Deutsche Gesellschaft
für Luft- und Raumfahrt
Lilienthal-Oberth e.V.

The Opinions

PREPARING FOR GREEN AVIATION

while preserving commercial transport aircraft development know-how in Europe

PRÉPARER UNE AVIATION VERTE

tout en préservant le savoir-faire de développement d'avions de transport en Europe

SCHAFFUNG DER VORAUSSETZUNGEN FÜR EINE "GRÜNE LUFTFAHRT"

bei Erhalt des Know-How in Europa zur Entwicklung großer Verkehrsflugzeuge

2020 AAE Opinion No. 11 | DGLR Opinion 2020-01 10€

Contents

PREPARING FOR GREEN AVIATION
while preserving commercial transport aircraft development know-how in Europe

The present opinion has been established by the two associations, AAE (Air and Space Academy) and DGLR (Deutsche Gesellschaft für Luft- und Raumfahrt), who are publishing it for the European general public interest. A joint ad hoc group was established. Its membership is given in Appendix 1. For practical reasons the English language version constitutes the reference version.

Executive summary

Commercial transport aviation is having to cope simultaneously with:

- huge economical shortfalls in the aviation industry and services operations resulting from the COVID-19 crisis;
- an absolute need to deliver much "greener" aviation to the market as soon as possible;
- and a global lack of financial resources to enable on-time development of the corresponding products.

An original path for securing these three requirements is proposed below.

The present pandemic has further highlighted the need to combat climate change due to the great risks to which the world population is exposed. As part of its contribution to the general effort, the aviation sector is being asked to make a significant step forward in proposing much "greener" operations in the next decade. The development and use of "greener" aircraft in the commercial transport category, the largest contributor to aviation emissions, is a priority but the traditional method of gradual enhancement, with application to existing products of partial new technologies, will not allow this challenging goal to be reached on time.

This goal can only be achieved by means of disruptive, step-change technologies together with possible new airframe configuration. While respecting paramount safety requirements, these solutions need to be matured and validated further up to a global level, a process that can only be achieved **by means of an integrated flying technology demonstrator** – as close as possible to the "future" aircraft. This is a new approach for the industry, both in Europe and the US (and the latter are pushing hard via NASA(1)).

The proposed new logic is to develop a flying demonstrator whilst at the same time creating advanced new technical equipment and functions, in close coordination. This would result in a more rapid, effective convergence and an overall gain in final product efficiency, schedule and costs. This logic in fact corresponds to a new method already employed in Europe for smaller systems, and very effectively used in America in the space domain: "rapid development".

It is important to mention that only such a demonstrator will provide the opportunity to maintain endangered know-how in large transport aircraft development in Europe (no brand new aircraft launched since 2007) and is the appropriate way of training today's inexperienced young engineers so that they can apply this later to the real production aircraft.

For the reasons given above, airframe, engine and systems manufacturers, together with the entire European development and production aviation community, must be financially supported for the time needed to manage this paradigm change.

Concluding, whereas the development of individual technologies is quite well under way (with funding secured for the next three or so years), it is thought that the four Airbus nations – France, Germany, Spain and the UK – should set up additional, timely funding for the required development of a flying technology demonstrator (similarly to what is being done in the US(2)). The demonstrator's flights should be planned between 2028 and 2030, enabling selection of future aircraft solutions, in view of entry into service of the new aircraft by 2035.

(1) *See Flightglobal.com "NASA hints at truss-braced X-plane to test technologies for next commercial narrowbody" – https://cutt.ly/WfSz6TG*

(2) *Worthy of mention, independently of a specific demonstrator, is the exceptional sole source contract of 23 billion dollars allocated to Boeing by the US Air Force for a new combat aircraft to be delivered in 2023 (sic!). See Boeing mediaroom "Boeing and U.S. Air Force Ink Historic Deal for F-15EX Fighter Jet" – https://cutt.ly/nfSc4kB*

On the basis of a total cost of five billion euros, the yearly contribution, over eight years, for a partner assuming a share of 35% (e.g. France or Germany) would be of 220 million euros.

