BULLETIN

AEROSPACE EUROPE

SESAR

INTERVIEW WITH FLORIAN GUILLERMET

EXECUTIVE DIRECTOR OF SESAR JOINT UNDERTAKING

CEAS
COUNCIL OF EUROPEAN AEROSPACE SOCIETIES

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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:

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The CEAS is governed by a Board of Trustees, with representatives of each of the Member Societies.
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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.

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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

THE COMING DECADES: A GOLDEN AGE OF AEROSPACE INNOVATION

Aerospace is obviously one of the most powerful instigators of technology change in many domains.

Thanks to endless progresses in digitalisation, innovation in aerospace is evolving at an unprecedented rate. Among major leading new development, are Industry 4.0 and 3D-Printing.
So, the future aircraft can be virtually designed, allowing to optimize their concepts very early in the process, a large part of their manufacturing can be automated and in addition, their maintenance is deeply improved with the help of tools gathering data from many hundreds of sensors correctly positioned. Aerospace is a wonderful test bed for further developments in automation, assembly and inspection.
The '3D-Printing', is revolutionizing the aerospace manufacturing: as a matter of fact, the additive manufacturing allows considerable weight reduction.
Intelligent assistance solutions appear in aircraft cockpits, thanks to which pilot workload is more and more decreased and safety increased, evolving towards the goal of 'Automated Flight'.
Huge progress is achieved in electronics, sensing, communications, new materials – composites and plastics –, development of modern, more efficient and sustainable engines, and in the alternative fuels. This is precisely through these innovations that the ambitious fixed by ACARE can be reached: 75% less CO_2, 90% less nitrogen oxide and 65% less noise by 2050.
Concerning air traffic management, digitalisation is key. Besides the insertion of drones in the airspace constitutes, a new challenge.
Electric Flight is stepping forward, from more electric aircraft present achievements to the E-aircraft projects and the future hybrid-electric commercial aircraft.
Defence is another powerful driver for innovation in aerospace. Among various programmes the Future Combat Air System (FCAS) is the best possible illustration: a complex system of systems including new generation fighter aircraft, Unmanned Combat Air Vehicles (UCAV), future air-launched missiles and swarms of small drones, all interconnected with satellites.
Of course Space whose projects are endless more ambitious as well for space exploration and fundamental research as for applications (navigation, Earth observation; communications, etc.) is always an extraordinary generator of innovations.

In short aerospace is facing an exponential increase of the rate of disruptive evolutions, so it is not exaggerated to say that this activity sector is entering into a new golden age: quite a fascinating era in perspective!

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INTERVIEW OF FLORIAN GUILLERMET, EXECUTIVE DIRECTOR, SESAR JOINT UNDERTAKING

By Jean-Pierre Sanfourche, Editor-in-Chief

Florian GUILLERMET was appointed as Executive Director in April 2014. Florian is responsible for leading the SESAR JU public private partnership, which is modernising Europe's air traffic management system. Florian has worked in the civil aviation field for 20 years. He is an engineer and graduate of the École polytechnique and Civil Aviation Engineering School in France. He holds a master's degree in aeronautics and airport management.

Jean-Pierre Sanfourche: *SESAR JU is working in view of the future SES (Single European Sky). Precisely, I would like to start our conversation by considering the status of progress of the SES Project. I know that recently IATA urged the European Commission to press ahead with SES: in effect SES has not delivered in important areas like integration of the airspace in Functional Airspace Blocks (FAB) and improvement of cost-efficiency of European ATM network. It also appears that the European Single Sky needs to be sharpened. The 2nd SES package (SES 2+) has been launched some months ago: what is your judgement about SES advancement and perspectives at mid-term time horizon?*

Florian Guillermet – IATA's call to move ahead with the Single European Sky (SES) is one echoed by other stakeholders because they see the potential that this policy can unlock, in terms of delivering a greener, safer and more efficient air transport system in Europe. There is a growing consensus also that technology can act as a potential enabler for the gradual establishment of a more integrated operating airspace. SESAR, as the technological pillar, works closing with the other pillars that make up the SES framework to ensure that the technologies are delivering the required performance for the network in terms of safety, capacity, the environment and cost efficiency. There is always room for improvement in this regard, which is why we regularly review with all the stakeholders the European ATM Master Plan – the roadmap which defines the research and development, and deployment activities for SES/SESAR for the coming years. In doing so, we can adapt to changes in the regulatory and operational landscape, while ensuring alignment with the high level performance goals of SES.

JPS: *From SESAR 1 to SESAR 2020: could you summarize the major achievements of the works accomplished until now and the most important goals which have been assigned by the EC for the three first years of H2020 in the three key areas which are Airport Operations, Network Operations, Air Traffic Services and Technology Enablers?*

FG – The success of SESAR is first and foremost the partnership that we have forged between stakeholders across the entire ATM community. With the support of our founding members, the European Union and EUROCONTROL, we have pooled the resources of over 100 companies, as well as research centres, universities and SMES, bringing together more than 3,000 experts in the field of ATM and aviation. These experts work in small project teams under time pressure of 2-3 years. In this way, SESAR encourages risk taking, and is more agile and responsive to emerging trends both within aviation and in the broader industry landscape.

The level of cooperation that the programme has generated has been unprecedented and it is the motor that has enabled us to fast-track modernisation efforts in a way that seemed impossible ten years ago. We have managed to shorten the innovation lifecycle from 30 years to 5 years (e.g. remote towers, extended arrival management).

We have succeeded in establishing SESAR has created an innovation pipeline through which promising ideas are explored and then moved out of the 'lab' into real operations. This is done in three distinct strands: exploratory research, industrial research and validation, and demonstrations. Thanks to this intensive work, we have been able to deliver more than 90 industrial prototypes as well as over 60 new or improved operational or technical solutions. These solutions provide all the material needed for stakeholders to deploy them, from the operational and technical specifications, to the supporting regulatory, environmental, safety and human performance assessments.

Approximately two thirds of these solutions are part of deployment activities in Europe (local and synchronised). Here are just some examples: *see page 7*.

SESAR also supports Europe's role as a world leader in aviation, as solutions are designed to be globally interoperable, contributing to the global harmonisation efforts. This has been achieved by SESAR through extensive worldwide outreach through cooperative agreements with key regions including Asia, America and the Middle East, and relevant organisations such as the International Civil Aviation Organization (ICAO).

JPS: *The world of aviation is changing. How is SESAR 2020 addressing these challenges?*

FG – The world of aviation is changing. Starting with the aircraft, which is set to become more autonomous, more connected, more intelligent, and more diverse. Air traffic is projected to grow significantly, moving from several thousands of conventional aircraft in operation every

Remote tower services: Remote tower technology draws on a range of advanced technologies, including high-definition, infrared and pan-tilt-zoom cameras to provide visual surveillance augmented by available radar and flight data to deliver additional information in real time. With this sophisticated technology, an out-of-the-window view from the tower is captured and reproduced at a remote facility with the level of detail and accuracy required for controllers to provide safe and expeditious air traffic control services. The SESAR JU has delivered several remote towers solutions, including for single low-traffic density aerodromes and airports with medium-density traffic, and as a contingency. Following SESAR R&D, the world'ss first remote tower was opened in Sundsvall, serving Örnsköldsvik airport over 150 km away. Other implementations are underway across Europe and R&D is ongoing into other remote tower applications.

Extended-arrival management (E-AMAN) In November 2015, the solution entered into force in Heathrow Airport by NATS and sees controllers from the four countries working together, including France, to slow down aircraft when there are significant delays at the airport, reducing the amount of time they'd otherwise have to spend in the fuel intensive holding stacks just outside Heathrow. To date, NATS has recorded a reduction of up to one minute in holding times for those aircraft influenced by the solution. This translates into over 4,700 tonnes of fuel savings (or 220,000 saved trees), which delivers approximately EUR 2.9 million savings for airlines per year. The solution, which is part of synchronised deployment plans (PCP), has already been implemented in several other locations in Europe.

Ground-based augmentation system (GBAS): Aircraft have become 75 % less noisy over the last 30 years, but growing air traffic means that EU citizens are still exposed to high noise levels. SESAR members are researching enhanced arrival procedures enabled by a ground-based augmentation system (GBAS) to reduce noise impact of arriving aircraft at airports. Within this framework, in March 2017, Frankfurt became the first airport in the world to fully implement GBAS aiming to counteract noise pollution for the neighbouring populations.

Runway status lights: Paris-CDG is one of the busiest airports in Europe with 4 runways and 1,500 flights per day. In 2016, the airport inaugurated Europe's first runway status lights. This solution is a fully automated safety system, which provides crews and vehicle drivers with immediate and accurate indication of the runway occupancy status. The system is expected to reduce runway incursion by between 50% to 70% while increasing the airport's runway capacity.

day to potentially hundreds of thousands of air vehicles (such as drones and air taxies), operating in all areas, including cities. Services must also evolve as tomorrow's passengers increasingly expect smart and personalised mobility options that allow them to travel seamlessly and efficiently.

To deliver this new era of travel, digitalisation is key. With the technologies on offer, the air traffic management system will be able to handle the growth and diversity of traffic efficiently, safely and with minimum environmental impact. In doing so, we will be able to deliver the best possible passenger experience while also unlocking tremendous economic value for Europe. With SESAR 2020, are progressively integrating into the programme digitally-enabled solutions, in line with the EU Aviation Strategy and with stakeholders' needs both now and in the future. These cover:

- Higher levels of autonomy and connectivity of all (air) vehicles coupled with a smarter, more automated traffic management, enabled by an "intranet of flight."
- Mobile, terrestrial, and satellite-based communications, that can provide real-time vehicle trajectory information, shared between vehicles and with the ground infrastructure.
- Digital and automated tools on board the air vehicle itself or as part of the ground-based infrastructure.
- Virtual technologies to decouple the physical infrastructure such as sensors, communication, or navigation devices from the services that are provided to manage the airspace.
- High-tech video and synthetic and enhanced sensor technologies to operate air traffic services for airports or to enable aircraft to land in low-visibility conditions.
- Big Data analytics and open source data usage to create new services and to allow for more integrated passenger transport.
- System modularity to allow for scalable/easier upgrades and greater interoperability.
- System flexibility to handle an increasing number of air vehicles, such as drones.

SESAR 2020 is building on its predecessor, SESAR 1, to deliver high-performing operational and technological solutions for uptake by the aviation industry. Today, we have over 60 projects underway in all three strands of research: exploratory, industrial and demonstrations, addressing many of the above mentioned technologies. We are also preparing for the next wave of projects which will begin in 2019. It is expected that we will already have a first set of solutions from the programme by then.

JPS: *How is SESAR addressing the integration of drone into the airspace?*

FG – The expansion of the drone market is accelerating and people are beginning to understand that this not some gadget, but an air vehicle that can bring important economic and societal value. Transforming infrastructure

to support such operations will be critical to harnessing the potential of the sector, unlocking market growth, jobs and services to EU citizens. SESAR's mission is to develop an advanced aviation environment that supports the traffic growth for both manned and unmanned aviation. However, a simple adaptation of our ways of working will not be enough; we also need to introduce a new approach and this is where U-Space will play a central role in the future transformation of our skies. The notion of U-space was first mooted by Violeta Bulc, European Commissioner for Transport, who noted that "the U may be for urban but it is above all also for You"! Supporting the Commissioner's call, the SESAR JU delivered a U-space Blueprint outlining the services and framework needed to handle the increasing number of drones, especially in urban areas.
U-space is a set of new services relying on a high level of digitalisation and automation of functions and specific procedures designed to support safe, efficient and secure access to airspace for a large numbers of drones, with an initial look at very low-level (VLL) operations. As such, U-space is an enabling framework designed to facilitate any kind of routine mission, in all classes of airspace and all types of environment - even the most congested – while addressing an appropriate interface with manned aviation and air traffic control.

The timing for U-space is critical given the speed at which the market is growing. The aim is to have foundation U-space services in place by 2019. As a first step towards this target date, the SESAR JU launched a series of exploratory projects with funding from the EU's Horizon 2020 budget. Through these projects, we are bringing together established aviation stakeholders, academia and new entrants into the sector as well as stakeholders from other industries, such as those from the mobile communications industry. Another series of large scale demonstrations are scheduled for later this year.
Of course, drone integration is not just about handling VLL drone operations. The airspace must accommodate large certified remotely-piloted drones with manned aviation. These RPAS must be able to interact with ATM in the same way as manned aircraft, with special provisions designed to compensate for the fact that the pilot is not on board the aircraft. Mindful of this, the full spectrum of drone operations are captured in "Roadmap for the safe integration of drones into all classes of airspace", which the SESAR JU delivered to its Administrative Board in December 2017. The document outlines the research and development (R&D) needed, as well as a rollout plan for these activities, keeping in mind cyber security and other associated risks. Over the course of 2018, the roadmap will be integrated in the next edition of the European ATM Master Plan as part of the update campaign, supporting the allocation of resources for the development and the deployment of drone operations in all kinds of operational environments.

JPS: *Regarding environmental matters, how is SESAR linked with CLEANSKY, with AIRE (Atlantic Interoperations to Reduce Emissions), and other relevant organisations?*
FG – SESAR aims to contribute to the SES 10% CO_2 reduction target by reducing fuel burn by between 250 and 500 kg per flight by 2035 – this corresponds to between 0.8 to 1.6 tonnes of CO_2 emissions per flight.
SESAR Solutions are green/de-carbonised by design: all projects assess R&D according to key performance areas, including the environment. The innovation lifecycle for SESAR is much shorter than engine manufacture, so our green solutions are already generating benefits:

- E-AMAN: Since its initial introduction on a trial basis in 2014, over 4,700 tonnes of fuel savings (or 220,000 saved trees) have been enabled per annum, which delivers approximately EUR 2.9 million savings for airlines per year.
- DMAN for integrated AMAN/DMAN: Deployed at t Paris Charles de Gaulle, the solution has resulted in an 8% reduction of taxi time, 4,000 tonnes of fuel savings annually, reduction of 13,000 tonnes of CO_2 emissions (170,000 trees saved) per year and a 10% increase of Calculated Take-Off Time adherence

In SESAR 2020, we have extended the scope of our environmental work to address noise pollution, looking in particular landing procedures that can mitigate noise for the populations in and around the airport.

JPS: *Towards Automated Flight Planning in Europe: a new digital tool able to provide Air Traffic Control centres across Europe was successfully tested by EUROCONTROL (NMOC) and Maastricht Upper Operations Centre (MUAC) in the last weeks. When do you think this digital flow tool can become operational and enter into service in the different countries of Europe?*
FG – The reader can refer to:
https://www.sesarju.eu/news/sesar-demonstrates-benefits-digitalisation-better-air-traffic-flow-europe (PJ24)

JPS: *A conference on future of digitalization in transport ("Digital Transport Days") was held in Tallinn, 16-18 October-2017. What are the major orientations expressed in the "Tallinn Digital Charter" which resulted from this working session?*
FG – European aviation and air transport leaders gathered in Tallinn to show their support for the digital transformation of their industry, and SESAR as the vehicle through which to achieve this ambitious goal. Initial analysis suggests that with a digitalised infrastructure, the industry could directly unlock around EUR 30 billion per annum. The meeting followed a declaration by industry underlining the urgent need to act now in order to enable more connected aviation ecosystem, and, with that, seamless travel and transport for all.
Given what's at stake stakeholders agreed there's no place for a silo approach in European aviation. We need

to work together to fully integrate the three components of the system: airspace, airport and aircraft enabled by technologies. They noted that we need to change our mindset and look at how we can create more value for our customers from digital technologies. They also agreed for the need to open up to those industries that are currently working outside our industry to achieve the digital transformation of aviation.

The SESAR JU and its members are now undertaking an in-depth stakeholder-wide consultation on the modernisation of Europe's aviation infrastructure and air traffic management (ATM) system. The results of this consultation will be published in the fourth edition of the European ATM Master Plan, due for publication at the end of 2018.

Detailed highlights:

- Digitalisation is not the goal but the means to ensure safe air connectivity with the lowest carbon footprint. A key issue is to have an open, progressive, risk-taking aviation ecosystem that nurtures innovation and ambition. Ultimately we need to change the mindset in Europe about embracing digital tech.
- Airspace is a finite resource that must be used more efficiently. However, one way of enhancing efficiency is via digitalisation and this is where we envisage opportunities for us. We believe there's a need for a more digitalised approach to coordinate all those entities that want to use airspace.
- There's no place for a silo approach in European aviation. We need to work together to fully integrate the three components of the system: airspace, airport and aircraft enabled by technologies. The European ATM Master Plan guides cooperation in aviation and is critical for the modernisation of the system.
- Regulators need to be proactive and as innovative as the technology on offer. The model for digital transformation should be based on great ideas but also tangible demonstrator projects.
- Passengers are the only focal point around which to discuss the future of aviation enabled by tech.
- We need to change our mindset and look at how we can create more value for our customers from digital tech.
- We need to open up to those industries that are currently working outside our industry to achieve the digital transformation of aviation. But whatever technological changes we make we have to be sure that the aviation system remains safe and secure.

JPS: *Inmarsat has signed an important contract with ESA to develop satellite services enabling 4D trajectory, which would constitute quite a major step forward in the in the ATM modernisation process. What are your hopes in this research programme?*

FG – Stakeholders are looking at the next set of ATM-oriented space-based services that will be made possible thanks to Europe's global satellite navigation system, Galileo, the updated satellite-based augmentation system (SBAS), EGNOS Version 3, and Iris' SATCOM or other infrastructures such as Aireon's Space based ADS-B technologies. The move towards space-based services as the primary means for CNS offer many benefits to ATM, which is why the SESAR JU is cooperates with the European Space Agency and The European GNSS Agency. Our ANSP members are showing that the number of terrestrial navigation aids can be reduced due to the flexibility of airspace design provided by PBN (including free routes), and the locations of this terrestrial support can be optimised. These technologies and resulting services will mean improved air-ground data exchange as well as increased flight predictability.

- The move towards space-based services as the primary means for CNS offer many benefits to ATM.
- Galileo - improved accuracy, integrity and resilience to the satellite navigation capabilities of today.
- ANSPs are showing that the number of terrestrial navigation aids can be reduced due to the flexibility of airspace design provided by PBN (including free routes), and the locations of this terrestrial support can be optimised. For example, in France there has been a reduction in the number of Cat I ILS infrastructure by up to 50%. Similar efficiencies can be expected within terrestrial based surveillance.
- In the communications domain, the Iris SATCOM system is set to complement the existing provisions for delivery of aeronautical telecommunications network (ATN) data link in continental Europe. This will increase the resilience and availability of continental controller–pilot data link communications (CPDLC), communications while also underpinning the i4D SESAR concept by increasing the bandwidth available for this essential data transfer. These technologies and resulting services will mean improved air-ground data exchange as well as increased flight predictability.

JPS: *Further testing activities are programmed at the end of 2018. They concern two SESAR projects which are progressing well: (i) Optimised Airspace User Operations; (ii) Advanced demand-capacity balancing. Could you in a few words give us some information concerning the main advances that will result from each of these research actions?*

FG – With our solutions, we aim to inject greater flexibility into the system to enable airlines and other airspace users to fly the most optimum trajectories, and making better use of the performance capabilities of the aircraft. Examples of solutions include:

- **UDPP** - The user-driven prioritisation process allows airlines to change the priority order of unregulated flights among themselves and in collaboration with the airport authorities. Airlines are given this flexibility in the pre-departure sequence (PDS) for last-minute disruptions, which usually lead to departure delays or cancelled flights.
- **Enhanced ATFM slot-swapping** - The SESAR solution

enhances slot swapping functionalities by making it possible to swap pre-allocated slots with allocated slots or carry out multiple swaps for a single flight. These functionalities allow airlines to swap between long-haul and short-haul flights, or split the delay assigned to one flight between a maximum of three flights.

- **Extended flight plan** - In Europe's future trajectory-based flight environment, where aircraft can fly their preferred flight paths without being constrained by airspace configurations, flight plan data will include additional information, which will allow both the Network Manager and the air traffic control units to have a more precise plan of how the aircraft will fly.

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JPS: *What is the state of advancement of the cooperative agreement with the Global Navigation Satellite Systems Agency (GSA)?*

FG – The cooperation is being formalised. Technical cooperation is already underway.

