistic and editorial tasks. Together, we form Leonardo Times' management team!

But this edition would not have come to fruition without a whole team of writing, researching and publishing students! This year, the editorial team has grown to 16 editors, ranging from BSc to MSc students across all ages. Without their enthusiasm, motivation and perseverance, Leonardo Times would simply not exist. It is a pleasure to work together with such a joyful team and it is truly inspiring to see a new edition come to life from scratch because of their efforts.

Additionally, my hat goes off to Penny Vossen and Raphael Klein, who form our team of hard-working external editors. Their help and expertise are instrumental to the success of every issue. Lastly, my gratitude goes to Ranjan Gaur for his help and guidance during the initial phases of our transition. During his time as Editor in Chief, his forever-lasting motivation and spirit were evident every day. It is my pleasure to be his successor, and I wish him well during his last efforts of writing his MSc thesis and beyond.

Last but not least, I thank you, our readers. There is no doubt that, without interested readers, Leonardo Times would not be what it is today. This issue again contains a number of original and interesting articles, which make for a captivating read. I can assure you that many new ideas are in the pipeline for the next editions, so stay tuned!

Ties Rozema, Editor in Chief



Last edition...

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CONTENTS

Aviation Emissions

The impacts of emissions from the aviation industry are complicated, but one thing is clear: their contribution to climate change is serious.

JWST

Planned for launch on December 18, 2021, the James Webb Space Telescope carries high hopes for its scientific contributions, as explained in this interview with instrument scientist Dr. Giovanna Giardino.

Airbus vs Boeing

After seventeen years of retaliatory import tariffs, the Airbus-Boeing has come to an end, potentially ushering in a new era of international cooperation

LeoLabs

In conversation with LeoLabs' Dr. Darren McKnight on monitoring and tracking the increasing amount of space debris in low Earth orbit.

DSE

A showcase of the designs from the annual spring Design Synthesis Exercise, the final project of the bachelor's degree.

COLOPHON

Year 25, NUMBER 3, Autumn 2021

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Coffee Dates

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The Coffee Dates provide you the opportunity to have a personal talk with a company over some coffee to ask all your questions. Companies select the students they want to get in touch with beforehand, based on your resume. The conversations will take place in a Coffee Bar like environment.

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The In-house Days are an excellent way to take a better look at the working environment of the companies you would like to visit. Often, the in-house day also involves a case to work on one of the daily topics of a company. Your resume will be sent to the companies of your choice, after which they will select the participants.

HOW TO JOIN

You can sign up via our website from the 3rd of January until the 16th of February 2022. Here, you can also find more information!

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A MESSAGE FROM THE BOARD

Dear reader,

First of all, let me express my gratitude to the editors of Leonardo Times for once again producing this remarkable edition. You keep inspiring your readers with a wide range of topics. It is a wonderful way to hear from the aerospace industry and to keep up with the undertakings of the VSV 'Leonardo da Vinci'.

The past year was all about thinking in terms of possibilities for our society. The COVID-19 pandemic has driven a lot of innovation in a short time and has made the role of the study association all the more important: to represent the students and to be there for them. Most of our classic events were operated successfully in a new form. Moreover, commendable examples of new initiatives are the VSV talk show livestream 'Aviation Beyond the Pandemic' that took place in June and the building kits of various aircraft models that were sent to every Aerospace Engineering student.

The way out of these special times remains interesting, but the new board has started with courage! On the 16th of September 2021, a new group of seven students was installed. Let me introduce to you from left to right on the picture above: Ties Hollander, Alune Greeve, Mariëtte de Groot, myself, Julius Caron, Lian Greijn and Maximilian Meijkamp. We welcome you on board for a fantastic journey together.

Events that are already planned are the Aerospace Diversity Day in December and the Space Symposium in March. Another exciting event will be this year's Studytour, which will travel intercontinentally, and a gala in celebration of our past lustrum.

Enjoy reading this edition of the Leonardo Times and I am looking forward to greeting each other in person!

With winged regards,

Stella Wessels
President of the 77th board of the VSV 'Leonardo da Vinci'

QUARTERLY HIGHLIGHTS

INSPIRATION 4 MARKS FIRST ALL-CIVILIAN SPACE MISSION

On Thursday, September 16, SpaceX's Falcon 9 blasted off from Kennedy Space Center's iconic Launch Complex 39A. Instead of carrying an ISS resupply or a large number of Starlink satellites, the Dragon capsule atop the rocket was carrying four space tourists — not professional astronauts. The mission, dubbed Inspiration 4, was fully privately funded by Shift4 Payments CEO and billionaire Jared Isaacman and aimed to raise awareness and money for St. Jude Children's Research Hospital in Memphis, Tennessee. Besides Isaacman, the other three occupants of the Dragon capsule were Hayley Arceneux, an assistant physician at St. Jude, Sian Procotor, a community college teacher, and Chris Sembroski, a Lockheed Martin employee who won his seat through an online lottery. After spending three days in orbit, Dragon successfully splashed down in the Atlantic Ocean, off the Florida coast. The mission's charitable focus has attracted a lot of media attention, and Netflix even released a five-episode series covering the mission called "Countdown: Inspiration4 Mission to Space."

For the first day of the Inspiration4 mission, there were a record-breaking fourteen people in space at the same time: four Inspiration4 crew members, three Chinese astronauts aboard China's Tiangong space station and seven professional astronauts aboard the ISS. The Chinese astronauts returned to Earth on Friday, September 17th. Following Jeff Bezos and Ricard Branson as the third billionaire to venture into space, Isaacman's fundraiser aimed to raise $200 million for childhood cancer research and surpassed that threshold after Elon Musk donated a generous sum after tweeting "Count me in for $50M".

WORLD'S LARGEST CO2-CAPTURING FACILITY BEGINS OPERATIONS

Swiss start-up Climeworks has begun operations of ORCA, the largest carbon dioxide (CO2) capture and storage facility in the world. On Wednesday, September 8, the carbon-capture plant switched on its fans for the first time just outside Reykjavik, Iceland. The plant is built near the Hellisheidi geothermal power plant, Iceland's largest geothermal facility, and Orca will run on zero-emissions electricity. Climeworks, which specialises in capturing CO2 from the air, has partnered with the Icelandic firm Carbfix, which specialises in storing that captured CO2 in the Earth, to run the facility and pump the captured CO2 down into the ground. ORCA, meaning "energy" in Icelandic, can store 4,000 tons of CO2 per year, equivalent to the annual emissions of around 790 cars.

ORCA is not only unique due to its high capacity, but also because it is the first Climeworks plant to permanently store captured CO2 rather than recycling it in greenhouses or selling it to producers of carbonated beverages. The capture and storage process works by first capturing the CO2 in so-called air collection containers, which use a fan to move air over carbon-capturing filters. The CO2 is then extracted from the filters, dissolved in water and pumped down to a depth of 750 m, where the water is heated by geothermal heat to ~250°C. This heated, carbonated water reacts with rock formations such as basalt to form solid carbonates within two years. These carbonates are stable over thousands of years and can thus permanently store CO2.

SOUTH KOREA'S HOMEGROWN ROCKET COMES UP SHORT ON MAIDEN LAUNCH

South Korea launched its first domestically-made rocket on Thursday, October 21 after almost nine years of absence in the launch business. The rocket, nicknamed Nuri, launched a 1500-kilogram dummy satellite with the aim of inserting it into a Sun-synchronous orbit from the Naro Space Centre at the southern tip of the Korean peninsula. The dummy satellite did not manage to reach orbit, however, after an unexpected premature shutdown of the rocket's third stage resulted in a velocity that was too low for orbit. It is common for first launch attempts to not go fully according to plan, with only a 30% success rate at first attempt.


YONHAP

South Korea is a relative latecomer to the global space development race and has recently increased its effort in its space program. A reason for this is that the country's rocket development program was previously subject to missile guidelines from the United States, which were abolished during a summit in May 2020. Nuri is developed by Korea Aerospace Research Institute (KARI) and all of its three stages are developed in-house. South Korea launched its first rocket, Naro, in 2013 but its first stage was built in Russia. Nuri's second launch attempt is already scheduled for May 19, 2022, and will attempt to reach the same orbit. South Korean President Moon said in a statement after the launch that the test launch of Nuri was completed and that he was proud of it. "Regrettably, we did not perfectly reach the goal, but we made a very creditable achievement in the first launch." South Korea aims to launch its first lunar orbiter next year.

BOEING EXPECTS 777X ENTRY FOR 2023


BOEING

Boeing commented on the expected entry into service of the 777X on October 20 during a media briefing ahead of the Dubai Airshow. The American planemaker now expects the 777X to be introduced in the fall of 2023, more than three years behind its original release date of June 2020. The comments came two weeks after Emirates President Tim Clark criticized Boeing for the delays of the programme, saying he wanted "another grown-up conversation" with Boeing over the delays of the twin-engined widebodies and warning that uncertainty in the delivery dates would cause significant disruption to one of the world's biggest carriers. Emirates is the 777X's largest customer with 115 orders.

The 777X is the latest addition to the 777-family and will boast greater cabin width, improved fuel efficiency and composite wings with folding wingtips. Originally launched in 2013, Boeing has struggled with the certification process of the 777X. The Federal Aviation Administration's (FAA) process of certifying the aircraft for commercial flight ran into a major problem on December 8 2020, when the plane encountered an "uncommanded pitch event" during a test flight. Given the similarity between this event and the cause of two deadly crashes of 737 MAX aircraft in 2018 and 2019, this has further delayed the FAA's certification procedure.

SPACEX'S STARSHIP BRIEFLY PAIRS WITH SUPER HEAVY BOOSTER TO MAKE WORLD'S TALLEST ROCKET

SpaceX's reusable Starship spacecraft was briefly mated with the Super Heavy booster on Friday, August 6. The 50-metre tall Starship SN20 ("Serial Number 20") was connected to the 70-metre Super Heavy at the SpaceX Starbase facility near the town of Boca Chica in Texas, US. Stacked on top of each other, the rocket stood 120 metres tall, making it the tallest rocket ever built. Placed upon the launch stack, the total height is 145 metres, taller than a 40-story building. For comparison, the largest ever flown rocket is NASA's Saturn V, which came in at 110 metres tall. The two huge, stainless steel rocket components were stacked for one hour to perform fit checks, after which Starship was lowered back down. SpaceX founder and CEO Elon Musk tweeted it felt like a "dream come true."

SpaceX is planning to conduct separate engine fire tests for both Starship and Super Heavy. Upon launch, the Super Heavy booster will boast a total of 29 Raptor engines which will produce enough thrust to lift 100 tonnes of payload into LEO. Before its first launch, however, the Super Heavy will first need to complete a series of engine and pressurisation tests. Starship's thermal protection system also remains to be fitted. SpaceX eventually wants to use Starship to provide flights between destinations on Earth at a fraction of the duration of air travel, to the Moon and, eventually, Mars.

DARE'S STRATOS IV MISSES LAUNCH WINDOWS

The Delft Aerospace Rocket Engineering (DARE) team has sadly not been able to launch their STRATOS IV rocket after four consecutive missed launch windows during their launch campaign at El Arenosillo Test Center (CEDEA), located near Mazagón in Spain. After three years of designing, building and testing, the team travelled to the rocket launch site to perform the launch of the fourth version of DARE's flagship project. The goal of the 8-meter tall STRATOS IV is to break the European altitude record, which is currently set at 32.3 kilometers, with a rocket fully designed and built by university students. After missing their final launch window on Saturday, October 23, the team had no other choice but to return to Delft with STRATOS IV.

Most of the problems that prevented the launch were related to the ground systems on the launchpad, which the team had not been able to test before the first launch window. The reason for the lack of a fully integrated test of all the ground systems was limitations to the team's early travel schedule due to COVID restrictions. This meant that, even though the rocket was ready and functioning normally, the launch attempts were hampered by problems on the ground. The main issue with the ground systems that the team encountered was a misbehaving filling arm, which is used to load the rocket with the oxidiser before launch. This arm is disconnected remotely and therefore has a specific quick disconnect coupling. This coupling failed and attempts to replace it with a spare were unsuccessful. The team's hypothesis was that the coupling contained a possible internal leak, but this issue could not be solved on location. During the final launch window, it was technically possible to fill the rocket at a reduced rate by allowing the arm to leak but, despite favorable weather conditions, the team was not confident that this would lead to a safe launch attempt. A unanimous decision was made not to proceed since safety is the team's top priority. DARE's goal remains to launch the rocket, even though the next launch opportunity remains unclear.

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STEM education, tomorrow

A conversation with an expert

Filippo Oggionni, Roosa Joensuu, Editors Leonardo Times

Following an article about remote education published in the last issue of this magazine, we talked about the same topic with Aldert Kamp, an expert in the field of higher engineering education. Starting from the pandemic, he shared his insight about the future with the Leonardo Times.

Aldert Kamp is the former Director of Education at the Faculty of Aerospace Engineering (TU Delft). He covered this role until 2020 when he had to retire. He was also one of the leaders of 4TU Center for Engineering Education, the federation of the four technical universities in the Netherlands. For the past six years, he has been involved in rethinking the future of engineering, science, technology, and society. He has attended several educational conferences, he is a member of international educational networks, and he has travelled around the world to learn about the current trends in strategies and practices used for teaching higher education across various countries. Particular attention is devoted to STEM (Science, Technology, Engineering, and Math) disciplines. In his own words: "I have been trying to find ideas on how we would have to change our education to match the future".

Mr. Kamp has also published two books on these topics ("Engineering Education in a Rapidly Changing World" in 2016 and "Navigating the Landscape of Higher Engineering Education" in 2020). The original purpose of the first book was to draft a vision for the Master's Degree in Aerospace Engineering. Mr. Kamp thinks that, while the world has changed drastically in the past two decades,


ALDERT KAMP

the programme has not evolved accordingly. "It was for me the trigger to start", he says. While the book does not provide real answers, it gives many ideas of what is going on in the world of higher education for STEM: he wrote it "with the goal of being inspirational". The second book is more about giving directions on how to introduce innovations in educational programs. The pandemic has been an accelerator for this process: we asked him about how that played out at the Aerospace Engineering Faculty at TU Delft in October 2020.

HOW THE AE FACULTY REACTED TO THE PANDEMIC

Mr. Kamp believes that the AE Faculty has done a great job in adapting to the pandemic, thanks to a flexible and hard-working staff. According to him, pre-recorded lectures were not appreciated much by the students, yet they were willing to adjust to them during the first wave, as everything had to be changed so rapidly. In his view, a combination of pre-recorded lectures with more interactive sessions worked much better; in addition, moderated courses, where moderators collect questions from students and forward them to teachers, were much more effective. However, he admits that "from September 2020 onwards the students will have higher expectations because more time has passed".

Mr. Kamp points out two major problems: the necessity to learn the engineering discipline through practice and the absence of teamwork in remote education activities. "Students cannot learn engineering from a book," he states, adding that "engineering is a very social activity. Many engineers are not aware of that, but once you are in the professional environment of the industry, it is all teamwork." He thinks we are lucky to have so many options to collaborate online, but remote collaboration is still very different from collaborating in person and we are not yet prepared for it.

REMOTE INTERNSHIPS

Mr. Kamp also spoke with Miranda van Haagen, Head of the Internship Office in the Faculty of Aerospace Engineering. "Internships are very valuable because students can get out of the academic environment, their cocoon. Students can enter a completely different environment, a professional world with different ethics of work. During the lockdowns, they are just sitting behind their screens, doing some work for companies, and that is not the same", Mr. Kamp says.

Kamp's opinion on remote internship is twofold. In the first place, he believes students are forced to learn new skills because of the pandemic. "As a student, you suddenly have to work with all kinds of new software tools and were thrown into a new way of learning, but you are discovering how to be flexible and resilient. These skills of agility and resilience are very valuable in today's volatile and uncertain world." In the industry, like at university, projects sometimes get cancelled or the requirements suddenly change. As a spin-off of the lockdown, students are learning to deal with that, even if they are not aware of it. According to Mr. Kamp, they are learning more of those aspects than previous generations of students.

"In the Industry 4.0, many companies are expecting, irrespective of Covid, to have more people working remotely; sometimes even having teams of people joining remotely from different countries. Online collaborative skills are essential in the modern world. They can for instance be learned in teams that are collaborating remotely together. In that sense, students of today might be more prepared for the new way of working in such an industry," he adds.

The negative aspects of remote learning without opportunities to meet in person, according to Kamp, will depend on how long this situation will last. While first-year Bachelor's students have a very poor start, detached from the university, they have time to catch up, Master's students could get their degree almost entirely remotely. "It does not sound great to me, I do not know what it will mean. It is difficult to say what companies think about the proficiency level of graduates that have hardly experienced the real academic study of environment", Mr. Kamp specifies.

THE NECESSITY OF A PHYSICAL SPACE

After asking Mr. Kamp what keeps us in lecture halls, he then referred to relevant studies on this topic. These conclude that university students mainly learn during the time they spend outside the classroom. He also cited an article by professor Govert Buijs and rector magnificus Mirjam van Praag from

the Vrije Universiteit Amsterdam, who believe that purely transferring knowledge through online means is not so difficult to do, although it is certainly not ideal. What is missing, according to van Praag, is the human factor. This is necessary for the personal and professional development of students. "That is something that you can hardly substitute by online means", Mr. Kamp confirms.

Mr. Kamp is particularly concerned about the people who have started their studies in September 2020. They do not know anybody in the city and they have no way to know how TU Delft works or how to work together with students here. He adds: "Their whole social environment is missing, which makes it very difficult". He has doubts about the strengths of friendships and social connections developed solely via online means. "Where can students catch up on those skills of working together, collaborating, understanding each other, expressing empathy, and reading the body language? It is almost impossible to observe that on a screen", he adds. He believes that young people from Generation Z live their lives online. As a downside, he thinks the same people have weaker social skills in communication. Therefore, students have to improve those social skills in their academic studies, but this has been very difficult lately due to the pandemic. "It is very challenging to develop some form of emotional intelligence in a remote setting", he concludes.

Some proposed to extend the study duration by half a year to focus on gaining those social skills, something that Mr. Kamp finds a very interesting proposal. In practice, it would mean giving study "vouchers" to young graduates who can come back to the university when Covid is over, so that they can learn and improve on those personal and social skills that the pandemic prevented them from assimilating properly.

CAN ONLINE TOOLS HELP DEVELOP THE HUMAN FACTOR?

