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Methodology for the Validation of Loads in Rational Turning Analysis

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A methodology for the validation of the turning loads is needed when the aircraft has a non- conventional landing gear configuration. This is the case for the A400M aircraft in which the main landing gear (LH and RH) consists of three independent articulated-type struts positioned along the aircraft longitudinal axis. As the legs are positioned along the aircraft in the longitudinal axis, during the turning manoeuvres the lateral loads reacted by the main landing gears are distributed between each of the three legs. The complexity of the landing gear is increased as all the struts have a twin wheel arrangement, fitted to the main fitting by a trailing arm assembly.
Aircraft regulation for turning load calculation is not entering in how the tyres mechanics affects the lateral load sharing in a multi-leg landing gear. In fact, the paragraph CS25.495 is sharing the lateral loads between the legs proportional to the vertical load of the leg. For the calculation of this vertical load, it is considered the aircraft in a static condition with the shock absorbers and tyres in their static position. This approach is far away from the physics of the manoeuvre. First, no effect of the steering angle is impacting the load sharing as occurs in the reality. In a real situation, the steering angle is affecting the side slip angle of the tyres contributing directly to the lateral load sharing.
Second, the vertical load is depending on the lateral load factor applied to the centre of gravity of the aircraft when this one is manoeuvring on ground.
Knowing that there is a huge difference between what is required by the rule and what is the real physics of the turning manoeuvre, it was decided to build rational models that approach real dynamic of the aircraft complying with the load factors required by the rules. This way it will be minimised the risks of load exceedance during the real operation of the aircraft.
The impact of this decision was affecting the validation of models as more parameters enter in the simulations. Due to that, it was necessary to develop tests to obtain the lateral load versus side slip curves associated to the tyres. Moreover, it was performed flight tests with a fully instrumented aircraft to obtain the validation of the loads over the landing gears during real aircraft turning manoeuvres.
The flight tests were performed with different aircraft configuration in order to capture the effects of different aircraft parameters: aircraft weight, centre of gravity position, steering angle, aircraft longitudinal speed, braking and thrust. For high speed turnings it was required to reach different levels of lateral load at the centre of the gravity till the maximum possible.

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Ground Test Vibrations as non-conservative mean of compliance for vibration airworthiness requirements of A/C mechanical systems design

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Vibrations requirements for A/C mechanical systems design are limited to series of standard environmental test conditions and procedures, which may be used to support compliance, as RTCA-DO160 or MIL-STD. Nevertheless, these procedures could be non- conservative in systems embedded in high airflow due to the fluid-structure coupling. This paper describes an example of real engineering equipment as the APU flap door where the previously described situation takes place.

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Wind tunnel high speed powered tests of the ERICA tilt rotor model in S1MA - NICETRIP Project

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Within the framework of European research programs, the NICETRIP (Novel Innovative Competitive Effective Tilt Rotor Integrated Project) project aims at building a flying demonstrator of a European civil tilt rotor aircraft. Previous projects like DART, TRISYD, TILTAERO, ADYN and ACT-TILT, studied various aspects of the tilt rotor concept and resulted in the definition of the ERICA (Enhanced Rotorcraft Innovative Concept Achievement) concept. Wind tunnel testing was therefore requested to prove the liability of the ERICA concept with respect to low speed interaction and high speed performances, in order to freeze the general architecture, flight control system and flight control laws and determine the operational performance.
The wind tunnel tests have been performed on a 1:5 scaled powered model and covered a wide range of flight envelope points, from low speed helicopter mode to high speed aircraft mode. Two test campaigns have been performed: one low speed test campaign in June and July 2013 in DNW-LLF wind tunnel facility (Netherlands) and one high speed test campaign in May 2014 in ONERA-S1MA wind tunnel facility (France).
The present paper aims at presenting the wind tunnel tests performed in the large transonic wind tunnel S1MA on the ERICA tilt rotor concept in conversion and aircraft conditions, with variations of several parameters. In order to assess the performance of the ERICA tilt rotor concept in high speed flight conditions, the full set of data is analysed by aerodynamicists from ONERA and European helicopter industries.
The main objectives of the high speed tests were the determination of the aerodynamic interactions and the rotor performance between Mach 0.176 (minimum speed in aircraft configuration) and Mach 0.550 (maximum speed in aircraft configuration).
More than 140 data points have been recorded during this test campaign. The model was heavily instrumented and largely remotely

controlled, allowing to perform several data points without any mechanical change of model configuration. Trimming points have been performed and variations of collective pitch and movable surfaces like flaps, flaperons, rudder and elevator have been tested. Incidence and sideslip sweeps have also been performed for "blade on" and "blade off" configurations.

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Thermally Induced Vibration Analysis of Flexible Solar Wing

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Flexible solar wings of large scale have been used to provide electricity for spacecrafts. When the solar wings running on orbits with spacecrafts, they suffer from periodic thermal loads. And the thermal loads will cause thermal deformations of the solar wings, even thermal vibrations. Finite element method and equivalent displacement method were utilized to investigate the thermally induced vibration of flexible solar wing. Some Python programs were written to implement pre- and post-processing for finite element analysis. The thermally induced vibration analysis method was verified by composite laminate, and it is proved that the method is accurate. Dynamic responses of a flexible solar wing under thermal loads were analysed, and the effect of the thermal loads on the flexible solar wing were illustrated by the displacement responses of some points of the flexible solar wing. The rigid-flexible coupling phenomenon of flexible solar wing was found by the displacement responses. The thermally induced vibration analysis with finite element method was accurate and efficient.

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An automated CFD analysis workflow in overall aircraft design applications

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Introduction

The increasing demand for commercial aviation, the rising fuel price, as well as the growing environment concerns have become the key drivers in improving aircraft fuel efficiency. Unconventional configurations, such as the Blended Wing Body [1] (BWB) and the strut-braced wing [2], are promising candidates to significantly improve the fuel efficiency. However, unlike for conventional aircraft designs, novel configurations suffer the lack of empirical knowledge. Hence, due to the high development costs and the economic risks associated with unconventional configurations, from the beginning of the design phase it is necessary to correctly predict the configuration's behaviour, in order to guarantee the promised performance.

