Clean Sky is the largest European research programme developing innovative, cutting-edge technology aimed at reducing CO2, gas emissions and noise levels produced by aircraft. Funded by the EU’s Horizon 2020 programme, Clean Sky contributes to strengthening European aero-industry collaboration, global leadership and competitiveness.
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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ADVANCING ENERGY TRANSITION IN AVIATION

Aviation represents today between 2 and 3% of CO₂ emissions at worldwide scale, but to only maintain this level, it is mandatory to accelerate innovation in energy transition because of the 5% per year traffic growth which is foreseen in the coming years.

It is to be reminded that as soon as 2000, the European Commission had been a pioneer in matters of environmental impact by setting up the Advisory Council for Aeronautics Research in Europe (ACARE) whose the works resulted in the important report edited in 2001: ‘European Aeronautics: a Vision for 2020’. This was the commencement of Clean Sky. In the continuity of the successful achievements of Clean Sky 1, Clean Sky 2 was launched in 2014 as part of the European Commission’s ‘HORIZON EUROPE 2020’ programme, with the aim to reach the ‘Flightpath 2050’ goals, notably: 75% reduction of carbon dioxide CO₂ emissions; 90% reduction in mono-nitrogen oxides NOx. And then Clean Sky 3, whose budget is to be voted in the end of 2019, will cover the period 2021-2027, will allow to continue and amplify the remarkable works achieved so far.

Besides in addition to research and trials of new more efficient aircraft designs and new more efficient propulsion systems, other ways are offering promising perspectives among which: alternative fuels, routing optimisation and more electrical aircraft.

In the near term, the use of biofuels will allow aviation improve its environmental sustainability and reduce its carbon footprint. Considerable fuel is wasted due to inefficient routing. So, by shortening flight distances thanks to optimised ATM, using satellite navigation systems, it would be possible to reduce fuel consumption by up to 10%.

The dream is the 100% electrical airliner is not realisable yet, this is the reason why the motto of the profession is simply for the time being: “More Electrical Aircraft”. From decades, the electrification of non propelling elements is regularly progressing: auxiliary power units, landing gears, de-icing, air conditioning, taxiing. Other hopes are all electric small drones capable of transporting 200-300 kg payloads between airport zones.

The ‘New Mobility Vehicles’ are also offering new perspectives: the electrical small vehicles E-VTOL (Vertical Take Off and Landing) for passengers and freight transportation and the flying taxis like the Nexus developed by Bell Helicopter for which Safran provides its new electrical serie ‘Ingenius’.

The hybrid solution consisting in mixing thermal and electric propulsions is quite a promising step. Here Airbus shows its ambitions with its E-Fan technology demonstrator the first test flight of which is expected in 2021. In 2025 fixed wing 10-20 passenger hybrid propulsion regional shuttles could be envisioned.

What could happen next? In 2040 a short-medium range 40 passengers regional all electrical aircraft, and later ... after 2050, an all electric 100- passenger airliner? This brief enumeration gives an idea about the broad field of technology challenges our European scientists and engineers will take up, bringing so an eminent contribution to energy transition in aviation and to the fight against climate change.
PRESIDENT’S MESSAGE

Zdobyslaw Goraj
CEAS President

TOWARDS AEC2020 CONFERENCE
(BORDEAUX, 25-28 FEB, 2020)

Abstract submission platform was opened at beginning of April and will be closed on July 31st. In order to assess the advancement of AEC2020 preparation, a meeting was hold on 18 June in Le Bourget, bringing together CEAS officers, Past Presidents and Presidents of DGLR, 3AF and RAeS, and members of AEC2020 Steering Committee. This meeting took place at Hotel Marriot Le Bourget Airport on the Panoramic Terrace (9th floor) which offered a wonderful view on Le Bourget Air Show. Dominique Nouailhas, in charge of AEC2020’s organisation within 3AF presented the progress report, underlining the major objective of the Conference: to bring together the aeronautics and space communities around the common and central subject: “How to achieve a cleaner and greener environment?” It is expected that the delegates will be provided with presentations of most advanced technologies and of the views about the future of aviation and space vehicles and systems. She concluded saying that so far the preparation is progressing well.

Selected CEAS executives got another interesting occasion for networking and discussing of important challenges CEAS is facing on. Patrick Daher, Commissaire Général du Salon du Bourget, and David Cook FRAeS, President of the Paris Branch of the Royal Aeronautical Society invited us for a Breakfast Reception on Wednesday 19 June 2019, at the SIAE chalet N 230. Among different topics of discussions there were issues devoted to CEAS PR and visibility and mutual relations between CEAS and RAeS. Both sides confirmed their strong interest to keep good relations and to strengthen future involvement in different scientific events. RAeS is one of the biggest European Aerospace Societies and for CEAS - composed of a few smaller Societies also – our cooperation and join activity is absolutely crucial.

During this networking Breakfast Reception a number of students were awarded for their academic achievements, see Photo 2.

FIGHTING FOR WIDER CEAS VISIBILITY IN EUROPE

CEAS, established 25 years ago, is an International Non-Profit Association, with the aim to be Europe’s foremost aeronautics & space community (Aerospace Europe) to further the advancement of aerospace sciences and engineering. Today, CEAS comprises 12 national member societies all across Europe with an outreach to roughly 35,000 professionals in aerospace. four corporate members (EASA, ESA, EUROCONTROL and EUROAVIA), and 7 partnering organizations are valuable partners in achieving our goals.

CEAS, as the obvious European focal point for fostering knowledge dissemination in aerospace, will organise its seventh biennial large scale European Air & Space event.
Aerospace Europe, being the new label for our event, will be a unique opportunity for aerospace industries, academia, organizations and associations to communicate, share and debate innovative concepts and technical solutions in the aerospace domain. The event aims at increasing European competitiveness in the field of aerospace by providing unique networking opportunities to its delegates.

In our dissemination activity, supporting European Institutions and organizing conferences, CEAS is not the only stakeholder (EUCASS, EASN, Air and Space Academy just to mention the biggest players). In the past we very often took initiatives to act together to fight against the fragmentation of this important segment of European research supporting and dissemination. However, there is still far away from harmonic collaboration and understanding. During the last Aerodays 2019 in Bucharest, CEAS had not been invited to participate. I deeply regret that: as a matter of fact, CEAS is the Pan-European Association representing more than 35,000 aerospace engineers and technicians, which in addition to the conferences it organises, publishes two scientific journals - the CEAS Aeronautical Journal and the CEAS Space Journal – as well as the quarterly AEROSPACE EUROPE Bulletin. I am all the more disappointed that certain not-European Aeronautics and Astronautics Associations had got invitations for keynote lectures, among others: American, Canadian and Chinese.

I asked in due time by official letter Mrs Clara de la Torre, Director Responsible for Aerodays organisation in Bucharest, for benefitting of invitations, but I unfortunately received a negative answer.

So, may I ask the following question: “Does Europe need CEAS?”

It is our deep conviction that “For sure it does”.

So, this episode demonstrates that hard work CEAS has still to be done to increase our visibility by improving more and more the quality of our achievements, but also by establishing reliable links with new friends and supporters.
INTERVIEW WITH AXEL KREIN, EXECUTIVE DIRECTOR OF CLEAN SKY

By Jean-Pierre Sanfourche, Editor-in-Chief

BIOGRAPHY

As of February 1st, 2019, Axel Krein is Executive Director of Clean Sky 2, the Public-Private-Partnership Program in European aeronautics.

From September 2014 to January 2019, Axel Krein headed the Cyber Security Program Directorate at Airbus Group. His responsibilities included the definition of the Group’s cyber protection strategy as well as the program management of the Group’s cyber security improvement projects. He also steered Airbus Group’s cyber security research & innovation agenda.

In 2007, Axel Krein was appointed Senior Vice President Research & Technology at Airbus. He led Research & Technology from strategy definition to programme management for all research activities. This also included partnership management, business development and intellectual property.

Prior to 2007, Axel held the position of Senior Vice President Strategic Development at Airbus. In this role he oversaw the development of strategies for Airbus’ strategic countries and business intelligence. Axel also led the definition of Airbus’ industrial strategy for Russia and the related negotiations with the Russian industrial and governmental stakeholders.

From 2000 to 2004, Axel was Senior Vice President and Chief Information Officer at Airbus. He led the organisation responsible for application development, application maintenance and information systems infrastructure through the integration of the four national Airbus companies into the integrated Airbus entity.

Axel joined Airbus in Hamburg in 1992 and held various positions in the Engineering Division including Future Projects and Standardisation and Engineering Methods & Support, before being appointed Vice President Information Services at Airbus Industrie in Toulouse in 1999.