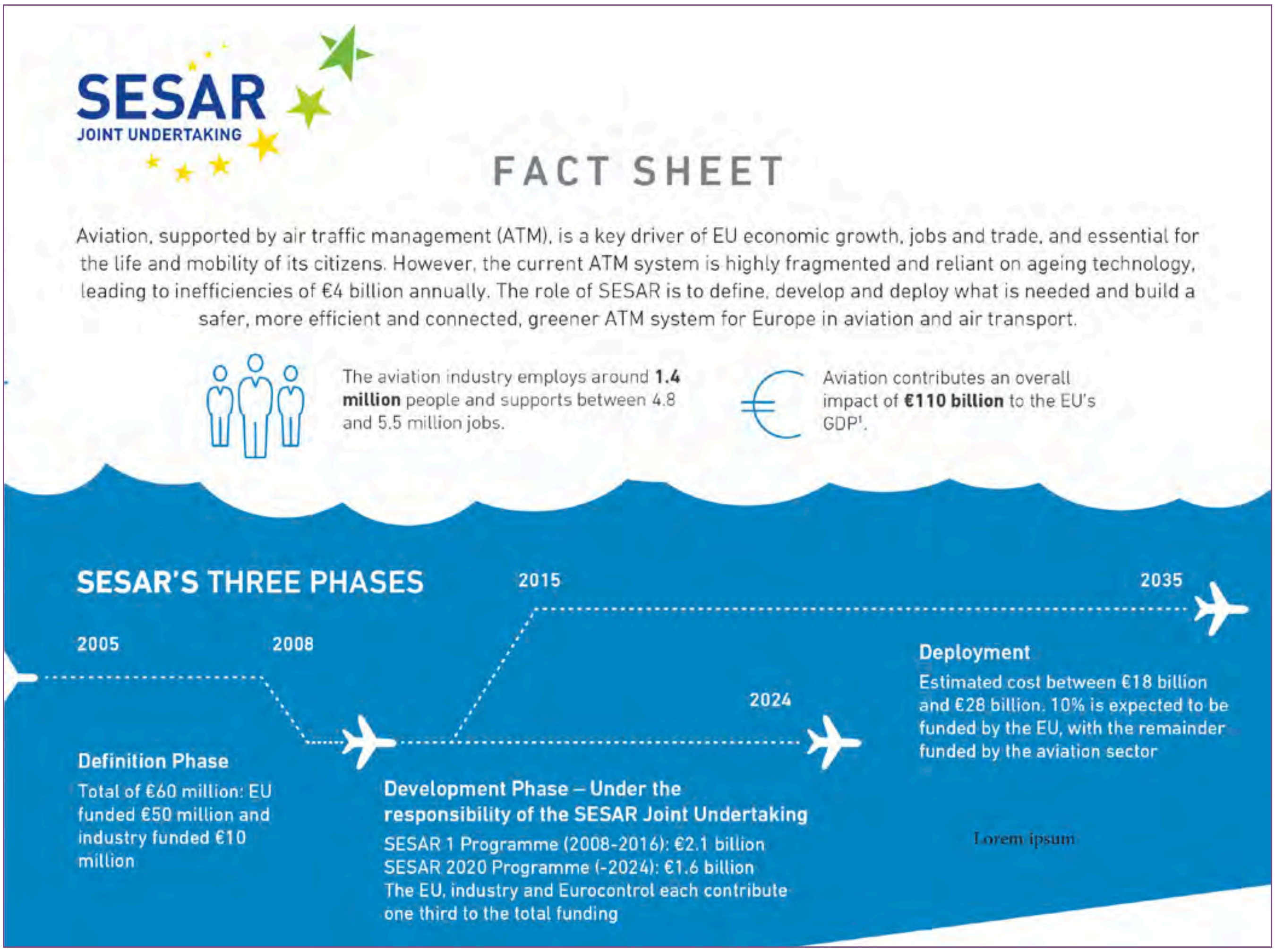
JPS: *Are some evolutions foreseen in matter of SESAR general organisational structures (the different boards)?*

FG –The SESAR JU governance structure brings together the European Union and Eurocontrol as founding members and 19 industrial partners. This core partnership, through consortia with third-parties, brings together over 100 companies and start-ups from across the aviation value chain. In addition, through open calls for exploratory research and demonstrations we are able to bring in academic research centres and universities, as well as new entrants. So our governance structure is paying off in terms of establishing a good cross-section of industrial and academic expertise and skills. Going forward, our aim will be to nurture the talent and skills of the next generation of aviation leaders, through a variety of educational and training activities.

JPS: *In conclusion of this interview, what are your top priorities for the coming months?*

FG – **The first priority** for SESAR will be to continue to deliver concrete results encouraging up-take by industry. These results will take the shape of operational and technological solutions, which will be published in the next edition of the SESAR Solution Catalogue, due for the end of 2018.

The second priority will be to prepare the ground for the future, which we will be addressed in the next edition of the European ATM Master Plan.



MILESTONES

In **2016**, **completion of SESAR 1** research activities and **delivery of SESAR Solutions Catalogue**.

In **2015**, the world's **first flight trial of a large civil drone integrated into commercial traffic**.

The opening in **2014** of **the world's first remote tower facility** in Sweden. These towers can serve Europe's remote locations and boost regional economies. Sweden plans to launch another 12 remote towers in coming years. Germany and Ireland have expressed interest too.

In **2013**, the SESAR JU delivered a first set of solutions selected by the European Commission for Europe-wide deployment[2], coordinated by the SESAR Deployment Manager. The **24 solutions** to be deployed between **2015 and 2024** across Europe are expected to deliver approximately **12.1€ billion worth of performance gains for some 3.8€ billion of investments**[3].

The world's first flight in four dimensions (4D spatial dimensions + time) in 2012 and 2014 to enhance flight predictability and therefore punctuality and efficiency.

OUR ACHIEVEMENTS

Since its establishment, the SESAR JU and members have taken ATM research 'out of the lab' into real systems and real-life air traffic operations across Europe and internationally. They have:

- Conducted **300** industrial research projects
- **350** validation exercises
- **30,000** flight trials
- More than **90** industrial prototypes
- **Dozens** of exploratory projects to push the boundaries of ATM knowledge and aviation
- **60** new or improved operational procedures and technologies (SESAR Solutions)

BENEFITS

SESAR offers benefits in several key areas:

Digitisation
Remote tower & virtual tech rollout, better information exchange and cross-border collaboration, all air vehicles (including drones) integrated into Europe's airspace

Investment
1.4€b in R&D (,(2024-2016
3.8€b in 24 deployment solutions, EU-wide (2024-2015) generating 12.1€b in performance gains

Decarbonisation
Greener flight routes, 500-250kg fuel savings per flight & 10kg per passenger

People
Shorter travel times, better mobility & connectivity, less noise & congestion around airports, consumer savings, 4-3 times better safety SESAR Solutions Catalogue.

SESAR 2020

SESAR 2020 provides the tools and funds to meet the goals set out in the EU Aviation Strategy **for a Single European Sky**. It builds on the results of its predecessor, capitalising on lessons learned, and helping to forge stronger relationships and focus energy on achieving critical scale to deliver market-ready innovations in a timely, cost-effective way.

Research and innovation activities will continue under SESAR 2020, **with focus on four areas:**

- High performing airports (estimated 25% of 2020 industrial research budget)
- Advanced air traffic services (24%)
- Optimised ATM network services (14%)
- Enabling aviation infrastructure (37%)

The programme will create an innovation pipeline, moving ideas into industrial research and large scale demonstrations.

- €20 million will ensure the safe integration of **drones** into airspace. By 2050, drones will represent a quarter of air traffic.
- €12-15 million will address **cyber security** to ensure information can be shared securely among all stakeholders.
- €85 million will be used to fund **exploratory research** projects.

2 Commission Implementing Regulation (EU) No 716/2014 of 27 June 2014 on the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan

3 Official proposal on the content of the PCP (edition 1.0), 6 May 2013, SESAR Joint Undertaking. All figures are undiscounted.

HOW WELL DO YOU KNOW CLEAN SKY ?

By Jean-François Brouckaert,
Clean Sky Project Officer ENGINES ITD

Clean Sky is the largest European research programme developing innovative, cutting-edge technology aimed at reducing CO_2, 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.

But how well do you know Clean Sky?

I admit I "borrowed" this appealing title from a recent Tweet of my colleague Maria-Fernanda FAU, Advocacy and Communications Manager at the CSJU, but with permission, of course. And I would like to expand a little on that as a first contribution of Clean Sky to the Aerospace Europe Bulletin, for which I would like to thank Jean-Pierre Sanfourche, Chief Editor, for involving Clean Sky in the Editorial Committee of this bulletin. There is too much to say about the programme and about Clean Sky in general for a single page article, so I would invite you straight away to our new website www.cleansky.eu for a wealth of additional information. Nevertheless, you will find our brand new infographics over the next two pages as a visual support to this brief overview. *See pages 13 to 15.*

Clean Sky 2 (2014-2024) is a natural continuation of the recently completed successful Clean Sky 1 programme (2008-2017) on the roadmap to innovation. Notwithstanding the flagship achievements as the Open Rotor or the BLADE Demonstrators, the environmental targets of Flightpath 2050 remain extremely challenging.

The 4 Bn€ budget allocated under H2020 is therefore addressing the aeronautics research priorities across the main aviation market segments ranging from Large (Long Range) Passenger Aircraft, Small/Medium Range Aircraft, Regional Aircraft to Small Air Transport, including also Fast Rotorcraft platforms such as the high-speed compound helicopter or Tilt-Rotor concepts, the IADPs (Innovative Aircraft Demonstrator Platforms).
For each of these market segments, one or several innovative concept platforms have been defined in terms of performance objectives under the so-called Technology Evaluator (TE), which will assess the environmental impact both at mission, airport and fleet level of the new technologies developed under the Airframe, Engines, and Systems ITDs (Innovative Technology Demonstrators).

Keeping in mind not only the aerodynamic performance of these new concepts and technologies, the Eco-Design Transverse Activity is covering the Life Cycle Analysis in order to assess the environmental impact at "ecolonomic" level.

The main demonstrators are depicted in the infographics on the next page and involve not only the main European industry players but an amazing number of Universities, Research Centers and SMEs all over Europe. Clean Sky 1 funded 486 projects for a funding value of ~200 M€, and to date (June 2018), Clean Sky 2 has already launched 335 projects for a funding value of ~315 M€, with 3 additional Calls for Proposals still to come until 2020, reaching in the end a total value of ~525 M€ of funding. Additionally, several waves of Calls for Core Partners have brought on board more than 192 entities for a similar funding value of 525 M€.

Including the leaders, the global funding allocation of Clean Sky 2 amounts to 1.8 Bn€.

Clean Sky has also signed Memoranda of Cooperation with SESAR and EASA with the aim of working together on issues such as optimisation of air traffic management and early certification issues related to new technologies. 16 Memoranda of Understanding have been signed with Member States and Regions in the frame of Smart Specialisation.

Taking into account the excellent results of the public-private partnership so far, as well as the private sector's continuous commitment to invest in the future of green aeronautics, there is a strong momentum to continue to build on the results achieved, towards more sustainable aviation for a stronger, more competitive Europe.

PARTICIPATION

912 participations (over 500 unique entities)*

250 INDUSTRY MEMBERS

246 SMES

232 RESEARCH CENTRES

184 UNIVERSITIES

27 COUNTRIES

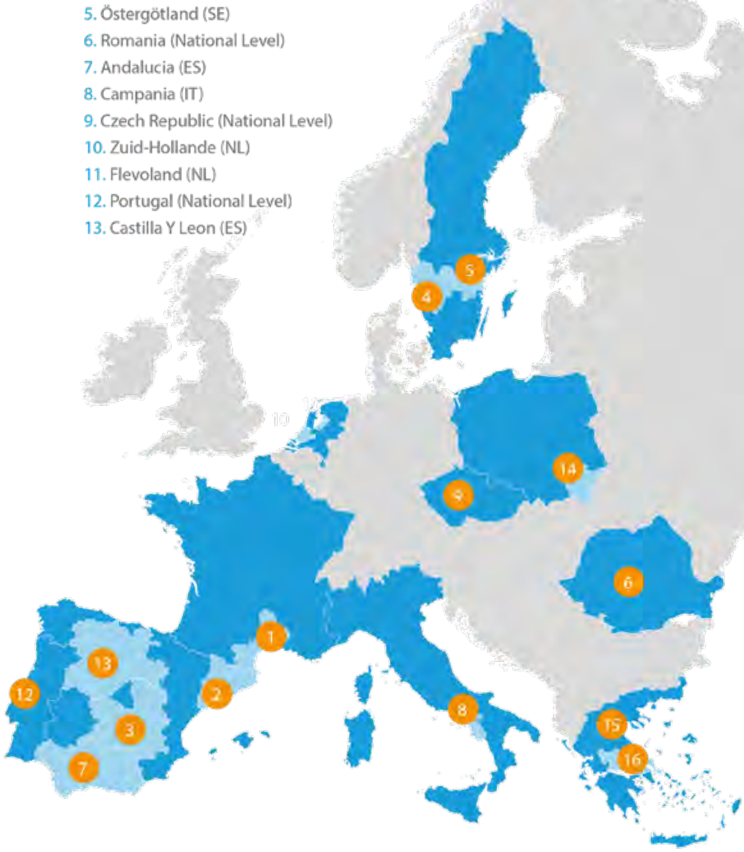
107 REGIONS

275 GRANTS

*in March 2018

WORKING TOGETHER ON SMART SPECIALISATION

1. Occitanie (FR)
2. Catalonia (ES)
3. Castilla La Mancha (ES)
4. Västra Götaland (SE)
5. Östergötland (SE)
6. Romania (National Level)
7. Andalucia (ES)
8. Campania (IT)
9. Czech Republic (National Level)
10. Zuid-Hollande (NL)
11. Flevoland (NL)
12. Portugal (National Level)
13. Castilla Y Leon (ES)
14. Podkarpackie (PL)
15. Greece (National Level)
16. Sterea Ellada (GR)



ROADMAP TO INNOVATION

Clean Sky Objectives

Clean Sky is actively contributing to the environmental goals of Flightpath 2050 Europe's vision for aviation by reducing gas and noise emissions.

	CLEAN SKY 2008-2017	CLEAN SKY 2 2014-2024	FLIGHTPATH 2050
$-CO_2$	-26%	-20% TO -30%	-75%
$-NO_x$	-60%	-20% TO -30%	-90%
NOISE	-50% TO -75%	-20% TO -30%	-60%

Clean Sky 2 is building on the successful Clean Sky 1 programme and its achievements.

Contra-Rotating Open Rotor

The highest propulsive efficiency to power next generation aircrafts delivering 30% reduction of CO_2

BLADE (Breakthrough Laminar Aircraft Demonstrator)

Natural Laminar Flow wing technology leading to 5% reduction of CO_2

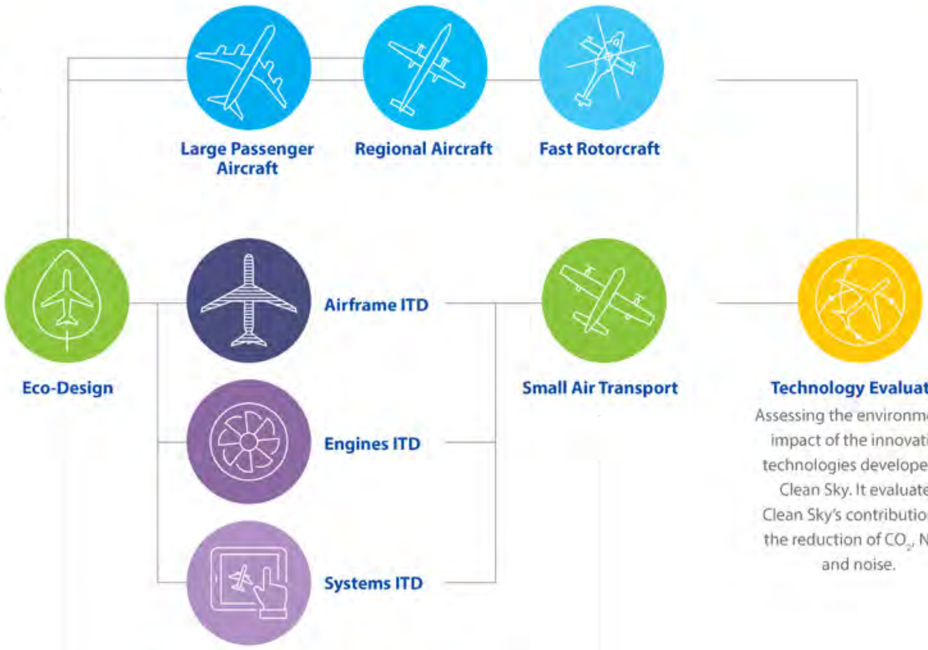
CLEAN SKY PROGRAMME - BUDGET € 4 BILLION

Innovative Aircraft Demonstrator Platforms (IADPs)

Integrating technologies and major systems innovations; demonstrating and validating their potential at the full vehicle level, towards future aircraft configuration.

Integrated Technology Demonstrators (ITDs)

Developing and integrating new technologies, with demonstrator projects validating these at major system level.



Technology Evaluator

Assessing the environmental impact of the innovative technologies developed in Clean Sky. It evaluates Clean Sky's contribution to the reduction of CO_2, NOx, and noise.

Transverse Activities

Focusing on specific applications and technology challenges across the IADPs and ITDs enabling synergies to be exploited between different platforms through shared projects and results.

MAIN DEMONSTRATORS

Breakthroughs in Propulsion Efficiency


Very High Bypass Ratio (VHBR) Large Turbofan
TRL 6 - 2023


Ultra-High Propulsive Efficiency (UHPE)
TRL 5+ - mid-2022


Advanced Geared Engine Configuration (HPC and LPT technology demonstration)
TRL 5 - 2023


Business aviation / short range Regional Turboprop
TRL 5 - 2022


Light weight and efficient Jet-fuel reciprocating engine (Small Aero-Engine)
TRL 6 - 2019


Reliable and more efficient operation of small turbine engines (Small Aero-Engine)
TRL 6 - 2019


Hybrid Propulsion Ground Test Bench
2020


Novel Aircraft Configuration & Scaled Flight Test
2021

Advances in Wings and Aerodynamics


Adaptive Wing Integrated Demonstrator Flying Test Bed
2022


Integrated Wing Technologies Flying Test Bed
2020 & 2023


Advanced Laminar Flow on Wings and Empennage


Laminar Nacelle Virtual
TRL 5 - 2019

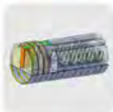
Innovative Structures and Production Systems


Advanced Rear End Demonstrator
2023


Functional Cabin & Cargo Demonstrator of new integrated systems


Next Generation Multifunctional Fuselage Demonstrator automated cabin assembly & structure integration


Advanced Lower Center Fuselage Demonstrator


Regional Aircraft Fuselage / Pax Cabin Integrated Demonstrator


Affordable aerostructures for Small Air Transport


Advanced Small Aircraft Wing Box in Out-of-Autoclave CFRP
2020

Future Cockpit and Flight Guidance Systems


Disruptive Cockpit Demonstrator (Function preparation test)
2023


Active Regional Cockpit
2020


BizJet Enhanced Cockpit Concept
2022


Avionics for Extended Cockpit Demonstrator -
2020


Affordable SESAR Compliant cockpit for Small Aircraft

Novel Aircraft Configurations


NextGenCTR demonstrator – Next Generation Civil


RACER - Rapid And Cost-Effective Rotorcraft

More Electric Aircraft & Systems


Regional Aircraft 'Iron Bird' Systems Integration – 2021


Innovative Electrical Wing - 2021


Electric Drive Landing Gear System (E-LDG)


Advanced Electrical Environmental Control System (E-ECS) Demonstrator


Full Chain demonstration: Electrical power generation, distribution and usage

Optimal Passenger Environment


Full Scale Mock-up of Business Jet Office Centered Cabin
2021


Innovative Cabin & Cargo Systems Technologies
2021

AMONG MAJOR DEFENCE PROGRAMMES

At ILA Berlin on 26 April 2018, German Defence Minister Ursula von der Leyen and her French counterpart Florence Parly signed a document outlining the high-level common requirements for three major defence programmes. These include the joint development of the Future Combat Air System (FCAS), the European MALE RPAS (Medium Altitude Long Endurance – Remotely Piloted Aircraft System) and a maritime warfare aircraft for the use from 2035 plus a concept of operations for a joint training and operations of fleet of C-130 J transport planes.

THE FCAS PROGRAMME

The Future Combat Air System (FCAS) will be a complex system of systems comprising new-generation fighter aircraft, future air-launched missiles, and swarms of small drones, all interconnected with satellites, other aircraft, NATO networks as well as national and allied ground and naval combat systems.

French and German Ministers of Defence with signed agreement.

« FCAS will revolutionize combat and our equipment, and allow more ambitious investments and innovations", French Minister of Defence Florence Parly said.

"When there is cooperation, nations must decide, and there is a lead nation, and for FCAS, it will be the French", German Minister of Defence Ursula von der Leyen said.

Dassault Aviation and Airbus will join forces to develop FCAS.

Dassault Aviation and Airbus Defence and Space have decided to join forces for the development and production of this European FCAS.

Eric Trappier (left), chairman and CEO of Dassault Aviation and Dirk Hoke (right), CEO of Airbus DS announce the FCAS programme at ILA 2018 in Berlin.