Most of the current large commercial aircraft operate in the transonic flight regime at the cruise phase, and accurate wave drag estimation is essential for the design trade-off. Further, unconventionally configurations are highly multidisciplinary, and MDAO (Multidisciplinary Analysis and Optimization) techniques become necessary to capture the interdisciplinary dependencies. Hence, physics based analysis and design automation constitutes the challenges for the early assessment of the unconventional designs.

The computational improvements, as well as the evolution in CFD algorithm over the past decades, allow engineers to make use of CFD based techniques, such as Euler based simulations, to accurately predict the flow field behavior, even at the critical transonic conditions, and within acceptable analysis time. However, compared with low fidelity simulation methods, CFD analysis requires that the aircraft is described in much greater detail. For instance the configuration model for the CFD requires an accurate, water-tight, representation of the wetted surface, or Outer Mould Line (OML). Besides, the generation of quality CFD meshes, requires extensive, and usually manual, pre-processing of the geometry components, with required times not acceptable to perform large geometry variations, such as at the early design stages. Consequently, the representation of overall configurations together with mesh generation has been the bottleneck to employ CFD within overall aircraft design applications. Hence, in this paper, an automated aerodynamics analysis chain, based of DLR CPACS data modelling, is presented.

Process Implementation

With the purpose of fostering the collaboration among disciplinary specialists and the integration of disciplinary expertise into the overall aircraft design process, the centralized data structure CPACS [3] has been developed by DLR over the last decade and it is adopted both within the DLR aeronautical branches[4], and with external projects[5]. It contains information on the model, such as its geometry description, and holds process data to control the overall analysis workflow. In order to support the handling of CPACS-described geometries to be progressed to the disciplinary analysis, the dedicated library TiGL [6][7] (TIVA Geometry Library) has been developed by DLR. The TiGL Geometry Library which is based on OpenCASCADE kernel represents the airplane's components geometry by B-spline surfaces, and it can export the geometry as CAD based format for further disciplinary analysis. The analysis chain here described makes use of the CPACS model description, with the objective to link it with automates high fidelity analysis capabilities, suitable for early design stages.

The first component of the implemented chain is a Python script, named Ggeo, which makes use of the TiGL library, available as API, to automatically generate a CAD model from an arbitrary CPACS description file. Ggeo makes use of the CPACS hierarchical structure to identify the aircraft geometry topology, such as the numbers of wings, fuselages and sub-components, and processes the information to automate the mesh generation step.

The mesh generation component, named Ggrid is an under development Python based tool , which automatically generates macros for the mesh generators, to produce isotropic tetrahedral meshes for inviscid flow simulations , and hybrid or anisotropic tetrahedral meshes for viscous flow simulations. In this study the macros exported are compatible with Pointwise [8] meshing tool. The open source CFD solver SU2 [9] is chosen for the solution step of the flow fields, both for the Euler or RANS equations.

The overall process, from the processing of the geometry CPACS description, to the results of the aerodynamics solution, has been implemented to be fully automated for arbitrary configuration input. The robustness of the developed process, which relies on the knowledge based layer implemented into the pre-processing components, allows taking advantage of high fidelity simulations, also for large explorations of the design space, as typically required at the early development stage.

The engineering framework chosen for the implementation of the process is the open source integration distributed environment RCE (Remote Component Environment), developed by DLR [10].

Preliminary Design Cases

In order to verify the described chain, the chain is initially applied to the well-known test case DLR- F6 wing body configuration.
A first grid convergence study is performed for both the viscous and the inviscid grids, and solutions are compared with the experimental and the CFD data available from AIAA drag prediction workshop 2[11] (DPW2). In addition, an angle of attack sweep from -3.8 degree to 1.82 degree is run for each grid refinement to generate drag polars at the design Mach number of M=0.75. A comparison is also shown between the solutions from the CFD analysis and from a vortex lattice code, as typically used for the polar estimation at the early MDO stages [12].
To demonstrate the advantages of the implemented CFD automated chain over the low fidelity method, a mission analysis is performed on a reference transportation aircraft. The overall fuel burn obtained by the mission analysis making use of the CFD computed polar is compared with the results obtained by using the vortex lattice code solution.
The paper shows the importance of using high fidelity physics based analysis in overall aircraft design applications.

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ESWIRP: European Strategic Wind tunnels Improved Research Potential – Program Overview