Mr. Kamp thinks we have been very lucky to have this Covid pandemic now and not ten years ago. Back then, the technology of online collaboration systems was not mature enough: "Everything would have collapsed", he adds.

Mr. Kamp hopes that new technologies, such as virtual and augmented reality, will enable a more in-person experience than what we have right now. He refers to examples, like Airbus and Shell, where three to four people can physically sit around a table, while five or six other people join the table from remote locations by being projected on the table (they are not 3D holograms yet, but only projections). However, it is not yet known how long it will take for these technologies to develop and become widespread. Developments go fast, so these technologies may enable remote meetings soon.

Nevertheless, Mr. Kamp wants to stress the importance of the human factor even in engineering disciplines, regardless of the pandemic: "What really is the most important aspect to me is how the students learn to collaborate, to appreciate each other, and to have empathy for each other. This is also my plea for the future." Looking again at the future, he believes Artificial Intelligence will take care of an increasing number of cognitive tasks that are now among the responsibilities of engineers. He believes that, maybe already in 10 years from now, every engineer will have a virtual assistant on his shoulder, who is constantly looking at what the engineer is doing: "Every now and then it will whisper: 'You are designing is not good, I have found a better design'. If you extrapolate this scenario further into the future, you have to ask yourself: 'What is still the uniqueness of an engineer of flesh and blood?'" Mr. Kamp believes it is the human factor - the collaboration, the sharing of experiences, and the ability to bring knowledge from one context to another. All of this is something that artificial intelligence will not be able to do in the coming ten, twenty, or even thirty years. "I think that learning these kind of competencies will therefore become more important than the learning of theoretical concepts and theories", he concludes.

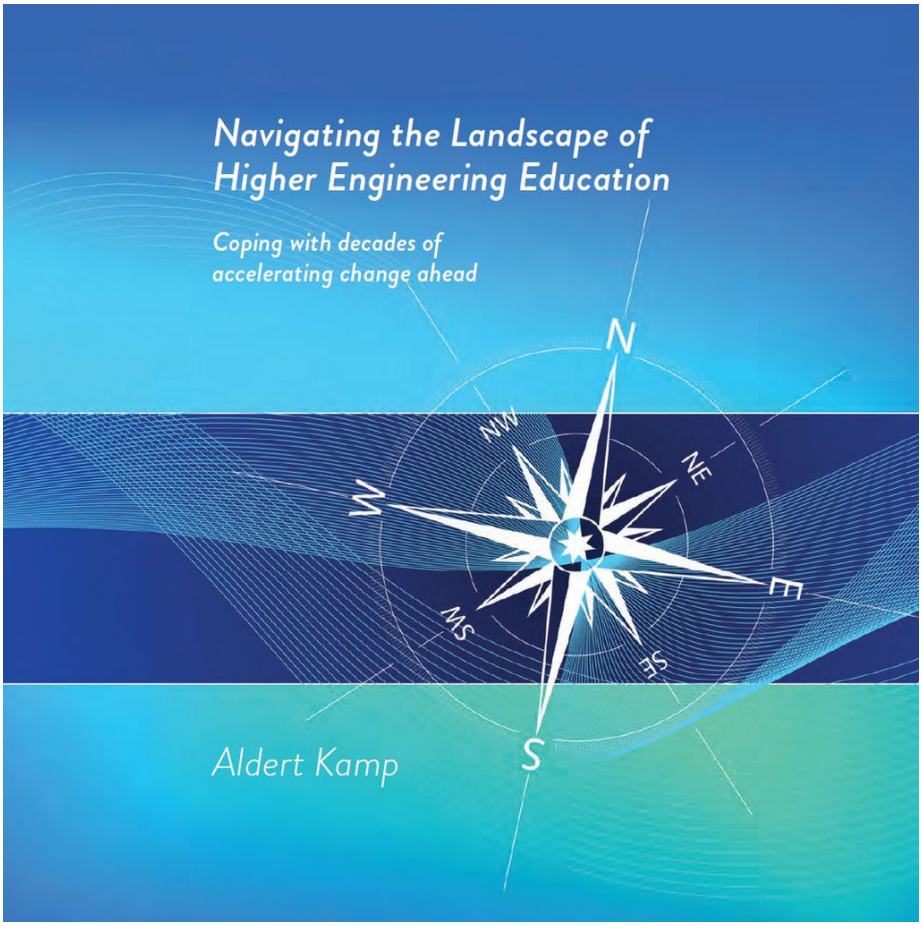
THE FUTURE OF HIGHER ENGINEERING EDUCATION

The faculty staff has been working on the "Master's vitalisation project". In this regard, Mr. Kamp proposed to have a significant but flexible module in the Master's curriculum that students can fill in with courses, training, extended thesis, or internship, to develop themselves professionally and personally.

Nevertheless, he doubts that the pandemic will function as an accelerator in the case of higher education: he expects that the academic staff will keep their focus on academic excellence, which is about the development of knowledge rather than people.. "You are learning a lot of knowledge, research skills, and design skills, but too little of developing yourself as a person. This aspect is suffering in the current situation of lockdowns and staying at home even more than ever. Generally, the faculty and the university are doing a fabulous job in teaching - they bring it forward and do the best they can."

Acknowledgements: we would like to thank Aldert Kamp for conceding us the interview.

Note: this interview was originally held in October 2020. Its content has been updated by Mr. Kamp and by the editors to reflect the changes occurred between the interview and its publication

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JET-LAGGING BEHIND

An overview of aircraft emissions and how they affect our environment

Varum Gottumukkala, Leonardo Times Editor

FPP

It is a well-known fact that aircraft have a significant environmental impact. Our climate is suffering while the demand for air transport rises. For this reason, the aviation industry must find alternatives to its current means of propulsion, which is not environmentally friendly.

While most of the world's largest emitters, such as power production and road transport - have scalable decarbonization solutions, the aviation sector is yet to find a breakthrough on that front. Global aviation accounts for 2.5% of Carbon Dioxide (CO2) emissions and 1.9% of total greenhouse gas emissions. These numbers are expected to rise given the growth of the sector and its relatively slower rate of decarbonization. [1]

Greenhouse gas emissions are in the spotlight due to their warming effect – these gases trap heat radiated from the Earth leading to increased surface temperatures. A quantifiable measure of this warming effect is called the Effective Radiative Forcing (ERF), of which 3.5% is attributed to aviation. Radiative Forcing (RF), usually expressed in W/m^2, is the net change in the energy balance of the Earth system caused by perturbations in the atmosphere. The 'forcings' refer to the climate response due to the presence of pollutants. However, Effective Radiative Forcing is a better metric to measure the warming effect of aircraft emissions, as it also accounts for rapid and short-lived fluctuations in the atmosphere. A positive value for the ERF of a chemical species indicates a resulting net increase in energy per unit time and area. This is directly proportional to the warming effect that the chemical species has on the Earth. [1, 3, 4, 5]

Aircraft emit numerous pollutants during all stages of their flight. The pollutants can have warming effects on the planet or lead to poor air quality. During the combustion process, these exhaust emissions are produced due to the oxidation of carbon in the fuel and the formation of other compounds. Carbon Dioxide (CO2) draws the most attention as an emission because it has been the highest contributor to climate change between 1750 and 2011 as measured in radiative forcing units [W/m^2]. Due to being chemically inert, CO2 lingers in the atmosphere for centuries, far longer than its usual partner in crime, the pollutant nitrogen dioxide (NO2), which is removed in decades. CO2 is a common product of the exhaust species of a combustion engine and has the second-highest share of aircraft emissions by mass, after water. [2]

NO2 is a pollutant emitted in smaller amounts than CO2 but can be much more potent. The effect of NO2 is often extended to the broader group of highly reactive gases known as Nitrogen Oxides, referred to as NOx. The effect of NOx on the atmosphere is dependent on the altitude at which it is released. NOx emitted at higher altitudes is significantly more detrimental to the local atmosphere. Unfortunately, for economic reasons, aircraft fly at these high altitudes and account for 3% of global NOx emissions. The NOx emitted near the surface of the Earth is removed by rainfall within days, while the NOx emitted at higher altitudes resides in the atmosphere for much longer and contributes to the breakdown of stratospheric ozone, which absorbs ultraviolet radiation from the sun. A study suggests that the RF of Earth's

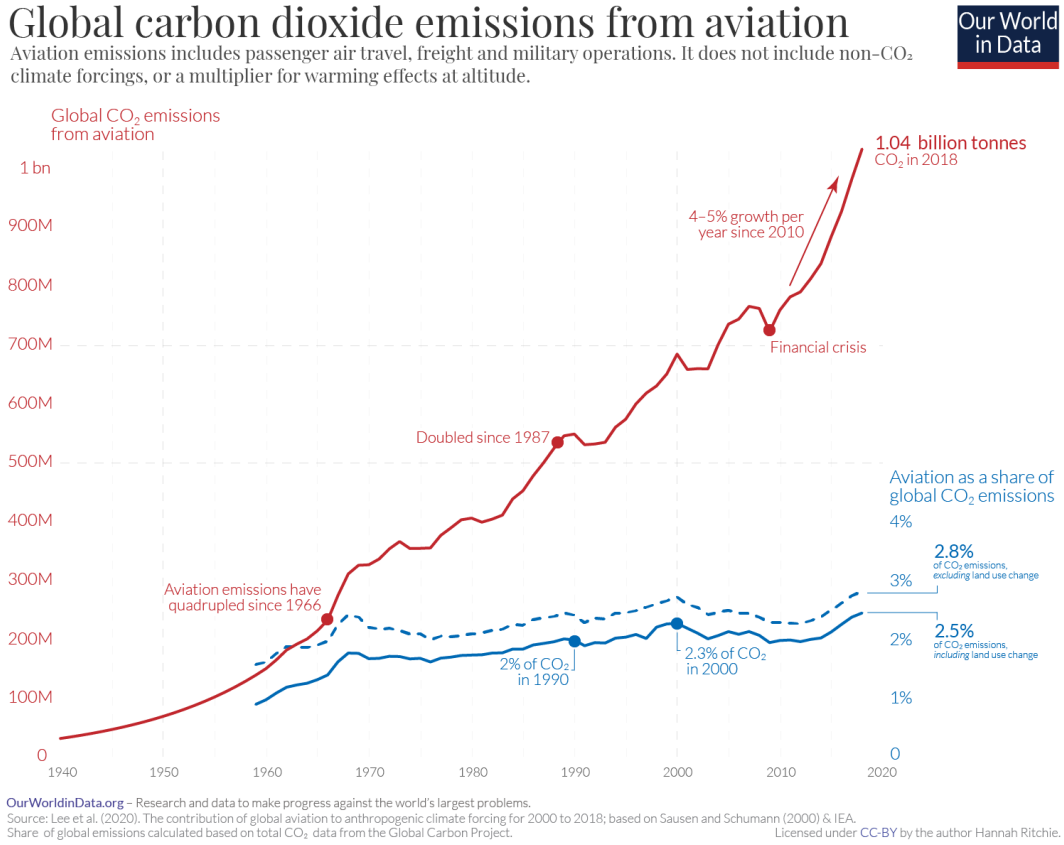


Figure 1: The growing aviation industry has increasing CO2 emissions.

surface temperature is 30 times more sensitive to aircraft emissions of NOx than surface emissions of NOx. While the sheer mass of CO2 emitted is much higher than NOx, the individual NO2 molecule can be about 100 times more damaging. NOx also functions as a precursor to the production of Ozone (O3), which is harmful to human health when emitted close to ground level, with an estimated 8600 premature deaths annually caused by aviation-attributed ozone. [2, 6]

A pollutant that often goes under the radar is water (H2O). It is the most effective greenhouse gas, but this goes unrealised due to it's movement weather cycles. However, it is the cause of the distinct trails left in the wake of high-flying aircraft. As a product of the combustion of Kerosene, H2O is emitted in the form of steam and rapidly freezes to produce clouds at high altitudes. These trails of condensation (contrails) remain in the wake of aircraft for hours and reflect thermal radiation back to Earth. The artificially created cirrus clouds known as contrail cirrus, although relatively short-lived, have a significant positive RF effect. [3]

Hydrocarbons (HC) and Carbon Monoxide (CO) are pollutants mainly emitted near the ground and contribute to warming in several ways. HC are unburned fuels, a consequence of jet engines not being fully efficient. They produce ozone and reduce the concentration of OH in the atmosphere, which increases the lifetime of methane, another greenhouse gas. Furthermore, HCs are eventually converted to CO2 and water vapour, two of the most effective greenhouse gases. [2]

Pollutant	Commercial aircraft emissions (10^3 tonnes/annum)
CO2	125000
CO	271
NO2	1625
HC	141
H20	169000

Table 1: Total emissions from commercial aviation

Carbon Monoxide is an intermediate product – all compounds containing carbon are first converted to CO when combusted in the presence of oxygen. With sufficient oxygen, most of the CO is oxidised to CO2, but

Operation phase	HC (g pollutant/kg fuel)	CO (g pollutant/kg fuel)	NOx (g pollutant/kg fuel)
Take-off	0.25	1.1	19.1
Climb	0.30	1.2	14.3
Approach	0.64	2.9	6.7
Taxi/Idle	2.02	12.5	3.2

Table 2: Pollutant emissions across operational phases

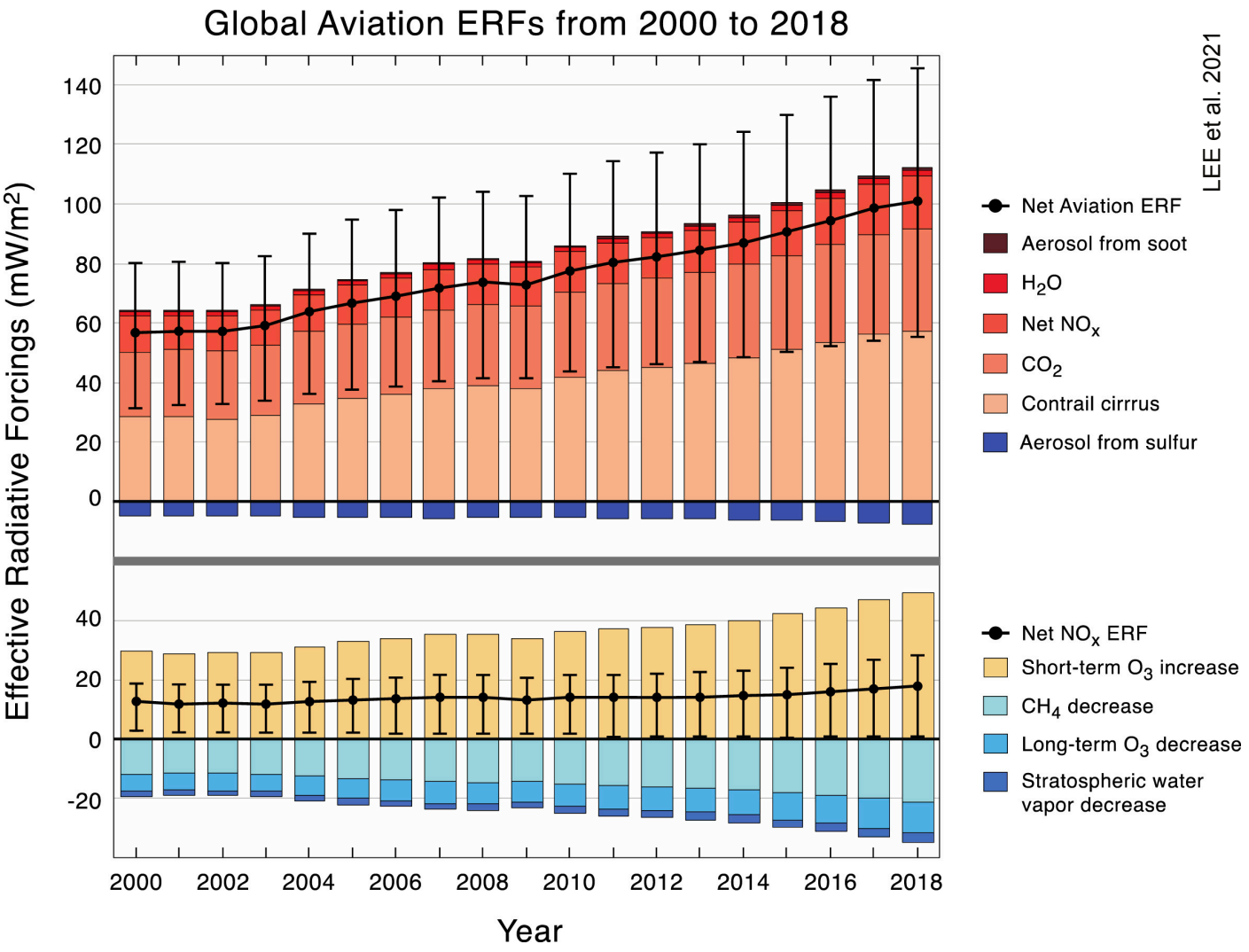


Figure 2: Timeseries of calculated ERF values and confidence intervals for annual aviation.

this is not true when engines are not running at full power. While not a major pollutant, CO emissions are high when the aircraft is on or near the ground and has detrimental effects on human health when inhaled. The presence of HC and CO indicate a loss in combustion efficiency in aircraft. [2]

The kind of pollutants emitted by aircraft depends on the stage of their flight. Aircraft engines are at their maximum possible efficiency while operating at full thrust. When taxiing or remaining idle, the amount of HC and CO emitted per kg of fuel increases by around 10 compared to take-off, when the engine operates at maximum power. For this reason, limiting the amount of time aircraft are operational on the ground is crucial to reducing emissions. Table 2 gives an overview of the number of pollutants emitted during the four main stages of flight of a Boeing 737-100. Better Air Traffic Control efficiency also increases fuel efficiency by reducing time aircraft queue on the ground and in the air. Due to excessive traffic, the flight crew is unable to tell beforehand whether the optimal flying altitude can be reached or not, leading to airlines adding additional contingency fuel, which is burnt simply to carry the extra fuel. [2]

One of the technical factors that influence fuel efficiency is the airframe design. The largest contributors to aviation emissions are single-aisle (SA) and twin-aisle (TA) aircraft - both have seen steady improvements in their structural design. A useful measure of aerodynamic efficiency is the Lift-to-drag ratio. Throughout the decades, a bigger and faster improvement in this ratio is shown for TA aircraft rather than SA aircraft. This difference can be attributed to the two most common SA aircraft, the B737 and the A320 - both designed decades ago. Since their introduction, only small incremental changes - such as the addition of wing-tips - have been made to their airframe design, preventing any significant improvements. However, evidence shows that the L/D of TA aircraft is approaching a plateau. Further improvements will require non-conventional aerodynamic designs, as engineers have extracted as much performance as they can from an airframe design that has remained largely unchanged for decades. [3]

The fuel consumption per passenger per kilometre has reduced at an average rate of 1.3% annually since the dawn of commercial aviation in the 1940s. Since then, aviation emissions have increased almost sevenfold, but air traffic volume – measured as the total distance travelled by paying passengers – increased almost 300-fold. A major reason for rising fuel efficiency over the years is due to the increase in the passenger load factor, which measures the extent to which an aircraft is filled. The average passenger load factor increased from 61% to 82% from 1950 to 2018, a sign of the sector's growth. [1][7]

It is uncertain what the future of aviation holds. While there are plans to increase efficiency by designing novel aerodynamic structures, that solves only part of the problem. An alternative energy source must be found, and whether that leads to future aircraft powered by hydrogen, biofuel, or batteries is yet to be known. Airlines are only concerned with increasing fuel efficiency to drive up profits – it is not in their interest to limit the kinds and amounts of pollutants that result from these changes. Therefore, it is essential to have legislation that pushes airlines and aircraft manufacturers to control emissions. The aviation sector may be lagging in the race to decarbonize, but we can expect rapid innovation as it strives to meet the ambitious climate goals. To learn more about the latest aviation climate policies imposed by the EU, read the next article.