This investment will not only be beneficial to Airbus, the engine manufacturers and the entire supply chain, including systems and equipment companies, but also to research establishments, universities and all associated testing facilities contributing to the demonstrator.

By doing so, Europe(3) will prepare the ground for Green Aviation while preserving its vanishing know-how for commercial transport aircraft development, thus maintaining its global leadership.

Background

Europe has been very successful in reaching a comparable level to the US as far as the commercial transport aircraft sector is concerned. The major development programs during the first decade of this century – the A380 and the A350, plus the A400M – boosted Europe`s position. This is true for the airplane manufacturer – Airbus – but also for the engine manufacturers, research establishments, universities and the whole supply chain.

How can European competencies be preserved and further enhanced?

There has been widespread concern in the aeronautical community as to the potential loss of experience for the successful development of a brand new large civil transport aircraft in Europe. Indeed, since the A350, launched in 2007, no entirely new aircraft has been decided, resulting in a progressive loss of experienced engineers, particularly in the critical areas of architects and integrators. **The know-how gained gradually, and with difficulty, from past programs is vanishing**. In a few years almost an entire generation of aeronautical engineers in Europe will have had no chance of applying and sharpening their skills, in the absence of any demanding new program launch. Consequently, a compensating development, even an experimental one, is necessary.

(3) It is thought that other European countries could join the initiative of these four countries.

What has changed in this respect in the course of the Covid-19 crisis?

In support of their industry, the French and German governments have increased R&D funding for 2020, 2021, 2022, with the goal of delivering technologies for "Green Aircraft"(4). This will be shared between the corresponding applications: middle-range aircraft, regional/general aviation, drones, helicopters, business jets and operations. For the middle-range aircraft application the corresponding parallel avenues consist of a) advanced development-fuel efficiency, b) step change configuration. This would pave the way to a successor of the A320 family with a first demonstrator between 2026 and 2028, and an envisaged entry into service (EIS) by 2035. This is very good news and the committed public support will be extremely useful not only for the aircraft manufacturer, but also for the engine makers, test facilities and wind tunnels, as well as for the entire supply chain.

Now the risks are that:

- the present funding, while sound for technology research solutions for the next few years, would not allow for development of a completely new, step-change airplane demonstrator,
- due to the envisaged timeframe for the aforementioned demonstrator, only matured technologies will be applied in order to mitigate the development risks.

Thus, we will very likely see some improvements in terms of performance, efficiency and emission reduction, **but full benefit will not be taken of disruptive technologies, associated with renewed configuration, in order to reach the prospective "green" aircraft(5).**

What is missing for reaching the ambitious "decarbonization" goal?

It is a common understanding that very low emissions in aviation can only be approached by applying disruptive technologies to the airframe and propulsion system. This objective is likely to significantly change the way this "green" aircraft is designed, and what it will look like compared to what we have seen in

(4) See Dossier de presse – Plan de soutien à l'aéronautique – https://cutt.ly/kfSvaMh

(5) To the aim of reducing aviation gas emissions to minimize likely induced climate effects, one has to add the simple need to reduce fossil based kerosene consumption because of the possible crisis after 2035 of its availability at acceptable commercial conditions, as mentioned in AAE Dossier No.38 and confirmed by miscellaneous sources.

the past and presently. A holistic approach will be necessary, not only continuing incremental developments to the airframe design, featuring more advanced materials and improving the engine, but also challenging all development steps with an unprecedented level of global integration.

This could be the case for applying advanced engine cycles including variable pitch blades, some appropriate level of electrical hybridisation, optimized combustion processes, sophisticated gust and manoeuvre loads alleviation, changing over to a natural and/or hybrid laminar flow design, entering a completely new configuration featuring reduced flight mechanic stability and providing the necessary fuel volume for LH_2(6) (if applicable), to name but a few. Propulsion and engine/airframe integration will of course play a major role. **Only by applying breakthrough technologies, daring to deviate from what we know** and have achieved so far and "thinking out of the box", can an aircraft be created that features very low emissions and meets the environmental goals set for the middle of this century.

How can such a "revolutionary" aircraft be developed without gambling with our future?