Before joining Airbus, Axel was Managing Director of a transport company and worked in air traffic control in the German Airforce.

Axel holds a Masters in Mechanical Engineering/Aerospace Engineering from the Technical University of Aachen and worked at the university in the field of hypersonic space transportation.

• The two-day event in April reflected on Clean Sky 2’s results so far: could you summarise the key messages which have emerged from this event?

Answer - The two-day event in April reflected on Clean Sky 2’s results to date and discussed the future of our Joint Undertaking. We brought together Clean Sky’s stakeholders – the European aeronautics industry leaders, SMEs, universities, research centres and European institutions – to share their points of view about the programme to date. We also dived deeper into some of Clean Sky 2’s innovative projects, with partners giving us a first-hand account of the expertise and collaboration that is making their research possible. Additionally, we also looked ahead to how we see a future European aeronautics partnership within Horizon Europe.

I am really grateful to everyone who participated in the event – we learned a lot from each other over the two days.

• We are now at mid-term evaluation of Clean Sky 2: What is your general feeling about the main new innovations achieved so far? What are your wishes and directives for the management of the end of this FP8: proposal selection, priority holder research subjects, new participants to be involved (among others academic research actors), approach to partnerships (accentuation of PPP policy) ...

Answer – Clean Sky received very positive feedback from the mid-term evaluation – you can take a look at the report on our website. It included a few recommendations that are being factored in during the next steps of the programme.

Concerning the innovations achieved so far, it is very gratifying to see that halfway through the Clean Sky 2 programme, we are delivering cutting-edge results for greener aviation in fields like propulsion, systems, aerostuctures, aerodynamics and overall aircraft configuration. These technologies are targeted for integration into global airline and operator fleets in the two next decades. In aviator terminology, we are at top-of-climb!

On the subject of new participants, it is a continuous objective of Clean Sky to be as inclusive as possible and bring new competent partners on board from as many European countries as possible. The current numbers already speak for themselves: following our most recent Call for Proposals, we have over 800 unique entities involved in Clean Sky 2, from 28 different countries, representing the whole European aeronautics sector: industry members, SMEs, research centres and universities. This strong collaborative effort is crucial if we are to achieve our ambitious environmental goals.
The next big thing is the preparation of FP9 “HORIZON EUROPE” which is a fundamental enabler to realise ACARE Flightpath 2050 objectives. What are the main milestones of the roadmap you have in mind to conduct this ambitious strategic programme, with its three main components: optimised energy aircraft, enablers supporting the connected and autonomous aircraft, aeronautics industry 4.0?

**Answer** – In short, in order to reach the ACARE Flightpath 2050 objectives, a future European aeronautics partnership must develop very focused, highly ambitious, and high-impact technological innovations. These innovations need to be matured and demonstrated very quickly in order to ensure their rapid implementation into products, which can be successfully introduced into the world market. Only by quickly penetrating the world market with eco-efficient technological innovations developed via Clean Sky and other initiatives, will Europe be able to face the environmental challenges specifically related to CO2 emissions.

To do this, we will certainly need to involve European institutions and all current Clean Sky stakeholders, as well as other highly-skilled European partners who are not yet part of our journey, but who have the expertise needed to reach our common goal!

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**Do you plan to increase the Clean Sky staff?**

**Answer** – Clean Sky 2 is running up to 2024 with a peak workload from 2019 to 2023. The technical work under the new partnership within Horizon Europe will start in 2021, so that we will have a few years of overlapping between the two programmes. By the beginning of next year, we will have completed the high-level definition of the technical work and the description of the main operating principles for the new partnership programme, both of which will determine the required budget and the skilled team to match the ambition!

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**Do you plan to reinforce your working links with other European institutions: SESAR JU, EUROCONTROL, EASA, ... ?**

**Answer** – We all share the same goal of a greener, more efficient European aviation system, so not only does it make sense to work together, but it is even mandatory to complement each other’s work for a sustainable aviation system. For example, we have engaged in an on-going dialogue with SESAR, with which we have signed and implemented a Memorandum of Cooperation. Regarding EASA, Clean Sky will involve them much more closely in the future in our technology development process, in order to benefit from their expertise and experience. Finally, we also need to consider the wider aviation infrastructure: air traffic control, airports and MROs will have to be connected to our work, as the ultimate aim is the integration of Clean Sky technologies into service.

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**What are your three priorities for the next coming months?**

**Answer** – 1. Work together with all stakeholders in order to develop the new aviation partnership programme, Clean Sky 3, with regard to the technical content as well as the appropriate operating principles 2. Deliver in line with the committed Clean Sky 2 milestones and communicate the results to the wider stakeholdership 3. Increase the effectiveness and efficiency of the Joint Undertaking organisation

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**Discover Clean Sky 2 results here:** [https://www.cleansky.eu/zoom-in-on-clean-sky-2-results](https://www.cleansky.eu/zoom-in-on-clean-sky-2-results)

**Stay up to date with Clean Sky’s news and events on** [www.cleansky.eu](http://www.cleansky.eu)

Photo of Airbus’s first flight test of the BLADE demonstrator (BLADE: Breakthrough Laminar Aircraft Demonstrator in Europe). BLADE is part of Clean Sky’s Smart Fixed Wings Aircraft programme within the EU’s Horizon 2020 Research & Innovation vision. It is the first test aircraft combining a transonic laminar wing profile with a standard aircraft internal primary structure. The demonstrator aims at bringing about a 50% reduction of wing friction and up to 5% lower CO₂ emissions. ©Airbus 2017. Photo by S. Ramadier

CS2: Tackling Key Environmental Challenges

Environmental Objectives*
- CO₂
  -20% to -30%
- NOₓ
  -20% to -30%

* vs today’s best aircraft

CS2: An Integrated Programmatic Approach

Innovative Aircraft Demonstrator Platforms (IADPs)

Integrated Technology Demonstrators (ITDs)

Transverse Activities (TA)
Safran Aircraft Engines is actively preparing the future of propulsion for next-generation short and medium range aircraft and is working at reducing the environmental footprint of aviation. Open Rotors are the most promising engine architectures to address the ambitious objectives set by ACARE to reduce pollutant & CO2 emissions. Open Rotors combine the ability to maximize the propulsive efficiency while keeping a high-speed cruise capability. This high potential motivated Safran major research investment from advanced concepts to a full-scale demonstrator tested for more than 6 month in 2017. The operation of the SAGE2 demonstrator confirmed the robustness of operation of such a disruptive layout, while enabling to explore the full scope of ground level static domain, enforcing confidence in the architecture potential.

OPEN ROTOR BENEFITS

Nowadays, the aviation represents about 3% of the global anthropogenic carbon dioxide emissions. Given the air transport growth close to 5% a year [1], it is necessary to further reduce fuel consumption, CO2, NOx and particles emissions. Reducing the environmental footprint of aviation is the target of the ACARE goals (Figure 1).

Safran Aircraft Engines is supporting these environmental objectives through the identification and development of new technologies for future CFM® engines. For Safran Aircraft Engines, the Open Rotor configuration remains one of the best candidates for a significant reduction in CO2 emissions.

The two spool turbofan configuration has experienced multiple and significant improvements allowing to reduce fuel consumption by half between 1960 and 2016 for short-medium range (SMR) aircraft. About 80% of this benefit is achieved by enhancing the propulsion efficiency through an increase of engines By-Pass Ratio (BPR). In this way, CFM International, a 50-50 joint-own company of Safran Aircraft Engines and General Electric, has chosen for the development of its first engine family, CFM56® generation, a BPR of 6 compared to a BPR of 1 for the in-service engines of that time. A BPR of 11 has been selected for the new Leap® generation thanks to progresses in lightweight materials and aerodynamics. The Open Rotor engines family, including the Counter-Rotating Open Rotor (CROR) engine, pushes the search of high by-pass ratio at its maximum, getting rid of duc-
ted turbofan limits. The objectives are to maximize propulsion efficiency with a low fan compression ratio, to reduce drag and weight penalty of the engine by removing outer nacelles and to reduce losses in the secondary flow path [2][3].

**FIRST OPEN ROTOR TESTS**
CROR investigations first turned out to reality through comprehensive design studies and test campaigns held in the 1980s, before the lack of market opportunities for such a disruptive concept put a halt to the related investigations [4].

Significant maturation was achieved during this timeframe, on both direct drive and geared pusher CROR configurations, from design to ground and flight testing, as summarized on Figure 2.

Interest towards CROR configurations was revived in the 2000s as it is still the most fuel-efficient architecture. However, it brings new challenges in a context of ever stricter noise and CO2 emission standards.