REGULATING EMISSIONS

From current means to future solutions.

Roosa Joensuu, Leonardo Times Final Editor

There are various international regulations in place to limit the emissions of the aviation sector. This article helps to navigate the maze of current and future European aviation emission regulations.

The aviation sector is implementing more sustainable technologies aimed at reducing its emission. Fuels based on organic waste are gaining market shares, small aircraft powered by electricity are gaining market popularity, and the next big step in aviation could be engines powered by hydrogen.

Apart from technological advancements in aviation and beyond, political decisions are also being made to impose the transition to more sustainable practices. The seventeen Sustainable Development Goals (SDGs) are in place, the European Green Deal has been implemented and there are various other plans to achieve emission reductions in different industries. However, it is sometimes difficult to see the complete picture in this globalized world with both national and international authorities. What exactly are the current regulations on the aviation emissions, and what can we expect to see in the future? Focusing on Europe, this article will answer the questions with a breakdown of the actions that are currently in place and the plans that the European Union (EU) has made to reach its climate targets.

ICAO AND CORSIA

On a global scale, the aviation sector is overseen by the International Civil Aviation Organization (ICAO). The organization has set many strategies to make aviation safer and more sustainable. One of the main aspirational goals of ICAO is to achieve carbon-neutral growth in the sector from 2020 onwards. One of the main strategies to reach this goal is by using a programme called CORSIA, which stands for Carbon Offsetting and Reduction Scheme for International Aviation. CORSIA aims to offset international aviation CO2 emissions according to the carbon-neutral growth goal. [1]

It means that the operators included in the CORSIA scheme are required to buy carbon credits according to their respective offsetting requirements. In the carbon market, the emissions can be purchased from various projects that have achieved an equivalent emission reduction. The offsetting requirement for an operator is calculated by considering the operator's annual emissions and a growth factor. The latter is based on the emission trends within the sector and the emissions from the operator. [1]

The CORSIA scheme is now in its pilot phase until 2023. Participating in this scheme is voluntary until 2027. However, all ICAO member states with international flights are already required to "monitor, report and verify the CO2 emissions" from these flights. [1]

EU AND ETS

The European aviation sector will be soon affected by one of the biggest political decisions regarding emissions. The European Emission Trade System (ETS) has been in place for years now, but there is a proposal to change the practices and to increase the

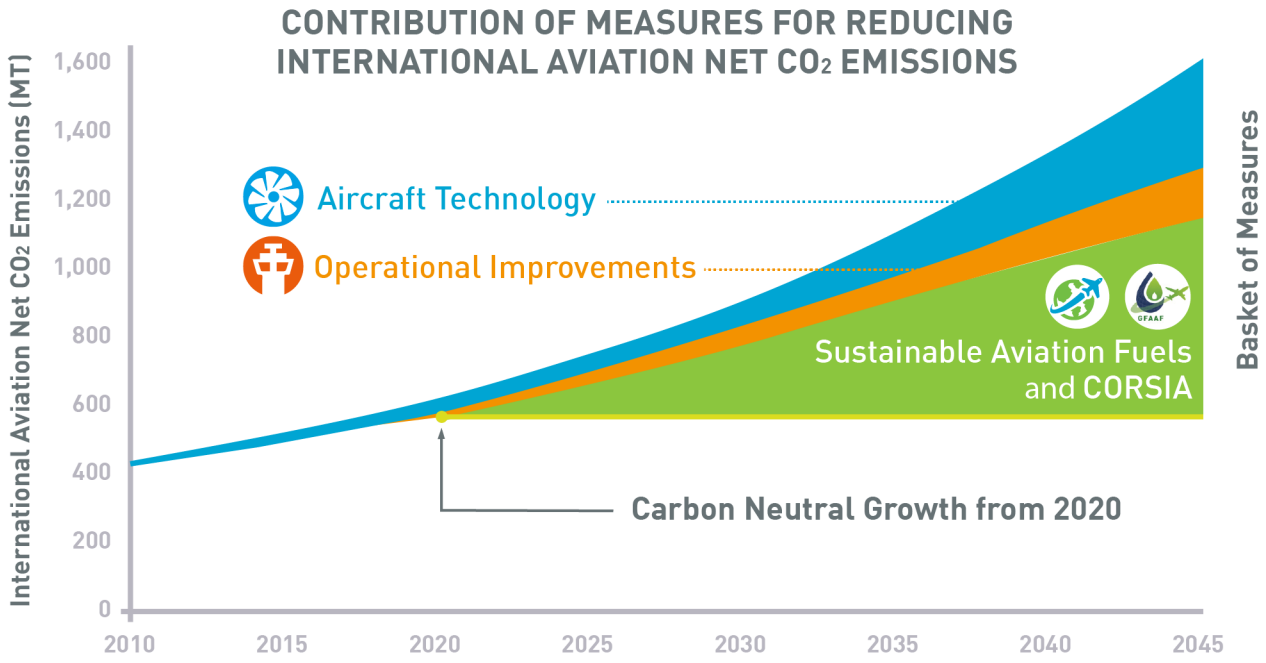


Figure 2: ICAO carbon neutral growth plan.

share of carbon emissions that the aviation sector must offset.

The ETS has included aviation since 2012. So far, the operators have been required to buy emission rights for only 15% of their emissions, while they have received 82% of their emission rights for free. The rest has been set aside as a reserve. To balance the ETS with the global-scale CORSIA, the system has only covered flights within the European Economic Area. [2]

However, the current directive is only applicable until 2023. If no amendments are added before this, the ETS regulations on the aviation sector will extend to flights to third-party countries outside the European Economic Area. It could lead to double counting of emission credits, where one credit could be used to prove compliance to multiple emission mitigation targets. In this case, a reduction of emissions would be registered both under the CORSIA and the EU ETS program, thus totalling double the emission reduction that was actually achieved. [3]

For this reason, in the current EU proposals, continuing the separation of the two schemes is seen as the preferred option. The EU ETS is recommended for flights departing and landing within the European Economic Area. Additionally, the EU wants to show support towards a global emission reduction scheme such as CORSIA and wants to ensure its correct implementation within the European Union. [3]

For flights within the EU, the free allocation of emission credits is expected to come to an end. There are suggestions of phasing out the free allocation within a few years, but the phase-out rate still needs to be decided upon. It seems likely that by the year 2030, all the 82% of currently free emission rights will have to be auctioned instead. [3]

ENVIRONMENTAL DUE DILIGENCE

The European Parliament and the European Commission are working towards mandatory due diligence for supply chains, focusing on environmental and human rights issues. Big companies in Europe have international supply chains that are not always regulated and monitored up to standards because of their geographical complexity. To minimize the negative impacts of company operations on local communities and the environment, a European due diligence framework could be adopted. [4]

This legislation is not directed towards the aviation sector only, at this stage, it is for all industries. The due diligence legislation would require companies to monitor and report the environmental impacts of their operations and supply chains. The set-up of such a procedure is not known yet. Whether the companies could be held accountable for their impacts is also a question yet to be answered. This legislation could be particularly important to the aviation sector when considering raw materials and fuel suppliers. [4]

These are not the only efforts towards more sustainable operations within the industries. Another proposal on Sustainable Corporate Governance is also on its way. This proposal aims to make long-term sustainability objectives more attractive to companies than short-term financial performance. This legislation could affect the corporate social responsibility requirements. [5]

ADDITIONAL STEPS

The decarbonization of the aviation sector is a complex challenge that requires more action than carbon offsetting schemes. Other urgent changes are needed to meet the carbon-neutral growth goals. This issue is recognized at EU level too. As a consequence, the Commission is supporting the shift towards alternative fuels. There is a proposal called ReFuelEu Aviation to incentivize the use of sustainable aviation fuels over kerosene. The EU wants to ensure that the policy decisions are in line with the developments of CORSIA. [3]

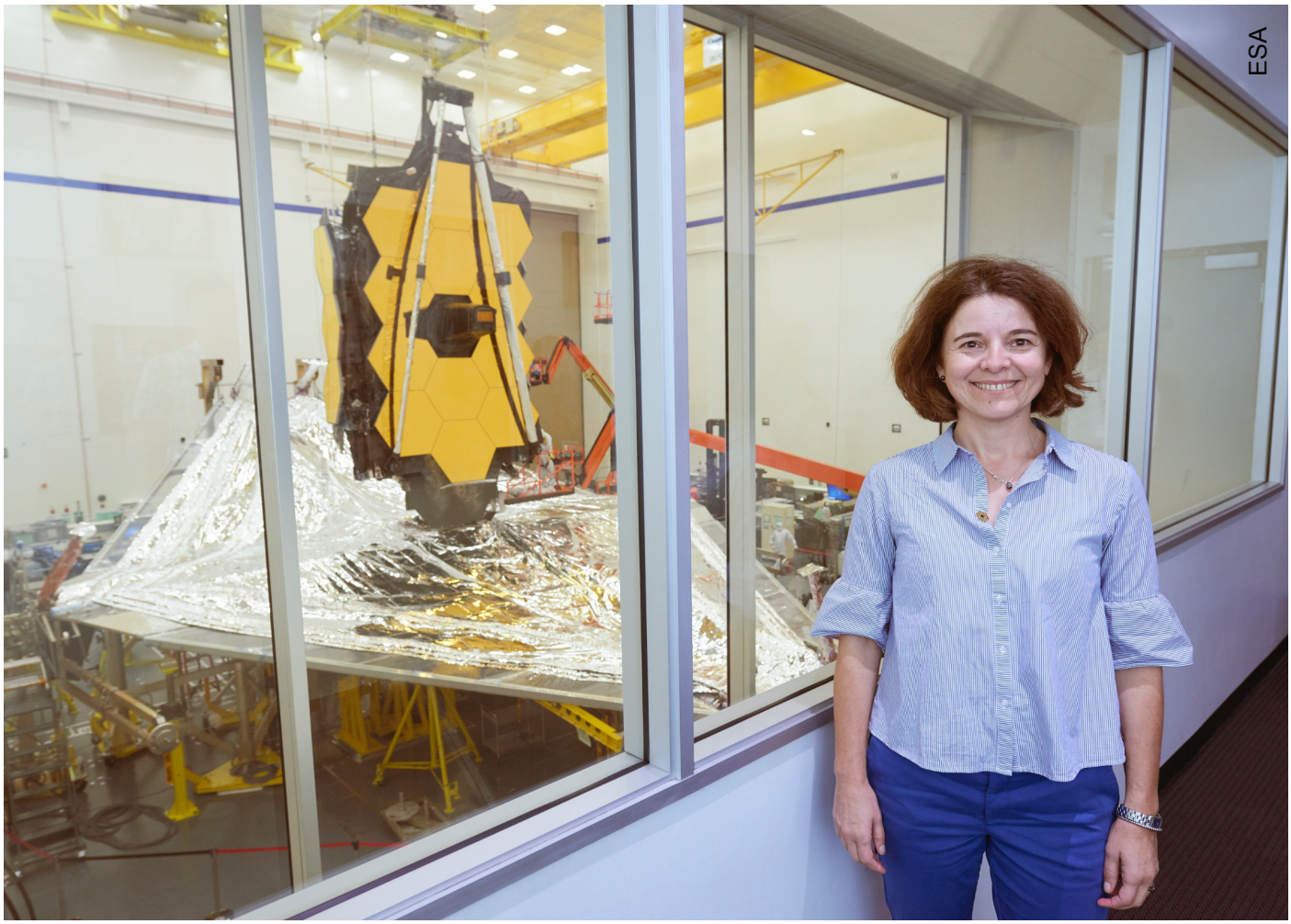
It has also suggested that some of the revenues from emission trading schemes go into developing sustainable technologies. This, in turn, could reduce the price of sustainable aviation fuels, making them more attractive to operators or boosting the development of hydrogen aircraft. [3]

As conclusion one should not forget that decarbonizing the aviation industry is a challenge that should be tackled by many parties, from both technical and political directions. The European Union shows keen initiatives towards reducing the social and environmental impacts, not only in the aviation industry but in all industries. Now, we should not sit back and relax while the legislative proposals are processed. Instead, we should continue with our efforts of making the sector more sustainable and prepare for the future.

LOOKING BACK IN TIME WITH JWST

In conversation with Dr. Giovanna Giardino, instrument scientist on the highly anticipated James Webb Space Telescope.

Naomi Lijesen and Ties Rozema, Leonardo Times Editors



The Leonardo Times sat down for an online interview with Dr. Giovanna Giardino to discuss her role in the development of the James Webb Space Telescope (JWST). Generally considered the successor of Hubble and the most versatile space telescope to date, the JWST is set to launch from French Guiana on December 18, 2021.

Dr. Giovanna Giardino has worked with ESA for the past 20 years as a part of ATG Europe, which is a Dutch consultancy based in Noordwijk, Netherlands. Dr. Giardino studied physics at the University of Milan and took a graduate degree in radio-astronomy at the University of Manchester. She then returned to Milan for her PhD in physics, followed by a postdoctoral position at ESA. Her professional career began at ESA with working on the Herschel & Planck mission, which launched in May 2009. Herschel was the largest infrared space telescope to date. Dr. Giardino worked on the Planck satellite, a satellite with instrumentation for the observation of the Cosmic Microwave Background. Following the launch of Herschel & Planck, Dr. Giardino transferred to the JWST mission in 2010.

The James Webb Space telescope is a so-called general-purpose observatory. This means it is a telescope with a variety of instruments on board, allowing it to be very versatile. As well as observing the early universe and studying exoplanets, JWST will be used to observe many different types of astrophysical objects, including planets and moons within our solar system. For example, scientists also try to confirm whether there is water on the moons of Saturn and Jupiter with JWST's data.

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

Q: Dr. Giardino, good morning! Thank you for taking the time to meet with us today.

GG: Good morning to you - I am delighted to talk to you too. I can imagine your excitement to write an article about JWST since we finally have a launch date now! The launch will take

place on December 18th, 2021 - we have all been waiting a long time for this announcement!

Q: Your contribution to JWST has focused on the NIRSpec instrument. Can you explain how it works and what the main challenges were in designing it?

GG: NIRSpec, as the name suggests, is the Near-Infrared Spectrograph. It is ESA's fundamental contribution to JWST regarding the telescope's instruments and was commissioned to Airbus D&S to develop and build. The spectrograph will be used to study stars and galaxies and derives data on the pressure, temperature and elemental make-up of those objects. One of the drivers for NIRSpec is to observe and investigate the youngest stars and galaxies in the universe, which are very faint and far away. NIRSpec's novelty is that it is the first multi-object spectrograph in space, capable of acquiring the spectra of many galaxies or stars simultaneously. NIRSpec contains a number of novel elements. A very important novel element is the micro-shutter assembly. This assembly contains four arrays of 250,000 tiny shutters approximately the same size as a human hair. This technology had to be developed from scratch. The main challenge was to design it so that it would perform at cryogenic temperatures (down to -230°C). The shutters have to be structurally stable at those low temperatures. Another example of state-of-the-art technology are the instrument's detectors. The detectors, or the chips that record the infrared light, are crucial to any instrument's performance. NIRSpec's detectors are reliable and extremely low-noise because they have to observe very faint objects. The detectors are cooled to -230°C to minimize the noise, but that brings along a new set of challenges. Because of these low temperatures, testing, in general, can be challenging. We place the instruments in a cryogenic chamber and operate them as if they were in space. We have to reproduce the conditions in space - which requires light sources that can reproduce the starlight. It is a crucial phase of the development, and can be very challenging.

Q: The JWST is a longly anticipated project. What is it like for you and your team to spend so many years in suspense of the data gathered by the instrument you have designed?

GG: In 1990, Hubble was launched and immediately the question arose: "What is next?". Naturally, the answer was "bigger is better"! The first proposals of the JWST began in the early 2000s, with initial manufacturing starting around 2005. So it has been in the works for decades. It can be both frustrating and exciting. The Herschel & Planck mission lasted ten years for me, while JWST even longer. Once you begin working on large and challenging science projects, you soon understand that they take a lot of time to design and manufacture. Luckily, there are also very interesting aspects during the design, manufacturing and testing stages. In general, we do not have to wait until the telescope is operating in space for exciting moments in our work. Perhaps, though, it is fair to say that for scientists, such as myself, the wait feels longer than for the engineers, for whom the achievement is in making the hardware work. We, as scientists, yearn to see the telescope working in space to obtain the data it was designed to procure. Extra frustrations surrounded JWST due to the numerous delays, though this also led to more improvements and better preparations. When preparing ourselves for the launch in 2019, we felt like we still had much to do. Now, we definitely feel more prepared, although there is always room for improvement, of course!

Q: What evidence do you personally hope to discover most eagerly, and what data would you be most excited about?

GG: The first is evidence and data describing the composition of early and first-generation stars. Elements heavier than hydrogen and helium are 'cooked' within stars, so astronomers believe there should be evidence of stars with hardly any of these heavier elements. Such an observation would add a missing piece in the puzzle of the formation of galaxies.

