BULLETIN

AEROSPACE EUROPE

THE EUROPEAN DEFENCE AGENCY'S WORK IN R&T IS IN LINE WITH ITS MISSION TO SUPPORT MEMBER STATES EFFORTS TO IMPROVE DEFENCE CAPABILITIES. EDA ORGANISES ITS R&T PRIORITIES IN DIFFERENT CAPABILITY TECHNOLOGY AREAS - 'CapTechs' – WHICH ARE FORA FOR EXPERTS FROM GOVERNMENTS, INDUSTRY, SMALL AND MEDIUM SIZE ENTERPRISES (SMEs) AND ACADEMIA

INTERVIEW WITH JEAN-FRANCOIS RIPOCHE, DIRECTOR RESEARCH, TECHNOLOGY AND INNOVATION (RTI) AT THE EUROPEAN DEFENCE AGENCY (EDA)

CEAS

The Council of European Aerospace Societies (CEAS) is an International Non-Profit Organisation, with the aim to develop a framework within which the major European Aerospace Societies can work together.

It was established as a legal entity conferred under Belgium Law on 1st of January 2007. The creation of this Council was the result of a slow evolution of the 'Confederation' of European Aerospace Societies which was born fifteen years earlier, in 1992, with three nations only at that time: France, Germany and the UK.

It currently comprises:

- 12 Full Member Societies: 3AF (France), AIAE (Spain), AIDAA (Italy), AAAR (Romania), CzAeS (Czech Republic), DGLR (Germany), FTF (Sweden), NVvL (The Netherlands), PSAA (Poland), RAeS (United Kingdom), SVFW (Switzerland) and TsAGI (Russia);
- 4 Corporate Members: ESA, EASA, EUROCONTROL and EUROAVIA;
- 8 Societies having signed a Memorandum of Understanding (MoU) with CEAS: AAE (Air and Space Academy), AIAA (American Institute of Aeronautics and Astronautics), CSA (Chinese Society of Astronautics), EASN (European Aeronautics Science Network), EREA (European association of Research Establishments in Aeronautics), ICAS (International Council of Aeronautical Sciences), KSAS (Korean Society for Aeronautical and Space Sciences) and Society of Flight Test Engineers (SFTE-EC).

The CEAS is governed by a Board of Trustees, with representatives of each of the Member Societies. Its Head Office is located in Belgium: c/o DLR – Rue du Trône 98 – 1050 Brussels. www.ceas.org

AEROSPACE EUROPE

Besides, since January 2018, the CEAS has closely been associated with six European Aerospace Science and Technology Research Associations: EASN (European Aeronautics Science Network), ECCOMAS (European Community on Computational Methods in Applied Sciences), EUCASS (European Conference for Aeronautics and Space Sciences), EUROMECH (European Mechanics Society), EUROTURBO (European Turbomachinery Society) and ERCOFTAC (European Research Community on Flow Turbulence Air Combustion).

Together those various entities form the platform so-called 'AEROSPACE EUROPE', the aim of which is to coordinate the calendar of the various conferences and workshops as well as to rationalise the information dissemination.

This new concept is the successful conclusion of a work which was conducted under the aegis of the European Commission and under their initiative.

The activities of 'AEROSPACE EUROPE' will not be limited to the partners listed above but are indeed dedicated to the whole European Aerospace Community: industry, institutions and academia.

WHAT DOES CEAS OFFER YOU ?

KNOWLEDGE TRANSFER:

- A structure for Technical Committees

HIGH-LEVEL EUROPEAN CONFERENCES:

- Technical pan-European events dealing with specific disciplines
- The biennial AEROSPACE EUROPE Conference

PUBLICATIONS:

- CEAS Aeronautical Journal
- CEAS Space Journal
- AEROSPACE EUROPE Bulletin

RELATIONSHIPS AT EUROPEAN LEVEL:

- European Parliament
- European Commission
- ASD, EASA, EDA, ESA, EUROCONTROL, OCCAR

HONOURS AND AWARDS:

- Annual CEAS Gold Medal
- Medals in Technical Areas
- Distinguished Service Award

YOUNG PROFESSIONAL AEROSPACE FORUM

SPONSORING

AEROSPACE EUROPE Bulletin

AEROSPACE EUROPE Bulletin is a quarterly publication aiming to provide the European aerospace community with high-standard information concerning current activities and preparation for the future.

Elaborated in close cooperation with the European institutions and organisations, it is structured around five headlines: Civil Aviation operations, Aeronautics Technology, Aerospace Defence & Security, Space, Education & Training and Young Professionals. All those topics are dealt with from a strong European perspective.

Readership: decision makers, scientists and engineers of European industry and institutions, education and research actors.

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EDITORIAL

Jean-Pierre Sanfourche
Editor-in-Chief

RESILIENCE

I would like first of all to thank very much all contributors to this bulletin thanks to whom we have been able to cover a wide range of subjects, from the interview with Jean-François Ripoche, Head of Research and Innovation at the European Defence Agency, to the training of candidate astronauts at Novespace, passing through aeronautics technology with articles about the future of aircraft propulsion, civil aviation operations with the presentation of the ESA 'IRIS' satellite communication system for Air Traffic Management (ATM), and a report on the latest Space missions.

Next, I have to express the warmest thanks of the CEAS management team to three persons who are leaving the CEAS Directorate, for their major contribution to the development of our association: Presiident Zdobyslaw Goraj, Director General Mercedes Oliver-Herrero and VP Awards and Membership Kaj Lundhal.

They are replaced respectively by Elected President Prof. Franco Bernelli, new Director General Prof. Andrea Alaimo and new VP Awards and Membership Prof. Anders Blom. May they receive warm congratulations and very best wishes of success.

In 2021, CEAS makes it a duty to continue increasing its notoriety and influence with notably its biennial Conference AEC2021 which, hosted by PSAA, will be held on 23-26 November in the Institute of Aviation & Warsaw University of Technology. The motto chosen "Restore, Rethink, Redesign" illustrates the level of ambition of this event. In addition to the current activities, another major axis of effort concerns the CEAS Aeronautical and Space Journals. As a matter of fact, it is planned to give their development a new impulse by sending the Calls for Papers to a wider range of potential authors.

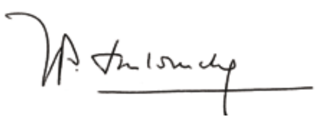
Resilience

Due the many constraints imposed by the pandemic situation, the work of CEAS will be all the more difficult. As everywhere, RESILIENCE will be the deadly quality to be cultivated to be able to overcome the obstacles.

Resilience[1] in psychology sciences is defined as a process of adapting well in face of adversity, threats and various sources of stress. This is the reason why the Dragon Capsule's astronauts of SpaceX Crew-1 mission of last November decided very opportunely to name their spacecraft 'Resilience' owing to the long succession of obstacles which had paved the way of the mission's preparation…

In the same manner, the resilience's spirit should dominate at CEAS during the coming months.

Dear readers, I wish you, your family and close, all the best for this New Year!



1. The famous Merriam-Webster Dictionary lists seven skills of resilience: (i) Cultivate a belief in our ability to cope with difficulties; (ii) Stay connected with sources of support; (iii) Talk about what we are going through; (iv) Be helpful to others; (v) Activate positive emotion; (vi) Cultivate an attitude of surviving ship; (vii) Seek meaning.

CONTENTS

2020 CEAS ANNUAL REPORT

Zdobyslaw Goraj
CEAS President 2019 -2020

The whole year 2020 for CEAS organisation was very different since CEAS was created in 1995. From the onset of the COVID-19 pandemic, the worldwide economy and especially aviation sector including research and dissemination is in permanent, very deep crisis. The CEAS Board of Trustees cannot idly wait on a full suppression of pandemic and must continue activity. It is extremely difficult for our members, officers and for me as the CEAS President. Some technical challenges, choice the proper electronic platform and voting mechanism sometimes dominate over the essence of our discussion. Nevertheless, I believe that we "passed the exam" were able to continue our main tasks following from our statute and mission.

AEC-2020, CEAS ROLE AND IMAGE

AEC-2020 was perfectly organized in the Conference Centre located at the Bordeaux outskirts. More than 400 participants not only from Europe, but also from USA, China, South Korea presented many interesting papers. Having in mind the violent spreading of COVID-19 it was really the last moment to organise AEC-2020. Unfortunately, all technical visits planned on the last day of the conference were cancelled due to recommendation of French Ministry of Health and French Foreign Office. AEC-2020 was organized by 3AF together with AIAA and CEAS as the main co-organizer. CEAS was well visible and really played the key-role at the conference. 2 of 5 plenary sessions were chaired by CEAS officers – plenary session n° 2 was chaired by Christophe Hermans and plenary session n° 5 by myself. The whole AEC2020 Event has been broadly reported in the issue 2-2020 of the AEROSPACE EUROPE Bulletin. In 2020, our Aeronautical and Space CEAS Journals continued to develop very positively and we plan to give them another strong impetus in the coming year by sending Calls for Papers to a wider range of potential authors.

CEAS IN ACTION

CEAS, in spite of the constraining conditions imposed by the pandemic situation has continued to hold as initially planned its meetings by phones and Skype. It was in particular the case for the Board of Trustees meeting on 25 June and recently for the General Assembly and Board of Trustees meeting on 30 November.

The General Assembly and Board of Trustees meeting, 30 November 2020

The General Assembly:

- Discussed and approved unanimously the 2020 accounts and the 2021 budget;
- Approved unanimously the 2019 accounts and balance, which will be presented to the Belgian Tax Authorities before the end of December;
- Unanimously approved the resignation of three Trustees and decided to re-elect five nominees as CEAS Board of Trustees members for a two-year period.

Then, the minutes of the two previous BoT meetings (45th and 46th) were reviewed ad approved.

Prof. Franco Bernelli was nominated and approved as the CEAS President as of 1st January 2021. Mr Pierre Bescond and Dr Cornelia Hillenherms were approved for a further two-year term as respectively VP Publications & External Relations and VP Finance. Prof. Anders Blom was nominated and approved as the new VP Awards and Membership. Dr Christophe Hermans and Mr Torben K. Henriksen agreed to continue in their roles as Branch Chairs, Aeronautics and Space respectively. Prof. Andrea Alaimo was nominated as the new Director General and after discussuin was unanimously approved.

Prof. Slobodan Bosanac from the Adriatic Aerospace Association presented to the board this organisation and expressed his interest to join the CEAS.

The CEAS Board of Officers, according to the decision made in the subsequent meeting is composed as follows:

Elected CEAS President: Prof. Franco Bernelli Zazzera
Vice-President Finance: Cornelia Hillenherms
Vice-President Publications and External Relations: Pierre Bescond
Elected Vice-President Awards and Membership: Anders Blom
Elected Director General: Prof. Andrea Alaimo
Aeronautics Branch Chairman: Dr Christophe Hermans
Space Branch Chairman: Torben K. Henriksen

About Voting Rights

It was decided that a formal decision concerning voting rights for Agencies could not be taken before the 2021 General Assembly (end of 2021) unless an Extraordinary General Assembly is organised sooner, hopefully in February or March 2021. It will be necessary to distribute in due time the text to amend the Statutes.

AEC2021

The AEROSPACE EUROPE CONFERENCE - AEC2021 - has been postponed from September 2020 to 23-26 November. Hosted by the PSAA, it will take place in Warsaw. The PSAA President Tomasz Goetzendorf Grabowski has presented its announcement in pages 10 and 11.

The preparation of this important event will require a considerable amount of work to be accomplished in a rather short time, but I am confident in the determination of PSAA and CEAS managers to take up the challenge!

ELECTED PRESIDENT'S MESSAGE

Franco Bernelli Zazzera
CEAS President

Franco Bernelli Zazzera is full professor of the Department of Aerospace Science and Technology at Politecnico di Milano. His teaching and research activities are in the domain of aerospace systems.
At Politecnico di Milano, he served as Erasmus coordinator in Aerospace Engineering, deputy Dean of the Faculty of Industrial Engineering, Director of studies in Aerospace Engineering, Director of the Department of Aerospace Science and Technology. He is currently the delegate for international relations of the School of Industrial and Information Engineering.
He has been Chairman of PEGASUS, the European network of Aerospace Universities, and has coordinated the H2020 PERSEUS project, aiming at defining measures to improve the quality of the European aerospace graduates.

The CEAS Board of Trustees appointed me as the next President of the Council. It is for me a privilege and a great honour to accept this nomination, which I consider a recognition of the historical contribution of the Italian association AIDAA to the development of CEAS.
Undoubtedly, the life and activities of CEAS have been impacted in 2020 by the Covid pandemic. Associations like CEAS have one of their main objectives in the creation of networks and relations within their domains, which has been impossible for major part of the year. In this terrible context, CEAS has been lucky enough to celebrate its Aerospace Europe Conference just before the global outburst of the pandemic.
The aerospace sector has been impacted by the pandemic at a different level depending on the specific domains and products. The most hardly hit is the civil aviation sector, we have all seen the sad pictures of airplane fleets parked in unused runways and in the most remote places. On the other hand, satellite industry has suffered much less and by the end of the year the number of launches should be inline with the past year.
In the critical situation created by Covid, the aerospace sector has proven to be fundamental in delivering infrastructure. Satellite technology kept people connected for remote work and remote health care. Satellite imaging made us clearly understand how deeply our daily activities impact our environment. Space technology allowed to setup mobile laboratories to support diagnostic activity in remote places. Aerospace industry started manufacturing medical equipment such as ventilators.

In general, the year 2020 has, if still necessary, proven the importance of education, research, and technology as drivers for a sustainable development. Furthermore, smart working or, better said, remote working, is becoming a reality in many contexts. These facts must be considered as drivers in any future decision-making process, even within CEAS.
CEAS has proven to be still attractive for new national associations and membership could be soon expanded with newcomers. Many ideas are on the table and I am confident most of them will become reality. The strongest idea under discussion is how to strengthen the link between CEAS and the European agencies, that have always contributed to the advancement of aerospace in Europe. A second important idea is to reactivate many of the existing Memorandum of Understanding with other societies around the globe, identifying clear actions and objectives to be achieved thanks to each MoU. A cross-check with all member societies is planned to make sure CEAS is aligned also to their objectives and can help local developments, a basic pillar for strengthening the aerospace community at national and European level. CEAS has a strong connection with Euroavia, the European association of aerospace students, which stimulates a long-term vision for CEAS and guarantees fresh ideas to discuss and promote. Last but not least, CEAS is planning to organise the next Aerospace Europe Conference by the end of 2021.
The achievement of the short-term and long-term goals needs a considerable effort, but all the Trustees and the past Presidents have declared commitment, this is the best guarantee for the success. CEAS is perfectly equipped in terms of human resources, new Trustees and a new Director General have been nominated. The two Journals edited by CEAS are gaining more visibility in the international research community and the periodic CEAS Bulletin is proposing up-to-date discussions relevant to the community. The human and instrumental resources are there to allow CEAS to achieve all its objectives.
Let me end this message with a farewell to the former Director General, Mercedes Oliver-Herrero, a warm welcome to the new Director General, Andrea Alaimo, and a big thank to the former President, Zdobyslaw Goraj. I am sure I am expressing the sentiment of the entire Board of Trustees of CEAS if I say that we would have liked Mercedes Oliver-Herrero as a permanent Director General, her dedication to the role has been always exceptional. CEAS wishes her all the best for her professional trajectories and duties. That said, I am sure the new Director General, Andrea Alaimo from the Kore University in Enna, Italy, has suitable competence and dynamism that will help CEAS as long as he is willing to hold this role. Welcome on board. The former President, Zdobyslaw Goraj, deserves the last words because he accepted and managed to organise the CEAS activities in the last years. I will chase him in the future to keep him engaged, his experience and competence will be of great help.

CEAS – MERCEDES FAREWELL AND NEW DIRECTOR GENERAL

Mercedes Oliver Herrero

MERCEDES OLIVER-HERRERO'S MESSAGE

"*Dear CEAS Member Society Presidents and Trustees,*
Dear colleagues,
As most of you already know, my time as CEAS Director General has come to an end. They have been eleven years of interesting work and excellent relationships. For me it has been an opportunity to grow personally and professionally and I hope to have contributed to what CEAS is today.

Let me tell you that I keep in my heart all of you and those who I had the opportunity to meet in the past.
Let me introduce my successor, elected last November 30th, Professor Andrea Alaimo (andrea.alaimo@unikore.it) in copy of this message.

I am sorry not to have had the pleasure to meet you in person for the last time. These are now the boundary conditions but I am sure that we will have other opportunities to meet in the future.
I wish you a Merry Christmas and a fruitful 2021!
Please take care and stay healthy",

Mercedes Oliver Herrero

THE ANSWER OF THE CEAS MEMBER PRESIDENTS AND TRUSTEES

"*Dear Mercedes,*
It is not without regret that we see you give up your functions as Director General of the CEAS. As a matter of fact, all of us are unanimous to appreciate the remarkable manner in which you accomplished your duties all over these past eleven years from the date when you were recruited by Joachim Szodruch until today.