**SAFRAN AIRCRAFT ENGINES’ DEMONSTRATION PLAN** (see Figure 3)
After comprehensive preliminary design studies enabling the down-selection of a preferred engine architecture based on geared CROR, efforts focused on major risks mitigation. Between 2006 and 2012, the optimization of the architecture, first numerically and then by subscale wind tunnel testing, aimed at finding the best aero-acoustic compromise. Thus, it has been demonstrated that an aircraft equipped with this kind of engine can be certified according to the current noise regulations (ICAO chapter 14) while allowing a 15% reduction in fuel consumption on mission compared to LEAP® engines.

After increasing confidence in the overall potential of the architecture, Safran Aircraft Engines took the decision to go into a full-scale demonstration enabling to increase confidence in whole propulsor design, behaviour, control and integration in representative ground conditions.

This project was made possible thanks to the European CleanSky program, which aims to support the development of innovative technologies for a more environmental-friendly aviation. With a total budget of around €200 million, the project involved hundreds of people in several Safran entities and European partners, from 2008 to the end of 2017. It ended with the success of the test campaign.

**THE OPEN ROTOR SAGE2 ENGINE**
The SAGE2 Engine, integrated by Safran Aircraft Engines, is a pusher, geared Counter-Rotating Open Rotor and is made of a gas generator aerodynamically linked via a power turbine to two counter-rotating propellers (see Figure 4).

The power turbine, mechanically free from the gas generator, drives the two propeller modules via a differential gear box. The gas generator is derived from a Safran Aircraft Engines M88 military engine. It was selected because it met the needs for power and operability while being very robust and available as an «off-the-shelf» engine.

Font and aft propeller modules integrate respectively 12 and 10 3D woven carbon fibre composite blades. They both integrate a pitch control mechanism, rotating frames and cowls.

The engine is controlled via an advanced Multi Input Multi Output (MIMO) control system acting on gas generator power and both propeller modules speeds. Specially developed for this project, it tackles the high couplings between these three parameters (see Figure 5).

**GROUND TEST FACILITY**
The SAGE2 engine was installed on a new test bench in March 2017, at Safran Aircraft Engines’ flight test facilities in Istres, south of France (see Figure 6). Both engine and bench were highly instrumented to allow the monitoring of the engine, its safe operation during the campaign and to carry out engineering tests.

*Figure 3 - Sage2 project timeline*
The first engine start took place on May 30, 2017 and the test campaign ended on December 14, 2017 after approximately 70 hours of operation and the completion of the entire test program.

The campaign was divided into two main phases, in order to reduce the risks associated with testing a new engine. The first phase was dedicated to the nominal engine operating line exploration at steady state and to the checking of every safety and fallback manoeuvres. The second phase was dedicated to engineering tests and engine’s operating limits exploration.

Figure 7 below shows the engine nominal operating line and nominal points (Ground Idle Feather, Ground Idle (GI), Flight Idle (FI), Max Climb (MCL) and Take Off (T/O)). Figure 8 gives an example of the propeller domain exploration around the nominal points.

The following tests were carried out.

During phase 1:
• Cranks: to validate communication between the bench and the engine
• Start and GI feather: first rotations of the engine
• Acceleration to GI unfeather: first speed increase of the propeller
• Acceleration to FI: first power increase of the gas generator and first activation of the Multi Input Multi Output control system
• Increase to MCL and T/O

During phase 2:
• PGB mapping: influence parameters on PGB behaviour evaluation
• Propeller domain exploration: Propeller operating limits and behaviour
• Fast transient
• Cross wind: impact of the wind on engine and propeller behaviour
• Vibe survey: Propulsor behaviour under additional unbalanced
• Reverse: transition to reverse mode and reverse thrust capability

Main test results
The SAGE2 results have proven that this architecture complexity is manageable with measured performance, in line with theoretical analysis. The engine showed a very good dynamic and thermal behaviour, therefore validating the integration of embedded technologies such as the gearbox, propellers, pitch control mechanism system and engine control system.

The main challenges related to thermal and engine dynamics come from the integration of the gearbox and the two large diameter rotors. The dynamic behaviour, monitored during the whole test campaign, gave excellent results.

Technologies integrated on Sage2 for cooling and lubrication of the gearbox and bearings have demonstrated good performance. Influence tests on the gearbox, lubrication and ventilation have been carried out to refine the models used during design.

The Multi Input Multi Output control system allowed safe and stable engine operations throughout the campaign, regardless of the power required by the propellers. Low sensitivity to external disturbances, such as crosswind,
has been demonstrated and several engineering tests have been performed to validate the robustness of this technology. The pitch control system, necessary for propeller control, operated as expected in stabilized and transient conditions with expected pitch accuracy and response time. This overall very good engine behaviour allowed extensive test and exploration to validate the predicted propellers operating areas. Propeller operating limits and the behaviour of rotors close to these limits have been validated. Transition to reverse and correct operation of the engine in reverse mode have also been validated. Although challenges remain at the end of these tests, particularly regarding the integration of this type of engine on tomorrow’s aircraft, this project is a real success with the completion test program and the demonstration of the robustness of this architecture. Moreover, several of the embarked technologies can be transposed to other architectures that Safran Aircraft Engines is considering for future engine generations.

This project enabled Safran Aircraft Engines to acquire Open Rotor engineering know-how from design to tests. Rewarded by the ‘2018 success award’ attributed by 3AF and by the Aviation Week’s 2019 Commercial Propulsion Award, this demonstrator exceeded the expectations of many aeronautics industry players. Safran Aircraft Engines is now able to fully confirm the potential of the Open Rotor for future engines.

REFERENCES


Over the past decades, all stakeholders in the European Union have managed to develop a flourishing aviation sector and a competitive aeronautics industry that significantly contribute to the European economic welfare, societal inclusion and scientific excellence. As per Flight-path 2050, the European Sector’s vision for Aviation, the European Union must maintain its global leadership and address its citizens’ mobility and security needs, while continuing to be at the forefront of the climate change challenge in line with COP21 objectives. Therefore, to keep a leading position in a highly competitive world, European stakeholders in aviation must be able to im-
pulse and drive bath incremental and disruptive innovation, and sustain its Research and Technology (R&T) excellence.

JOINT STATEMENT

EASN (European Aeronautics Science Network), EREA (Association of European Research Establishments in Aeronautics) and ASD (AeroSpace and Defence Industries Association of Europe) have decided to speak with a common voice and join their forces to:

- guarantee the full coherence of research and innovation actions across the aeronautics sector;
- create synergies between research and innovation initiatives driven by other sectors;
- deliver the most compelling technologies, products and systems.

The three associations believe that a renewed effort for Research and Innovation (R&I) including an ambitious Innovation impulse will be necessary to provide affordable and higher mobility for citizens while facing present and future challenges, such as safety and environmental challenges, despite a huge expected air traffic increase and growing (cyber) security risks.

The associations believe that a dedicated and renewed Research and Innovation aeronautics programme is required to cope with the specificities of the sector. Such a programme should come with a dedicated and significantly increased public and private R&I budget for aeronautics, which is crucial to face the challenges lying ahead and to foster competitiveness of the sector at the European and international level. Public funding should be delivered through grants to cope with the long terms cycles and the huge investments needed in the sector.

JOINT RESEARCH APPROACH

In the context of the preparation of the next Framework Programme and willing to bring a common contribution and reinforce European Research, Technology and Innovation capability, EASN, EREA and ASD would like to propose a joint approach to foster coherence and coordination of Research and Innovation actions across the aeronautics sector.

This R&I European aeronautics programme should address the entire R&I scope (all Technology Readiness levels (TRLs)) in a strong and coordinated manner, fostering collaborative research among the whole EU community, with an adequate balance between top-down and bottom-up research.

The intent is to approach the aeronautics research in Horizon Europe (FP9) by three investigation streams:

- **Explore**: Innovative and disruptive technology exploration,
- **Mature**: Technology maturation, partial integration or technology benchmark and potential benefit evaluation,
- **Demonstrate**: Representative context demonstration for performance assessment and social and market acceptance.

Integrating bottom up collaborative research and top-down high TRL research under the same organizational umbrella would foster a seamless approach and ensure that provided results from bottom-up research would feed easily into the high-TRL activities.

In that respect, ASD, EREA and EASN propose to enlarge the scope of activity of the future Aeronautics Research Partnership or any other Initiative (succession of Clean Sky), with adapted organizations, governance and associated budgets to optimize the tailored use of public and private funding.

Specific streams would be elaborated:

A **bottom-up collaborative research**, basic/applied research driven and research/science led involving all stakeholders.

