LEONARDO TIMES

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

VOLCANOES ON VENUS

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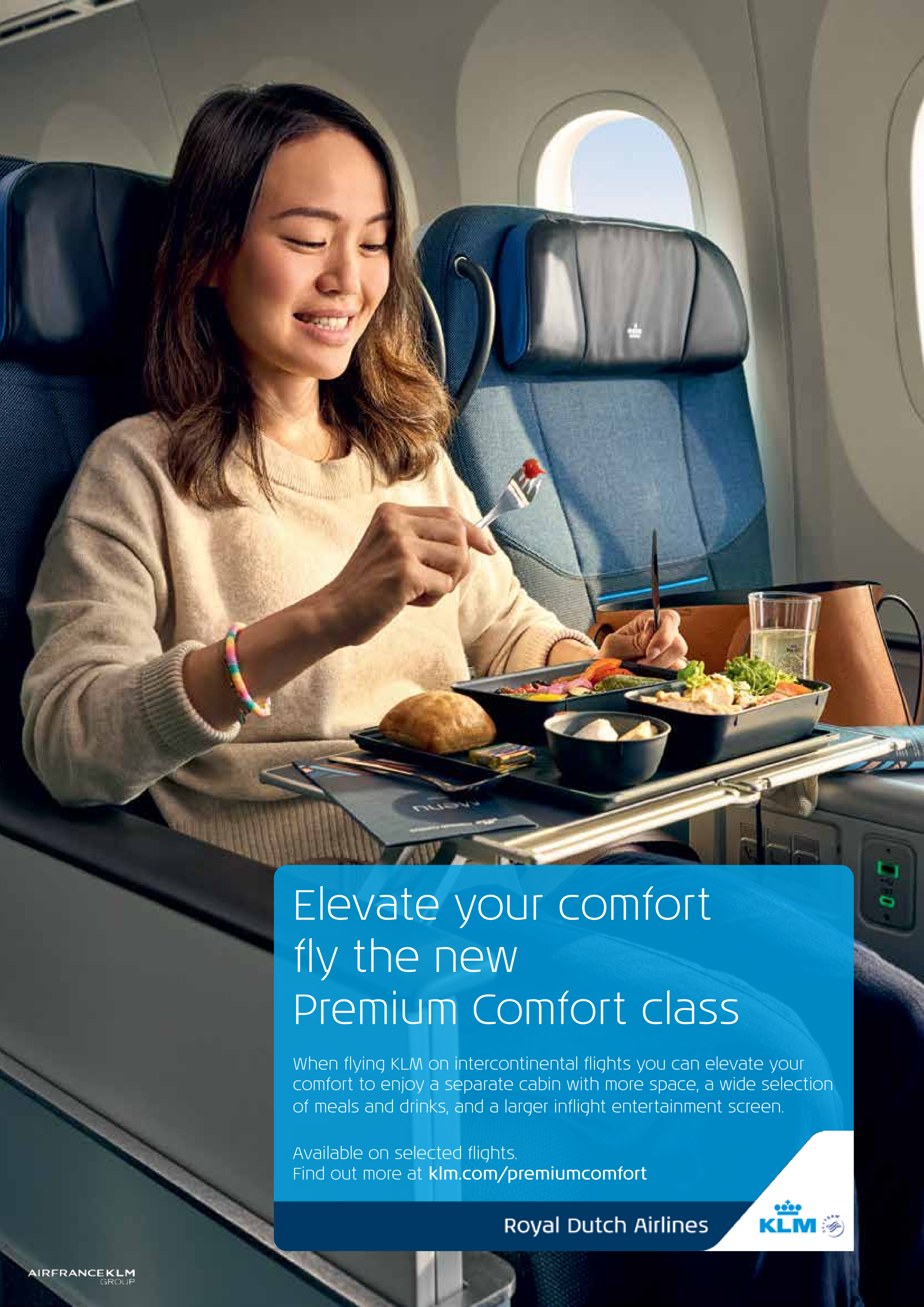

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EDITORIAL

PASSING ON THE TORCH

Dear reader,

"The lion was on fire". These were the exact words of a high school friend from a few years back. What he was referring to was a poem in which a lion saw itself surrounded by bombs falling down, lighting up a ring of hopelessness despite its wild spirit. Similar to the lion, the world has once again found itself in the midst of a turbulent age in the last few months. With global headlines predicting the inevitable eventual onset of the next recession and banking scares from around the world. Furthermore, the events in Sudan and Ukraine are far from over. Nevertheless, glimpses of optimism find their way around the doom and gloom of the zeitgeist, all the way to this magazine.

This edition includes articles analyzing the potential of different countries' respective space economies, alongside discussing Delft's capacity to drive global innovation in hypercompetitive industries, such as New Space. Furthermore, we get to explore the novel innovation of shape memory alloys and hear more from our Faculty's very own Aerospace Diversity Department.

I've enjoyed my role immensely over the course of the last four editions. From pushing the website to this decade's standards to the many interviews and the social activities with the editorial team, steering the magazine this year has truly given me a lot. I am happy to announce that I will be leaving the Leonardo Times in the highly competent hands of Ruth Euniki Vraka. She will take over the magazine's leadership alongside Arham Elahi (final editor) and Lisanne Vermaas (managing editor). I wish you three all the best.

I wish you all an exquisite and relaxing rest of the summer.

Topias Pulkkinen
Editor-in-Chief, Leonardo Times

Last edition ...

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Aircraft accidents always draw attention from the media, but how are the investigations actually conducted?

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Starship's maiden flight was truly explosive, but SpaceX considers it successful. For other companies this would be a big setback, what makes this company so different?

COLOPHON

Year 27, NUMBER 2, Summer 2023

The 'Leonardo Times' is issued by the Society for Aerospace Engineering students, the VSV 'Leonardo da Vinci' at the Delft University of Technology. The magazine is circulated four times a year with a circulation of around 5000 copies per issue.

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DESIGN, LAYOUT: vanStijl, Rotterdam
PRINT: Quantes Grafimedia, Rijswijk

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

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

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

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IN MEMORIAM

MEMBER OF HONOUR VAN GHESEL GROTHE

With great sadness, we learned that on the 4th of June 2023, Prof. ir. Van Ghesel Grothe has passed away.

Prof. ir. J.A. van Ghesel Grothe has been dedicated to the VSV 'Leonardo da Vinci' and the Faculty of Aerospace Engineering with great enthusiasm for many years. What was remarkable about Mr. Van Ghesel Grothe is that he witnessed the establishment of our association during his time as a student at the faculty 78 years ago. From 1977 to 1986, he served as dean and made valuable contributions to all students studying at the faculty. As a professor, he also assisted with the relocation of our faculty. In 1980, he was installed as Member of Honour of the VSV 'Leonardo da Vinci'.

As a board and association, our thoughts are with his family and other loved ones. Mr. Van Ghesel Grothe is remembered as a respected icon for his long-standing dedication to both the VSV 'Leonardo da Vinci' and the faculty.

A MESSAGE FROM THE BOARD

Dear reader,

It is with great pleasure that I welcome you to the latest edition of the Leonardo Times, the summer edition. This issue is already the last one of the academic year 2022-2023, and the last edition written in the 78th year of our society. This 78th year has been a hugely successful one, and the first year in a while that has been fully covid-free. From the first Belgian Beer Drink since 2019 to the return of Limitless: This year has marked the return of classic events on top of the set of hallmark events we organise each year, such as our symposium or the study tour.

Over the last few months, we have organised many activities for our students to enjoy. We had the return of Limitless, our faculty party hosted on the field next to the Fellowship. Exciting to know that it will happen again next year! Furthermore, we organised the Design Battle Competition on a sunny Saturday. All the teams worked hard to quickly build their inventions from scratch. On top of this, the Akcie organised an event that the VSV did not host before. They set up a day-long car rally, where participant got to the next checkpoint by solving challenging puzzles. It was a day filled with joy and laughter! Another unique event was the ADDinner in the Dark, organised by ADD. During this dinner, participants got to experience how it is to have dinner while being blind. The restaurant was completely darkened, which caused the students to have to rely on their other senses. A unique experience! Lastly, during this quarter we had the honour to host Minister Mark Harbers from the Ministry of Infrastructure and Water Management for an Interview to Inspire in our faculty. It was inspiring to hear about his time as a student, his early career and his view on the future of mobility!

In the upcoming future, we will host our annual freshmen weekend. Here, we will offer our upcoming freshmen the opportunity to meet fellow students and form friendships. We sure are excited to meet this new generation of aerospace enthusiasts! A week after freshmen weekend, study tour 'Daedalus' will leave for Paris. Here, they will visit various companies from the aerospace sector. Following this, they will travel through Toulouse, Switzerland, Greece and Italy. Highlights include a visit to the Athens Flying Week airshow, a visit to the Airbus facilities in Toulouse and of course seeing many of the different cultures that Europe has to offer. During the study tour, the new academic year will already start, and events such as the Top Gun event and the Fresh Prince of LR party.

Now, for one last time writing this introduction, I want to truly thank the editorial of the Leonardo Times for delivering such an excellent edition yet again. This year, they have really impressed me with the excitement and curiosity they have in writing all the articles. Each edition, they surpass the quality of the preceding one. Enjoy the read and have a lovely summer!

On behalf of the 78th Board
of the VSV 'Leonardo da Vinci',

With winged regards,

Max van Hugten
President of the 78th Board of the
VSV 'Leonardo da Vinci'

SAUDI ARABIA IN SPACE

Saudi Arabia's rapid push for modernization won't come as a surprise to many after over half a decade of Muhammed Bin Salman's rule. The reformist ruler has seen Saudi Arabia take steps in many areas, not least towards gender equality. As testament of this, Rayyanah Barnawi, the country's first female astronaut, reached the ISS on May 22nd of this year and spent just over 9 days in space. During the mission, she was accompanied by her colleague, Ali AlQarni, the first Saudi male astronaut to visit space. Ms Barnawi, a biomedical researcher by discipline, worked on stem cell and breast cancer research as part of the mission.

The Saudi citizens were launched on a SpaceX Falcon 9 rocket as part of a mission by Axiom Space, a private company specialized in providing private spaceflight for commercial astronauts. Founded in late 2018, Saudi Arabia's space program, also known as Saudi Space Commission, is in its early stages, but that hasn't stopped Saudi citizens from pioneering the country's space economy and putting their names in history.


SAUDI SPACE COMMISSION

THE LAST ROUND FOR VIRGIN ORBIT

In January of 2023, Virgin Orbit's historic and inaugural take-off from Spaceport Cornwall ended in mission failure, marking the beginning of the end for the company after it filed for bankruptcy in early April, less than three months later.

Founded in 2017, Virgin Orbit spun-off from Virgin Galactic, Richard Branson's space tourism venture. In contrast to its mother company, Virgin Orbit targeted the small satellite launch market, with its vehicle: the LauncherOne. This rocket first reached space in 2021, where it deployed 10 cubesats. But after a string of successful launches out of the Mojave Spaceport in the following years, the company experienced a mission failure in its first and only launch from the UK.

The modified Boeing 747-400 jet, dubbed Cosmic Girl, carried the rocket out of Newquay, Cornwall, over the Atlantic Ocean where it was successfully dropped and ignited, then sent into the heavens. But, moments later, the mission suffered an anomaly and failed to reach its target orbit, inevitably losing the nine satellites in its payload.

The setback crippled Virgin Orbit. Its share price fell, rendering them unable to secure more funding and forced the company to lay off most of their staff and halt all activities. The company, once valued at $3.5 billion on the Nasdaq stock exchange, ultimately never reached profitability and its assets were since sold to other commercial space giants such as Rocket Lab and Astrolaunch. So sadly, while the company has set records conducting the first ever satellite mission out of the UK, it will cease to make history again.


VIRGIN ORBIT

PARIS AIR SHOW 2023

By the time you're reading this, Paris has hosted its biennial Air Show, gathering aviation industry giants from around the world. This year, the most speculated attractions at the Air Show include the Air Mobility event, the Air Lab as well as the Start-up Initiative. The first of these is expected to showcase the rapidly developing eVTOL market from established names like Airbus to the industry's rising stars, like Ascendance and Volocopter. The second item on the list will present the prospects of decarbonizing the aviation industry by the target year of 2050, highlighting the enterprises working on emerging breakaway technologies necessary to enable this. Finally, the Start-up Initiative will allow nearly 300 aeronautical engineering start-ups to promote their case in the public spotlight. These numerous start-ups include the German Lilium GmbH, working on electric-powered personal aviation as well as many of its future competitors; such as Joby Aviation and Archer.


PARIS AIR SHOW

GOVERNING SUPERINTELLIGENCE

From villainous mastermind to technological marvel, Artificial Intelligence consistently makes sensational headlines. Even since the Leonardo Times' last edition, solely dedicated to the subject of AI, there has been a flurry of AI news. Most recently, the center for AI safety – a San Francisco non-profit – issued a statement declaring that "mitigating the risk of extinction from AI should be a global priority alongside other societal-scale risks such as pandemics and nuclear war". Signatories include executives from OpenAI and DeepMind, such as Sam Altman, Ilya Sutskever, and Demis Hassabis as well as a remarkable number of experts in the field including professors and researchers from universities globally. Though, it's not the only statement of its kind - an earlier open letter, requesting AI developers to pause progress, was signed by over 1000 experts including Elon Musk and Steve Wozniak to name-drop a few. These statements legitimize the horror stories circulating the news in which AI is used in nefarious means. For example, that ChatGPT-4 was able to manipulate a person into helping it bypass a CAPTCHA by claiming it was a visually impaired human. Or the rising number of reports where AI is used in scams to make them increasingly personal and convincing. Unsurprisingly, multiple governments and companies have increased promises of regulating the exploding growth of AI. After meetings between Prime Minister Rishi Sunak and US President Joe Biden, the UK announced it will host a global summit to tackle the dangers associated with AI. These proactive approaches and unified cooperation between researchers, governments and industry leaders will be crucial as we balance the advancement of AI with the mitigation of the risk of our own extinction.

CNBC

ADVANCING FAIRNESS IN AI

Mirthe Dankloff on inclusive AI systems for the public sector

Aerospace Diversity Department

MIRTHE DANKLOF

Mirthe Dankloff is a PhD candidate at the Civic AI Lab in Amsterdam, which aims to foster an inclusive society through fair and transparent artificial intelligence (AI). The Aerospace Diversity Department interviewed her about her research, which focuses on fair outcomes in algorithmic decision-making and aims to develop fair and unbiased algorithmic systems for equitable public decision-making.

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

Q: How did your background influence research choice?

MD: As a student, I combined two master's programs: AI and Philosophy. By combining these, I wanted to overcome the lack of attention to ethical and societal issues in the AI curriculum. At the time, innovation and ethics were seen as one anothers antagonists, something I strongly disagree with. I value the importance of seeing disciplines as complementing rather than opposing. Fortunately, there is increasingly more attention to these topics nowadays, but there is still room for improvement. I also completed an internship at the Scientific Council for governance policy (WRR) where I co-wrote the advisory report requested by the Dutch government on "the impact of AI on public values". These experiences taught me the importance of translating between research fields: from conceptual to applied research, but also from research to policy.

Q: How do you ensure that your research reflects the most current knowledge and best practices, especially with the progress in development of AI?

MD: AI has been getting a lot of attention lately, where progression is especially highlighted in the domain of large language models. Regarding the fairness of AI, there were a few notorious cases in recent years where algorithm usage in high-stake scenarios led to wrongful accusations of citizen minorities (e.g. the COMPAS case in the US, but also Systeem Risico indicatie (SyRI) and the child benefit scandal in the Netherlands). These cases received much media attention and nowadays the problem of fairness in AI is widely recognized in legal and ethical guidelines. But most of the proposed guidelines remain generic. At the Civic AI lab, we aim to aid citizens by translating these higher-level guidelines into practical methods. These methods include making error analysis understandable for civil servants and oth-

er decision-makers in the public domain. Based on error metrics and the task at hand, public authorities can balance the risk and benefits to ensure equal treatment of citizens and non-discrimination.

Q: What is a key challenge you have encountered in developing a framework for assessing fairness in AI systems used by the public sector?

MD: One challenge is that fairness in AI has predominantly taken on a technical approach, addressing mostly model (dis) functionalities. However, an automated decision system should not be understood in isolation from its social-technical ecosystem. This also means that the models reflect people's design choices and criteria. Often public practitioners think that they lack the required technical skills to contribute to the development of AI. However, in our case, they are the experts when it comes to answering questions such as which features are important to predict 'eligibility for a loan' or what being a 'fraudster' entails. These are not properties that citizens intrinsically lack or possess but social constructs that we need to determine beforehand.

Q: In your opinion, what are some of the most pressing ethical concerns related to the use of AI in the public sector?

MD: We often see that public practitioners work together with engineers from private parties for model development. A pressing ethical concern is when all (apparent technical) decision-making is outsourced to (private) developers, the mandate for important policy decisions will also be outsourced (i.e. deciding what acceptable error rate differences between subpopulations are). This can affect citizens outcomes in terms of fairness, which in this context refers to predujice or favoratism towards individuals or groups based on their inherent or acquired characteristics through algorithmic decision-making. These decisions must not rely only on engineering teams, but also on (public) domain experts and even citizens and these decisions should be transparent. Furthermore, outsourcing these important decisions, and thus responsibilities, can make it harder to publicly scrutinize the decision outcomes. Models are often called black boxes, but for me, the governance structures and decision-making around the model are often the real black box.

"Models are sometimes referred to as black boxes, but for me, the governance structures and decision-making around these models are often the real black boxes."

Q: How does your research address the specific needs and experiences of marginalized or underrepresented individuals and communities when developing and deploying AI systems in the public sector?

MD: Public authorities need to balance the risks and benefits to protect their citizens. One way to do this is by making error analysis transparent and understandable. In my research, I try to identify and address the information gap that exists between engineers and model end-users such as public practitioners who often report to having no technical skills. Therefore, my research is mainly about making fairness assessments explainable and interpretable to a variety of stakeholders. Moreover, at the research lab, we also try to think about how to fruitfully involve citizens and public practitioners in data projects. We can do this by giving them a voice through focus groups, interviews, and through user feedback mechanisms.