The partnership, sealed in Berlin by Dirk Hoke, Airbus Defence and Space Chief Executive Officer, and Eric Trappier, Chairman and Chief Executive Officer of Dassault Aviation, represents a landmark industrial agreement to secure European sovereignty and technology leadership in the military aviation sector for the future: an initiative fully supported by Germany's Chancellor Angela Merkel and French President Emmanuel Macron.

The FCAS will be developed as a system of systems including unmanned aerial vehicles, connectivity and secure communications. It will combine a wide range of elements connected and operating together, including a next generation fighter aircraft together with Medium-Altitude-Long-Endurance air vehicles, the existing fleet of fighter aircraft which will operate beyond 2040, future cruise missiles and drones flying in swarms. The overall system will be interoperable and connected in a large perimeter with mission aircraft, satellites and land and naval systems.

The overall development contract will follow an initial joint study this year. Demonstrators to support FCAS are planned as of 2025.

It is also the intention of the two partner aerospace companies to include BAE Systems in the FCAS project at some time in the future, building on its involvement with the Anglo-French combat drone being developed with Dassault Aviation (nEUROn and Taranis UCAVs).

"Never before has Europe been determined to safeguard and foster its political autonomy in the sovereignty in the defence sector. Airbus and Dassault Aviation have absolutely the right expertise to lead the FCAS project. Both companies are already cooperating successfully on MALE new generation drone programme. FCAS takes its successful cooperation to the next level and we are ab-

A full scale of the European MALE RPAS was unveiled on 26 April 2018 at ILA Berlin.

solutely committed to tackling this challenging mission together with Dassault Aviation. The schedule is tight, so we need to start working together immediately by defining a joint roadmap on how best to meet the requirements and timelines to be set by the two nations. It is therefore of key importance that France and Germany launch an initial joint study this year to address this task." Dirk Hoke said.

Eric Trappier declared: "We are convinced that by deploying our joint expertise, Dassault Aviation and Airbus can best meet the operational requirements of the Forces in the development of this critically important programme. Both companies fully intend to work together in most pragmatic and efficient manner. Our joint roadmap will include proposals to develop demonstrators for the FCAS programme as of 2025. I am convinced that sovereignty and strategic autonomy can and will only be ensured through independent European solutions. The vision that France and Germany have set forth with FCAS is a bold one and it is an important signal in, and for Europe. The FCAS programme will strengthen the political and military ties between Europe's core nations and it will reinvigorate its aerospace industry."

THE EUROPEAN MALE RPAS

Partners commit to the European MALE RPAS

MALE RPAS will be multilateral programme. Germany will lead it with Airbus and Dassault Aviation partnering with Leonardo of Italy and Spain's Indra.

The first full-scale model of the European Medium-Altitude Long- Endurance Remotely Piloted Aircraft (MALE RPAS) was unveiled on 26 April at ILA Berlin Air Show. Dirk Hoke, Airbus Defence and Space Chief Executive Officer (CEO), Eric Trappier, Dassault Aviation Chairman and CEO and Lucio Valerio Cioffi, Leonardo's Aircraft Division Managing Director, confirmed the commitment of the four European States and Industrial partners to jointly develop a sovereign solution for European Defence and Security. The unveiling came after a definition study launched in September 2016 by the four participating nations Germany, France, Italy and Spain and follows the Declaration of Intent to work together on a European MALE unmanned aerial system signed by the countries in May 2015. "While still a lot of work lies ahead of us, this full scale model represents a first milestone of what Europe can achieve in a high-technology sector if it bundles its industrial strength and know-how " said Dirk Hoke, CEO of Airbus Defence and Space. "The MALE RPAS will become an integral part in guaranteeing Europe's sovereignty in the future. This programme is ideally suited to meet urgent capability requirements of Europe's armed forces. This innovative partnership also eases the countries' constrained budgetary situation through clever pooling of research and development funds." He added.

Eric Trappier, Chairman and CEO of Dassault Aviation said that the unveiling reflected the companies' total dedication to the European Defence and Security sovereignty. Cooperation and high technology legitimate the leadership of the European Industry and guarantee the strategic autonomy of Europe. Innovative programmes through efficient partnerships will serve European competitiveness and will offer new alternatives to the off- the-shelf acquisition of non-European products. Dassault Aviation reaffirmed its full support to Airbus Defence and Space as programme leader of the MALE RPAS."

"Unmanned technologies and their applications represent one of the key technological foundations for the future evolution of European Defence Industries" said Lucio Valerio Cioffi, Leonardo's Aircraft Division Managing Director. "The European MALE RPAS is orientated to foster the development of high technologies and will contribute to sustaining key competencies and jobs within Europe providing Armed Forces with an high performance and sovereign operational system" he added.

The MALE RPAS is the first unmanned aerial system designed for flight in non-segregated airspace, its characteristics will include mission modularity for operational superiority in intelligence, surveillance and reconnaissance, both wide area and in-theatre. Entry-into-service of European MALE RPAS is planned for the middle of the next decade.

Synthesis written by J-P Sanfourche on the basis of Press Releases published after ILA Berlin.

THE JOINT ARMAMENTS COOPERATION ORGANISATION (OCCAR)

By Arturo Alfonso Meiriño, Director of OCCAR-EA

The Joint Armaments Cooperation Organisation (OCCAR) celebrates this year the 20th anniversary of the signing of its Convention by the governments of Germany, France, Italy and the United Kingdom on the 9 of September 1998. This Convention was later on ratified by the Parliaments of those countries in 2001 and by Belgium in 2003 and Spain in 2005.

THE OCCAR CONVENTION

The OCCAR Convention, based on the Baden-Baden Principles of 1995 issued by France and Germany, has the specific vision of promoting cooperation in armaments, improving efficiency and reducing costs in order to become a center of European excellence in the management of complex armaments programmes. It pursues the promotion of cooperation in armaments among nations, the promotion of free competition, industrial consolidation and the improvement of the regulatory framework of the defense market.

SUPPORTING THE EISD AND THE EDTIB

With a clear European vocation referenced in its preamble and articles, one of the missions assigned to it by the founding fathers was precisely to support the European Identity of Security and Defence, as well as strengthening the EDTIB (European Defence Technological and Industrial Base).
This vocation is reflected in its current portfolio, with 13 complex programmes for the acquisition of defense capabilities of an economic volume of more than 60 billion Euro, with the participation of the 6 member states and another 5 non-member states (soon to be 6 with Slovenia joining the BOXER Programme), all of them having the same rights and obligations as far as programme issues are concerned. This is a unique feature of OCCAR. Moreover, OCCAR can manage cooperative programmes that count only with the participation of non-member States. A good example is the Multinational MRTT Programme (MMF) that was launched with the only participation of the Netherlands and Luxembourg, that were later on joined by Norway, Germany and Belgium.

AN EFFICIENT MANAGEMENT

There are other factors that differentiate OCCAR from other management organisations. For example, the current size of OCCAR-EA, with its flat hierarchy (maximum of 3 hierarchy levels), allows fast and uncomplicated management of corporate and programme aspects, and a very lean structure, that entails a low administrative cost overhead of only 1.3%.
The authority and responsibility to manage a Programme is entrusted to the Programme Manager by delegation from the Director. Thus the PM is directly accountable to the Director for the effective and efficient management of the Programme; supported by a multi-disciplinary Programme Divisions with all functions necessary for the programme management, it can work autonomously.
Besides being the staff of the OCCAR-EA Director for the corporate management and governance, the Central Office supports the OCCAR Programmes by providing services (HR management; financial planning, accounting and banking, Security, ICT, Site Management, etc.), as a corporate knowledge pool and with dedicated workforce.
The OCCAR Convention and the underlying OCCAR Management Procedures (OMPs) are harmonised and agreed by all OCCAR Member States and are therefore the common basis for the management of cooperative armament programmes. It makes the integration of new programmes/new phases/new Participating States rapid and easy, as they can draw on the agreed existing rules.

The defined roles of the OCCAR Programme Boards and Programme Committees give the Participating States (PSs), as the customers, full transparency and control over their respective programmes as required by them.
The legal framework of OCCAR (Convention, OMPs, the Programme Decision and the Letter of Offer/Letter of Acceptance (LoO/LoA) process for non-Member PSs) has proven to be robust as it protects the joint and individual interests of OCCAR, its MS and the non-Member PS.
OMP 5 and OMP 6 provide an established framework including contract placement procedure and standard contract terms & conditions and is regularly coordinated with the ODIG (OCCAR Defence Industrial Group, representatives of the industry associations of the OCCAR Member States).

2018: DECISIVE YEAR FOR EUROPEAN DEFENCE

The year 2018 will be also a decisive year for the European Defence, as the European Defence Industrial Development Programme (EDIDP) regulation, in which the EC has been working, together with the Parliament and the Council, will come to light. Also the next Multiannual Financial Framework (MFF) budget is being prepared, and

its proposal encompasses funding for Defence research and development as well. Given that OCCAR core's business is the management of cooperative programmes, I firmly believe it to be a very well suited organisation for the management of programmes derived from the EDIDP or its successor in the next MFF.
With regard to current programmes managed by OCCAR, there are two of them that are clear candidates to be selected under the ongoing European Union initiatives related to the EDIDP and PESCO (Permanent Structure Cooperation).

THE MALE RPAS

Firstly the European Medium Altitude Long Endurance Remote Piloted Air System Programme (MALE RPAS), is an excellent candidate to test the functioning of EDIDP. RPAS are one of the shortfalls of defense capabilities identified by the EU. The programme is currently in its definition phase and is scheduled to enter the development phase in 2019. This programme, which was launched in 2015 by France, Germany and Italy, was soon joined by Spain. The Programme counts with Airbus Defense and Space Gmbh at the level of main contractor, and as Major Subcontractors with Leonardo, Dassault Aviation and Airbus Defence and Space S.A.U, but it will undoubtedly bring on board a broad spectrum of European small and medium-sized companies for future phases, and is particularly ripe to be chosen as one of the projects of EDIDP.

Artist view of the future MALE- RPAS

Then the Software-Defined Radio Programme (ESSOR), the result of the joint work of the Governments of Finland, France, Italy, Poland, Spain and Sweden, being one of the PESCO projects, might also benefit of the defence funding coming from the EU initiatives. In this case it might receive an additional 10% given that is one of the 17 identified PESCO projects. This programme has an important requirement for interoperability and a clear European identity and is aimed at providing efficient communications at the level of brigade and below, building a secure high-speed mobile ad hoc network. Currently in the operational capabilities phase OC1, already without the participation of Sweden, but with the integration of Germany under way, the ESSOR programme is undoubtedly another excellent candidate for the EDIDP.
Ultimately, it will be up to the EU Member States, in coordination with the European Commission (EC), to decide on the capability building projects that will be eligible to receive funding from the EC derived from the EDIDP and as well as its governance and thus, the potential role of OCCAR in this whole process.
Besides MALE RPAS, OCCAR has 3 other Air programmes in its portfolio.

THE TIGER

The Tiger Helicopter

The TIGER Helicopter Programme for example, another of the complex capability-building programmes managed by OCCAR, is currently in a transition phase. With the recent certification of block 2 of the HAD model and the future completion of the production phase, it is evident that this system, already operational in the Armies of Germany, France and Spain, which are its Programme Participating States, faces an important update. An update that will have the double objective of managing both the obsolescence and the modification of their systems and therefore with an important component of technological development, primary objective of the EDIDP.

Landing of an aircraft A400M during a test performed in Automn 2015

THE A400M

The A400M, a tactical and Strategic Airlifter designed to meet the demands of modern military operations, is at the forefront of developments in new technology for a large transport aircraft. The Contract for the Development, Production and Initial In-service Support was signed with Airbus Military SL (AMSL) in 2003. Since then the programme, managed by OCCAR-EA on behalf of the 6 Programme Participating States has faced some challenges, including a contract rebaselining in 2011, but has also achieved some significant milestones: the first flight took place in December 2009, the Initial Operating Capability (IOC) was achieved in 2013 and the first Aircraft delivery respectively to France in August 2013, to Turkey in April 2014, to the United Kingdom in November 2014, to Germany in December 2014 and to Spain in November 2016. As of today, 63 out of 170 A400M aircraft have been delivered to the Air Forces of France, Turkey, the UK, Germany and Spain. Belgian deliveries are planned to start in 2020.

THE MMF PROGRAMME

The air-to-air refueling capability was one of the critical shortfalls recognised in the European defense framework during the last years, in particular, in the conclusions of the European Council of 20 December 2013. The Multinational Multirole Tanker Transport Fleet (MMF) was launched on July 28, 2016, with the signature of the contract for the acquisition of 2 A330-200 MRTT aircrafts for the Netherlands and Luxembourg with Airbus D & S. The MMF Programme has evolved very positively ever since. The total number of flight hours demanded by the, so far, 5 participating nations (the Netherlands , Luxembourg, Norway, Germany and the recently incorporated Belgium), is 8,800 hours per year and therefore the MMF fleet consists currently of 8 planes, with an option for 3 additional aircrafts to be exercised before the end of 2019.

For the MMF programme, OCCAR acts as Contract Executing Agent for the NATO Support and Procurement Agency (NSPA), through a Cooperation Agreement between both Organisations. The OCCAR MMF Programme Division manages the Acquisition and two years of Initial In-Service Support of the 8 aircraft currently on contract; this fleet could be easily increased to 11 units if the MMF Nations decide to execute one or more of the three additional aircraft options included today in the contract to cover the operational needs on new or current members of the Programme. The NSPA, on the other hand, will be the owner of the fleet and will be responsible for its operation and maintenance for the MMF Nations. A detailed OCCAR-NSPA Transition Plan is currently under development to detail the transfer of responsibilities aligned with the delivery schedule of the assets.

However, although the «pooling» of this capability certainly implies the renunciation of full ownership of the aircraft, there is no impairment of sovereignty. Each member nation of the MMF programme may have access to the requested flight hours, when and as desired.

2018 : A CRUCIAL YEAR FOR OCCAR

I believe 2018 will be a crucial year for OCCAR taking into account the rapid evolution of the Defence initiatives launched in Europe. This is a big challenge for OCCAR which will, no doubt, have an impact in its future in terms of governance and dimension. Nonetheless, consideration will have to be given to OCCAR's 17 years of experience, its deliveries and good outputs, based on its manageable size, its flexibility and its scope, limited to the domain of the complex international cooperative armaments programmes. OCCAR stands ready to face these challenges subject of course to nation's wishes in entrusting additional programmes and responsibilities to the organisation.

Air-to-Air Refueling sequence with an aircraft A330-200 MRTT

SPACE SYSTEMS SUPPORTING SECURITY AND DEFENCE

By Gérard Brachet

THIS IS A SHORTENED VERSION OF "SPACE SYSTEMS SUPPORTING SECURITY AND DEFENCE: A NEW EUROPEAN APPROACH", DOSSIER No 43 OF THE ACADÉMIE DE L'AIR ET DE L'ESPACE/AIR AND SPACE ACADEMY PUBLISHED IN APRIL 2018.

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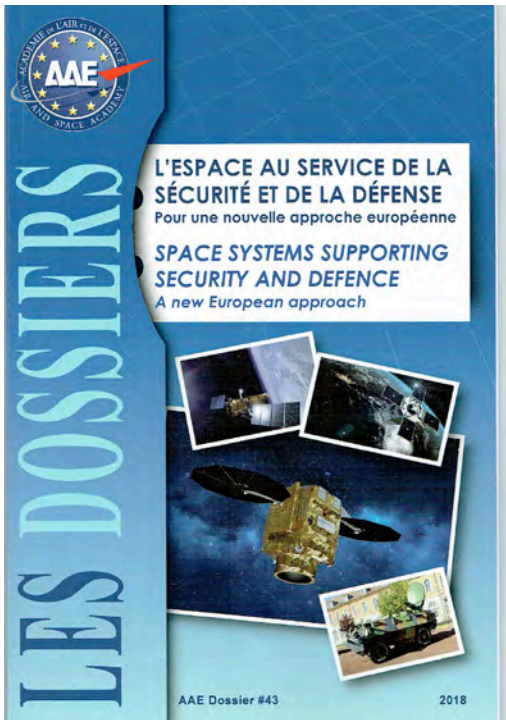
EXECUTIVE SUMMARY

Space-based capabilities serving military requirements offer wide-ranging pooling and sharing possibilities and should therefore be a privileged area for European cooperation. However, with the notable exception of the EU Galileo positioning/navigation system, the many attempts to set up such services in European cooperation have proved unsuccessful. These initiatives were too focused on deployment of the space infrastructure - with a strong "national" connotation - when the real objective is to provide a service. An analysis of military requirements for space-based services shows that it is possible to meet needs for the most part with dual-use systems or, for those that are military specific, to consider a "service purchase" approach. Such an initiative has the advantage of facilitating a pooling and sharing of capabilities. This would help relaunch European cooperation in the area to plan for the post-2030 or 2035 generation of space-based services capable of meeting EU military needs in the mid-21st century.

These space-based services correspond to the following defence and security missions:

- Intelligence and military geography, with optical and radar observation satellites as well as electronic intelligence satellites;
- Command and control of military operations with telecommunication satellites and navigation/positioning satellite constellations;
- Freedom of use of Outer Space, ensuring the security of our space-based assets by means of space surveillance techniques;
- Protection of our territory, improving our deterrence capability with early warning systems.

An overview is given of present and planned capabilities of European States. Although significant, they are scattered and poorly coordinated. However, substantial progress towards European strategic autonomy has been achieved firstly in the shape of independent access to outer space by the Ariane and Vega launchers, and more recently by means of the Galileo positioning and navigation system, with its PRS service restricted to government uses. Other EU initiatives, such as Govsatcom for secure satellite telecommunication services, show the way forward and, in the future, innovative approaches by industry to offer competitive services should facilitate the selection of the "service purchase" option, less costly and more flexible than traditional procurement of dedicated infrastructures.
The vulnerability of space systems does however call for specific protective measures. The security of Outer space assets, operated by, or on behalf of, European States and the European Union, is threatened by the proliferation of space debris and, in the case of dual-use or military space systems, new risks related to the deployment of in-orbit inspection and intervention vehicles by other space powers. To mitigate these risks, Europe must improve the resilience of its space infrastructures and their associated ground segments and enhance its space situation awareness capability by pooling existing space surveillance systems operated by member states and developing additional EU capability.



1. INTRODUCTION

In the recent past, and particularly since the Brexit referendum of 23 June 2016, many voices have been raised underlining the compelling need for a reinforced European approach to defence issues. The presentation at the end of June 2016 by Federica Mogherini, High representative of the European Union for Foreign Affairs and Security Policy, of the "Global Strategy for the European Union's Foreign and Security Policy", together with the implementation document in the areas of security and defence published in November 2016[1], have given a new impulse to theses reflections, based on the need to maintain Europe's autonomy in its strategy and decision process. This new dynamic once again appears very strongly in the European Commission's Communication to the European Parliament and the Council: « A European Defence Action Plan » published on 30 November 2016[2], which proposes the setting-up of a « European Defence Fund » aimed at funding defence-related research on the one hand, and the joint development of new capabilities on the other.

The first concrete implementation step was the setting-up in 2016 of a small budget for a pilot action on defence research, followed in 2017 by the Preparatory Action as a precursor to a future defence-oriented research programme (European Defense Research Programme, ERDP), at a level of € 500 million per year for the 2021-2027 period, within the next EU Framework Research Programme beyond "Horizon 2020".
More recently, on 7 June 2017, the president of the European Commission, Jean-Claude Juncker, presented a contribution called «Reflection paper on the future of European Defence»[3] which considers three possible scenarios for the evolution of European defence:
a) Security and defence cooperation. This scenario corresponds to a continuation of the present situation, with more active involvement of the European Union.
b) Shared security and defence. In this scenario, the 27 EU Member States would move towards shared security and defence. They would show far greater financial and operational solidarity in the field of defence.
c) Common defence and security. This scenario assumes that Member States would be ready to deepen cooperation and integration further towards common defence and security, leading to a genuine European Security and Defence Union. The European Council of June 2017 confirmed Member States' interest and agreement in principle with this initiative. The European Parliament also expressed its support.

The fact remains that more systematic development of defence systems in a European cooperative mode could prevent certain duplications and increase efficiency, provided that appropriate management rules are accepted and implemented.
Focusing on space systems supporting security and defence, these should be a key area for European cooperation because the services provided can easily be shared in principle. However, the numerous attempts - mostly on a bilateral basis - that have taken place over past decades have had limited, disappointing results. One possible explanation is that these initiatives were overly focused on space infrastructure, perceived as a national asset, while the purpose is essentially to provide services to the armed forces. It is therefore necessary to modify the approach taken for the last 30 years and adopt a new approach, based on a clear definition of services that need to be provided, with a view to relaunching a broad, ambitious proposal in this area. This cooperation could either go on within a European Union framework, or take the shape of multilateral cooperation programmes involving certain European nations, relying on the OCCAR organization which was set up in the early 2000s for this purpose.
It is now time to launch a new plan for broad, ambitious European cooperation.
This initiative should concern all sectors where space-based systems play an essential role in meeting security and defence requirements, i.e.:
- Intelligence and military geography, with optical and radar observation satellites as well as electronic intelligence satellites;
- Command and control of military operations with telecommunication satellites and navigation/positioning satellite constellations;
- Freedom of use of Outer Space, insuring the security of our space-based assets with space surveillance techniques;
- Protection of our territory, improving our deterrence capability with early warning systems.