A **top-down high-TRL research** similar to the existing JU (that could be based on article 187 of the TFEU and known as Joint Undertaking JU), demonstration-driven and industry led.

CONCLUSION

Reaching the desired impacts on European citizens’ life, even beyond the Flightpath 2050 ambitious objectives and goals, will require an increased R&I effort at all levels to enable breakthrough innovation including the emergence and de-risking of disruptive technologies.

A continuous funding support is mandatory from both the European Commission and the industrial sector, characterized by long lead cycles and high up-front investments associated with high levels of safety, reliability and demanding certification processes.

EREAS, EASN and ASD are fully committed to achieving these ambitious goals, which require a dedicated and increased R&I budget, via grants. This joint engagement is crucial to make European aviation safer, greener and to keep its competitiveness over the next decades.

« Europe for Aviation » was the theme around which European aviation organisations working to implement the Single European Sky (SES) gathered at the World ATM Congress which took place in Madrid on 12-14 March 2019. The “Europe for Aviation” stand and theatre hosted a wide range of debates, presentations and guided walking tours, Single European Sky Awards, illustrating the collaboration in action between European organisations working to implement SES, namely the European Commission, EUROCONTROL, SESAR JU, SESAR Deployment Manager (SDM), the European Aviation Safety Agency (EASA), the European defence Agency (EDA), Innovation and Networks Executive Agency (INEA), and EUROCAE. Highlights included:

✓ 8,000 visitors from around the world, including 253 exhibitors and more than 200 speakers;
✓ 16 walking tours, as well as one dedicated to press and one to representatives from DG MOVE and FAA, with some 100 presentations, promoting SESAR members activities across the SESAR 2020 and SESAR deployment programme;
✓ 15 sessions in which SESAR JU presented its work in areas of U-space, civil-military collaboration, global interoperability, CNS, exploratory research, among others;
✓ 1 virtual reality tool on seamless data exchange in the ATM;
✓ 1 SESAR winner in the Jane’s awards, the exploratory research project COCTA (COordinating Capacity orde ring and Trajectory pricing for better performing ATM).
✓ Numerous announcements by SESAR JU members and partners on important milestones including:
  • First FAN-C equipped A320 aircraft to Easyjet – an important piece of kit to demonstrate SESARi4D for more predictable flights and ATM;
  • Update on preparation of live U-space/SESAR trials in the Gulf of Finland;
✓ 300 distributed SESAR Solution Catalogues 2019, Airspace Architecture Study, as well as many more publications.

The Status of SESAR R&D in 2019

The SESAR Joint Undertaking has published the third edition of the SESAR Solution Catalogue just in time for the recent World ATM Congress (Madrid, 12-14 March 2019).

This catalogue is the result of strong collaboration between the public-private-partners that make up the SESAR JU. Together the SESAR JU partners have created a SESAR innovation pipeline through which concepts are transformed into tangible solutions. The pipeline is composed of 85 research projects and demonstrators, more than 50 test sites and is staffed by 2,500 researchers, controllers, pilots and engineers from across Europe. All that R&D is carried out in a cooperative and integrated manner following the vision of the ATM Master Plan, which is the fundamental planning tool for ATL modernisation, and in support of the Single European Sky (SES) and the EU Aviation Strategy.
The SESAR Solution Catalogue 3rd edition (2019) provides a holistic view of the status of SESAR R&D in 2019 and offers solutions to a number of pressing challenges presently facing European aviation. It covers the results of SESAR 1, the first R&D programme: more than 60 solutions, many of which are in the process of deployment at local and European levels. Then it presents details of the ongoing R&D (candidate solutions) as we reach midway in the current programme SESAR 2020. Finally the catalogue gives a flavour of some of the promising results coming out of the SESAR’s dedicated exploratory research programme.

**SESAR Solutions Explained**

SESAR solutions refer to new or improved operational procedures or technologies that aim at contributing to the modernisation of the European and global ATM system. Each solution includes a range of documentation, including:

- Operational services and environment descriptions;
- Safety, performance and interoperability requirements;
- Technical specifications;
- Regulatory recommendations;
- Safety and Security assessments;
- Human and environmental performance reports.

**A RELEASE PROCESS**

To deliver solutions for deployment, the SESAR JU and its members have built a ‘Release Process’ whereby solutions are tested or validated in real operational environments including direct airport interfaces. With validation sites across Europe, R&D is taken out of the lab and connected with the real world. Validations take place in simulation platforms, on board commercial flights, dedicated airport test beds and air traffic control centres. Exercises are not limited to a specific location but can be used to test multiple environments irrespective of the location where the physical validation is held.

**Three Latest Solutions**

- **REMOTELY-PROVIDED AIR TRAFFIC SERVICES FOR MULTIPLE AERODROMES**

  The cost of providing air traffic services are high and need to be reduced, especially at low and medium density airports. Control towers are relatively expensive to build and maintain, but the services they provide can be vital to rural and regional communities. Since the first remote tower services gained certification in 2015 in Sweden, several projects have been launched – including some which envisage a controller maintaining situational awareness for more than one airport at a time. SESAR has already delivered a solution enabling remote tower service provision to two low-density airports and basing on this, the latest SESAR research aims to test the feasibility of multi remote tower operations in airports with high traffic volumes.

  In order to enable more airports, or high traffic volume, to be controlled simultaneously from a multiple remote tower module, the work aims to validate advanced features of the visual information displayed to controllers and to integrate additional voice services in the module.

- **ENHANCED AIRBORNE COLLISION AVOIDANCE FOR COMMERCIAL AIR TRANSPORT NORMAL OPERATIONS-ACAS Xa**

  Airborne collision avoidance systems (ACAS) currently receive information only from Mode C/S interrogations, yet there are other surveillance sources available, such as the more accurate ADS-B, which could enhance this safety layer. In addition, the performance of collision avoidance can be improved by updating the mathematical processes and modelling used in today’s traffic alert and collision avoidance systems (TCAS).

  Both these improvements form part of the ACAS XA being designed for commercial with the aim of delivering the next generation TCAS beginning in the 2020-2023 timeframe. By introducing additional surveillance data and optimised resolution advisories, ACAS Xa is expected to improve on today’s system without changing the cockpit interface, i.e. using the same alerts and presentation. It forms part of ACAS X, a series of systems being developed for different users. ACAS Xa implements the surveillance improvement through the surveillance and tracking module (STM) which processes the raw surveillance data coming from the surveillance sensors. Meanwhile the resolution advisory improvement is dealt with by the threat resolution module (TRM), which uses the estimated intruder parameters provided by the STM to choose an appropriate avoidance manoeuvre, if necessary.

  **Benefit:** Enhanced safety

- **FLIGHT OBJECT OPERABILITY**

  Today each ASNP relies on data contained in their respective systems to predict aircraft trajectory for their portion of airspace, with no synchronised view of the trajectory nor the factors that may constrain it. This is where SESAR’s IOP or initial ground-ground interoperability comes in.
The candidate solution
The candidate solution allows controllers to conduct silent coordination between adjacent units. In this way, all concerned air traffic control units hold in a consistent view of the flight at all times, which supports seamless cross-border operations, including cross-border free route operations.

Through continuous exchange of up-to-date and consistent trajectory information between all units, the solution enables more efficient operations, from tactical planning and complexity management, to early conflict detection and arrival management. Work is ongoing in SESAR to validate and update the EROCAE’s ED-133 flight object interoperability specification, the standard behind being ground-ground interoperability (IOP), which defines the system-to-system interfaces between different flight data processing systems (FDPS). It will truly seamless navigation across borders in Europe, allowing controllers to coordinate with counterparts in neighbouring ACCs in the same way as they would with colleagues seated next to them. The solution is also part of the PCP, with synchronised deployment across Europe and entry into operation as of 1 January 2025.

Five benefits: (i) Increased cost efficiency; (ii) Enhanced security; (iii) Enhanced safety; (iv) Enhanced predictability; (v) Reduced fuel consumption and emissions.

Solutions' interactive wall

Access SESAR interactive wall to interact with the SESAR-enabled air traffic management system of the future. By clicking on the "wall", you zoom into different parts of the system to check out the innovative digital solutions developed and delivered so far, as well as the deployment activities underway across Europe.

Synthesis written by J.-P. S. on the basis of information available on: www.sesarju.eu/
COMMANDER EATC’S MESSAGE

« EATC looks back at nearly ten years of experience in the air transport, air-to-air refuelling and medical evacuation domains. Today we stand for one of the most successful multinational military cooperation in Europe: our performance is confirmed by our member nations who increasingly pool and share EATC’s complete and diverse fleet of 170 assets representing 34 types of aircraft.