Q: What is your vision for AI's role in future public governance, and how can we ensure its effective, ethical, transparent, and accountable use?

MD: Algorithmic decision-making offers several benefits: machines do not become tired or bored and surpass humans in pattern recognition and making predictions in well-defined scenarios. But it falls short in general world knowledge, common sense, and other human capabilities such as collaboration, adaptivity, explanation, and awareness of norms and values. These are essential when dealing with real-life scenarios where critical or unfair situations could arise unexpectedly. I envision the future of AI in public governance as solely a supporting decision tool. In terms of accountability and transparency - the people who use, make, and sell the system remain accountable for ensuring transparency of their products.

Q: How do you think we can educate the public about the potential benefits and risks of using AI in the public sector?

MD: Researchers (but also private AI practitioners) could start by demystifying what AI actually is to the public. This means that AI shouldn't be presented as an independent agent or as an exogenous force that acts on its own. I often still hear researchers attribute human or even superhuman qualities to AI systems. In the media especially, AI is often described as sexist, racist, or something we are in conflict with (e.g. it might take over our jobs). In this view, a certain agency is ascribed to AI without directly considering its developers, owners, and manufacturers - and their responsibilities. People should be responsible for the products they make, design and sell. I think there is a responsibility for researchers here to steer away from terminological confusion and anthropomorphizing of AI systems which can hamper a fruitful debate on the risks and benefits of AI.

Q: How can researchers and academics take diversity and inclusion (more) into account in their work?

MD: Researchers could start by collaborating with researchers from different fields and even engage with disciplines outside of research. I know this is a bit of an easy point but I still see that social and technical researchers don't collaborate or talk to each other, consequently under or overestimating each other's work. There has been long standing research in areas such as psychology, philosophy, and other disciplines, that research in AI can clearly benefit from. Why reinvent the wheel and frame every social problem as solely a technical fix? Let's acknowledge each other's hard work and join forces to tackle and address societal problems.

BREEZING THROUGH SPACE

A deep dive into Aeolus, the first satellite mission to gather global wind data using a doppler lidar instrument

Varun Gottumukkala, Leonardo Times Editor

ESA

Named after the "keeper of winds" in Greek mythology, Aeolus is fifth in the family of ESA's Earth Explorer missions, aiming to address the most urgent Earth-science questions of our time. Aeolus went through an arduous development process and its originally planned launch was delayed by over a decade [1]. But once in orbit, it proved to be worth the wait.

THE MISSION

The European Space Agency's (ESA) Aeolus satellite was launched in August 2018 onboard a Vega rocket from Kourou, in French Guiana [1]. But 30th April 2023 marked the end of operations for the mission. Having already surpassed its planned three-year life by over 18 months, Aeolus will now slowly descend into Earth's atmosphere, waiting for its demise [2].

Increased solar activity has forced Aeolus to end its four and a half year mission. Every once in a while, the sun spews waves of particles and radiation which heats up the Earth's atmosphere. As the heated air rises, the atmosphere around the Earth swells, engulfing the orbits of satellites in low earth orbit. This increases the atmospheric drag experienced by satellites, sometimes causing them to lose nearly a third of a mile of elevation daily during extreme magnetic storms [2]. For Aeolus, it meant using extra fuel to maintain its orbit, as it battled against the denser atmosphere. At the time of writing, Aeolus is naturally descending from its orbit of 320 km to an orbit of 280 km, as it gets caught up in wispy winds, the very phenomena it was observing. From then on, operators at ESA's mission control center in Darmstadt, Germany, will descend the satellite down to 150 km, after which the increasingly thick atmosphere will cause Aeolus to burn up as it flashes 80 km above the Earth's surface. Mission operators have ensured that the satellite targets open ocean waters, to prevent the risk of fragments falling over land [3].

Aeolus was a pioneering mission carrying the first instrument of its kind. The mission's purpose was to fill the knowledge gap of winds above the oceans, tropics and polar regions, where data was sparse. In its sun-synchronous polar orbit, Aeolus orbited the earth once every 90 minutes and

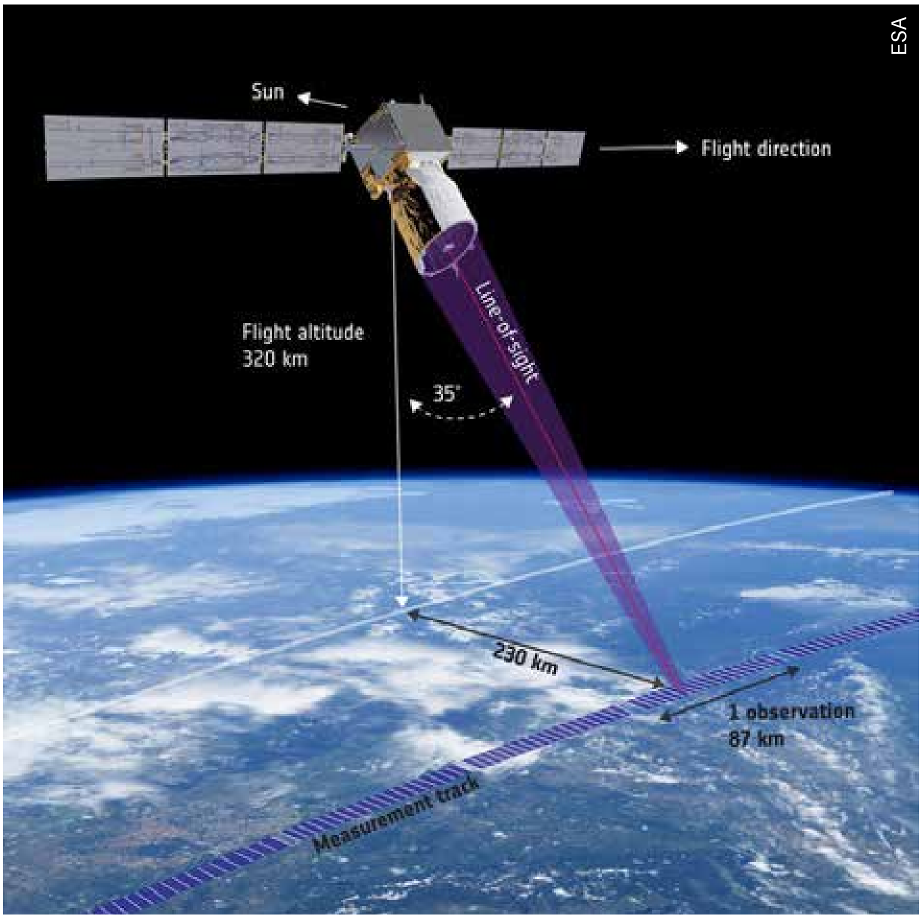


Figure 2: The measurement geometry of the Aeolus satellite

covered the entire globe in seven days, or 111 orbits. Before the launch of Aeolus, wind measurements were primarily taken by ground-based sensors, aircraft, and weather balloons. These systems provide localized measurements, which are extrapolated using cloud tracking and simulations. Aeolus was the first mission to provide global, three-dimensional profiles of wind measurements. It managed the feat with the help of an instrument using laser pulses and the good-old Doppler effect to derive wind speeds [4].

THE INSTRUMENT: ALADIN

The instrument onboard Aeolus was ALADIN, the Atmospheric LAser Doppler INstrument. It relied on laser profiling principles, scattering theory, and doppler effect phenomena. In short, a laser pulse is emitted and the nature of the reflected pulse, or backscatter, is observed. But let's dig deeper into the instrument's development and operation [9].

The ALADIN development began all the way back in 2000. During the design process, the team faced several obstacles, leading to the generation of over 500 designs. ESA's director of Earth Observation at the time, Volker Liebig, attributed the development delays to a lack of knowledge on the "ultraviolet-laser-induced damage on optical surfaces in a vacuum" [6].

In the early stages of its testing, ALADIN faced incessant damages dominated by laser-induced contamination. Aeolus scientists had to assemble their own UV laser, as existing ones had been built for nuclear weapon simulations and were thus classified. After developing a suitably powerful and stable laser by 2005, the team tested the device in vacuum, only to realize that the potent beam was heating the surfaces of the lenses to over 1700 degrees Celsius, damaging their coatings [8]. Organic contaminants from the laser equipment were carbonized by the UV laser and accumulated on the lenses. These deposits absorbed energy from the laser and distorted the beams. The solution to the problem turned out to be rather simple: injecting small amounts of oxygen causing the contaminants to burn up and clean the lenses. The delays and additional development increased the mission cost to 481 million euros, 50% higher than its original estimated cost [22].

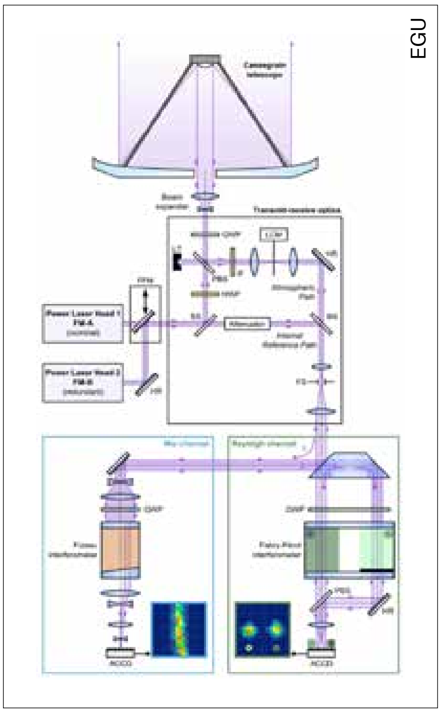


Figure 1: The lasers, telescope, optics, and detectors of ALADIN

ALADIN contains a telescope with a 1.5 m diameter, responsible for receiving the backscattered light and directing it towards the detectors. The lasers operate in the near-UV band of 355 nm. The vertical resolution of 250 m to 2 km results in up to 24 vertical measurement bins in the atmosphere from the surface up to 30 km [7]. The instrument has a horizontal measurement resolution of 3 km, which is averaged to obtain a horizontal observation resolution of 87 or 10 km, depending on the nature of the backscattered light [23].

As can be seen in Figure 1, ALADIN consists of two redundant and switchable UV laser transmitters. In 2019, the energy levels of the first laser dipped to a point where the wind data quality was compromised. This prompted the mission operators to switch off the laser and activate the second laser, which did the trick [12]. In addition to the telescope, ALADIN contains transmit-receive optics and a dual channel receiver. The transmit-receive optics, as the name suggests, separates and directs pulses for transmission and those that have been received [18].

Once the backscattered pulse has been directed from the telescope, it is separated into Rayleigh and Mei channel receivers. Each channel contains an interferometer, which acts as a spectral filter. The spectra are imaged at the ACCD (accumulation charge coupled device) detectors to determine the frequency shift, and consequently the wind speed [9]. The Internal Reference Path directs a small portion of the transmitted beam to the receiver channels to accurately measure the difference in frequency between the transmitted and received beams [12].

MEASURING THE WIND

Now, how exactly is the wind speed derived from the backscattered signal, and what do Rayleigh and Mei mean? Rayleigh and Mei refer to two different types of scattering that occur when light interacts with particles, depending on the particle size and the wavelength of the incident electromagnetic (EM) pulses. Particles significantly smaller than the wavelength of incident EM pulses induce Rayleigh scattering, while particles similar in size to the pulsed induce Mei scattering. In the atmosphere, molecular substances cause Rayleigh scattering, while larger particles such as dust, aerosols and water droplets cause Mei scattering [5]. It is assumed that the molecules and particles scattering the pulses are carried by the wind, and that their movement is representative of the wind itself. It is a fair assumption due to the powerful viscous forces between particles in the atmosphere [9].

Once the UV pulse is emitted towards the atmosphere, it interacts with molecules and particles in its path. A fraction of the scattered pulse is reflected back at a shifted frequency and is detected by the telescope. Comparing the difference in frequency of the emitted and reflected pulse leads to the determination of the Doppler shift. However, in addition to the Doppler shift due to the wind velocity, the received frequency is also shifted due to the satellite's motion and the Earth's rotation. In the time that it takes a laser pulse to leave the instrument and return, the satellite would have moved some 15 m in its orbit and the Earth would have rotated less than 0.00001 degrees, but every little motion must be accounted for in order to ensure the measurement accuracy [9].

Rayleigh and Mei scattering are elastic scattering processes, meaning the scattered light frequency from static particles does not change significantly. It leads to the assumption that the frequency shift of the backscattered light is caused solely by the particle motion, after accounting for the satellite's and Earth's motion. Once these motions have been corrected, the residual doppler shifted frequency is proportional to the speed of the backscattering particles and molecules. The wind velocity derived from the doppler shifted frequency is along the line-of-sight of the laser, which is at 35 degrees to the nadir, as seen in Figure 2. The horizontal component of the velocity can be calculated using the known angles [24].

A typical measurement profile consists of the wind velocities over a range of latitudes and altitudes. The altitude of the particles reflecting the pulses is established by knowing the speed of the pulses and the time interval between emitting and receiving the pulse. The pulse repetition rate is 50 Hz, meaning that laser pulses are fired 50 times a second. [9] This is still slow enough to allow the backscatter of each pulse to return before the next pulse is sent out, since it only takes about five hundredths of a second for a pulse to leave the instrument and return. Thus, the measurement altitude is obtainable by multiplying the speed of the laser pulse, assumed to be the speed of light in a vacuum, by the time interval, the distance traveled by the beam. Assuming the laser pulse speed to be equal to the speed of light in vacuum introduces small uncertainties, since the beam travels through dense atmosphere for a portion of its journey [25]. However, even on the Earth's surface, the speed of light is only 0.03 % slower, and given that the beam travels through near-vacuum space for most of its journey, the discrepancy is negligible [26].

THE DATA AND ITS IMPACT

Throughout its operational life, Aeolus beamed down over seven billion laser pulses, and the ground station enabled 99.5% of the data to be available to users within three hours of the measurements [10]. The data obtained by Aeolus is used to improve weather forecasts and climate models, and track the real-time development of extreme weather events. Only months after launch, the retired head of ESA's Opto-electronics section claimed that Aeolus is "returning more wind data than all ground-based measuring systems put together". It is estimated that the total mission benefits of Aeolus' data to European stakeholders and society is 3.5 billion euros [13].

Figure 3 shows the orbital coverage and collected wind data of Aeolus over a twelve hour period. The slices are tilted 35 degrees from the vertical, and represent wind component information on 9 February 2020, a day with record-breaking jet-stream winds over the Atlantic. Most of the information is gathered from Rayleigh scattering of air molecules, as shown on the left, but the Mei scattering from aerosols and clouds have smaller random errors and have a better horizontal resolution. Level 2B in Figure 3 refers to the processing level of the raw data [15].

Figure 4 shows the impact of assimilating Aeolus data on the accuracy of numerical

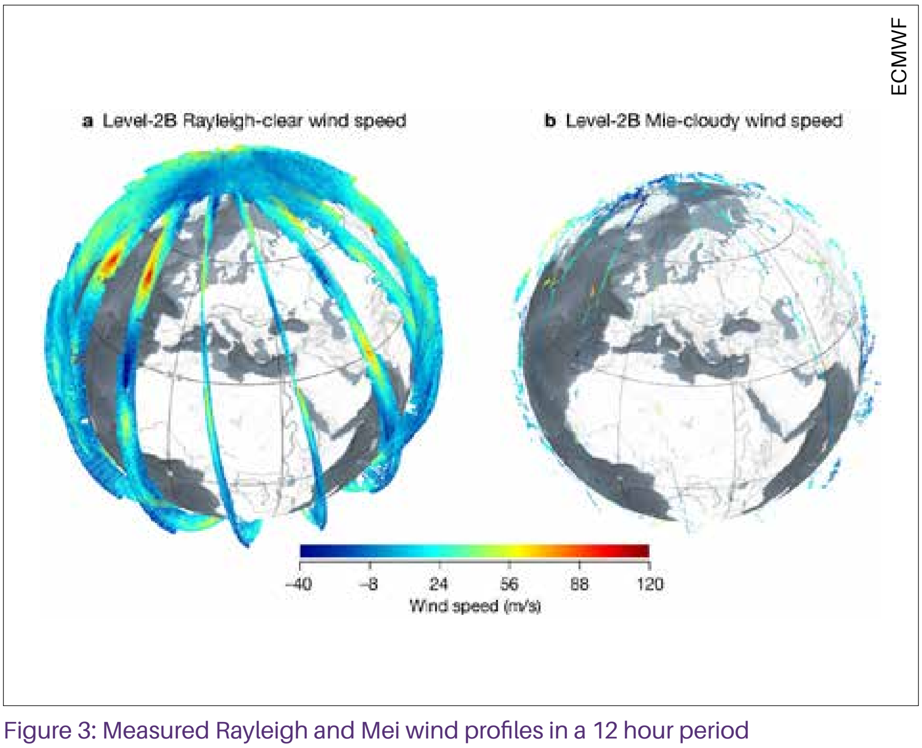


Figure 3: Measured Rayleigh and Mei wind profiles in a 12 hour period

weather forecasts. The four images show the change in forecast errors after assimilating Aeolus data at four different altitudes. A negative value indicates that Aeolus data reduces the forecast error, thus improving the weather predictions. As can be seen, the impact of Aeolus data is mostly positive, and is particularly significant near the tropics in the East Pacific Ocean at 100 hPa. This is mainly because the coverage of in-situ measurements from weather balloons and aircraft is scarce in the region [15].

An example of using Aeolus data was when monitoring the series of Hunga Tonga-Hunga Ha'apai volcano eruptions in December 2021. As shown in Figure 5, a drop in backscattered Rayleigh signals indicated the presence of volcanic ash. Thanks to the near real-time data from Aeolus, scientists could track the volcanic explosion as it traveled westward. The sensitivity of Aeolus allowed scientists to monitor the effects of the eruption months after its occurrence [14][17].