2. CONTRIBUTION OF SPACE-BASED SYSTEMS TO SECURITY AND DEFENCE

2.1 The role of space systems to meet security and defence requirements

The security and defence missions that can be supported by space assets are in general well known and all concern data and information exchanges: telecommuni-

1. Implementation Plan on Security and Defense, note from the High Representative of the Union for Foreign Affairs and Security Policy, Council of the European Union, 14392/16, 14 November 2016
2. Communication from the European Commission to the European Parliament and the Council: « European Defense Action Plan » (COM(2016) 950), 30 November 2016
3. Reflection paper on the future of European Defence, Federica Mogherini and Jyrki Katainen, European Commission, 7 June 2017

cations and data transmission, in particular to and from external theatres of operations, intelligence gathering and surveillance missions for strategic and sometimes tactical purposes, positioning and guidance systems, electromagnetic intelligence, early warning and space situation awareness. They should not be seen as limited to operational support missions as their contribution is often essential before the development of crises, hence their importance within the framework of the reinforcement of strategic autonomy underlined in the Global Strategy for the EU's Foreign and Security Policy. Consequently, a great deal of attention should be given to what is specific to space assets, and therefore irreplaceable: the capacity for observation on a global scale with the highest degree of discretion, the instantaneous nature of information gathering, and the capacity of satellites to relay information without delay.

The notions of crisis and operations are naturally understood in the military sense, but can also be applied to situations of crisis following natural, human (migration) or industrial disasters, or resulting from acts of terrorism.

The main contribution by far is that of telecommunication satellites. It is worth noting that requirements for military telecommunication capacity grow by a factor of 10 every ten years due to the modernization of information and command systems, and the very large data bases that support them. This explains the priority given to them in most European states (Skynet satellites in the UK, Syracuse in France, Sicral in Italy, SatcomBW in Germany, Secomsat in Spain, etc.). One must note here that high speed telecommunication requirements are growing at a very high rate with the rapid deployment of military Unmanned Air Vehicles (UAVs), in particular for reconnaissance and weapon delivery.

The second largest contribution of space systems to security and defence is that of reconnaissance satellites, thanks to low Earth orbit observation satellites, optical initially (the Helios I and Helios II systems deployed from the mid-1990s, Pleiades, a dual system, and tomorrow, CSO), then complemented by radar imagery from the early 2000s (the German military system SarLupe and its follow-up SARah, the Italian dual system COSMO-SkyMed). One should also note the important contribution of civilian observation satellites to meet military mapping requirements (SPOT-1 to 5 satellites programme funded by France, Belgium and Sweden, 1986 to 2012, followed by SPOT-6 and 7 funded by Airbus Defence & Space). The Sentinel-1 and 2 satellites of the EU Copernicus programme now help to satisfy this type of requirement.

In this area, **satellites are also used for electronic intelligence (Elint) and early warning of missile launches** but so far in Europe, only France has deployed demonstrator satellites for such services, with satisfactory results. An operational Elint satellite system (CERES) will be deployed by France in 2020 within a strictly national framework.

The other major contributions of space systems to security and defence are in the field of positioning and navigation, thanks in large part to the American GPS system, whose military navigation signal (Code M) is accessible to some European states through specific bilateral agreements. The gradual introduction of the complementary European Galileo positioning services over the next few years, whose open service (OS) is interoperable with the GPS civilian open service, will reduce European dependence on the US system and increase the robustness of satellite-based positioning and time synchronization services, thanks to a larger number of satellites and increased orbital diversity of the two constellations. In addition, the Galileo PRS service, restricted to government uses, will deliver to the armed forces of European states an autonomous positioning capability, independent of the US-controlled GPS.

To be comprehensive, one might note **the important contribution of meteorological satellites to weather forecasting over operation theatres** and of oceanographic satellites for modelling the propagation of acoustic waves within the oceans. Most of these satellites are deployed and operated by civilian entities, for example the European organization EUMETSAT. See section 2.2 for a discussion of dual use of certain satellite systems.

A specific requirement that needs to be described in more detail is that of space situation awareness. An analysis of new threats highlights the need to take account of orbital debris, ballistic missile proliferation and weapons of mass destruction (although strictly forbidden by the Outer Space Treaty), and even the possible appearance of space weaponry (which might entail "killer" satellites or "neutralizing" satellites), and the potential threatening presence in orbit of nuclear or chemical devices. If such threats were to emerge, capabilities to oppose them should be developed. Space situation awareness also includes space weather monitoring. Like meteorological forecasting, space weather and in particular monitoring of solar flares, have important military implications, not only on satellite operations, but also on terrestrial infrastructures.

It is now urgent for Europe to reinforce its capacity for monitoring space, which means possessing an autonomous capacity to detect and track space objects, including debris, and to be able to identify them. Europe is still very dependent on the United States for the provision of information by the Space Surveillance Network even though significant progress has been made thanks to the French GRAVES monitoring radar, in operation since 2005, and the TIRA experimental imaging radar in Germany. Space surveillance is clearly of dual civil and military interest because it helps to prevent the risk of collision and to predict fall-out zones for space objects, thus ensuring the safety of the population.

Concerning military threats, another form of surveillance involves space-based systems able to detect missile launches,and provide early warning. The first of these missions consists of monitoring a given geographical zone, detecting ballistic missile launches by the signature of the plume and determining the location of launch sites as well as giving an early estimate of the missile trajectory. The second mission, early warning, can play a role in the context of deterrence thanks to its capacity to identify the aggressor and to support missile interception. It is thus an essential component of anti-ballistic missile defence.

Generally speaking, a prerequisite to European cooperation in the area of space infrastructure for security and defence is the notion that national sovereignty and the control of certain systems must evolve towards an assumed mutual dependency, ensuring greater autonomy at the European level. In most cases, with the notable exception of specific systems for nuclear deterrent forces, it seems that national sovereignty is not placed in jeopardy by sharing space-based systems provided that operational rules for the shared infrastructure are carefully negotiated beforehand. **A new notion of European "sovereignty" should progressively take over from the more traditional one of national sovereignty. Only a strong political vision can promote the emergence of this notion, but is this not precisely what has happened with the implementation of the Galileo positioning/navigation programme?** On this topic, the notion of "structured cooperation" as provided in the Lisbon Treaty, is generating renewed interest today and could constitute the ideal framework for new military or dual-use space programmes.

2.2 Duality of certain space assets

The space assets used to meet the needs of certain security and defence missions, can be civil systems, whether commercial or not (e.g. mobile telecommunications via Inmarsat, European meteorological satellites Meteosat and MetOp, the series of French-American oceanographic satellites Jason and the Sentinel 1, 2 and 3 satellites within the Copernicus programme of the European Union), or dual purpose assets (e.g. the Galileo positioning/navigation system, the Pleiades and COSMO-SkyMed observation satellites). The advantage of using commercial or dual-purpose assets, besides avoiding the cost of a dedicated infrastructure, is that available capabilities can be mobilized rapidly in the event of a crisis, as long as the regulatory and contractual arrangements have been properly anticipated.

A specific service, the public regulated service (PRS) of the European satellite navigation system Galileo, for instance, is dedicated to government applications with controlled access. The Pleiades optical satellites (France) and the COSMO-SkyMed radar satellites (Italy) are managed in dual-use mode, with specific arrangements in place to properly satisfy military requirements. The United States is calling increasingly on commercial sources for high resolution satellite imagery to satisfy its geo-intelligence requirements.
A well thought out approach to duality leads to carefully distinguishing between space systems which are dual in their objectives, for which specifications for military requirements are taken into account from the design stage, and space systems for dual usage, for which the initial design does not take account of specific military needs and military users are just ordinary customers. Clearly, systems in the former category should benefit from adequate financing from defence budgets.

3. EUROPEAN SPACE SYSTEMS CURRENTLY CONTRIBUTING TO SECURITY AND DEFENCE

With its operational systems - Syracuse for telecommunications, Helios I and Helios II, soon to be followed by CSO, for optical observation, GRAVES for space surveillance, and demonstrators like Essaim and ELISA for electro-magnetic intelligence, soon to be followed by the operational CERES system, Spirale for preparatory experiments in view of the definition of a future early warning system - France has made considerable investments since the 1980s but is more and more hindered by economic and budgetary considerations. The same is true of the other European countries active in the space domain: United Kingdom, Germany, Italy, Spain.

The report published by the European Parliament in January 2014 entitled «Space Sovereignty and European Security, building European capabilities in an advanced institutional framework»[4] comprehensively describes the efforts of the European states in the field of space infrastructure for Security and Defence. The report examines those space systems dedicated to access to space, observation satellite systems, telecommunication satellite systems, positioning/navigation systems, electronic intelligence systems and early warning systems.
An updated (as of August 2017) table of European space systems serving Defence requirements is provided *page 25* (not including the launchers segment).

Note that for the new generation of optical reconnaissance satellites, known as "CSO" (Composante Spatiale Optique), which will take over from the Helios II satellites from 2018 onwards, three spacecraft have been ordered from industry, one of which has had about 70% funding from Germany, which will therefore benefit from a priority access to this new constellation.
Also, note that no cooperation is planned at this stage for the operational electronic intelligence system CERES and no early warning satellite system is planned by a

4. Report EXPO/B/SEDE/2012/21, January 2014, ISBN: 978-92-823-5370-7

Telecommunications	Earth observation/ Reconnaissance	Positioning/ navigation	Elint	Space surveillance
Syracuse 3 (France) Athena-Fidus (France & Italy) Syracuse 4 (France)	Helios II (France Pleiades (France) CSO (France, Germany, Belgium, Sweden)		ELISA (France) CERES (France)	GRAVES (France)
SatcomBW (Germany)	SAR Lupe (Germany) SARAH (Germany)			TIRA (Germany)
SICRAL-1 & 2 (Italy)	COSMO-SkyMed (Italy) COSMO-SkyMed Second Generation (Italy) Optsat-3000 (Italy)			
Secomsat (Spain)	PAZ (Spain) SEOSAT/Ingenio (Spain)			
Govsatcom (EU)*		Galileo (EU)		EUSST initiative (EU)
Skynet-5 (United Kingdom) Skynet-6 (United Kingdom)				Starbrook (United Kingdom)

**Govsatcom is a proposal by the European Commission to set up an EU-wide telecommunication satellite system dedicated to government communications. See below.*

European state.
The table includes only governmental systems, to which should be added the « VHR 2020 » system initiated by Airbus Defense & Space Intelligence. VHR 2020, now renamed "Pleiades Neo", a constellation of four optical observation satellites collecting very high-resolution imagery (40cm), is scheduled to be launched in 2020 and 2021. This programme, representing an investment of around € 600 Million, is entirely self-funded by Airbus Defence & Space. Of course, their business plan includes a significant level of usage by the governmental authorities of certain European states, among which France and Germany, but no purchase commitments have been made at this stage.

4. THE NEED TO MAINTAIN INDEPENDENT ACCESS TO SPACE

The very concept of space systems for security and defence requires control over launch operations, and therefore to have an autonomous capacity, on the part of European states, to place their own satellites into orbit. The United States prohibits the launch of satellites exclusively funded by the Federal government by non-American launch vehicles or from a base not located on American soil.
Europe must continue to maintain independent, reliable access to space, access ensured so far thanks to the Ariane family and the French Guiana launch site, now complemented by the VEGA light launcher. The decision taken in 2014 to develop the new generation Ariane 6 launcher to take over from Ariane 5 will restore the flexibility that largely contributed to the success of Ariane 4.
The vital importance of independent access to space is now fully recognized by most European partners, but this autonomous access has its price, in terms of the cost of maintaining the launch base, the infrastructure, the industrial teams' necessary for the launcher production and the cost of the development teams who prepare vehicle evolutions and guarantee performance. It is advisable to take this into account in any budgetary planning for space activities for security and defence in Europe.

Looking beyond the current generation of launchers, the means necessary to realize this ambition should be tailored to operational requirements, in accordance with the evolving satellite design, notably in terms of mass and missions (orbits, integration into wider systems, support to ground operations). In particular, regular and low-cost access to orbit for very low mass micro- or nano-satellites is a real challenge, not necessarily met by smaller launchers! In this respect, a robust policy of support to technological research and openness to innovative solutions, remains indispensable. Reliable, cost-effective technical solutions should also be sought so that the cost of access to space weighs less heavily on the economy of new programmes.

5. RISKS AND THREATS, MITIGATION AND PROTECTION

Threats to Space Systems

The theme of the vulnerability of space systems is frequently mentioned nowadays because of the increasing dependence of the main space powers on these systems. This vulnerability comes firstly from the inherent risks of occupying the space environment which is, in itself, a hostile and demanding milieu that puts technologies to the test, with multiplies risks of breakdowns or mission failures. Added to this are the fears of strategists regarding possible attacks on the systems, which are currently deemed to be "vital". The deliberate destruction by China in January 2007 of one of its own spacecraft nearing the end of its useful life, as well as creating over 3000 additional orbital debris in the vicinity of the Sun-synchronous orbit, also raised awareness world-wide that the risk of an aggression in outer space is not purely theoretical!

Space was used for military purposes from the outset, indeed most past expenditure in space has gone into military applications.

The military use of space comprises all space assets that enable armed forces to improve their military efficiency. This means, for example, the use of satellites for intelligence gathering (observation or electronic intelligence), encrypted telecommunications, early warning, navigation and positioning. It is widely understood that this is covered by the Outer Space Treaty with its call for the use of space for peaceful purposes, and more precisely by the requirement that "*States Parties to the Treaty shall carry on activities … in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security …*"[5]. In this case, states that master access to space and the use of space for defence motives use space in a non-aggressive and pacific manner.

The Outer Space Treaty prohibits placing in earth orbit or stationing in space in any other manner objects carrying weapons of mass destruction, but it says nothing about "conventional" weapons. Up till now, no state has claimed to have placed weapons in outer space, and it is therefore assumed that this has not yet happened. However, several states like Russia, the U.S. or China, have demonstrated their capability to destroy orbiting satellites from the ground or from air-based platforms. The placing in space of weapon systems directed against other satellites would create a new operational option for a potential attacker and could have a destabilizing effect on the international environment in crises.

In addition to weapon systems intended for kinetic interference with satellites, there are numerous other options to destroy targets in space or to disrupt their functions, including for example, the use of directed energy (such as lasers) and electronic interference like jamming or cyber-attacks. Such attacks may be directed against the space assets, their ground infrastructure or the communication links between the two.

In addition, technologies are emerging to approach and interact with space objects in orbit for entirely non-aggressive purposes, such as servicing and repairing of satellites or active removal of debris. These technologies could also be employed with hostile intent, however.

Europe, the European Union and its Member States, should thus take existing and potential future threats into account in their future plans for the use of space, whether the applications in question are essentially civil or directly concern security and defence.

Faced with such a threat, and within the framework of a space effort to enhance its Security and Defence component, it is important for Europe to strengthen the protection of its systems and develop autonomous means to monitor the space environment around the Earth, in order to gain a better understanding of this environment and identify possible hostile or illegitimate acts.

Space surveillance systems should be developed to enable Europe to monitor and to characterize any abnormal event that takes place in orbit. Some actions have been taken on an experimental level: in France, the bistatic radar Graves, in Germany, the FGAN-TIRA radar, and in the United Kingdom the PIMS optical instruments, which provide a capacity for detection, orbitography, catalogue management and identification of objects in orbit. It is important to maintain this effort and an increase these capabilities on a European level, as planned in the EU "Space Surveillance and Tracking" (SST) programme initiated in 2014, although its current level of funding seems to be far too low. Europe needs a sensor configuration which provides a situational picture sufficient for its own security requirements. For this, additional sensors are required. The current systems in Europe were designed neither to operate in complementarity with each other and nor to guarantee the necessary operational readiness.

Furthermore, the European SSA/SST capability must ensure that Europe will be a credible and relevant partner for cooperation with the United States who are now providing the bulk of space surveillance data.

Hostile actions in space cannot be separated from the overall political and military situation. Deterrence against acts of aggression targeting space assets does not necessarily require a capability to respond in kind by anti-satellite systems. While the definition of proportionality might raise questions, retaliation could also take place in the land, sea, air or cyber domains or simply

5. *Article II, Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (abbreviated)*

through economic sanctions. What is essential is to be able to detect, characterize and identify the threats and to attribute responsibility with some certainty in order to produce indisputable proof.

Another important element of deterrence is the deployment of redundant systems to increase resilience, so that to knock out an entire capability (such as satellite navigation or telecommunications) would require the destruction of so many spacecraft that it would be unfeasible in practice or constitute an act of war that would invoke a major military response in other domains. This resilience may also be obtained by multinational agreements: allied nations (European and non-European) could negotiate mutual support agreements in order to minimize the loss of an operational space system, whether accidental or due to hostile actions. This type of mutual support agreement would apply equally to telecommunication and electronic surveillance and possibly to early warning. For global navigation/positioning functions, allies will benefit from the redundancy between GPS and Galileo.

This type of redundancy (often called « resilience » in specialized literature), is not accessible to a single country and not easy either to organize at the European level, although it would clearly be within the remit of the European Defence Agency to conduct studies on this issue. This explains why a broader framework has been sought to maximize the resilience of our space systems, the main factor in deterring an attack on our space systems in the next ten to fifteen years. The allied countries have been working on this topic for a few years already.

6. HOW TO PREPARE FOR THE NEXT GENERATION OF EUROPEAN MILITARY SPACE SYSTEMS BEYOND 2030 ?

6.1. Defining mission requirements

An enhanced synergy between European states for the utilization of space systems supporting security and defence missions must first rely on a convergence of the analysis and definition of mission requirements. Space systems are not weapons but essentially provide services, so this entails not only a very precise definition of the required services but also the need for this definition to be commonly accepted by all partners, including specific military aspects such as the protection of information and ensuring secure communication. This convergence in the definition of services has so far been difficult to achieve, in part due to the wide differences of appreciation between states as to the role of space systems in satisfying the requirements of the armed forces, whether in telecommunications, intelligence gathering or positioning/navigation. As for early warning, this function is often considered as falling under NATO responsibility.

The necessary convergence of understanding as to how certain requirements can best be satisfied by space systems could be a task devoted to the European Defence Agency (EDA), in line with its terms of reference, but subject to the explicit agreement of EDA's Member States. This is essential, in particular for requirements associated with Intelligence where the traditional way of operating is to proceed by exchange of information rather than by sharing of information.

6.2.Choice between purchasing services and owning and operating dedicated systems

Another issue to be considered by European states before initiating new satellite programmes is whether to buy services, as the United Kingdom did for example with the Paradigm mechanism for its Skynet 5, and more recently Skynet 6, telecommunication satellites, or to possess their own space infrastructure dedicated to satisfying their military requirements. Intermediary solutions are also possible, as in the case of Germany's Bundeswehr for its SatcomBW telecommunication satellite, in which Germany retains ownership while its operation is contracted out to a commercial company. Besides the economic dimension of this choice, which remains a major parameter, an important consideration is control of the space infrastructure and its operation. This issue comprises questions as to the physical protection of the infrastructure in case of conflict, the risk of a take-over by enemy entities and the protection of confidential information concerning the infrastructure or of data information relayed by it.

Nonetheless, since the objective of a space system is to provide a service to the armed forces, the option of purchasing the service rather than the whole system should be considered very seriously, even though this option is sometimes seen as going against the traditional approach within the military community. The one exception to this is the early warning mission, which is inherently linked to anti-missile defence and deterrence. The fact of purchasing services also offers the additional advantage of being able to call on dual-use systems which, since they also serve the commercial markets, can benefit from lower prices.

6.3. Managing procurement programmes

Principles for the efficient management of joint defence-related development programmes were established following in-depth discussions within the Defence commission of the Air and Space Academy and were published in a formal « Opinion » of the Academy in 2016:" A robust management system for joint European defence programmes"[6]. The main principles contained in this opinion paper, summarized below, are directly applicable to

6. A robust management system for joint European defense programmes, Air and Space Academy, Opinion no 7, 2016, ISBN 978-2-913331-67-9, ISSN 2426 3931 the management of space systems development programmes. However, they will need to be adapted if the option of purchasing services is selected instead of the procurement of a dedicated infrastructure.

A. Responsibility for overall programme management should lie with the EDA, assisted by a Programme Committee comprising representatives of the participating member states. The European Defence Agency could delegate some programme management tasks of certain programmes to the European Space Agency (as is the case already for the demonstration phase of Govsatcom), or to a member state. In particular, this would be appropriate when the programme was initially proposed by a member state ready to bear a large share of its funding. In both cases, the supervisory role of the EDA should remain unchanged.