EATC is a dynamic and innovative command that relishes the trust and confidence of its seven member nations. Why is that so? Because …
...EATC acts at any moment multinational;
...EATC is a 24/7 operational command with a diverse and complete fleet;
...EATC offers excellence, proficiency and experience through an integrated staff of 200 experts.

And because we are constantly listening to the needs of our member nations and satisfying their particularities, sharing common ideas, planning for the future as well as dealing effectively and efficiently with many challenges.»

DUTCH AND FRENCH MINISTERS OF DEFENCE VISITED EATC

On Monday 6 May 2019, the Minister of Defence of the Netherlands, Ank Bijleveld-Schouten and the Minister for the French Armed Forces, Florence Parly, were warmly welcomed by the EATC Commander, Major General Laurent Marboeuf.

Major General Marboeuf presented EATC’s business model and outlook into the future. He then guided the ministers on an interactive and dynamic tour through the headquarters. Experts informed the ministers on the operational processes, showcased the successes of the medical evacuations and introduced them to EATC’s functional domain. Mrs Bijleveld-Schouten and Mrs Parly also visited EATC’s “Mission Control”, where EATC’s worldwide flight activities are monitored on a 24/7 basis. Both ministers highlighted EATC’s recognized success in the European defense domain and congratulated on the excellent cooperation among the partners, as well as the important trust and confidence that EATC gained from its member nations. The ministers endorsed the importance to comply with harmonised procedures and common regulations. They support any opportunity to achieve more by working closely together.

At the end of the visit, Mrs Bijleveld-Schouten and Mrs Parly met with representatives of the respective Dutch and French contingent at EATC.

EATC AND THE MMU SIGN A WORKING AGREEMENT

On 16 April 2019, Major General Marboeuf, Commander EATC, and Colonel van der Biezen, Commander MMU, signed a working agreement regarding the joint optimisation and cooperation in the operational and functional domains of the A330 MRTT aircraft. The MMF and EATC will closely work together, both in operational and functional domains. They aim to enhance synergies and interoperability, facilitate common action and contribute to the best use of respective resources. The signature confirms the two partners’ intent to achieve an efficient European air-to-air refuelling, air transport and aeromedical evacuation capability. In due time the Commander EATC will receive operational control of the first MRTTs. Thus EATC will provide planning, tasking and mission control of this significant A330 MRTT fleet.

The signature of this working agreement is the starting point of a fruitful cooperation between the two entities and
prepares the way for the MMU to become the first multinational force provider to EATCs’ capabilities portfolio. The EATC and the MMU are both based at the Eindhoven airbase. The airbase has developed into a center of international cooperation in air transport with the EATC, the MMU and the MCCE located on its premises.

**NATO/EU MILITARY REPRESENTATIVES VISIT EATC**

On Tuesday 4th June 2019, for the first time, all NATO/EU Military Representatives from the seven member nations were visiting the EATC.

Major General Marboeuf, EATC Commander, presented EATC’s business model and outlook into the future. He then guided the Military representatives on an interactive and dynamic tour through the headquarters. Experts informed at that occasion on the operational processes, showcased the successes of the medical evacuations and introduced them to EATC’s functional domain.

Recognising the operational nature of EATC and the value of using common and harmonised procedures and regulations, the MilRep underlined the high potential of the EATC to further improve the interoperability in the field of Air Mobility and possible use of EATC in the NATO/EU defence domain.

During the tour, they visited also the MICON where EATC’s worldwide flight activities are monitored on a 24/7 basis.

By J.-P. S. from information available on https://eatc-mil.com/

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EATC and the MMU sign a working agreement Commander EATC

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EATC Pictures. Fact Sheets and Leaflets can be consulted on: http://eatc-mil.com/en
INTRODUCTION
Since 2002, first with the orbit topping of ARTEMIS and then with the launch of SMART-1 in 2003, the European Space Agency (ESA) has paved the road for highly efficient space transport using electric propulsion (EP). After consolidation of several EP technologies and thrusters for a decade, since 2012, all-electric satellites have been progressively consolidating their attractiveness in the SatCom market as they provide a significant propellant mass efficiency improvement and, thus, substantial reduction of in-orbit payload costs.

In 2013, OHB-System AG, SES and ESA initiated an ESA Public-Private-Partnership (PPP) under ESA ARTES Programme aiming to develop a flexible, high performance, cost-effective full-electric platform (Electra) in the three Tons range. The baseline design has undergone a Platform Preliminary Design Review (PDR) in 2015 and it is now approaching to its Platform Critical Design Review (CDR) in June 2019.

The following sections give an overview of the Electra platform requirements, the system design and the development status.

ELECTRA CONCEPT OVERVIEW AND KEY REQUIREMENTS
Electra platform avionics concept is based on a modern 100V fully regulated/modular bus. Modularity is key in establishing an efficient and flexible solution able to accommodate very different payloads and is achieved through decentralised power and data distribution based on fuse boxes and micro Remote Terminal Units (uRTUs). The available payload real state may be tailored to needs by adjusting the number of decks perpendicular to the central tube, which may be thermally connected to the Repeater Module radiator north/south panels. Also the satellite heat rejection may be adapted depending on the payload needs by installing one, two or no Deployable Thermal Radiators (DTR).

Precise satellite three-axes stabilised attitude control relies on a set of star trackers and reaction wheels supported by Gyros for contingency cases and outages. Electra is also equipped with a GNSS receiver for accurate satellite orbit and position determination, used both during Orbit Raising and on-station, and with Course Sun Sensors for early mission phases and contingency modes. But modularity and high performance must be combined with cost effectiveness to establish any new SatCom product aiming to succeed in the competitive commercial environment, in specific in the current market situation. With the guidance of SES, one of the largest SatCom operators world-wide, demanding cost & schedule targets were set during the early development phases to match market request to decrease as much as possible the satellite in-orbit costs and addressing early in the development the needs for fast delivery times. Trade-offs in early phases included but were not limited to the use of Electric Propulsion for Orbit Raising.

For conventional geostationary satellites, Electric Orbit Rising (EOR) typically allows reducing about 30% - 40% the launch costs (the smaller the satellite, the larger the saving). This yields to about 10% overall savings in the Operators’ capital investment. Furthermore, expanding the lifespan, e.g. to 18-20 years in orbit compared to 15 years for a conventional SatCom using chemical propellant, also translates in another 10% overall cost reduction per transponder [1].

Propulsion Subsystem
All Electric thrusters are operated with Xenon. This sensibly simplifies the propellant storage and distribution system. To achieve this in a mass-efficient and cost-effective manner, the use of a Large Xenon Tank developed under ESA ARTES programme and with a dedicated Qualification Model for Electra has been envisaged. In particular, Electra tank has a 440 liters tank capability, which allows storing 800 kg of propellant, sufficient to fuel any mission in the 16-up to 20 years lifetime range. This tank is a Composite Overwrapped Pressure Vessel with carbon fibres wrapped around a Titanium alloy liner and a CFRP mounting skirt integrated into the overwrapping (figure 1).
The Xenon stored in the tanks is distributed through piping to the Regulator Subassembly, the heart of the Electric Propulsion Subsystem, which takes care of providing the correct operating pressure and flow rate to the thrusters. For nominal manoeuvres, 5 kW Hall Effect Thrusters are used. During Orbit Raising, two of these thrusters are operated simultaneously, which eases the momentum build-up that would be caused by the continuous operation of only one thruster and allows increasing the overall thrust, essential to minimise the transfer duration. During Station-Keeping, however, only one thruster is fired every time. The firing of the Electric Propulsion Hall Effect Thrusters is managed by dedicated Power Processing Units (PPUs), arranged in a fully redundant scheme which prevents mission degradation in case of a single failure (figure 2).

For contingency manoeuvres, de-tumbling, attitude control in satellite safe modes when reaction wheels are not available as well as in case of momentum management contingencies, a set of redundant Cold Gas Thrusters is foreseen.