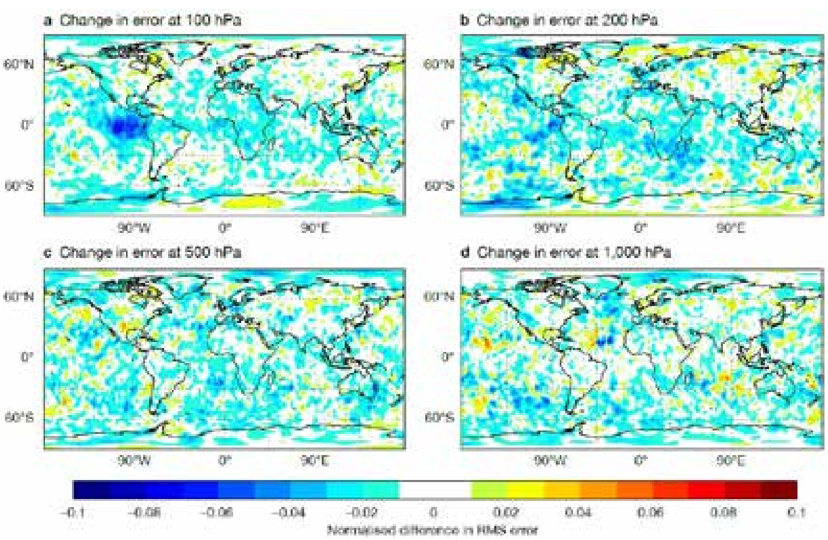


Figure 4: Change in error of weather forecasts after assimilation of Aeolus data

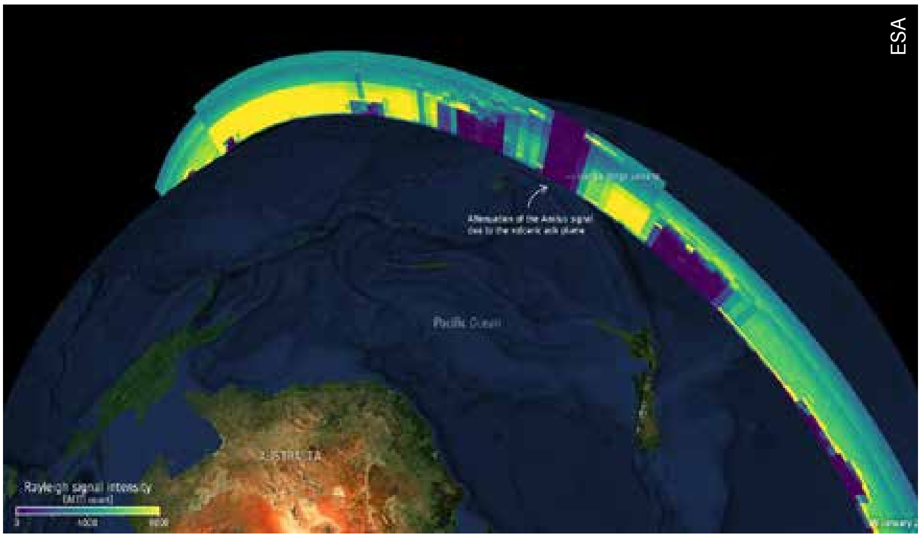


Figure 5: The impact of volcanic ash clouds on Aeolus measurements on 15 January 2022

Aeolus' data is used by major weather-forecasting services worldwide. The European Centre for Medium-range Weather Forecasts (ECMWF) started assimilating Aeolus' data in 2020, and since then the satellite has become one of the highest impact-per-observation instruments in history. Aeolus' strength lies in measuring winds where data is scarce. During the COVID pandemic, for instance, when planes were grounded, Aeolus could provide data that filled the gaps for weather forecasts. Weather balloons and aircraft only provide localized measurements along restricted vertical and horizontal profiles, but Aeolus provided a three-dimensional mapping of the atmosphere globally. However, the importance of in-situ measurements from weather balloons and aircraft should not be overlooked, as they are often used as ground-truth to validate the accuracy of measurements from remote-sensing satellites such as Aeolus [1].

CONCLUSION

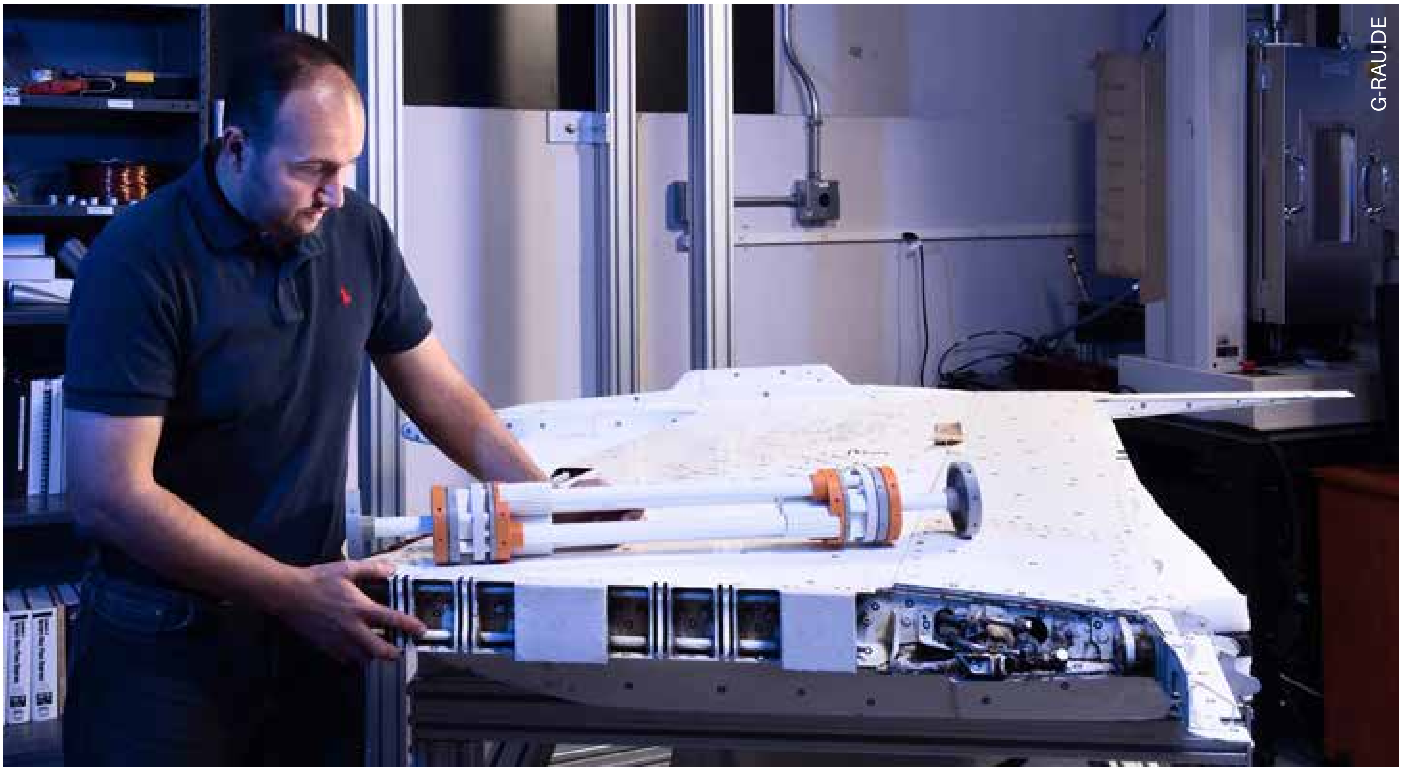
The impact of the Aeolus mission was profound, and warrants a future mission of a similar kind. A follow-on mission, Aeolus 2, is in the works and part of ESA's FutureEO program. For now, EUMETSAT's newest satellite, the Meteosat Third Generation - Imager 1 (MTG-I1), will help predict extreme weather events with its Flexible Combined Imager instrument. MTG-I1 captured its first image on 18 March 2023, revealing stunning detail of cloud cover over the Earth's surface [20]. Needless to say, we cannot overstate the importance of satellites in improving weather forecasts and climate models. The wealth of data they provide will pave the way for a better understanding of how our atmosphere behaves, and will consequently add immense value to societies and economies [21].

METAL MEMORY MARVELS

Unlocking the Potential of Adaptive Materials in Modern Applications

Muhammad Arham Elahi, Leonardo Times Editor

ASM



G-RAU.DE

First discovered in the 1930s, Shape Memory Alloys (SMAs) are smart materials with unique properties. This article aims to demystify their extraordinary behavior, explore their varied applications, and discuss their promising potential in the realm of engineering and technology.

WHAT ARE SMART MATERIALS?

A smart material, also known as a responsive or intelligent material, is a type of material that can adapt its properties in response to external stimuli, such as temperature, pressure, electric or magnetic fields, light, etc. These changes in properties can be reversible, allowing the material to return to its original state after removal of the stimulus, or they can be permanent. They react to these stimuli in a predictable manner and therefore their unique abilities can be manipulated for a wide range of applications in numerous industries. This is a major focal point for active research and scientists continue to test the limits of their use cases. Some examples include piezoelectric and electrochromic materials.

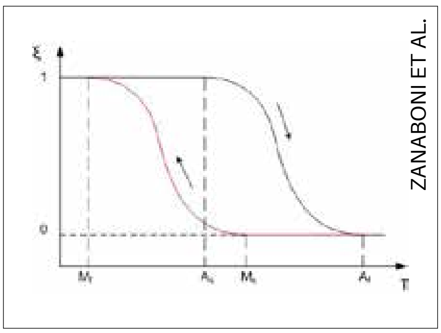
WHAT ARE SHAPE MEMORY ALLOYS?

Shape memory alloys are alloys which can return to their original shape when heated, this is known as the shape memory effect. In addition to that SMAs also exhibit superelasticity which enables them to undergo large elastic deformations and return to their original shape with little to no permanent effect on the material shape and properties. The most common shape memory alloy is a Nickel-Titanium alloy, also called NiTi or Nitinol. Other examples include Copper-Aluminum-Nickel, Copper-Zinc-Aluminum, and Iron-Manganese-Silicon.

HOW DO THEY WORK?

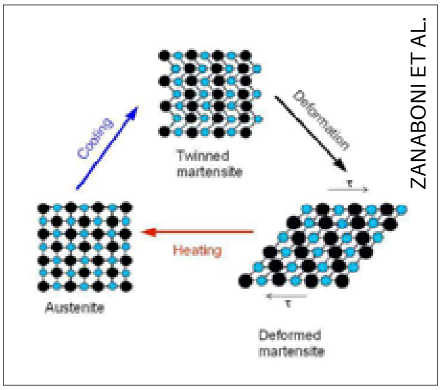
SMAs contain two distinct phases, austenite and martensite. Austenite is an ordered crystal structure that SMAs exhibit at higher temperatures while martensite is a twinned, less ordered structure more prevalent at lower temperatures. The phase transition is captured in Figure 1, when the temperature of an SMA is raised to As the material starts to transition from martensite to austenite until Af when the entire material is now austenite. The material can then be cooled and starts to transition back to martensite at Ma, a much lower temperature than Af, and it turns completely into martensite at Mf. This transition is not dissimilar to the phase transition between liquid and solids but unlike the liquid-solid phase shift, it doesn't have the same 'melting point' temperature both ways.

Martensite has 2 different crystal structures, a twinned and a detwinned version. When stress is applied to an SMA, the martensite becomes detwinned, creating plastic defor-



ZANABONI ET AL.

Figure 1: Martensite fraction as a function of Temperature



The distinct structures of SMAs

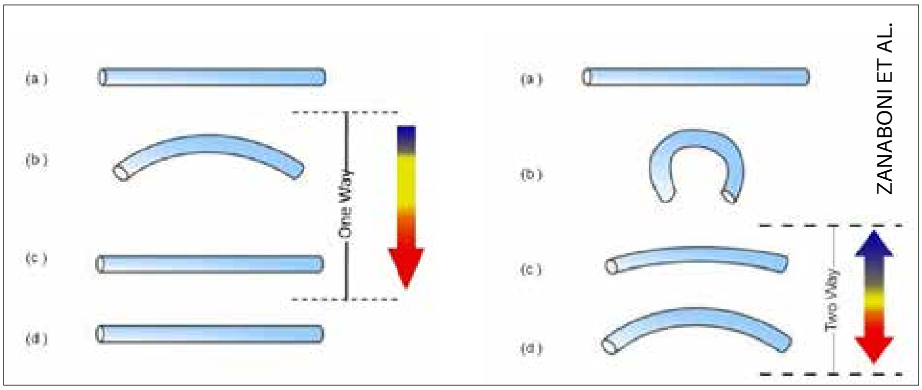


Figure 2: a - martensite state, b - deformation applied, c - heated, d - cooled

mations within the material, however when the material is reheated. The material reverts back to its ordered austenite phase regaining its original shape. The structure "remembers" its original shape is due to the way martensite is detwinned. The detwinned martensite has all the atoms stay in the same position relative to one another and none of the chemical bonds between them are broken or reformed, therefore, when the material is reheated, the austenite structure remains unchanged.

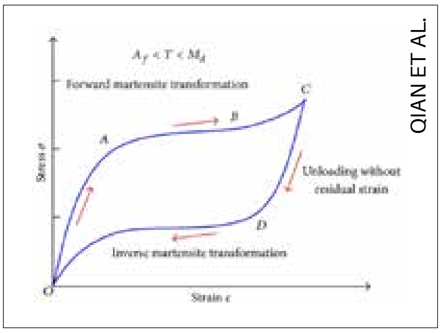


Figure 2: Stress strain curve demonstrating superelasticity

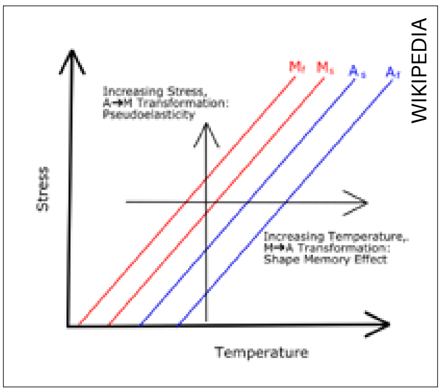


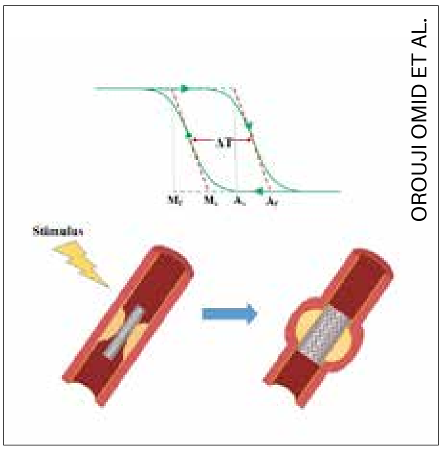
Figure 3: Stress plotted against temperature

ONE-WAY VS TWO-WAY

There are two types of SMAs, One-way and Two-way, the difference between them is very intuitive. A one-way SMA only has a memory of its austenite form and reverts back to it exactly when heated up. A two-way SMA, on the other hand, also has a memory of its martensite shape, meaning heating up the material doesn't completely restore the shape and it still retains some of its martensite shape.

SUPERELASTICITY

SMAs also exhibit extremely large elastic strains (strains even greater than 10%), uncharacteristic of any type of metal. this is known as superelasticity or pseudoelasticity. Temperature isn't the only stimulus that can cause a phase change in SMAs, stress is a factor too. Figure 2 demonstrates this with a stress-strain curve. The temperature is above Af so at point O, the material is fully austenite, once stress starts being applied, the austenite first deforms normally until at point A when it starts to change phase to martensite. This allows massive elastic deformation until point C where all the austenite has transformed into martensite. If the structure is further loaded the martensite becomes detwinned and plastically deformed. If the structure is slowly unloaded then it reverts back to its original shape in its austenite form. The relation between stress and phase transition temperature is given in Figure 3.



Medical application of Nitinol

APPLICATIONS

There are 3 main industries in which the potential of SMAs is being realized: Biomedical Engineering, Automotive Engineering, and of course Aerospace Engineering.

Biomedical Engineering: Since some SMAs (Nitinol in particular) are biocompatible, their application in the industry has been prevalent since the1970s [1]. These applications usually use an SMA with a transition temperature near body temperatures. In orthopedics, broken bones can be held in place using an SMA plate which wants to contract and retain its original shape thus applying a compressive force and helping the bone heal. In hip replacements, they can also be used due to their superelasticity. For vascular surgeries, a stent made from crushed SMA tube can be inserted into veins and the body temperature will cause it to revert to its original state allowing for easy insertion and as the metal expands to fill up the clogged blood vessel. This removes the need for a balloon to expand the stent as used in the conventional method. They

One significant concern is fatigue caused by repeated cycling, which can lead to a decline in performance over time, limiting the lifespan of SMA-based devices.

are also used in the manufacture of catheter (the wire that guides a stent through blood vessels) due to their superelasticity and kink resistance. In orthodontics, they make braces from them as they apply a consistent and gentle force, allowing for a more comfortable realignment of teeth. Lastly, they are also used in eyeglass frame manufacture to enable a better fit for each person due to their ability to bend back and forth.

Automotive Engineering: In cars, the ability of SMAs to absorb large amounts of energy and their superelasticity makes them enticing for a multitude of applications. They can act as thermal actuators replacing conventional hydraulic or electromechanical ones and are much more compact, lightweight, and reliable. SMAs can also be used for vibration and noise damping as they exhibit high damping properties, enhancing the driving experience. They can also be used for safety as their superelasticity means that they can absorb large amounts of energy, especially useful in crumple zones for cars. Lastly, a really cool and futuristic application could be shape-changing body panels to increase efficiency and performance at different environmental conditions.

Aerospace Engineering: Similar to cars, aerospace vehicles also benefit from using SMAs as thermal actuators to replace the less reliable, heavier and larger hydraulic actuators. They also use SMAs for vibration and noise damping, especially useful for spacecraft on launch vehicles where the superelastic effect of the SMA can reduce the vibration loads experienced by the payload immensely. They can also be used for thermal management by making valves that automatically open and close at certain temperatures. For spacecraft, many deployment mechanisms for parts like solar panels, antennas and other protruding appendages can use SMAs so that the spacecraft is more compact and fits in smaller payload fairings. Morphing structures can also be used to optimize the aircraft shape for all phases of flight, one such example is the VAFN. Variable Area Fan Nozzles (VAFN) have been developed from SMAs to allow for a quieter and more efficient operation by adjusting the exit nozzle size to be optimum relative to the current operating conditions (airspeed, fuel flow etc.). Lastly, an extremely interesting use case for SMAs is self-healing materials which can recover from damage caused by fatigue or impact. So if embedded inside a composite material, a simple heating process can repair the majority of the damage, reducing the need for extensive maintenance and increasing the lifespan.