Let us briefly list the major tasks you conducted:

- Participation in the organisation of four CEAS European Air & Space Conferences: Venice (2011), Linköping (2013), Delft (2015), Bucharest (2017);
- Participation in the organisation of the first Aerospace Europe Conference 'AEC2020' in Bordeaux (February 2020);
- Organisation of all annual General Assembly meetings, all regular Board of Trustees and Board of Officers meetings: agenda, venues, social events, etc…;
- Drafting of all meetings minutes;
- Permanent control of all Actions Items implementation;
- Supervision of the CEAS publications: CEAS Aeronautical Journal, CEAS Space Journal, AEROSPACE EUROPE Bulletin;
- Management of all Constitution and Statutes legal & administrative issues with adequately chosen law firms whenever needed;
- And last but not least Management of the Finances in close support of the VP Finance.

All this you always performed with diplomacy, courtesy, elegance, showing a very high sense of human relations. So you are right when writing: "I hope to have contributed to what CEAS is today". We can definitely tell you that yes you played an eminent role in the development of our association within which a friendly European spirit prevails. Your merit is all the higher since you did all that on a voluntary basis, in addition to your enormous workload within the framework of the Military Airbus A400M programme at Airbus Defence and Space in Madrid.

So dear Mercedes please accept our highest thanks and congratulations.

Happy New Year, hoping that we shall see the end of the dark Covid-19 tunnel in 2021!"

The CEAS Management Team

THE NEW DG OF CEAS: PROF. ANDREA ALAIMO

Born in 1978, prof. **Andrea Alaimo** obtained degrees in Aerospace Engineering at the University of Palermo and the PhD in Aerospace Structure at the University of Pisa. In 2003 he was visiting student at the Queen Mary University of London and, between 2005 and 2009, he held a position as postdoc research fellow at the University of Palermo.

Since 2010 he belongs the University of Enna "Kore", at the beginning as Assistant Professor and since 2018 as Full Professor in Aerospace Structures. He is President of the Aerospace bachelor degree course at the "Kore" University and he is Director of the M.A.R.T.A. Centre, one of the biggest research facility in Europe for Aviation Human Factor. Andrea Alaimo belongs the AIDAA, the Italian aerospace association, since 2004 and he is a member of the ICAS Programme Committee since 2018.

PROF. ANDERS BLOM: NEW VP AWARD AND MEMBERSHIP

Current position: Director Innovair, the Swedish strategic innovation programme for aeronautics, which runs research and demonstrator programs for both civil and military aeronautics and involves all national actors, i.e., large industries (Saab and GKN Aerospace Sweden), SMEs, universities, institutes (FOI, RISE), agencies (Armed Forces, Swedish Defence Materiel Administration) and governmental bodies, see www.innovair.org.

Previous positions: Head of fatigue and fracture, head of structures and materials, head of aeronautics, and research director at FFA and FOI 1980-2020. Adjunct professor at the Royal Institute of Technology (KTH) from 1987-1996.

Academic background: Ph.D. (1984) and D.Sc. (1985) in Lightweight Structures at the Royal Institute of Technology (KTH) in Stockholm. Member of the Royal Swedish Academy of Engineering Sciences since 1994.

Technical work: Over 1000 citations and some 150 papers on fatigue and fracture, fibre composites, nonlinear finite element analysis, structural and materials testing, damage tolerance and durability of aircraft structures, etc. He has worked on structural issues for various civil and military aircraft, introduction of damage tolerance criteria for the fighter 37 Viggen, certification of the new Swedish fighter Gripen, multiple cracking in Finnish Air Force´s F-18, failure analysis of Ariane 5 rocket for Arianespace, etc.

International experience: Swedish national delegate to ICAF (International Committee on Aeronautical Fatigue and Structural Integrity) 1985 - 2005, general secretary of ICAF 2005 - 2017. Previously board member of EREA, IFAR and head of the Swedish Garteur delegation.
Swedish representative, appointed by Ministry of Enterprise and Innovation, in ACARE General Assembly (Advisory Council for Aviation Research and Innovation in Europe) and national council member of ICAS (International Council of the Aeronautical Sciences).

Awards: F.J. Plantema Award by ICAF in 2001. Thulin silver medal, for development of fatigue and fracture mechanics for metallic structures, in 1997, and the Thulin gold medal, for his contributions to Swedish Aeronautics, in 2016. The latter are awarded by the Swedish Society for Aeronautics and Astronautics together with the Royal Swedish Academy of Engineering Sciences. He is the recipient of the 2016 US Air Force Lincoln Award for Aircraft Structural Integrity in 2016 and the ICAS 2018 von Karman Award for the International Cooperation performed in ICAF over the years. EREA Award for outstanding contributions in 2019.

AEROSPACE EUROPE CONFERENCE 2021

The Aerospace Europe Conference 2021 will be held in Warsaw, 23-26 November 2021. The conference will be organized by CEAS together with Polish Society of Aeronautics and Astronautics , Łukasiewicz Research Network - Institute of Aviation & Warsaw University of Technology. Due to the uncertainty related to the COVID-19 pandemic, two forms of conference are considered - traditional (face-to-face) and on-line. Maybe the hybrid form that will combine classical sessions for limited number of participants with on-line connection will be the best solution.

The main motto for the conference is 3R triptych "Restore, Rethink, Redesign". It contains the following topics:

- digitalization
- artificial intelligence
- more electrical aircraft
- hybrid propulsion
- alternative fuels
- H_2 propulsion
- design of the future aircraft

However the conference will also cover the typical topics for aerospace conference:

- General Aviation
- Aircraft Design
- Aerodynamics (incl. CFD)
- Flight Dynamics
- Helicopter Dynamics
- Materials and Structures
- Control and Flight Tests
- UAVs
- Green Aviation
- Space (incl. 'Clean Space', 'Less debris' etc.)
- Civil Aviation financial and economic aspects
- Airports
- Maintenance and Repair Overhaul (MRO)
- Defence and Security
- SESAR and EUROCONTROL (ATM) challenges

AEC2021 will be held in promises of Łukasiewicz Research Network - Institute of Aviation - one of the largest scientific and research institution in Europe, with over 90 years of experience in aeronautical engineering and space research. Institute of Aviation is located very close to the International Frederic Chopin Airport (only 3 km) and just 5 km from the City Center.

The key dates:

- **1 Jan 2021** First Announcement and call for papers, website open
- **1 Feb 2021** Abstract uploading open
- **1 Apr 2021** Abstract uploading deadline
- **1 May 2021** Acceptance of papers finished
- **30 Jun 2021** Deadline for full length papers submission

The extended abstracts will be collected in the proceedings in the form of a CD/USB and distributed during the seminar. All full length papers will be sent to reviewers and then the best articles will be recommended to publish in one of the following journals:

• CEAS Aeronautical Journal

The CEAS Aeronautical Journal has been created under the umbrella of CEAS to provide an appropriate platform for excellent scientific publications submitted by scientists and engineers. It is supported by the German Aerospace Center (DLR) and the European Space Agency (ESA).

• CEAS Space Journal

The CEAS Space Journal has been created by the CEAS Space Branch to provide an appropriate platform for the excellent scientific publications submitted by scientists and engineers. Under the umbrella of CEAS, the German Aerospace Center (DLR) and the European Space Agency (ESA) support the Journal.

• Transactions on AEROSPACE RESEARCH (TAR)

The Institute of Aviation has been publishing Transactions of the Institute of Aviation since 1956 and since 2 years renamed into TAR and edited by SCIENDO . It publishes new, original articles written by researchers collaborating with the Institute, including those from abroad. The scope of the publication is closely related to the area of activity of the Institute and the scientific conferences organized there. All articles are reviewed before publishing.

The other publishing options are also considered and they will be presented in the second announcement.

The conference fees depend on the final form of the conference and on the form of participating in the conference. The fees will be announced as soon as the form of the conference has been fixed.

Some pictures:

Title page of Transactions on Aerospace Research

PZL-130 Orlik - MPT (PZL-Airbus Poland)

ILOT – the biggest wind tunnel

Warsaw University of Technology (exhibition for the 100th anniversary of WUT)

CEAS SPACE JOURNAL

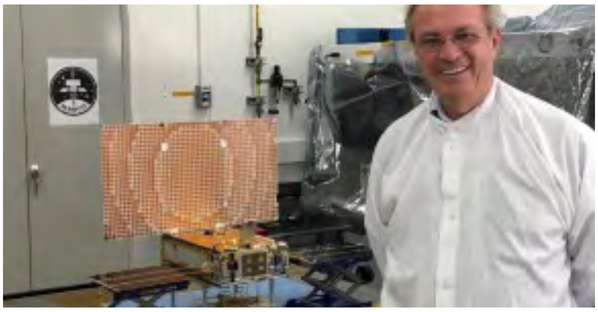
Volume 11, issue 4, December 2020

SMALL SATELLITES BEYOND BOUNDARIES

P. Tortora / Published: 23 January 2020

EXPLORING OUR SOLAR SYSTEM WITH CUBESATS AND SMALLSATS: THE DAWN OF A NEW ERA

Anthony Freeman / Published: 22 January 2020



IN-ORBIT AIS PERFORMANCE OF THE NORWEGIAN MICROSATELLITES NORSAT-1 AND NORSAT-2

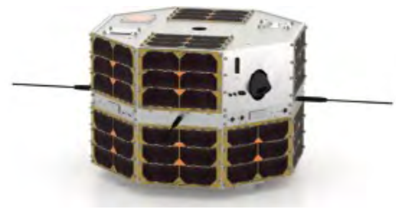
Torkild Eriksen, Øystein Helleren, Andreas Nordmo Skauen, Frode A. S. Storesund, Anders Bjørnevik, Harald Åsheim, Eirik Voje Blindheim & Jon Harr

Published: 21 November 2019

FROM TECHNOSAT TO TUBIN: PERFORMANCE UPGRADE FOR THE TUBIX20 MICROSATELLITE PLATFORM BASED ON FLIGHT EXPERIENCE

Karsten Gordon, Merlin F. Barschke, Philipp Werner

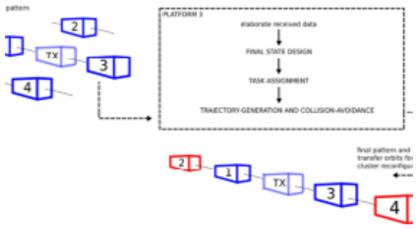
Published: 08 January 2020



AUTONOMOUS RECONFIGURATION OF A DISTRIBUTED SYNTHETIC APERTURE RADAR DRIVEN BY MISSION REQUIREMENTS

S. Sarno, M. D'Errico, J. Guo & E. Gill

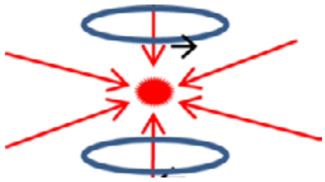
Published: 30 June 2020



GRAVITY SENSING: COLD ATOM TRAP ONBOARD A 6U CUBESAT

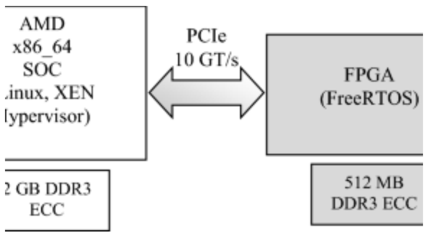
Diviya Devani, Stephen Maddox, Ryan Renshaw, Nigel Cox, Helen Sweeney, Trevor Cross, Michael Holynski, Raffaele Nolli, Jonathan Winch, Kai Bongs, Karen Holland, David Colebrook, Neil Adams, Kevin Quillien, James Buckle, Anupe Karde, Mark Farries, Tom Legg, Richard Webb, Corin Gawith, Sam A. Berry & Lewis Carpenter

Published: 04 August 2020



ENABLING RADIATION TOLERANT HETEROGENEOUS GPU-BASED ONBOARD DATA PROCESSING IN SPACE

Fredrik C. Bruhn, Nandinbaatar Tsog, Fabian Kunkel, Oskar Flordal & Ian Troxel / Published: 15 June 2020



SMALL SATELLITE TT&C ALLOCATIONS BELOW 1 GHZ: OUTCOME OF ITU WRC-19

Martin von der Ohe

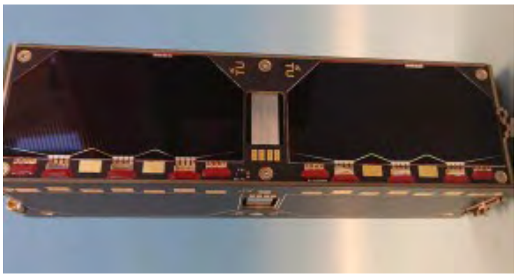
Published: 15 April 2020

CEAS AERONAUTICAL JOURNAL

Volume 12, issue 4, December 2020

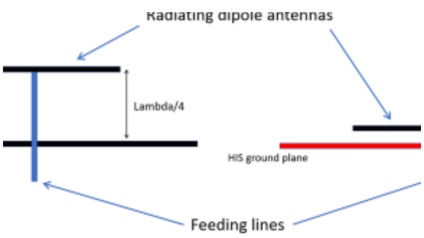
UTILITY AND CONSTRAINTS OF POCKETQUBES:

J. Bouwmeester, S. Radu, M. S. Uludag, N. Chronas, S. Speretta, A. Menicucci & E. K. A. Gill / Published: 05 February 2020



COMPACT S-BAND AND X-BAND ANTENNAS FOR CUBESATS

Benedikt Byrne, Nicolas Capet, Maxime Romier
Published: 06 August 2020

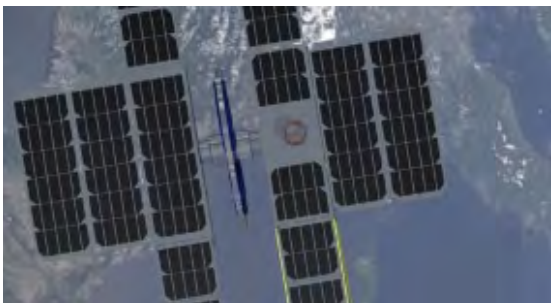


AUTOMATIC MASS BALANCING SYSTEM FOR A DYNAMIC CUBESAT ATTITUDE SIMULATOR: DEVELOPMENT AND EXPERIMENTAL VALIDATION

Anton Bahu, Dario Modenini / Published: 15 April 2020

A CUTTING EDGE 6U CUBESAT ADCS DESIGN FOR EARTH OBSERVATION WITH SUB-METER SPATIAL RESOLUTION AT 230–380 KM ALTITUDE:

Hans Kuiper, Dennis Dolkens / Published: 18 June 2020



EDITORIAL FOR THE CEAS AERONAUTICAL JOURNAL SPECIAL ISSUE ON ACTIVE FLOW CONTROL RESEARCH WITHIN THE AFLONEXT PROJECT:

Jochen Wild / Published: 17 October 2020

DESIGN OF A SYNTHETIC JET ACTUATOR FOR FLOW SEPARATION CONTROL

Perez Weigel, Martin Schüller, André Gratias, Mathias Lipowski, Theo ter Meer & Michiel Bardet
Published: 21 October 2020

ACTIVE FLOW SEPARATION CONTROL AT THE OUTER WING

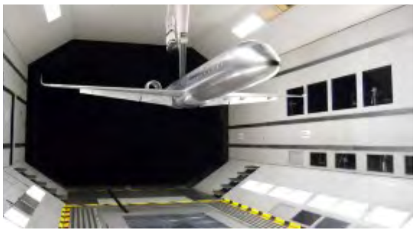
J. P. Rosenblum, P. Vrchota, A. Prachar, S. H. Peng, S. Wallin, P. Eliasson, P. Iannelli, V. Ciobaca, J. Wild, J. L. Hantrais-Gervois & M. Costes
Published: 22 June 2019

A CFD BENCHMARK OF ACTIVE FLOW CONTROL FOR BUFFET PREVENTION

Fulvio Sartor, Mauro Minervino, Jochen Wild, Stefan Wallin, Hans Maseland, Julien Dandois, Vitaly Soudakov & Petr Vrchota
Original Paper Published 26 August 2019 (pp. 837-847)

EVALUATION OF THE NOISE IMPACT OF FLAP-TIP FENCES INSTALLED ON LAMINAR WINGS

Lorenzo Burghignoli, Alessandro Di Marco, Francesco Centracchio, Roberto Camussi, Thomas Ahlefeldt, Arne Henning, Stephan Adden & Massimiliano Di Giulio
Published: 08 June 2020



CLOSED-LOOP MIMO DATA-DRIVEN ATTITUDE CONTROL DESIGN FOR A MULTIROTOR UAV

A. Zangarini, D. Invernizzi, P. Panizza & M. Lovera
Published: 11 June 2020

CONCEPTUAL DESIGN ANALYSIS OF A VARIABLE SWEPT HALF-SPAN WING OF A SUPERSONIC BUSINESS JET

Alvaro Martins Abdalla, Felipe de Castro Baraky, Matheus Urzedo Quirino / Published: 13 June 2020