Table 1 provides an overview of the key characteristics of the Small GEO platform and shows how this Electric Propulsion subsystem allows substantial mass savings with respect to the Hispasat AG1 mission [2] which used chemical propulsion (MON/MMH) for transfer from GTO to GEO and electrical propulsion for station keeping with Electra: table 1

<table>
<thead>
<tr>
<th>Small GEO</th>
<th>Launcher</th>
<th>A5 low, Soyuz GSC, A6, Falcon 9, Proton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite Mass</td>
<td>up to 3,3t</td>
<td></td>
</tr>
<tr>
<td>Satellite height</td>
<td>up to 5m</td>
<td></td>
</tr>
<tr>
<td>Satellite diameter</td>
<td>up to 4m</td>
<td></td>
</tr>
<tr>
<td>Propulsion Configuration</td>
<td>CP+EP</td>
<td>EP</td>
</tr>
<tr>
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<td>HAG1</td>
<td>Electra</td>
</tr>
<tr>
<td>Payload Mass (kg)</td>
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<td>800</td>
</tr>
<tr>
<td>Payload Power EOL (kW)</td>
<td>3,6</td>
<td>9,5</td>
</tr>
<tr>
<td>Payload Dissipation EOL (kW)</td>
<td>2,3</td>
<td>5,0</td>
</tr>
</tbody>
</table>

**Table 1 – Small GEO platform characteristics (Hispasat AG1 vs Electra)**

**THOR Boom**

One of the trade-offs performed concluded that the optimum accommodation of the Electric Propulsion Thrusters is achieved by means of a deployable thruster module assembly, called ‘THOR Boom’. In its launch configuration, the THOR Booms are attached to the satellite North and South panel by means of Hold-Down Release Mechanisms (HDRM). See figure 3.

After launcher separation, the HDRMs are released by actuating their low shock non-explosive release devices during the first hours of the mission, so that the each of the THOR Booms may be brought to its functional position. During orbit raising, the functional position points mainly along satellite Z-axis. Once at its final location into the Geostationary slot, THOR position vector mainly points to North and South direction through satellite’s Centre of Gravity. THOR position vector is slightly off-pointed in East/West directions to allow the satellite house-keeping; i.e. the control of the inclination, the longitude and eccentricity, as well as the control of the angular momentum by carefully planning the daily thrusters firings (figure 4).

**Figure 3 – Accommodation of Electric Thrusters on Electra deployable THOR Booms**

To allow all this, the THOR Boom has been designed with flexible wiring and tubing that goes through their rotary joints and reach the Electric Propulsion Thrusters mounted on the THOR Boom plates. Each of the rotary joints contains a motor that can be controlled through the satellite On-Board Data Handling system. As a result, the THOR vector may be re-positioned as much as required through its entire life-time (e.g. to transfer the satellite to graveyard orbit after its operational life-time, THOR vector may be made to point into Z-axis again).
Details of the Electra Orbit Raising and Station Keeping may be found in [2].

**GNSS Receiver**
The use of a continuous low EP thrust results in an inherent degree of uncertainty in satellite position, which needs to be corrected regularly in order to achieve an efficient transfer. For this reason, Electra is equipped with a redundant GNSS receiver allowing autonomous orbit determination during the transfer phase with affordable operations costs. GNSS receiver will also be available for orbit determination at its final GEO location, which may help to reduce ground operations on-station as well as to predict a more accurate thruster performance, which will also improve the overall satellite pointing performance. The GNSS receiver system (figure 5) is essence consists of two antennas, connected via LNAs to redundant GNSS receivers.

![Figure 5 – GNSS Receiver Assembly EOM (Photo Courtesy of Ruag Austria)](image)

**Payload Capacity**
To demonstrate the flexibility of the Electra platform to accommodate a wide variety of Payloads, a number of payload reference cases have been defined and studied, as follows:

1. **Multiband in X-, Mil-Ka-, Ku- and C-band) Payload**
2. **High Throughput Satellite (HTS) Ka-band Payload (with 64 user beams)**
3. **Hybrid Ku-band HTS & Ku-band Shaped & EGNOS Payload**
4. **Direct To Home (DTH) Ku-band Payload (TV broadcast)**

The envelope of these missions may be characterized by the following accommodation capabilities:

- Radiative Cooled TWTA up to 48
- Conductive Cooled TWTA up to 20
- Side Deployable Reflectors: up to 4 with diameter of up to 2.8m
- Earth Deck antenna farm

This has also yield to the sizing of the overall maximum Payload envelope:

- Up to 800 kg of Payload mass
- Up to 5 kW of heat dissipation
- Up to 95 kW of Payload power consumption

An example the HTS payload accommodation is shown in figure 6:

![Figure 6 – Electra HTS payload reference case](image)

**DEVELOPMENT STATUS**
At the end of 2018, most of the EMs/EQMs required by the Avionics Test Bench (flat-sat) are delivered so that after integration the interface testing and functional validations may be performed in parallel with the Subsystem CDRs and Platform CDR, which are taking place from September 2018 to November 2019. The majority of testing shall be completed before. The first Mission implementation is planned by early 2020, aiming to a first launch followed by a low thrust “electric” transfer and in-orbit validation in 2023.

**CONCLUSION**
The Electra platform is being developed under ESA Public Private Partnership (PPP) within the ESA ARTES Programme, and it has been conceived to be a cost-effective, high-performance platform able to accommodate different payloads with a mass up to 800 kg and a power consumption up to 9.5.

Being compatible with most of the commercial launchers and because of its full electric transfer capability, the Electra platform is fully in line with Operators’ continuous demand to reduce in-orbit costs in the segment of the medium-range Satcom market (i.e. 3 Tons launch mass).

Platform development is approaching its Critical Design Review (CDR), planned in June 2019, and aims to a first launch by 2023.

**Acknowledgements**
The authors want to thank the support of all Electra participating Member States, with special mention to DLR, as well as the work of the industrial consortium led by OHB System AG.

**References**
TELEROBOTICS DEVELOPMENTS AT ESA

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INTRODUCTION TO TELEROBOTICS

Telerobotics is the area of robotics concerned with the control of (semi)autonomous robots from a distance by a human operator. To this extent Space Robotics is almost always concerned with telerobotics, as space robots are at distance with respect to their operators. Figure 1 shows present and foreseen applications of robots in space. Whether in low-orbit, in GEO, on the Moon, or on Mars robots are from hundreds to millions of kilometers away from their operator on ground.

Distance does make a difference on the way telerobotics works. This is because communication, between the human operator and the remote robot, travels at most, at the speed of light. Hence increasing distances mean that communication between the operator and the remote robot accumulates delays. It also means that if the operator controls the robot through the OODA cycle (Observe, Orient, Decide, and Act) this cycle cannot be faster than the delays accumulated by the communication on the way from the robot to the operator (needed to observe and orient) and the communication from the operator to the robot (needed to transmit the Action).

Delay and control cycles allowed by the different uses of robot in space can have huge difference. For example a robot on the International Space Station (ISS) can be controlled continuously from ground by means of the Tracking and Data Relay Satellites (TDRS) with typically 800 ms delay. The ExoMars rover on the surface of Mars will be controlled by means of the data relay service of the Trace Gas Orbiter (TGO) allowing about 12 hours control cycle. While in the case of the ISS the delay may slow a bit the operation of the robot, in the case of Exo-Mars the delay can hamper severely operations.

TELEROBOTICS: A BALANCE OF HUMAN ROBOT INTERACTION AND ROBOT AUTONOMY

Depending on the distance from the remote robot, telerobotic techniques have been invented in order to allow efficient operation. When the control frequency slows down, some aspects of the robot control must be delegated to the robot itself. This delegation implies that the robot must have some autonomy. The level of autonomy is one way to define different telerobotics modes.

The European Cooperation for Space Standardisation (ECSS) has defined in its standard ‘ECSS-E-70-11A Space segment operability’, four levels of Mission execution autonomy listed in Table 1.

Table 1: ECSS Mission execution autonomy levels

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>Mission execution under ground control, limited on-board capability for safety issues</td>
<td>Real-time control from ground for nominal operations. Execution of time-tagged commands for safety issues</td>
</tr>
<tr>
<td>E2</td>
<td>Execution of pre-planned, ground-defined, mission operations on board</td>
<td>Capability to store time-based commands in an on-board scheduler</td>
</tr>
<tr>
<td>E3</td>
<td>Execution of adaptive mission operations on-board</td>
<td>Event-based autonomous operations Execution of on-board operations control procedures</td>
</tr>
<tr>
<td>E4</td>
<td>Execution of goal-oriented mission operations on-board</td>
<td>Goal-oriented mission re-planning</td>
</tr>
</tbody>
</table>

The ECSS levels, while being well suited for the operation of satellites, are too coarse to describe the much more complex telerobotics possibilities. Since the beginning of robotics, several taxonomies have been proposed to define autonomy modes, leading to different numbers of autonomy levels.

At ESA we came to use a Space-robotics specific taxonomy. The taxonomy, articulated in 5 distinct levels, is detailed in Table 2. The relationship between delays/control frequency and telerobotics levels allowed by them is illustrated in Figure 2.