Others: SMAs have also been used as artificial muscles in robots due to their elasticity. They are utilized in civil engineering structures to provide seismic damping and build adaptive structures and even self-repair in case of damage. Consumer electronics also use micro-actuators built from SMAs, especially for smartphone cameras, these help in optical image stabilization (OIS).

LIMITATIONS

Although shape memory alloys (SMAs) possess unique properties that make them suitable for various applications, they also exhibit several limitations that may impede their widespread adoption. One significant concern is fatigue caused by repeated cycling, which can lead to a decline in performance over time, limiting the lifespan of SMA-based devices. Their low efficiency and actuation speed, which is largely dependent on the rate of heat transfer, can restrict their effectiveness in applications that demand rapid response times.

Manufacturing SMAs can be challenging due to difficulties in machining, welding, and processing them using conventional techniques. Their unique properties and phase transformation characteristics often complicate the production process. Additionally, their limited temperature range can be restrictive for applications in extreme environments, as their shape memory effect and superelasticity are only expressed within specific temperature ranges.

Unintended actuation is another concern, as environmental temperature fluctuations may inadvertently trigger the shape memory effect, resulting in undesired outcomes. Moreover, SMAs are highly sensitive to impurities, which may alter their properties and result in inconsistencies in performance. This makes achieving precise alloy compositions crucial, further complicating the manufacturing process.

Lastly, the use of expensive and rare constituent materials in some SMAs, such as Nitinol, can make them cost-prohibitive for certain applications, particularly those requiring large volumes of material. These factors combine to present a range of challenges that must be addressed to maximize the potential of shape memory alloys in various industries.

CONCLUSION

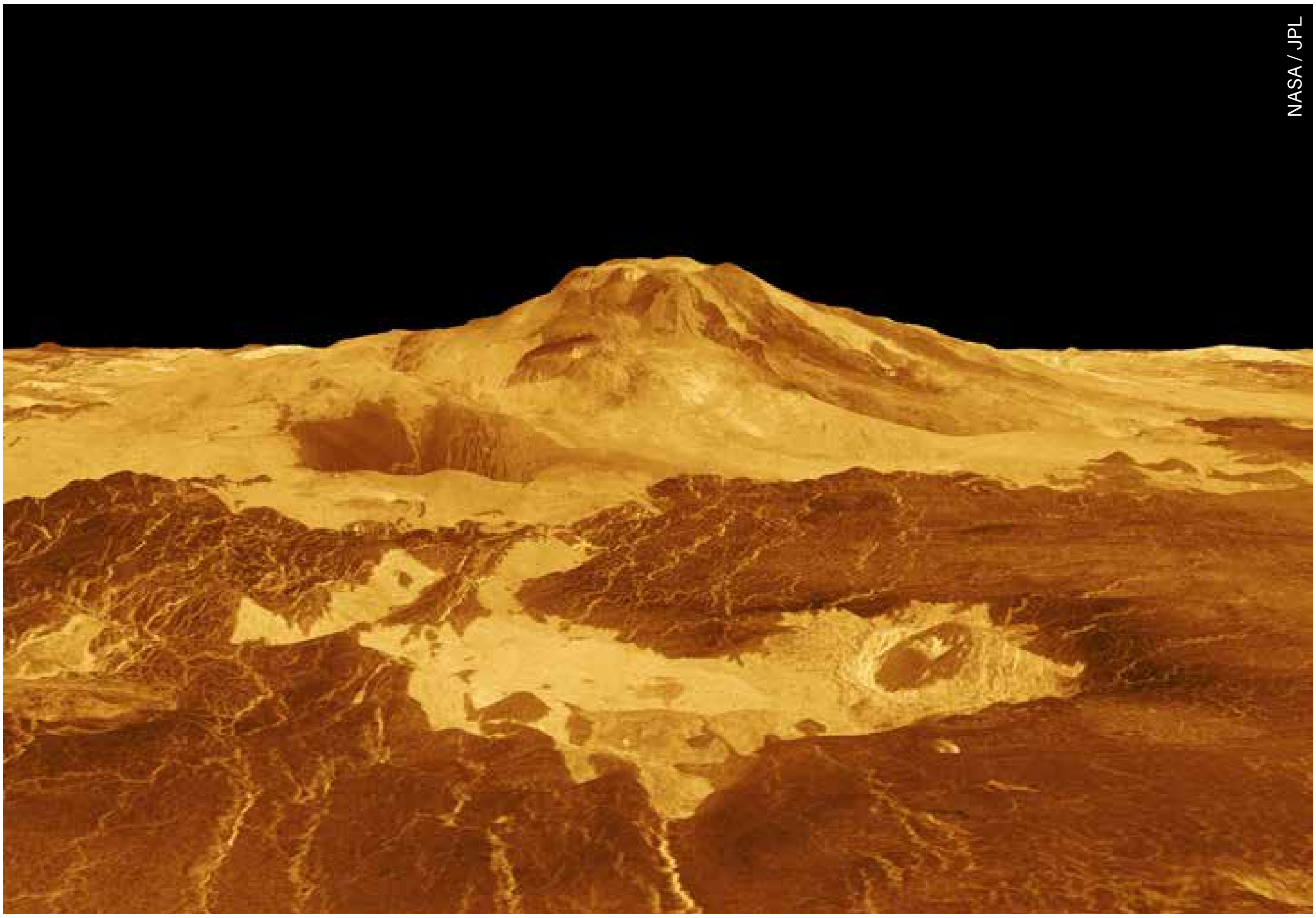
In conclusion, shape memory alloys (SMAs) are a remarkable class of smart materials with unique properties, enabling diverse applications across various industries. While limitations and challenges exist, ongoing research continually expands their potential uses and improves performance. As new alloys and techniques emerge, SMAs will play a pivotal role in revolutionizing technologies and shaping the future. Their adaptability and versatility promise to transform industries and the way we live, solidifying SMAs as key contributors to the ever-evolving world of smart materials.

MISSION INFERNO: UNEARTHING VENUS' VOLCANIC SECRETS

How 30-year-old images connect
Roman myths to geological science

Naomi Lijesen, Final Editor and Lisanne Vermaas, Leonardo Times Editor

SPACE



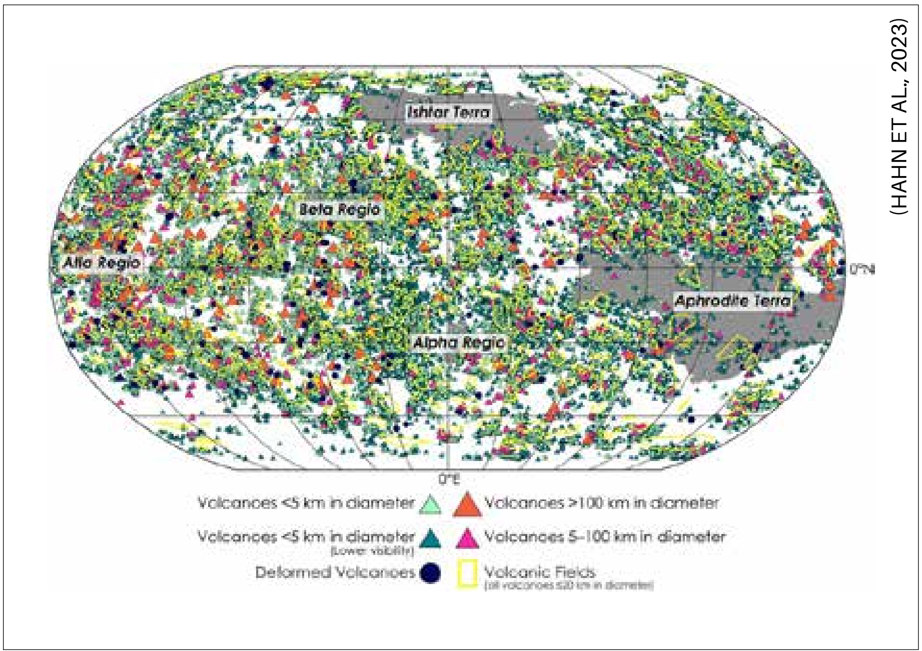
Computer-generated 3D model of Venus' largest Volcano Maat Mons

According to Roman mythology, Venus had the power to make a volcano erupt; not just any volcano, but Mount Etna on the Italian island of Sicily. This was her husband, Vulcan's workshop, where he forged metal to create divine weapons. The crater of Etna was the chimney from where all smoke left the workshop. Whenever Venus and Vulcan argued, he would flee to his workshop and worked the metal with so much vengeance that sparks and smoke gushed out of the chimney, eventually causing an eruption [1]. This ancient myth has found its way to reality in space: Venus erupts!

VENUS AND HER GEOLOGY

Venus is the second closest planet to our sun and is often referred to as Earth's twin. She has approximately the same size and density as Earth, as well as a hot magma core. However, Venus took a very different path in the early stages of the solar system. Venus used to have large amounts of water, similar to Earth, but lost her oceans very quickly [2]. This had a major impact on the planet's further development: no tectonic plates were developed, because water is crucial for this. Without water, the asthenosphere (a layer several hundred kilometers below the surface) is too viscous, preventing subduction, a process in which tectonic plates dive beneath each other [3]. Even though Earth's main source of volcanism is this subduction, which does not occur at Venus, the planet has found another way to let the hot magma escape the core.

Venus's surface shows the most volcanic-like features in the solar system, more than 85,000 volcanoes have been identified. 90% of her surface consists of basalt, a type of rock formed as a result of rapid cooling of low-viscosity lava. Next to that, 60% of her surface is characterized by a mosaic-like pattern, composed of collided lava flows [4]. Venus' skin however, holds a mystery still debated by scientists today. The impact craters present at her surface, more than 900 in total, have barely undergone any transformation by volcanism or deformation; they appear very fresh, especially when compared to the Moon or Mars [5]. This has led researchers to the following hypothesis: 500 million years ago, a big resurfacing event must have taken place, changing the appearance of Venus catastrophically. Other experts argue that this resurfacing process was much slower, and therefore referred to as steady state [6].



A recent global survey of over 32000 volcanic features on Venus shows the variation in feature sizes and types as well as the high number of features crowding the planet

IT'S NOT A BLAST - PANCAKES, TICKS, ARACHNOIDS AND ANEMONES

Whilst, as mentioned, the vast majority of Earth's volcanism is on mid-ocean ridges or volcanic arcs above subduction zones, the Venusian surface does not currently have any plate tectonics and yet eighty percent of it is covered by volcanic features [15][16]. In fact, Venus has an estimated 85,000 volcanoes to Earth's 1,350 [11]. Here on Earth, volcanoes are generally categorized into two groups, namely shield volcanoes and stratovolcanoes. However, other volcanic features form from erupted magma such as lava domes and calderas [11]. While Venus' hostile surface has similarities, in that it also exhibits shield volcanoes, calderas and lava flows, it also has many volcanic structures unseen on our watery planet. Next to this, there is no evidence of stratovolcanoes and their explosive, ash-forming eruptions. This is probably due to the crushing air pressure stifling eruptions and the lack of water which provides the stream to fuel these lava blasts [14]. Furthermore, it differs in that shields make up the majority of its volcanoes and are generally more squashed/flattened than those on earth. Often, they are categorized into small or large classes. Small shields, usually below 20 km in diameter, are common and are scattered across the Venusian surface, often clustered in relatively high spatial concentrations called "shield fields" [11][14]. Large shields are massive. Typically, they reach 100 to 600 km across, with heights between about 0.3 and 5.0 km [11][14]. For reference; one of Earth's largest shields, Mauna Loa, is ~120 km across at its base, and it has a total height of ~8 km (from the sea floor) [14]. This comparison outlines how flattened and elongated these shields on Venus can be.

It is perhaps not surprising, that a subclass of volcanoes, unique to Venus, has been dubbed the "pancake" (see Figure 1). These crepe-looking structures are a type of steep-sided lava dome and are the most common non-shield volcanoes [14]. They are often found in clusters of five to ten, sometimes overlapping, each dome with a central pit or vent structure. Their creation was likely the result of very viscous lavas in Venus' high-pressure atmosphere (90 times that of Earth) [14].

An alternative of the pancake is the Venusian "tick" (see Figure 2). Our instrumentation is not yet so advanced to observe Venus' potential insect population – tick formations are similar to pancake structures but with relatively short, radial ridges surrounding the dome which resemble legs. These insectile volcanic features have mysterious origins, though some explanations suggest the ridges are avalanche scars or possibly dikes [14].

Another aptly named feature is an "anemone" volcano. This subtype of shields is characterized by multiple petal-shaped radial bright flows and an intermediate diameter size (between 5 km and 100 km) though morphologically similar features also occur among the small-shield category [11][17]. Other volcanic edifices exclusive to Venus have been discovered, including coronae (oval features displaying concentric ridges); novae (showing sets of close, radial fractures) and another insect-like structure, namely "arachnoids" (similar to coronae with rings of ridges, except the rings are encircled by a larger set of radial ridges, resembling a spider web) [11][14][16].

Figure 1: A collection of "pancake" volcanoes found near the equator on the edge of Eistla Regio of the Venusian surface. The larger domes are roughly 65 km in diameter

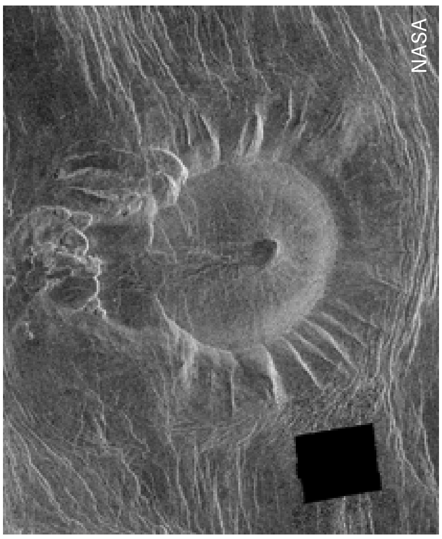
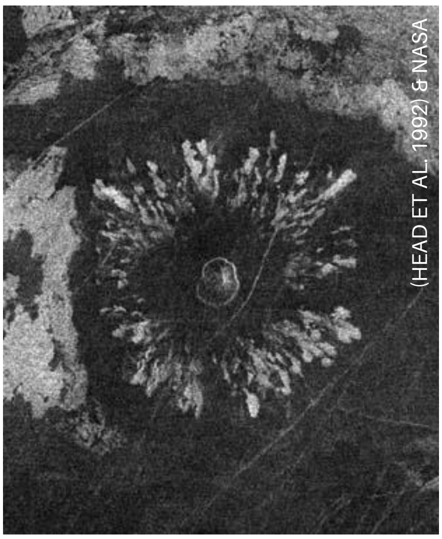


Figure 2: One of the stranger volcanic features are these insectile-looking lava domes dubbed "ticks". This particular example is found near the edge of Eistla Regio and is about 35 km wide



This example of an "anenome" shield volcano, named due to its resemblance of the flower type of the same name, is found in the southern Atla Regio, and is nearly 40 km across

MISSION MAGELLAN

This knowledge of Venus' surface long remained a mystery due to its thick atmosphere inhibiting telescopes' vision [15] until 1989, when NASA's Magellan spacecraft was launched. It was a pioneer in many aspects: not only was this the first probe ever to image Venus' entire surface, it was also the first deep space probe launched by the space shuttle, Atlantis. After Challenger tragically exploded in 1986, Magellan's launch was delayed for over a year [7]. The spacecraft was built from spare parts: the antenna was a Voyager spare part and most of the computer system was recycled from Galileo, a mission to the gas giant Jupiter [8]. After orbiting Venus for more than four years, the probe intentionally crashed on the planet's surface on the 12th of October 1994.

There was little information on Venus' surface prior to the Magellan mission, as Venus has an atmosphere 80 times as dense as that of planet earth. This made it difficult to make a map of the planet and gather geological information. Magellan made use of synthetic aperture radar (SAR) to create a map of Venus' surface. SAR makes use of doppler frequency and range resolution to obtain an image which is not dependent on range and is not affected by the dense clouds that cover the surface [9]. Next to these radar maps, the topography (elevation maps) and gravity field were also researched.

VENUS' TRIO OF FUTURE ADMIRERS

Though an impressive number of discoveries have been made from Magellan's mapping of the Venusian surface with radar, a proper catch-up with the planet is long overdue. While ESA's Venus Express dutifully orbited from 2006 till 2014, evidence gathered amounted to indirect signs of general hotspots of volcanic activity [18]. A new candidate with hopes of providing fresh information on Venus' surface is NASA's VERITAS orbiter (or Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy) [19]. The mission was approved in 2021 and hopes to answer how Venus diverged into such an inhospitable, sulfurous inferno while still dwelling in the same "Goldilocks zone" as our glorious blue home [13]. Next to this, VERITAS will improve on Magellan's data and provide high-resolution radar maps of present day geologic processes and surface rock composition, as well as specifically searching for the thermal signatures of active volcanism and the chemical signatures of recent volcanism [13]. After some recently announced delays, VERITAS is now scheduled to fly no later than 2031, four years later than originally planned [20].

A second NASA mission is set to complement VERITAS and descend to the scorching surface itself. The agency's DAVINCI mission (or Deep Atmosphere Venus Investigation of Noble gasses, Chemistry, and Imaging) will involve spacecraft flybys to study the planet's clouds and highlands, as well as a small surface probe, equipped with five instruments to measure the atmosphere's chemistry and take hundreds of images during its hour-long descent in the Alpha Regio mountains [21]. Before the delay of VERITAS, DAVINCI was scheduled to launch in June 2029 and enter the Venusian atmosphere in June 2031. It is now unclear whether the mission will overtake or follow VERITAS [19].

The final Venus visitor is ESA's EnVision mission. Similar to VERITAS, EnVision's orbiter hopes to deliver a holistic examination of the planet from its inner core to its upper atmosphere [22]. In collaboration with NASA, its instruments include a Synthetic Aperture Radar (VenSAR) for surface mapping and spectrometers to study trace gasses in the atmosphere and surface composition, in hopes of linking results to signs of volcanism [22]. EnVision will launch on an Ariane 6, at its earliest opportunity in 2031 – meaning in the next decade, Venus will have more admirers than ever before.