EVALUATION OF AN ADVANCED SLUNG LOAD CONTROL SYSTEM FOR PILOTED CARGO OPERATIONS

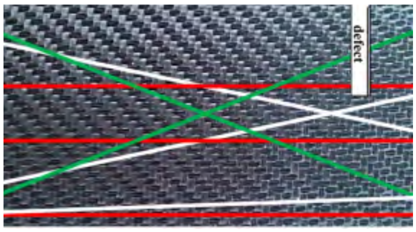
Daniel Nonnenmacher & Hyun-Min Kim
Published: 03 July 2020

AEROELASTIC ANALYSIS OF A SLENDER WING

Sheharyar Malik, Sergio Ricci, Luca Riccobene
Published: 01 August 2020

DAMAGE DETECTION AND LOCALISATION OF CMCS BY MEANS OF ELECTRICAL HEALTH MONITORING

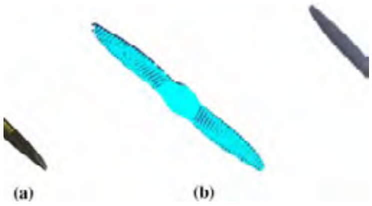
Tina Staebler, Hannah Boehrk, Heinz Voggenreiter



Published: 04 August 2020

BLADE ELEMENT MOMENTUM NEW METHODOLOGY AND WIND TUNNEL TEST PERFORMANCE EVALUATION FOR THE UAS-S45 BÀLAAM PROPELLER

Maxime Alex Junior Kuitche, Ruxandra Mihaela Botez, Remi Viso, Jean Christophe Maunand & Oscar Carranza Moyao / Published: 08 August 2020



DESIGN AND FLIGHT TEST OF A LINEAR PARAMETER VARYING FLIGHT CONTROLLER

Christian Weiser, Daniel Ossmann, Gertjan Looye
Published: 28 August 2020

ASSESSMENT OF THE EFFICIENCY OF AN ACTIVE WINGLET CONCEPT FOR A LONG-RANGE AIRCRAFT

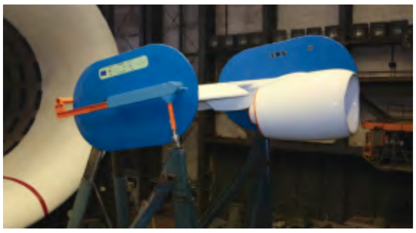
K. O. Ploetner, C. Al Haddad, C. Antoniou, F. Frank, M. Fu, S. Kabel, C. Llorca, R. Moeckel, A. T. Moreno, A. Pukhova, R. Rothfeld, M. Shamiyeh, A. Straubinger, H. Wagner & Q. Zhang / Published: 30 August 2020

LONG-TERM APPLICATION POTENTIAL OF URBAN AIR MOBILITY COMPLEMENTING PUBLIC TRANSPORT: AN UPPER BAVARIA EXAMPLE

K. O. Ploetner, C. Al Haddad, C. Antoniou, F. Frank, M. Fu, S. Kabel, C. Llorca, R. Moeckel, A. T. Moreno, A. Pukhova, R. Rothfeld, M. Shamiyeh, A. Straubinger, H. Wagner & Q. Zhang / Published: 30 August 2020

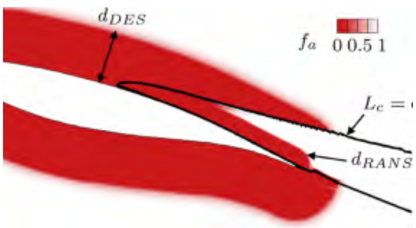
REYNOLDS NUMBER AND WIND TUNNEL WALL EFFECTS ON THE FLOW FIELD AROUND A GENERIC UHBR ENGINE HIGH-LIFT CONFIGURATIONE

Junaid Ullah, Aleš Prachař, Miroslav Šmíd, Avraham Seifert, Vitaly Soudakov, Thorsten Lutz & Ewald Krämer / Published: 31 August 2020



SIMULATION OF TRANSONIC BUFFET WITH AN AUTOMATED ZONAL DES APPROACH

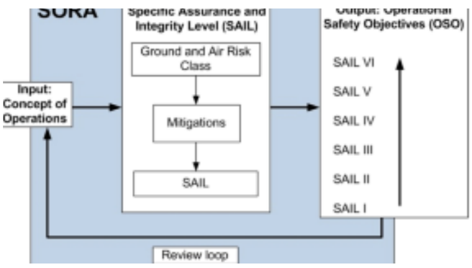
Maximilian Ehrle, Andreas Waldmann, Thorsten Lutz & Ewald Krämer / Published: 01 September 2020



OPERATION AND OPERATION APPROVAL OF HIGH-ALTITUDE PLATFORMS

F. NikodemS. Kaltenhäuser

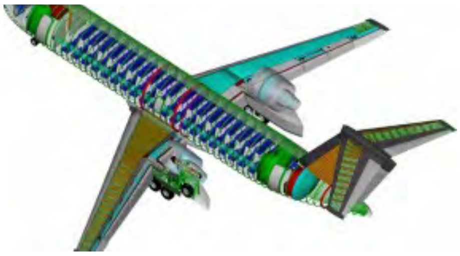
Published: 03 September 2020



AEROELASTIC BEHAVIOUR OF A WING WITH OVER-THE-WING MOUNTED UHBR ENGINE

N. Neuert & D. Dinkler

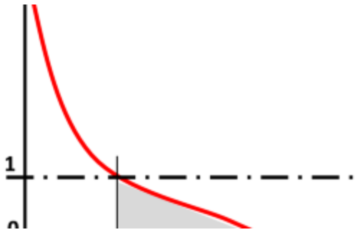
Published: 04 September 2020



AN EXTENSION OF THE STRUCTURED SINGULAR VALUE TO NONLINEAR SYSTEMS WITH APPLICATION TO ROBUST FLUTTER ANALYSIS

Andrea Iannelli, Mark Lowenberg, Andrés Marcos

Published: 09 September 2020



ADAPTIVE PREDICTION FOR SHIP MOTION IN ROTORCRAFT MARITIME OPERATIONS

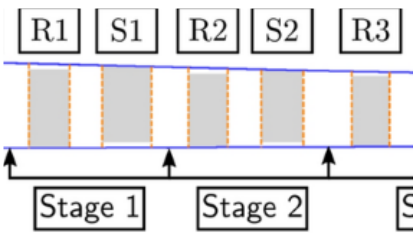
Antoine Monneau, Nacer K. M'Sirdi, Sébastien Mavromatis, Guillaume Varra, Marc Salesse & Jean Sequeira

Published: 09 September 2020

DESIGN OF A REAR-STAGE SUBSONIC AXIAL COMPRESSOR WITH CASING TREATMENTS

C. Kendall-Torry & V. Gümmer

Published: 09 September 2020



INTERVIEW WITH JEAN-FRANCOIS RIPOCHE, HEAD OF RESEARCH, TECHNOLOGY AND INNOVATION DIRECTORATE AT THE EUROPEAN DEFENCE AGENCY (EDA)

By Jean-Pierre Sanfourche, Editor-in-Chief

Jean-François Ripoche

Jean-François Ripoche joined the European Defence Agency (EDA) on 1 May 2019 as the Research, Technology and Innovation (RTI) Director. He previously held the position of Research and Technology Director at the Strategy Directorate of DGA (Direction générale de l'armement), the French Ministry of Defence Procurement Agency. Mr Ripoche graduated from the Ecole Polytechnique (X90) and the Ecole Nationale Supérieure des Techniques Avancées in Paris, and holds a PhD in laser Physics. With his engineering background, Jean-François Ripoche brings to EDA years of experience in Research and Technology in the military field. He started his career in 1998 at the DGA and worked across various domains such as UAVs, Landsystems, Space and Cybersecurity.

Holding the position of Deputy Director for Industrial Affairs in charge of the electronics, land systems and naval systems industries from 2008 to 2012, he developed a sound experience of relations with industry.

Jean-Pierre Sanfourche **– RTI promotes and supports defence research at EU level, based on the OSRA agenda (Overarching Strategic Research Agenda). Could you briefly summarize the present strategic objectives fixed by OSRA regarding the military aerospace domain?**

Jean-François Ripoche - I will not directly answer your question because many research actions we are conducting in my directorate are concerning cross-cutting technologies, so that each of them applies to several defence systems. For example materials, electronic components, etc., i.e. transversal disciplines. In order to give a clear image of what EDA is doing in matter of research technology and innovation, I am obliged to first briefly explain the main lines of our approach's logics.

- The **Capability Development Plan** (CDP) in its 2018 revision defines 11 priorities;
- To cover the technology needs related to those eleven priorities, we have structured our R&T task force around several Capability Technology Groups named **'CapTechs'**, whose today's number is 13 (plus one permanent working group). They bring together experts from governments, industry and academia. These CapTechs are being run by my directorate.
- The **OSRA** you are mentioning (Overarching Strategic Research Agenda) precisely align the Strategic Research Agendas (SRAs) of these various CapTechs. It constitutes a tool which provides a harmonized view of relevant European defence research priorities and all possible paths to achieve them, taking into account the different available funding mechanisms.
- Building upon the CapTechs SRAs and CDP priorities, the OSRA common defines R&T priorities in the form **Technology Building Blocks** (TBBs), each of them being focused on a specific R&T domain. Every TBB informs on existing technology gap in a given domain, its relevance for CDP, Technology Readiness Level (TRL), links with other TBBs, as well as related projects within and outside the EDA framework. The TBBs (currently around 140) refer to a wide range of technology areas, each of them dealt with by a specific CapTech.
- There is a CapTech dealing with air systems (CapTech "Air") and for example CapTechs covering guidance, navigation and control or materials. For the CapTech Air, examples of strategic objectives found in TBBS are concerning
  - system level (next generation platforms) for fixed and rotary wings
  - major sub-system level (Next generation propulsion systems, for instance)
  - essential cross-cutting (air-platform-focused) capabilities, required for future platforms (for example: Autonomous systems, including cooperative)

This introduction was necessary to make clear that the R&TI mission of EDA is also conducted in a transversal technology domains approach and not only in a vertical final product approach. Now I am in a better position to answer your aerospace specific questions.

J-P. S. **– Among the 11 Capability Development Priorities, 4 are more precisely related to aerospace: air mobility - air superiority - Integration of military air capability in a changing aviation - space based information and communications services. Could we review these four areas, with the objective to highlight for each of them the most important research projects and actions being conducted?**

J-F. R. - The **CapTech Air** deals with the identification and prioritisation of technology gaps in different domains such as:

– Heavy air carriers (outside cargo air transport);
– Very heavy rotorcraft next generation high performance lift;
– Artificial Intelligence for:
  - ➢ Development of autonomous systems development

- ➢ Autonomous air vehicle operation;
- ➢ Cooperative air vehicle operation;
- ➢ Test automation;
- ➢ Safety (flight termination systems).

– Detect/sense/avoid systems;
– System diagnosis/fault prognostics/self repair;
– Human-machine –interface/cognitive ergonomics;
– Propulsion, power generation and distribution;
– Secure Command and Control (C2) systems.
– Concerning space, the Earth Observation satellites massive image data processing is an important part of our activities (relations with ESA and SatCen).

To this end, this CapTech Air seeks to prepare and conduct R&T projects pertaining to the above focus areas.

It presently constitutes a working group of around 75 engineers. A symposium on Hypersonic Vehicle recently organised by EDA brought together over 100 Experts.

The objective of the CapTech Air System and their environment is to generate innovation and collaborative R&T projects around air systems through a system approach. The CapTech deals with air systems in general including fixed and rotary wing platforms as well as unmanned systems, their design (aerodynamics, propulsion, etc.) and operations (training missions objectives in particular). The technical areas assigned to it are more precisely:

– Propulsion and power plants: gas turbines, transmissions and power trains, air propellers and rotors;
– Design technologies for platforms and weapons (aerodynamic design);
– Integrated platforms: combat aircraft, helicopters, lighter-than-air platforms, logistic support and surveillance aircraft.

The work of the CapTech is generally of TRL (Technology Readiness Level) in the range 2 to 6. Its activities are generated using "technology push", but also capability driven, mainly by the Capability Development Priorities (CDP), more particularly the priorities valid at a moment in time. Cross-cutting applications of interest include Human Factors (HF, Command and Control (C2) as well as Information, Acquisition and Processing of data. With regards to its technological scope, CapTech Air explicitly identifies synergies and interdependencies with CapTech CBRN (Chemical, Biological, radioactive and Nuclear) & Human Factors, Navigation and Information. Furthermore an analysis of key R&T research areas implicitly reveals correlation to CapTech Materials, Ammunition and Components. The work of the CapTech Air also interfaces with the work of EDA project teams in the Capability, Armament and Planning (CAP) directorate and contributes to the identification of Critical Defence Technologies. The CapTech Air also identifies thematic linkages to activities conducted within the framework of Joint investment Programmes (JIP) Remotely Piloted Aircraft Systems (JIP RPAS) or the activities performed by the EDA team dealing with Single European Sky matters.

Prominent EU research initiatives that relate to topics covered by CapTech Air take into account those managed by SESAR and Clean Sky (now HORIZON EUROPE).

In addition to Air, we have twelve other CapTechs. Let's rapidly review some of them, just to highlight the fact that we are always working in multi-product transversal approach.

The **Captech Materials and Structures** aims to develop technology on materials and structures, production processes, test procedures and solutions that are applicable in different defence forces.

The **CapTech Technologies, Components and Modules** deals with electronic, photonic and micro-mechanical technologies to enable or enhance defence applications for a wide spectrum of defence system technologies in areas such as C4ISR (Communication, Command, Control, Computers, Intelligence, Surveillance and Reconnaissance)) – a particularly important component of air systems - and radiofrequency, microwave as well as optronic sensing.

The **CapTech Radio Frequency Sensors Technologies** deals with sensor and electronic warfare systems applying radio frequency, magnetic and electronic technology. It also deals with directed energy weapons.

The strongest European coordinated action concerning RF is the effort towards a RF Gallium Nitride (GaN) European supply chain.

The CapTech Electro-Optical Sensors Technology deals with sensors and electronic warfare weapon systems which apply electro-optical technology, signal processing, laser radar technologies, electro-optical countermeasures, image processing.

The **CapTech Guidance, Navigation and Control (GNC)** provides technology watch and research in the underpinning technologies for future capability needs of increased prevision, localisation, performance and robotisation, including autonomy. GNC is of in particular of higher importance in the air systems.

The **CapTech Communication, Information Systems (CIS) and Networks**: this domain is a key enabler for crisis supports technologies including, deployable, mobile secure and robust broadband communication.

The **CapTech Experimentation, Systems of Systems, Space, Battle and Modelling & Simulation** covers all defence systems. In particular the "system of systems" approach includes the famous "Space as a system" but also methodology and tools for complex projects (system engineering), the interoperability issues, the constraints between systems as well as the global assessment of the assembly of systems.

Within the framework of air defence we are working on autonomous systems and the cooperation between platforms (swarms of Unmanned Air Vehicles). Here a large part of our works can be related to the Future Air Combat System (FACS) programme. Also of higher importance is the Space Surveillance Awareness (SSA).

J-P. S. **– : How is EU-Funded Defence Research Unit working with the European Commission? EDA provides a technical support to the EC's EDF: how is selection**

process of the research themes being implemented?

J-F. R. - Two basic tools are used to deal with this subject: on the one hand the European Defence Industry Development Program (EDIDP) and on the other hand the PADR (Preparatory Action Defence Research) which was launched in 2017 by the European Commission. This PADR is run by EDA following the mandate of a Delegation Agreement between the EC and EDA signed in 2017. By this agreement, EC entrusts EDA with the management and implementation of the research projects to be launched by the PADR. The 2019 PADR's objective is to prepare the Multiannual Financial Framework 2021-2027 and the European Defence Fund which will potentially cover the full spectrum of the defence technologies.

This is effectively my EU funded Defence Research Unit which is in charge of conducting the selection process of the research topics: calls for proposals and then evaluation for the PADR. We are targeting future programmes and projects conceived to be performed in cooperation and then supported by Member States.

Three Projects in (or supporting) the aerospace domain can be mentioned:

- EURODRONE;
- ESSOR (European Secure Software defined Radio);
- Power laser TALOS (Tactical Advanced Laser Optical System).

J-P. S. **– How are the CapTechs' R&T topics determined?**

J-F. R. - This is a responsibility of my directorate. Within the limited envelope of EDA'sbudget, we conduct preliminary studies (projects phase A, and elaborate roadmaps). We are also here to provide a framework so that EDAMember States can pool together their R&T budgets on a topic of common intereset. So we have established a portfolio of R&T subjects which counts a total of some 250 topics since the creation of the Agency.

J-P. S. **– EDA involves around 4,000 experts: what is the proportion of experts dedicated to aerospace defence?**

J-F. R. - Due to the fact that we are working in multi-purpose and multi-product approach, it is difficult to answer your question. I would say about 1,600 very approximately.