B. Programme management from the initial design studies should be the responsibility of a prime contractor with recognised competencies and with all necessary decision powers.

6.4.Organising the exploitation phase

When a space system is used by several partners, it means that once deployed and tested in orbit, the infrastructure is shared between them. This situation requires agreement on a set of clear, precise exploitation rules from the system's initial definition phase. These rules have a strong impact on the architecture of the ground segment and determine operational procedures, capacity sharing and rules for information protection, etc. As an example, the experience gained through the exploitation of reconnaissance satellites, both optical (Helios II and Pleiades by France and its partners) and radar (SAR Lupe by Germany and COSMO-SkyMed by Italy), has shown that sharing of capacity on a daily basis is a challenging job and requires efficient, rapid interaction between the authorities responsible within each partner country. To be effective, this interaction must be based on mutual trust and a good understanding of the technical constraints affecting the system. Specific attention must therefore be given to organisation of the exploitation phase from the outset of discussions on any new cooperative space system. If not adequately prepared, the early phase of exploitation will face considerable difficulties which could negatively affect partners' confidence in each other.

7. CONCLUSIONS AND RECOMMENDATIONS

Contrary to the situation in the United States and Russia, the contribution of space systems to meeting security and defence requirements, has long been underestimated by the armed forces of European states. However, this contribution is better recognized today. In addition, the cost of deployment of space systems has significantly decreased, thanks to the availability of new technologies, e.g. mini- and microsatellites, and also because sharing space-based capabilities between civilian and military needs has proved to be feasible.

One must regrettably observe that European cooperation in the development and deployment of space systems serving security and defence has been very limited since the years 1980 - 1990. An analysis of the many failed attempts to set up European cooperation programmes for the development of military space systems points to two main obstacles which have proved difficult to overcome:

- Major differences between states in their degree of understanding how space-based services should be integrated within their military operation plans because of lack of experience in using such services, particularly to support military operations on foreign theatres.
- Priority given to building-up dedicated space infrastructures with a strong national character, with a clear objective of supporting national industry.

This situation has led to a proliferation of uncoordinated space systems, all funded by national defence budgets at a time when these same defence budgets are under extreme stress. In addition, some areas of space systems serving security and defence requirements are poorly covered, such as space situation awareness and electronic intelligence, or not covered at all in the case of early warning.

The new approach suggested in this dossier, for the next generation of space systems serving security and defence, is to go back to basics, i.e. to start from a better definition of the expected services without any blanket assumption on the technical architecture of the space infrastructure, nor of its ground based component. This approach should facilitate the sharing of capacities between partners and encourage, whenever possible, the purchase of services from industry operators, as is often the case today for satellite telecommunications.

Finally, one specific recommendation needs to be highlighted, the setting up of an EU-owned space surveillance capability that goes much further than merely improving on the radar systems already available in France and Germany. The security of both civilian and military activities in outer space of the European states and of the European Union is threatened by the deployment by the other major space powers of new inspection and potentially aggressive orbital systems. Europe must be better equipped to face these threats.

EUROPEAN LARGE UNFURLABLE SPACEBORNE REFLECTOR ANTENNAS : CURRENT STATUS AND FUTURE PERSPECTIVES

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1. INTRODUCTION

Reflector antennas are in general known to provide a high gain over a desired area, while being broadband and lightweight. The satellite accommodation constraints for the on-board antenna are mostly stemming from both the available volume under the launcher fairing and the volume occupied by the spacecraft platform. The need for unfurlable reflector antennas is dictated by the performance requirements that can only be fulfilled by an antenna aperture size that is not compatible with the accommodation constraints in the case the reflector would be made of a single rigid piece. The unfurlable reflector antennas are therefore made of multiple pieces that can either be solid and/or flexible. In that way, the deployable reflector antenna can be accommodated on the platform while it is stowed under the launcher fairing, and its radiating aperture can be unfurled once the satellite is placed in orbit.

It is mandatory that a multi-disciplinary approach is put in place since a broad perimeter of engineering expertise such as electromagnetic, thermo-mechanical and technological ones is necessary for the design and development of unfurlable reflector antennas. Furthermore, a closely coordinated approach between all these engineering fields is needed such that this complex system meets the stringent reliability requirements imposed by the space missions.

In order to ensure European non-dependence with regards to this technology, the European Space Agency (ESA) is undertaking a number of initiatives and is running different activities supported by ESA's EOEP, CTP, TRP, ITI, GSP, GSTP and ARTES programs to develop and mature the technologies and concepts required for the realisation and application of deployable structures. Recent developments have allowed to advance European technologies to a TRL of up to 4/5 at assembly level. These developments performed by several European companies (*see Figure 1*) allow to envisage performances which are competitive with respect to existing commercial products and enable a large variety of missions.

2. CONTEXT

Few countries have successfully flight proven large unfurlable reflector technology up to now (US, Russia, Japan, Israel, India and China) and the current accessible commercially available large reflector products for European missions are procured outside Europe. Based on this, in 2010, ESA created a Working Group on Large Reflector Antenna in order to define a vision on the way forward for the development of large reflectors in Europe. An ESA analysis concluded that there is a future need of large unfurlable reflectors. It also observed that a market in this technology domain is accessible for emerging European players. Moreover, it was indicated that large unfurlable antennas are a critical space technology for European strategic non dependence.

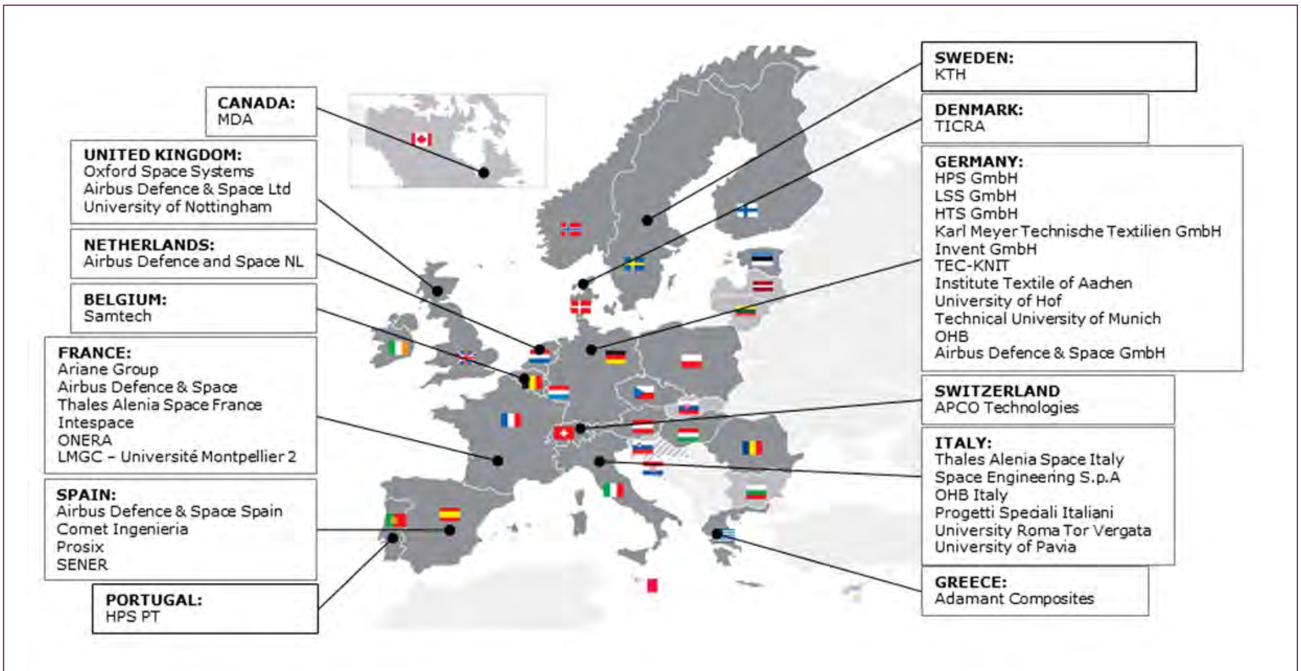


Figure 1: European entities involved in the ESA R&D for large unfurlable reflector technology

3. STATUS OF THE EUROPEAN TECHNOLOGY

3.1. Overall reflector antenna architecture

A large unfurlable reflector antenna in general consists of:

- A deployable structure for the reflector (typically circular or elliptical when deployed);
- A RF reflective surface, connected to the deployable structure;
- A deployable arm connecting the reflector and spacecraft for offset antennas;
- A single feed or a feed array.

3.2. Reflector concepts and deployable structures

Among the possible reflector concepts and deployable structures, ESA has identified promising concepts which are the conical or cylindrical ring based reflector, the triptych reflector, and the umbrella reflector. These reflector concepts have been developed in different R&D activities and are currently being further matured.

As far as the reflector based on conical or cylindrical ring structure (*see Figure 2*), it can be deployed by either V-folding bars, single or double layer pantographs; deployable tetrahedrons forming a ring when deployed; or unit cells arranged next to each other as a modular assembly. Different patents have been filed by ESA and also the contractors in the different activities to protect the IPR for Europe.

Regarding the triptych reflector (*see Figure 3*), the concept relies on solid CFRP parts of a central section with two side deployable curved panels with dedicated deployment and hold-down mechanisms to deploy the solid reflector in-orbit. This concept is known to be limited in terms of radiating aperture size (up to 6-7 meters) due to accommodation constraints.

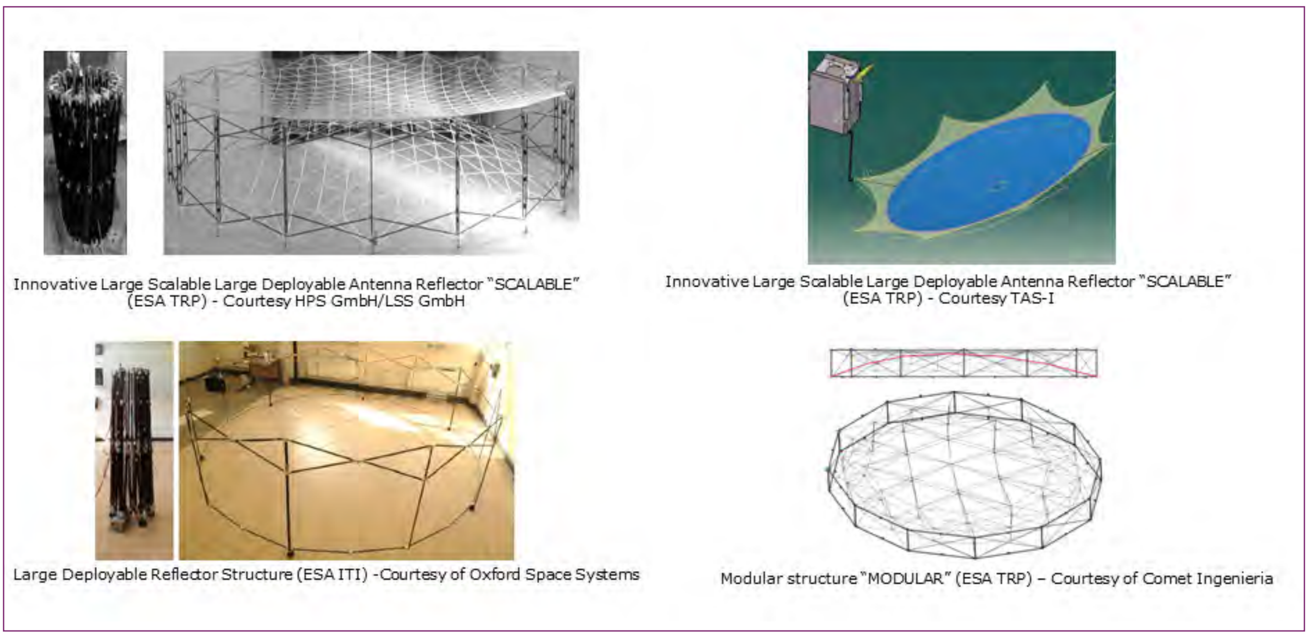
The umbrella reflector concept (*see Figure 4)* is suitable for center-fed antenna geometries such as the cassegrain antenna or the splash plate/ring focus antenna. It consists of curved rigid ribs that need to be deployed synchronously and a reflective surface connected to the ribs. Depending on the application and the overall antenna geometry, it may be necessary to increase the number of ribs in order to meet RF surface accuracy requirements. Furthermore, the size of this antenna can be limited in terms of radiating aperture size due to accommodation constraints.

Figure 3: MSURA triptych reflector development (ARTES AT) – Courtesy of Ariane Group – Les Mureaux [FR]

3.3. RF reflective surface technologies

For the RF reflective surface two configuration are under development and verification: Knitted metal mesh technology and Carbon Fiber Reinforced Silicone Membrane Technology (CFRS).

The metallic mesh is considered a good solution for the RF reflective surface of the reflector since it is lightweight, and can be designed with low RF loss up to Q-band. In addition, it can be expanded after launch



Innovative Large Scalable Large Deployable Antenna Reflector "SCALABLE" (ESA TRP) - Courtesy HPS GmbH/LSS GmbH

Innovative Large Scalable Large Deployable Antenna Reflector "SCALABLE" (ESA TRP) - Courtesy TAS-I

Large Deployable Reflector Structure (ESA ITI) -Courtesy of Oxford Space Systems

Modular structure "MODULAR" (ESA TRP) – Courtesy of Comet Ingenieria

Figure 2: Deployable Ring Structures

Figure 4: Umbrella reflector concept, DASS Deployable Antenna Structure for Small Satellites (ARTES AT) - Courtesy of PROGETTI SPECIALI ITALIANI S.r.l. (IT)

by a deployable structure and shaped by a tensioning system, by either symmetrical nets or wire network. The mesh is made of electrically conductive wires arranged to provide an elastic surface, which can be stretched to achieve the prescribed surface profile once the reflector is deployed on orbit. Several alternative configurations (*see Figure 5*) can be envisaged for the mesh design in terms of material (e.g. molybdenum or tungsten), yarn configuration (e.g. single or multiple wires), stitch pattern.

As an alternative solution to the metallic mesh, a flexible RF reflective membrane has been developed. The membrane is based on Carbon Fiber Reinforced silicone (CFRS) with a silicone matrix featuring a low temperature

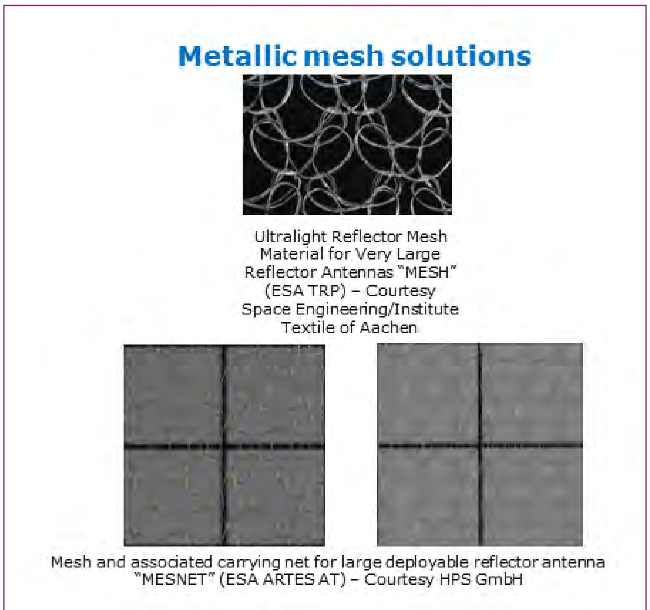


Figure 5: Metallic mesh as RF reflective surface

Figure 6: Flexible membrane made of CFRS as RF reflective surface

for glass transition, and high flexibility over large temperature range *(see Figure 6*). Furthermore, this technology has excellent RF properties in terms of RF reflectivity and Passive Intermodulation (PIM).

3.4 Deployable booms for reflector

Two concepts of deployable booms have been developed (*see Figure 7*):

- the articulated boom
- the linear structure consisting multiple deployable unit cells

These deployable booms have been designed to be modular and scalable. Moreover these booms provide a good deployment accuracy and repeatability, and dimensional stability when deployed.

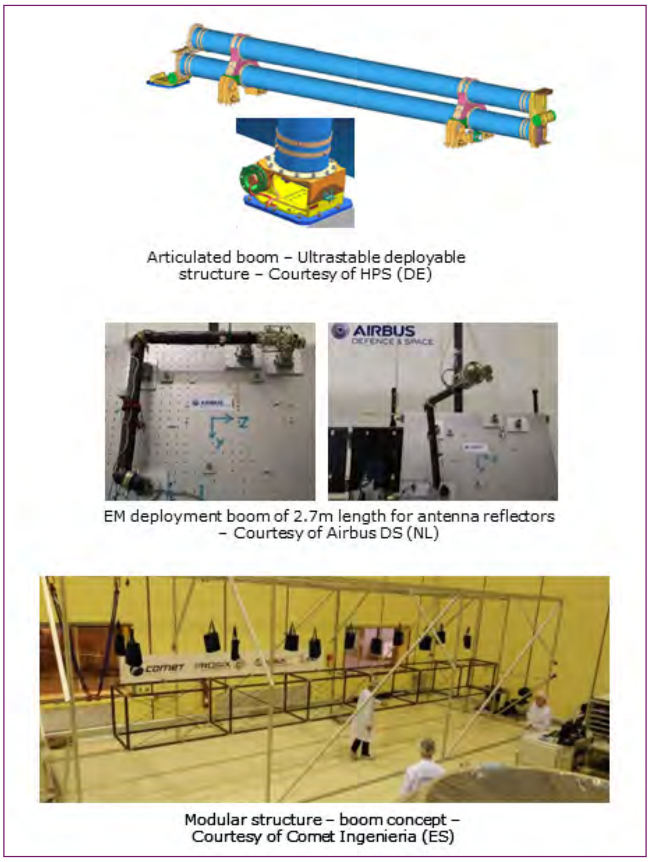


Figure 7: Reflector antenna deployable boom concepts

4. FUTURE PERSPECTIVES IN EUROPE AND CONCLUSION

Several applications have been identified by ESA where the large reflector antenna is considered as a mission enabler. The space telecommunication sector is currently asking systems delivering high throughput to compete with or to complement terrestrial communication systems. Since the frequency spectrum for space communication is a limited resource, the high throughput systems are currently based on multiple beams. The more beams produced over a desired area, the higher are the frequency spectrum reuse and the resulting data rate capacity. In order to achieve multiple cells with a narrow footprint, a large antenna aperture is required to produce extremely narrow beams from a geostationary orbit. Very high throughput satellites placed in geostationary orbit (GEO VHTS) shall be able to produce several hundreds of Ka-band beams of typically 0.2∞ in order to meet Terabit/s capacity. Due to increased spatial resolution and sensitivity requirements, advanced active and passive microwave instruments of remote sensing satellites for Earth Observation need more and more a large radiating aperture. Among the different antenna solutions, large unfurlable reflector antenna solutions are often selected. Two Copernicus Expansion missions funded by the European Commission (EC), EROS-L, a L-Band SAR instrument satellite, and CIMR, a passive imaging microwave radiometer instrument satellite, that may be based on large unfurlable reflector antenna solutions are currently under phase A/B1 study at ESA.

In order to further mature the large deployable reflector technology, ESA is engaged to pursue the unfurlable reflector technology effort along several complementary axes:

- Large unfurlable reflector technology for Ka-band applications;
- In-Orbit Demonstration of LDA;
- Large unfurlable reflector technology with increased size for low frequency applications;
- Large unfurlable reflector for nanosats/microsats.

THE COPERNICUS SENTINEL 4 MISSION – THE LATEST DEVELOPMENTS IN THE GEOSTATIONARY IMAGING UVN SPECTROMETER FOR AIR QUALITY MONITORING

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I. INTRODUCTION

Sentinel-4 is an imaging UVN (UV-VIS-NIR) spectrometer, developed by Airbus DS under ESA contract in the frame of the joint EU/ESA COPERNICUS program. The mission objective is the operational monitoring of trace gas concentrations for atmospheric chemistry and climate applications – hence the motto of Sentinel-4 "Knowing what we breathe". Sentinel-4 will provide accurate measurements of key atmospheric constituents such as ozone, nitrogen dioxide, sulfur dioxide, methane, and aerosol properties over Europe and adjacent regions from a geostationary orbit (*see Fig. 1*).

In the family of already flown UVN spectrometers (SCIAMACHY, OMI, GOME & GOME 2) and of those spectrometers currently under development (TROPOMI on Sentinel-5p and Sentinel-5), Sentinel-4 is unique in being the first geostationary UVN mission. Furthermore, thanks to its 60-minutes repeat cycle measurements and high spatial resolution (8x8 km^2), Sentinel-4 will increase the frequency of cloud-free observations, which is necessary to assess troposphere variability.