MAGELLAN'S FIERY ENCORE

The maps created by Magellan led researchers to the definite conclusion on the presence of volcanoes peppering the surface of Venus. However, it was only in 2023, almost 30 years after the end of Magellan's life, that researchers found something even more exciting: Venus is volcanically active!

Robert Herrick, research professor at the University of Alaska Fairbanks and member of the VERITAS science team, manually searched for hundreds of hours through Magellan's images. He was responsible for the research of the archive in preparation of the VERITAS mission, again, with Venus as the scientific research object. While searching through these documents, his attention was drawn towards two pictures, taken of the same geographical location on Venus, but with a time separation of eight-months [10].

The images depicted Alta Regio, close to Venus' equator. This region houses two of the largest volcanoes on the planet; Ozza Mons and Maat Mons. In the two subsequent images, a volcanic vent on Maat Mons changed shape significantly, from a circular crater with steep walls to an odd shaped hole, double the initial size. The images, however, were taken from different viewing angles, which made comparison difficult. Therefore, computer models for different scenarios were developed: volcanic activity was concluded to be the most likely cause [10].

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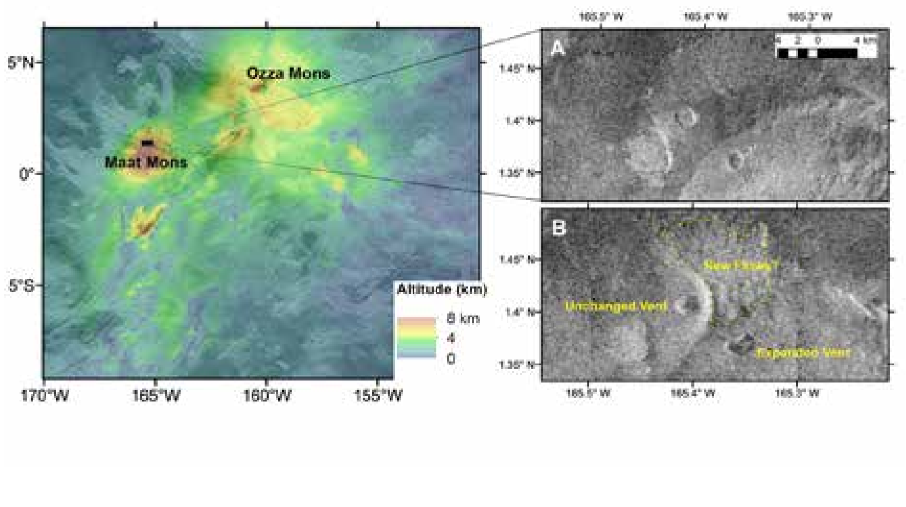

The two images compared, showing the change in geology due to volcanic activity

CONCLUSION

With the aforementioned trio of missions set to deliver the most comprehensive study of Venus to date and recent research revealing more of our fierce and mysterious twin, the next decade is sure to hold an exciting prospect of discoveries. After all, it is about time we come to know how our once habitable sister planet fell into such a harsh, volcanically plagued state. Is Venus Earth's fiery-fate? Is it possible our planet will suffer the same catastrophic greenhouse effect? Understanding the evolution of our planetary siblings is imperative to understand our planet's future. In an era of exoplanet discovery, it is particularly intriguing what we might uncover on other terrestrial Earth-like planets.

RISING FROM THE RUINS: BRAZIL'S SPACE DREAM

Twenty years since the accident that almost ended it all

Marcos Talocchi, Leonardo Times Editor

Satellite image of Brazil

August 22, 2003, is a day every Brazilian would rather forget. During the preparations for what would have been the first ever successful launch of a Brazilian rocket, everything went wrong. But has the industry recovered in the past twenty years?

THE BRAZILIAN SPACE PROGRAM

In 1956, the first contact the country had with space flight came through the building of a ground station in Fernando de Noronha, an archipelago located Northeast of Brazil. The station was built in partnership with the American government with a goal of tracking the payloads in orbit sent from Cape Canaveral [1]. However, a few years later the station became obsolete and was shut down.

In the 60s, the contact with rockets was mainly for military use. Various training instructions with American and French missiles were organized for technicians of the Brazilian army. On the civilian side, NASA also did some training sessions with Brazilian engineers to qualify them for different areas of spaceflight [2]. With their help, the first sounding rocket launched from Brazilian soil in 1969. The program didn't achieve much during the upcoming two decades, apart from launching a couple of sounding rockets. Additionally, the Alcantara Launch Center, a launch base in the Northeast, was inaugurated in 1989. It happened with the Sonda IV launch, the first Brazilian sounding rocket with an attitude control system.

The following year, in 1990, the first Brazilian satellite was put into orbit onboard an Ariane rocket launched from Kourou. Since 1994, all developments have been centralized under the Agência Espacial Brasileira (AEB, Brazilian Space Agency), and more rocket experiments follow with newly created prototypes. In 1997, the VLS-1 had its first launch, but it had to self-destruct after some trajectory issues. Similarly, the VLS-1 V2 had to be destroyed after a malfunction of the second stage during flight in 1999.

THIRD TIME'S THE CHARM?

Finally, after 18 years of development and multiple launch attempts, the VLS-1 V3, a four-stage rocket, was ready to launch. The rocket had undergone various improvements done with the data gathered by the previous two failures and had two satellites for science missions in its payload bay. Then, on August 22, 2003, during the preparations three days before the launch, one of the first stage engines was accidentally ignited. The rocket was still mounted on the supports inside the hangar and couldn't lift off. It resulted in an explosion followed by a fire that destroyed the hangar, the launch pad, the payload, and took the lives of 21 engineers and technicians working on the launch, some of the best in the country [3].

THE AFTERMATH

After the accident an investigation was launched to find the cause of the ignition. At first, some even suspected it was caused by other countries to delay the Brazilian space program. The conclusion of the report, however, denies this possibility. The most probable cause was that the unplanned ignition occurred due to an electrostatic discharge inside the detonator through lack of insulation [4]. Overall, the project had also suffered in the years prior to the accident due to lack of funding, personnel and interest from the government.

NEW BEGINNING?

After the accident, the entire base had to be rebuilt, taking more than a decade and millions of dollars. The program for the VLS-1 continued with an attempt to finally launch the V4 in 2016, but was canceled due to lack of funding when 70% of the structure was ready. All Brazilian satellites have been launched by external rockets since then.

Other programs were launched by the government, the most notable one the VS-40 rocket, a small sounding rocket initiative with the purpose of conducting experiments in orbit. As it is not suitable for satellite launching, there was also interest in developing the VLM 1, a small satellite launcher. However, to date, there is no launch date [5].

Regarding the satellites themselves, Amazon 1, launched in 2021, was the first satellite completely designed, built and operated in Brazil. It was launched from India with the PSVL-DL launcher with the goal of monitoring deforestation in the equatorial rainforest in South America. There are also on-going developments with the defense and security satellite Carponis, which in partnership with the young Brazilian private industry, is supposed to generate high-resolution colored images.


ROSE BRASIL

Aftermath of the Explosion

WHAT IS HAPPENING RIGHT NOW

The private sector is currently experiencing some growth while also facing many challenges. Companies are met with inconsistency with available projects to work with, making it extremely difficult to stay in business and keep their expertise in the country [6]. They usually go months without seeing a new project or contract, making it hard to stay afloat. In early May, the main companies and figures in the sector gathered at the SpaceBR Show, organized by the Brazilian Space Agency (AEB) and the Ministry of Science, Technology, and Innovation. They discussed the private race for space exploration, along with advancements in communication systems and Brazil's role in this industry and its potential as a leader in Latin America.

The theme of the event was Space Exploration and New Businesses. According to Emerson Granemann, CEO of MundoGEO and one of the organizers of the SpaceBR Show 2023, Brazil has the potential to position itself as a leader in various sectors beyond communications, including mining, nutrition, medicine, tourism, logistics, law, and insurance [7].

Elcio Oliveira, CEO of Kvantum and president of the Latin American Space and Cybernetics Association, emphasizes the need for the national market to understand the evolution happening in Brazil and how it can adapt in the coming years. Oliveira believes that the space market will experience significant growth in Brazil, requiring the establishment of connections between institutions, governments, and companies, as well as the provision of courses and support for affiliates [7].

Paulo Vasconcellos, COO of C6 Launch Systems of Brazil and vice president of the Latin American Space and Cybernetics Association, highlights the steps currently being taken to increase the country's participation in the space industry, including creating conditions for foreign customers to access space from Brazil, envisioning a future where vehicles are assembled and launched [7].

Leonardo Souza, CEO and founder of Ideia Space, a space education startup, believes it's important to view Brazil's space sector from a global perspective, considering both the upstream and downstream aspects. Souza emphasizes the need to expand discussions, increase Brazil's presence, and to foster closer ties with the global South [7].


INPE

Amazônia 1 Satellite

CONCLUSION

Brazil's space program has faced numerous setbacks over the years. From a slow start of the space race to multiple failed attempts at building their own rockets, including an absolute catastrophe twenty years ago, the country's presence in the sector is yet to solidify. However, over the past decade, a growing private space industry is now working with the government to finish what began decades ago: to put the country in space.

ONWARD TO JUPITER!

Experiencing the launch of JUICE at Europe's Mission Control

Danny Tjokrosetio, Leonardo Times Editor

The penultimate Ariane 5, designated as flight VA260, launches JUICE from the Kourou Space Center in French Guiana

Sitting among the palm trees in Kourou, an Ariane 5 rocket awaits its moment of being awakening. Perched above is no ordinary passenger. Alone and shrouded in darkness, a silver bird is about to begin her 8-year lonesome journey towards a giant's neighborhood.

Launch days are always nail-biting affairs. However, the unique payload of the day stirred an extra dash of excitement and anxiety into the air. From the jungle to Jupiter, the Jupiter Icy Moons Explorer (JUICE)'s point of departure is the Guiana Space Center. In Darmstadt, Germany, the characteristically cool-headed Flight Control Team at the European Space Operations Center (ESOC) made final preparations as they awaited the rocket's launch. Meanwhile, in the adjacent building, tension filled the room as a cluster of journalists waited in anticipation for the moment of ignition. As one of the thirty social media influencers invited by ESA to attend the launch event at ESOC, I had the privilege to sit among the press in its packed conference hall, with our eyes glued to the screen. However, the clouds in Kourou had other plans.

At less than T-10 minutes, we received news from French Guiana: due to the risk of lightning, the launch had to be scrubbed, with another opportunity the following day. Disappointment wafted through the air as journalists slowly made their way to the exit. How ironic, I thought, that we are a species capable of building interplanetary machines, yet we cannot accurately predict what will happen in our skies in the next hour. As I paced through the door, information about the spacecraft that I had retained from the press conference earlier that morning flashed through my mind.

JUICE

The origins of the JUICE mission can be traced back to the Jupiter Ganymede Orbiter, ESA's contribution to the proposed joint NASA and ESA Europa Jupiter System Mission, also known as EJSM-Laplace [1]. It was scheduled to launch by 2020. However, any hope for a joint American and European interplanetary mission was dissolved in early 2011, due to NASA's current budget. ESA decided to continue the project independently as JUICE.

JUICE will explore Jupiter and its icy moons to investigate its five main scientific objec-

The author poses in the Main Control Room at ESOC in Darmstadt, Germany

tives [2]. First of all, it will study Jupiter's environment in detail. It is a chaotic combination of harsh conditions: a constantly changing turbulent atmosphere, strong magnetic fields, extreme radiation levels, and its dusty rings. By studying Jupiter itself and its extreme environment, JUICE will provide answers to two of its goals: to understand the formation and mechanisms of gas giants in the universe, and how Jupiter's environment affected the formation of its moons and vice versa. Moreover, JUICE will explore three of Jupiter's icy moons: Ganymede, Europa, and Callisto, to investigate what ocean worlds are like and whether there might have been or will be life on them. These three moons have an icy crust and are believed to harbor oceans underneath them. Ganymede, the largest moon in our Solar System and the only one to generate a magnetic field, is of particular interest for the mission; JUICE will study what makes this moon stand out from others.

When I asked JUICE project scientist Olivier Witasse what he believes will be the most interesting JUICE discovery, he confidently said it would relate to liquid water on Ganymede. "You want to search for liquid water in the Solar System; in Ganymede, there is maybe more liquid water than on Earth. But we want to know where it is: how deep beneath the surface, how much water there is, and its composition. These are very important questions to understand habitable places around Jupiter and maybe for the search for life." Witasse emphasized that one should always expect the unexpected in every mission. "The most surprising results will come from what we don't know yet... I look forward to the surprises of JUICE ten years from now."

JUICE costs a total of around €1.6 billion, involving 23 countries, 83 companies, 18 institutions, and over 2000 employees [2]. Primarily built by Airbus Defence and Space, the spacecraft has to endure the hostile Jupiter environment; this includes operating in near darkness, with 25 times less sunlight than on Earth [3]. For this, Airbus takes pride in its two solar wings, measuring 85 m^2 each. JUICE carries ten instruments, including the NASA-developed Ultraviolet Spectrograph. Shortly after launch, its Radar for Icy Moons Exploration (RIME) ran into trouble when its 16-meter antenna was jammed [4]. A tiny pin prevented it from fully deploying. This was cause for concern as the instrument is responsible for subsurface measurements. More than three weeks later, flight controllers ingeniously freed the antenna by firing a non-explosive actuator located in its mounting bracket, which delivered a shock force that shook the pin down by a few millimeters.

JUICE is a mission of firsts, not only because it is Europe's first mission to Jupiter, but it will also perform the first lunar-Earth gravity assist in August 2024 as part of its trajectory to Jupiter [2]. A year later, it will also use Venus for a gravity boost, and make two more Earth flybys in 2026 and 2029. Arriving at the Jovian system in July 2031, it will tour Jupiter and make 35 flybys around Ganymede, Europa, and Callisto before finally inserting into Ganymede's orbit in December 2034, making it the first spacecraft to orbit a moon outside our own. JUICE is planned to deorbit and crash into Ganymede's surface in September 2035.

ESOC

Following the launch delay, us social media influencers were given a tour around ESOC's facilities. The picturesque Main Control Room (MCR), characteristically equipped with large overhead screens and littered with flight controller consoles, is a textbook example of what the mind conjures upon hearing the words "mission control". This is where mission operations begin after handover from Korou during launch and on a mission's early phase. Operation from the MCR typically lasts a few weeks before being transferred to a "dedicated mission room", a smaller room where specific missions, or families of missions, are operated throughout their lifetime. ESOC is also home to the Network Operations Center, a room where the ESA tracking station network ESTRACK is controlled. ESTRACK consists of seven core ground stations located in Europe, South America, and Australia, which act as mediators between ESA spacecraft and ESOC. At ESOC, specific teams work in their respective rooms, such as flight dynamics, and training and simulations. The flight dynamics office consists of steely-eyed missile men and women who calculate mission trajectories. "If you don't know anyone who's great at mathematics, then you've obviously never met these guys!" chuckled spacecraft operations engineer Simon Wood. "These are the people who effectively mapped out the way to get to Jupiter."

In addition, the center provides facilities and services for specific areas of research in relation to spacecraft operations, such as space debris and situational awareness, space safety and security, and facilities for developing and testing ground segment systems.

THE LAUNCH

After taking a stroll around the quaint city center of Darmstadt the following day, I returned to ESOC that afternoon just in time for the launch. As the number of attendants has

Signal received from JUICE (center) at the Main Control Room at 2 hours and 27 minutes after launch

A sloth photobombs the JUICE launch livestream

Winning art that decorated the Ariane 5 launching JUICE by Yaryna from Ukraine, aged 8 at the time of submission

decreased, the launch viewing was held in the press room in lieu of the conference hall. Despite this, it felt somewhat routine; a flock of journalists transfixed by the screens in the room relaying live pictures from Kourou.

At T-10 seconds, the launch site cameras transmitted a brief closeup of the fairing. This particular fairing is unique as it is adorned with a vibrant work of art, featuring anthropomorphic planets. This watercolor painting depicts a cheerful Earth with open arms and a grateful Jupiter, surrounded by its three icy moons, holding JUICE by its solar arrays. This adorable artwork is the winning entry of ESA's "JUICE up your rocket!" competition, where children up to the age of 12, all around the globe, were encouraged to submit artwork inspired by JUICE and its destination. Selected among 2600 children from 63 countries, the winning artist is none other than Yaryna from Ukraine.

"I wanted to portray and give a human image to the Earth, Jupiter, and its satellites." At ten years old, Yaryna appeared at the conference hall the day prior to explain her painting.

"Each of the satellites of Jupiter has its own character. Europa peeks from behind Jupiter, Ganymede looks surprised, and Callisto sleeps." The room burst into laughter at the thought of the oldest object in the Solar System depicted as the tired one.

"My picture shows that Earth and Jupiter are friends and want to play together. Earth gives Jupiter a toy satellite (JUICE) and they become friends and play. My planets have human faces because space has soul and character."

The little girl and her artwork were not the only ones to raise emotions of endearment from the crowd throughout the event. A sloth in front of the Final Assembly Building appeared for a few seconds in the broadcast during a montage of the Ariane 5's preparation for the mission. The sloth, called Gérard by ESA, undoubtedly stole the show and the hearts of netizens, who nicknamed him Jerry.

"Trois, deux, un, top!" Before I knew it, the Vulcain engine began to ignite. As the rocket rose from the pad, it took a moment for me to grasp the fact that Europe was on its way to Jupiter. Everyone in the room applauded as the penultimate Ariane 5 cleared the tower. This however, was only the first of four milestones to be completed throughout the day, the others being separation from the launch vehicle, signal acquisition, and solar array deployment. After the separation phase, following another round of applause, the room gradually tensed up, slowly turning somewhat restless as ESOC awaited the reception of JUICE's first signal. Half an hour passed - beyond the expected time of signal acquisition. Then an hour. Some had left their seats to pace around the room or speak with other press members to shake off their nerves. An announcement from the Main Control Room was made when least expected, with deputy flight director Bruno Souza confirming that a signal had been received. "These are the words that every spacecraft operations manager wants to hear." Sighs of relief were audible in the press room, which erupted into the largest applause heard throughout the day. About 40 minutes later, champagne was poured after the full deployment of JUICE's solar arrays. "Europe has a mission. We are on our way to Jupiter." reported Souza. The silver bird has spread her wings and is now bound to explore strange worlds.