J-P. S. **– Could you say some words about the way in which you manage altogether all CapTechs with a limited staff?**

J-F. R. - Our work at EDA consists in huge coordination management, our CapTechs being formed with external experts coming from different participating Member States' industry, research institutions and academia.

First, the selection process of experts in each CapTech is conducted in a rigorous manner, with the non-governmental experts participation being approved by their national authoritites.

Second, for each CapTech the elaboration of the SRA is achieved with particular care. As a matter of fact the SRA is used to provide strategic guidance for the R&T priorities addressed to the CapTech.

Third each CapTech functions under the responsibility of an EDA moderator, whose role is absolutely essential. And thanks to the use of present powerful e-management tools, we are able to control the R&T tasks being performed by the different CapTechs. Coordination is ensured through forums and conferences. I also have to acknowledgem the engagement of all the experts which is key to the success of these activities.

J-P. S. **– Is R&T cooperation between civil and military aviations being considered at EDA?**

J-F. R. - Within the framework of the "transversal" R&T actions conducted by the CapTechs, there are necessarily commonalities: energy saving, more electrical aircraft, rethinking of infrastructures, more and more use of Artificial Intelligence (AI), etc. In a general manner the "dual-use" aspect is highly taken into account in all CapTechs.

It is also to be mentioned that EDA is the entry of military aviation within the future Single European Sky (cooperation with SESAR and EUROCONTROL)

J-P. S. **– Could we briefly review the relationships between EDA and EC, Eurocontrol, OCCAR and ESA?**

J-F. R. - Within the framework of the European Defence Fund (EDF) we are in permanent relation with the EC team in DG DEFIS.

We have of course regular contacts with CleanSky for aeronautics technology subjects.

For airspace matters, we are also in close contact with SESAR and EUROCONTROL.

For space affairs, our cooperation with ESA is becoming more and more intensive.

As regards cybersecurity, I would like to say that we are seeking to establish more and more synergies between EC, relevant European agencies and EDA.

As regards OCCAR, relations are very close at top management level but for R&T, our respective missions are quite different since OCCAR is responsible for final operational products deliveries whilst EDA is more working for R&T aiming at preparing for the future.

J-P. S. **– A last question: is EDA working for the FACS programme (Future Air Combat System)?**

J-F. R. - Indirectly, through R&T actions being conducted by some of our CapTechs. Among them I wish to highlight the area of power electronic components, especially the Gallium Nitride (GaN) above mentioned as an example of technology enablers which can contribute to the FACS.

The Captech Air SRA and its associated Technology Building Block Roadmaps already incorporate key elements of the FACS requirements, and the MS are working hard to identify the areas of collaboration and the technical domains requiring actions at short and mid-term. I am convinced that as the FACS programme will advance, EDA can be providing more and more support.

THE EDA AT A GLANCE

MEMBER STATES

Following the mission of the Agency, "to support the Member States and the Council in their effort to improve European defence capabilities […]". Cooperation with the Member States is very close; be it on the top-level through the Steering Board which sets EDA's priorities or at the working level in expert teams. Indeed, EDA currently connects around 4,000 national based-experts in cooperative defence projects.

EDA GOVERNANCE

The European Defence Agency (EDA) is an intergovernmental agency of the Council of the European Union. It receives guidance by the defence ministers of its Member States (currently 26), meeting in the EDA Steering Board.

JOSEP BORREL, HEAD OF EDA

Josep Borell is a Head of EDA and High Representative of the European Union for Foreign Affairs and Security Policy/Vice-President of the Commission.

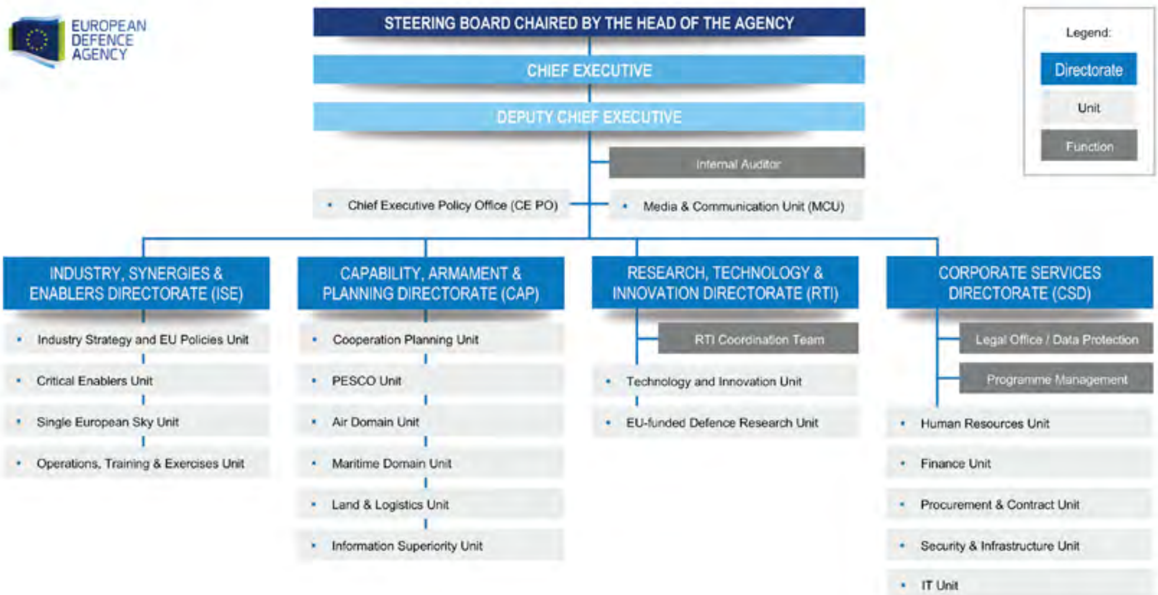
JIRI SEDIVY: CHIEF EXECUTIVE OF EDA

Jiri Sedivy is the Chief Executive of the European Defence Agency since May 2020.

EDA MANAGEMENT

- **Jiri Sedivy:** EDA Chief Executive
- **Olli Ruutu:** Deputy Chief Executive
- **Emilio Fajardo:** Director Industry, Synergies & Enablers
- **Martin Konertz:** Director Capability Armament & Planning
- **Jean-François Ripoche**, Director Research, Technology & Innovation
- **Luigi Sandrin**, Director Corporate Services

ORGANISATION



THE MANY CHALLENGES OF A HYDROGEN AIRCRAFT

By Eric Dautriat, Vice-President of the Air and Space Academy

Eric Dautriat has spent his career in the aerospace sector engineering and management. He was in particular Director of Launchers at Centre National d'Etudes Spatiales (French Space Agency) from 1997 to 2003 Quality Vice President of Snecma Engines then Safran Group as a whole from 2003 to 2009, and Executive Director of Clean Sky Joint Undertaking from 2009 to 2016. He was awarded the CEAS Medal in 2017. Retired, he is now Vice President of the Air and Space Academy.

The author indicates that these considerations reflect only his personal views.

Notwithstanding early research & technology programmes aimed at reducing the impact of air transport on climate change, this issue has long occupied only a modest place in the strategic agenda of political leaders and stakeholders, and even in the concerns of the general public. Continuous efforts to stay ahead of the competition by steadily reducing fuel consumption have seemed to suffice.

Recently, however, the topic has become a political issue due to a growing awareness on the part of the European population, particularly young people. Often excessive and out of proportion, this approach sees air transport as a figurehead of blind and boundless growth, an arrogant symbol of globalisation, even an allegory of social inequalities...
Without deferring to such exaggerations, the air transport sector must nonetheless find ways of reducing its "carbon" footprint very significantly in the coming decades, especially since prospective analyses anticipate a tripling of traffic by 2050 (or rather "used to anticipate", because the COVID crisis has moved the goalposts, but that is another subject, too crucial and still too uncertain to be dealt with in a few lines here.)

The problem is that the means to achieve this drastic reduction in the carbon footprint of aviation are few and far between, if some common-sense rules are borne in mind:
- focus on what is really relevant and not on attractive pipe-dreams;
- consider all needs by a given date instead of thinking in closed circuit for a particular sector;
- for such planetary issues (air transport and the greenhouse effect are equally global!), give no credence to a purely national approach if it does not include the means for a worldwide strategy;
- last but not least, constantly bear in mind questions of order of magnitude.

In other words, focus on what really matters, namely commercial aviation – short-, medium-haul and, even more so, long-haul – so as not to be enticed by apparently attractive solutions such as battery or fuel cell aircraft which will remain marginal for a long time to come, incapable of playing in the big (aircraft) league, except as solutions for some kind of hybridation.

WHAT ENERGY SOURCES FOR TOMORROW'S AIRCRAFT?

Designers today still dispose of a panel of possible performance improvements which are sometimes (and a bit condescendingly) described as "incremental". These should of course be encouraged because they will be necessary in whatever case, but experts agree that the resulting improvements – a total reduction in emissions of around 20-30%, with an underlying asymptotic trend – will remain largely insufficient to bring about a satisfactory net reduction in emissions.

It is therefore crucial to consider new fuels

The biofuels presently envisaged can be criticised from the point of view of their total life cycle, overall effect on the planet, competition with other crops, etc. This a well-known debate and a great deal of work remains to be done, under often contradictory constraints. Organic waste may have its virtues, but it is difficult to imagine it fuelling a significant part of the global air transport fleet.

"Drop-in" synthetic fuels, i.e. possessing very similar properties to current kerosene, may constitute an interesting solution – despite requiring a high level of electrical energy for their production. However, it is not these that are currently attracting support, but rather hydrogen.
Hydrogen is also a synthetic fuel, but not a "drop-in", to say the least, requiring radically different aircraft and operations. So why hydrogen? To make it simple, it offers two main advantages:
- on the one hand, the possibility - at least theoretical - of a totally decarbonated propellant;
- on the other hand, a very high energy density, three times that of kerosene (120 MJ/kg vs 43 MJ/kg).

So much for the advantages. It can be feared however that all other characteristics of hydrogen will be classified among the disadvantages, or at least the difficulties.

However, let us not get ahead of ourselves.

A POLITICAL CRAZE

A small diversion is necessary by way of recent enthusiastic political declarations which have given hydrogen a third trump card (although a dangerous one because by nature ephemeral): media hype.

This relates first to hydrogen in general, as:

- a storage means for intermittent energy produced by wind and solar sources;
- an electrical power supply of fuel-cells for road and rail transport;
- an energy vector for industry, for example steel works.

Germany, for example, has launched a €9bn plan into this subject. France has followed suit with €7bn, and the EU itself is not far behind. Of course, the first question that arises – leaving aside uses for energy storage, naturally, which do not really constitute a form of "production" – is that of "green" hydrogen generation, bearing in mind that at present 96% of this gas comes from hydrocarbons, with the remaining 4% being generated from H_2O electrolysis, with an electricity supply which is only very partially decarbonated worldwide. The European Commission has opened a door to so-called "blue hydrogen" (i.e. a little less green than green), still made from hydrocarbons but with carbon dioxide capture, a still uncertain process.

Was it inevitable then that aviation would also be affected by this craze? No doubt. It all happened rather suddenly (in late 2017, for example, the Hydrogen Council – an international lobbying group - did not even mention the propulsive applications of hydrogen in its list of possible applications and considered the utilisation of fuel cells for aviation to be unlikely). In France, government aid to the aeronautical sector in June 2020 was accompanied by the "requirement" to develop a hydrogen powered aircraft by 2035. Airbus publicly committed to this goal. Until recently, it had been a question of 2050, but France intends to be the leading nation on this subject. How France could today successfully bring a hydrogen-powered aircraft and its infrastructure into service on its own, if not for confidential uses, is unclear… But fortunately, the EU is also promoting this same solution, notably in its SRIA Strategic Research and Innovation Agenda recently proposed by industry for the future Clean Aviation private public partnership. The latter is supported by an analysis carried out by McKinsey, which considers hydrogen propulsion to be the best solution (around 2040 for short-haul flights and in the longer term for medium- and long-haul flights). This report, based upon a number of interviews with players in the hydrogen and aviation sectors, certainly highlights a number of important questions for in-depth study, but does not describe at this stage a global preliminary project for a hydrogen aircraft with its associated infrastructures. It is though urgent that an overall, coherent and, by its very nature, inexpensive study, if not already available, demonstrate the viability of the concept. Since we live in a rational world, this analysis will undoubtedly be available before committing the hundreds of millions of euros covering high Technical Readiness Level (TRL) technology plans, logically including flight demonstrations.

So, for the time being, let us limit ourselves to formulating a few open questions.

There do in fact exist several studies from the past. Among them is the "Cryoplane", a research action funded by the EU in its 5th Framework Programme in 2003 and carried out by Airbus together with several other participants. The final report is optimistic (not unusual in such cases) but, maybe due to financial limitations, most key topics are not dealt with in sufficient depth to demonstrate convincingly the feasibility of the overall concept. There was also a Russian demonstrator, which flew in the 80's. Indeed, the hydrogen aircraft concept is far from being a new one: the first studies on the subject date back to 1930! They were followed by many others, subsequently shelved.

LIQUID HYDROGEN PRODUCTION AND TRANSPORT

The hydrogen aircraft concepts use *liquid* hydrogen LH_2. Pressurized hydrogen – usually at 700 b – is not considered because it seems to lead to an unacceptable structural weight. However, LH_2 is rarely used in industry: its main use so far is in space launchers, due to the excellent specific impulse provided by cryogenic H_2/O_2.

But before considering the question of the aircraft itself, one must first find out how to produce sufficient quantities of "green hydrogen". It is not a question of flying a few aircraft here or there, *but of converting as much of the worldwide air fleet as possible*. Otherwise this concept would remain anecdotal – a waste of time and money. LH_2 has an efficiency ratio of about 30%, i.e. 3 kWh of (green) electricity is required to produce 1kWh of energy stored in LH_2. Now the global air fleet consumed 288 million tonnes of kerosene in 2018. Let us forget, for the time being, the tripling of global traffic forecast by 2050 and keep to this figure. 288 MT of kerosene transposed into LH_2 leads to a requirement of around 10,000 TWh, i.e. 40% of current world electricity production. In other terms, a little more than the entire decarbonized part of this production, nuclear included.

Besides, this reasoning demonstrates the fragmented vision we criticised above. What actually counts is not the hydrogen that will be necessary for aviation alone, but the total quantity necessary for all uses. The same applies even more to decarbonated electricity. Such figures shed a rather worrying light on the German, French

and EU hydrogen plans.
Of course, we must be optimistic and move forward without having ironed out all the kinks, but wouldn't it at least be useful to have some prospective answers to these basic questions before committing considerable R&D funding to road transport, steel works, aviation and others?
Let us assume for present purposes that it is possible, that a bright future is reserved for photovoltaics (why not?), or for the use of so-called "blue hydrogen", i.e. generated from methane with CO_2 capture.

Next, this hydrogen has to be transported. By tanker trunk as a first step, possibly. But let us skip this "pioneering" first step because what interests us is large-scale, global viability. So, by pipeline to the major airports? Circulating liquid hydrogen through these pipelines evidently raises prohibitive thermal problems, over long distances. How about transporting gaseous hydrogen then and equipping airports with (huge) liquefaction facilities? There is yet another variant that would involve delegating to the airports not only the liquefaction, but also the electrolysis itself. To this of course must be added storage – at 20K. Before setting all of this in place, airport authorities would, of course, need to be convinced of the commercial superiority and promising future of the whole concept. Only state investment, on a massive scale, would be capable of breaking this vicious circle. This aspect once again highlights the fact that national or European investment in hydrogen makes sense only if it is capable of generating active support internationally, even beyond Europe.

As indicated above, the main industrial application of LH2 is focused on space launchers, which is good news for Europe which, with the Ariane family, has a great deal of experience with this propellant. However, it is extremely difficult to transpose from a space launcher to a commercial airliner. Many aspects, including safety (one major incident per million flight hours), aircraft lifetime (60,000 to 100,000 hours), liquid hydrogen storage time (24/24 – 7/7), as well as environment, infrastructures, architecture, operational coverage, logistics, etc. are clearly quite different for air transport than for space launchers. For all items, LH2 utilisation for aviation would be more challenging than for space launchers. At least the experience of LH2 use for space launchers enables us to anticipate the main stumbling blocks.

Clearly, it is a totally new aircraft concept that would be needed, even for short-medium range only, to begin with.

HOW TO ENSURE SAFETY?

Safety on board and on the ground is a central theme. Looking beyond the necessary objective respect for different certification obligations, to be defined, we are living in an era where subjective "risk aversion" on the part of the public and politicians is reaching unprecedented heights. Sooner or later, decision-makers and the media will realize that liquid hydrogen and safety are not an easy match.
LH2 has a very low density = 70 kg/m³, which presents a disadvantage in terms of tank size (we will come back to this later) and also, due to the small size of the molecule, with regard to the high risk of leakage, a pervasive concern in space launching activities. The risk of leaks and of an explosion in confined spaces will naturally require a multitude of safety measures to be set in place: sealing levels (cryogenic!) for all junctions, out of all proportion with existing systems; multiple redundancies; frequent verification procedures; numerous detection sensors: flushing systems for certain enclosures; etc.