The other discovery I look forward to has to do with the Webb telescope's ability to probe the atmosphere of exoplanets. Using NIRSpec, scientists will be able to analyse the composition of these exoplanets' atmospheres. It will be particularly exciting to observe terrestrial-like planets within the habitable zone whose atmospheres possibly contain water and/or oxygen. As you can imagine, it could give us an idea to what extent life on other planets is possible and where it may be. Personally, I see these as the most exciting potential discoveries. Both topics require a lot of sensitivity and therefore observing time. However, if everything goes as planned with the launch and the functionning of the JWST, I predict we can expect some major advancements in these subjects.

Q: Critics of the project have argued that the budget overruns and numerous launch delays have wasted taxpayer money. What would be your response to this?

GG: This is an interesting question. There are two ways of looking at it. Firstly, our experience shows that basic scientific research -, from particle physics to astrophysics - ultimately drive many advancements in technology. People push for technological solutions when faced with fundamental challenges. To observe far-away galaxies and learn more about them, we have to propel the technology beyond what currently exists. These advancements in technology are one way where investment in basic physics research

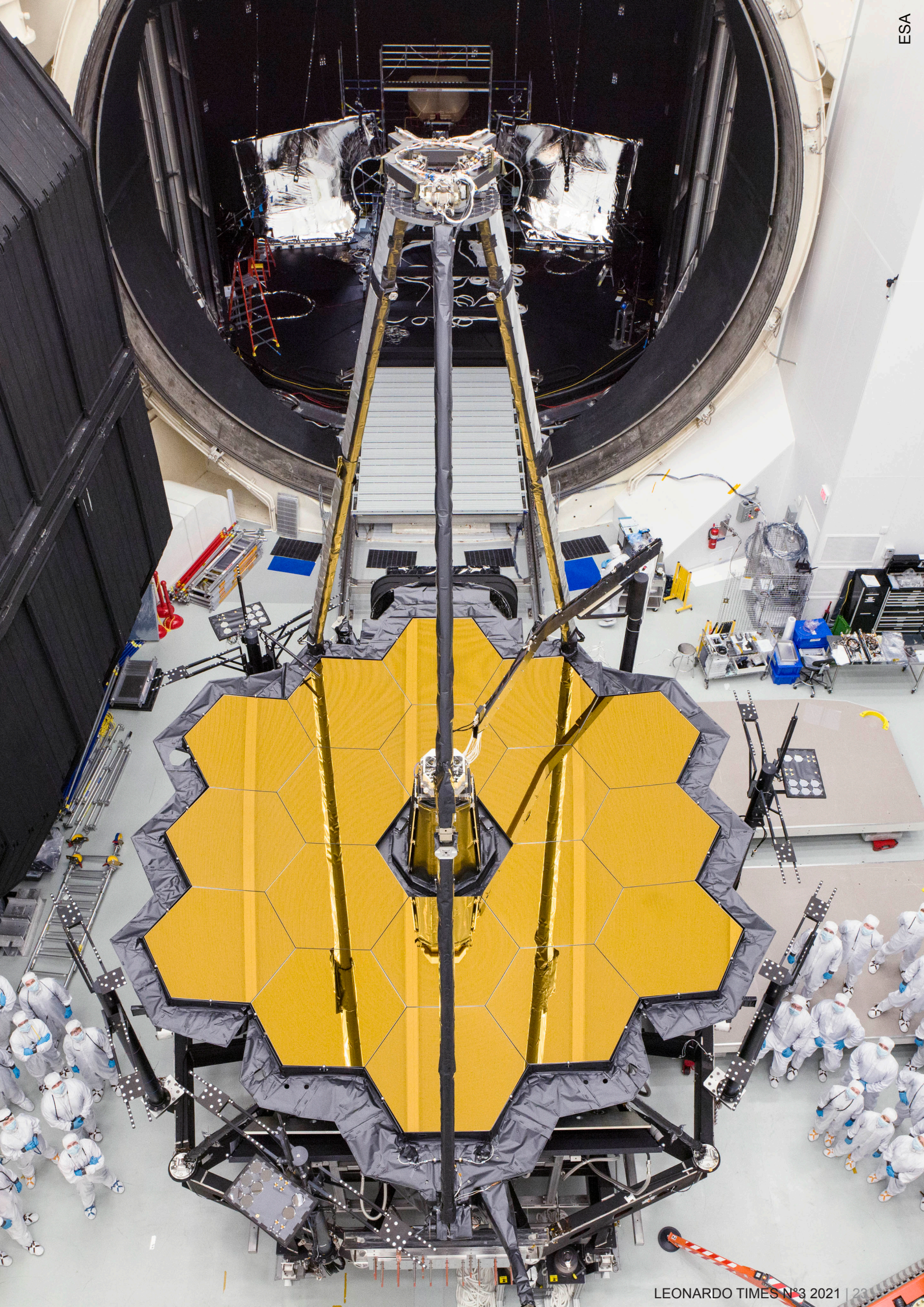
JWST IN A NUTSHELL

The JWST will be sent to orbit into the second Lagrange point at a distance of 1.5 million km from Earth, or approximately four times the distance between the Earth and the Moon. This journey will take one month. During this journey, the sun-shield will unfold, creating a passive cooling effect for the telescope on the shaded side of these shields. The surrounding temperature will be roughly that of deep space (~3K), enabling instruments to collect data without infrared interference from the JWST itself. Once in orbit, the commissioning phase begins. It entails switching on, testing and calibrating the instruments, plus checking the attitude and orientation using nearby stars. JWST will also start its two-month process of aligning and adjusting its 18 hexagonal mirrors to the required curvature for optimal focus. Each mirror has seven actuators that can push and pull the mirror to obtain the correct curvature. This process starts as soon as the mirrors have cooled down to their cryogenic operating temperatures and finish contracting due to the cold condition. After this is complete, scientists will start calibrating the other instruments: the MIRI (Mid-Infrared Instrument), the NIRCam (Near-Infrared Camera), the FGS/NIRISS (Fine Guidance System/Near-InfraRed Imager and Slitless Spectrograph) and NIRSpec, to prepare for the measurements. These intricate start-up processes explain why JWST requires six months after launch until it is ready for scientific observations.

Unlike Hubble, that was located sufficiently close to Earth for any necessary human repairs and maintenance, JWST will be too far away in case this would be necessary. This constraint makes it both exciting and stressful for the engineers and scientists involved. It is why the telescope is designed with extensive risk mitigations and redundancy in all mechanisms, such as the wide flexibility of movement in the mirror segments.

In general, the JWST is seen as the successor of Hubble due to the overlap in their purpose. However, the science community hopes Hubble and JWST can reign side-by-side for a while. It is valuable to compare data from JWST's new measurements to Hubble's well-known performance and capabilities. Besides this, having both telescopes operational will allow scientists to observe objects in both UV and infrared wavelengths simultaneously.

JWST is a much more powerful telescope than Hubble, which means objects further afield can be observed. Besides JWST's much more advanced design, it also has a mirror surface area seven times larger than Hubble. According to Dr. Giardino, "The bigger the bucket, the more water it can contain. Similarly, the bigger the mirror, the more photons it can collect and, therefore, the higher the sensitivity that can be obtained in the observations, leading to lower noise". Currently, the farthest visible galaxies are 12.8 to 13 billion years old (another way to look at it is that they are 12.8 to 13 billion light-years away) and with the JWST, galaxies even farther away will become visible as well.



ESA

underpins technological research in many other areas. Eventually, there are many practical applications of this basic research that benefit many people. Some of today's image processing techniques were conceived for the Hubble Space Telescope. The Internet, as we currently know it, was first developed at CERN in Geneva. Then there is the other, more philosophical way of looking at this. In my opinion, we, as human beings, are at our best when we work together, collaboratively, to overcome practical challenges and advance our knowledge. It is in our nature to push the frontier of our knowledge to work together, to solve problems and to understand more of why the universe looks and behaves the way it does. That is humanity's quest.

Q: The pandemic has forced all industries to adapt to new challenges. What have been the biggest challenges for you and your team?

GG: As for everybody, we also had to start working remotely. It was more difficult to share ideas from behind your laptop screen. Due to the pandemic, the project accumulated another 6 months of delay. However, in some sense, we were lucky because JWST had already been built when the pandemic started. The components and instruments were already integrated, so it only had to go through the testing phase during the pandemic. Many adjustments had to be made to the safety protocols at the Northrop Grumman facility in Los Angeles, where JWST was being integrated and tested. The main challenges for us were in terms of communication and cooperation. Luckily, the pandemic was not very disruptive due to the phase the project was in. Had the pandemic started 3 years earlier, the disruption would have been worse. A lot of credit goes to NASA and Northrop Grumman, which minimized project disruptions.

Q: You were included in the ESA #WebbTelescopeWomen series and you have experience working in a male-dominated STEM industry as a woman. Do you have any wisdom to pass along to the next generation of female engineers?

GG: I think the science field is an incredibly interesting and stimulating environment and, as more women continue to join the sector, I hope it will become increasingly more accessible for the next generations. The percentage of female engineers and scientists in the various institutions is expected to rise, which leads to a more balanced environment. The challenge of having both a career and a family is not easy. Men experience this challenge too, of course, but depending on the situation, it is perhaps fair to say it is still particularly relevant and substantial for women. As with all personal challenges, you can adjust and be flexible. There are many ways to succeed in this rewarding and fascinating profession.

Q: What are the plans for the successor to the JWST?

GG: There are already people discussing telescopes with 15-metre or even 25-metre primary mirrors, but this is still far away. We first need to launch JWST to think concretely about its successor. Until we operate this machine and see how it works, the plans for its successor remain somewhat theoretical. But the successor will be bigger and more powerful than the JWST for sure!

Q: What will you be doing during the highly-anticipated launch in December 2021?

GG: We will have a launch event at ESTEC where we follow the launch live on a big screen! My colleagues at ESA in the US and from Airbus in Germany will also be watching. In non-Covid times, the family would also be allowed to come, so, hopefully, that will also be possible now. I am not personally going to the launch site in Kourou. ESA only sends essential personnel and directors, so there are few people travelling to the actual launch site. I am sure that everyone who has been working on the project will be watching the launch live, though. There is a lot of anticipation and excitement for JWST, so there will be many cheers and celebrations if the launch goes well!

Interview with Dr. Giardino and Leonardo Times.

Previous page: James Webb emerges from the cryogenic chamber after testing.

LVNL

Enabling aviation together

LVNL is responsible for providing air traffic services to civil air traffic in the Dutch airspace in a safe, efficient, and environmentally sensible way.

Besides the provision of air traffic services we are responsible for the provision of communication, navigation and surveillance services including the modernization and management of these technical systems.

At LVNL you can work in many different fields such as technology, procedures and training. There are many opportunities to develop yourself and to take up new challenges. All this within a company where it is of the greatest importance that we can perform our operations safely and efficiently every day.

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

MARTIJN DUIJKERS - AIR TRAFFIC CONTROLLER TWR/APP

"The public opinion on the aviation industry is one of the essential conditions allowing the continuation and development of the sector. Working for the strategy and capacity management department I find myself at the intersection of community management and providing the desired services to airline operators, where conflicts of interest might occur. Resolving these conflicts in an open and transparent manner together with all involved parties contributes to sustainable development of the aviation industry."

MAX HEILIG - BUSINESS ANALYST ENVIRONMENT

Airbus vs. Boeing

Airbus-Boeing dispute timeline

Roosa Joensuu and Noah van Santen, Leonardo Times Editors

FPP

After seventeen years, the longest running dispute in the history of the World Trade Organization (WTO) has come to an end - or at least to a halt. This dispute on Large Civil Aircraft, more commonly known as the Airbus-Boeing dispute, has been a gnawing issue in the relationship between the European Union (EU) and the United States (US). Starting from aircraft subsidies and ending with import tariffs on dairy products, the dispute cost businesses over USD 3.3 billion in duties. In this timeline, the reasons behind this conflict and the main incidents on the way are explained.

2004

The US files a case at the WTO against the EU. The US accuses the EU of illegal financial support from the member states to the European aircraft manufacturer Airbus, targeted towards the development of commercial aircraft.

2005

The EU files a case at the WTO against the US. The EU accuses the US of illegal financial support to the American aircraft manufacturer Boeing, including space and military contracts to cover civilian aircraft development costs.

Valdis Dombrovskis

2006

Airbus announces the design of the A350 XWB aircraft as a response to the 787 Dreamliner. Government investment from European countries is requested for the development of the new aircraft.

2010

The WTO orders all parties to end unjust financial aid to the development of jets. The WTO had previously stated that European aid to Airbus violated rules on subsidies. A year later another WTO group working on the EU countercase agrees that the US has given illegal support to Boeing.

Boeing 777X

2013

Boeing launches the 777X as a response to the A350 XWB. The aircraft will be built in Washington State due to an expansion of tax breaks to boost the aerospace industry in the area.

2014

The EU files a separate complaint at the WTO against the Washington State tax breaks.

2016

Brexit referendum takes place, the UK votes for leaving the EU. Throughout Brexit negotiations, Airbus indicates interest to keep production operations in the UK, but later threatens to pull out in case of a no-deal Brexit.

Boeing 737 MAX

Trump starts in office as president of the United States.

2017

Boeing 787

May: The WTO states that the EU has not complied with the previous rulings. As a countermeasure, the US is allowed to impose tariffs against EU exports worth USD 7.5 billion.

2018

Jan: Brexit negotiations conclude, and the United Kingdom withdraws from the EU.

March: The COVID-19 pandemic spreads to the western world, stimulating economic fear and uncertainty.

July: Following the ruling of the WTO, Airbus complies with their international obligations, and requests the US to suspend its countermeasures against the EU.

November: Biden is elected president of the United States. The EU imposes retaliatory countermeasures on US exports to the EU totalling USD 4 billion - an act authorized by the WTO.

2020

March: The US and EU call for a temporary halt on tariffs while negotiations take place regarding the future of the dispute. This halt is scheduled to last 4-months.

June: The suspension of tariffs is extended to a duration of five years as the EU and US come to an agreement, covering a volume of USD 11.5 billion worth of progress crippling tariffs. The agreement is inspired by collective aspirations to achieve collaborative growth and environmental sustainability. It is likely that the agreement is partly fuelled by rising concerns over a competitor, namely a Chinese aerospace manufacturer, Comac.

2021

2019

March: Mirroring its previous decree, the WTO confirms the history of Boeing's continued illegal support financed by the US. It continues to state that this directly impedes the progress of Airbus and the European aerospace industry.

March: Following the calamitous performance of the Boeing 737 MAX, the U.S. Federal Aviation Administration grounds the aircraft from operating.

Katherine Tai

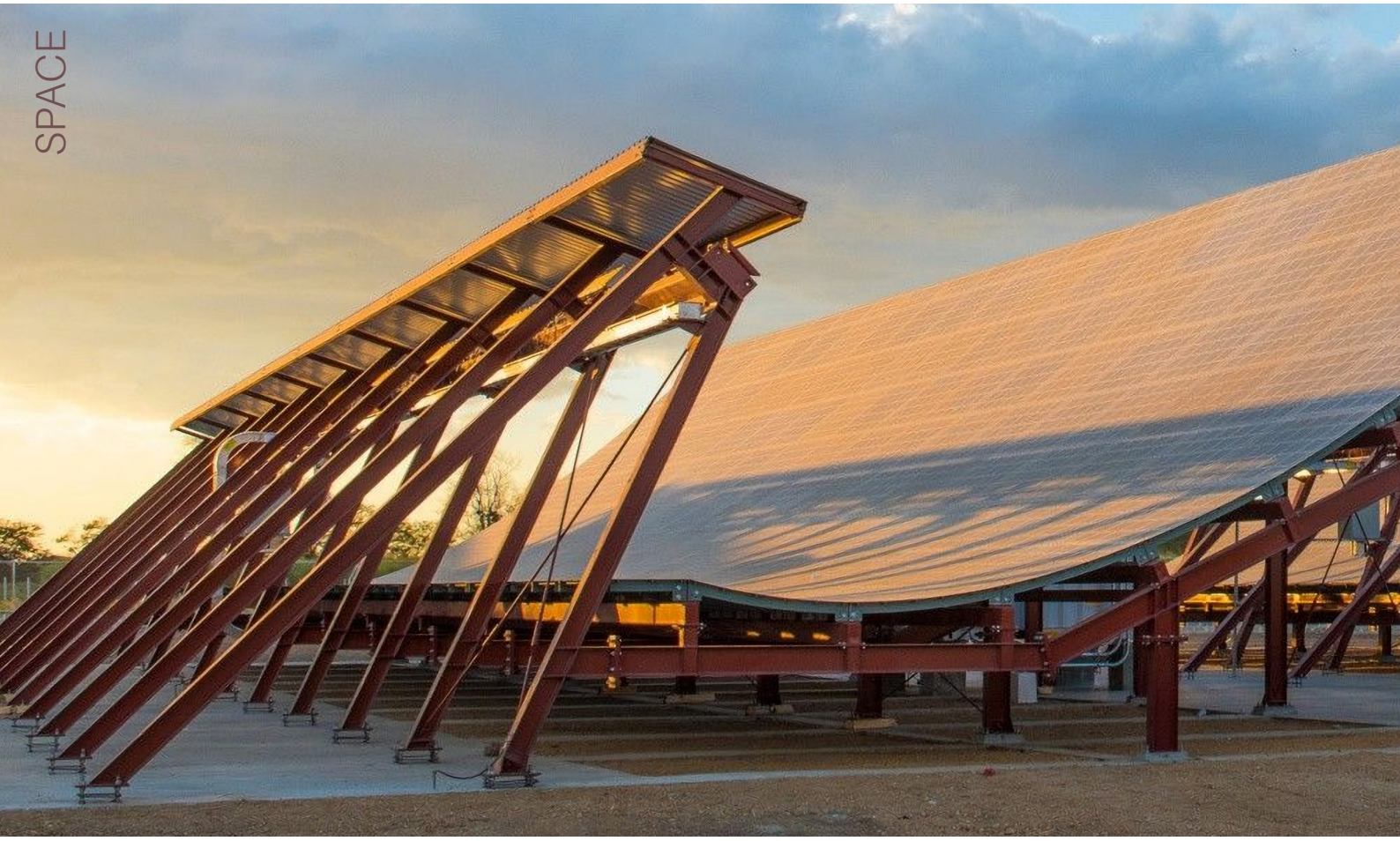
FUTURE

The recent alliance between the EU and US could inspire future economic cooperation across all industries. The airline industry is far from being the only industry to suffer from the effects of the pandemic and international collusion will only help shoulder the burden. Nevertheless, the West's view of China as an uprising competitor could also inspire division as opposed to collaboration. As such, it remains to be seen how the precedent established by this long running dispute's hiatus will influence further diplomacy.