JUICE unpacked at the Guiana Space Center

CONCLUSION

A spectacular sendoff is just the beginning for JUICE and it still has a long voyage to go. It will be less than a decade before it can bring us a fresh taste of the mysteries of the Jupiter system, but it will, without a doubt, quench our thirst for knowledge about our own Solar System and worlds beyond.

AIR CRASH INVESTIGATIONS: SOLVING THE 4D PUZZLE

Building up the accident from scratch

Marcos Talocchi and Gerard Mendoza Ferrandis, Leonardo Times Editors


GODOFREDO A. VÁSQUEZ

Aftermath of McDonnell Douglas MD-87 crash in Brookshire, Texas (USA)

A blip disappears from the radar. An air traffic controller receives a mayday call. A thunderstorm sends a plane down. Those scenarios are all the end of the line for many, but for the team of air crash investigators, it's just the start. This is how they use evidence to reconstruct what actually happened.

WHAT IS AN AIRCRAFT SAFETY INVESTIGATION?

Although aviation is considered the safest means of transportation, it is not completely immune to accidents. Over the past 5 years, there have been an average of 7 fatal and 36 non-fatal accidents out of 34.4 million commercial flights [1]. Despite the rarity of accidents, they provide valuable insights to further enhance aviation safety. This is where aircraft safety investigations come into play, as defined in Annex 13 of the 1944 International Civil Aviation Convention.

In the annex, investigations are defined as "a process conducted for the purpose of accident prevention which includes [...] the determination of causes [...]" [2]. Therefore, it is relevant to realize that they are performed to identify the most probable cause of the accident rather than to find a culprit. Any legal action or prosecution typically falls under the jurisdiction of the state authorities.

Moreover, the annex specifies the investigation procedure, and the manner in which the results of said investigation must be presented. It ensures that aircraft safety boards, airline operators, and aircraft manufacturers worldwide know what to expect and how to interpret the reports.

Now that we understand the concept of aircraft investigations, questions may arise regarding technicalities such as when, where, and how they are conducted. We have seen many investigations carried out in documen-

NTSB investigators at the scene of the crash of a Hawker 125-700 into an apartment building in Akron, Ohio (USA)

taries, on the Internet, and on television, but how are they actually done? To find out how, we spoke to Joris Melkert, an engineer and professor at TU Delft.

CONTACT LOST

When does a safety investigation get initiated? Investigations are not necessarily the first response by air traffic control (ATC) after contact is lost with an aircraft. Instances of radio contact loss are relatively common occurrences. "That normally happens when you have to switch from one frequency to another due to entering another air traffic area and the pilots misdial the frequency or you forget to switch" - explains professor Melkert. These problems usually resolve themselves quite quickly, but if contact is not restored, a quick reaction force may be dispatched. The most concerning loss of contact that ATC can experience is loss of radar contact. If an aircraft stops being observed on radar, ATC may ask nearby pilots for assistance in locating and contacting the aircraft. If this fails, primary radar may be used as it has a higher resolution and range than the secondary radar used by ATC. If all fails, an emergency response activates, and a safety investigation initiates.

This protocol is quite standard. For example, both Air Traffic Control in the Netherlands (LVNL) and the Federal Aviation Administration (FAA) have a 30-minute limit without contact before issuing an alert [3][4]. After this time, emergency services must be alerted. However, this is not a hard-limit and, as stated by the FAA, if there is reason to suspect distress before this timeframe, immediate action must be taken [4].

THE INITIAL RESPONSE

The first response comes from either the air traffic controller, who will initiate a search at the point of lost radar contact, or by the general public, if the accident is evident and emergency services are contacted. If the accident occurs at or near the airport, the airport emergency services are the first on scene.

While the first responders primary focus is to rescue the victims, they also play a vital role in mitigating potential hazards arising from the crash and preventing unauthorized access or tampering with evidence. Unfortunately, this has occurred on several occasions, such as the Lauda Air Flight 004 or Malaysia Airlines Flight 17, where victims valuables, electronic equipment, or even the black boxes were extracted from the site [5][6].

THE INVESTIGATION

Once the first responders have rescued all the injured and survivors and the scene has been secured, the investigation begins. The team responsible for the investigation assembles in the country where the accident took place, as stated by Article 26 of the International Civil Aviation Convention [7]. It is also possible, however, to transfer the investigation to a different country under certain conditions. Melkert explains, "The MH17 crash in eastern Ukraine of Malaysia Airlines was initially a Ukrainian investigation, but they transferred it to the Dutch Aircraft Investigation Board" [8]. Once the airline operator receives the news of an accident occurring, they will also send their own "go-team" to the crash-site with the goal to assist the investigators, while also handling the press and offering humanitarian support to victims and families.

When investigators arrive at the scene, they ensure it is safe and call a meeting to discuss how to conduct the investigation. The site is photographed and evidence is collected from the scene [9]. Furthermore, where possible, eye-witness accounts from by-standers or survivors are recorded for any details that may direct the investigation in a specific direction.

One of the most important pieces of the wreckage that must be found are the black

A Flight Data Recorder (FDR), one of the plane's black boxes, being opened for analysis

boxes: the cockpit voice recorder (CVR) and the flight data recorder (FDR). The CVR will provide information on what the pilots were saying for the last 30 minutes of the flight, as well as detecting sounds from the cockpit such as warnings and button or switch clicks. The FDR, on the other hand, stores data of the entire flight, including speed, attitude, bank angle, positions of actuators, along with hundreds of other data. The black box data, if available, is then compared with the material evidence at the crash site. Among many actions performed during the on-site investigation, structures are inspected for unusual damage, fuel tanks are checked for fuel level determination, and engines and other actuators are analyzed to determine their state during the crash. In Melkert's words: "It's a piecing together of a four dimensional puzzle. Three dimensional object moving in time. [...] And sometimes it's literally piecing together a three dimensional puzzle. Sometimes they rebuild a part of the wreckage to see what has happened. It's a very expensive thing to do so it's not used very often."

Furthermore, to assist with the investigation, manufacturers are commonly involved if it's suspected that one of their components was part of a malfunction. Boeing and Airbus engineers are contacted when their planes are involved, just like systems, engines and instrumentation manufacturers. Even the fuel suppliers might get involved if the board of investigation suspects the fuel might have played a role. University and other industry experts are also called when needed. Most importantly, reading the flight recorder data is a highly specialized task: since it's such a rare occurrence, only a handful of countries have the appropriate facilities, so usually international cooperation is required. Melkert explains how Washington has a facility but so too does France, Russia and the UK.

REPORTING

As defined by the Annex 13, within 30 days of the start of the investigation, the board should issue a fact-finding report giving some clues on where to narrow down the investigation with the final goal being to find the most probable cause of the accident. Within one year, the board should publish the final report in which they explain the crash, the sequence of events and also the most probable cause and recommendations for the future, according to professor Melkert.

The recommendations are for the manufacturer, for the aviation authorities and for system suppliers. These can be studied and applied by the responsible agents, but there is no enforcement with regards to the outcomes of the investigation and its recommendations. One of the most significant changes implemented after air crash investigations was the collision avoidance system. This was introduced after numerous catastrophic two-plane crashes, and the weather radar, which is required to detect conditions where the wind shear might push the plane directly into the ground [10].

THE OUTCOMES

With the investigation wrapped up, the most probable cause found, and the recommendations made, the investigation board can be disbanded. The crash site land is returned to the owner, and most of the aircraft scraps are recycled for the materials with some of the relevant parts in the investigation being archived for years to come, should it be needed to perform any further inspection. Some parts are also sent to museums to be exhibited or studied. "It's interesting to see how the structure was, and I think we [the Aerospace Engineering faculty] once also got a tailplane from an F-16 left over from a crash site" reveals Melkert.

CONCLUSION

Air crash investigations are as rare an event as aircraft accidents are. Despite this, they are essential and comprehensive processes that play a pivotal role to ensure and advance aviation safety. Gathering an extensive array of evidence, meticulously reconstructing the events, and determining the most probable cause are all vital steps in this journey. Through their diligent efforts, investigators contribute to making aviation safer by uncovering valuable insights that lead to improvements in aircraft design, operational procedures, and safety measures. Air crash investigations will always serve as a powerful reminder of the unwavering commitment to safeguarding the remarkable safety record of air travel.

KICKSTART YOUR CAREER AT ESA

A look into what the European Space Agency offers for students

Tuomas Simula, Leonardo Times Editor

ESA

The European Space Agency is known for their scientific missions and human spaceflight program, but did you know that education is also one of the agency's goals? This article gives an overview of the opportunities ESA offers for students and young graduates to kickstart their career in the European space industry.

In 1975, the convention of the European Space Agency was signed by ten European nations. Article V of the convention mandates that education is a crucial activity of the agency, alongside research and information distribution [1]. The goal of the educational activities is to inspire young people to work in the European space industry, to increase their awareness about space research and its impact, and to enable them to learn more about science and technology than their school curriculum and university education allows [2].

Since 2016, the educational activities of ESA have been led by the ESA Academy program [3], consisting of diverse courses and projects aiming at university students of all academic levels. The ESA Academy is further divided into two programs. The Hands-on Space Projects program invites university students and student teams to participate in space-related projects, allowing them to conduct research using the space agency facilities. The ESA Training and Learning Program offers university students intensive week-long courses about various space-related subjects.

ESA TRAINING AND LEARNING PROGRAM

The ESA Training and Learning Program mainly consists of over twenty courses organized by ESA annually, about various aspects of space technology, research and exploration [4]. The courses are arranged as online, on-site or blended training sessions, with on-site training held at the ESA Education Training Centre in the south of Belgium. Some courses also include visits to other ESA facilities, such as a ground station or the European Space Operations Centre.

The courses offered as part of the Training and Learning Program, cover various space related topics. There are courses on space technology, such as communications, robotics or concurrent engineering. There are also courses on other aspects of space exploration, such as spacecraft operations, space weather and space debris, including some non-technical programs, such as space law and space physiology. Depending on the topic, the courses are open to students on BSc, MSc or PhD level of a relevant field, which doesn't necessarily need to be directly related to space; for example, for the course on spacecraft operations, participants are selected from various fields of engineering, computer science and physics.

HANDS-ON SPACE PROJECTS

Besides the courses of the Training and Learning Program, ESA offers students the opportunity to participate in various projects aimed at gaining experience with research and technology. The projects currently offered are Fly a Rocket!, REXUS/BEXUS, PETRI, and the Fly Your Satellite! Program [2]. While Fly a Rocket! is specifically aimed at individual Bachelor students in their first or second year of study, the other projects are for teams of university students. In these projects, students can gain hands-on experience in completing a research project using the same equipment and procedures used by ESA and other organizations in the aerospace industry.

Of these projects, the Fly a Rocket! program is the most introductory. It is organized every two years in a collaboration between ESA Education, the Norwegian Space Agency and Andøya Space Education. The program consists of an online course and a sounding rocket launch campaign at Andøya Space Center in northern Norway. During the week in Andøya, students get to assemble the payload of a sounding rocket, participate in its launch, and analyze the data recorded by the payload [2]. Fly a Rocket! is a great opportunity for students still early in their studies to gain first-hand experience in how a rocket launch is carried out, and what kind of work is carried out before, during and after a scientific sounding rocket mission.

The REXUS/BEXUS program also involves a sounding rocket launch campaign. The acronyms REXUS and BEXUS stand for Rocket and Balloon Experiments for University Students, respectively. As one might guess, the yearly REXUS/BEXUS program consists of launching two sounding rockets and two stratospheric balloons. Both the rockets and the balloons are launched from the Esrange Space Center in Sweden. Like Fly a Rocket!, it is organized in collaboration with national space organizations, namely the German Aerospace Center and the Swedish National Space Agency. Because of this, part of the payload capacity is reserved for teams from German universities. The payloads for REXUS/BEXUS are designed and manufactured

The highlight of the Fly a Rocket! programme is the launch of a sounding rocket from Andøya Space Center

The PETRI programme allows students to do research in microgravity on parabolic flights

by participating student teams, and admission to the program is based on the originality and research value of the proposed payloads [6].

Another program allowing student teams to test their proposed experiments using ESA facilities is the new PETRI (Practical Education in Technology, Research, and Innovation) program. In this annual program, teams are able to test their research projects or technology demonstrators in various platforms for micro- and hypergravity research. Depending on the requirements of the experiment, the platforms available are a centrifuge, a drop tower, a parabolic flight, and even a test platform on the International Space Station [2].

Yet another project allowing student teams to actually reach space is the Fly Your Satellite! program. It is aimed to support established university CubeSat teams, and to allow them to use ESA facilities during the project. The program also includes training, financial support and a launch opportunity. Application into the project is open every few years

STUDENTS FROM ESA MEMBER STATES

The application procedures for different ESA Academy programs vary, but all have one thing in common: applicants must be citizens of one of the ESA member states, or of a country with agreements with ESA regarding education. Therefore, besides students from most European countries, also students from Canada can apply for the programs [3].

The ESA Academy activities are organized all over Europe: most of the Training and Learning Program courses take place in Belgium while the different hands-on projects can take place in, for example, Germany, Norway or Sweden. To ensure that all students have an equal opportunity to take part in the various programs, the participants are sponsored by ESA. Travel, accommodation and food is arranged or finanched by ESA for the duration of the course or project.

Many of the ESA Academy programs occur yearly or every two years, and the application and admission for each program generally takes place some months before. Usually, for the application, at least a motivation letter and CV are required. For some programs, a recommendation letter from a professor or academic supervisor is also necessary, and for the hands-on space projects, a payload or research proposal is an important part of the application.

INTERNSHIPS AND WORK OPPORTUNITIES

In addition to courses and projects, there is the opportunity to gain actual work experience at ESA, already as a student or as a recent graduate. Students nearing graduation from a Master's level program can apply for a three or six month long internship as part of their Master's degree. Internships are available at most ESA facilities in both technical and non-technical fields, ranging from engineering to law or finance. Applications for internships are open in November every year [2].

For those recently graduated with a Master's degree, there is the Young Graduate Trainee (YGT) program. The YGT program offers young graduates a one or two year work contract in an ESA facility, helping them transition from studies to the professional world. The YGT positions are published yearly in early spring. Just like the internships, there are YGT positions in most ESA facilities with various positions available in both technical and non-technical fields [2].

CONCLUSION

The European Space Agency offers various opportunities for students and recent graduates to gain knowledge and experience in space and related fields. They are also a place to meet students from all over Europe and make connections with the next generation of European space engineers.

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FAILING WITH FLYING COLORS

Starship exploded, but was it all that bad?

James Perry, Leonardo Times Editor

C&O

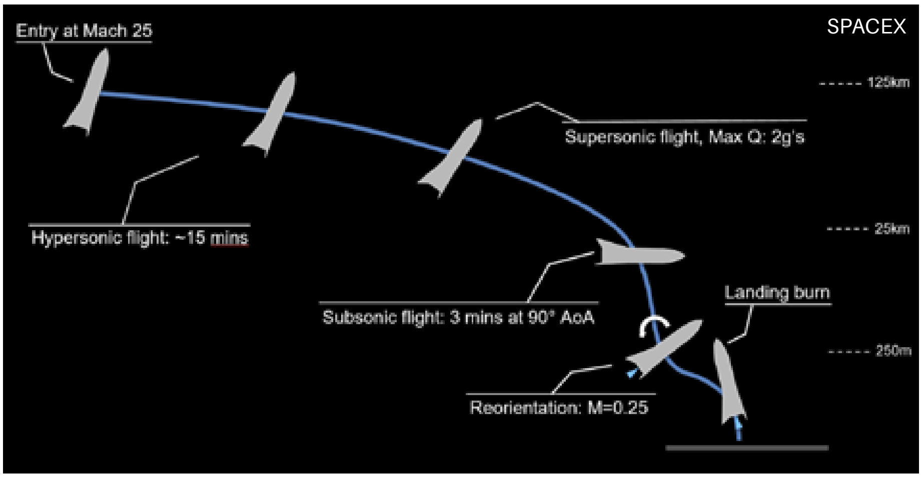
Starship fully stacked on its launchpad in Boca Chica, Texas. Black ceramic heat tiles for re-entry can be clearly seen covering the upper stage

On its first test flight, SpaceX's enormous Starship rocket experienced engine failures, tumbled through the sky and eventually exploded. Despite the spectacular flight, the commercial space giant seems unfazed. When a similar mishap would be disastrous for NASA, and proved fatal for Virgin Orbit, how can this be?

ALL ABOUT SPACEX

To gain insight into SpaceX's position in this situation, it is vital to understand who SpaceX are and what they are setting out to achieve. The company was founded in 2002 out of the then-millionaire Paypalfounder Elon Musk's pocket, who has remained the CEO and chief engineer. Their first launch vehicle, Falcon 1, did not experience immediate success – the first three attempts failed to reach orbit, following an engine fire, roll control and stage separation issues respectively [1]. The fourth, and last possible launch attempt before funding would run dry, was a success, and in 2008 Falcon 1 became the first liquid-fueled rocket developed by a private company to reach orbit [2]. Its successor, Falcon 9, perfected the previously inconceivable art of reliable propulsive landing, making headlines on first pulling off the feat in 2015 [2]. Nowadays, over 180 successful landings have taken place, each time enabling the booster stage to be re-flown on cheaper future missions, with landings now so commonplace they go unnoticed by the public eye.

Falcon 9 was also the launch vehicle for the long-awaited Demo-2 mission in 2020, which saw the first NASA astronauts launch to the ISS aboard a Crew Dragon capsule, also developed by SpaceX. This was planned to be just part of the Commercial Crew Program, alongside Boeing's Starliner



A visual depiction of the Starship landing sequence on Earth, as proposed to NASA

capsule, but at the time of writing, three years later, Boeing is yet to deliver [3]. Since then, six crewed NASA missions have flown on Falcon 9, in addition to three private missions to orbit [3]. SpaceX is the only private company currently providing such an offering to space tourists. Both Falcon 9 and the Falcon Heavy rocket, which consists of three Falcon 9 booster stages strapped together, provide launch services for commercial satellite customers, and SpaceX itself as the company develops their Starlink constellation of internet satellites.