Two identical Sentinel-4 instruments (PFM and FM-2) will be embarked, as Customer Furnished Item (CFI), fully verified, qualified and calibrated respectively onto two EUMETSAT satellites: Meteosat Third Generation-Sounder 1 & 2 (MTG-S1 and MTG-S2), whose Flight Acceptance Reviews are presently planned respectively in Q4 2021 and Q1 2030.

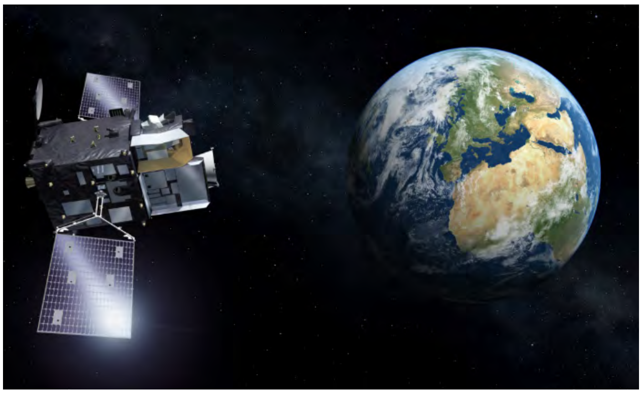
This paper gives an overview of the Sentinel-4 system[1] architecture, its design & development status.

II. SENTINEL-4 REQUIREMENTS AND CONCEPT OVERVIEW

A. Sentinel-4 Requirements

The spatial coverage over Europe and adjacent regions will be achieved by continuous East/West scanning of the image by a push-broom mirror mechanism, which will cover a field-of-regard of about 11 degrees, while the North/South instantaneous field-of-view (IFOV) will be equal to 3.85 degrees.

1. In this paper the term Sentinel-4 system refers to the instrument (flight) H/W & S/W, operations concepts, on-ground and in-flight calibration, L1b algorithms and processing.



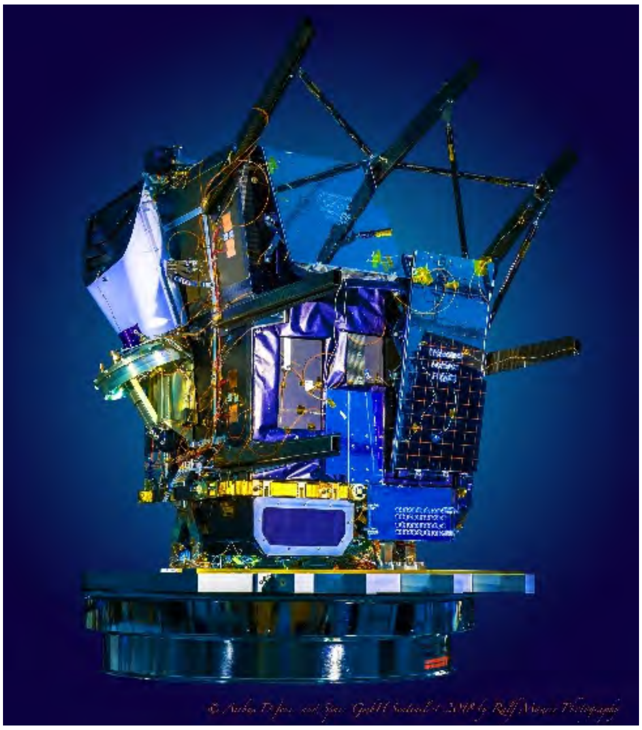


Fig. 1: Upt: artistic impression of Sentinel-4 embarked on Meteosat Third Generation-Sounder. Bottom: photo of the instrument e-EM (without MLI) currently under testing.

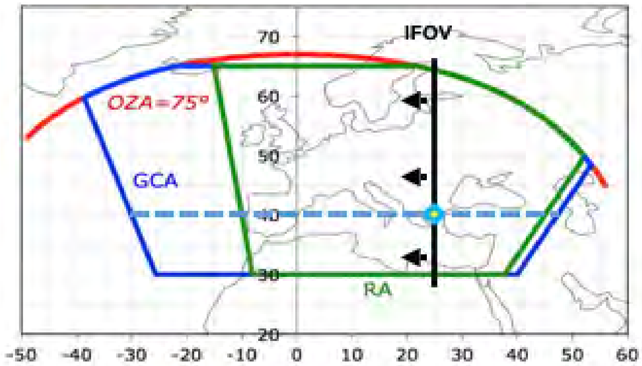


Fig. 2: Earth coverage from the geostationary Sentinel-4 perspective.

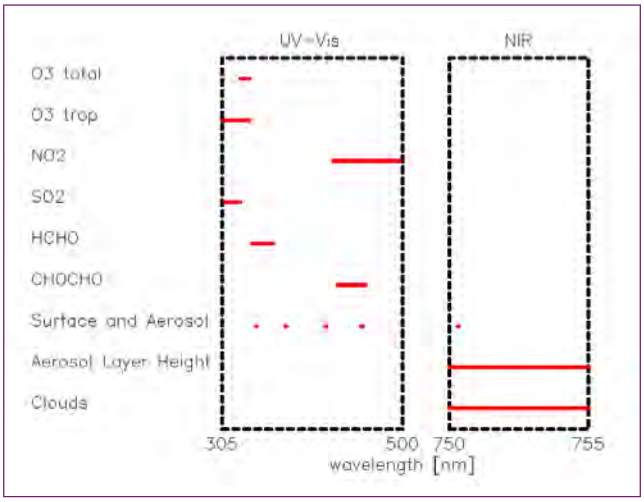


Fig 3: Spectral ranges exploited for each Sentinel-4 product during Level-2 processing

Blue and red lines, shown in *Fig. 2*, indicate the borders of the specified Geo-Coverage area (GCA), which is the total area to be covered every day. The overall daily Earth observation pattern consists of a series of 1 hour-long East-to-West scans ("repeat cycles") with a fast West-to-East retrace in-between.

The green border indicates the size of a 1-hour repeat cycle (Reference Coverage - RA). Depending on the seasonally varying duration of Earth illumination by the Sun, the daily Earth observation scan series consists of 16 (winter) to 20 (summer) 1h-scans.

The first scan starts at the eastern edge of the Geo Coverage area. The 1 hour repeat cycle coverage is shifted westward in two steps during each day in order to follow the Sun illumination and to achieve full Geo-Coverage.

While observing Europe and its adjacent regions, the Sentinel-4 imaging spectrometer will acquire continuous spectra of Earth radiance using the Sun as a light source illuminating the Earth. It will cover the Ultra Violet (305-400 nm), the Visible (400-500 nm) and the Near Infrared (750-775 nm) wavelength bands, with spectral resolution of 0.5 nm in the first two bands and 0.12 nm in the third band (*see Fig. 3* for the link between the acquired spectral bands and the Level-2 products).

Additionally, Sentinel-4 will provide Sun irradiance data product every 24 hours, which will be used for instrument calibration purposes and for the determination of the Earth reflectance.

Table 1 page 34 gives an overview of the Sentinel-4 instrument main design and performance requirements. There are also many specific pointing and scan accuracy and stability requirements not explicitly listed in Table 1, which are the main drivers for the scanner subsystem and for the instrument thermo-mechanical design.

Table 1: Main design and performance parameters of Sentinel-4

SPECTRAL			
Parameter	**UV-VIS values**	**NIR values**	**Comments**
Wavelength range	305-500 nm	750-775 nm	
Spectral Resolution / Spectral Oversampling	0.5 nm /3	0.12 nm /3	Oversampling is Resolution divided by spectral pixel sampling
Spectral Calibration Accuracy	0.0017 nm	0.0020 nm	

GEOMETRIC AND TEMPORAL COVERAGE		
Parameter	**values**	**Comments**
Spatial Sampling Distance (SSD)	8 km x 8 km (E/W) (N/S)	On-ground-projected SSD at reference point in Europe (45°N latitude; sub-satellite-point longitude)
Integrated Energy	70% over 1.47SSDEW*1.13SSDNS 90% over 1.72SSDEW*1.72SSDNS	Integrated energy is a measure for the spatial resolution of the instrument
N/S slit field-of-view (swath)	4.0°	
E/W coverage & Repeat cycle	See Fig. 2	See Fig. 2
Daily Earth observation time	Summer max: 01:40 – 21:40 Winter min: 03:40 – 19:40	Adjusted to seasonally varying solar Earth illumination on monthly basis
Spatial co-registration	Intra-detector: 10% of SSD Inter-detector: 20% of SSD	2-dimensional (E/W & N/S) absolute co-registration

RADIOMETRIC			
Parameter	**UV-VIS values**	**NIR values**	**Comments**
Optical Throughput	~50% (in UV)	~60%	End-to-end scanner-to-detector
Radiometric Aperture	70 mm	44 mm	Circular diameter
Earth Signal-to-Noise-Ratio (SNR)	UV: >160 VIS: >1600	759-770nm: >90 Rest NIR: >600	For specified Earth radiance Reference scene
Earth Absolute RA	< 3%	< 3%	For Earth radiance & reflectance
Sun Absolute RA	< 2%	< 2%	For sun irradiance
Polarization Sensitivity	< 1%	< 1%	
Polarization spectral features	< 0.015%	< 0.1%	
Sun diffuser spectral features	< 0.042%	< 0.076%	Caused by speckle effect
Power	212 W (average in operating mode)		
Mass	200 kg		
Data	25.1 Mbps (instantaneous, during acquisition)		
Number of units	Three (3): • Optical Instrument Module (OIM), which contains the optical and detection part • Instrument Control Unit (ICU) • Scanner Drive Electronic (SDE)		
Dimensions	OIM : 1080 x 1403 x 1785 mm ICU: 460 x 300 x 300 mm SDE: 300 x 200 x 100 mm		

B. SENTINEL-4 MEASUREMENT CONCEPT

The instrument measurement concept, illustrated in *Fig. 4*, can be described as follows:

- A scanning mirror (not shown in the figure), operating in push-broom mode, selects a strip of land whose "white light", reflected by the Earth and transmitted through the Earth atmosphere, is collected by the telescope.
- The collected "white light" is split into two 2 wavelength ranges (i.e. the Ultraviolet & Visible-UVVIS and the Near-Infrared-NIR ranges) by a dichroic beam-splitter mirror and focused onto the two slits of the two separate spectrometers.
- The light is then first collimated onto the dispersing optical elements of the two spectrometer channels (either a grating or a grism) and then dispersed in the spectral direction.
- The generated spectra are re-imaged onto two 2-dimensional charge coupled device (CCD) detector arrays. One dimension features the spectrum, the other dimension the spatial (North/South) direction corresponding to the selected strip on Earth (ground swath).
- At the end of this scanning process which lasts about 1 hour, spectra of multiple strips of land, which make up the complete field of view, are acquired and a complete spectral image of the Earth atmosphere over Europe is created. The process is repeated daily n-times so long as the relevant strip of land is illuminated by the Sun.

Observation from GEO orbit fulfilling the above mentio-

Fig. 4: Sentinel-4 instrument measurement principle.

ned requirements presents several challenges. Optical coatings have to fulfill simultaneously very challenging requirements related to polarization (incl. pol. spatial & spectral features), throughput, and straylight (ghost suppression) performances. Grating structures on the dispersers have also to fulfill simultaneously requirements related to polarization- and throughput-performances. To suppress straylight, very low micro-roughness on the order of 0.5 nm (rms) from essentially all surfaces in the nominal optical path is required. In addition the lens mounts have to meet very demanding tolerances & stability requirements in the 1µm range, and compensate for the different thermal expansion coefficients of the various materials. Calibration OGSE and correction algorithms have to be developed for the correction of straylight, and also the corresponding on-ground straylight characterization measurement concepts and OGSEs are very demanding, in particular the fine-tunable monochromatic light source needed to characterize the ISRF. Very demanding pointing and scan accuracies are required from the scanner leading to the development of a dedicated encoder for SENTINEL 4. The detector requires a very high full well capacity of about 1.5 Me^-.

III. SENTINEL-4 INSTRUMENT DESIGN

A. Instrument description

The Optical Instrument Module (OIM) unit is the core of the instrument and contains the main instrument subsystems including the structural parts, the optics, the focal plane detection & read-out, the calibration assembly, the scanner, the aperture cover and the thermal subsystems. The OIM is mounted on the MTG-S Earth panel. Two other instrument electronic units, namely the Instrument Control Unit (ICU) and the Scanner Drive unit (SDE) are mounted inside the MTG platform. The location of the OIM, ICU and SDE units and of the Sun Reflector Shield (SRS, mounted on the MTG-S platform deck to prevent Reflection of the Sun into the instrument) on MTG-S is shown in *Fig. 5*.

The ICU is the core of the instrument intelligence, and ensures that all the tasks of the instrument are performed correctly. It controls the timing for the execution of the measurement sequences, triggering the Front End

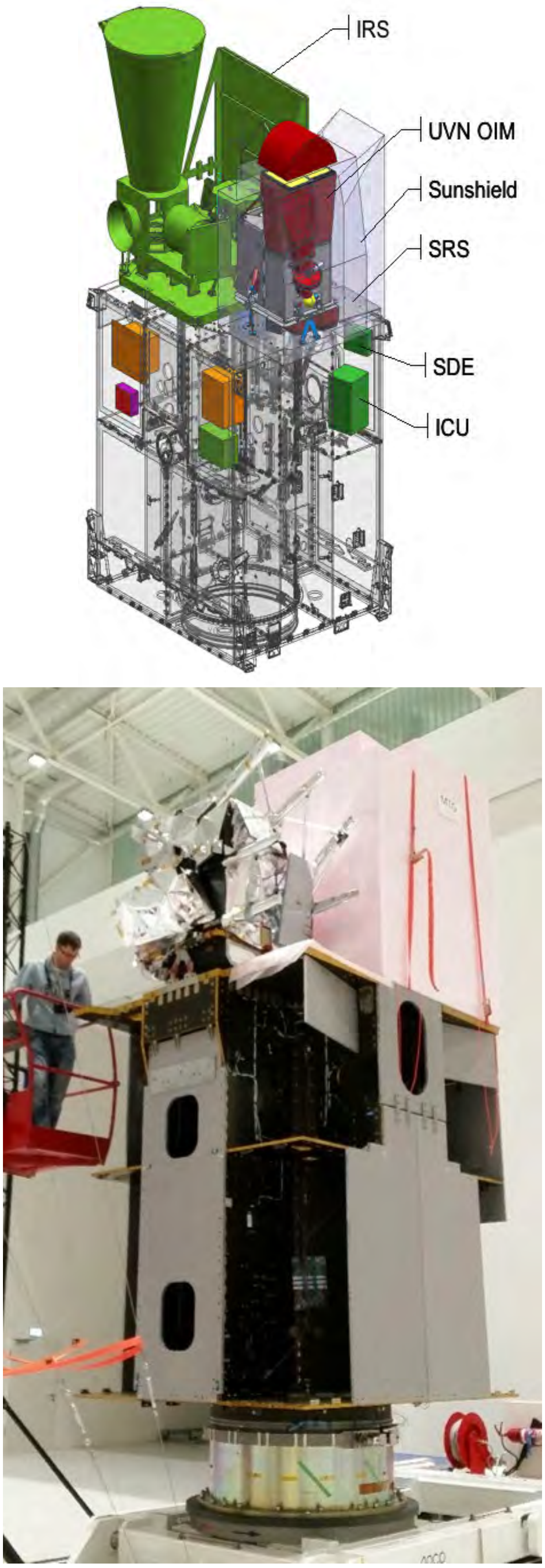


Fig. 5 Up: Sentinel-4 units location, configuration together with the IRS instrument on the MTG-S satellite. Bottom: Sentinel-4 STM mounted on MTG-S STM for the fit check (courtesy of OHB).

Electronics / Front Support Electronics (FEE/FSE) measurements, the activation of the Calibration Assembly unit, the Aperture Cover mechanism and commanding the SDE that controls the scan mirror motion. The ICU manages also the instrument thermal control and all the needed ancillary services. All the Sentinel-4 control & telemetry data, the science data links and the power links are channelled to the MTG-S platform through the ICU, which is the only electrical interface with the platform.
The OIM cross-section is shown *in Fig. 6*. It has two main view ports to carry out its observation: an Earth view port (Nadir) and a Calibration view port. This configuration allows for four views settings. Three views are external: the Earth (radiance) observation view; the star viewing, both through the same nadir port and the Sun irradiance observation view, through the Calibration port. The last view is internal: the white light sources view through the Calibration port.

The Earth port allows deep space measurement aimed at star viewing for instrument calibration purposes. This function is enabled by the extension of the Nadir baffle clear FOV towards the East so that the entire spectrometer slit points beyond Earth to deep space to capture stars early in the morning or late in the evening.
A single two-axis scan mirror, fulfils two main functions: 1- it switches between the two view ports; 2- it scans the Earth in East/West direction, when set in the Earth observation mode. The scan mirror in mounted of a 2-axis flexible hinges, and it is driven by voice coils. The power to the voice coils is provided by the SDE, which performs also the control of the mirror angle. The Qualification Model of the scan mirror is shown *in figure 7a*

The Earth port can be closed and opened through a motorized aperture cover (ACV) mounted on the top of the nadir baffle.

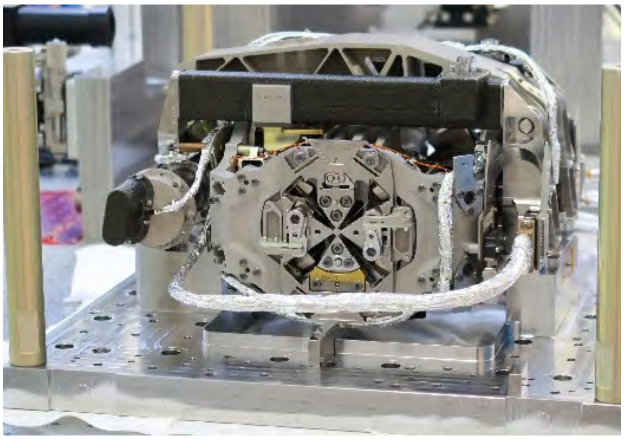


Fig.7a: Scanner Mechansm Qualification Model

The calibration port can be closed or can switch between the internal and external view by rotating a wheel mechanism hosting diffusers and mirrors. In the first setting (external view) the Sun is observed through one of two selectable diffusers. In the other setting (internal view) the flat-field White Light Source (WLS) is observed for instrument transmission degradation and for pixel response diagnostic purposes.

The ACV and the CAA qualification Models are visible in *Fig.7b*, where the ACV is still assembled on its mounting frame

The OIM structure provides the support for the accommodation of the other equipment, and it is basically constituted by a rigid CFRP baseplate mounted on MTG via 3 titanium kinematic mounts and by a nadir baffle. The scanner is mounted below the baseplate, on top of which is mounted the Telescope-Spectrometers Assemblies (TSA) structure, shown *in Fig. 8*. The TSA provides a rigid frame where the optics (the two spectrometers

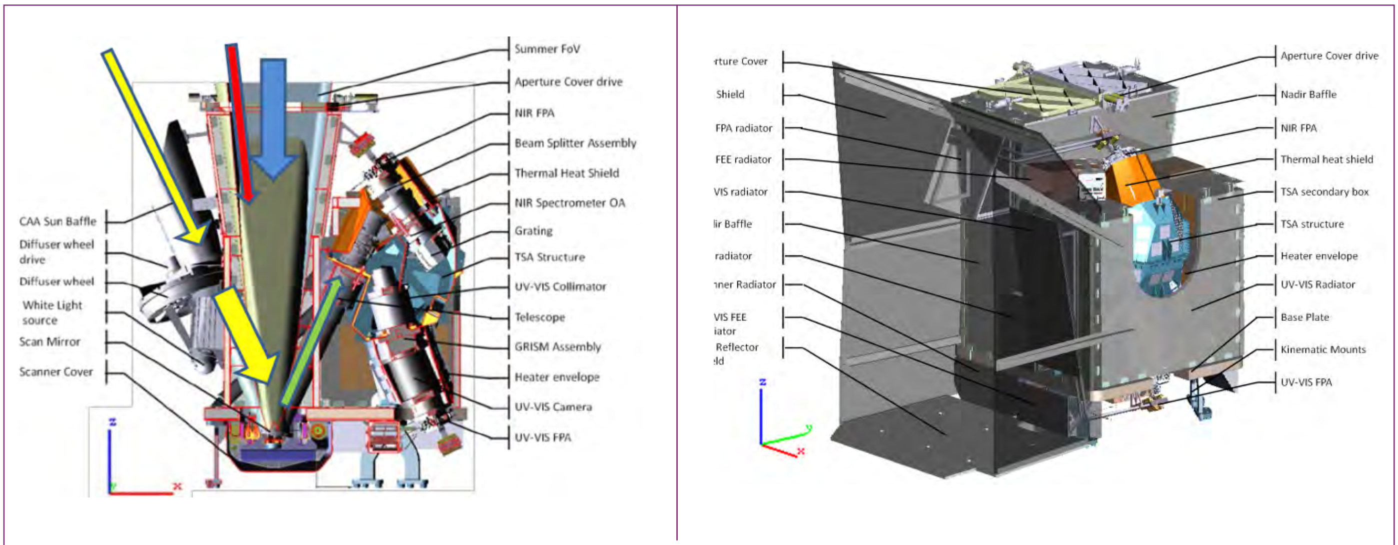


Fig. 6: OIM unit cross-section (The blue arrow indicates the Earth radiance path, the yellow arrows the Sun irradiance path, the red allow the star viewing path. The green arrow indicates the observation path from scanner towards the telescope, which is common to all viewings (Earth, Sun, stars, white light sources and to all spectral bands (UV, VIS and NIR).

and the telescope) are integrated such that their relative position and alignment does not change.