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"European Strategic Wind tunnel Improved Research Potential" ESWIRP is a project in the EU 7th Framework program (FP7), which was designed to improve the performance capabilities of three strategic wind tunnels in Europe, by strengthening the cooperation between these wind tunnels in a new consortium. The research consortium members are ONERA (operating the S1MA as its largest sonic wind tunnel), DNW (operating the LLF as its largest low speed wind tunnel) and ETW (operating its cryogenic transonic wind tunnel). Together these wind tunnels cover a wide range of experimental situations of relevance for civil aviation and other aeronautical research.
The project started in October 2009 for a period of 5 years. The European financial contribution was € 7.2 million.
The project consist of two major parts: 1) the improvements to the testing infrastructure; and 2) the provision of wind tunnel access to research groups which do not usually have the means to access such large-scale test facilities. These topics also involved public dissemination and information activities.
Although the tunnels covered in this project are of complementary nature, the infrastructure activities are joined together, by a common representation of, and approach to, the tunnel performance characteristics. To this end, a generic model of a virtual wind tunnel was developed, enabling operators to assess the effect of the control parameters upon the testing conditions. The final aim of all participants was to provide the user community with an improved capacity to test their innovative ideas, and to be able to do this with increased reliability.
Providing access to those major wind tunnels, mainly concerned research groups from European universities, who had been targeted. The approach taken has included maximum transparency of the process, and support of the researchers by the organizations responsible for the tunnels. In addition, when possible, we encouraged research groups to work together, to obtain the full benefit of economies of scale in research projects.
ESWIRP responds to the targeted approach of the Integrating Activities of the FP7 Capacities
Work Programme:
*Networking activities, essentially focused around 4 topics:
Ø Organization of information campaigns, lectures and workshops to disseminate knowledge between the partners and future users,
Ø Opening of a website for the consultation of wind tunnel standards,
Ø Exchange of personnel between the Consortium partners to foster spreading of good practices and the exchange technical know-how,
Ø Joint development of a reference wind tunnel parameter database.
Trans-national access and/or testing services: After the call for proposals by the facility providers, groups of researchers had the opportunity to have free wind tunnel services, including technical assistance to support the corresponding scientific research team(s).
Joint research activities: Through innovative modelling of wind tunnels, it has helped designers to make better decisions, before the implementation of novel hardware. This is the first time that mathematical modelling has created a standard for wind tunnels. The infrastructure improvements targeted the capability to obtain unsteady test data with high accuracy in the ETW, to improve the capability to simulate aircraft behavior in ground effect in the LLF, and to establish a reliable closed-loop Mach number control in the S1MA wind tunnel.
ESWIRP is European support for strategic wind tunnels, key research infrastructures in the development process of current and future aircraft. This is the first time that European authorities have given such support.

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Advanced composite for space applications: Design and Structural Analysis of CFRP Electronics Housing

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Hosting a payload straight up to escape Earth's gravity requires a phenomenal expenditure of energy, and every gram of weight saved in either launch space vehicle or payload weight translates to lower overall costs. Satellite payload includes also among others electronic unit housings, traditionally made in aluminium alloys. The paper presents the geometrical design study, three types of CAD models being developed along with materials structural new concept design to be developed using autoclave technology, validated by FEM analysis for a composite electronic housing. Regarding the mechanical stresses study, static and dynamic loads calculations were made. From these calculations optimum CAD3 model and structural design were validated for manufacturing, but with increasing stiffness of the frame with box beam, for natural vibration frequency higher than 100Hz, during launching. The proposed CFRP composite electronics housing was designed in order to fulfil the multiple requirements set for the housings providing large mass savings.

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Unsteady surface pressures measured at a pitching Lambda wing subjected to vortex dominated flow including transonic effects

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A Lambda-wing is a common shape for modern UCAV designs (Unmanned combat aerial vehicle). At higher angles of attack (AoA), medium sweep angles and combinations of round and sharp leading edges, lead to complex vortex systems. The goal of the IWEX wind tunnel model (Instationaeres Wirbel Experiment – Unsteady Vortex Experiment) is, to study the vortex development at a purely round leading edge of a lambda wing. Pitch oscillations are performed to gain insight to motion induced aerodynamic loads, subjected to this kind of flow. This will be used for aeroelastic analysis. At higher free stream speeds, shocks can occur. They have an impact on the development of the vortical flow and the resulting surface pressure distribution. The unsteady pressure distribution is dominated by the motion of the shock, the vortex and the interaction between them.
Pressure distributions from Unsteady Pressure Sensitive Paint (iPSP) measurements will be presented for steady and unsteady AoA. Two test campaigns were conducted in the Transonic Wind Tunnel Gottingen. Angle of attack oscillations with a mean AoA of up to 20° were performed at free stream Mach numbers from 0.5 to 0.7. The half wing model is attached to a hydraulic actuation system. The influences and the aerodynamic phenomena will be explained. The special emphasis is on the conditions where transonic effects occur.
At steady AoA at subsonic free stream Mach numbers, the pressure distributions are dominated by the strong suction peak at the leading edge and its breakdown, when the vortical flow separates from the surface. At higher AoA, the main vortex (Figure 1) moves inboard and detaches from the surface. The results from the measurements without the coating of the model showed that at transonic flow conditions, vortex development occurs at lower angles of attack and a smaller maximum lift is reached than at subsonic flow. That can be explained by a vortex –shock interaction triggering the vortex development at a further inboard position. In the presented results, this is visualized by the pressure distribution at the surface. Furthermore, it is analysed at different sections in combination with the data of the unsteady pressure sensors. The supersonic flow at the leading edge and the shock, terminating this area, also changes the breakdown of the suction peak. The region of high suction is broader and the breakdown caused by the separation of the vortical flow from the surface less prominent. The supersonic flow induces additional suction and hereby lift.
The measurements of the pitch oscillations revealed a fairly harmonic behaviour of the pressure below the vortex core. However, a high level of fluctuations is found in its vicinity and between the main and the tip vortex. A change in the behaviour of the phase exists between the response of both vortices to the angle of attack oscillation. The characteristics strongly depend on the mean AoA and the applied amplitude. At lower angles of attack, the shock motion is dominant. At higher angles of attack, when the vortex has moved inboard, the vortical flow induces effects in a similar order. With increasing pitching frequency, an increasing phase lag of the aerodynamic response is found.

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Development of laser beam welding concepts for fuselage panels