Monitoring Low Earth Orbit

Why LeoLabs is deploying a global radar system to track space debris

Filippo Oggionni, Aravinda Jagarlapudi, Editors Leonardo Times



LeoLabs is a US-based company aiming to track objects, including space debris, in Low Earth Orbit (LEO). Founded in 2016, it is now expanding its global network of radar stations to ensure global coverage in monitoring the LEO ecosystem. We interviewed Dr. Darren McKnight, Senior Technical Fellow at LeoLabs, to understand the current situation of space debris and what LeoLabs is doing to address it.

It is safe to consider that Dr. McKnight is one of the most experienced professionals in the world to talk about space debris. He was the first person to get a PhD in orbital debris at the University of Colorado Boulder. Dr. McKnight has also co-authored the first book on space debris ("Artificial Space Debris"), published in 1987 and written with Nick Johnson, former Chief Scientist for Space Debris at NASA between 1996 and 2014. He is a member of the Space Debris Committee at the International Academy of Astronautics and holds a prominent position in organizing the International Astronautical Congress. At LeoLabs, Dr. McKnight provides perspective to the topic and identifies the most important issues. He strives to maintain company focus and the entire space ecosystem on the real problems, rather than the most debated ones.

Q: What is the motivation behind LeoLabs's mission?

DMK: As the LEO gets more populated, our ability to continue to operate reliably will depend on the frequency and accuracy of the updates of what's going on. In the past, the 18th Space Control Squadron (18SPCS) has been the most prominent organization in the orbital debris tracking field. The founders of LeoLabs thought that they could track smaller objects with more precision and responsiveness by building more radars with higher quality. Based on the current capabilities of traditional LEO monitoring systems, the orbital parameters are updated every eight hours per object on average. At LeoLabs, we do that every eleven minutes. Years ago, when there were around 300 operational satellites and 5000 objects in LEO, having an eight-hour update frequency was perfectly fine. However, we now have thousands of operational satellites and tens of thousands of pieces of debris in the LEO: this makes it a much more congested system, needing frequent and accurate assessment. It is quite difficult for governmental organizations to directly provide technological advancements required to reach this goal - which is where commercial companies like LeoLabs


LEOLABS

come into play. As a commercial entity, LeoLabs is much more agile in leveraging new tools and technologies, so we can guarantee a sufficiently high development pace for our tracking systems that can address the current needs of LEO satellite operators. Of course, the 18SPCS has done and still does a great job in orbital debris tracking, but it just cannot keep track of the very high number of launches and satellites deployed in Low Earth Orbit. Think of satellite imagery or launch vehicles - thirty years ago, these were provided solely by governmental organizations. Today, many commercial companies are active in these fields - think of Planet or SpaceX, for instance.

Q: Besides the US military, what other entities provide tracking services?

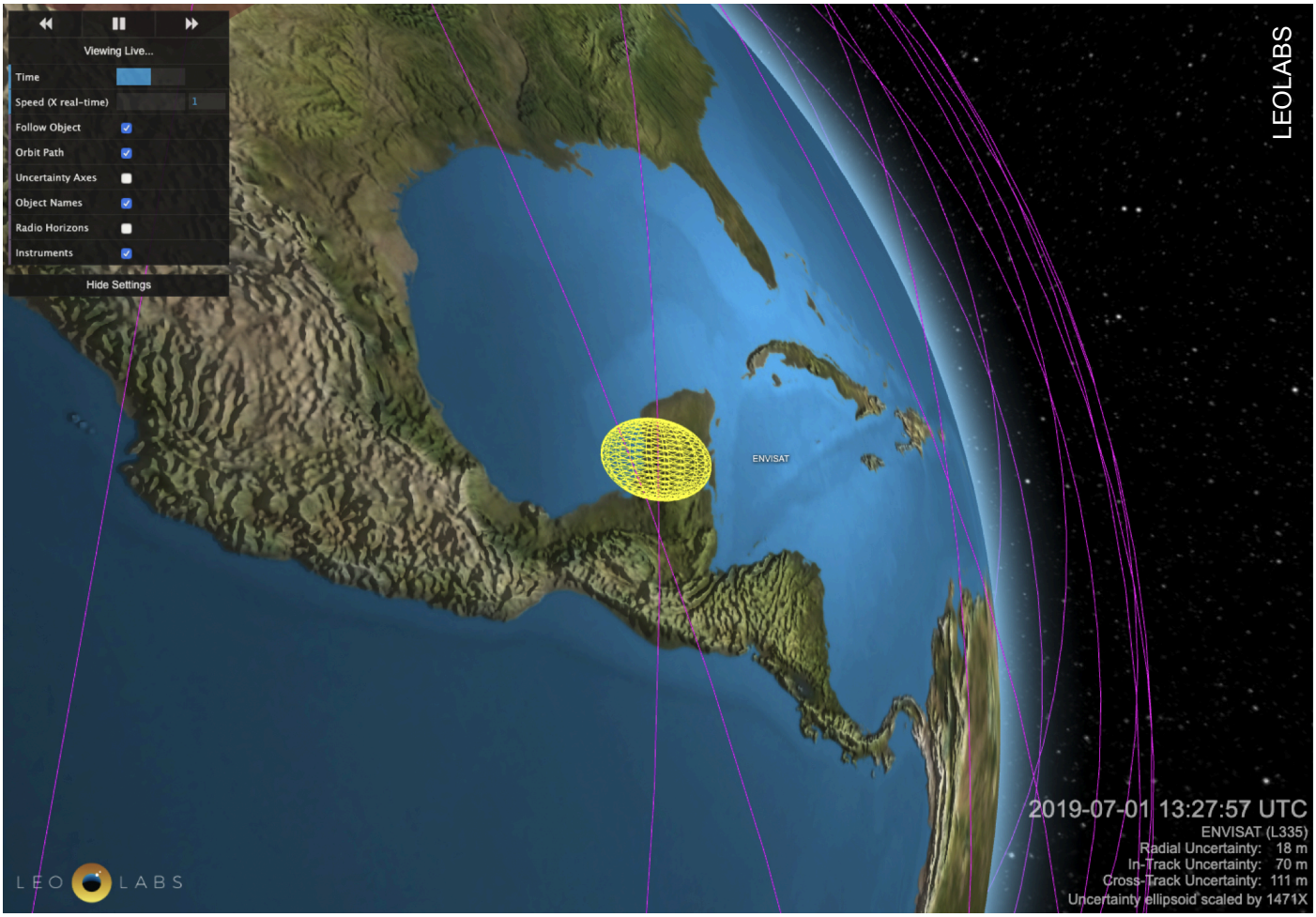
DMK: There are some 'spotty' tracking capabilities scattered throughout Europe. While military providers can afford radar systems, non-military tracking services for LEO objects are based on telescopes. These optical systems are more suitable for looking beyond Low Earth Orbits. In addition, optical instruments are affected by environmental conditions, such as clouds. As a result, they cannot provide consistent and timely measurements. The few other existing radar systems are not part of an extended (or even global) network, which seriously impairs their capability of providing frequent measurements.

Q: What are the advantages of having a global network, then?

DMK: The accuracy of orbital debris tracking largely depends on how many measurements can be done in a given time frame. If you can 'see' an object more often, your uncertainty decreases. As a result, the accuracy of the propagated orbits and their related conjunction messages is much higher. Furthermore, the orbit propagation is also shorter because you are confident that you have new measurements sooner. This aspect also contributes to reducing the error. LeoLabs already has ground stations in Costa Rica, New Zealand, and the Azores. By the end of 2022, we will have a tracking site in each continent (except Antarctica), creating a truly global network. With such a system in place, measurements of the same object will be available every few seconds.

Q: Do you think the growth in the NewSpace field will worsen the current space debris situation?

DMK: I think today's satellites, especially the small ones and the ones launched by constellation companies, are actually much more equipped to perform collision avoidance manoeuvres, thanks to their agility provided by Electric Propulsion for instance. My view is that the industry, in this case, has



A screenshot from LeoLabs's API. LeoLabs has developed a subscription-based online platform where the user (such as a satellite operator) can receive conjunction messages, analyze and visualize collision risks, check when the next overpass will occur, and so on.v

behaved very responsibly - large constellations are not and will not be responsible for the worsening of the space debris problem. On the contrary, they will likely be the victims of this situation. Indeed, the most dangerous threats in Low Earth Orbits are posed by inactive objects, such as dead rocket upper stages.

Q: If I understand correctly, you are saying that the situation we face today is due to inadequate practices of the past? In your opinion, what has not worked well so far?

DMK: I honestly think that national space agencies and international organizations, such as the United Nations with their Office for Outer Space Affairs, have not done a good job in the past. The regulations for debris mitigation and remediation have not kept pace with the rest of space technology. For example, take the 25-year rule that requests satellite operators to deorbit their platforms after 25 years from launch: it has never been modified, just because nothing too dangerous has happened so far. Back in the 1990s, this rule was based on the fact that most satellites were chemically propelled. Today, alternative propulsion systems can be mass-produced and be much cheaper. I strongly advocate for a 1-year deorbit rule: every satellite should have collision avoidance capabilities (which, by the way, is not required by law) and sufficient propulsion capabilities to move below the orbit of the International Space Station (around 400km) in less than one year. There is no reason for a mission that lasts one or two years to linger around for 25 years: this is really silly.

Q: Speaking of the 25-year rule and its necessity to be reduced, we would like to delve more into this issue. We have interacted with different companies working with the launch of satellites; they claim that this 'rule' is solely a guideline, but nothing more. It means no consequences for whoever breaches that rule. Will it be effective even if we lower the period of the rule to five or even one year? What actions must be taken to reinforce this rule instead of it being seen simply as a guideline?

DMK: The reinforcement is really about regulation. We have licensing boards, such as the Federal Communications Commission (FCC) for commercial spacecraft in the United States, which demand specific requirements for each mission. Many of these requirements are based on debris mitigation guidelines. However, since most of these are guidelines, there is no enforcing agency to penalize companies if they don't follow them. It suffices if a company can show on paper that the requirements are achievable. I believe there should be something that I call the "Coca-Cola bottle". There used to be a policy such that if you purchased a bottle of Coca-Cola and returned the bottle to the storekeeper, you got 5 cents back. I understand that if you buy the drink, you actually pay extra money for the bottle. So, if you return the bottle, you get your money back! Likewise, I believe that every entity that launches has to put in a certain amount of money into a pool and, if they followed the guidelines to the letter, they get that money back. If they don't, that money goes into an effort dedicated to removing that object from orbit to keep the environment safe. The sum of money is to be decided based on the mass of the satellite. Universities should not be investing half a million dollars for a satellite that costs only fifty thousand dollars. An alternative can be such that academic satellites can launch from the International Space Station (ISS) such that there is no propulsion required. It means that the ISS gets business, universities get to do their research and, they don't add to the risk of operating commercial, civil and national security satellites. However, this brings about compliance issues. The only country that has the 25-year rule and all mitigation guidelines as a law is France. Everyone else has it as a guideline.

LeoLabs's existing radar network, with the visibility of each station depicted in red. LeoLabs is planning to build two new radar stations: one will be located at the Azores and the other is yet to be announced.

Q: In the webinar, you mentioned that Electric Propulsion (EP) could be a game-changer in terms of compliance due to mass efficiency. However, since EP is a low-thrust method, how fast can the manoeuvres be executed and, consequently, how much earlier must notice be provided to perform collision avoidance manoeuvres?

DMK: That is really dependent on each constellation. Based on my experience at LeoLabs, I can tell you from working with customers that use EP that the determining factor for the time before the notice is the thrust-to-mass ratio. Lower thrust could be a problem, but a correspondingly small mass implies that you end up with the same force, and required Delta V. Should you be one of our customers, we would provide you with a conjunction date and message you within 11 minutes after any of your objects crosses any of our six radars around the world. In this time, you would be updated and informed how that potential conjunction could have an interference within the next 5-6 days. We would also tell you when one of our radars will see your satellite next. You get to look at your orbital path while looking at real-time data on our website while knowing when you will see your object next. So customers delay their choice of action since the errors involved in propagating their orbits to the target position reduce over time, as the body approaches the conjunction date and time with increasing incoming data. So we wait, and there is a chance that you may not have to take any action at all. With the system we have, knowing when you will see your satellite next allows you to plan your move much later – changing your path a day or half a day before an estimated collision. In doing so, we are trying to make low Earth orbit safer. If we have more frequent measurements (more radars), we can make this operation much more frequent and therefore require less time on the customer's end to make a decision.

Q: How do you feel about reducing existing space debris via space lasers keeping military activity in space in mind?

DMK: I think laser applications for nudging a satellite from its orbit and avoiding collisions is viable and makes sense. To use lasers to remove it from orbit makes no sense. I say this for several reasons. Usually, the object the laser is supposed to move is not visible; you need a small mass for the laser to give it sufficient force. If an object is 1 cm wide, how can it be seen? On the other hand, an object as large as a rocket can be nudged. There is a system called "Just in time collision avoidance" that I invented. The concept is such that, with predictable conjunctions, a dead object can be nudged to avoid collision and, afterwards, it would be a lossless expense to grab and remove the object. A laser, in this case, might be effective in generating the aforementioned 'nudge'. Large and heavy objects could use some nudging to prevent large-scale collisions and avoid losses by the millions. These are the technical applications that I believe a laser will be useful for.

Acknowledgements: We would like to thank Dr. Darren McKnight for the interview.

LEO LABS

THE RISE OF THE 5TH GENERATION

The global fleet change of revitalised air forces

Topias Pulkkinen, Editor, Leonardo Times

US Air Force F-35

Air forces worldwide are updating their fleets in response to geopolitical risks and adjustment to the new stealth technology. Countries like Japan, Switzerland, and Finland are among those that have taken part in the global push for fleet innovation.

It is early morning in the Panamanian airspace in December 1989. A US Air Force F-117 Nighthawk is approaching the Rio Hato Airfield - ready to bomb [1]. The aircraft demonstrated its stealth capabilities as it stayed unobserved by the radars employed on the ground. Two years later, the Nighthawk was deployed again by the Americans during Operation Desert Storm in Kuwait. This mission upheld the same record for stealthiness, marking the start of a new era in military aviation. The age of stealth had begun.

Global military spending is on the rise. It has led to an increase in the relative and absolute spending on armaments technology in different regions worldwide. Air force commanders have also risen to the occasion, reminding the public and the governments of

the necessity of air dominance in maintaining national sovereignty. This article will go through some of the most impressive upgrades that air forces worldwide are undergoing in the 2020s.

Anyone reading the defence headlines in the summer of 2021 must have come across Switzerland's decision to upgrade its fleet with the American 5th-generation multirole fighter F-35 later on in the decade. The key characteristics of the 5th generation fighter jets separate them from previous generations - mainly their lower radar cross-sections, as a result of the stealth techniques employed by the manufacturers in material, paint, and geometrical aspects of the design. The new jets are meant to provide the Swiss Air Force the necessary performance capabilities to ensure its territorial integrity and neutrality. The purchase of the F-35 fleet by the neutral nation could also be seen as a Westward push, possibly indicating future interest in more American trade collaboration.

The Swiss justified the choice of the fleet of F-35s in rather unsurprising ways: the fighter and its spare parts' long-lasting availability, supply-chain reliability, and the advantages of stealth technology [2]. The choice to favor the F-35 by the Swiss Air Force is not a standalone event, but is part of a larger global trend to update air forces with stealth-capable aircraft. This recent technology enables the aircraft to have a radar cross-section the size of a golf ball, thereby reducing a conventional radar system's ability to detect a potential threat [3]. This is where air forces worldwide see an opportunity to obtain a technological edge, as most countries do not possess radar systems sophisticated enough to identify these aircraft. On the flip side, many countries have realized this and are working on counter stealth technologies, including next-generation anti-stealth radars [4].

Switzerland is far from being an isolated case in its aspirations to acquire 5th generation fighters. They join the list of many countries that have expressed interest or that have already bought them. Belgium, the Netherlands, Norway, the UK, Singapore, South Korea, Denmark, and Italy are prime examples of countries looking to add 5th generation fighters to their fleet [5].

Another country renewing its fleet is Finland, which aims to replace its entire fighter fleet by the end of the decade. The country is due to acquire new fighters from a selection of five: those being the F-35, the Super Hornet, Eurofighter Typhoon, Dassault Rafale, and Saab Gripen 39-E. The Finnish military is expected to announce its decision in late autumn 2021, but the F-35 remains a favorite among the experts and speculators [6]. In Finland's case, the notable support for the acquisition of the F-35 stems not only from its 5th generation capabilities, but also its status as the future NATO "go-to" -aircraft, leaving wiggle room for a possible future membership in the alliance.

Despite its success in making a mark for itself as the global 5th generation standard setter, the F-35 does not come without issues. The jet suffers from a bloated budget, costing $1.7 trillion to the US taxpayers by the mid-2030s, as well as a high unit cost repelling some potential customers [7]. Additionally, some defence analysts have said that the jet has "failed to achieve its goals". Lockheed and the US Air Force (USAF) have admitted to many shortcomings - most notably the poor supersonic performance, numerous pilot blackouts during training flights as a consequence of dysfunctional masks, and poor manoeuvrability in more extreme flight conditions. Furthermore, the aircraft reports having a mission capability rate of 69%. This value stands for the ratio of the times the aircraft flies and performs at least one mission to the number of total flights, thus being 11% below the military's benchmark requirement [8].

Japan, on the other hand, has decided to update its fleet via two avenues; one being the acquisition of 147 F-35s, and the other the development of a domestic fighter jet. In East Asia, Japan also wants to improve its defence capabilities. Yet, they chose a very different approach in comparison to the other countries discussed here. In 2020, Japan announced the development of a locally made next-generation fighter jet, thus giving the island nation a more independent defence system. The contract of the F-X project was awarded to Mitsubishi Heavy Industries in the autumn of 2020. The aircraft is promised to enter production by 2031 and be operational in 2035 [9]. Despite being a 5th gener-

ation, or according to some, even a 6th generation fighter, Japan is aiming to reach air superiority through manoeuvrability and speed over other jets in the stealth category [10].