Figure 1: Different applications of robots in space. The red arrow indicates increasing distance from Earth

Figure 2: Delay, control frequency and different telerobotics levels to cope with them. Under each telerobotic level a picture shows a possible realisation of the Human-Robot Interaction device
DEVELOPMENTS IN HAPTICS TELEPRESENCE

Haptics telepresence offers unmatched ability to employ the operator perceptual, cognitive and motion abilities. It has been proposed as the way to implement control of maintenance robots on space exposed infrastructure. In present infrastructure (i.e. the ISS) astronauts have to perform lengthy, tiring and intrinsically dangerous Extra Vehicular Activities (EVA) to fix problems created by failing equipment/debris impact. In the future humanoid robots could be used to do the same while being teleoperated from inside the station or from ground.

At ESA we have been developing for some time the most intuitive means to command humanoid robots: exoskeletons. An arm exoskeleton is a hollow robot arm that once worn on the human operator arm, it allows to control a remote robot arm. Every motion of the human arm is replicated by the remote robot arm. Also any touch, contact, or constraint of the motion of the robot arm, is reflected by the exoskeleton to the operator, who can then adapt the commanded motion.

The latest incarnation of a sequence of arm exoskeleton is being developed in project SPOC. SPOC was specifically designed to be operated on the ISS and it will be delivered to ESA during 2019.

DEVELOPMENTS IN TELEMANIPULATION/TELEDIVING

While an exoskeleton is the most intuitive means to control robots, it presents discomfort of use when delays are no longer negligible. These delays will be present in the scenarios offered by the Lunar Orbital Platform-Gateway (LOP-G). The LOP-G will be used to operate robotics assets on the Moon. Likewise a future space station orbiting Mars could allow efficient teleoperation and tele-driving of robotics assets on the Martian surface.

Table 2: Taxonomy of Human-Robot-Interaction and autonomy used in ESA Space Robotics Developments

<table>
<thead>
<tr>
<th>Level</th>
<th>Description of HRI and related Autonomy</th>
<th>When it is needed</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Haptic Telepresence</td>
<td>The operator controls every aspect of the system’s operation and is sensationally immersed in the environment around the robot.</td>
<td>Delay between operator and robot is negligible and there is a good bandwidth availability</td>
<td>Operator’s perception, decisional power and dexterity are used at the best. Most complex handling tasks are possible and quickly executed</td>
<td>High bandwidth requirements. Operator effort is the highest</td>
</tr>
<tr>
<td>2. Telemanipulation / Teledriving</td>
<td>The operator gives a complex command involving a sequence of declarative actions; the system implements the actions by coordinating its motion systems. Robot system provides visual feedback to the operator.</td>
<td>Delay between operator and robot is still negligible but not compatible with the patience of the operator. There must be a good bandwidth availability to allow the operator’s situational awareness.</td>
<td>Operator’s perception, orientation, decisional power and dexterity are used efficiently. Effort is reduced in the interaction.</td>
<td>Execution of tasks become more cumbersome. Observation and orientation become more difficult.</td>
</tr>
<tr>
<td>3. Supervisory control</td>
<td>The operator sets desired and necessary actions/tasks/ procedures that the robot must attain. The robot then implements these actions/tasks/ procedures on-board sensors and control.</td>
<td>Delay is too great for the operator to participate in the action. Perception capabilities and programming of the robot are compatible with the complexity of the operating environment.</td>
<td>Operator is not involved in the control loop that the robot can safely perform autonomously.</td>
<td>Operator still needs to observe and direct the robot with the limited visibility provided by the robot.</td>
</tr>
<tr>
<td>4. Interactive/autonomy</td>
<td>The operator provides goals the robot must attain; the robot then plans a course of actions to attain the goals. While executing the plan, the robot changes the plan as needed to meet the goals.</td>
<td>Delay is so great that robot most of the time would be waiting for the operator’s assessment of the situation and decision. The robot has full capability to perceive, model and plan motion within the environment.</td>
<td>Operator can focus on the “strategic” selection of the goals of the robot; all the “technical” implementation is delegated to the robot.</td>
<td>So far only fairly simple goals can be attained.</td>
</tr>
<tr>
<td>5. Full autonomy</td>
<td>The operator sets emission objectives to the robot. The robot, based on its perception of the operating environment and its opportunities, sets and attains its goals.</td>
<td>Delay is so great and bandwidth is so limited that the operator cannot have adequate assessment of the environment/situation and consequently cannot take informed decision.</td>
<td>The robot is fully delegated with the mission.</td>
<td>The technology is not yet there.</td>
</tr>
</tbody>
</table>

Figure 3: Artist’s depiction of the human arm exoskeleton SPOC.

TELEDIVING

While an exoskeleton is the most intuitive means to control robots, it presents discomfort of use when delays are no longer negligible. These delays will be present in the scenarios offered by the Lunar Orbital Platform-Gateway (LOP-G). The LOP-G will be used to operate robotics assets on the Moon. Likewise a future space station orbiting Mars could be used to control a variety of robots on the Martian surface, as visualised by Figure 4.

Figure 4: A space station orbiting around Mars could allow efficient teleoperation and tele-driving of robotics assets on the Martian surface.
Astronaut’s perception of touch and force changes when in orbit. Therefore ESA has carried out a series of investigations aiming at determining the effective abilities in orbit of an astronaut operating a remote robot system. For these experiments (the METERON Haptics-1, Haptics-2 and Interact) astronauts on the ISS were tasked to operate robotic devices in ESA labs. The most recent experiment, planned for end-2019 will test astronaut’s abilities to work as geologist from orbit. In the ANALOG 1 experiment, an ESA astronaut on the ISS, by means of a dedicated haptic station (Figure 5), will control an ESA robot in the island of Lanzarote to identify and collect geologically interesting rocks. The Human and Robotics Exploration Directorate of ESA has initiated the ANALOG 1 experiment as a means to size the resources required at the LOP-G to efficiently carry out Lunar field geology from orbit.

Another critical aspect of Teleoperation/Teledriving is the situational awareness of the robot operator. Particularly in the Lunar South Pole exploration scenario, the perceptual and orientation ability of the operator are put under severe stress due to the darkness of the operational environment.

ESA has tested a variety of situational awareness techniques in the LUNar scenario Concept validation and Demonstration (LUCID) and Rover Speed Characterisation for Lunar Exploration (RaCER) research projects. In both projects a rover was driven during the night in a Lunar analogue terrain. The Rover was equipped with many sensor systems and the control station used by the operator was engineered to allow different presentations of the data produced by the Rover sensors. Also the efficacy of the teleoperation was tested against different communication delays and bandwidths.

**DEVELOPMENTS IN SUPERVISORY CONTROL**

The cooperative German Aerospace Center (DLR) and European Space Agency’s METERON SUPVIS Justin space telerobotics experiments, addressed advanced supervisory control. During the experiments astronauts on-board the International Space Station commanded DLR’s humanoid robot Rollin’ Justin to survey and maintain a simulated Martian solar farm on Earth. Astronauts on the ISS were provided with a tablet computer that showed an image of the operating scene, as seen by the Justin robot. Also a set of context sensitive buttons was displayed. The astronaut could tap on the image to indicate particular objects in view, and the tablet would display buttons associated to the operations the robot could perform on the indicated object. Only actions possible at that specific location/time were displayed.

If the astronaut tapped on a button, Justin would then autonomously execute the desired operation.

**DEVELOPMENTS IN INTERACTIVE AUTONOMY**

All Interactive Autonomy developments at ESA, or coordinated by ESA, are geared towards the implementation of capable Martian Rovers. Rovers like the Rosalind Franklin ExoMars one, can only communicate indirectly with operators on Earth and with an average frequency links of twice a day and for few tens of minutes of duration.

The ESA ExoMars project is developing a Rover Operation Control Centre (ROCC) located in Turin, which will use Rover mission planning and control software based of derivative of the 3DROCS control station, prepared in ESA’s technology programme.

ExoMars operations are rather complicated, however a simplistic cycle of operation is here described:

- The ROCC is used by operators to plan rover activities on a 3D map of the area of Mars where the rover is;
- The plan of activities is then validated by simulation against all environmental and resource constraints;
- The validated plan is then sent to the rover on Mars at next upload time;
- At a following link time, data collected by the rover during execution of the plan, is downloaded and inserted into the ROCC to update status of the rover and of any model used in further planning.

While ROCC represents the HRI part of the mission, the rover will implement the autonomous execution of...
the plan by means of a Mission Management System software and two alternative autonomous navigation software packages. One package is being developed under ESA funds; the other is being contributed by CNES.