Let us note that the Ariane launching zone in the European Space Port in Kourou is cleared before the "cool-down" of the ground supply lines. This will not only concern aircraft, but also airports. Then, however efficient the thermal insulation, hydrogen evaporates continuously, there is no way around this. For a space launcher that stays in the launching zone only a few hours, with cryogenic fillings at the last moment, and has a flight of about half an hour, this is manageable. For an aircraft, in the current state of play, this is more difficult to imagine. These safety-related points are key issues.

UNPARALLELLED TECHNICAL AND OPERATIONAL CHALLENGES

For an A320 equivalent with a capacity of 23 tonnes of kerosene, the same energy requires only 9 tonnes of LH2. But these 9 tonnes, due to the low density of LH_2, will require around 150 m³ of tank (including the necessary "dead" volume), i.e. over four times higher than for kerosene. This storage cannot be envisaged in the wings; a logical place would therefore be to store it at the rear of the fuselage, but this will lead to a considerable lengthening of the latter, inducing increased drag and some balance issues. What extra weight will result? This will depend, among other things, on the insulating materials. Ariane-type thermal protection (cellular polyurethane) would lead to unacceptable thicknesses. Contrary to space launchers, tanks must be partially filled at all times, with low evaporation rates. It would seem more logical to move towards a vacuum multilayer insulation … but with much larger dimensions than existing lightweight space devices using this technology. Is this economically feasible? In terms of weight ratios, it is not relevant to try to transpose these space vehicle solutions to the scale of the aircraft, given all the differences.

Some attempts were made to design a liquid H2 tank for cars, for fuel cells or even internal combustion engines (by BMW), but were then abandoned. In this area again, there is no point transposing from the automobile to aviation on the back of an envelope, due to the huge differences in scale and operational conditions.

Anyway, just to be clear, we might well be looking at an aircraft tank/hydrogen weight ratio of between 5 and 10 (let's remind that the weight of hydrogen for an A320 equivalent would be 9 tonnes and that the current maximum take-off weight is 79 tonnes). The ensuing snowball effect would lead to a complete resizing. Major progress must therefore be made as regards tank weight. How?
The swing of LH_2 provoked by the attitude changes creates centring difficulties as well as additional evaporation. These attitude changes are much higher (around 50°) for an aircraft than the modest nozzle swivelling of a space launcher. Anti-swings will be necessary, contributing - if it works - to a further weight mass increase.

The engine bleed air supply requires a high pressure – up to approximately 100 b – in gaseous form this time. Cryogenic pumps will be necessary (with variable flow rate within a wide range) as well as heat exchangers. A series of cryogenic equipment and lines will be exposed to the risk of icing. How can this be avoided given the diversity of conditions and duration of aircraft utilisation?
Once ready, the aircraft has to be fuelled from ground storage. But a liquid hydrogen tank cannot be filled like a kerosene tank. A long sequence of actions is necessary: cleansing the lines, cool-down, and then the fuelling itself which must conducted slowly enough to avoid too much boiling, all this performed far from the passengers naturally. At the very least this sequence will take a couple of hours for a mid-range airliner. This is not easily compatible with the daily utilisation rates of present fleets! (Will these rates continue in the future? That is another subject).
One could also mention the risk of hydrogen embrittlement of certain materials, incompatibility with the elastomers etc., which will impose choices of different materials from those of today with possible cost increases.

On the engine side, on the contrary, while hydrogen combustion requires (or rather allows) a re-sizing of the chamber (shorter) and other changes, it would not seem to create insurmountable problems.

UNCERTAIN COSTS

All in all, assuming that such a concept can overcome all these obstacles and come into being "technically", the overall cost of ownership must be estimated. Admittedly, the final cost of liquid hydrogen should not be compared with that of today's fossil kerosene, but with that of the 2035-2050s. Whether due to taxes or rarefaction, everything leads us to believe (and even to hope, from an ecological point of view) that this kerosene price will be much higher than presently, thus perhaps making a hydrogen aircraft, even a complex and heavy one, somewhat "competitive".
But the hydrogen solution must also be compared with the synfuel (or e-fuel) solution, generated in two steps: H2 produced by electrolysis; then combination of this hydrogen with the carbon dioxide CO_2 contained in the air, (or with industrial trapped CO_2, thus killing two birds with one stone!).
This results in a neutral carbon-balance. By definition, the additional stage leads to an even higher fuel cost, but once this purely industrial process has been performed, the rest would be mostly unchanged (transport, storage… and airplane design). Admittedly, such a drop-in fuel would necessitate more investments in the energy industrial sector than in aeronautical R&D, but nobody would think of building an argument in favour of one or other solution out of this difference in the direction of future public funding. Many other excellent avenues would still require hard work in aircraft technology.

Finally, some alternative, "simili-hydrogen" solutions are mentioned in the scientific literature, such as ammonia or metallic hybrids, without having yet demonstrated their viability.

A BENEFICIAL BUT STILL UNCERTAIN IMPACT ON CLIMATE

The benefits of hydrogen (or of synfuels or biofuels) remain to be clarified in terms of the greenhouse effect. It is increasingly stressed that the impact of air transport is not limited to CO_2 emissions; according to some studies, contrails and the altitude clouds (cirrus clouds) they induce produce a greenhouse effect roughly equivalent to CO_2. But these are very complex phenomena for which little data is currently available. In addition, nitrogen oxides NOX have a complex impact, on the one hand generating ozone O_3 (increased greenhouse effect) and on the other hand reducing the presence of methane CH_4 (weakened greenhouse effect), so that the resulting effect is still uncertain. In any case, hydrogen should generate more water vapour, but no particles contributing to contrails aggregation, therefore *in fine*, an inconclusive relative effect, and less nitrogen oxides, thanks to rapid combustion. All in all, models predict an average reduction in the greenhouse effect of 50 to 70%, provided, of course, that the hydrogen is 100% "green".

Studying and specifying the effects of aviation on the climate, and setting up possible technological solutions, will still take a very long time. This response should take two forms:
- maximum reduction in energy needs through major advances in aircraft design and propulsion systems;
- development of an accessible non-fossil fuel (or several if possible).

It will have to be achieved by including aeronautical demand within a global approach to primary energy sources.
This will require a great deal of perseverance, humility and honesty.

IRIS: THE SATELLITE COMMUNICATIONS SYSTEM FOR SAFE AND SECURE AIR TRAFFIC MANAGEMENT

DATA LINKS AND VOICE

By Elodie Viau, Director of Telecommunications and Integrated Applications & Antonio Garutti, Head of Telecommunications Systems Project Office - ESA/ESTEC

Elodie Viau joined ESA as Director of Telecommunications and Integrated Applications from 1 September 2020. For 12 years prior to this, Ms Viau worked for SES, one of the world's leading satellite owners and operators, based in Betzdorf, Luxembourg. As Vice-President for Technology Program Management, she led the SES-17 infrastructure design and implementation enabling new integrated services such as aviation connectivity. Prior to this role, in SES's field office in Toulouse, France, she acted as Program Manager of three and as Program Manager deputy of six Airbus satellite programmes from the contract negotiation up to the satellite launch activities. Furthermore, she led innovation projects with satellite vendors and key launcher players. She has also worked for Arianespace. A French national, she gained her Master's degree in telecommunications from Télécom SudParis in 2007 and holds further qualifications from the International Space University and the Open University in the UK.

Iris is one of the projects under the direction of Elodie Viau.

Iris is a Data Link Service (DLS) and secure voice channels system funded and promoted by the European Space Agency (ESA). It is based on Inmarsat SwiftBroadband-Safety (SB-S) mobile satellite technology that is already approved for Air Traffic Service (ATS) oceanic use. Iris extends SB-S oceanic/remote service to busy continental areas, starting with Europe, and is scalable for global coverage.

In 2008, ESA kicked off the Iris programme with a world-class industrial consortium led by Inmarsat, targeting a full integration of Iris into the overall European Air Traffic Management (ATM) Network. In 2012, after a four-year research phase involving major European space companies, ESA started the development and validation/demonstration phase of a first generation service "precursor" based on the SwiftBroadband-Safety (SB-S) service of Inmarsat and relying on the L-band satellite infrastructure of this satellite operator.

Iris will provide Data Link ATS services in the European continental airspace including Aeronautical Telecommunications Network (ATN) B1 and ATS B2, as well as ACARS for Airline Operational Communications (AOC). Iris technology is based on important milestones of technical validation achieved within the SESAR1 programme, where Iris is solution #109 of the SESAR catalogue.

Currently, ten major European Air Navigation Service Providers (ANSPs) are already part of the Iris consortium, defining the entry into Iris services following the last validation step. Iris is indeed getting ready for the execution of a large-scale validation using certified avionics flying on revenue flights from commercial airlines (the so-called "Iris Early-implementation" in 2022-2023). The observed performances will be analysed with the support of several European ANSPs and in preparation of the Iris Service provider, in cooperation with EUROCONTROL/Network Manager and EASA, while airlines will exploit Iris commercial and operational benefits.

"Iris early implementation" will pave the way to the full deployment of Iris system whose roadmap is being defined with major European stakeholders as part of the European ATM infrastructure.

Iris helps to fulfil the objectives of European ATM Master Plan, which calls for a more efficient use of airspace by implementing novel ATM approaches such as i4D (in a Trajectory-based operational context). The use of such new techniques can deliver a greener approach to air travel by reducing unnecessary trajectories and associated fuel consumption along with flight delay reduction with economic advantages for passengers and, last but not least, provision of better services to airlines experiencing increasing needs for efficient flight operations and preventive maintenance. Together, these operational benefits could yield savings for the global airline industry of US$5.5-7.5 billion annually based on existing connected aircraft numbers, rising to US$11.1-14.9 billion by 2035. A 0.75–1.00% reduction in the IATA consolidated US$764 billion annual global airline cost of operation.

The high level architecture of the Iris system, omitting redundancy, is shown in **Figure 1**. It consists of two main new components: Iris Ground Segment and Iris Aero Segment.

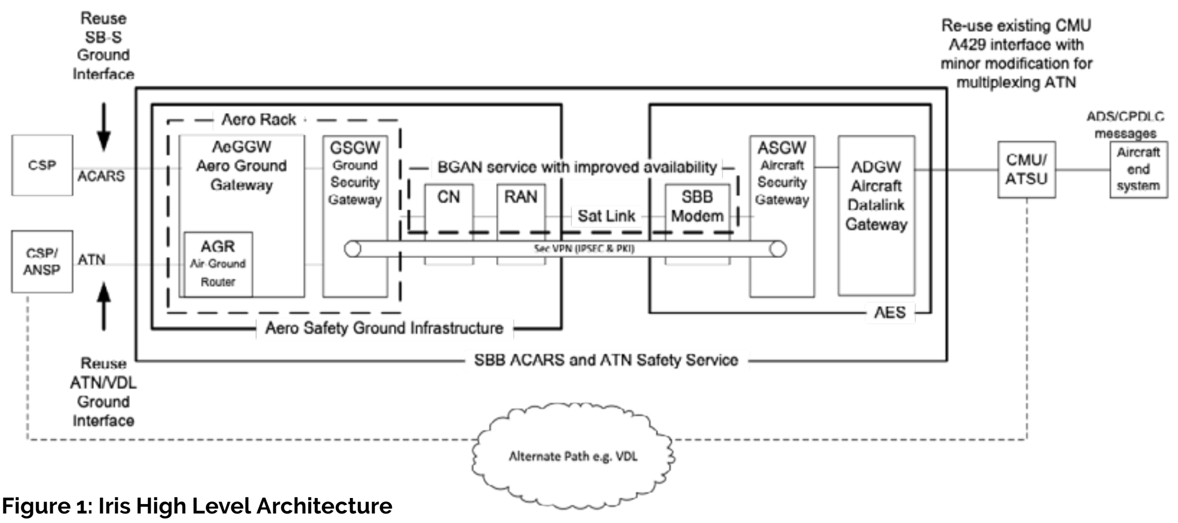


Figure 1: Iris High Level Architecture

The main **Iris ground segment** components are integrated in the Aero Rack:

- The **AeGGW** (Aero Ground Gateway) is the physical entity handling ATN/ACARS traffic to and from an AES., including ATN/OSI router software function
- The **GSGW** (Ground Security Gateway) terminates the IPSec secure VPN tunnel established by the Aircraft Earth Station (AES).
- The **GDGW** (Ground Datalink Gateway) supports combined delivery of ATN and ACARS traffic via the satellite link.

The main **Iris Aero Segment components** are implemented within the Satellite Data Unit (SDU) on the Aircraft Earth Station (AES) SATCOM terminal:

- The **ASGW** (Aircraft Security Gateway) is responsible for establishing the Secure VPN tunnel between the aircraft and its GSGW, for the provision of an IPSec VPN for secure air-ground data link communication.

- The **ADGW** (Aircraft Datalink Gateway) is a functional block within the AES that is responsible for encapsulating ATN/ACARS messages in an IP wrapper to allow them to be sent to the ground. The ADGW also de-encapsulates received ATN/ACARS IP messages for transmission to the aircraft Communication Management Unit.

- The **CMU** (Communication Management Unit) manages aircraft communication across multiple sub-networks such as Terrestrial, HF, VHF radio and satellite-based communications, selecting which subnetwork to use based on availability and local routing policy.

Once the required specifications become available, it is expected that it will be easy to customize the Iris ground network to interconnect it to the future CEAB.

Iris provides a readily deployable system to support the terrestrial technology system known as VDL2, which is mandated by the European Commission (EC). VDL2 has demonstrated limitations in meeting DLS performances, which impacts the operational European ATM network and fulfilment of the EC European Aviation Strategy (December 2005).

Iris was designed to provide enough capacity for short-term needs with scalability potential for future demands. A recent capacity study, performed by the Iris consortium in line with SESAR Deployment Manager traffic growth assumptions, confirms that Iris has the required capacity to support both the volume of data expected to be offloaded from VDL2 and the increase in traffic in the coming years.

COVID-19 is having far-reaching consequences on the global economy, which includes the impact on the aviation sector driven by a severe collapse in passenger traffic. Even at this time, the integration of all suitable and available technologies into a DLS architecture will provide the opportunity for Europe to achieve the digital transformation and Green Deal being pursued by the EC. The present crisis could even spark a digital transformation for industry in order to quickly increase efficiency and cut costs. At the same time, this transformation would help prepare for a future in which performance, safety and capacity requirements will be more demanding.

Iris is recognised by all major ATM stakeholders as the only ready-technology that can immediately deliver the required ATS performances for complementing VDL M2 and, at the same time, provide far greater data link capacity and availability. Another SATCOM based technology which could also deliver similar services is IRDIUM whose development roadmap is ongoing, but it is not yet clear if the technology is at the same level of readiness as Iris.

In order for Iris to have an effective impact on VDL-M2 off-load, a sufficient number of airspace users must be equipped with it soon. An appropriate number of ANSPs are also required to provide the service. A suitable deployment plan should be implemented as soon as possible, so that an operational Iris service is ready and available as passenger traffic begins to increase again. ESA is actively engaging with European Stakeholders to facilitate the implementation of such a deployment plan. In order to facilitate Iris uptake in support of European aviation, it would be useful for a proper regulatory package, including appropriate funding schemes and incentives for airlines and ANSPs, to be implemented as soon as possible. This would support a ready Iris service timely with passenger traffic re-growing expectations after COVID-19.

In summary, Iris is a readily available solution enabling the EC's aviation strategy. It is based on the following main pillars:

- Compliance with ATS safety and performance requirements for ATN B1 and ATS B2,respectively. This includes ADS-C applications (EPP) which are key enablers for i4D that can deliver route optimizations and reduced fuel consumption due to fewer holding patterns resulting in less CO_2 emissions per flight
- Resilience to malicious attacks, due to end-to-end secure and redundant mechanisms, including security mechanisms to ensure authenticity and integrity of ATS data link exchanges within the SATCOM environment.
- High capacity, guaranteeing the required performances for ATS safety services whilst also supporting the data-hungry AOC services needed for airline operations
- High network availability and stringent low service outage. In order to meet these demanding operational requirements, a comprehensive redundant system solution has been conceived, with no single points of failure and the ability to detect and switch over quickly to standby equipment in the event of failures
- Immediate European coverage and scalability potential for a global worldwide component of air-ground ATM communications
- Future proofing, as upgrades to the current system can be gradually implemented to fulfil future requirements for improved performance in compliance with upcoming ATN-IPS standards.
- Ready to interconnect to the Common European ATM Backbone (CEAB)infrastructure.

The results achieved so far draw on the involvement of leading European institutional stakeholders (EC, SESAR Joint Undertaking, SESAR Deployment Manager, EASA and EUROCONTROL). ESA is committed to continue this cooperation with European institutions in support of the Single European Skies policy set by the EC.