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To meet the future demands of the aerospace industry with respect to safety, productivity, weight and cost, new materials and joining concepts have been developed. The platform Green Regional Aircraft of the European Clean Sky Programme has set the objective to investigate lightweight metal components for lighter aircraft structures. Fuel saving and environmental advantages can be achieved through lighter airframe structures. Laser beam welding as an efficient joining technology for fuselage structures is already established in the aircraft industry for lower fuselage panels, because the welded panels provide a higher buckling strength and lower weight compared with the classical riveted designs [1,2]. Recent developments in the metallurgical field make it now possible to use laser-weldable Al-alloys of the 2xxx series such as 2198 and 2196 with a high structural efficiency index due to their high strength and low density [1,3].
In the present work the laser weldability of Al-Li alloys 2198 and 2196 was studied to determine the process parameters needed to obtain consistent laser welds, and to compare the mechanical behaviour with the conventional fuselage aluminium alloy combination 2024 and 7050. To optimise the dual laser welding process for skin-stringer structures (Fig. 1), a comprehensive finite element model has been established based on ABAQUS and Finite Element Analysis Toolbox using the Welding Modelling Toolbox module. The model is able to predict the thermal history and size of fusion zone for various welding conditions and also able to expand to more complicated welding configuration. The microstructures of the welds (Fig. 2) are investigated and the strength loss in the heat affected zone is also characterised. A noticeable equiaxed grain zone is found in all welding conditions which impose reliability risk. Porosities and microcracks are also spotted inside the fusion zone and, even along the fusion boundary when the laser power reaches to 2000W. A detailed EDX mapping has been done to reveal the inhomogeneity of composition within the fusion zone. In addition, a hot cracking susceptibility modelling has been carried out on the basis of the composition characterisation.
The study also emphasizes the mechanical properties of the weld joint to gain an understanding of the underlying factors controlling the performance of the welds. During the demonstration phase the developed laser beam welding technology was applied for welding stiffened flat panels. The mechanical performance of the welded panels was investigated through the compression tests.

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Design and analysis of the control and stability of a Blended Wing Body aircraft

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Future aircraft generations are required to provide higher performance and capacities with minimum cost and environmental impact. This calls for the design of revolutionary unconventional configurations, such as the Blended Wing Body (BWB), a tailless aircraft which integrates the wing and the fuselage into a single lifting surface. It has been proven in previously published works that this concept is feasible, has an efficient economical performance and is a promising candidate for solving the current air traffic problems, despite its challenging control and stability features. Moreover, the size of the vertical surfaces, such as the winglets, condition the radar detectability of the BWB model, especially for military missions. A current research problem is to find new ways to improve the aircraft conceptual design process in a multidisciplinary environment. For this project, the CEASIOM (Computerised Environment for Aircraft Synthesis and Integrated Optimisation Methods) software for aircraft design was enhanced by implementing DLR’s CPACS (Common Parametric Aircraft Configuration Scheme), as

an unified and more versatile software framework. This improvement was performed in order to enable the design and analysis of future unconventional aircraft configurations, which was not possible previously.
After investigating the latest developments in the BWB concept, a BWB aircraft baseline was designed and its aerodynamic behaviour and performance analysed with a special emphasis on its stability and control features. A Vortex Lattice Method (VLM) and a 3D panel method were employed for the aerodynamic analysis and both showed a close agreement. The allocation and sizing of the control surfaces was then iterated over to find the optimum winglet size for minimum drag and radar detectability conditions. All in all, the satisfactory performance of the BWB concept and the usefulness of new design software were confirmed.

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Comparative study of European RPAS regulations

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Civil aviation contributes to a chain of logistic integral transport that has as aim serve better the citizens and the society. It contributes a value added across offering rapid, trustworthy and resistant connections in a global net. For 2050, there is waited a number of different categories of aircraft to be operative, diverse in size, performance and type, in spite of some still having a pilot on board, but many directed by remote or totally automated control. The opening of the European market for remotely piloted aerial systems (RPAS) therefore, is an important step for the aviation market of the future [1, 2] RPAS form part of the wider category of Unmanned Aerial Systems (UAS). The term UAS (Unmanned Aircraft System) refers to those systems which involve the movement of air vehicle without a human operator on board and includes the aircraft as well as supporting ground, air, and communications infrastructure.
The RPAS is a subcategory of this family, indicating all those UAS that have a human operator (or Remote Pilot - RP) operating the air vehicle from a remote position (Remote Pilot Station - RPS) and in constant control of the vehicle [3]. The aerial vehicle, called Remotely Piloted Aircraft (RPA) has been considered by ICAO as an aircraft, so it has to comply with the Rules of the Air [4]. The term system refers to the complex nature of the RPAS, where several components need to be coordinated.
RPAS integration in non-segregated airspace has been set as an objective for the future of several Civil Aviation Authorities and the industry alike. The expected integration is being studied by several agencies, providing detailed and valuable information on how to proceed step by step. Such is the case of the European RPAS Steering Group in their European Roadmap for RPAS integration [5] and the Federal Aviation Administration [6].
Also, the International Civil Aviation Organization (ICAO) has set the objective of establishing the principles and rules for the RPAS to operate in airspace mixed with manned aircraft, under Instrumental Flight Rules (IFR) and Visual Flight Rules (VFR) adhering to the requirements of the specific airspace in which they are operating [6][7][8].
The study of RPAS operations involve several perspectives to consider, like regulation, airworthiness, communications and interoperability. The current lack of a common and specific regulation makes the RPAS operations available only into segregated airspace for specific military or experimental operations (after the issue of a notification of approval by the authorities). The regulation is usually beyond technical improvements so that in the RPAS operations, there are no valid standards for their integration in non-segregated airspace with the required level of safety [9]. If RPAS are to be integrated, either for civil or military applications, they will have to comply with the same rules and procedures as the other airspace users, without degradation of the safety, without disruption of current operations and without modifying ATC procedures. Therefore, it is considered that RPAS behaviour in operations must be equivalent to manned aviation, including for the air traffic control (ATC).
In the European Union, the aviation safety regulator is the European Aviation Safety Agency (EASA) and, by the moment and until the actual regulations does not change, the RPAS responsibilities are divided between the very light aircraft (MTOW under 150 kg), owned by the National Authorities, and the heavy RPAS (MTOW over 150 kg), competence of EASA [10].
While the moment when the previous division finishes (envisioned more or less by 2017 according to [1] and [5]) there are several European national authorities who are establishing their own regulations in order to facilitate the commercial expansion of the small RPAS business in their territories. This multiplicity of legislations is generating a confusing regulatory map across Europe which is hindering the natural expansion of small RPAS manufacturers and operators through the common market.
This work aims to present a concise comparative study of all the available approved national regulations for small RPAS in Europe in order to highlight the main differences and coincidences among them, trying also to extract a set of conclusions that may help the regulators in order to the future establishment of a set of harmonized standards in the UE. By the moment, the study has started by analyzing and comparing the regulations approved at United Kingdom, Sweden, Czech Republic, Italy, France and Spain, but as soon as more regulations are put into force, they will be included in the study.