ESA is also studying the contribution of a Sample Fetching Rover (SFR) for the NASA led Mars Sample Return mission. The SFR, being tasked to cover several kilometres of Mars in relatively short time, will necessarily feature less interactivity to the ground and more autonomy.

More performing combinations of the ExoMars autonomous navigation packages and hardware-accelerated mapping and localisation system are being evaluated at the time of writing.

DEVELOPMENTS IN FULL AUTONOMY

A fully autonomous robot, which could be tasked by operators of a mission and report back to them the results at the end of the mission, is conceptually possible but not technologically achievable today. Highly autonomous robots of today just do not have the capabilities to successfully and reliably overcome the many challenges space presents. So they cannot be entrusted of the success of a mission.

Nevertheless fully autonomous operation can be implemented in some of the not mission-critical functions of a rover.

ESA has been investigating the possibility of endowing robots with a Novelty and Anomaly Hunter (NOAH) function. Such function, running continuously in a Rover and not affecting critical functions, could watch the environment surrounding the rover and detect events/features that are different from anything the rover normally sees. The NOAH software, prototyped in an ESA technology study, showed the desired detection ability. A derivative of it, called Goal Oriented Data Analysis (GODA) agent, was demonstrated during the ESA coordinated, European Commission funded, ERGO field trials in the desert of Morocco (Figure 7). GODA allowed the detection of interesting feature in the desert while the Sherpa Rover roamed in it.

CONCLUSIONS

This paper has provided an overview of the topic of Telerobotics, an essential part of space robotics, and the way it is organised and developed at ESA. Telerobotics requires a balance between Human-Robot Interaction (HRI) and Robot Autonomy (RA). ESA has established a number of Telerobotics levels, representing different balances of HRI and RA that are suitable for the missions/environments ESA robots are anticipated to work in.

The subject of Telerobotics is vast and has too many facets being subject to development activities at ESA to be thoroughly described in this article. Therefore it provides just an introduction to the concepts and for each of the levels, few examples of activities pursued/coordinated by ESA, are presented.

Figure 7: The DFKI Sherpa rover moving in the Moroccan desert during the EC funded test campaign in November-December 2018. The rover has been endowed with the ERGO autonomous software, which includes the GODA agent.
THE EUROPEAN DREAM OF AEROSPACE COOPERATION

“A good cooperation of aerospace and astronautic industries of different countries”. This was the name of the first group of students that in 1956 in Aachen, Germany, decided to make a step forward, towards the lack of cooperation between the aerospace industry and the major European stakeholders of that time.

Those students realised that European collaboration was the only way to foster the aerospace economy in European countries. Within this initiative, in September 1958, students coming from Aachen, Delft, Paris and Pisa founded a “comité provisoire” with the goal to shape the organisation of an association with the name “EUROAVIA”.

And six months later, in Aachen, their dream came true. On the 16th of March 1959, the official Statute of EUROAVIA, the European Association of Aerospace Students, was presented and accepted by thirty students coming from ten universities in four different European countries.

Peace, freedom, equality, cultural diversity and exchange were just some of the main values of the European spirit that led to the establishment of the European Union and which were also the cornerstones of EUROAVIA.

Since then, thousands of young students have been inspired by those values, contributing to boosting the European aerospace scenario.

WHERE IT ALL BEGAN: THE EUROAVIA LUSTRUM 2019

And after all this time, on Saturday May 4th, 2019, EUROAVIA members from all over Europe came back to Aachen to celebrate that day of 60 years ago.

The EUROAVIA Lustrum, organised by the local chapter in Aachen, was an intense moment for all of them, an occasion to meet old and new friends.

Important guests from the industry and academia were also present to celebrate and honour the association. Ms Grazia Vittadini, CTO of Airbus, held an inspiring speech on digitalization and quantum technology in aerospace the day before. She encouraged the new generations of students to keep dreaming to shape the future of the European sector.

On the day of the event, instead, Professor Ulrich Rüdiger, rector of RWTH Aachen University, officially welcomed the students and the alumni of EUROAVIA, who actively participated with a series of presentations concerning their experience in the association and how it enriched their career.

Later in the day, former Airbus CEO, Mr Tom Enders, honoured us with an invaluable speech, sharing his expertise with the audience through an interesting debate on the future of European aerospace.

Key moments of the event were also two panel discussions on air urban mobility and on the new challenges of the space sector in Europe, during which EUROAVIA members had the chance to hear the opinions of Mr Juan de Dalmau, President of the International Space University (ISU), and Mr Jean-Sebastien Lemay, General Delegate of CVA, the Community of Ariane Cities.

The celebration of the 60th anniversary of EUROAVIA concluded with a memorable Gala Dinner, which was sponsored by CAE Elektronik GmbH, whose representatives contributed to the great success of the event.
EUROAVIA TODAY

Today, the dream of that small group of students of 60 years ago is still alive.

With **42 local chapters** spread in **18 countries**, EUROAVIA assumes, nowadays, the key role to represent the interest of thousands of students to the European aerospace sector, connecting the youth generations with the industry and the institutions.

These days, EUROAVIA provides more than **10 international events** per year and a lot of career opportunities, while relying on a **strong European network**.

The **EUROAVIA Training Systems** also offers **soft skills education** to EUROAVIA members. Today, the association can count on **53 trainers** who have delivered more than **1000 hours** of training sessions in around **120 workshops** throughout Europe. "**Soft skills are the new hard skills**," said Tom Enders during his speech at Lustrum. And with this regard, EUROAVIA commits to preparing its members to become the qualified and well-rounded workforce that the European aerospace industry needs.

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42 local groups
18 countries
2200 + members
500 + alumni
10 + events every year
### AMONG UPCOMING AEROSPACE EVENTS

#### JULY

**12** July – ERCOFTAC – 17th ERCOFTAC Osborne Reynolds Day – Manchester (UK) – Manchester University – [https://www.ercoftac.org](https://www.ercoftac.org)

#### AUGUST

**19-23** August – AIAA – AIAA Propulsion and Energy Forum and Exposition – Indianapolis, IN (USA) – [www.aiaa.org/events](http://www.aiaa.org/events)

#### SEPTEMBER

**03-05** September – EASA – Area 100 KSA Workshop – Cologne (Germany) – EASA/HQ – [https://www.easa.europa.eu/](https://www.easa.europa.eu/)

**03-06** September – EASN – 9th International Conference on Innovation in Space & Space – Athens (Greece) – National Center for Science Research Demokritos (NSCR) – Agia Paraskeir – [https://www.easn.net](https://www.easn.net)

**04-06** September – EASA/ETH Zürich – 7th International Conference on Scientific and Fundamental Aspects of GNSS – Zürich (Switzerland) – ETH Zürich – [https://atpi.eventsair.com/](https://atpi.eventsair.com/)

**09-12** September – AIDAA – XXV International Congress AIDAA – Rome (Italy) – Faculty of Civil and Industrial Engineering of the Sapienza University of Rome – [https://www.aidaa2019.com](https://www.aidaa2019.com)


**17-19** September – ACI-EUROPE – ACI EUROPE Aviation Security Summit – Conference and Exhibition – Tel Aviv (Israel) – Dan Tel Aviv, Israel – [www.aci-europe-events.com/security-summit](http://www.aci-europe-events.com/security-summit)


**24-26** September – SAE International – AEROTECH Europe Congress & Exhibition – Bordeaux (France) – [https://sae.org/](https://sae.org/)


**24 Sept./04 October** – ICAO – Assembly 40th Session – Montréal (Canada) – ICAO/HQ – [https://events.icao.int](https://events.icao.int)


**30 September/02 October** – DGLR – DGLR Congress 2019 – Darmstadt (Germany) – [http://www.dglr.de](http://www.dglr.de)

**30 September/03 October** – ESA – FAR2019 – Flight Vehicles Aerothermodynamics and Re-Entry Missions & Engineering – Monopoli (Italy) – [https://atpi.eventsair.com/](https://atpi.eventsair.com/)


#### OCTOBER


AMONG UPCOMING AEROSPACE EVENTS


**NOVEMBER**

**04-06** November – China Aviation Development Foundation – IASS2019 – 72nd annual International Air safety Summit – Taipei (Taiwan) – Mandarin Oriental Hotel – https://www.flightsafety.org/events


**06-09** November – ESA – 7th International Conference on Astrodynamics Tools and Techniques (ICATT) – Oberpfaffenhofen (Germany) – DLR Centre – https://www.esaconferencebureau.com


**DECEMBER**

**09-10** December – AAE/AM – ITowards unmanned ships and aircraft – Paris (France) – Ecole militaire Amphithéâtre Foch – www.academieairespace.com

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**FEBRUARY**


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**APRIL**


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