Safety is paramount in aviation. No aircraft developer can accept undue risks in order to achieve higher performance or greatly reduced emissions. Risk assessment and risk mitigation are essential when developing a new aircraft. Thus a technology for which the risk of failure is considered to be too high will not be applied to a new product. Due to these facts aviation is sometimes considered to be "conservative" compared to other "avant-garde" businesses.

But this time the typical "conservative" approach will not result in the needed "step change". So what is the solution? The only way the aviation industry can dare to make this "step change" is by maturing and validating new technologies thoroughly enough before applying/integrating them into a brand new aircraft that meets both market expectations and environmental needs. In aviation, development programs are common in research

(6) Liquid Hydrogen

activities that assess, further mature and validate technologies. But these are individual technologies that – especially if publicly supported – do not go beyond a Technology Readiness Level (TRL)[7] of 6. Past experience shows that a) the demonstration needs to go well beyond TRL 6 and b) new technologies have to be tested and proven in an integrated manner in order to mitigate the risks.

These steps, up to the appropriate levels of progressive integration (e.g. engine-level demonstrator, flight controls demonstrator, etc.) are necessary. But if a whole bunch of new technologies need to be validated in an integrated way, in addition to partial conventional validations such as analyses or partial test beds, the only solution will be a **global flying technology demonstrator,** which would raise the chances for subsequent application in a new aircraft program meeting environmental needs, market expectations and competitiveness goals, while mitigating risks. Concerning large civil transport aircraft this has so far not been the approach of the aircraft manufacturers (either in Europe or in the US). For Airbus this would be a real paradigm change.

Why an airborne technology demonstrator – and what should it look like?

Without a flying demonstrator to integrate and validate step change technologies under realistic conditions, as foreseen for the later series aircraft, no aircraft manufacturer will dare to incorporate those technologies into a new product because of the important risks, and thus will not achieve the ambitious goals. Partial flying and ground-based demonstrators can be sufficient for sets of technologies applied to one equipment (including the engine), but not for the significant step changes required for a "green" aircraft, for which an unprecedented level of integration is expected, whatever the still-to-be-made technological choices. If we want to achieve this in the envisaged timeframe, **a flying technology demonstrator is a must**, capable of integrating all essential, interacting technologies.

It is important to note that a high enough ambition for the said demonstrator would ensure that thousands of existing employees, either architects, or integra-

(7) TRL: Technology Readiness Level – a criterion adopted by NASA to overcome insufficient technology maturity when applied. This approach is now being applied in the whole sector of aerospace research in the world. See NASA Technology Readiness Level – https://cutt.ly/dfSxjzu

tors or even detailed designers will maintain and even further sharpen their know-how and skills[8] by applying step changes solutions. Additionally, such a demonstrator will be an appropriate (almost unique) opportunity for today's inexperienced young engineers to gain sufficient knowledge of development up to aircraft certification so that they can apply this later on to the real production aircraft.

Of course it is up to the aircraft manufacturer and its partners to define the demonstrator and the technologies that will need to be incorporated, bearing in mind that the future product will have to meet both market requirements and environmental demands. **But in order to achieve maximum risk mitigation and the best chance of application, the technology demonstrator should be close enough to this future product in terms of size, configuration and critical technologies (including the airframe/engine integration).**

How to define the technology demonstrator and the technologies that will be incorporated?

The definition of the flying technology demonstrator needs to combine a "top-down" with a "bottom-up" approach. The airframe and engine manufacturers that need to meet both market and environmental requirements must define the technology demonstrator in a top-down way – derived from the requirements – in terms of configuration and technologies to be integrated. This includes a roadmap setting the need date and required maturity level for individual technologies and for each step of integration as well. It is then up to the major manufacturers, internally, but also the supply chain members (including system suppliers) and research establishments (RE), to work on these technologies (up to the concept of pre-industrial modular demonstrators) within publicly supported research programs, and up to the engine manufacturers for integration first into the engine and then into the airframe. In addition bottom-up proposals of suitable

(8) *For this it will be mandatory that sufficient experienced staff be kept on board and not massively released for early retirement – as happened some time ago at one of the Airbus partners, resulting in a painful loss of know-how and experience and causing several billion euros of extra development costs for Airbus.*

technologies will come from REs, the supply chain, the systems companies and engine manufacturers – the latter will be very important since propulsion will very likely contribute significantly to emissions reduction itself (LH_2 use is a big challenge in particular), and optimal integration into the airframe will be challenging but a key success factor.