To Japan's west, China is also increasing its military budget. The country's rapid economic growth has enabled it to create its own arsenal of domestically designed and produced 5th generation fighters, the J-20s. The aircraft, introduced to the public in 2011, now numbers 150 in the People's Liberation Army Air Force (PLAAF), constituting about one fifteenth of their entire fleet [11]. Despite relatively fast employment by the PLAAF, it is far outdone in international popularity by the likes of the American F-35, which has already seen 690 built, with a planned 3,100 jets operational by 2035 [12]. Furthermore, analysts say that the jet's stealth capabilities are not on par with its American counterparts - the F-22 and the F-35 [13]. Thus far, due to lack of actual real-world experience, the jet is unfortunately not en route to become the most well-known 5th generation fighter jet globally.

To China's north, Russia is also developing its next-generation fighter jets. Russia's Su-57 aims to be Russia's competitor to other 5th generation aircraft. The Su-57 is one of the longest-lasting projects in the history of military aviation, as primary plans were implemented in the last years of the Soviet Union. As of 2020, despite its long development time, the jet reportedly numbered 12, with orders for another 64, all coming from the Russian Air Force [14]. The current low number attributes to a variety of factors, including supply chain issues and lack of funding.

The Chinese J-20 stealth fighter mid flight

Unlike many of its counterparts, the Russian fighter actually has some real-world experience. This, on the other hand, has led to many analysts saying that the fighter's stealth features are poor, so much so that titles from reviews evaluating the aircraft read "the Su-57 may be the "worst" 5th generation fighter, but it's still a highly capable machine" [15]. Despite the Su-57's mediocre public image, the aircraft manufacturers keep on pushing forward.

In conclusion, it appears that the strategic zeitgeist worldwide is shifting towards a greater preference for stealth technology and the operations it enables. This is felt more vigorously in countries planning to update their fleets regardless of technological advancements, although these certainly play a role. So far, the only stealth aircraft that has demonstrated the numbers to shift global trends is the American-made F-35, but bear in mind that no radar can track the future.

The Russian Su-57 taking off

STUDY TOUR 'HARBINGER'

What does the Dutch aerospace industry hold for our students?

Jilles Andringa, Previous VSV board member, QQ of the Study Tour committee

VSV

Study Tour group in front of a Boeing 747.

Initially conceived as a three-week international trip, the VSV's Study Tour turned into a one-week trip within the Dutch borders because of COVID travel restrictions. Nevertheless, the annual Study Tour lived up to its reputation, providing 20 students with unique experiences and insights into the aerospace industry of the Netherlands.

The Study Tour aims to provide students of the Aerospace Engineering faculty in Delft a unique opportunity of visiting various (aerospace) engineering companies around the world; while also visiting exciting new countries! Traveling has, of course, not been as straightforward as it was prior to the pandemic. After Study Tour 2020 had to stay within the Dutch borders, Study Tour 2021 had hoped to go abroad again. Unfortunately, the pandemic stayed with us for longer than anticipated, and the trip had to remain within the Netherlands. However, our expectations were not marred, and in the end the Study Tour committee of 2021 brought 19 of our students and one staff member on a unique trip through the Netherlands.

On the 29th of August 2021, Study Tour 'Harbinger' was ready for take-off! The trip's first destination was Enschede, where the group arrived on Sunday evening and enjoyed a dinner in a unique setting. On Monday, the tour began with an action-packed day where we visited five companies! The first was the Technology Base at Twente Airport. We got a tour of the campus where all the other companies were located. What makes the Technology Base so special is the fact that it used to be a military airbase. This allows companies to move into and renovate old F16 shelters to function as a base for their operations. Also, since the landing strip was designed to withstand a variety of military aircraft, the largest passenger aircraft is certified to land at the Technology Base, thus providing companies such as AELS (more on them later) with the ideal location for their business models. This, combined with the pandemic, also gave the Technology Base an exceptional business opportunity. As many airlines had to temporarily store a part

The inside of a stripped aircraft, being prepared for recycling.

of their fleet, including aircraft such as the massive Boeing 747, the Technology Base provided airlines such as Lufthansa with storage places. During our visit, a Lufthansa 747 was being prepared by engineers to enter active service. Consequently, our group could talk to the engineers and get a close look at the aircraft – both inside and out!

The next company was AELS, Aircraft End-of-Life Solutions. This company, founded by a TU Delft Aerospace Engineering alumnus, buys retired aircraft and removes, refurbishes or recertifies, the working parts of these aircraft and sells them. After this, the aircraft is broken down and the remaining materials are recycled. Upon arrival, the group was invited into their latest addition in their fleet of retired aircraft, which just started its end-of-life process. The company founder gave us a presentation inside the aircraft. He explained their business model and also the challenges they currently face. After this, we got a tour of the current aircraft they were deconstructing. Walking into the bare aircraft gave us a new perspective of the intricate machinery, cables, ventilation systems, etc. Also, some of us got to fulfill some childhood dreams - such as opening an aircraft door or walking in the cargo compartment. The tour continued in the storage hangar, where all the removed parts were refurbished and made ready to be sold. These parts ranged from old black boxes to entire empennage sections!

The next company was Space53, a drone company specializing in providing testing facilities for drone applications for the government, first responders or businesses. During our time there, we received a visit from the Drone Bird Company. They explained their revolutionary implementation of drone technology by mimicking nature. Their drone birds can be applied by airports to scare away birds - thus reducing the risk of bird strikes.

Finally, we ended the day at TKH Airport Solutions. TKH is a company that specializes in specific engineering areas, the largest one being cable production. The airport solutions branch focuses mainly on airport lighting. Their revolutionary CEDD system (Contactless Energy and Data Distribution) aims to become the airport standard by implementing an easy, reliable and high-tech option for airport lighting. Combined with their software, they aim to relieve a significant workload from the pilots and ground controllers while taxiing. As part of our visit, we got to experience a "Dinner by Airport Light", where we enjoyed a meal together with the staff, surrounded by their airport lighting products.

The next day was not a day full of companies but rather experiences, as the Study Tour is not solely designed around company visits. The entire group embarked on a trip with old classic cars on a rally throughout the eastern part of the Netherlands. A truly unforgettable experience.

On the following day, on Wednesday, we had our next company visit, Aeronamic. The company focuses on the production and servicing of high-speed components in aircraft, their most common products being a variety of compressor and turbine parts. However, before we could enter the facility, an extensive security check was needed, as Aeronamic is situated on the same campus as its original mother company, URENCO, which operates in the uranium enrichment industry. When we were all inside, we first got a presentation and a Q&A session organized

Cultural activity: classic car tour.

by the employees working at the facility. After this, we went on a tour in the large production hall where their high-speed components are designed, developed, built and tested. Next to their impressive developments using 3D-printed for manufacturing, we were also surprised by the number of complex control systems and extensive software needed to have their products run optimally. Our visit concluded with a communal lunch together with some of the employees.

On Thursday morning, the group travelled to Schiphol Oost to visit the next company, JetSupport! JetSupport specializes in handling the maintenance and servicing of business jets. Their specialties are their quick turnaround times and flexible servicing schedules. During our visit, we were given a presentation, followed by a tour of the facility. During our tour, we got to see a variety of business jets at varying stages of maintenance. The tour ended at the facility of the Dutch coast guard, as JetSupport also provides the maintenance and servicing of the coast guard Dornier 228-212 aircraft, soon to be replaced by the more modern Dash-8 aircraft.

After JetSupport, the group traveled to Leiden to visit Airbus Defense & Space. The location we visited specialized mainly in the development and production of satellite solar panels. During the presentation, the complexity of producing these panels was explained. After the presentation, the group split up into three groups that would then rotate between three activities. One group was given a workshop on how to test complex solar array deployment structures. The main challenge in testing the deployment structures is that they are designed for zero-G, but the testing occurs on Earth where gravity is a dominant force. The second group was given a pitch workshop, where they had to pitch Airbus DS's project Sparkwing, an off-the-shelf standardized solar array for small satellites. The third group got to go into the cleanroom and see the production and testing of the solar arrays firsthand. It gave us insight into the precision and care needed to produce a space-grade solar array.

Friday started with a relaxing brunch before heading out towards the last company visit of the Study Tour. We visited the consultancy company, Simon Kucher, in Amsterdam. During our visit, we listened to a presentation on what it is like to work for a consultancy company. The visit then continued with a case workshop. The mock-up case was related to Tesla's launching strategy. Each group was given an hour to determine which option configuration they should launch first in the Netherlands for their new model Y, based on Tesla's consumer data and its closest competitors. The case concluded by presenting the findings. Afterwards, we were invited to join the Friday afternoon drink with the other employees, many of whom were aerospace alumni. There we had the opportunity to converse and ask questions in a more casual setting. The tour ended on Saturday with a literal high point, as the group got to experience parachute jumping out of an aircraft! Of course, we did the jump with an instructor.

All in all, even though the Study Tour could not make it beyond the Dutch borders, we are glad that we had the opportunity to discover the Dutch (aerospace) engineering industry. We also enjoyed exploring the country in general. We can't wait to see what the next edition of the Study Tour has in store for us!

OUR STORIES

"SES enabled me to spread my wings, and now I can fly"

Sabrina Alam, Senior Specialist, Social and Environmental Impact, SES

Sabrina Alam and Christina Kor sat down with us to share some great insights into their experience with SES's Technology Associate Programme—a programme (one of the Four Doors opportunities) for young talent to enter the world of SES, a leading global satellite-solutions provider headquartered in Luxembourg.

Both embarked on their journeys and have now moved on to the next chapters of their career story at SES. They were more than eager to let us in on their unique take on the process of applying to the Programme, what it was like to be an Associate, and what they're up to now.

So tell us, how did you hear about SES's Associate Programme and how was the application process?

"I heard about the Associate Programme while attending a career fair at my university.", Christina recalls. "I spoke to some bright SES representatives, which excited me and encouraged me to apply to the programme. So, I did. About a month later, I was given my first of several rounds of interviews in Princeton, New Jersey. I wish I could say it was easy, but it was super challenging! In addition to the interviews, I attended several informative presentations and site tours. It was a lengthy, but super fascinating process! By the end of it, I felt wholly welcomed by SES. Their facilities and programmes are modern and technology-centric, which spoke volumes to our shared love of space. I also felt that there would be plenty of opportunities to advance within the Associate Programme at SES, which is why I couldn't hesitate once I was given an offer."

"My own path to SES was quite a bit different than Christina's", Sabrina chimes in. "I attended the International Space University for my undergraduate studies, where I also planned to eventually complete my Master's Degree. As part of my course there, I visited SES on a field trip coincidentally on the same day that a current SES Associate was giving a presentation. He was nearing his second rotation in the programme, which was at the time in Washington, D.C. Funnily enough, this was the same place I was about to relocate to for a work project for NASA. It took no time for him to sell me on it. He lauded the benefits of the programme, its opportunities, and his prospects. I knew immediately that I had to apply... and the rest is some of my best work history. After several rounds of interviews, which were admittedly tense because I was the only woman in the candidate pool, I was given an offer that I couldn't pass up. From start to finish, I knew that the role with SES would push me in the direction that I was dreaming that my career would go, especially considering my background in physics paired with my natural curiosity of the commercial aspect of space."

Amazing! You got through. What was it like being an Associate at SES?

Sabrina starts off first by reminiscing about her first rotation which started with the SES-17 launch project. "I was able to travel all over the world, having meetings with vendors and clients, which gave me a lot of experience. In the beginning, I put a lot of effort into the vendor side of things, like creating presentations and negotiations. The second rotation focused on software development and global traffic models. I eventually went on to work in corporate finance. Still, for my final rotation, I got to actually make the impact I had hoped for when interviewing for the SES Associate position—I started working on a brand new program focused on sustainability. Since I came in at the beginning of it, I got an immeasurable amount of learning experience

building the whole programme up from scratch. I learned from every single rotation that I had while I was an SES Associate. Although they were all different in their day-to-day capacities, I took away a host of personal and professional positives from every single one. Once the programme was over, I knew it wasn't actually over, SES enabled me to spread my wings, and now I can fly."

Christina Kor, Engineer, O3b mPOWER Programme Integration, SES

Christina adds, "My experience as an Associate at SES was enriching and diverse. My first rotation felt familiar because it was where I did my interview at Princeton. During my first rotation, I mainly worked on software engineering. Although my future rotations pushed me into specific roles, I worked entirely on O3b mPOWER programmes throughout them all. From start to finish throughout all of my rotations, I did everything from research and evaluation to technical writing, worked with new satellite simulation software, and eventually ended up working my final rotations at the O3b mPOWER field office in Los Angeles in a much more hands-on roles that allowed me to develop the most as a professional, a scientist, and a leader. I really did so much more than I could've ever imagined! I could talk about this for hours but just imagine it... I spent weeks inspecting batteries, observing O3b mPOWER Solar Wing Deployment tests, and even watching the life solar arrays unfold right in front of my eyes! It was beyond my wildest dreams. I learned so much, and the SES team was the absolute best in leading me through this experience."

Now that you have completed your SES Associate Programme, what are you up to now?

"I'm currently an Engineer on the O3b mPOWER integration team, which I achieved thanks to a lot of guidance from my manager during the Associate Programme.", Christina says with pride. "This position requires a depth of knowledge that is intimidating at first. Still, I am empowered to take on this challenge after having completed my rotations with SES. I'm focused on documenting use cases of all of our products—in very close detail —so that the program functions as expected by the end-user and the operator while also delivering on the promises that O3b mPOWER makes to its customers."

Sabrina is working as a Senior Specialist within the Social and Environmental Impact team. "This has me regularly working with legal and regulatory departments to ensure that the program management of our social governance and sustainability initiatives are kept on track. My responsibility is to understand which materials are essential to SES from an ESG (Environment, Social & Governance) perspective, the things on which we are performing well and not so well, and how we further strategise on achieving future improvements to our programmes. I'm working a lot with governments to ensure that sustainability is a crucial focus."

Would you recommend the SES Associate Programmes to others?

Christina and Sabrina both smile without hesitation and nod enthusiastically in agreement.

Christina explains, "The SES Associate Programme gives you unmatched experience in the space industry, which is super cool and always inspiring. Being an Associate also provides you a solid start in a company with so much opportunity for personal and professional growth. Once you're in the program, there's endless support for you, which allows you to choose which type of work you want to do—even when you want to change your path, take on new tasks, and grow within the company and the role."

Sabrina adds, "Even those outside of the space sector with any level of interest in the industry I can recommend to apply. Seriously, even if all you have is a passion for satellites, you can apply! The resources available to participants in this program make it possible for any candidate to learn while also having the necessary support from the company to truly grow into a career in this industry."

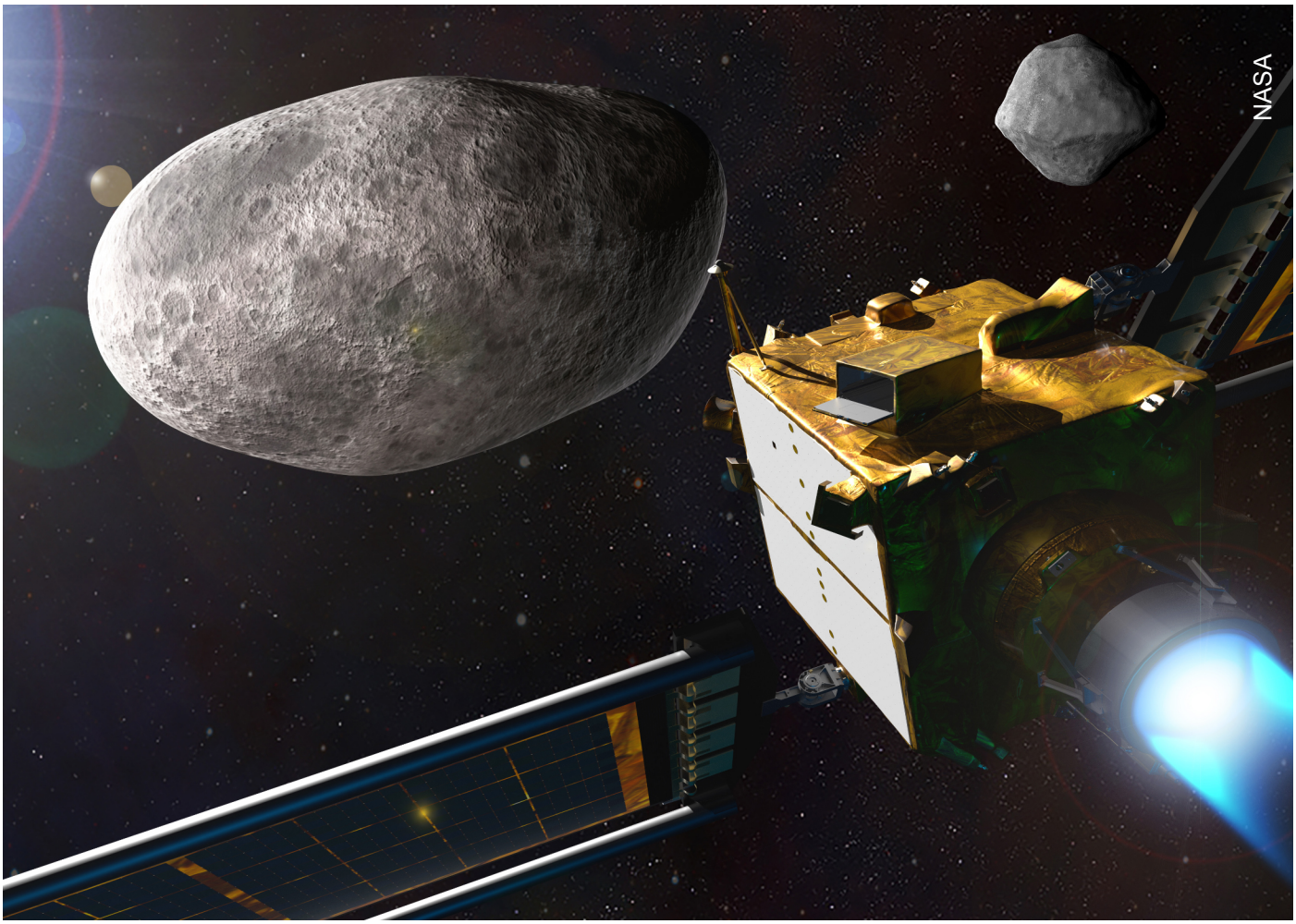
Start your own story at SES and visit: www.ses.com/fourdoors

SES

A DART IN SPACE

Crashing into an asteroid for Science

Diego Sánchez de Lerín, Editor Leonardo Times



An asteroid ended the age of dinosaurs. If a similar disaster were to occur now, it would end the human race. The Double Asteroid Redirection Test, DART, marks the start of a new era: one of accommodating outer-space for human needs and planetary defence. The spacecraft intends to crash into an asteroid several hundred times its size named Dimorphous. Its mission seeks to measure how well a probe can be aimed and how collisions could stop incoming asteroids.