Iris' technology is based on important milestones of technical validation achieved within the SESAR1 programme, where Iris is solution #109 of the SESAR catalogue. Iris is now getting ready for the execution of a large-scale validation using certified avionics flying on revenue flights from commercial airlines (the so-called "Iris early-implementation" in 2022-2023). The observed performances will be analysed with the support of several European ANSPs in cooperation with EUROCONTROL/Network Manager and EASA, while airlines exploit the commercial and operational benefits conferred by Iris.

"Iris early-implementation" will pave the way to the full deployment of the Iris system whose roadmap is being defined with major European stakeholders as part of the European ATM infrastructure.

Iris is therefore helping to maintain the leading position of Europe in this process in a united European front, and will give European industry a competitive advantage compared to other global players, whilst also contributing greatly to common global aviation goals.

ACRONYMS List

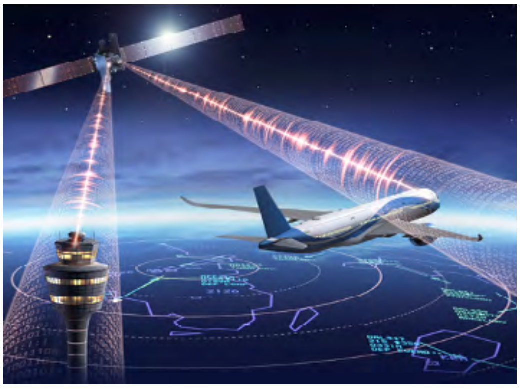
ACARS	Aircraft Communications Addressing and Reporting System
ADS-C EPP	Automatic Dependent Surveillance – Contract Extended Projected Profile
AES	Aircraft Earth Station
ANSP	Air Navigation Service Provider
AOC	Airline Operational Communications
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Services
CEAB	Common European ATM Backbone
DLS	Data Link Services
EASA	European Aviation Safety Agency
i-4D	Initial 4D or Initial Trajectory Based Operations
IATA	International Air Transport Association
SB-S	Swift Broadband-Safety
SESAR	Single European Sky ATM Research
VDL2	VHF Digital Link Mode 2

Please visit IRIS website: https://artes.esa.int/iris

ESA Video links:
https://www.youtube.com/watch?v=2aSF_WDRBPI
https://www.youtube.com/watch?v=Iai289B_maM

INMARSAT Video Link:
https://www.youtube.com/watch?v=DCjVgMVbzbI&feature=youtu.be

IRIS FLIGHT TRIAL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RESEARCH AND INNOVATION FOR NEXT GENERATION AIRLINERS PROPULSION

By Arnaud Lebrun, Leader of Research and Innovation on future fuels at SafranGroup Aicraft Engines

AMBITIONS FOR THE NG AIRLINERS PROPULSION

For decades, aircraft manufacturers and engine manufacturers have been improving their products through steady research and development efforts. Air transportation is therefore increasingly safer, increasingly more fuel efficient, while being cleaner and cheaper per passenger-kilometre. For the next generation airliners propulsion, the research and innovation efforts are focused on the reduction of carbon dioxides emissions. It leads Safran engine advanced design teams not only to value emerging materials, methods and shapes for incremental progress on engine components, but also to consider new engine architectures and new fuel types. It's the overall life-cycle of engines and fuels that are also being reconsidered. Research and innovation aim at igniting the launch of the development of the safest, the most environment friendly and still affordable propulsion system for the next generation airliners.

THE 4D RESEARCH AND INNOVATION FOR NG AIRLINERS PROPULSION

In order to invent the best propulsion system concept for the next generation airliners, four dimensions are concurrently explored by Safran:

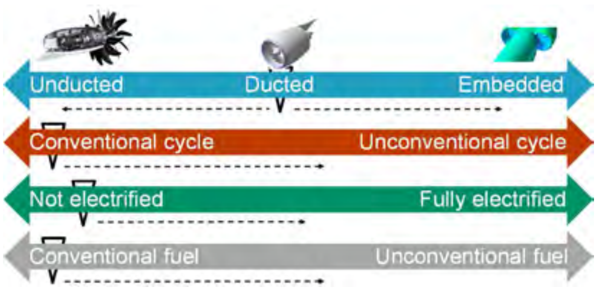

Figure 1 - Source: Safran

The first dimension to explore aims at maximizing the propulsive efficiency. Under that dimension, engine concepts may go from unducted engine concepts to embedded engine concepts through conventional, ducted engine concepts.

The second dimension to explore aims at maximizing the thermal efficiency. Here, engine thermodynamic cycles may go from conventional, Brayton cycle to less conventional cycles.

The third dimension involves exploring the electrification potential of the engine. Under that dimension, thrust and power generation concepts may go from conventional (gas turbine + mechanically driven electrical generators) concepts to unconventional (electrical motors + fans only) concepts.

Finally, the fourth dimension entails exploring fuel alternatives. Under that dimension, fuel types may go from conventional, kerosene fuel to unconventional, non drop-in fuels.

Now we have set the cursors for the propulsion of the current generation airliners, we need to determine where to stand for the propulsion of the next generation airliners. The last four dimensions are described in the coming sections.

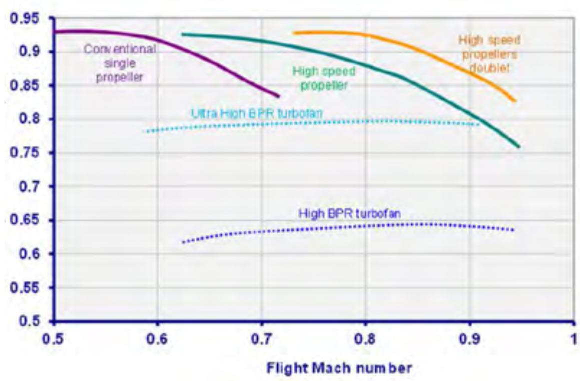

Figure 2 - Source: Safran

THRUST GENERATION CONCEPTS

Fuel consumption, pollutant emissions and greenhouse gases emissions are determined by the engine propulsive efficiency. The later can be increased by reducing the jet velocity and/or by ingesting the aircraft fuselage boundary layer. The jet velocity decreases as the fan/propeller pressure ratio is reduced and as the engine diameter is increased:

Various propellers combinations are considered in addition to the well-known turbo-prop, such as:

- high-speed, counter-rotating, rear propellers doublet,
- high-speed, counter-rotating, aft propellers doublet,
- high-speed, single propeller and outer guide vane.

Safran ran with Clean Sky Partners the Clean Sky Open Rotor Demonstrator in 2017:

Figure 3 - Source: Safran

Still significant research and innovation effort is required to make an unducted engine powering the next generation airliners: high reliability, low noise, low drag and low mass solutions are under maturation.

Ducted engines are powering all current airliners but the smallest ones. Their propulsive efficiencies, reflected by their by-pass ratios, have been increased generations after generations. For instance, the by-pass ratio of the CFM56 engine that powers the second generation B737 and the first generation A320 is between five and six, whereas the by-pass ratio of the LEAP engine that powers the third generation B737 and the second generation A320 is between eleven and twelve. That increase was achieved thanks to composite materials developed by Safran for the fan module:

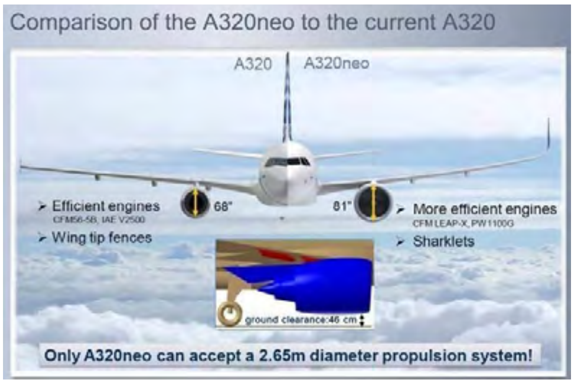

Figure 4 - Source: © Airbus

There are still opportunities for making easy to install, ducted engines more fuel efficient: research and innovation effort is ongoing to make them even more reliable, less noisy and more efficient.

The aircraft fuselage boundary layer could be partly ingested by engines that would be partly or fully embedded within the aircraft fuselage. Thus the aircraft drag would be reduced on one hand and compensated on the other hand, by the engines. No such aircraft exists yet. Various boundary layer ingesting propulsion systems are considered, including for instance:

- twin turbofan engines installed in the rear section of the aircraft fuselage,
- two turbofan engines as installed under the wings and powering a fan installed in the rear section of the aircraft fuselage through an electrical power transmission for instance:

Such propulsion system concepts are under exploration.

Figure 5 - Source : ONERA

Figure 6 - Source: NASA

THERMODYNAMIC CYCLES

As does the engine propulsive efficiency, the engine thermal efficiency determines the fuel consumption, the pollutants emissions and the greenhouse gases emissions. In addition to increasing the overall pressure ratio and to increasing the turbine entry temperature, the engine thermal efficiency can be improved for instance by replacing constant pressure combustion with constant volume combustion, by cooling down the air under compression, by warming up the combustion products under expansion, by recuperating heat from the combustion products after expansion, by reducing turbines cooling air flow, by cooling down turbines cooling air.

Some of those functions have been already implemented into static and marine gas turbines. However, so far, there has never been aircraft gas turbine under service implementing non Brayton cycle because of mass and volume limitations of current technologies. Many research and innovation efforts are required to make an unconventional thermodynamic cycle down-selected for the next generation airliner propulsion system: disruptive combustion technologies are under exploration, lighter and more efficient thermal management components are under maturation; in addition, specific properties of new fuels may be exploited.

ELECTRIFICATION CONCEPTS

Electrification could also contribute to reducing energy consumption, pollutants emissions and greenhouse gases emissions, at least locally. The aircraft propulsion could be electrified for instance by replacing, or complementing, fuel tanks with electrical accumulators, by replacing, or complementing, gas turbines with electrical motors, by replacing mechanical power transmission with electrical power transmission, by replacing mechanical gearboxes with electrical gearboxes and/or by inserting electrical actuators. The rail transportation has been largely electrified for a long time (and without batteries!). The road transportation is under electrification. We can observe that worldwide, huge research and innovation efforts are dedicated to electrical systems. Some low speed, short range and low capacity air vehicles are even being demonstrated or being put into service:

One may believe that lighter, more compact and compatible with air transportation electrical technologies

Figure 7 - Source : Parrot

Figure 8 - From the first round the world solar flight. © Solar Impulse Foundation

Figure 9 - Airbus - Electric flight - Laying the groundwork for zero-emission aviation". © Airbus

will emerge enabling electrical propulsion for larger aircraft. In between, aviation may be inspired by the electrical hybridization of cars' powertrains. However, the typical airliner mission does not provide opportunities for energy recovery, as most of car activities do. Therefore, the benefits of the electrical hybridization of an airliner powertrain will be more limited. Even the benefits of the distributed propulsion, where there would be numerous fans/propellers driven by electric motors supplied by gas turbines driving electrical generators and auxiliary electrical accumulators, are not yet proven: additional drag, complexity and masses of thrust and power generation and distribution systems are limiting factors. It should then require a lot of efforts spent on electrical technologies and how to integrate/connect them into/with gas turbines to make a hybridized electrical power train down-selected for the next generation airliner.

FUEL TYPES

Complementarily with disruptive technological solutions, introducing new fuels are necessary to meet the requirements of air transportation decarbonisation. Indeed, on one hand, we know that batteries are not applicable to airliners for the predictable future, and on the other hand, we cannot assume that capturing and sequestrating the carbon that will still be emitted burning kerosene would be the full solution.

Therefore, synthetic hydrocarbons and synthetic hydrogen are the main fuel types candidates considered for the title of "Sustainable Aviation Fuels (SAF)". Each of them can be synthesized through chemical or biochemical processes. Those processes are more or less environmentally–friendly. They require primary energy, ground space. They are more or less mature and costly. A full lifecycle analysis is then required to properly assess their environmental benefits, the feasibility and the affordability of their use for aviation.

Depending on their synthesis processes and on their physical and chemical properties, synthetic hydrocarbons would either behave as kerosene or would behave differently. Should they behave as kerosene, they would be fully "drop-in fuels": no specific propulsion technologies would be required and rapid insertion into the fleet would be possible, making an evenly rapid impact on environment. Should they behave similarly to kerosene, blending with kerosene may be enough not to change propulsion technologies: some biofuels are already under use if blended with kerosene up to 50%. However, should they not behave as kerosene, specific propulsion technologies would be required. The insertion into the fleet would be slower but the positive impact on the environment may end up greater. Indeed, with this last solution, pollutants as Non Volatile Particle Matters (NVPM) emissions could be reduced, improving air quality and reducing the harmfulness of contrails. Moreover, other solutions exist in burning methane, as the shortest hydrocarbon chain could lead to carbon dioxide emissions reduction with respect to burning kerosene. In that case, cryogenic solutions would be required.

Cryogenic solutions will also be required for the hydrogen to fuel airliners. Indeed, the hydrogen density is so low under usual conditions that compression or liquefaction is required before storage on board. Besides, high pressure tanks are much heavier than low temperature tanks: technological solutions under use for cars can thus not be reused for large aircraft. When reacting with the air in fuel cell or in gas turbine combustor, hydrogen delivers power and does not produce any carbon dioxide during flights. This way, substituting kerosene with hydrogen in flight, and generally substituting kerosene fuelled aircraft with hydrogen fuelled aircraft, may directly and progressively reduce carbon dioxide emission by aviation. Safran has engaged a major research and innovation effort to face numerous environmental and technological challenges. Firstly, burning hydrogen instead of kerosene will not produce soot but will eject more water and may generate more contrails that may be less harmful each. Modelling, in flight characterization and models calibration need to be created to provide us with more insights on these phenomenon. Secondly, burning hydrogen instead of kerosene will still produce nitrogen oxides which is why specific combustion technologies have yet be explored and matured. Thirdly, it is relevant to consider dual fuel gas turbine as able to burn simultaneously, sequentially or alternately sustainable hydrogen and sustainable hydrocarbons: single fuel and dual fuel, combustion technologies will be explored too. Fourthly, fuel cells are already being considered for non-propulsive power generation and for small aircraft propulsion. When their power capabilities, densities and operating temperatures are high enough, fuel cells and e-propellers may become an alternative to replace large gas turbine, then offering a zero NOx emission solution. Fuel cell technologies and integration technologies are under exploration and maturation by Safran and other manufacturers. Fifthly, hydrogen pressure and temperature at tanks outlets shall be increased before the hydrogen being reacted with the air: hydrogen conditioning and distribution technologies, together with safety management technologies, are also under exploration and maturation. On a side note, let us remember that sustainable/renewable hydrogen, as sustainable/renewable hydrocarbons, may be more expensive than kerosene. That is why the propulsion frugality remains a key item for the future airliner.

DMD SOLUTIONS IS LAUNCHING ROBIN, THE RAMS ASSISTANT BUILT FOR THE AEROSPACE INDUSTRY

by Joana Verdera, DMD Solutions

A team of aerospace engineers experts in Reliability, Availability, Maintainability and Safety analyses release a software suite that will enhance the efficiency of the aerospace industry in certification processes for airborne systems.

Barcelona, Spain | October 20, 2020
DMD Solutions announces the release of its flag software tool: Robin RAMS. Robin provides assistance in navigating airworthiness standards and five calculation modules for the most challenging analyses in the field: Fault Tree Analysis (FTA), Failure Reporting and Corrective Actions System (FRACAS), Reliability Prediction, Maintainability (MSG-3 & Zonal Analysis) and FMECA. With the aid of Robin, companies that build, operate or maintain airborne systems will be able to track malfunction data and extract reliability insights, calculate probability of failure and analyse failure effects, and plan maintenance tasks to optimise operations.
The reliability, availability, maintainability and safety of aerospace systems have always been of paramount importance to the sector and yet, until now, all software tools aimed at supporting RAMS engineering analyses have been catch-all products for industries as diverse as energy, chemical, health & pharmaceutical and then also aerospace.
At DMD Solutions, an engineering company located in Barcelona and Luzern, this state of affairs seemed unacceptable. For a team of aerospace engineers fully dedicated to providing RAMS studies for aerospace systems manufacturers it was clear that a tool focused on their needs was necessary. The requirements for certification in the aerospace industry are very demanding and engineers aiming at proving the solidity of their system's design need highly specialised support.
This is how Robin RAMS was born. Dario Di Martino, CEO and founder of DMD Solutions explains: "After 10 years working in the field I had tried every available software, but nothing responded to the actual needs of aerospace companies. There are a few platforms with thousands of features aimed at different industries and bulky licensing processes. But why purchase an expensive license where half of the functionalities remain unused? This might not be a stopper for big companies, but what happens with medium-sized companies, such as trainer aircraft integrators, business jets, light helicopters, drones or urban mobility vehicles?
Robin is a good fit for companies which need a straightforward tool to support and speed up their efforts towards safety, reliability and maintainability analyses in aerospace."