SpaceX's self-proclaimed end goal is to enable people to live on other planets [2]. It is evident that Musk's approach to this is to attempt to develop as cheap launch vehicles as possible, and more recently as powerful as possible too. He hopes this will enable his company to establish a colony by the end of the decade [4] on the first new planet in humanity's sights: Mars.

SO WHAT'S STARSHIP?

The name itself can somewhat confusingly refer to two different things. Most commonly, "Starship" is used to mean the mega-rocket which SpaceX is currently developing, as contracted by NASA to provide the human landing system for at least the first manned mission returning to the moon, Artemis III [5]. The rocket consists of a lower boost stage, known as the "Super Heavy rocket" and an upper stage designed for orbit transfers and re-entry, referred to again as the Starship spacecraft [2] (in this article the word "spacecraft" will be used to mark the distinction where necessary). The company plans for the rocket to eventually form the foundations for regular, inexpensive manned launches to orbit, the moon and Mars. This would be thanks to two important vehicle characteristics. Firstly, it has an extremely high capacity to orbit, 100-150 tonnes [2], which enables costs to be shared between the customers, similar to economy class on a long-haul flight. The second has already been key to SpaceX's success - reusability. Both stages of this rocket should be able to land under their own engine power and fly again. Previous large rockets, such as the Saturn V of the Apollo moon missions, were completely expendable, which could be economically likened to throwing away that same long-haul aircraft after just a single flight. It is far cheaper to simply land safely, maintain and reuse the same vehicle.

SpaceX has made steady progress in realizing this skyscraper of a rocket (quite literally as it stands 120m tall [2], higher than the Statue of Liberty!). This began with the Starhopper prototype, which made two short flights in summer 2019, shortly followed by two more "hops" of prototypes with serial numbers (SN) 5 and 6. The company then progressed to the more explosive tests of the Starship spacecraft's landing system, see Figure 1.

In just five months, SpaceX saw four failed attempts before the final success of SN15 [6], reminiscent of the trial and error days of Falcon 9's propulsive landing attempts.

THE FLIGHT

On April 20th this year, SpaceX concluded their test campaign of static fires and dress rehearsals with a test flight of the complete Starship vehicle. The planned trajectory would see the Starship spacecraft reach just shy of orbit, while the booster landed softly in the ocean, before returning to earth and splashing down off the coast of Hawaii. The actual events were perhaps far more spectacular!

Fog on the day of the launch caused poor visibility, and while there was concern that the launch would be invisible in such bad weather, it soon cleared up as the countdown began. At the forty second countdown mark, the launch entered a hold while engineers resolved an issue. For a moment, it seemed as if the colossus might not launch that day after all, it was similar to the scrubbed attempt three days prior [7]. The countdown soon resumed, and millions watched with bated breath for what might happen next. Would the simultaneous ignition of all 33 engines cause some kind of explosion, destroying all launch infrastructure and leaving SpaceX's program in tatters? Would the engines simply be unable to provide enough power to lift such a giant off the ground, or might they be shut down before that was permitted to happen? Or, just maybe, might it actually work? At 08:33 local time, the engines ignited. For seven long seconds, the great beast roared and shook but nothing seemed to happen. And then, very slowly, it began to rise. Before long it had cleared the launch tower, leaving the so-called "Megatron" stage zero safe for future flight attempts, and began to make progress skywards [7]! The most powerful vehicle in history was alive and free.

Looking up at the rocket, it was clear for onlookers that not everything was going smoothly. The circular engine patterns were becoming increasingly disjointed, as engines failed and shut down, and one was leaving a spectacular green exhaust trail – recognizable as "engine rich" combustion [7]. Telemetry showed the vehicle to be underperforming; it successfully passed max Q (maximum aerodynamic forces on the vehicle), but significantly lower than expected. The time then came for stage separation, achieved by a sudden pitch up of the booster

Virgin Orbit's Launcher One falling away from Cosmic Girl as part of a drop test stage in the hope that the upper stage would fling outwards and separate. No such separation occurred, and the starship spacecraft remained stubbornly attached to its booster as they both began to tumble through the sky. Just four minutes into its launch attempt, Starship was destroyed by SpaceX using the flight termination system, to ensure the safety of those on the ground [8].

BAD NEWS?

Normally it would be. Earlier this year, on January 9th, Virgin Orbit attempted the first orbital rocket launch from the UK, on the sixth flight of their LauncherOne launch vehicle. Similar to SpaceX, the millionaire-founded American company also boasted an innovative launch system, by first carrying the rocket to an altitude of around 11,000m under the wing of a Boeing 747 ("Cosmic Girl"), as shown in Figure 2. Despite an initially successful flight, the upper stage failed to reach orbit after a filter in the fuel tank outlet dislodged during flight, traveling through the fuel system and eventually reaching the Newton-4 engine [9]. Three months later, a lack of funding caused the company to file for bankruptcy protection in the USA. By this point, the six-year-old company was valued at just $60 million, compared to a peak of $3.5 billion reached the previous year [10]! Investors were scared by the failed launch and dwindling funds, as the company of 800 employees furloughed its workforce in an attempt to stay afloat [10].

Even for government-backed companies well-established in the market, a launch failure can be a massive setback. On January 28th, 1986, seven crew members tragically died in the Challenger disaster. As one of the astronauts was a high school teacher, the flight was broadcast live to schools across the USA and shocked the public. The space shuttle did return to flight, after three years out of service and with over one hundred improvements made, but the accident was determined to have been avoidable [11]. It was caused by the failure of a rubber O-ring on a solid booster, embrittled due to the cold temperatures on the morning of the launch, and NASA were aware that the ring had not been tested to such temperatures when they made the decision to "go" [11]. This so-called "go-fever" was deeply rooted in the working culture of NASA at the time, and was arguably necessary to put man on the moon – such a risky endeavor should never have taken place so hurriedly under modern safety standards. But the exposure of this urge to fly, even at risk to life, exposed this approach as immoral and simply unsustainable for a company that relied on taxpayer funding. Although many devastating accidents have occurred in the history of manned spaceflight, this example was particularly pivotal for the universal approach to space exploration.

Since then, NASA claims they are working to build a culture of safety, and prides safety as one of five core values. They describe their culture as "how an organization behaves when no one is watching" [12], strongly suggesting that they have learned from incidents such as Challenger and that to rely on regulators such as the FAA to decide what is safe is insufficient. While legal restrictions may provide a baseline safety standard, if space-faring companies are to ever be fully trusted by the public, they must have a proven track record. This can only be achieved at even higher standards. These are rooted in the companies' policies and culture; whether individual employees consistently make the right decision in the interest of safety when it counts - potentially against the interests of the company which employs them.

So when it all goes wrong, why doesn't SpaceX appear concerned? Firstly, it is important to remember that this first test flight carried no humans, yet also no commercial payload. The same was true for their first two Falcon 1 launches, and Falcon 9 was proven through 84 cargo flights before carrying humans [13]. While this was risky in the early days of the company, SpaceX has developed a method to draw on its own profits to iteratively test at very low commercial risk. Their test articles are not designed to survive but rather be constructed quickly and cheaply, at least in comparison to NASA's latest $2 billion moon rocket so that by the first operational iteration the vehicle type already has hours of flight time. This experience generally prevents the need for last-minute acceptance of previously undiscovered risks just in order to fly, avoiding "go-fever" when lives are at stake.

This brings us to the answer to the original question of why the explosion of Starship wasn't that big of a deal for SpaceX. For a brand new prototype it was almost expected, but SpaceX was happy to launch anyway to learn from their mistakes. This is just another, very public example of SpaceX's "fail fast" methodology, a so-called "hardware rich" approach in which prototypes are produced and tested as quickly as possible, quite evidently well before the design is perfected [14]. This agile approach removes the focus on getting everything right first time, allowing faster testing and innovation so that the system can be comprehensively tested and improved before the design is finalized. Compared to NASA's slow and careful approach, SpaceX's new methodology appears quite radical. But the company's approach has proven itself to be cheaper, faster [14] and a lot more fun to watch!

CONCLUSION

While the space industry is a harsh environment, there is by no means just one way to guarantee survival. Different approaches have seen successes and failures, and that of SpaceX is no exception. However, learning to embrace failures as part of the process has served the company well so far, and is expected to continue to in future. The maiden flight of Starship and its dramatic conclusion might just be another failed mission. Yet, if all goes well, it might also be the start of mankind's journey to the stars.

SEIZING THE OPPORTUNITY

There's no age limit in the space race

Topias Pulkkinen, Editor-in-Chief and Syed Muneeb ur Rahman, Leonardo Times Editor

Nathan Monster, the young entrepreneur

A-SpaX is a Delft-based startup that focuses on enabling in-orbit manufacturing, one of the most booming fields in the New-Space Economy. In this interview, we take a deep dive into the story of Nathan Monster, the young entrepreneur who founded the company.

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

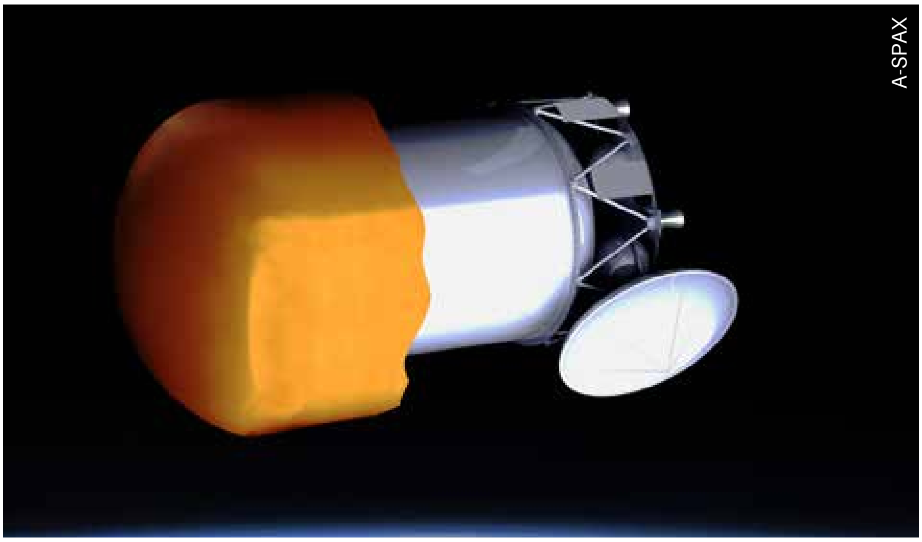
Q: Can you tell us about the founding idea behind the start-up?

A: I had the idea around five years ago when I was studying mechanical engineering in Utrecht. It addressed the reusability of rockets in a way where a launch vehicle's first stages could be reused together with the upper stages. My idea was using this to enable in-orbit manufacturing, so I started looking into that. After finishing my bachelor's in mechanical engineering, I began working on the start-up company. At the start, I was working on the infrastructure that enables in-orbit manufacturing. Back then the idea was different, and it gradually morphed into what we are currently working on - creating a re-entry capsule, something in which customers could place their objects or payloads. Though, this is still the long term goal. We want to provide the infrastructure, so people can start thinking about the new space environment, enabling the opportunities that space has to offer. We are still considering different niches to break into along the way.

Q: With the many already established space companies and agencies, how can A-SpaX be a worthy competitor?

A: Established space agencies such as NASA, ESA and JAXA continue to work on things that can't be done by commercial companies, mainly for financial reasons. Established space agencies tend to work on things that are fascinating, but don't have a commercially viable case in the free market. On the other hand, the bigger private companies - our competition - work on similar products in a different way. For example, if we investigate the case of launch providers, they are nearly irreplaceable market players as the service they provide is technically very difficult

- even without considering the great capital investment that is required. There are some other smaller players that are working on in-orbit transportation and kick stages, for example;something we're also looking into. Critically, we don't aim to compete with any large space conglomerates, but rather provide our customers with a novel and competitive service not offered by the established entities as of now. Right now, at A-SpaX, we are working on a dedicated platform with a fiber optic machine, a life science experimental module, a module in which we can manufacture artificial tissue. We will provide the physical condition it requires - anything from temperature to power and more. We also have a dedicated re-entry capsule in the making so we will get the capsule back as soon as the mission is finished.



A render of a re-entry capsule in LEO

Q: Can you tell us about your team and the way recruitment is done?
A: Due to difficulties forming a team, I moved to Delft after my graduation to utilize its aerospace talents. In Delft, I attended a lot of networking events to find team members who agreed with the mission and vision of the team. Anyone possessing the skills needed to work on the topic could do so, although at the start I was mainly looking for more technically inclined people who could provide insight. A team requires knowledge of a lot of disciplines - I was mainly looking for passion and talent, and if we agreed on the vision, I would invite them onboard. By attending the networking events, I found a business developer, Jerry, at a Summer School at LDE (Leiden, Delft and Erasmus) campus. The Summer School was a great and useful experience, since you spend quite a bit of time together with other people passionate about space. A funny anecdote that springs to mind from this time is that, during a 24hr-hackathon in Leiden focused on 'space challenges", another group coincidently pitched an almost identical idea to A-SpaX's business idea.

Q: Can you shine some light on pitching your business case?
A: You need to have an overarching understanding of the topic, rather than just memorizing a few sentences, to pitch well, especially in such a technical field. It always helps if you can convey that you are really passionate about the idea. Basic communication skills get you quite far; you need to be really clear about the idea, be able to articulate its point and the potential business case.

Q: How do you manage to externalize or share responsibilities within the team?
A: It all has to do with their skills - the main thing is acknowledging the other party's competencies and letting go of control. I have found this to be difficult sometimes but it is necessary, as I can't do everything by myself. Something I've found really critical is reporting progress with your colleagues continuously, so that there is a constant shared understanding over what's being done. In the beginning, you will inevitably have multiple roles.

Q: What aspects of developing the start-up has taken the most of your time?
A: In the beginning, it was orienting and figuring out what actually the problem we can and should provide a solution to is. It's also important and sometimes time-consuming to talk to the customers; figuring out the technology that is the most mature; where there's a demand; where we should focus on and create a business case around it. An analysis of your market can also be very laborious. Keeping your ears and eyes open for both the customers as well as the market as a whole, since it is the only way you can develop a solution that satisfies the partners and suppliers. Some other things that took me quite some time were figuring out legal aspects and deciding what our holding structure should be. Another critical question is how you approach the market, because there are players like NASA and ESA, with whom you'll likely end up working with. Finally, researching available subsidies can take some time. Right now, we are writing our business plan - making our case to argue that there is demand for our product..

Q: Where do you see the company in five years?
A: We hope to see the first launch with our products onboard in 2025, using a kick stage, which means that we only have to build the key subsystems. In five years we would like to have moved away from the kick stage and have integrated all these subsystems in the entire capsule: a fully reusable capsule. We hope to have frequent launches to orbit. For the life sciences customers we hope to be cultivating organoids i.e. organ tissue in space, and bring it back to Earth to pharmaceutical companies to accelerate their drug development. Another thing we hope to provide would be crystallized medicine, which is a lot purer than the current best available option. It's used in, just to give an example, Prozac, an antidepressant.

Q: Can you tell us about the obstacles or uncertainties you've faced in the past years?
A: It's not that you just come up with the perfect idea one day and then start building towards it the day after. I personally wanted to graduate first with a degree in mechanical engineering - I find it crucial to understand the technical difficulty that many space applications entail. I started reading this 800-page book called Rocket Propulsion Elements during the covid pandemic, as I felt that my understanding was still lacking at the time. Sometimes, when things don't go your way, you must still be able to make decisions, even in times of uncertainty.

Q: How do you transform yourself from being a student to an entrepreneur?
A: It's not difficult to start a company. You can just pay 500 euros and start a BV. But next to this, you need to be passionate about it, you need to make sure there is demand for it and you should like it. If you can check these boxes, there shouldn't be any reason that you shouldn't start the company. Once you do, you will learn a lot of valuable skills that will help you in your career anyway. There is always a financial risk that you are taking which may be mentally most difficult to take. Personally I don't mind that I am really fortunate to have my basic financial needs met. Most people are smart enough to figure out a way to get back up again, if something were to go wrong. I would strongly emphasize the need to create a network around you to answer the questions you might have, be it financial, technical, legal or anything else.

Q: How is your work-life balance?
A: Not great, it's a lot of work, since there are a lot of things that need to be solved. For any aspiring entrepreneurs out there, expect to put in a lot of hours. I average around 60 hours a week, even though it can vary greatly. That being said, it's something I love and find meaningful, so the hours are predominantly a reflection of that, rather than the need to work.

We'd like to thank Nathan for taking the time to speak with the Leonardo Times.

ENTREPRENEURIAL OASIS

Unleashing the Power of Innovation: Stories of Delft's Start-ups

Muhammad Arham Elahi, Ruth Euniki Vraka, Leonardo Times Editors

Founders of Dawn Aerospace

Delft's start-up scene is gaining momentum, with entrepreneurs flocking to the city for its supportive ecosystem, top-notch research institutions, and abundant funding opportunities. The Delft start-ups are driving innovation in a range of fields. In this article, we explore what makes Delft such an attractive destination for aspiring entrepreneurs.

Startups can be characterized as the infants of the industrial and technological ecosystem. And just as any young form of life, whether they survive and thrive depends on a plethora of factors. The feasibility of what they strive to achieve and the current market's needs are undeniably some of the major influencers, but their role in the environment they initiate is often underestimated. Resources, both manpower and financial, facilities, and strong industry networks are just a few of the nutrients that could tip the scale for an ambitious group of people with a great idea. If you are an entrepreneur in Delft, this scale has a high chance of tipping in your favor. According to the "Entrepreneurial Ecosystem Index" compiled by Utrecht University and Birch Consultants every two years, Delft was

considered "the best place for entrepreneurship" in both 2020 and 2022 [1]. The study states that "important elements making these regions so strong are leadership, knowledge and networks" [1].

WHAT MAKES DELFT A GOOD START-UP CITY?