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Assessment of aircraft noise sources variability using an acoustic camera

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The continuous increase of air traffic and stricter noise regulations have caused that aircraft noise is one of the main current issues which the industry has to currently deal with. In fact, noise restrictions are nowadays the limiting factor for the increasing capacity of many airports. In order to reduce the produced noise levels, it is essential to know which elements (engines, airframe, etc.) of the aircraft contribute to it and their relative importance. Aircraft noise is a function of many parameters such as the aircraft type, the engine settings, aircraft speed and the flight configuration. Therefore, this research consisted in the measurement of 115 flyovers in the Amsterdam Airport Schiphol using a low cost, high resolution acoustic array of 32 microphones, developed in TU Delft. The scope is limited to commercial jet aircraft during the final approach stage due to the lower engine noise levels in this stage, which allows a better distinction of the airframe noise. Moreover, the trajectories tend to be more uniform in the final approach stage than during the take-off.
An accurate trajectory estimation is crucial in order to account for the Doppler effect and atmospheric propagation effects. Therefore, a combination of ADS-B (Automatic Dependent Surveillance-Broadcast) data, ground radar data and optical camera measurements was

employed for the calculation of the aircraft trajectory, showing a close agreement between them. Once that the flight paths had been calculated, a detailed study of the variation of the noise levels for single aircraft types and engine settings was performed. From the spectrograms, the engine settings can be derived by estimating the Blade Passing Frequency (BPF). Three different methods were employed and it was found that both the tonal and broadband noise levels increase with increasing power settings. Airspeed, however, did not have such a strong influence on the emitted noise, increasing just slightly the noise levels.
Finally, different beamforming algorithms (such as the conventional frequency domain) were applied to the measurements in order to better evaluate the location of the noise sources and it was found that the airframe noise is often comparable to the engine noise during the landing. All in all, it was confirmed that acoustic arrays are very useful tools for evaluating noise sources and that airframe noise is getting more important, as engines keep reducing their noise levels.

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Interactive 3D Visualization to Support Concurrent Engineering in the Early Space Mission Design Phase

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Planning a space mission and designing a spacecraft involves complex interdisciplinary systems engineering. Space mission projects are typically expensive, of long duration and require experts from various domains, such as power, communication, thermal, structure, propulsion and payload. In order to manage the project complexity, the lifecycle of a spacecraft is commonly divided into seven phases as defined by European Space Agency (ESA) in ECSS (European Cooperation for Space Standardization). Phase 0/A refers to the beginning of mission planning, in which the feasibility study is carried out. Over the past ten years, the concurrent engineering (CE) process has been widely adopted for such early space mission design activities. At the German Aerospace Center (DLR) in Bremen, the Concurrent Engineering Facility (CEF) is setup for this purpose. It is a specially designed room that offers the space and technical equipment for a group of discipline experts to collaboratively develop a concept of a proposed space mission. It allows the co-located experts to discuss the various aspects face-to-face, present ideas, draw sketches and build ad hoc groups to discuss sub-topics. It especially allows to overseeing the contributions from all disciplines at a whole and, thus, spotting conflicts or design issues early in the design phase. The ability of spontaneous interactions between the experts can immensely speed up the design phase. Similar facilities have been used at NASA, ESA and other space agencies.
Although the CEF and similar facilities allow all discipline experts to work closely together improving communication, the fragmentation of used domain-specific data and specialist tools still induce issues of data exchange and data consistency. To tackle the problem of interdisciplinary data exchange, DLR's department of Simulations and Software Technology in Braunschweig is developing a software tool called 'Virtual Satellite' (VirSat) to support concurrent engineering in the CEF. The tool implements principles of model-based systems engineering (MBSE). Throughout the planning phase, it collects data from all relevant domain experts, exchanges the data between different domains as per requirements and always maintains consistency. It generates a common system level model based on the data from all domains, linking data from all disciplines together, and shares it between all. It provides a common understanding of a system to all domain experts. Based on this system model, VirSat additionally supports data analysis, inter-disciplinary dependency management, data synchronization and graphical modelling of a space system.
Although VirSat solves the problem of data sharing, the general issues of inter-domain communication still exist. Different domains have different means of communicating their data. For example, the expert of a payload instrument may not intuitively understand the numbers, graphs and diagrams of the thermal expert. Thus, in technical discussions very often experts do not understand each other in detail, leading to misinterpretation or even failure to notice important constraints. In this paper, we propose to combine and utilize interactive three-dimensional (3D) visualization and Virtual Reality (VR) technologies as a tool to unify some of the different views and parameters seen by the experts from diverse disciplines in CE and to make these more accessible. Complex scenarios can be illustrated and animated using 3D graphics. This is already used by the configuration engineer, for example, or often when presenting simulation results. Interactive 3D visualization lends itself well as a medium for sharing expert knowledge within a group. Complex processes can be explained more easily when parameters can be changed and its effect is shown instantly. VirSat already includes support for interactive 3D visualization, e.g. for space craft configuration and orbit simulation. However, the current implementation is limited to desktop-based display systems only, typically using a PC mouse or keyboard as input devices. However, although a mouse is an intuitive input device which allows precise pointing, every monitor has finger prints. This is because people find it much more intuitive to point with their finger at objects while discussing with others. VR technology can bridge the gap between the users and the visualized content. Motion tracking devices and suitable interaction techniques support the intuitive and natural selection and manipulation of the displayed virtual objects. Using large scale display systems or networked VR environments supports collaboration around visualization within a group of users.
Interactive visualization and VR has been used already in later design phases of space missions. However, we argue that it is highly beneficial in the early design phase as well. It enables all domain experts to get an overview of the complete system in one view at an early stage of mission planning. Design flaws or conflicting constraints may be recognized easier. For example, data of mission analysis, spacecraft structure and orbit simulation could be combined in one view. All relevant data is extracted from the shared system model and reconstructed to a VR scenario showing a 3D model of the spacecraft with its internal components moving along the proposed orbit. The engineers could interactively move around the virtual spacecraft; visualize the sun and shadow phase of Earth, as well as results from a thermal simulation mapped onto the 3D model; change parameters and visualize the effect of change in parameter value. Thus, experts from the configuration, orbit, payload and thermal domain can easily explain and discuss together the effects of heat propagation inside the spacecraft and better understand the dependencies of various parameters in the design. Furthermore, the involvement of interactive 3D visualization from the planning phase and its link to the common system model creates a concrete base for later phase design. In later phases, a more detailed design and domain specific simulations can be visualized and maintained in synchronization with the common system model developed in the planning phase. Typical use cases include collaborative design review, maintainability analysis of a spacecraft or astronaut training. For example, VR allows to realistically simulating an on-orbit servicing mission in a safe environment without the need for a physical mock-up, supporting visibility and reachability analysis of spacecraft parts for a servicing robot based on data from the central system model
In order to take advantage of the shared system model generated during CE, it is necessary to link the visualization model to the common system model created by VirSat. This is done using model- to-model transformation techniques. The transformation from the system data