For two years, the development team has worked on building a web application that is modern, flexible and suited to the daily work of OEMs and integrators which need to obtain Type Certificate or prove the safety of their product to suppliers and quality boards. The lead developer, David Duran explains: "We started building the platform we would have wanted, with the user experience of the engineer always in our minds: clean interfaces, precise documentation and fast calculation times. While implementing FRACAS for our customers, we saw how traditional databases failed to provide the solidity and team integration needed to manage fleets. For Fault Tree Analysis we have developed a calculation algorithm that allows both Minimal Cut Sets and Direct Evaluation methods with faster results than any other in the market. I think aerospace engineers will welcome Robin with enthusiasm, it's a big improvement from the catch-all platforms that we've had until today."
Several customers are already enjoying the benefits of Robin RAMS. They have highlighted the flexibility of the tool and its adequacy to cater for aerospace needs. The engineering team at the aircraft manufacturer Daher Socata have been the beta-testers of the platform, providing invaluable live environment feedback to the development team. Other companies such us UMS Skeldar, drone builder in the defence sector, Civitanavi Systems, providing Global Navigation Satellite Systems to a European space launcher program or FIMAC, supplier of Environmental Control Systems for both rotorcraft and business aviation aircraft, are among the satisfied early users.
As Robin deploys in the market, the DMD solutions' team continues the endeavour to improve the platform and make it the reference in the sector. Additional libraries and standards are being developed for the Reliability Predictions module in partnership with Quanterion. With the inclusion of new users to the Robin community, DMD Solutions expects to increase its worth for the aerospace industry.

ABOUT

DMD Solutions is an engineering company located in Barcelona (Spain) and Luzern (Switzerland) founded in 2014 by Dario Di Martino. A team of highly specialised aerospace engineers caters for the needs of the aerospace industry in the Reliability, Availability, Maintainability and Safety fields, providing consultancy services both remotely and on-site.

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DMD Solutions'site: www.dmd.solutions
Robin RAM's site: www.robinrams.com

SPACE X CREW-1 *RESILIENCE*

By Jean-Pierre Sanfourche

The Crew Dragon spacecraft 'Resilience' was launched on 16 November 2020 at 00:27 UTC on a Falcon 9 from KSC LC-39 carrying four astronauts: three NASA astronauts – Michael Hopkins, Victor Glover and Shannon Walker – and one JAXA astronaut, Soichi Nogushi.

THIS MISSION IS THE FIRST OPERATIONAL MISSION TO THE ISS IN THE COMMERCIAL CREW PROGRAMME.

The Falcon 9 first-stage booster (SN B1061) landed on the autonomous spaceport drone ship not long after. The astronauts entered a stable orbit 9 minutes after launch. Crew Dragon Resilience docked to the International Module Adaptor (IDA) on the harmony module on 17 November 2020 at 04:01 UTC.

The mission is expected to last 180 days, meaning the flight will return to Earth in May 2021, via splashdown in the Atlantic Ocean for another future mission.

Over the course of the mission, the four astronauts will live and work alongside the three astronauts of the Soyuz MS-17 missions: together the two missions form **ISS Expedition 64**.

CREW

- Spacecraft Commander: Michael S. Hopkins, NASA, 2nd spaceflight
- Pilot: Victot J. Glover, NASA, 1st spaceflight
- Mission Specialist 1: Soichi Nogushi, JAXA, 3rd spaceflight
- Mission Specialist 2: Shannon Walker, NASA, 2nd spaceflight

1. Falcon 9 with Resilience lifts off from KSC LC-39, 16 November 2020 at 00:27 – © Credit NASA

2. Crew-1 astronauts – (l-r) Walker, Glover, Hopkins and Noguchi – © Credit NASA

3. The crew inside the capsule during the rendezvous © Credit NASA

> To see the video click to the link

SpaceX Crew-1 launch and Falcon 9 first stage landing
https://www.youtube.com/watch?v=SBj2KsnAKb4

Watch NASA's SpaceX Crew-1 Mission Arrive at the Internal Space Station
https://www.youtube.com/watch?v=aT4rlTutAwA

NEW COPERNICUS SATELLITE – SENTINEL 6A - TO MONITOR SEA-LEVEL WAS SUCCESSFULLY LAUNCHED ON 21 NOVEMBER 2020

Illustration of the Sentinel-6 Michael Freilich spacecraft in orbit above Earth with its deployable solar panels extended

THE LAUNCH OF SENTINEL – 6A MICHAEL FREILICH

On 21 November at 17:17 UTC, the Falcon 9 rocket lifted off from the Vandenberg Air Force Base in California, USA, carrying the Sentinel-6A Michael Freilich1 the European Copernicus programme. The satellite was delivered into orbit just an hour after lift-off.

See the video:
https://www.esa.int/ESA_Multimedia/Videos/2020/11/Copernicus_Sentinel-6_Michael_Freilich_liftoff_replay

THE SCIENTIFIC MISSION

Sentinel-6 mission is to continue the measurements of sea level needed to understand and monitor the worrying trend of rising seas. With millions of people living in coastal areas around the world, rising seas are at the top of the list of major concerns linked to climate change.
Monitoring sea-surface height is absolutely essential to understand the changes taking place.
Over the last three decades, the French – US (CNES-NASA) 'Topex-Poseidon' and 'Jason' mission series served as reference missions. In combination with ESA's earlier ERS and Envisat satellites, together with today's Cryostat and Copernicus Sentinel-3, they have shown that sea-level has been risen about 3.2 mm on average every year. More alarmingly, this rate of rise has been accelerating. As a matter of fact, over the last few years, the average rate of rise has been 4.8 mm per year.
The data at regional level for some coastal areas around the world is even higher.

TWO SENTINEL-6 SATELLITES

The Sentinel-6 mission comprises two identical satellites: Sentinel- 6A presently in orbit plus Sentinel-6B which will be launched in five years (2026). The sentinel-6 mission as a whole will ensure delivering data until at least 2030.

- Mass: 1191 kg (incl. 230 kg fuel)
- Dimensions: 2.35 X 4.17 X 5.30 m
- Life: minimum 5.5 years
- Orbit: polar orbit at 1336 km altitude, inclined at 66°, allowing provide measurements to map the height of the sea surface over 95% of the world's ice-free oceans every 10 days.
- Re-visiting time: 10 days
- Receiving stations: Kiruna (Sweden) and Fairbanks (USA)
- Funding: ESA, EU and EUMETSAT, with in-kind contributions from NASA
- Prime Contractor: Airbus Defence and Space, with Thales Alenia Space for the altimeter.

Satellite instrument package

Radar altimeter developed by ESA - Each satellite carries a radar altimeter which works by measuring the time it takes for radar pulses to travel to Earth's surface and back again to the satellite. The Altimeter Radar is for the first time operated as *Synthetic Aperture Radar*, providing enhanced performance already demonstrated a few days after its launch while still on the way to reach its final orbit.

GNSS Precise Orbit Determination (POD) receiver, developed by ESA - Combined with precise satellite location data, altimetry measurements, altimetry measurements yield the height of the sea surface.

Doppler Orbitography and Radiopositioning Integrated Satellite (DORIS)'s receiver.
Microwave radiometer provided by NASA - An advanced microwave radiometer (AMR-C) measures the amount of water vapour in the atmosphere which affects the speed of the altimeter radar pulses.

Laser Reflector Array (LRA) provided by NASA.
GNSS-R0 provided by NASA for radio occultation.

COOPERATION

The implementation of Sentinel-6 is a result of cooperation between European Commission, ESA, EUMETSAT, NASA and NOAA, with the important contribution of CNES (French Space Agency).

Inside SpaceX's Payload Processing Facility at Vandenberg US Air Force Base (CAL), the US-European Sentinel-6A Michael Freilich is being encapsulated in the SpaceX Falcon 9 payload fairing, 3 November 2020. © Credit NASA

RESPONSIBILITY SHARING

- ESA: development of first satellite 6A – procurement of 6B on behalf of the European Commission - launch and early operations phase (LEOP) of 6A and 6B.
- EUMETSAT: Ground segment development – operations of satellites after LEOP conducted by ESA – operations of European part of the ground segment – processing of altimeter data and delivery of product services to European users.
- NASA: provide microwave radiometer – GNSS RO – launch services – ground segment development support – data processing on USA Instruments.
- NASA and NOAA: distribution of data products for research and operational users in the USA to users in the USA.
- NOAA: ground station for tracking and command of the satellites + data downlink.
- CNES: processing of high-level products (orbit determination with DORIS and altimeter data) and providing technical support..

VERY FIRST RESULTS

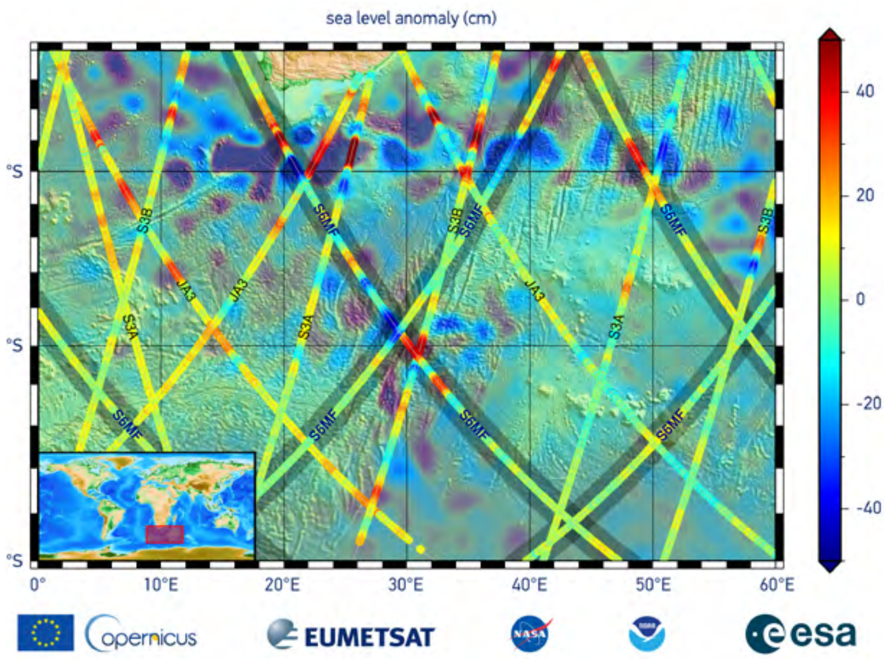
Sea-level monitoring satellite first results surpass expectations. The here below image shows sea-level anomaly data, overlaid on a map showing similar products from the Copernicus altimetry missions. The data for this image were taken from the Sentinel-6 'Short Time Critical Level 2 Low Resolution' products generated on 5 December 2020 *(see figure here below).*

LINKS TO VIDEOS

Video of the launch (about 2 minutes)
https://www.esa.int/ESA_Multimedia/Videos/2020/11/Copernicus_Sentinel-6_Michael_Freilich_liftoff_replay

Video of the launcher-satellite separation (0:10 minutes) :
https://www.youtube.com/watch?v=EK-edpLvDwo&feature=share

1. Dr Michael H. Freilich led NASA's work on Earth Science over more than 12 years until he retired in February 2019. Owing to the outstanding contribution to Erath science worldwide and also in advancing the Sentinel-6 mission, it had been decided name the latter by his name.



FROM ARIANESPACE

• FLIGHT VEGA VV17: FAILURE OF THE SEOSAT-Ingenico –TARANIS MISSION

On 16 November 2020 the VV 17 Vega launcher lifted from the Guiana Space Centre. It was carrying two payloads:

- The Earth science observation satellite SEOSAT-Ingenico, for ESA;
- The TARANIS satellite, for the Space French Agency (CNES).

Eight minutes after liftoff, following the first ignition of the engine of the Avum upper stage, a deviation of the trajectory was identified, entailing the loss of the mission. The launcher fell in a 10% uninhabited area, the drop zone planned for the Zefiro 9 stage.

On 17 November, an independent Enquiry Commission was set up, in order to explain the origins of the failure and to propose a roadmap for the Vega's return to flight under conditions of complete reliability.

• SOYUZ FLIGHT VS 64: SUCCESSFUL LAUNCH OF FALCON EYE

On 2nd of December 2020 at 01:33 UTC, Arianespace successfully launched 'Falcon Eye' with a Soyuz launcher from Guiana Space Centre.

Falcon Eye is a very high-performance optical Earth Observation satellite for the United Arab Emirates Armed Forces (UAEAF). This satellite had been developed in a consortium led by Airbus Defence and Space and Thales Alenia Space as well as with their client, the UAEAF for Falcon Eye, along with the French Space Agency (CNES) and the French Armament Procurement Agency (DGA).

The launch of Falcon Eye satellite with a Soyuz launcher from European Spaceport, French Guiana, on 2 December 2020 at 01:33 UTC. Credit Arianespace.

NOVESPACE : THE EUROPEAN LOW GRAVITY-FLIGHT OPERATOR

By Jean-François Clervoy, Former Novespace Chairman CEO and CNES, ESA, NASA Astronaut, Founder of Air Zero G

NOVESPACE

Novespace, a subsidiary of CNES, the Space French Agency, has been a partner of space agencies for scientific microgravity research since 1989. Novespace opened the discovery flights to the public in 2013 and selected Avico to market them. Novespace was created in 1986 to promote the transfer of space technology to the non-space sector. At the same time, following my thesis work as a flight test engineer, I initiated the first parabolic flight programme in Europe together with my fellow astronaut Jean-Pierre Haigneré. I named the programme 'Zero G' which I managed as a part-time secondment to the French Flight Test Centre in partnership with Novespace. The latter took over the overall management of the programme when both of us started training for our respective space flights in Russia and in the USA. The Flight Test Centre remained the flight operator providing the cockpit and cabin crew. After my duty as mission specialist on three space shuttle missions and as ATV (Automatic Transfer Vehicle) senior advisor astronaut, I was seconded again part-time from the active astronaut corps as Chairman Chief Executive Officer of Novespace which activities became almost exclusively dedicated to providing European countries and their space agencies with independent access to reduced gravity parabolic flights. Previously only the USA and Russia operated such flights.

Based in the Bordeaux-Mérignac airport (France), Novespace operates up to about 30 parabolic flights a year, mainly for space agencies (including CNES, ESA, DLR) as part of their scientific and technology research programmes.

ZERO G AIRCRAFT HISTORY – 20 000 PARABOLAS AND 120 HOURS OF WEIGHTLESSNESS

From 1986 to 1996, Novespace ran more than 50 parabolic flight campaigns in the Caravelle Zero G. In 1997, it was replaced by the Airbus A300 Zero G which was used for 113 campaigns. It also completed 3 observation missions of the atmospheric re-entry of the cryogenic main stage (EPC) of Ariane 5 for CNES. In October 2014, the Airbus A300 zero G was decommissioned after 17 years of service. It is now displayed at Cologne airport (Germany). From 2015, Novespace owns and operates a third aircraft, the Airbus A310 Zero G which has flown 40 campaigns so far. All together the 3 aircraft have flown more than 200 scientific campaigns and 30 discovery flights representing about 20 000 parabolas and more than 120 hours of weightlessness. Since 2015 Novespace has received full delegation from the French authorities to certify the hardware flown on board its own aircraft. Note that Novespace subscribed to a CO_2 compensating programme for all its emissions.

FLYING TECHNIQUE

The weightlessness state provided during a parabola is real as opposed to the various types of simulations which only mimic the possibility to move in three dimensions like for example under water when the Archimedes force balances weight. The aircraft is actually literally inserted into an arch of Earth Orbit, during which a specific piloting technique allows zeroing the sum of all aerodynamic forces as if the plane was freefalling in vacuum subject to no other forces than the Earth gravitational attraction force. Basically the angle of attack is close to zero, providing zero lift and the thrust is adjusted to exactly balance air drag. The manoeuvre is flown by three pilots all acting simultaneously on their respective control: one controlling the pitch, one controlling the roll and one managing the throttle for thrust control.

The whole maneuver comprises three main phases:

- **A pull-up:** In order to keep the plane within the flight envelope defined by the manufacturer and to maximise the time of weightlessness, the manoeuvre is initiated at maximum speed and aims at rising the nose up for about 20 seconds.
- **A ballistic phase** in Zero G for 22 seconds.
- **A pull-out** symmetrical to the pull-up taking the plane back to steady horizontal flight.