Apocalyptic asteroid impacts are a common topic in dystopian science-fiction. It seems like these events belong to fantasy rather than real-life science. A surprise collision may indeed seem far-fetched, especially given the efforts that space agencies are putting into tracking large objects in the solar system. NASA's Deep Space Network Goldstone complex has been tracking near-Earth asteroids for over 50 years now, and recently NASA celebrated their 1000th asteroid observation. Most potential near-Earth asteroids deemed large enough to destroy civilization are already being tracked.

Yet, only most of them are tracked. The fact that it still leaves room for human extinction is alarming, especially since simply 'tracking' an asteroid is not equivalent to 'avoiding' a collision. Commencing such efforts only when a disaster is confirmed is a gamble. Therefore, researching and securing a response in case of an incoming collision is both prudent and necessary.

While there have been proposals to blow up asteroids with nuclear weapons, such a solution is not advised. The remnants from the explosion would cause serious danger to humanity and our planet. In addition to that, it would be a destructive solution, which takes away from the elegance of space mission design. There is no need to obliterate a complete asteroid to avoid collision with Earth. Our planet is constantly moving - we are orbiting the Sun at an astounding speed of 30 kilometres per second. It means that a collision can be avoided simply by slowing down the asteroid by a few millimetres per second. Such a shift would be more than sufficient to let the asteroid harmlessly cruise past us.

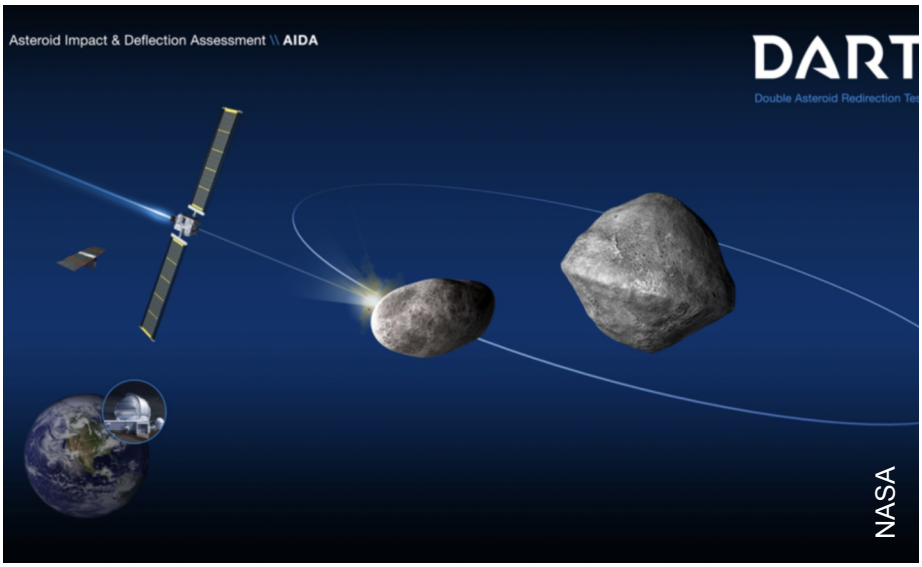


Figure 1: Illustrator's concept of DART.

The challenge lies in measuring such a seemingly insignificant velocity change in an object several millions of kilometres away. The reason why a similar mission has not been done before is because of the ingenuity required to not make it astronomically expensive. The original plan for DART was to launch two spacecraft - one designed to crash and the other designed to film. However, by choosing the target asteroid cleverly, only one needs to be launched. Dimorphous orbits another asteroid named Didymos, which makes it an extremely appealing target as it allows astronomers to make exceptionally precise position measurements. An object orbiting another can be compared to a clock - think of Earth as a clock that represents one year. By observing when Dimorphous is hidden by its brother's shadow, it is possible to accurately estimate by how much the clock has been slowed down. Hence, the target's change in velocity can be calculated. Hint: don't try this at home with your knock-off Rolex.

The speed change is necessary to ascertain the momentum transfer efficiency, beta, which helps in the design of future planetary defence missions. The larger the beta, the larger the effect that DART will have on Dimorphous. However, this number will only be an approximation, because it is based on the mass of the asteroid. The mass can only be estimated. It is computed from the size and the density of the asteroid, both of which are again estimates. These values are obtained from analyzing pictures. The uncertainties introduced in this series of estimations could suggest that the mission will never provide any scientifically valuable information. However, the fact that the mission was approved is itself a testament to how necessary this knowledge truly is. The question now becomes: how do you target a relatively small object that is in motion millions of kilometres away?

NASA's answer to this was SMART. It stands for "Small-body Maneuvering Autonomous Real Time Navigation" and was developed by the Department of Applied Physics at Johns Hopkins University. SMART uses autonomous control methods to reduce the need for human interference in the mission. "It's about conducting the entirety of the last four hours of the mission without any human intervention," said Mark Jensenius, a guidance, navigation and control engineer for the SMART team [1]. The techniques employed for the algorithm are similar to those used in self-guided missiles. One of the methods is detection-blobbing, allowing the algorithm to identify blobs of light, such as stars and reflective objects. This is followed by centroiding, which means finding the centroid of each light blob. Following this, the algorithm starts the process of targeting. In this phase, the destination, Didymos, is selected based on its estimated brightness and size. The algorithm will then begin to employ guidance controls, enabling it to reach the destination safely and securely. Finally, the algorithm will suggest optimal maneuvers for fuel conservation. This loop will run continuously for the last four hours of the mission, about once per second. As one of the project engineers stated: "It's now just a matter of waiting for that tiny, pixel-sized point of light to come into view and watching SMART Nav work its magic."

Aside from the sophisticated navigation, the mission employs a plethora of new technologies. The propulsion system for the mission is ion propulsion in the form of NEXT-C, a solar-powered electric system. It uses a gridded ion engine which produces thrust by electrostatic acceleration of ions formed from the xenon propellant. Furthermore, techniques using multi-colour analysis of the asteroidal environment will be employed with the use of a wide-field RGB camera [2].

The spacecraft is set to launch on 23 November 2021 on board a Falcon 9. DART will travel for 14 months before impact, and will only adjust its trajectory one month before it collides. With its target in view, the spacecraft is finally ready to complete its mission. As it slams into the asteroid, most of its parts will get pulverized and ejected into space. From there on, it will be the astronomer's task to ensure that this sacrifice will not be in vain. Astronomers will be measuring the minute, yet meaningful impact that DART had on the clock - the asteroid Dimorphous. As the first mission with a primary focus to alter the natural order of outer space, DART marks the start of a new era for space exploration. As the first mission that aims to accommodate our surrounding space to human life on Earth, this mission could also become the first step towards extra-terrestrial colonization and planetary defence. Everything from terraforming Mars, building cosmic megastructures to displacing planets, could all start with this innocuous collision. Still, let's not get ahead of ourselves - there is quite a long way to go until this becomes a reality.

THAT'S NO MOON!

Looking closer at some real (?) spacecraft

Ranjan Gaur, MSc Aerospace Engineering (ASM)

Arguably one of the most iconic franchises in popular culture, the Star Wars universe has been a host to a plethora of spacecraft in its universe. We take a journey through the different kinds of spacecraft, the influences that inspired them and some real-life instances of technology inspired by them!

As avid fans of the Star Wars franchise would attest, the spacecraft in the Star Wars universe are some of the most iconic and inspired designs (albeit their technical performance can be argued about, if there is such a thing about fictitious spacecraft). From the Millenium Falcon to the Death Star, they have transcended the dimensions of their fanbase and found their place into mainstream pop culture.

A small disclaimer - this article uses the term 'spacecraft' quite liberally, yet fully acknowledges their fictional nature.

LORE

Given the immense amount of canon and non-canon information about the spacecraft depicted in various Star Wars (from here on referred to as SW) media, this article will function merely as an overview. Firstly, for the uninitiated, the SW franchise takes place in a galaxy far, far away, and one central theme of the story is the eternal struggle between the Jedi and the Sith, two factions of a group of individuals who can control the 'Force' – an omnipresent and all-encompassing energy field that connects all matter. Who gains the upper hand in the struggle between the Jedi and the Sith defines and dictates the socio-political climate within the galaxy.

Within this vast universe, there are a number of vehicles and/or ships serving different functions, both on land and in air or space, but for the sake of conciseness, this article will just focus on 'starships'. Starships are defined as any ship that is capable of interstellar travel through the inclusion of a 'hyperdrive'. Better explained in sci-fi mumbo jumbo - a starship would have a dual-drive propulsion system; a sublight drive for escaping a planet's gravity and a hyperdrive for interstellar, travel. Officially, there are multiple types classified, such as starfighters, freighters and starships. While starfighters are the smaller, one- or two-person aircraft seen in the dogfights portrayed in the franchise, the starships are classified as bigger ships capable of carrying a larger crew and more armament. As those familiar with the lore, the franchise and the fanbase of SW would heartily testify, there have been numerous disagreements about inconsistencies within the media portrayals of these spacecraft. In 2012, author Jason Fry invented and published a corrected system (which has its own critics calling out some inconsistencies) called the Anaxes War College System (it is called so, because according to canon, it was established by the Republic Navy War College on the fort planet Anaxes). This system essentially classifies all starships in terms of size and crew capacity, into seven categories. Broadly speaking, these follow commonly familiar naval conventions known to us on Earth, such as corvettes, cruisers and frigates, followed by more fictional classifications like star destroyers.

Some of the most commonly known and familiar starships are the Millenium Falcon (Figure 1), the X-Wing fighters and the TIE fighters, which can be spotted in the cover image.

Figure 1: The *Millenium Falcon*, which made the Kessel run in slightly over 12 parsecs.

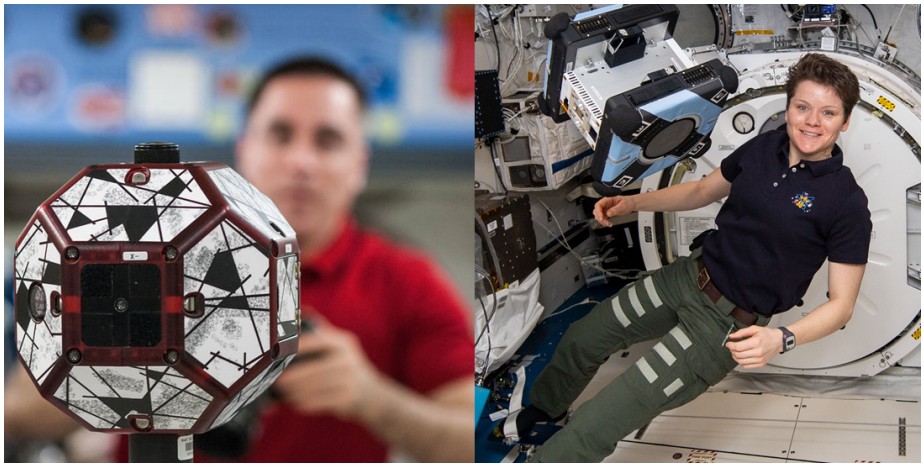


Figure 2: ISS: A close-up of SPHERES with NASA astronaut Chris Cassidy (L), NASA astronaut Anne McClain with the first ASTROBEE called Bumble (R)

Figure 3: "That's no moon... It's a space station", or more precisely, the *Death Star.*

REAL-LIFE INSPIRATIONS

As the lore is purely fictional, the spacecraft depicted are aimed to be more aesthetic and therefore are technically less practical. However, there are many real-life inspirations for some of these iconic designs. The original designs for most spacecraft seen in the franchise are by Colin Cantwell, an animation graduate from UCLA, who, quite interestingly, worked with NASA before his career in special effects and concept design for films. While in NASA, he was responsible for developing visual tools for the purpose of educating people. His concept for a Star Destroyer evolved from warships in general, but also imbued the aesthetic of a dagger to make it more menacing, whereas the inspiration for the X-wing came to him while watching a game of darts in a British pub. Joe Johnston, who designed the Millenium Falcon, took inspiration for the internal view from the cockpit of a Boeing B-29 Superfortress heavy bomber (Fig 1). The J-327 Nubian Royal Starship may remind the reader of the SR-71 Blackbird.

INSPIRING REAL-LIFE

With the amount of influence that the SW franchise carries, it is only natural that many have found it an inspiration for real-life endeavours. For instance, in Episode IV: A New Hope, Luke Skywalker is seen sparring with a floating droid to hone his lightsaber skills. In 1999 MIT professor David Miller, who later served as NASA's Chief Technologist, showed his students this film on their first day and asked them to build this droid. The result was a Synchronized Position, Hold, Engage, Reorient Experimentational Satellite (SPHERES), which was used aboard the ISS to test spacecraft rendezvous and docking maneuvers since 2003. Following its footsteps, another robot called ASTROBEE was sent to space with the purpose of aiding and assisting astronauts (Fig. 2).

Aboard the ISS is another robot called Robonaut 2, who is more affectionately referred to as R2, a name that fans will recognize as being similar to the franchise's beloved droid R2-D2. It should also be noted that the Robo-

Figure 4: An *X-Wing* fighter (L) and a *TIE Figther* (R).

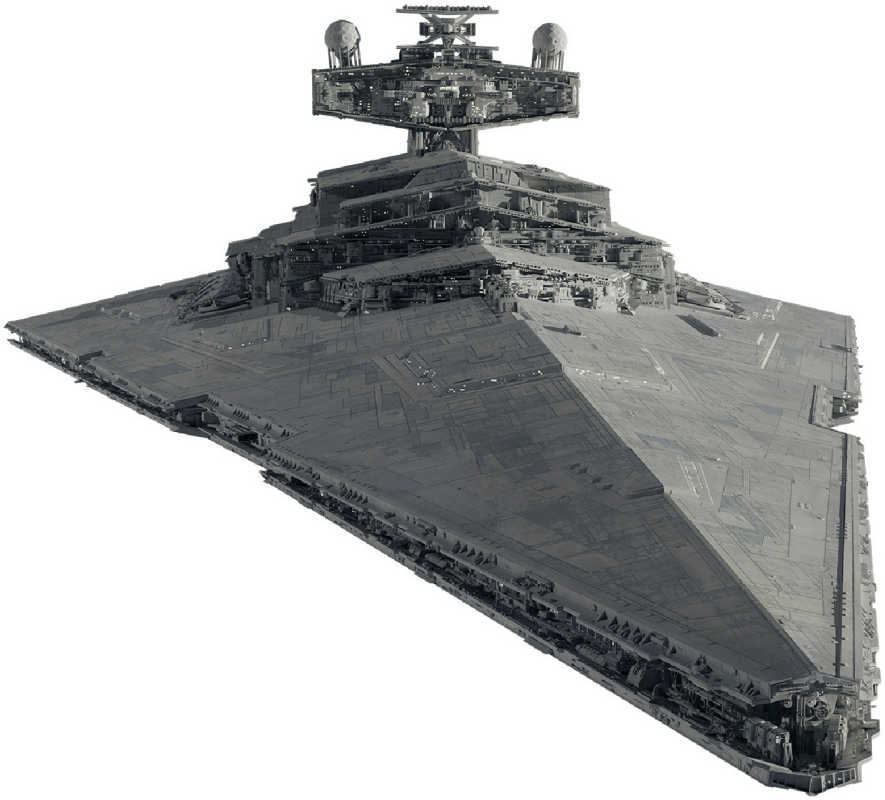
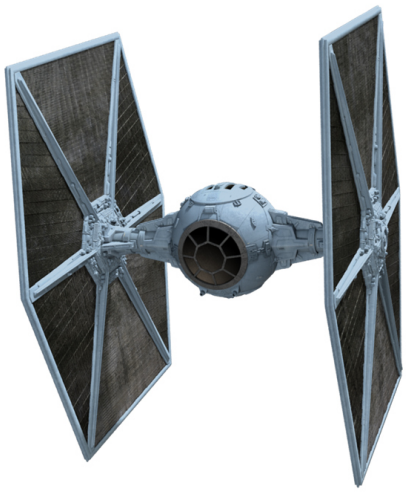


Figure 5: An *Imperial-class* Star Destroyer.

Figure 6: NASA Astronaut Kjell Lindgren's referencing *Star Wars* in his tweet (L), and in the official mission poster (R)



naut 1's appearance bore strong resemblance to the famed bounty hunter Boba Fett.

It is quite wholesome to see that astronauts themselves indulge their affection for SW while at their job. Kjell Lindgren, an ardent fan who has served multiple missions aboard the ISS, has often made his love for the franchise known via his tweets. (Fig. 6)

CONCLUDING NOTE

Fiction, and more broadly storytelling, have always had a powerful impact on our society. Stories like these find purpose in inspiring people, making them think beyond the 'regular', to hope and dream for things that don't exist just yet.