model to a visualization model can be one-directional when only visualization is required. A bidirectional transformation allows both, visualization of data and inserting design changes back into the system model. The transformation can be automatic based on pre-defined rules. Furthermore, the visualization model can be reduced to the necessary data only. For example, a visualization model used for maintainability analysis in a VR system would include not only the geometric shapes of spacecraft components, but also a set of physics properties in order to simulate collisions, kinematic behavior and visual effects, such as reflections of the sun on object surfaces. In contrast, a visualization model used on a mobile device, such as a tablet, for design review purposes might include basic shapes only, as well as relevant meta data to be displayed in text form.

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Design of UAV for photogrammetric mission in Antarctic area

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The history of UAVs is relatively long and many such vehicles are in service for different tasks. They can be used even in environment, which is inhospitable for a human, e.g. in case of extreme temperature. Moreover, they can perform a task that is difficult or impossible for manned aircraft because of its size and usually relatively high airspeed. The photogrammetric tasks belong to this group, especially if we need to make the high resolution pictures during low level flight. The advantages of a small UAV for such missions are more evident if we want to investigate the natural environment, where there are wild animals. The paper presents the small UAV designed for special task, which is the counting of penguins in Antarctica. Inhabited area, extreme weather conditions, the fearfulness of penguins and the goal of the mission put up certain requirements for the UAV. It had to be a reliable, stable platform, which is able to take photogrammetric equipment and to perform precise flight to cover the whole investigated area.

Design evolution

A decade ago in Warsaw University of Technology a project of simple training glider (PW- USZATEK) was developed. The glider had wings placed on the high pylon, just to be able to operate in rough terrain where there are often no prepared landing strips or runways (like the hang-gliders taking-off from the mountain slopes). In order to investigate dynamic properties of such configuration and compare them with the results of calculations a scaled model of this glider was built. This model was later redesigned as the UAV platform for testing different propulsion systems. The skills gained during realization of this project became very helpful for the current project devoted to designing the UAV for photogrammetric missions, which has to operate from the area with many obstacles on the landing fields. The basic aim of photogrammetric mission is the orthophotomap, which consists of the set of orthophotos. There are several requirements for successful result of photogrammetric work:

The optical axis of the camera should be vertical,

The photo-shots should be in the same scale, which means that the flight level should be constant, The photo-shots frame should be overlapped in both – longitudinal and lateral directions,

The flight trajectory should exactly follow a planned grid, and this requirement is not so easy to fulfil.

Aerodynamic design

The initial configuration was designed as glider with relatively small wing loading. For windy conditions in Arctic area such configuration could be very sensitive to gusts. Therefore, the span of main wing was reduced to obtain lower wing loading and also span of horizontal tail was reduced respectively to save similar stability margin. The airfoils for main wing were selected based on computation of basic performance and taking into account small Reynolds number (Re=500 000). Finally Eppler 205 airfoil was selected.

The complex aerodynamic calculation for the modified configuration was made using panel code (PANUKL package). All characteristics, including stability derivatives were computed. Some damping derivatives with respect to acceleration (with respect to) were computed using ESDU reports and handbook methods.

Flying qualities

The requirement of strong stable flight causes, that very good flying qualities are necessary. Therefore stability analysis was made in early stage of design using SDSA package. First static stability analysis was done. The results were satisfying and static margin was in range 15-35% of MAC. The dynamic analysis proved that, all modes of motion are stable in almost whole airspeed range and only phugoid can be unstable in small airspeed regime. First test flight confirmed good stability and correct flying qualities.

Current state of the project and close future

Currently two built UAVs called “PW-ZOOM” are on the trip to Antarctica. They will be used to investigate areas inhabited by penguins, starting from November 2014. First results are expected in the beginning of 2015.

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Methods of flight-path planning for UAV photogrammetry missions with consideration of aircraft dynamic properties

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The authors' intention of presenting this paper is to share experience of photogrammetry missions carried by the UAV. Relevant knowledge was gained by participation in the Polish- Norwegian Research project named MONICA (oriented on aerial monitoring of impact of climate change on the Antarctic ecosystems). The basic aim of the photogrammetry mission is to provide the ortophotomap which consists of a set of merged ortophotos. There are several factors that contribute to achieving successful results from photogrammetry missions, namely parameters of a photogrammetric grid together with an orientation and a quality of the ortophotos. The effectiveness of photogrametry work depends on dynamic properties of the UAV and the accuracy of the flight trajectory over the intended photogrammetric grid. This accuracy is influenced by the elements such as wind and turbulence. Another important problem in question is programming the turns at the ends of the photogrammetric-grid lines by inserting the net of some additional points in those lines. It helps the autopilot to follow a fixed flight path after each turn. In relation to that, the authors present some methods of flight-path planning with either their advantages or disadvantages.