For the A310 airbus the corresponding parameters are :

- Initial altitude = 20,000 feet
- Initial velocity = 340 knots
- Pull-up at 1,8g
- Transition to ballistic flight at 50 degrees nose-up (which represents a slope of about 40 degrees)

(figure 1)

SCIENTIFIC FLIGHTS

Weightlessness or microgravity is a unique environment for most scientific disciplines. It allows scientists to study in situ phenomena that, on Earth, are masked or modified by gravity. Gravity-free flights on board the Airbus

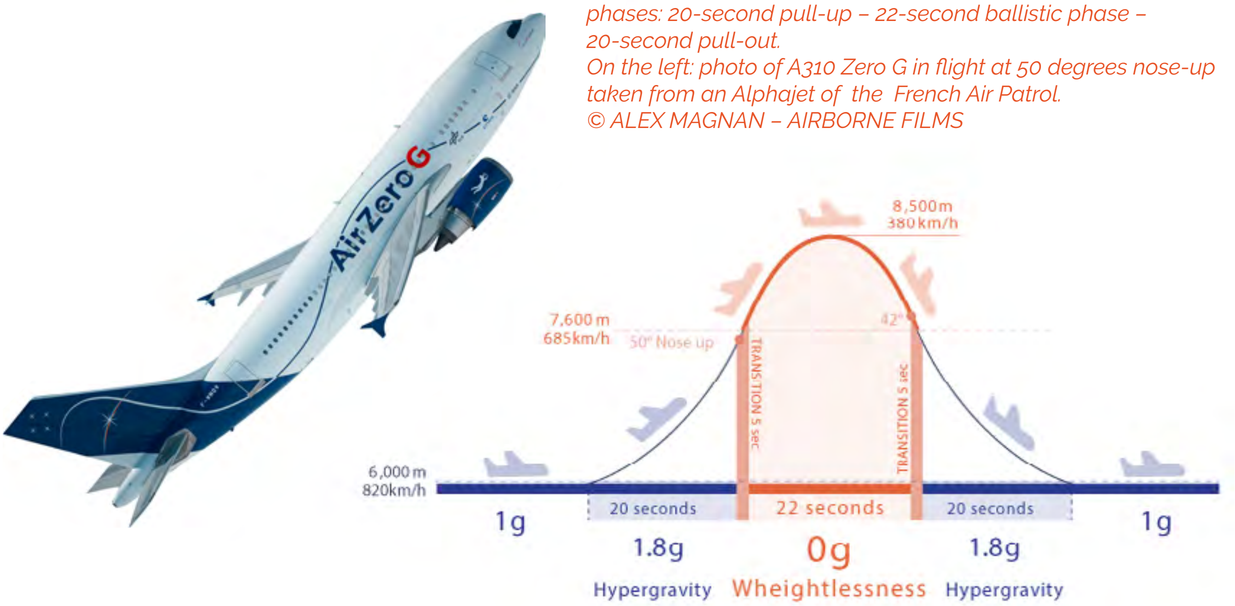


Figure 1 - The whole parabolic flight maneuver comprises three phases: 20-second pull-up – 22-second ballistic phase – 20-second pull-out.
On the left: photo of A310 Zero G in flight at 50 degrees nose-up taken from an Alphajet of the French Air Patrol.
© ALEX MAGNAN – AIRBORNE FILMS

A310 Zero G therefore help to increase knowledge in almost every area of science: combustion, fluid, material, particle physics, chemistry, animal and vegetal biology, physiology, etc. The Airbus A310 Zero G is a true flying laboratory shared by multidisciplinary and multinational teams which are often the same exploiting also the International Space Station (ISS) but with the following differences: on board the Zero G plane, the continuous time of weightlessness is far shorter but scientists work by themselves on their experiments and don't have to delegate the tasks to astronauts. Besides the design and qualification of the experimental hardware benefits a far quicker turnaround. It takes typically six months to design and build a qualified hardware for a Zero G flight as opposed to several years for an ISS flight qualification.

DISCOVERY FLIGHTS

Following a process defined by the French Civil Aviation Authority, verified by the aircraft manufacturer Airbus and approved by the European Aviation Safety Agency (EASA), Novespace was granted in 2012 a formal airworthiness certification for weightlessness discovery flights opened to paying passengers or private companies, the first wishing to experience the incredible sensation offered by true weightlessness, and the latter for eye-catching communication advertising and filming purposes. Composed of 15 parabolas, each discovery parabolic flight produces the same weightlessness as astronauts experience in space. Accompanied by myself, passengers take part in exciting free-floating activities.

A 100% EUROPEAN PRODUCT ADAPTED TO REDUCED AND ZERO GRAVITY FLIGHTS

The A310 Zero G left the Airbus production line in 1989. Operated for two years by the East german Interflug airline, it was bought by the German government and refitted to transport Chancellor Angela Merkel as well as other members of the German Government. It was then named 'Konrad Adenauer' in honour of the post-war German Chancellor.

PARABOLIC FLIGHTS: SPECIAL FEATURES

The aircraft was refurbished for parabolic flights from September 2014 to March 2015 by Lufthansa Technics in Hamburg. Most of the changes were made to the cabin. All seats have been removed along the twenty meters long front part of the cabin thus providing 100 m² of experimental area, which has been fitted with foam on all surfaces, LED ceiling lighting bars, solid hand rails, power supply panels and venting lines. The original seat tracks arrangement have been kept for the fixation of any experimental hardware on the floor. It offers a volume of 200 m³ (length 20 m, width 5 m, maximum height 2.25 m) for a wide range of microgravity experiments sizes and weights.
The upper stowage compartments have been removed and security nets have been added in the front and rear limits of the area (*figure 2*).

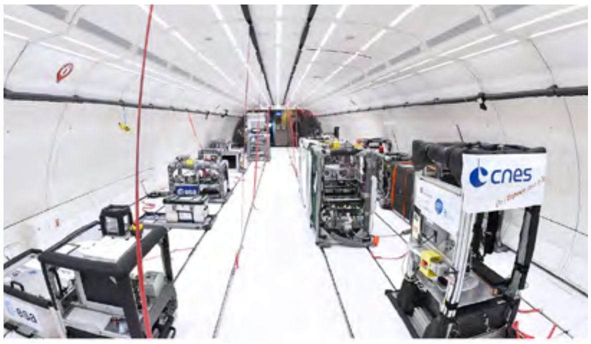


Figure 2: In the cabin of the Airbus A310 Zero G aircraft, all seats were removed along the 20 meters long front part of the cabin, thus providing the largest ZERO G aircraft experimental area in the world.

The rear part of the cabin offers the usual public transport aircraft configuration with about 50 seats installed on 7 rows.

ZERO G FLIGHT SPECIFIC EQUIPMENT AND MAINTENANCE

Passengers are seated during the take-off and landing. In addition to the standard safety equipment, each seat is equipped with a smoke protection hood. The aircraft structure, engines and systems were not modified. Special Flight instruments were developed and fitted to the cockpit to allow pilots to fly precise parabolic manoeuvres. Airbus defined a specific maintenance programme which was adapted to reflect the specific characteristics of parabolic flights.

ORGANISATONS OF THE FLIGHTS

Scientific flights are organised in standard campaigns over a two-week period each, and most of the time based in Bordeaux-Mérignac airport. But they may sometimes be organised from another airfield like in recent years from Frankfurt (Germany), from Dubendorf (Switzerland), or few months ago from Padenborn (Germany) where the campaign operations were possible with regards to the COVID-19 sanitary restrictions. The first week is dedicated to hardware assembly, checkout and installation in the aircraft. The second week is dedicated to flight operations. It starts with a safety visit followed by a safety briefing on the first day (Monday), followed on each of the three or four following days by a morning flight of 31 parabolas, a short post landing debriefing and the preparation for the next day. Each flight provides 12 minutes of cumulated weightlessness.

Discovery flights marketed under the brand 'Air Zero G' represent less than 10% of Novespace activity. They last one day. An optional diner where the passengers can meet the cabin crew is proposed the evening before the flight. The flight day includes the safety briefing, a 2-hour and 15 parabolas flight, a post-landing ceremony with a Certificate delivery to each passenger, a lunch cocktail and a spaceflight presentation of my 3 space shuttle missions. Twelve fixed cameras and three photo/video professionals take images all along the flight, available on line the same day.
All financial benefits from discovery flights are retroceded to space agencies in order to increase their space research activity.

MARS AND LUNAR GRAVITY FLIGHT

The technique used to fly parabolic manoeuvres can be easily adapted to reproduce a reduced non-zero gravity field in the cabin such as 0.16 g for Lunar and 0.37 g for Mars parabolas. Once in a while scientific campaigns are fully dedicated to such low gravity research. One Mars and two Moon gravity parabolas are flown at the beginning of all discovery flights.

SPECIAL DISCOVERY FLIGHTS

Among special customers of Novespace, we have seen: Universal studio for a movie with Tom Cruise, the company Big City Beats for a dancing party in Zero G similar to night-club in weightlessness, the company GH MUMM for a demonstration of the "Grand Cordon Stellar" the only bottle capable of serving Champagne in weightlessness, the company Orbital Views for an augmented Lunar or Zero gravity experience thanks to a virtual 3D-360 headset worn during the parabolas.
Novespace also organized a flight for disabled teenagers who enjoyed floating freely without feeling any legs handicap.

TAKE A LOOK INSIDE OUR AIRBUS A310 ZERO G FLIGHTS

Discover photos and videos of aviation and space fans, sport personalities, actors and top scientists working or floating in gravity-free conditions on board the Airbus A310 ZERO G: https://www.airzerog.com/fr *(figure 3)*

Figure 3: A view of weightless fans floating like a human wing around astronaut Jean-Francois Clervoy on board the Novespace's Airbus A310 Zero G. © Novespace.

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AMONG UPCOMING AEROSPACE EVENTS

2021

JANUARY

11-15 January – AIAA – **AIAA – AIAA SciTech Forum 2021** – Two-Week Virtual 2021 AIAA SciTech Forum – Accelerating Innovation through Diversity – https://www.aiaa.org/SciTech - https://www.aiaa.org/events

11-15 January – ECCOMAS – **ECCOMAS Congress2020 and 14th WCCM** – VIRTUAL CONGRESS DIGITAL VERSION – https://www.eccomas2020.org/frontal/

28 January **- 04** February – COSPAR-K – **COSPAR 2021** – 43rd Scientific Assembly on Space Research and Associated events - Initially programmed to be held on **15-23 August 2020** has been postponed to this new date – COSPAR-K A Free Space STEM Event - Thematic: Connecting space research for global impact – Sydney (Australia) – International Convention Centre – https://www.cospar2020.org – www.cospar2021.org/stem

FEBRUARY

03-07 February – Aero India – **13th Edition Aero India Air Show** – Ylahanka, Bengaluru – Air Force Station – www.aeroindia.gov.int

16-18 February – Saudi Arabia – **2nd Edition Saudi International Airshow** – Aviation, Aerospace, Defence and Space – Riyadh, KSA – Tumamah Airport - https://saudiairshow.aero

MARCH

09-11 March – CANSO/EUROCONTROL – **World ATM Congress** - Madrid (Spain) – IFEMA – Feria de Madrid – https://worldatmcongress.org – events@canso.org POSTPONED TO OCTOBER 2021

17-19 March – 3AF/ESA - SP 2020+1 – **SPACE PROPULSION 2021** – VIRTUAL CONFERENCE – 100% Digital Event – https://spacepropulsion2020.com

23-25 March – ESA/CNES/DLR – **ECSSMET2021 – 16th European Conference on Spacecraft Structures, Materials and Environment Testing** - Braunschweig (Germany) – Steigen Parkhotel Nime strasse 2 – https://www.ecssmet2021.de/

APRIL

06-09 April – ERCOFTAC – **EDRFCM2021** - European Drag reduction and Flow Control Meeting – Paris (France) – CNAM – https://www.ercoftac.org/events/

07-10 April – IndoAerospace – **INDO AEROSPACE 2021** - 9th Indo Aerospace Expo & Forum – Jakarta (Indonesia) – Jakarta International Expo Kemayoran – https://indoaerospace.com

12-14 April – 3AF – **55th International Conference on Applied Aerodynamics** - Poitiers (France) – ISAE-ENSMA – 86961 Futuroscope Chasseneuil – www.3af.fr – www.aerosociety.com/events/

12-16 April – EUROTURBO – ETC14 – **14th European Conference on Turbomachinery – Fluid Dynamics and Thermodynamicss** - Gdansk (Poland) – https://www.euroturbo.eu - https://www.euroturbo.eu/review-platform/index.php/ETC/14

13-21 April – ICAO – **ICAO DRONE ENABLE SYMPOSIUM 2021** – ON LINE – https://www/icao.int/Meetings/Pages/upcoming.aspx

19-22 April – CEAS/ESA – **2nd International Conference on High Speed Vehicle Science & Technology – HiSST** - Bruges (Belgium) – Oud Sint-Jan – https://atpi.eventsair.com/

21-24 April – AERO – **AEROFRIEDRICHSHAFEN** - Leading Show for General Aviation – AERO e-flight-expo - Friedrichshafen (Germany) – Airport – https://www.aero-expo.com/aero/en/index.php

26-30 April – IAA –**13th Symposium on Small Satellites for Earth Observation** – Berlin (Germany) – https://iaaspace.org/event/

MAY

09-14 May – ESA – **Space optic Instrumentation Design and Technology –** Course – Poltu Quatu (Italy) – https://atpi.eventsair.com/

12 May – RAeS – **Team Tempest – The Future Combat Aircraft –** Lecture 19:00 – 20:00 local time – VIRTUAL On Line via ZOOM – By Michael Christie, director Future Combat Aircraft, BAE Systems – RAeS/HQ – www.aerosociety.com/Events

17-21 May – ICAO – **HLSC2021 –** Third High-Level Safety Conference – Montréal (Canada) – ICAO/HQ – https://www.icao.int/Meetings/Pages/upcoming.aspx

18-20 May – NBAA/EBAA – **EBACE 2021 – European Business Aviation Conference & Exhibition** – Geneva (Switzerland) – Geneva's Palexpo – Geneva International Airport – https://ebace.aero/2021

31 May **- 02** June – State Research Center of the Russian Federation Elektropribor – **28th Saint Petersburg In-**

AMONG UPCOMING AEROSPACE EVENTS

ternational Conference on Integrated Navigation Systems - Saint Petersburg (Russia) – 30, Malaya Posaskaya – https://www.elektropribor.spb.ru/en - https://acanud.ru/en/events/list

JUNE

02-03 June – FSF – **BASS 2021** – Business Aviation Safety Seminar – Savannah (USA) – Svannah Convention Center – GA 31421 USA – https://flightsafety.org/event/bass-2021

07-11 June – AIAA – **2021 AIAA AVIATION Forum** – Washington, DC (USA) – Marriott Wardman Park Washington - https://www.aiaa.org/aviation

11-13 June – ICCIA – **ICCIA2021 - 6th International Conference on Computational Intelligence an Applications** – Xiamen (China) – Huaquio University – iccia@zhconf.ac.cn – www.iccia.org

15-17 June – 3AF/SEE – **ETTC'21 – European Test and Telemetry Conference 2021** – Toulouse (France) secr.exec@3af.fr

20-24 June – EUROMECH – **EFMTC2021** – European Fluid Mechanics and Turbulence Conference – Zurich (Switzerland) – https://euromech.org/

20-25 June – ESA/ICATT – **11th International ESA Conference on GNC and 8th Internal Conference on Astrodynamics Tools and Techniques** – Sopot (Poland) – Sheraton - https://atpi.eventsair.com/

21-27 June – GIFAS/IPAS – **International Paris Air Show** – Le Bourget (France) – CANCELLED – Next IPAS in 2023 - https://www.siae.fr

JULY

04-09 July – EUCASS/3AF – **EUCASS/3AF CONFERENCE** – Lille (France) – Grand Palais – https://www.eucass.eu/

11-16 July – EUROMECH – **10th European Nonlinear Oscillations Conference –** Lyon (France) – https://euromech.org/

AUGUST

09-11 August – AIAA – **AIAA Propulsion & Energy Forum –** Denver, CO (USA) – Sheraton Denver Downtour – https://www.aiaa.org/events-learning/Forums

23-26 August– EUROMECH – **ETC18 – 18th European Turbulence Conference** – Dublin (Ireland) – https://euromech.org/

SEPTEMBER

01-04 September – EASN – **11th EASN International Conference** – Salerno (Italy) – https://easnconference.eu

12-17 September – ICAS – **ICAS 2021 - 32nd Congress of the International Council of the Aeronautical Sciences** – Covering the World of Aeronautics – Kyoto Kyoto (Japan) – www.icas.org/Calendar.html - [PREVIOUS INFORMATION: Shanghai – Change due to COVID-19 situation]

OCTOBER

19-24 October – SeoulADEX – **Seoul International Aerospace & Defense Exhibition** – Seoul (South Korea) – Seoul Airport Seongnam Air Base – www.seouladex.com

25-29 October – IAF – **IAC 2021** – **72nd International Astronautical Congress** – Inspire, Innovate & Discover for the benefit of Mankind – Dubai (UAE) – https://www.iafastro.org/events/iac/iac-2021/

26-28 October – CANSO/EUROCONTROL – **World ATM Congress 2021 –** ATM congress and Exhibition - Madrid (Spain) – IFEMA Feria de Madrid – https://www.worldatmcongress.org

NOVEMBER

19-24 November – CEAS/PSAA – **AEC2021 – AEROSPACE EUROPE CONFERENCE 2021** – Warsaw (Poland) – Luksiewiez Research Network – Institute of Aviation – www.psaa.meil.pw.edu.pl