Concerning timely availability of the technology demonstrators, the integrated in-flight demonstrator and their results, it will be mandatory to properly orchestrate the various technology development activities of the different players, independently of the funding sources – whether Clean Sky, national or even regional research programs –, as long as those activities are focused on stepwise demonstration and later application in a new large civil transport aircraft. An adequate management organization needs to be set up.

With these properly managed approaches on technology solutions demonstrators and the integrated flying demonstrator, risks and development timing will be reduced for both.

At the airframe side the definition phase of the demonstrator will mainly draw on architectural and integration skills, whereas in the demonstrator development phase the complete spectrum of engineering skills, be it non-specific and specific design work (at the aircraft and engine manufacturers, the supply chain, REs and universities), will be needed.

At this stage it is of the utmost importance to mention the need for having a "living" research network driven by the need to elaborate concrete applications with the necessary pressure from the application users. Academics have a big role to play, particularly in establishing/validating radical new changes, by principle not yet sufficiently known. Theoretical studies at academic level with subsequent studies and testing at the level of the research establishments (such as the DLR in Germany, INTA in Spain, ONERA in France, ATI in UK). The academics' role is broad: from educational aspects to solution finding. Their survival at the top world level depends on regularly launching new challenging programs, essentially in Europe.

The attached Appendix 2 summarizes different aspects of the necessary flight physics competences for developing a completely new airplane program.

Costs, timeframe and financing of a flying technology demonstrator

There will be two cost elements of a flying technology demonstrator: The demonstrator itself (developing, building and flying/testing, analysis results) and the development and validation of sets of technologies that will be integrated in the demonstrator – provided they are suitable for integration and matured enough to ensure reliable and safe operations of the demonstrator.

Depending on the size and the closeness to future product configuration, the flying demonstrator will be at a cost level of four to five billion euros (including the definition phase), and will take six to eight years to be developed and tested. The pre-definition phase at the start of the program, resulting in a suitable configuration of the demonstrator and a "top-down" established list of required technologies, will take some two years. Overlapping with the pre-definition phase and continuing over another three to four years, the detail technologies will be developed and validated already with some level of integration (e.g. engine) (up to TRL 6) in the course of various research programs (Clean Sky 3 / Clean Aviation, national research programs like LuFo in Germany, CORAC in France, ATI in the UK), and even regional research programs, as long as they are on the short list of the demonstrator program and aiming at a "green" or "climate neutral" commercial transport aircraft. Additional funding has to be ensured within these programs if not all needed technologies are covered.

Overall – and taking reasonable overlapping into account –, the airborne technology demonstrator program will take between eight to ten years.

Whereas the technology development research programs are funded in the usual way, considering the difficult financial situation due to the Covid-19 crisis, the airframer, engine manufacturers, systems manufacturers and the involved suppliers will not be capable of financing the activities at the above mentioned level in the indicated timescale. **Consequently, the flying technology demonstrator will require special public funding that has to go well beyond the usual 50% public funding rate, spread over its lifetime.**

Why enter now the logic of a flying technology demonstrator for a commercial aircraft?

The EU is committed to reaching the ambitious goal of significant emissions reduction in aviation by the middle of this century. In order to achieve that goal, the entry into service (EIS) of a first “green” aircraft has to be in the mid-thirties. For that, the development of such an aircraft needs to start in the late twenties. Taking the total program time of 8-10 years for the demonstrator program into account, **this program** – with the necessary steps – **needs to be launched shortly** in order to deliver results by the end of the present decade. Thus no time should be lost in order to meet the 2050 target.

Remarks: it is interesting to mention that:

- flying demonstrators are considered as normal steps for advanced military programmes (e.g. in Europe: Rafale A, nEUROn, or even the New Generation Fighter for the Future Combat Air System) for exactly the same reasons of needing to minimize risks,
- one has to differentiate this complete new flying aircraft demonstrator from other partial ones like the BLADE or others made on existing airplanes,
- clearly lessons learned from this ambitious topic will also have beneficial effects on business and regional aircraft and,
- logically, the same will apply to the future long-range aircraft, as happened after the A320 entry into service.