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Impacts of a Prognostics and Health Management System on Aircraft Fleet Operating Cost during Conceptual Design Phase by using Parametric Estimation

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The scope of the study is to analyse the operating cost of an aircraft fleet during conceptual design phase, when installing a Prognostics and Health Management (PHM) system. Part of the work is devoted to the process and related methodologies aimed at estimating the cost in in a very preliminary phase of the life cycle, as an approach for the necessary trade off. The cost estimation is carried out by using commercial and proprietary software in order to show common views of different approaches. These tools perform parametric cost estimation exploiting a relative small quantity of cost drivers, which are available since the initial phase of the project. Maintenance parameters are identified through statistical methods, "knowledge based" approaches. To quantify the effect of the introduction of a PHM on a complex system, such as a commercial transport aircraft, is quite uncertain in early design phase and it is worth to be investigated. PHM technology can be adopted for each aircraft main component [1, 2, 3] and, as the other aircraft on-board systems, introduces additional maintenance cost (even the PHM system sensors and computer may have a fault) and sometime it notices false positive detections determining unnecessary maintenance actions. On the other hand, PHM is able to: extend the aircraft components service life, reduce the number of necessary spare parts, lessen the repair time (maintainers are aware of the failure location) and optimize the maintenance activities also increasing the aircraft availability. For a commercial transport aircraft, more availability means more flights and revenue. To properly estimate the effect of the maintenance optimization it is necessary to examine a complete aircraft fleet. This is suitable considering that maintenance team, maintenance management and aircraft operation are subjects designed for a fleet of aircraft instead of the single one. To better calculate aircraft fleet parameters, it was necessary to develop an environment in which the fleet operation is simulated. Moreover, to obtain actual operating parameters the model has to include Monte- Carlo methodology [4, 5] in which some important variable, such as failures, repair time etc., should be simulated using a stochastic approach. From the cost estimation point of view, to evaluate the effect of the PHM system it is essential to include each items of the Life Cycle Cost (LCC). The tools used [6, 7] has to evaluate the cost before the detailed design phase. Spares and maintenance labour cost are directly affected by PHM system, however considering maintenance optimization issues, also fuel and spares management have to be taken into account. Other important cost items are related to the number of flight (i.e. aircraft availability) and the reduction of flight delay and cancellation due to unscheduled maintenance action. A final comparison based on LCC is made between aircraft fleets in a configuration with and without the PHM system, to show the results and the main differences.

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21st Century Skills for the Aerospace Industry Workforce and Their Translation to the Classroom

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The European Union has now one of the highest unemployment rates all over the world. In 2013, almost a quarter of young people in the EU labour market were unemployed. Furthermore, the youth unemployment rate has been 20 percent or above for 11 of the past 20 years1, therefore it has been for long time an issue which finally turned into a burning one during the recent economic downturn. With so many young people looking for work, one might assume youth unemployment to be purely an issue of demand and that employers would be able to pick excellent talent at modest cost. However, according to a recent survey2 an overriding reason for young people being held back is a lack of skills relevant to the workplace.

In Greece, the country with the highest unemployment rate in Eurozone, employers still complain they cannot find suitable entry-level hires; the same is true even for countries with lower unemployment rates. Across all countries which took part in this survey, most employers (61%) were not confident they could find enough applicants with the right skills to meet their business needs. Companies today are often challenged with entry-level workers who lack the practical skills it takes to create, build and help sustain a business. The private sector needs employees who have the ability to respond flexibly to complex problems, to communicate effectively, to manage information, to work in teams, to use technology and to produce new knowledge.

The imperative to help young people build skills for employment is unlikely to disappear. The 2012 Programme for International Student Assessment (PISA) which measures student performance at secondary level for mathematics, reading and science, saw the scores of three of the eight countries go down and the rest rise only minimally3. As the current generation of secondary students graduates it seems that skills shortages will become even more of a challenge for both post-secondary institutions and employers in the coming years.

An industrial-age curriculum will not fully equip students for living and working in an information- age society. To succeed in this knowledge-based economy, everyone must learn to collaborate and connect digitally — both in their local communities and around the globe. Translating these 21st-century skills to the classroom will shape the economic and social development of countries and communities for years to come. However, one of the most striking findings of the survey is that the education providers are the only ones who, in general, (74%) believe that their graduates are adequately prepared for entry level positions in their chosen field of study, in contrast with 35% of the employers and 38% of the youth themselves.

All the mentioned above facts send alarming signals to both the aviation industry and the aviation educational establishments. The aviation industry has always been at the forefront of the excellence and innovation, attracting and retaining highly skilled employees and because of that it is anticipated that this potential skill shortage will adversely influence the capacity of the industry to develop and maintain both existing and future air platforms and their systems. New skills have to

be identified for the future workforce of the aviation industry, which have then to be translated to the classroom.

The objective of the paper is to propose a generic skill set and the respective changes at the existing curricula, to raise the awareness for this challenging issue and to call for a European-wide action based on close collaboration between industry and academia.