The OIM is then completed by the nadir baffle and the TSA secondary box, shown *in Fig.9*, which provide additional structural stiffness and a protection against straylight.

B. OPTICAL DESIGN

The Sentinel-4 core optical design is shown in *Fig. 10*.
It consists of the following optical modules, designed to be independently manufactured and aligned: Scanner, Telescope Module (including beamsplitter & slits), UVVIS and NIR Spectrograph Modules. The main end-to-end performances driving the optical design are the polarization (polarization sensitivity and its spectral & spatial

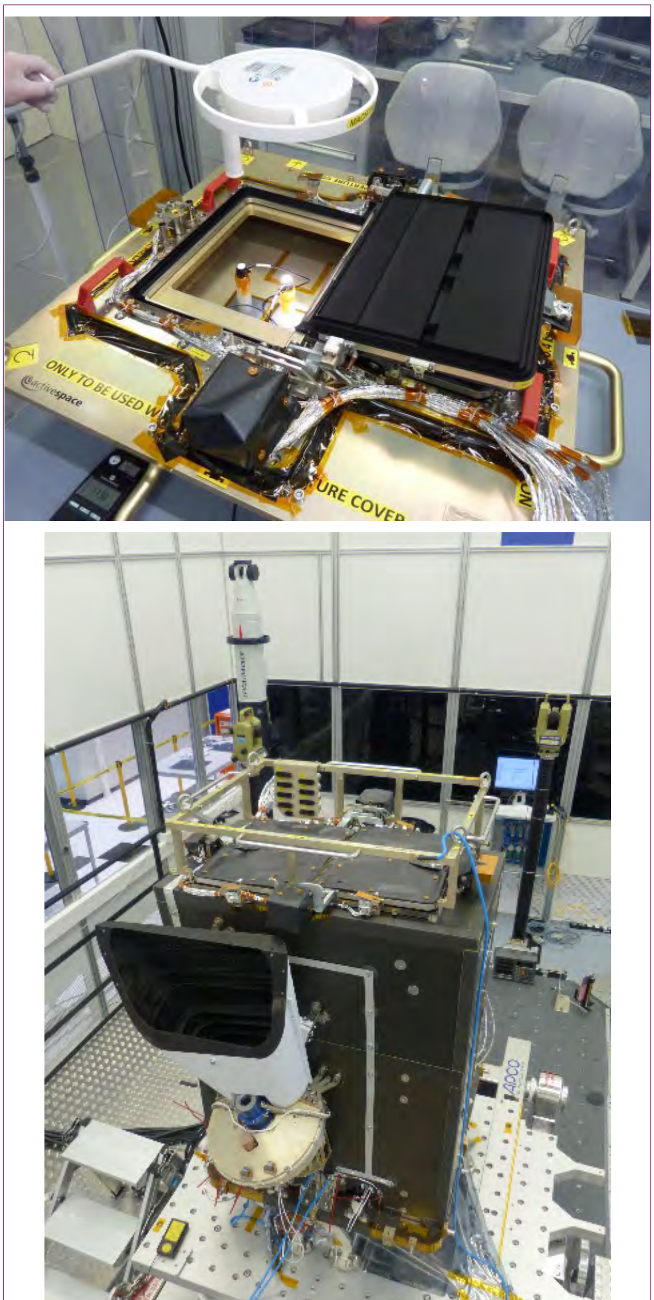


Fig.7b: Up: Aperture Cover Qualification Models
Bottom: Calibration assembly and ACV QM assembled on the Instrument EM

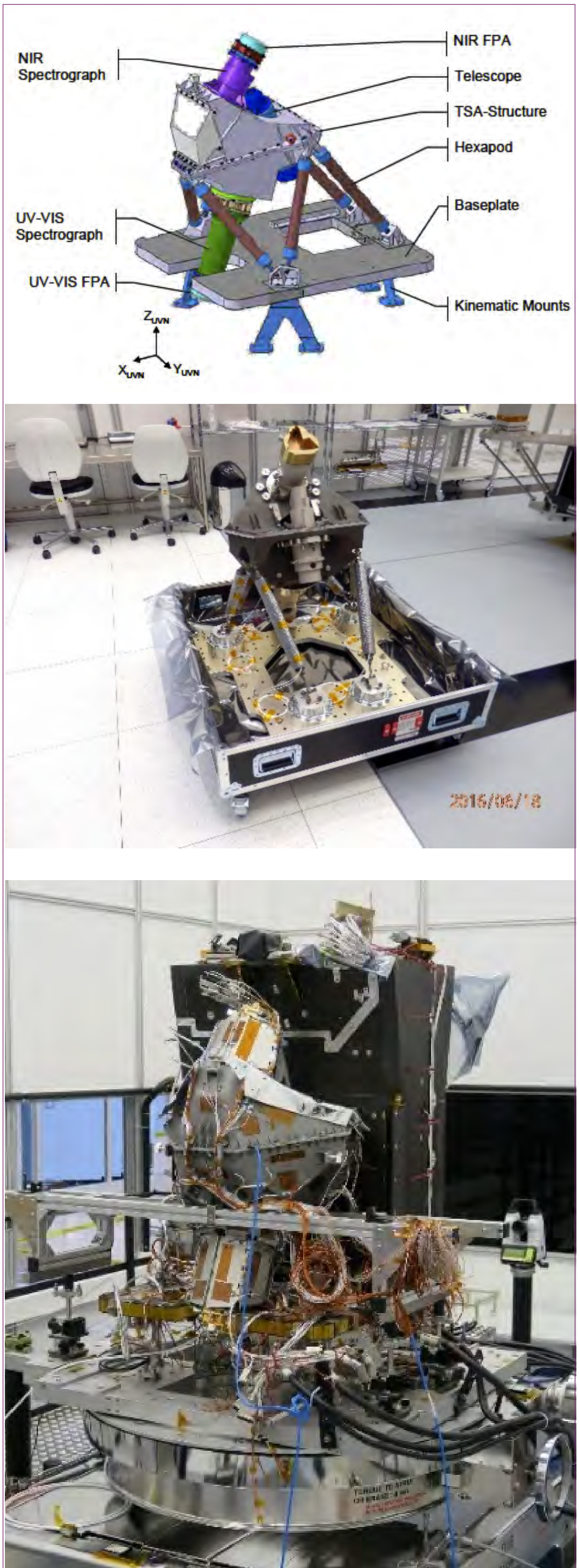


Fig.8 Up: TSA mounted on the CFRP Baseplate with Titanium kinematic mounts. Middle: TSA Qualification Model
Bottom: Nadir Baffle, TSA and thermistors assembled on Instrument EM

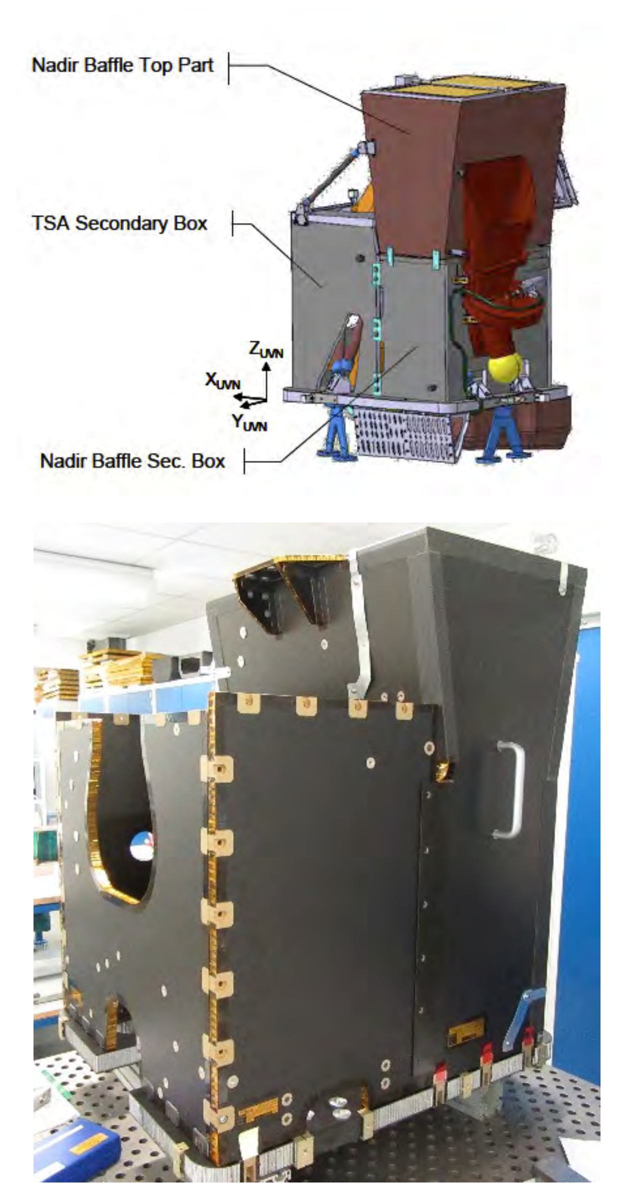


Fig.9 Up: OIM structure Bottom: OIM Structure Qualification Model

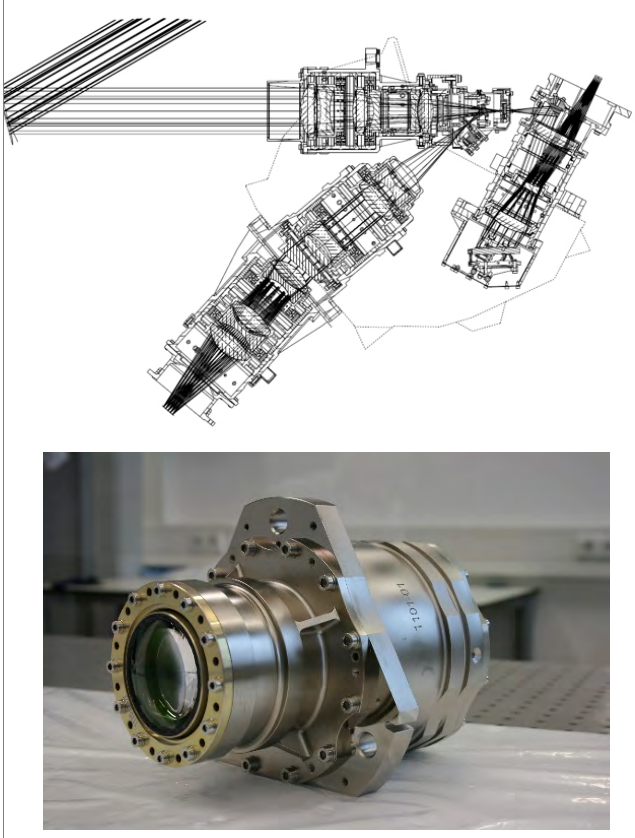


Fig.10 Up: Optical design sketch Bottom: Telescope Engineering Model

features), the straylight and the co-registration.
Since the system level spatial co-registration requirements are defined on an absolute and not on a knowledge accuracy basis, very good co-registration has to be achieved by design. For the optics design this means ultra-low optical distortion and also extremely good matching of the effective focal lengths of the UV-VIS and the NIR optical path.
The planar symmetry of the core optics, the on-axis lenses, and a general optimization for low angles of incidence (e.g. on scanner) and low angles of dispersion, allow achieving almost neutral polarization behavior by design. These optical architecture features are also enabling factors for the low optical distortion. Since some optical elements still inevitably are polarization sensitive and show spectral features (e.g. the grism) a depolarizing element, the polarization scrambler, is introduced before these elements in the optical path. The pre-optimization of the optical architecture towards low polarization effects has two advantages regarding this polarization scrambler: 1) The front optics, including scan mirror and telescope optics, features sufficiently low polarization effects that the scrambler can be introduced after these elements. This leads to a significantly smaller scrambler, which has great advantages in terms of manufacturability; 2) A rather weakly depolarizing scrambler, which is directly associated with a very small degradation of the optical point-spread-function (i.e. image quality), can still meet the system level polarization requirements.

Another main optimization criterion of the optics design is the minimization of straylight: the main sources of straylight are scattering from surface roughness and particulate contamination, as well as ghosts. The term ghosts encompasses a variety of false light effects, such as multi-reflections from anti-reflection (AR)-coated surfaces, unwanted reflections from mechanical surfaces outside the nominal optical path (lens mounts, optical stops, baffles, etc.), and unwanted or multiple diffractions from the dispersers. All these straylight sources are mitigated by minimization of the number of optical elements. Furthermore, ghosts are suppressed by dedicated optimization of the optics design in all areas, e.g. spectrograph and disperser architectures, as well as by a sophisticated straylight baffling architecture; namely the beamsplitter-slits-assembly and in the FPAs.

C. DETECTION CHAIN

The UV-VIS and NIR detectors are both frame-transfer CCDs featuring frame shift along the spectral direction. The NIR detector architecture is simpler, with a single frame, a single shift register and a single read-out port, while the UVVIS detector is divided into two spectral frames (effectively two individual CCDs), UVVIS1 and UVVIS2, with a frame split at about 340 nm. In addition, the UVVIS1 shift register has two read-out ports with different gain, the high gain being used for the low-signal spectral ranges below about 316 nm, and the low gain for wavelengths above. Furthermore, the UVVIS2 is divided

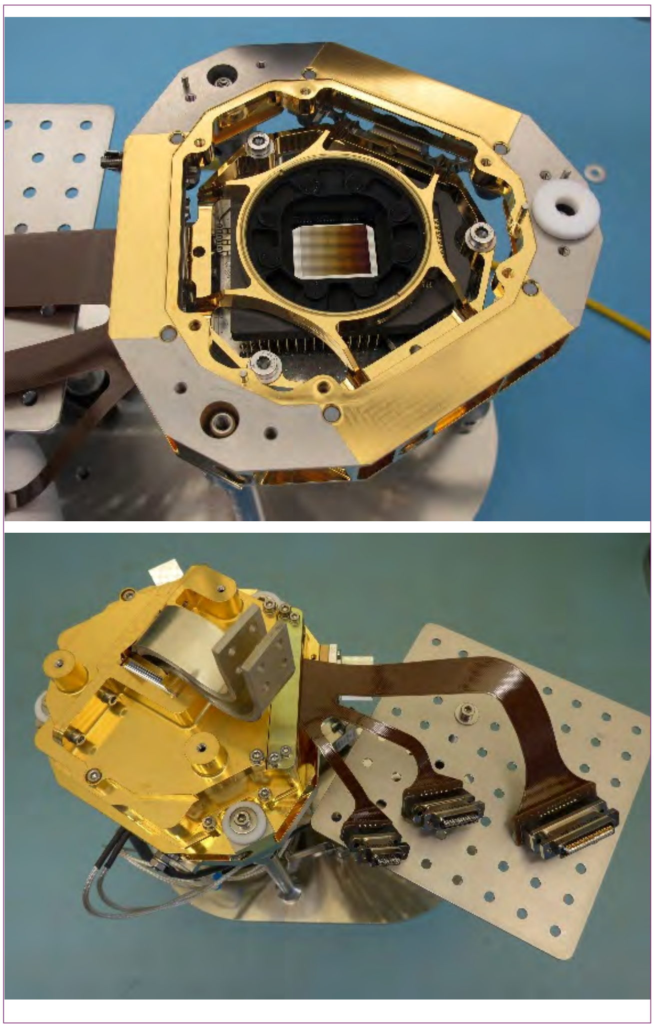


Fig. 11. Detector assembled in the FPA Qualification Model, top view (up) and bottom view (bottom)

into 4 individual shift registers and read-out ports. This architecture not only allows that the three main frames UVVIS1, UVVIS2 and NIR have individual gains, but also that their signal integration times can be individually adjusted so that optimum system SNR performance can be reached taking into account the particular spectral dynamics of the Earth radiance scenes. Furthermore, the frame periods of UVVIS1, UVVIS2 and NIR are set in multiples of the same time increment. This allows for a synchronized operation scheme (integration, frame transfer image-to-memory zone, read-out) of the three main frames, which is used in all nominal Sentinel-4 measurements. This synchronized UVVIS1-UVVIS2-NIR-sequencing avoids EMI signal distortions, which is mandatory in order to achieve the required radiometric performances. *Figure 11* shows the detector integrated on its housing (FPA)

IV. INSTRUMENT DATA PROCESSING AND CALIBRATION

The L0 and L1b performance requirements will be verified partly on ground and partly in orbit, during the commissioning phase. For this reasons, the instrument characterisation and calibration will be carried out in two different phases: 1- the on-ground characterisation and calibration phase; 2- the in-flight characterisation and calibration phase throughout the in-orbit commissioning period and with daily calibration key parameter updates during the routine operation period.

A. ON-GROUND L0 PERFORMANCE VERIFICATION AND CALIBRATION

The on-ground measurement activities of the flight instrument are divided into two phases: a Level-0 (L0) data performance verification programme phase and a calibration programme phase. During the L0 performance verification programme phase the applicable instrument performance requirements are verified to ensure that the instrument is fully performant; in other words the L0 programme objective is to verify if the instrument is built as designed.

Once compliance to all L0 performance requirements has been demonstrated, the instrument is calibrated in a comprehensive on-ground calibration programme phase during which all the instrument calibration key parameters that are required for the L0 to L1b data processing are obtained.

The on-ground L0 performance verification will include instrument measurements in flight representative environmental conditions, carried out at a dedicated thermal vacuum chamber calibration facility, at the Rutherford Appleton Laboratories (RAL) in the UK. .
Specific ground support equipment will be used for the on-ground testing phases: they will include, for example, dedicated turn-tilt tables to rotate the instrument within the thermal vacuum chamber in suitable orientations, as well as dedicated optical ground support equipment (OGSEs) to mimic different light sources, which will be used to simulate different in-orbit illumination conditions. Electrical ground support equipment will also be used to command the instrument and receive all the necessary data (raw and housekeeping data) for the ground processing.

B. GROUND PROCESSING & ALGORITHMS

The calibration key parameters and related accuracies that are required for L0 to L1b data processing are specified in the Algorithm Theoretical Baseline Document (ATBD), which defines the interface between the calibration and the L0 to L1b data processing software.
Based on the ATBD specifications, the algorithms necessary to transfer L0 digital counts data, with the help of calibration key parameters, allow the L1b data to be generated in physical units.
The different modes in which the L0 to L1b prototype processor (L1bPP) will be used require a specific level of flexibility of the data processor software. For example, depending on the type of processing, it will be possible to change the processing flow by adding, removing or changing the order of algorithms, thus allowing the optimization of the L1bPP to its specific usage.

C. IN-FLIGHT CALIBRATION

The Sentinel-4 in-flight calibration concept hinges on two main activities: 1) the "calibration measurements", which will be used for characterizing an external effect; 2) the "application of correction" which will be applied either to the scientific data or to the instrument in order to correct / mitigate the external effects.
The in-flight activities will verify if the calibration of the instrument is maintained throughout its lifetime and which ageing effect, due for example to the very severe external radiation environment, will need to be taken into account.
External in-orbit geometric calibration of the absolute pointing by means of star observation will be performed each day for typically 15 minutes in the early morning immediately before the start of Earth observation and in summer also immediately after the end of Earth observation.
The remaining night-period (4 to 6 hours) will be used for internal in-orbit calibrations (darks, White-Light-Source (WLS), LED light source- & detection-chain-calibrations).

V. DEVELOPMENT STATUS AND SUMMARY

Sentinel-4 has passed its system Critical Design Review (CDR) in 2017. The results available from unit level breadboards and engineering/qualification models has allowed consolidation of compliance to major performance requirements (*cf. Table 1 page 34*).
All the S/S, excluding the Optics for which a protoflight approach is baselined, have completed their Qualification Testing, and the Qualification Models were delivered to the Prime Contractor for their integration onto the Instrument EM, shown *in Fig 1.* The Instrument EM integration was completed in March 2018 and the testing campaign has started. The testing program includes microvibration, which has already been completed, and

Fig. 12: OIM structure STM mounted on the vibration bench at IABG

will be followed by the EMC, the Thermal Vacuum and a series of interfaces tests with the Calibration OGSE. Mechanical Qualification was already achieved with the OIM structure Qualification Model (*see Fig 12*) prior to the CDR after successful vibration, shock and acoustic tests. The flight Units of the detectors and of the ICU have already been delivered to the Prime Contractor, and the vast majority of the other flight units will be delivered in the course of 2018. The ACV and the CAA FMs are completing their testing and are expected during the summer 2018. The Scanner Mechanism is also under testing and the delivery is expected in early Q4, 2018, while the OIM structure flight unit is due by December 2018.