Conclusion

The Covid-19 crisis has dramatic financial consequences for aviation, both for airlines and aircraft-engines-systems manufacturers, and governments are doing much to support the sector. The French government support plan is showing the way and one would expect other countries in Europe with similar concerns to follow. Germany has initiated its own one as well.

The present pandemic has further highlighted the need to combat climate change due to the great risks to which the world population is exposed. Thus important efforts are required from aviation to limit its effects on the climate. Part of this effort will be the timely development of a “green” aircraft – especially in the large commercial transport aircraft category. The classical way of gradually enhancing and applying advanced technologies in the next generation product will not be sufficient for reaching the challenging goal – this can only be achieved by disruptive, step-change technologies, which all indications show will have an unprecedented level of integration. To respect the paramount safety requirements, these technologies need to be matured and validated upstream to a level that can only be attained by using **an integrated flying technology demonstrator** – as close as possible to the "future" aircraft. This is a new approach for the airframers, both in Europe and the US (and the latter is pushing hard to do so via NASA[9]). The airframe and engine manufacturers and the entire aviation community involved in commercial transport aircraft development and production in Europe need to be supported in the management of this paradigm change – for the twin benefits of maintaining a leading global position and helping protect our climate.

Whereas the development of technologies is quite well under way, it is mainly the four Airbus nations – France, Germany, Spain and UK – that will have to initiate the principle of complementary, timely investment in order to finance the required flying technology demonstrator (similarly to what is done in the US[10]). On the basis of a total cost of five billion euros, the yearly contribution, over eight years, for a partner assuming a share of 35% (e.g. France or Germany) would be of 220 million euros.

This investment will be beneficial not just for Airbus, but also for the engine manufacturers, the entire supply chain including systems companies, as well as research establishments, universities and associated testing facilities contributing to the demonstrator.

By doing so, Europe (the four major Airbus nations with, possibly, other European nations willing to join "the club") will prepare the ground for Green Aviation while preserving its development know-how for commercial transport aircraft.

(9) See note 1.

(10) See note 2.

APPENDIX 1: MEMBERS OF THE AD HOC AAE-DGLR WORKING GROUP

Membres du groupe de travail ad hoc AAE-DGLR
Mitglieder der AAE/DGLR-Arbeitsgruppe

The present Opinion is the result of a joint exercise undertaken by a mixed team of members from the Air and Space Academy (AAE) and the Deutsche Gesellschaft für Luft- und Raumfahrt e.V. (DGLR).

Le présent avis est le résultat d'un exercice conjoint entrepris par une équipe mixte de membres de l'Académie de l'air et de l'espace (AAE) et de la Deutsche Gesellschaft für Luft- und Raumfahrt e.V. (DGLR).

Das vorliegende Positionspapier ist das Ergebnis der gemeinsamen Arbeit einer gemischten Arbeitsgruppe, bestehend aus Mitgliedern der Académie de l`Air et de l`Espace (AAE) und der Deutschen Gesellschaft für Luft- und Raumfahrt e.V. (DGLR).

- André Bord (AAE)
- Wolfgang Engler (AAE)
- Philippe Escarnot (invited expert/expert invité/beteiligter Experte)
- Axel Flaig (AAE and DGLR)
- Jean-Michel Fourtanier (AAE)
- Pierre Froment (invited expert/expert invité/beteiligter Experte)
- Alain Garcia (AAE)
- Patrick Gavin (AAE)
- Mario Heinen (invited expert/expert invité/beteiligter Experte)

- Rolf Henke (DGLR)
- Ernst H. Hirschel (AAE)
- Jürgen Klenner (AAE and DGLR)
- David Marshall (AAE)
- Rolf Radespiel (DGLR)
- Cord Rossow (DGLR)
- Peter Schmollgruber (invited expert/expert invité/beteiligter Experte)

APPENDIX 2 : HIGH-FIDELITY MULTIDISCIPLINARY PRELIMINARY AIRCRAFT DESIGN

Tool capabilities, user competencies, application scenarios in flight physics

The following considerations are focused on high-fidelity multidisciplinary flight physics design tools. High-fidelity design means that the corresponding methods and tools are based on “first principles”, i.e. the underlying physics are represented by their fundamental laws. High-fidelity simulations require the use of Computer Aided Design (CAD) tools for geometry definition, and at least Computational Fluid Dynamics (CFD) and Computational Structural Dynamics (CSD) for flight physics analysis. Due to the computational effort, such simulations have to be run on High Performance Supercomputing (HPC) systems.