There are several characteristics that define a good start-up city. Among them is the availability of large amounts of capital, a skilled talent pool, supportive infrastructure and facilities, as well as an acceptable quality of life. The large amount of capital required can be supplied through venture capital firms, angel investors, and government and educational grants. To acquire a skilled talent pool, you need strong foundations in education or to attract external talent through the presence of large established industries. Supportive infrastructure and facilities imply access to relevant high-tech equipment, as well as affordable office space and a good internet connection. It also includes having a robust network of industries collaborating and interacting with one another. An acceptable quality of life means that the city has affordable housing, good healthcare facilities, and a clean and safe environment.

When taking a closer look into how Delft can provide the aforementioned elements, amongst the various resources, two main categories can be distinguished: funds, and "incubation" centers. Funds provide a financial boost to help kickstart making an idea a reality. Additionally, since funds are usually given after a competition, they also provide exposure and connections with relevant larger companies or investors who hear the pitch. Incubation centers, on the other hand, are a start-up community and other established companies interested in innovation. They give their start-ups a more complete survival kit: working spaces, facilities, networking events, training in leadership and other soft skills, and a motivating environment of people with the same goals. The current largest incubation center in Delft is YES!Delft. With 80% of their start-ups alive after 5 years, and more than 65 service and corporate partners, they have become one of the leading incubators in Europe, offering support to start-ups since 2005 [2].

In addition, another Delft strength is the presence of the Delft University of Technology (TU Delft). It not only provides a very skilled talent pool straight from the source, but also allows for numerous grants and fosters innovation and entrepreneurship. The Delft ecosystem is a magnet for ambitious forward-thinking entrepreneurs from all over the world, as the innovation culture and support is unique and hard to find elsewhere. The research and innovation facilities in Delft also give start-ups access to cutting-edge technology which they may be unable to fund outrightly. Lastly, but by no means least, the quality of life in Delft is in a sweet spot with a very diverse and culturally rich atmosphere, all the required facilities without being outrageously expensive like other start-up cities (eg. New York, Silicon Valley etc.).

AEROSPACE INNOVATION HUB

Startups focusing on aerospace have an additional resource in Delft: the Aerospace Innovation Hub. Located on the top floor of the Faculty of Aerospace Engineering, it aims to connect start-ups, academics, students, corporates, and industry professionals. It also facilitates the "Start-up Voucher & Coaching Program" which awards 2,500 euros and provides coaching opportunities to five ambitious groups every year. According to its community manager, Maximilian Meijkamp, what makes Delft special in terms of start-up development is the high level of research and the activeness of students at the Delft University of Technology, as well as a well situated geographical location. The Randstad area is home to many large companies in the aerospace industry, including the European Space Agency's "Business Incubation Center" (BIC).

The Innovation Hub's start-up success rate is also significantly high, with approximately 85% of its start-ups still active. The inactivity of the other 15% is mainly due to the founders moving on to a different phase in their careers. Additionally, a striking fact is that over half of BIC's start-ups come from the Innovation Hub. When asked about the variety of the start-ups in the hub, Maximilian mentioned that it houses start-ups focused on all the different aspects of aerospace engineering: drones, artificial intelligence, wind energy, solar panels, and of course aviation and space engineering. The balance between aviation and space-oriented start-ups is relatively even, with a slightly larger number of aviation-oriented ones.

DAWN AEROSPACE - A DELFT SUCCESS STORY

The best way to understand the way Delft fertilizes its start-ups is, of course, to get their

“Starting a company is not just about a good idea; it's about surrounding yourself with the right people, tapping into supportive networks, and constantly learning. Delft provides an excellent ecosystem for this. Embrace the challenges, celebrate the successes, and remember that every setback is an opportunity for a comeback.”

JEROEN WINK, DAWN AEROSPACE FOUNDER

side of the story. Dawn Aerospace is one of the community members of the Innovation Hub. They are a company focused on space launch and satellite propulsion, and have successfully established themselves on the aerospace industry map. Jeroen Wink, one of Dawn’s founders, believes that Delft’s fertility can be attributed to “a unique blend of factors nurturing creativity, innovation, and entrepreneurship”.

He adds: “The University, with its emphasis on applied learning and practical problem-solving, has been instrumental in our journey. During our studies, the founding team was heavily involved in various projects at Delft Aerospace Rocket Engineering, including the record-breaking Stratos II project. It was this environment that enabled us to lead projects, make critical design decisions, handle manufacturing challenges, manage operations, and even navigate the complexities of fundraising. We believe that such immersive learning opportunities are unparalleled in preparing an individual for the dynamic and challenging world of start-ups.” Jeroen also praises the assistance of the incubation centers (such as YES!Delft and the Innovation Hub) in the legal and financial aspects of start-ups, as well as the sense of community that they foster.

During its up-scaling, Dawn Aerospace expanded to New Zealand, where a large part of its operation is now based. However, approximately half of its operations, connections, and employees are still tied to Delft, including half of the founding and executive team. “This distribution not only highlights the global nature of our operations but also underscores the enduring significance of Delft”, says Jeroen.

“Reflecting on our journey, it's clear that starting and building Dawn Aerospace in Delft has been an incredibly rewarding experience. We've been fortunate to grow in a city that values innovation, supports entrepreneurs, and fosters a culture of creativity and ambition. That said, success in the start-up world is not a destination; it's a journey of continuous learning, adaptation, and growth. It's about taking calculated risks, embracing failures as learning opportunities, and staying focused on your vision. As we continue to evolve, our aspiration is not only to contribute to the space industry but also to give back to the Delft community which has given us so much. We hope to inspire the next generation of entrepreneurs, just as we were inspired by those who came before us.”

DELFT STARTUP STORIES

In addition to Dawn Aerospace, there are several other start-ups that originated in Delft and went on to have a major impact in their respective industries. These are brief stories about some of their developments and achievements.

Physee

Physee is a technology company specializing in developing sustainable and smart solutions for the built environment. The company was founded by Ferdinand Grapperhaus and Willem Kesteloo, TU Delft alumni who finished their MSc Applied Sciences degree before the advent of their company in 2014.

Their flagship platform, SENSE, establishes a symbiotic connection between buildings and the natural world. By equipping buildings with SmartSkin windows embedded with internal sensors, SENSE enables precise monitoring of solar irradiance and other various environmental parameters like temperature, humidity, and air quality and their localized impact on the building.

In conjunction with the SmartSkin windows, SENSE Connect serves as a comprehensive data platform, seamlessly integrating all sensors and actuators within the building. This aggregation of data enables the creation of a digital twin, providing a holistic view of the building's operations. With accurate solar irradiance measurements and real-time indoor climate monitoring, SENSE enables precise control over sun blinds, optimizes energy consumption and fosters a comfortable indoor environment. Energy savings of up to 30% can be achieved through these intelligent functionalities [3].

The Ocean Cleanup

Boyan Slat, the founder of The Ocean Cleanup, started as an aspiring aerospace engineer at Delft University of Technology (TU Delft) in the Netherlands. However, he dropped out of university to pursue his passion for solving the problem of plastic pollution in the oceans. Slat was motivated to take action after a diving trip in Greece where he witnessed more plastic than fish in the ocean. In 2013, at the age of 18, Slat established The Ocean Cleanup as a non-profit organization. He and his team developed innovative technologies and systems to tackle the issue of ocean plastic pollution. The organization gained significant attention and support through successful crowdfunding campaigns and donations, allowing them to raise over $30 million.

The first major system developed by The Ocean Cleanup was System 001, also known as "Wilson", which was launched in

2018. It was a 600-meter-long floating barrier designed to capture and collect plastic debris in the Great Pacific Garbage Patch. Although System 001 encountered some technical challenges and was not as effective as expected, it provided valuable insights for further improvement. Building upon the lessons learned from System 001, The Ocean Cleanup launched System 002, known as "Jenny", in 2021. This upgraded system featured design enhancements and aimed to address the shortcomings of its predecessor. System 002 is currently being phased out and will be succeeded by System 003, which is expected to be ten times more effective at collecting plastic debris [4].

In addition to their efforts in the open ocean, The Ocean Cleanup recognized the importance of addressing plastic pollution at its source, since 1% of the world's rivers are responsible for 80% of the pollution. To tackle the issue of riverine plastic pollution, they developed a specialized device called the Interceptor. The Interceptor is a scalable and self-sustaining system placed in rivers to capture plastic waste before it reaches the ocean. To date, 20 Interceptors have been deployed in various locations worldwide [5].

Kitepower

Kitepower, founded in 2016 by Johannes Peschel, a Computer Science student at TU Delft, and his mentor and supervisor Roland Schmehl, is a pioneering company that emerged from the wind research group at Delft University of Technology. The group itself was established by Wubbo Ockels, a Dutch ESA astronaut. They began with the development of a 20kW prototype kite power system, demonstrating the feasibility and potential of kite-based wind energy generation. Building upon this success, they have successfully scaled up their technology to a 100kW system, showcasing their commitment to advancing the field of renewable energy [6].

What distinguishes Kitepower from traditional wind turbines is its emphasis on efficiency and reduced material usage. By utilizing kites that fly in the air, their systems require far less material compared to conventional wind turbines with large towers and rotor blades. This streamlined design not only reduces the environmental impact but also allows for greater flexibility in deploying wind energy solutions.

Kitepower's innovative approach employs a pumping system. The kite flies in a figure-eight pattern, generating tension in the tether that drives a ground-based generator. This conversion of kinetic energy into electrical power provides a sustainable and efficient solution for electricity generation, particularly in areas where traditional wind turbines may face limitations.

Hardt Hyperloop

Hardt Hyperloop is a Dutch company founded in 2017 with the goal of revolutionizing transportation through the development and implementation of hyperloop technology. It originated from the renowned Delft Hyperloop team, which emerged victorious in the Hyperloop pod competition organized by SpaceX, led by Elon Musk. Since its establishment, Hardt Hyperloop has become a prominent player in the global hyperloop industry, driving innovation and pushing the boundaries of high-speed transportation. To support their ambitious goals, Hardt Hyperloop has successfully raised almost 30 million in funding and has a dedicated team of approximately 50 individuals. [7]

Hardt Hyperloop has made significant progress in developing its technology and infrastructure. They have established multiple test rigs, including a 30-meter-long tube at the Green Village in Delft, which serves as a facility for research, development, and testing. In addition, Hardt Hyperloop is now planning the construction of a larger rig spanning almost 3 kilometers near Groningen. [8]

WHAT CAN STILL BE IMPROVED UPON?

Even though Delft has many advantages related to start-up development, there are also aspects for improvement. According to the Innovation Hub, there is a need for more support in the pre-incubation phase. This includes the birth of ideas, gaining education on them, and activating them. Additionally, there is still room for improvement in the number of networking opportunities and the opportunities of gaining financial assistance. Finally, the Innovation Hub believes that Delft also lacks the necessary number of facilities and workshops to help start-ups realize their physical products.

Jeroen Wink of Dawn Aerospace agrees that one of the main issues Delft faces is the lack of space for growing companies. In his words, "as start-ups find success and begin to scale, they often face difficulties finding suitable buildings within Delft or its immediate surroundings. It's a challenge we're currently grappling with at Dawn Aerospace. Many of the available locations are quite distant from Delft, though we have a strong desire to remain in the city that has played such a significant role in our development". He also adds that the Netherlands in general can improve with respect to the bureaucracy of setting up a start-up. "Compared to countries like New Zealand or the USA, setting up a company, handling taxation matters, and offering shares to employees can be more complex and time-consuming in the Netherlands. A streamlined bureaucracy that's more attuned to the needs and dynamics of start-ups would greatly benefit Dutch entrepreneurs."

TIPS FOR FUTURE ENTREPRENEURS

The best advice on a topic comes from those who have already experienced its challenges. If you are a student or professional with an idea, and aspire to make it a reality in Delft, one of Dawn's founders, Jeroen, has a few words of advice: "If you're considering founding a start-up in Delft, my first piece of advice would be to immerse yourself in a student team or project. This experience offers unparalleled preparation; it provides first-hand insight into leadership, teamwork, problem-solving, and project management - all of which are essential skills in the start-up world. Secondly, make sure you fully utilize the resources available in Delft. Initiatives like YES!Delft and the Aerospace Engineering Innovation Hub, among others, are designed to support and nurture start-ups. They offer invaluable guidance and learning opportunities, particularly in the early stages of your entrepreneurial journey."

FCAS

The future of European military aviation

Juan Avila Paez, Leonardo Times Editor

FFP

A Eurofighter Typhoon, the aircraft to be replaced by the NGF

In an era defined by technological advancements and evolving security challenges, the Future Air Combat System (FCAS) program stands as Europe's response to assert its position in advanced combat aircraft development. This article examines its significance, achievements, and the critical questions it raises for the continent's defense industry and strategic autonomy.

WHY IS FCAS SO IMPORTANT FOR EUROPE?

The development of advanced combat aircraft has been a cornerstone of military strategy for decades, providing countries with critical capabilities for air superiority, strike missions, and intelligence gathering. Although major agents in the world's defense scene, like the United States, Russia, and China, have made the continuous development of such aircraft a priority, the same cannot be said about Europe. In fact, with the last European fighter project being the Eurofighter Typhoon, it has missed out on the entire fifth generation of fighter aircraft.

Being a continent largely under the protection of the United States through NATO, European defense budgets have largely remained low in modern times, with most countries spending less than the NATO-mandated 2% of GDP. More shockingly, in the decade from 2007 to 2017, these budgets saw an additional decrease of 12% [1]. Therefore, European security has been reliant on the United States for most of what has been of the 21st century. However, sentiment on Europe's strategic autonomy and defense started to change in 2017, when the United States threatened to scale back its global military commitments during the Trump presidency. Worried about its weak position in terms of security, Europe decided to focus on its domestic defense industry and invest in new projects. This led to the creation of, among others, the Future Combat Air System (FCAS) program.

WHAT TECHNOLOGIES ARE BEING DEVELOPED?

The FCAS is what is known as a System of Systems (SoS), in which independent systems are combined to amplify their capabilities as a whole [2]. Therefore, the program consists not only of the development of the Next Generation Fighter (NGF) aircraft, but also of remote carrier manned-unmanned-teaming (MUMT) and air combat cloud (ACC) systems [3]. In essence, the goal is increased integration of new manned and unmanned combat air vehicles that are in constant communication, leveraging their data-gathering capabilities and cloud processing to give them the edge on the battlefield. As a result, the FCAS program is truly enormous, requiring a lot of cooperation between the firms and countries involved.

WHO IS BEHIND THE PROGRAM?

With this in mind, it is no surprise that some of Europe's defense giants - Spain, Germany, and France - are the ones behind the program. In the industrial framework, they are represented by Indra, Airbus, and Dassault Aviation, respectively [4]. The proposal for the FCAS was unveiled in 2017, with French President Emmanuel Macron and then German Chancellor Angela Merkel wanting to strengthen Europe's domestic defense industry [5]. Two years later, in June of 2019, Spain officially joined the program [6]. Therefore, the FCAS is still in its initial development stages. Nonetheless, it has still suffered from common issues stemming from the cooperation between different countries: a difference in priorities from member states and disagreements between the involved companies. For instance, French military doctrine is very different to that of Germany. France prioritizes the development of its own fighter aircraft, as evidenced by the Dassault Mirage and Rafale. It is also very much involved in global security affairs, playing an active role in military operations around the globe. The same cannot be said about Germany who, until the 2022 Russian invasion of Ukraine, held a much more restrained approach in terms of security and defense, characterized by the post-WWII consensus in the country.

In spite of these setbacks, the program has also achieved major milestones during its development. Looking no further than its very beginning, it involved a €155m deal between Dassault Aviation and Airbus for the first phase of the development of the Next Generation Fighter [7]. With Indra later joining the program, it progressed well from the first phase, 1A, to the current phase, 1B, which involves the development of flight demonstrators. In fact, the contract for this phase was recently awarded to the involved companies on December 16, 2022. The deal was worth a total of €3.2b euros, showing how much of a step up it is from the previous phase. The demonstrator for the NGF aircraft, as well as the other technologies under the FCAS umbrella, are expected to begin flight testing in 2028-2029 [8]. By then, the program's vision is not only to evaluate the performance of the NGF in the real world, but also to test the MUMT component: fighter aircraft operating in conjunction with UAVs and connected to the cloud.

THE FUTURE OF FCAS

Now, there is still much speculation about the future of the program, and whether it will ever be finished in the way it is currently envisioned. This is because, aside from the NGF, there is another fighter jet project included in the FCAS program: the UK-led Tempest Team. Alongside the UK, Italy and Sweden are also involved in the Tempest fighter development [9]. This rightly raises the following concern: can Europe really afford, both strategically and financially, the development of two novel fighter aircraft? Italy's Air Force Chief of Staff, Gen. Luca Goretti, does not think so, going so far as saying that "it is natural that these two realities will merge into one, because investing huge financial resources in two equivalent programs is unthinkable" [10]. This has been echoed by other military officials in Europe, such as Germany's Air Force Chief of Staff, Lt. Gen. Ingo Gerhartz [11]. Therefore, it is certainly possible, and even desirable, for Tempest and NGF to merge in the future. In the end, both fighters are being designed with similar philosophies, and both are meant to replace European countries' Eurofighter Typhoons. On the other hand, as evidenced by FCAS' initial troubles with disputes among member countries and involved companies, expanding collaboration will prove hard and time-consuming, something that Europe might be unable to afford if it wants the upper hand in its defense. This is especially true in this case, with the UK now drifting apart from the rest of Europe after Brexit, and seeking security alliances elsewhere, such as with the AUKUS pact among the UK, the USA, and Australia.

CONCLUSION

All in all, the Future Air Combat System (FCAS) program represents Europe's determined effort to reclaim its position in the development of advanced combat aircraft. Even while facing challenges of cooperation and differing priorities, significant milestones have been achieved, highlighting the program's potential. However, when both the NGF and the Tempest projects are considered, there are doubts about the feasibility of developing two novel fighters simultaneously. As Europe navigates a changing security landscape and seeks strategic autonomy, the FCAS will test the limits of European cooperation and development logistics. This demonstrates that, for the path forward for European military aviation, good collaboration, innovation, and resource allocation will be key.

TIRADEN

Mock-up of the NGF and accompanying UCAVs at the 2019 Paris Airshow

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