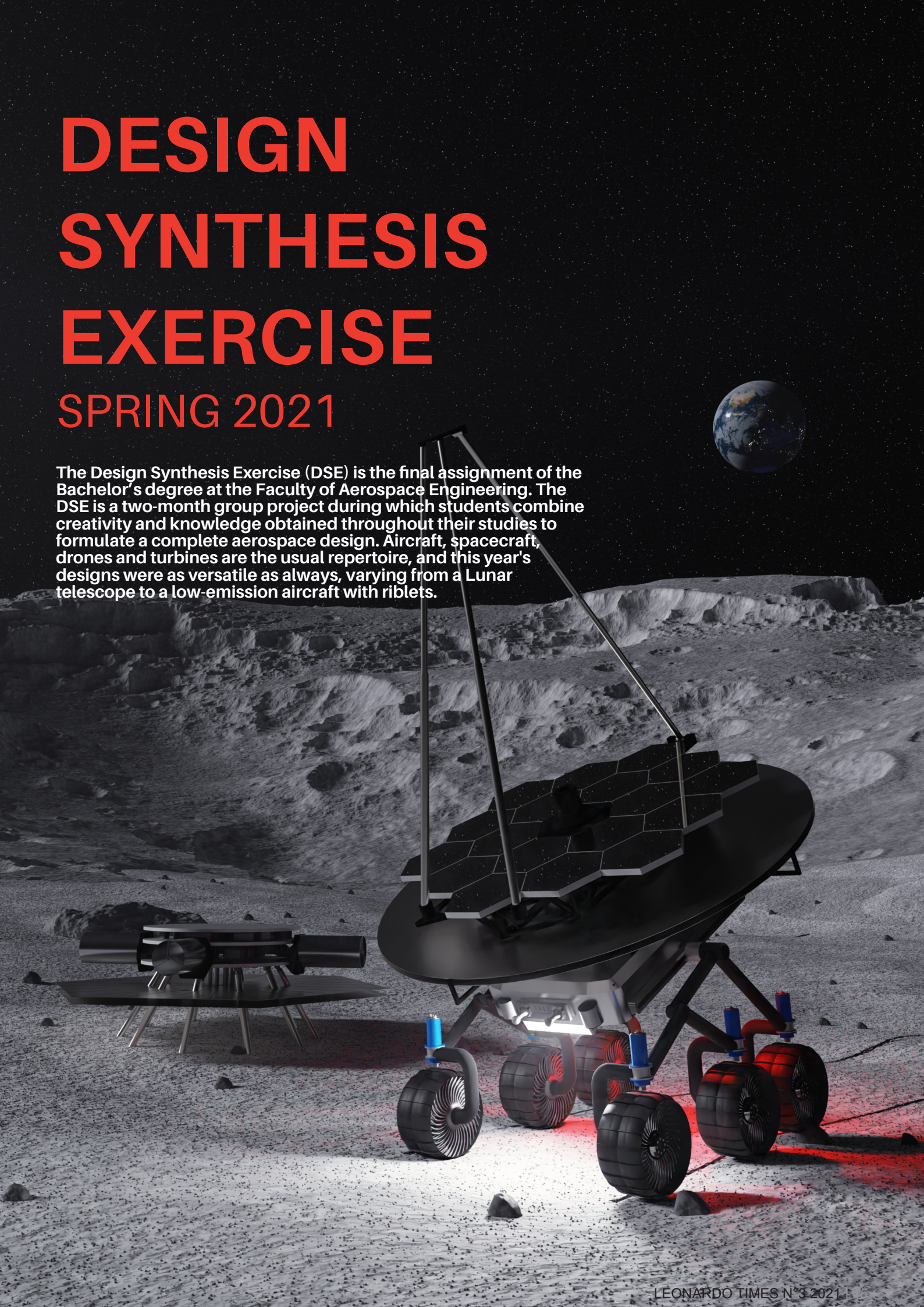
I thank the editorial team at the LT for giving me the opportunity to write this article. I have loved the SW franchise since I was a kid and this article was a great way of expressing my love towards spacecraft as well as the franchise. As scientists and engineers, it is our jobs to find out more and to 'make' things, and I hope this article reminds you of things that make you want to do what you do.

May the Force be with you!

DESIGN SYNTHESIS EXERCISE

SPRING 2021

The Design Synthesis Exercise (DSE) is the final assignment of the Bachelor's degree at the Faculty of Aerospace Engineering. The DSE is a two-month group project during which students combine creativity and knowledge obtained throughout their studies to formulate a complete aerospace design. Aircraft, spacecraft, drones and turbines are the usual repertoire, and this year's designs were as versatile as always, varying from a Lunar telescope to a low-emission aircraft with riblets.



WIGEON

Group 06

Currently, regional intercity travel is bugged by long travel times, a high environmental impact and expensive infrastructure. To mitigate these, the Wigeon is an electrical VTOL aircraft that can carry 4 passengers over a range of 400km, providing much shorter travel times and more flexibility without any emissions.

Despite being a relatively new transportation method; eVTOLs promise emission-free and fast intercity transport. Other advantages include a high level of comfort, low operating costs and low noise levels. Although none of these aircraft are commercially available, their future impact is not to be underestimated. In 2021, already USD 1,200,000,000 have been invested into eVTOL research, a market size that is expected to increase to USD 15,000,000,000 by 2024.

After conducting an extensive market study, it was found that an eVTOL carrying four passengers over a range of 400km fulfills the needs of a large customer base and outperforms most competitors. The customers mainly include commuters, business travelers and tourists with a higher income, with the aircraft being operated either by companies or privately. Furthermore, the initial investment is minimal. Marginal infrastructure is required for operations, as the Wigeon can take off from a regular helipad. The high-level requirements are captured in the mission need statement:

"Provide sustainable, personal aerial transportation for inter-city travel that is competitive with the current transportation methods while requiring minimal infrastructure."

As the range of 400km would be the highest in the eVTOL market, a large demand is anticipated. Because the battery technology required to fulfill the range is not yet available, the first aircraft will not be sold until around 2031. The maximum production capacity is 200 aircraft per year and is attainable in 2035. The retail price per aircraft will be USD 2,000,000.

The Wigeon has a tandem wing design with two equal-sized wings. Transitioning between vertical and horizontal flight is done by rotating both wings. The thrust provided by twelve electrical engines is distributed equally over the leading edge of both wings. This positioning of the propellers enables the Wigeon to provide sufficient lift, even at lower speeds. Aerodynamic efficiency is increased by placing propellers in the wingtips with outboard rotation, counteracting the effect of the wingtip vortices. The total power required to operate the aircraft is provided by 500Wh/kg solid-state lithium batteries.

Throughout the design process, safety was considered of utmost importance, thus redundancy was built into critical systems. The Wigeon can safely land after an engine failure in any flight phase. Furthermore, the design of the aircraft structure considered crashworthiness a vital aspect. It can withstand a fall from five meters without serious passenger injuries, thanks to an energy-absorbing honeycomb structure and wings that shear off the cabin to release it from stiff structures.

With a cruise speed of 260km/h, the aircraft can fly a 400km mission in just over one hour and fifteen minutes. Charging the batteries takes thirty minutes, keeping turnaround times low. Since the aircraft is operated by a single pilot and uses electricity as an energy source, operating costs are minimal. A commercial aircraft that is used for three flights a day has an expected operational lifetime of fifteen years and requires new batteries only once. Waste at end-of-life is minimal, as the Wigeon is constructed mainly out of recyclable aluminum 7075-T6.
To further improve the Wigeon, an optimization framework using OpenMDAO was created. On the first iterations of the optimizer, reductions of 24% in the maximum take-off mass were achieved, together with a 35% reduction in energy consumptions and 30% cost reductions.

All in all, the Wigeon will provide fast, comfortable, convenient and emission-free transport for the regional market. It will also have low noise levels and minimal operating costs, making it competitive with current alternatives, and putting it at the forefront of inter-city travel.

GAIA

Group 15

Currently, regional intercity travel is bugged by long travel times, a high environmental impact and expensive infrastructure. To mitigate these, the Wigeon is an electrical VTOL aircraft that can carry 4 passengers over a range of 400km, providing much shorter travel times and more flexibility without any emissions.

While C02 emission plays a substantial role, it is not the sole driver of global warming; other factors such as nitrates and altitude at which the gasses are released also play a role. Therefore, average temperature response (ATR), which includes all aforementioned factors, is a more accurate measure to quantify global warming. It is expected that policymakers will also express their future restrictions in terms of ATR, and thus, project Gaia aims to minimize ATR instead of just C02.

The two most drastic changes will come from implementing bio-fuels and from changing the flight trajectory. The biofuel implementation only requires the engine to change so that it can handle these fuels. The

flight trajectory change is more complex, however. Current aircraft fly at roughly 10km altitude and a cruise Mach of 0.8-0.9 to minimize DOC. An aircraft would have to fly at roughly 5km with a much lower Mach to minimize ATR; Mach 0.55 remained acceptable. Current aircraft, however, are designed to fly at the DOC optimal cruise conditions, not ATR, which causes their DOC to become unbearable for airliners. This is where Gaia comes in: an aircraft completely optimized to fly at ATR optimized conditions. Currently, Gaia expects to produce 72% less ATR with a 15% DOC increase compared to an Airbus A330-200 neo.

One of the advantages of flying in these conditions is that formerly unrealistically efficient technology is now possible. The most notable is the propfan, a crossover between an unducted turbofan and a turboprop. This engine is a lot more efficient than a turbofan but was previously unfeasible for commercial aircraft as it did not provide sufficient thrust. However, the thrust is sufficient for the ATR conditions, and initial estimates predict this engine will produce 30% less ATR than a turbofan. While this engine is unconventional, it will not be impossible to design; several military aircraft have used similar propfans. Another form of new technology available is laminar flow airfoils, optimized for cruise conditions similar to the ATR.

Besides these, one further improvement to be implemented is passive flow control. Initially inspired by mako sharks, it has been established that microscopic riblets significantly reduce skin friction drag when a surface is exposed to turbulent flow. Gaia will have these riblets on large parts of the fuselage, wing and engine nacelles. The riblets are installed by covering a surface with a coating or film. This technology is proven to be economically and durably feasible. As riblet technology reduces drag, less thrust is required, which in turn lowers ATR.

A final area looked into are materials and their manufacturing. Initial estimates predict Gaia to produce 35% less CO2 during primary production, secondary production and recycling than an Airbus A330-200. Two factors influence this: lower structural weight and more efficient processes. The structural weight reduction is achieved by using carbon fiber composites for the wing, empennage, fuselage and propfan blades. The more efficient processing was achieved by prioritizing sustainability while selecting materials.

While Gaia is far from a complete aircraft, it does pave the way towards a more sustainable future. This is achieved by analyzing the feasibility of still unconventional technology and by estimating the respective ATR reduction. Even if the project does not go ahead in the future, it will still spread awareness about the importance of ATR, the propfan engine, riblets and sustainable manufacturing. Achieving climate change requires rapid change and Gaia offers a potential solution to deal with these changes.

SALT

Group 4

The Synthetic Aperture Lunar Telescope (SALT) is a next-generation space telescope positioned on the lunar South Pole. SALT aims to form part of the return to the Moon. It will investigate the atmosphere of hundreds of exoplanets to answer the question: Are we alone?

Modern mid-infrared telescope designs are approaching their performance limits. Ground-based telescopes are impeded by atmospheric disturbances, and while space-based telescopes eliminate atmospheric interference and reduce thermal disturbances, they are far from a panacea for all difficulties. Their mass, power, and volume limitations lead to high costs and limited apertures, which leads to less frequent launches and slower development of capabilities. The SALT project goal is to sidestep these limitations and provide revolutionary spectral measurements of exoplanet atmospheres. Its novel design exploits recent advancements in metrology, precision mechanisms, and launcher capabilities to provide angular resolution exceeding any existing telescope, with sensitivity even better than the James Webb Space Telescope.

SALT is a new class of nulling interferometer for measuring exoplanet spectral emissions. The system consisting of four independent unit-telescope rovers is located near the lunar South Pole and manoeuvres freely around a central beam combiner. Rover independence enables fine spacing control over a wide range while maintaining complete control over the angular position of each unit telescope. It allows SALT to optimize its configuration for each target system in a way no other system can. The rover design also enables easy expansion to eight or more unit-telescopes, while an upgradable optical system allows for instrument upgrades. This, along with the continuous involvement of astronauts for installation and maintenance, makes the SALT system more flexible than all space-based competitors and even most ground-based telescopes.

SALT's location in Sverdrup crater perpetually shields the telescope from sunlight and provides it with an undisturbed view of the cosmos. SALT's power is gathered at the crater's rim and distributed to the rovers inside the crater through charging stations. The lunar vacuum obviates the need for many noise reduction procedures which significantly reduce the throughput of ground-based systems. This vacuum also eliminates many internal disturbances that limit the performance of other systems. The surface of the Moon is not without challenge, being host to frequent moonquakes. Each of SALT's components features a moonquake mitigation mechanism activated by a surface-based early-warning system.
We conducted a performance analysis based on the optical characteristics of the

SALT system and known exoplanets. It showed that where most currently existing systems can only detect exoplanets, SALT will be able to characterize hundreds of them at resolutions of 5mas or better and SNRs of at least 10.

SALT's target launch is three years after the next manned moon mission. The initial mission will last five years. An extension of up to ten years with four additional unit-rovers further expands the number of exoplanets that can be observed and improves the telescope's performance.
Humanity has never been satisfied with stagnation. From man's early days, we have toiled not just to do the minimum, but to do more, bigger, better, faster, and further. The Wright brothers, Lipperhey and Einstein shared a common aim: to expand the range of human ingenuity physically and intellectually. SALT is the next step in that storied tradition.

ECHO-1

Group 9

More than ever, the world is seeking disruptive innovation to reduce carbon emissions. ECHO-1 is a battery-powered 48-seat passenger aircraft that achieves near-zero carbon emissions during operations. Capable of flying 800km, it will serve as the front-runner in the sustainable regional air transport market by 2035.

Climate change is a global problem of rapidly increasing importance, and polluting industries such as aviation play an undeniable role through the emission of greenhouse gases. Aircraft must be designed to operate sustainably. Currently, electric aviation is unable to compete with existing kerosene aircraft. With increasing battery energy density and improved aerodynamic design, this will inevitably change in the near future.

ECHO-1, the winning design of the spring DSE Symposium 2021, draws its power from 575Wh/kg batteries, as forecasted by the industry for the entry into service of 2035. The aircraft, which has a maximum take-off weight of 20,937kg, carries 5,588kg of payload using 6,919kg of batteries. A three-seats abreast configuration together with high aspect ratio truss-braced wings, reduce viscous and induced drag. It leads to a lift-over-drag ratio of 28.2 for the full aircraft. The truss, which connects to the wings at 30% of its span, greatly relieves bending moments in the wings, allowing for a lighter wing structure.

The propulsion system of the aircraft consists of sixteen propellers distributed along the wingspan. These propellers cause a blown wing effect which increases the lift-to-drag ratio of the ECHO-1. Whereas traditional turboprop engine efficiency suffers greatly when the motor size decreases - this is not the case for electric motors. Each propeller is powered by a highly efficient H3X electric motor which allows for a total powertrain efficiency of 76%.

Besides benefits, electric aviation also presents unique challenges. Most importantly, electric batteries degrade over time. To maintain flight performance, these need replacing every two years. Another obstacle is the thermal management of the batteries. To overcome this, the batteries are insulated from the cabin and use a liquid cooling sys-

tem to prevent overheating. Lastly, there is the need for charging between aircraft landing and take-off. This is achievable by using four MCS chargers, which allow for a turnaround time below thirty minutes.

With its ability to operate from 1,500m runways and its 800km nominal range at the end of battery life, ECHO-1 makes flying the vast majority of high demand regional routes feasible. Furthermore, refueling costs are 48% lower compared to kerosene competitors for similar mission profiles. Due to the simplicity of electric engines and reduced vibrations due to the truss, less maintenance is necessary, leading to lower direct operational costs. Moreover, to accelerate the transition to sustainable aviation, subsidies for flying carbon neutral are conceivable. These would further strengthen the position of ECHO-1 on the market.
Besides the competitive operating costs of ECHO-1, the aircraft also outperforms conventional aircraft in all environmental sustainability metrics. The aerodynamically efficient structure combined with the high propulsive efficiency means that ECHO-1 requires four times less energy during flight. Moreover, due to cleaner energy production, the total greenhouse gas emissions are reduced by 87% compared to kerosene aircraft.

In a nutshell, ECHO-1 is a promising design that stands to revolutionize the aviation industry. The truss-braced wings with distributed electric propulsion allow the aircraft to be financially competitive while being a front-runner in the field of sustainable aviation.

KUMO

Group 18

The recent potential detection of phosphine in the Venusian cloud tops has placed Venus in the prime focus of scientific interest, adding to the mystery of our closest planetary neighbor with its scorching surface shrouded by acidic clouds. The Kumo mission aims to investigate the secrets of our sister planet.

Venus — the ephemeral Morning Star that has fascinated humanity for millennia and is Earth sister planet. Once found to mimic depictions of biblical hell, our closest planetary neighbor is now the subject of discussions about the existence of extraterrestrial life. Contrary to the high temperatures and pressures at the surface, the conditions in the Venusian cloud tops may, in fact, be hospitable to life as we know it. In light of this, the Kumo mission, named after the Japanese word for "cloud", is designed to investigate the evolution of Venus, the presence of biomarkers, and the nature of the unknown UV absorber present in the planet's atmosphere.

The Kumo mission consists of two main scientific elements: The atmospheric flying probe Tori (Japanese for "bird") and the orbiter Tsubuyaki (Japanese for "to tweet"). Tori will be an inflatable flying wing, designed to fly around Venus ten times in an equatorial band at altitudes of 55km to 65km and making use of flexible solar arrays laid out along its hull to power its electrical propellers. Tori's unprecedented hybrid airship design will allow it to harness buoyancy to float along with the zonal winds on the night side of the planet. It will provide an optimal shape for flight performance, thus allowing for visiting a wide range of measurement locations while traversing the dayside of the planet. The data collected from the in-situ measurements will be transmitted to Tsubuyaki, which in turn, will then "tweet" the information back to the ground stations on Earth. Additionally, Kumo's orbiter Tsubuyaki will conduct measurements of its own to match up with Tori's and to fill in other knowledge gaps.

Tori will take measurements within the Venusian atmosphere for approximately 60 Earth days, far surpassing the comparatively short-lived missions preceding it. After completing its nominal mission, it will continue to conduct measurements as long as feasible before beginning to descend deeper into the atmosphere. It will provide valuable data on material degradation within the highly acidic environment it will be subjected to. First, Tsubuyaki will go around the planet, in an orbit designed for optimizing relay for the first half of Tori's nominal mission, followed by an orbit optimized for scientific coverage and yield. Tsubuyaki will remain in its science orbit after Tori concludes its end-of-life mission and conducts further measurements while optionally serving as a relay satellite for future missions to Venus for at least one year. The mission will be extended within reason while also tracking orbit and material degradation as Tsubuyaki passes through the Venusian exosphere and gradually begins to spiral into the atmosphere.

Using a reusable Falcon 9 launcher, state-of-the-art technology, and an atmospheric flight plan to optimize a reduction in energy consumption, the Kumo mission aims to be as sustainable as possible. The measurement data gathered by Tori and Tsubuyaki will provide revolutionary insights into the past and present of Venus, as well as possible clues about the future of our own home planet. Thus, closely studying the Morning Star once more from the clouds and above could be crucial to understanding the history of our solar system, the future of mankind, and whether we, perhaps, are not alone.

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