To get the full benefit of high-fidelity tools for future designs, it is a prerequisite to establish a “fully digitalized” company environment which allows seamless and consistent data and information access. “Full digitalization” is assumed to be an absolute prerequisite for future economic competitiveness. Therefore, it will not be addressed but considered as a “secondary virtue” which must be mastered by every company anyway (aerospace or non-aerospace).

Definitions (partly based on Raymer, 1992)

- **Feasibility phase**: definition of “Top Level Aircraft Requirements” (TLARs) based on market, customer, company, and certification requirements by taking into account available and achievable technology levels.
- **Conceptual aircraft design**: definition of configuration arrangement, size, weight, performance; result is an aircraft configuration which meets the TLARs.

- **Preliminary aircraft design**: the configuration is mainly assumed to be frozen, definition of outer skin shape and inner structure (e.g. wing box) with respect to performance and loads requirements; result is a full-scale development proposal.
- **Detailed aircraft design**: design of actual parts/systems to be built including fabrication and production requirements; result is the fabrication of the aircraft.

In Airbus terminology, preliminary aircraft design is part of “non-specific design work”, and detailed design falls in the category “specific design work”.

Capabilities of tools for preliminary aircraft design

- The main tools are based on “first principles”, i.e. the underlying physics are represented by their fundamental laws.
- All tools are acting on a general master model which is documented and which is tracking all changes.
- All tools allow for coupling of the main disciplines relevant for flight physics assessment (e.g. aerodynamics, structures (stiffness & masses), and systems (flight control for trim & redistribution of loads)).
- Multidisciplinary simulation methods can be run in analysis (performance assessment with highest accuracy) mode as well as in design (optimization with all relevant forces considered) mode to ensure data consistency for the different applications.
- Modeling representation may vary from fast & approximate to costly & accurate (e.g. structural representation by beam or FE model), but all model properties are tied and consistently checked with the master model (e.g. beam properties are continuously updated with the FE model).
- Local design changes (e.g. airfoil changes) are possible to allow designers “free space”, but results are always directly linked to and checked by integration into the multidisciplinary master model to enable direct feedback of the impact of such local changes on overall performance.
- The “loads process” is broken down into clearly defined components to provide designers with the full understanding of arising restrictions when the aircraft operates at the borders of the flight envelope.
- A “loads hierarchy” is established as early as possible and continuously updated to incorporate the relevant loads cases early and directly into the design process.

- The "hierarchy of loads" will change during design iterations; these changes are assessed by data analytics methods (e.g. machine learning, artificial intelligence, …) to gain a full understanding of the mutual interdependencies to improve future designs.
- Multidisciplinary optimization routinely includes a loads process, preferably with critical cases identified beforehand to reduce computational effort.
- Multidisciplinary design can be performed either by direct solution of equations (e.g. CFD/CSM) or by using appropriate surrogate models (e.g. established by machine learning, etc.).
- Aerodynamic data are generated by numerical as well as experimental (wind tunnel) simulation, whichever is more efficient; data consistency is established by data fusion using data analytics methods (SEN: Synthesis of Experiment and Numerics).
- When targets from conceptual design are not met, conceptual design parameters (e.g. planform size, wing sweep, aspect ratio) are incorporated into the high-fidelity design process while still respecting major dependencies (e.g. fuel volume, trim & control, landing gear requirements); the resulting design is then again assessed by conceptual design methods to check TLAR compliance.
- All data generated during all design processes are collected in company data bases; data analytics methods (especially artificial intelligence) make these data available for current and future designs to continuously enlarge and update the knowledge base of the company (inherent knowledge capturing).
- All tools are supported by accompanying artificial intelligence algorithms to enhance applicability and design decisions.
- HPC resources are seamlessly accessible from every workplace.