VI. ACKNOWLEDGEMENTS

The authors would like to express their thanks to their respective colleagues at the European Space Agency and Airbus DS, as well as to all the partner companies within the Sentinel-4 industrial consortium for their valuable contributions to the continuing success of this very challenging programme. This article has been produced with the financial assistance of the European Union.

■

EUROAVIA – THE EUROPEAN ASSOCIATION OF AEROSPACE STUDENTS

• FOR THE STUDENTS, BY THE STUDENTS – JEAN ROEDER EUROAVIA FOUNDER•

By Daniele Vangone, CEAS Representative, and Juan Manuel Alonso, EUROAVIA Internal Board President

ALMOST 60 YEARS EXPERIENCE

With almost 60 years' experience, EUROAVIA - The European Association of Aerospace students still actively contributes today to bring the students interested in aviation and space together with the aerospace industry. Founded in 1959, EUROAVIA counts over 2300 members from 18 European countries, Israel and Egypt work voluntarily in order to develop and improve their skills and become capable and competent professionals through high profile activities.

EUROAVIA mainly offers its members academic, technical and social events at the international and local level every year. They not only have the opportunity of developing their potential as leaders and project managers but also, they meet other students exchanging ideas, explore new cultures and get in contact with specialists from universities and the industrial environment.

Nowadays, the Association is an articulate network that grounds on the expressions of common needs and potentially offers a wide range of benefits for the whole student community as well as for its potential partners, enhancing the stakeholder collaboration across the value chain.

40 FULL MEMBERS

By increasing its visibility towards European and non-European universities, people are encouraged to get more involved and to be part of the greatest European aerospace student's network. As a matter of fact, the growth in terms of new branches has been relevant since the last two years.

The cities of Bologna (Italy), Bordeaux (France) and Kocaeli (Turkey) have joined the organisation together with the 40 Affiliated Societies, full member of EUROAVIA as of June 2018.

The main outcomes from this trend emphasizes how EUROAVIA is on the right path to become part of the ever-accelerating global landscape, strengthening the European cooperation among students and other organisations.

THE 59TH INTERNATIONAL BOARD OF EUROAVIA

The 59th International Board of EUROAVIA took office on the 14th September 2017 during the Annual Meeting of EUROAVIA Congress in Cluj-Napoca. Since then, it has paid specific and customized attention to the requirements and the needs from all the part of the Association in order to achieve members' satisfaction. The main aim is to inspire them to chase and reach their goals, both on professional and personal level and to "Build the wings of their future", which is actually the EUROAVIA motto.

To increase the productivity forward in time and strive to go one-step further, the International Board has been taking on a new challenging strategy. A deep internal structure change was performed right after the aforementioned Congress in Cluj-Napoca in order to improve the EUROAVIA showcase. Furthermore, the new roadmap is part of a renewed mind-set, both in terms of communication and business core activities.

EUROAVIA current partners and third parties get in contact with highly qualified students and the most prestigious European universities. They have access to crowdsourcing and research platform of fresh-minded and creative students for new ideas and challenges. Above all, they experience a diverse, international and intercultural network of brillant young engineers, trainers and leaders.

INTERNATIONAL EVENTS

International Events are the solid products of EUROAVIA, which bring the people together and give them the opportunity to have both an exchange of knowledge and to gain different experience according to the type of event organized.

THE TRAIN NEW TRAINERS

The Business Year 2017-2018 has been characterised by the amount and quality of the international projects. Indeed, the Formation Workshop and the Train New Trainers are the crown jewels of the Soft-skills development within EUROAVIA together with the diverse Symposia and Fly-ins in the technical and academic fields.
The Train New Trainers is the second EUROAVIA Training System event. The main goals were to develop, improve and consolidate the internal training system with EUROAVIA trainers and internal material about leadership and management skills. As a result, a managing board of trainers were elected and an active group of +20 international trainers was finally set.

By this, it has been demonstrated to be possible that internal trainers can teach new ones and generate a network with high-motivated members, which is already resulting in an improvement of the quality of the Association.
The Train New Trainers has permitted the growth Young Europeans all across Europe since there has been a training session delivered in every single International Event ever since leading to a high degree of personal development of the members. It is facilitating EUROAVIAns to improve their performance and efficiency as a group that will be beneficial for them in EUROAVIA as well as in their future careers in the aviation industry.

CLOSE COLLABORATION WITH DIFFERENT BODIES

Moreover, the activity of EUROAVIA towards the European Union has increased remarkably. Not only EUROAVIA has achieved to earn European funds to develop their activities but the collaboration with different bodies has been tighten over the last months.
In this way, different organizations such as JADE, Nereus, CVA and PEGASUS have taken part into the activities organized by EUROAVIA such as the Space Symposium. This event took place during the first week of March where EUROAVIAns had the chance to attend highly valued technical presentations brought by these organizations together with companies like Deimos, Alter Technology or even the Andalusian Administration for environment and agriculture with interesting Earth observation technologies. Besides, representatives of EUROAVIA have earnt prominence at third parties committees like CEAS, Clean Sky, IT Aérea or IFISO just to mention some of them.
This commitment allows EUROAVIA to lead in the application of European projects under the H2020 program for international cooperation like the "Science With and For Society" with the S.P.A.C.E proposal. Demonstrating the added value of such a network capable to bring different stakeholders together on the same page.

A WIDE NETWORK

The strength of EUROAVIA lies in its wide network based upon teamwork, friendship, collaboration between local groups and the shared commitment to common efforts. Therefore, the enhancement of this network is essential on a long-term basis for the further improvement. Within this scenario, a well-structured framework is required to realise the social mission whatever the fields of interest are with the crucial support of the human resources together with companies, academic institutions, research facilities and governments.

It is evident that a good appearance to the outside can only be reached with a healthy skeleton. Therefore, the effective communication that has been seen so far will be promoted through the main agents of the Association in order to retain the atmosphere where common and strategic projects are carried out with the collaborative and mutual support of cooperative parties.

THE ROYAL AERONAUTICAL SOCIETY – INFORMING DEBATE AND INFLUENCING POLICY

By Emma Bossom, RAeS, CEAS Trustee

The Royal Aeronautical Society (RAeS) is the longest established independent and impartial professional body made up of members from across all the aerospace disciplines. The RAeS aims to provide an international forum for discussion and debate on all matters relating to aviation and space and is proud of the breadth and depth of its technical, academic, military and commercial membership.

Each year, across the globe, the Society's Divisions and Branches run varied and topical programmes and seminars with the aim of informing and stimulating thinking on aerospace matters and the months ahead indicate there will be much to discuss.

No.4 Hamilton Place, home of the RAeS, London.

INFORMING DEBATE

The demand for more aviation capacity, the growth in airline routes and numbers, the re-organisation of airspace and remoting of Air Traffic Control away from airfields are going to demand some sound thinking and decision making. Equally, in space, the greater and greater commercial 'leadership' of the use of space and accessibility to space will lead to dramatic increases in space utilisation. At the same time, the potential return of supersonic (or even faster) passenger flights, offers an exciting adjunct to future demands on our environment. So, no shortage of relevant demands and need for the expertise for which the RAeS is renowned and great opportunities for industry to participate in the discussion and the debates on these and many other issues in the year ahead.

In the latter half of 2018, the Society will be hosting an Applied Aerodynamics Conference, the International Powered Lift Conference (IPLC), discussing a new era for pilot training and assessment at the 13th International Flight Crew Training Conference in London, UK and reviewing how to reduce the environmental impact of aviation at the RAeS President's Conference. The wide range of topics under consideration by RAeS members demonstrates the exciting and demanding industry we all work in.

INFLUENCING POLICY

Furthermore, with Brexit fast approaching on the horizon, the RAeS has been taking a leading role in briefing the UK government about the global nature of the aerospace and aviation industry and informing stakeholders on the implications for the sector.

Recently, Chair of the **RAeS Space Group**, Phil Davies FRAeS highlighted to the House of Lords EU Internal Market Sub-Committee the mutual benefit for both the UK and the EU from continued participation in the EU space programme and urged a swift resolution to the UK's participation in Galileo to avert of loss of UK expertise.

The **RAeS Air Power Group** have provided views on security, defence and foreign policy to Peers in the House of Lords and the Society's Unmanned Air Systems (UAS) Group have been influential in advising about future drone policy.

The **Special Interest Groups** that are active across the RAeS members' network consistently contribute to policy work at national, European and international levels, engaging with groups within CEAS, as well as the International Council of Aeronautical Sciences (ICAS), International Civil Aviation Organisation (ICAO), International Air Transport Association (IATA), and International Federation of Air Pilots (IFALPA).

One pertinent issue for the **Flight Operations Group** has been the emergency evacuation of commercial passenger aeroplanes. The Group has recently published a specialist paper which aims to provide aviation authorities, aircraft manufacturers, operators and air accident investigation agencies with a wide range of information on evacuation issues. The focus of the paper is on aircraft evacuation and analyses 30 incidents between 1970 and 2017 to explain what lessons were learned and how they have identified the need for improvements to airworthiness regulations and operational requirements, resulting in changes to aeroplane manufacturing and maintenance procedures, as well as to operators' crew procedures and training. This critical analysis of the emergency evacuation of commercial passenger aircraft concludes with several recommendations and is generating much needed discussion on this topic area.

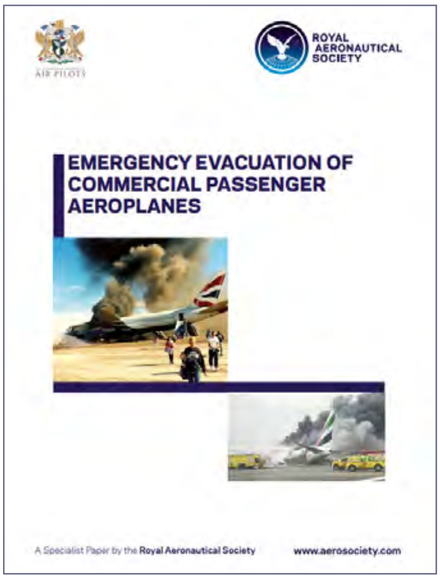
INSPIRING FUTURE GENERATIONS

While airing the current issues of today is an essential part of the objectives of a Learned Society, so too is inspiring the next generation of aerospace and aviation professionals to learn about, study and work in our industry. 2017 was an important year for the Society's work with young people as we celebrated 20 years of dedicates careers activities following the launch of the **RAeS Careers Centre** in 1997. The work broadly fits around the objectives of encouraging those with an early interest in the sector, spreading the word about what being involved in the industry can offer and supporting and retaining talent within aerospace and aviation. The 20th anniversary provided an opportunity to reflect on key achievements over the last two decades and look ahead to the next 20 years.

The Society runs a "Cool Aeronautics" programme aimed at 7-11 year olds providing themed talks and interactive workshops and has offered the opportunity to meet with airline Chief Engineers, fighter jet pilots, and even an astronaut when Tim Peake HonFRAeS visited No.4 Hamilton Place in London following his Principia mission to the International Space Station.

The RAeS and Boeing Schools Build-a-Plane Challenge has won numerous awards for its work as Best Educational Programme and seen pupils from varied backgrounds across the UK work with teachers, engineers and project managers to build, test and fly in a light aircraft. The highlight of this programme has been showcasing the aircraft at the Farnborough International Air Show and participating in the flying display.

In addition to these programmes, the **Career FlightPath magazine** offers careers advice and guidance to students and job seekers with special features, interviews and career development articles to continue to support young professionals in their quest to join the exciting world of aerospace and aviation.



Specialist Paper by the RAeS: Emergency Evacuation of Commercial Passengers

A view projected on the occasion of an Airspace Lecture

School pupils at the RAeS

AMONG UPCOMING AEROSPACE EVENTS

2018

JULY

02-06 July – EUROMECH- **10th European Solid Mechanics Conference** – Bologna (Italy) – www.euromech.org/ www.esmc2018.org/drupal18

05-06 July – SESAR- **SES/SESAR Airspace Architecture Study First Workshop** – Brussels (Belgium) – EC, Breydel Building, Avenue d'Audergheim 45 – https://www.sesarju.eu/events/

09-11 July – AIAA – **AIAA Propulsion and Energy Forum and Exposition** – Cincinnati, Ohio (USA) – Duke Energy convention Center - Propulsion – Energy Conversion Engineering - www.aiaa.org/events - https://www.propulsionenergy.aiaa.org

12-13 July – AIAA/IEEE – **EATS – Electric Aircraft Technologies Symposium** – Cincinnati, OH (USA) – Duke energy Convention Center – https://propulsionenergy.aiaa.org/EATS

14-22 July – COSPAR – **COSPAR 2018** – Pasadena, California (USA) – **42nd COSPAR Scientific Assembly – 60th anniversary of COSPAR's creation** – https://cosparhq.cnes.fr/ http://www.cospar-assembly.org/ http://cospar2018.org

24-26 July – RAeS – **Biennial RAeS Applied Aerodynamics Research Conference** – Bristol (UK) – www.aerosociety.com/events/

16-22 July – **Farnborough International Airshow 2018** – International Exhibition and Conference Centre – Farnborough, Hampshire (UK) – https://www.farnboroughairshow.com/

AUGUST

19-23 August – AAS/AIAA – **Astrodynamics Specialist Conference** – Snowbird, UT (USA) – http://www.space-flight.org

27-29 August – AIAA – **AIAA Space and Astronautics Forum and Exposition** – New Orleans, LA (USA) – www.aiaa.org/events

SEPTEMBER

04-06 September - DGLR – **DLRK Congress** – Friedrichshafen (Germany) – www.dlrk2018.dglr.de

04-07 September - EASN-CEAS – **8th International Workshop** – Glasgow (UK) – University of Glasgow – Theme: Manufacturing for Growth and Innovation – https://easnconference.eu

09-13 September - EUROMECH – **12th European Fluid Mechanics Conference** – Vienna (Austria) – www.euromech.org/

09-14 September – ICAS – **31st ICAS Congress** – Belo Horizonte (Brazil) – Av. Augusto de Lima, 785 – Centro – www.icas.org – icas@icas.org

11-12 September – ESA – **Industry Space Days 7th Edition – ISD 2018** – Noordwijk (NL) – ESTEC – https://www.industryspacedays.com

17-19 September – AIAA – **AIAA SPACE and Astronautics Forum and Exposition 2018** – Orlando, FL (USA) – Hyatt Regency Orlando - Complex Aerospace Systems – https://www.space.aiaa.org

18-21 September – ERF – **ERF 2018 – Delft (NL) – 44th European Rotorcraft Forum** – www.erf2018.org

25-26 September – RAeS – **A new Era for Pilot Training and Assessment** – London (UK) – RAeS/HQ – https://www.aerosociety.com/events-calendar

26-28 September – ESA – **SECESA 2018** – Glasgow (UK) – Technology & Innovation Centre (TIC) - Systems Engineering and Concurrent Engineering for Space Applications Conference – https://www.esaconferencebureau.com

26-28 September – ERCOFTAC – **ETTM12 – 12th International Symposium on Engineering Turbulence Modelling and Measurements** – Montpellier – La Grande Motte (France) – www.ercoftac.org/

OCTOBER

01-05 October – IAF – **IAC 2018 - 69th International Astronautical Congress** – Bremen (Germany) – Exhibition & Conference Centre, Bremen – Theme: IAC2018 involving everyone – https://www.iac2018.org www.iafastro/bremen-germany

02-05 October – 3AF – **ES 2018 – 14th European Forum – Economics Intelligence Symposium** – Chartres (France) – CCI – www.aaaf.asso.fr – www.ies2018.com

03-05 October - 3AF – **IES 2018 – 14th European Forum – Economics Intelligence Symposium** - Chartres (France) – CCI – www.aaaf.asso.fr www.ies2018.com

09-11 October – RAeS – **6th Aircraft Structural Design Conference** – Bristol (UK) – Bristol Science Centre – www.aerosociety.com/events/

16-18 October – Aviation week – **MRO Europe 2018** – Amsterdam (NL) – RAI Convention Centre Amsterdam – Theme: Maintenance, Repair and Overhaul - www.mroeurope.aviationweek.com - www.rai.nl

AMONG UPCOMING AEROSPACE EVENTS

22-26 October – ESA – **ESA Earth Observation Full Week – EO Open Science and Future EO** – Frascati (Italy) – ESRIN – https://www.esaconferencebureau.com

23-25 October – 3AF – **AEGATS'18 – Advanced Aircraft Efficiency in a Global Air Transport System** – Toulouse (France) – www.aaaf.asso.fr

NOVEMBER

06-08 November – SAE International – **SAE Aerospace Systems and Technology Conference** – London (UK) – www.sae.org/events/

06-08 November – Dubai – **Helishow Dubai 2018** – Al Maktoum International Airport, Dubai South (United Arab Emirates) – https://www.milavia.net/

06-11 November – China – **Air Show China 2018** – Zhuhai, Guangdong (China) – https://www.milavia.net/

12-14 November – FSF – **71st Annual International Air Safety Summit: IASS2018** – Seattle (USA) – https://flightsafety.org/events/

13-14 November – RaeS – **Autumn Flight Simulation Conference** – London (UK) – RAeS/HQ – https://www.aerosociety.com/events-calendar

14-16 November – Bahrain – **BIAS 2018 Bahrain International Air Show** – Sakhir Air Base, Bahrain – https://www.milavia.net/

18-19 November (TBC) – ESA – **Space Engineering and Technology Final Presentation Days** – Noordwijk (NL) – ECTEC – https://www.esaconferencebureau.com

26-30 November – CANSO – **CANSO Global ATM Safety Conference 2018** – Banff (Canada) – Hosted by NAV CANADA – Fairmont Banff Springs, 405 Spray Avenue – https://www.canso.org/canso-global-atm-safety-conference-2018

26-28 November – ICAO – **ICAO Global Aviation Safety Symposium 2018** – Montréal (Canada) – ICAO/HQ – https://events.icao.int

27-29 November – ACI-Europe – **ACI Airport Exchange 2018** Oslo (Norway) – Hosted by AVINOR OSLO Airport – Norway Convention Centre – www.airport-exchange.com

29-30 November – ICAO – **2nd Global High-Level Conference on Aviation Safety** – Montréal (Canada) ICAO/HQ – https://events.icao.int

DECEMBER

03-04 December – **International Business Convention for Aerospace Additive Summit** – Aeropspace Additive Summit – Toulouse (France) – www.advbc.com/en/events/

03-06 December –GSA/CNES – **GSA European Space Week –Challenges for ActinSpace participants** – Marseille (France) - https://www.gsa.europa.eu/

2019

JANUARY

07-11 January – AIAA- **AIAA SciTech Forum (AIAA Science and Technology Forum and Exposition)** – San Diego, CA (USA) – www.aiaa.org/Events

FEBRUARY

19-21 February – ESA- **2019 Conference on Big Data from Space – BiDS'19** – Munich (Germany) – Alte Kongresshalle Munich – https://www.bigdatafromspace2019.org/

APRIL

03-05 April – CEAS – **2019 EuroGNC – 5th CEAS Conference on Guidance, Navigation & Control** – Milan (Italy) – www.eurognc19.polimi.it

08-12 April – EUROTURBO – **ETC2019 – 13th Conference on Turbomachinery Fluid Mechanics and Thermodynamics** – Lausanne (Switzerland – EPFL – www.euroturbo.eu

MAY

21-23 May – EBAA – **EBACE 2018 – European Business Aviation Conference and Exhibition** – Geneva (Switzerland) – Geneva's Palexpo – http://ebace.aero/2019/

27-29 May – Elektropribor – **26th Saint Petersburg International Conference on Integrated Navigation Systems (ICINS2019)** – Saint Petersburg (Russia) – www.elektropribor.spb.ru/icins2019/en

JUNE

17-23 June - SIAE – **International Paris Air Show (IPAS) – Le Bourget (France)** – https://www.siae.fr

JULY

1st week of July – EUCASS – **EUCASS 2019 – 2019 Edition of the biennial European Conference on AeroSpace Sciences** - Madrid (Spain) – Universidad Politecnica de Madrid (UPM) – https://eucass.eu

AMONG UPCOMING AEROSPACE EVENTS

OCTOBER

15-20 October – Seoul – **Seoul Adex 2019 – Seoul International Aerospace and Defense Exhibition 2019** – Seoul (South Korea) – Seoul Airport – Seongnam Air Base – www.milavia.net/airshows

NOVEMBER

17-21 November – Dubai – **Dubai Airshow 2019 – Connecting the Aerospace Industry** – Dubai –UAE) – Dubai World Central – Al Maktoum, Jebel Ali – www.dubaiairshow.aero