Designer and Engineer (D & E) competencies for preliminary aircraft design

- All (!) D & E active in preliminary aircraft design must have a basic training in conceptual aircraft design to develop and continuously extend their knowledge of the sensitive interdependencies which drive full aircraft design.
- All D & E in preliminary aircraft design must have a basic understanding of the loads process to identify the origin of restrictions occurring during the design process.
- All D & E should at least once visit production lines.
- The disciplinary designers (which will be still required!) have to understand the reasons for arising restrictions to enable "educated trading" with specialists from other disciplines

when conflicts with the specified targets arise; multidisciplinary optimization will not resolve intrinsic and/or hidden conflicts.

- D & E need to be fully “fluent” in the use of CAD tools, and should have a basic understanding of all disciplinary high-fidelity tools (e.g. CFD, Finite Elements) to know the inherent sensitivities and limitations.
- All D & E should be well acquainted with employing data analytics methods (e.g. machine learning, artificial intelligence, etc.) to support their own decisions, without however giving up a basic physical consistency checks based on “gut feeling”.
- Data analytics methods should permanently be used to train and hone the “engineering judgement” competencies (“gut feeling”) of D & E.
- Data analytics methods should be used ubiquitously but with care: such methods are very well suited to finding patterns and correlations (extracting the “what”), but they do not give reasons for interdependencies (explaining the “why”).

Application scenarios

- The application of high-fidelity multidisciplinary design tools is requiring extensive skills and continuous training of D & E.
- Do not expect that new tools which were not put to practical use before, can be efficiently employed in an actual aircraft design process.
- The design process itself depends substantially on the tools employed; therefore appropriate efficient design processes need particular “apply, check, learn, change, re-apply” phases for their maturation.
- High-fidelity multidisciplinary design tools inherently account for disciplinary interdependencies, essentially they automatically reflect the “concurrent engineering” philosophy; as a consequence, when properly applied significant reduction of design time and risk should be realized.
- To leverage the full potential of high-fidelity tools, users need routine and confidence in application, judgement and design decisions; therefore design exercises are an absolute prerequisite before employing such methods in an actual aircraft design.
- It is well advised to validate the results of a newly defined high-fidelity based design process against known state-of-the-art top level aircraft designs.

- The flight physics redesign of the A350 may serve as an appropriate example: the TLARs are known, time & effort of the original process are known together with corresponding deficiencies & errors; a newly defined design process with high-fidelity tools should be executed in competition to quantify potentials and to cure deficiencies.
- Define TLARs and perform conceptual design for an “exotic” configuration with advanced technologies; then apply the validated high-fidelity design process to get experience for application in a difficult and contradicting design space.
- Dismiss the slogan of “first time right – right first time”: multidisciplinary high-fidelity tools are complex and demanding, consequently D & E must be experienced in their application. According to common sense, “experience is the sum of all errors”, and therefore one has to provide D & E the possibility to acquire and enhance professional experience, before starting an ambitious industrial design program with very tight budget and time restrictions.

Dépôt légal octobre 2020

ISBN 978-2-913331-85-3
ISSN 2426 3931

Crédits images couverture: A.Ribes

Achevé d'imprimer octobre 2020

Imprimerie LES CAPITOULS

2 Chemin de Rebeillou - 31130 FLOURENS

BP 83117 - 31131 BALMA CEDEX - FRANCE

ACADÉMIE DE L'AIR ET DE L'ESPACE
Ancien observatoire de Jolimont
1 avenue Camille Flammarion
31500 Toulouse – France
contact@academie-air-espace.com • Tel : +33 (0)5 34 25 03 80
www.academieairespace.com

DEUTSCHE GESELLSCHAFT FÜR LUFT- UND RAUMFAHRT
Lilienthal-Oberth e.V.
Godesberger Allee 70
53175 Bonn
info@dglr.de • Tel +49 (0)228 308050
www.dglr.de

9 782913 331853

ISBN 978-2-913331-85-3
ISSN 2426 3931

10€