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Experimental Investigation of Small Scale Homogeneous Isotropic Turbulence in S1MA wind tunnel

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The first scientific observation of turbulence probably dates back to Leonardo Da Vinci, who named, for the first time in history, turbulence the complex swirling motion of water. Leonardos drawings already emphasize two of the main properties of turbulence: its randomness and its multi-scale aspects, with small random eddies being embedded in larger ones. Since then, although our understanding of the phenomenon has significantly progressed, no complete framework has yet emerged which is able to fully explain the origin and the dynamics of turbulence. Reynolds has shown that turbulence appears whenever the viscous forces are small compared to the driving forces. In practice this includes most macroscopic natural and technological flows, what makes turbulence an enormous challenge for the future. Beyond its fundamental interest, piercing the mysteries of turbulence, may indeed help improving aerodynamics design, weather forecast, understanding of stars evolution, models of blood flow, and a thousands of other applications. Paradoxically, an exact theory for turbulence does exist, though the mystery remains: Navier-Stokes equations are indeed expected to actually rule the motion of flows, even in the turbulent regime. However, the complexity of these equations (in particular due to their non-linearity and non-locality properties) seems to have ruled out any hope of ever finding an analytical solution to the problem. The alternative strategy is then to characterize, as precisely as possible, the main properties of the unknown solutions of these equations. Because turbulence is random, this description is to be statistical. Most ongoing researches in turbulence are done in the perspective of finding such an accurate statistical description of turbulence.

The first stone in building a statistical description in modern history of turbulence starts with Richard- son, who proposed in the 1920s a multi-scale description of the phenomenon in terms of an energy cascade, where turbulence appears as a hierarchy of random eddies with sizes ranging from the scale where energy is injected (which could be hundreds of meters for atmospheric

flows for instance) down to the scale where it is dissipated by viscosity (which could be microns). This range of scales (between injection and dissipation) is known as the inertial range of turbulence. This qualitative description was put in a more quantitative framework by A. Kolmogorov in 1941 [Kolmogoroff(1941)] who developed a phenomenological description of the turbulent cascade, based on dimensional considerations and assuming homogeneous and isotropic turbulence (HIT) with a self-similarity of statistical properties of eddies within the inertial range of scales. One of the big successes of K41 is the prediction of the spectrum of the kinetic energy of turbulent eddies (the celebrated k−5/3 law). However, as rapidly objected by Landau, K41 fails predicting one important statistical property of turbulence known as intermittency. This appears as the fact that energy dissipation (which is related to the viscous friction between fluid elements at small scales) is highly unevenly distributed in space. To account for intermittency, Kolmogorov proposed in 1962 a refined version of his self-similar phenomenology, including Obukov suggestion that the energy dissipation rate exhibits strongly non-Gaussian fluctuations. However the description of intermittency and its origins are still mysterious, and its modelling remains an active field of research [Parisi1985, Arneodo2008] whose development still requires accurate experimental data (reference measurements for intermittency date back to the 90 [Arneodo et al.(1996)]).

In this context, there is a strong need from the scientific community for high quality data, suited to test, validate and calibrate models and simulations of the fluctuations of turbulent flows at the smallest scales. The demand is particularly important concerning homogeneous and isotropic turbulence (which remains the field of predilection to investigate fundamental properties of turbulence) at large Reynolds number (for which asymptotic limits are generally investigated to derive scaling laws of turbulent dynamics). State of the art strategies to produce high Reynolds numbers in laboratory experiments consist in injecting a huge mechanical energy in a small volume of fluid. One of the most studied configuration to produce HIT remains the grid-generated turbulence in wind-tunnels [G. & S.(1971)]. This turbulence is produced by the interaction of the wake from the rods forming a grid with appropriate geometry. However the limited dimensions of academic wind-tunnels only allow moderate Reynolds numbers to be reached, and limits the possibility to finely explore Reynolds number effects on inertial scaling and intermittency. One limitation when large Reynolds numbers are considered appears in our capacity to experimentally resolve the smallest scales of the flow. The scale separation between the largest scale L (where energy is injected) and the smallest η (where it is dissipated) in a turbulent flow goes as L/η Re^3/4, with Re = UL/ν the Reynolds number of the flow. For this reason, dissipative scales in academic facilities can be as small as a few tenth of microns, and hence inaccessible to usual anemometry techniques. This has motivated the present project, aiming at producing and investigating grid-generated turbulence in the ONERA S1MA wind tunnel in Modane (France). The unique size of this facility (the diameter of the test section is 8 m, hence typically one order of magnitude larger than usual academic wind-tunnels) allowed us to achieve decametric injection scales, hence making the smallest scales millimetric and fully resolvable down to the deep dissipative range for the first time.

To this end, the ESWIRP Turbulence Collaboration has accomplished the largest grid-generated turbulence experiment ever performed. To achieve this, a giant inflatable grid (10 meters in diameter, with mesh M=0.625 m) was conceived to induce slowly-decaying homogeneous isotropic turbulence in a large region of the test section, with minimal structural risk. An international team or researchers collected hot wire anemometry, ultrasound anemometry, resonant cantilever anemometry, fast pitot tube anemometry, cold wire thermometry and high- speed particle tracking data of this canonical turbulent flow. We will present the preparation of this unique experiment, including the design of the giant grid for optimal turbulence generation and

aerodynamic compatibility with the S1MA wind-tunnel. First results on the fully resolved multi-scale characterization of turbulence will be presented. New theoretical predictions of high order statistics of the energy cascade and turbulent intermittency down to the smallest scales will be presented and confronted to this new experimental dataset.

Note. The ESWIRP Turbulence Collaboration is formed by an international consortium of scientists federated by LEGI laboratory (Grenoble, France) to investigate experimentally the smallest scales of turbulence. Access to S1MA wind-tunnel was funded by the European Union, via the ESWIRP program. We also thank University of Grenoble and CNRS for extra funding.

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Thermal Properties of C919X EHAs Operating During Whole Flight Envelope

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China's first large commercial aircraft C919 adopts a conventional central hydraulic system as the power of flight control actuation system. Meanwhile, the new type aircrafts A380 and B787 adopts more-electric technology, including power-by-wire actuators. It focuses more on

security, power-weight ratio and clean sky performance. The next generation single channel airliner of COMAC, namely C919X, will consider power-by-wire actuators as an interesting option, such as active EHAs, which will be on operation during the whole flight time. Research is ongoing to reveal the cooling and heating demand of different EHA in different conditions. Hence, the first priority should be given to the methodology of controlling thermal equilibrium temperatures of EHA under entire flight envelope.
This paper studied the thermal characteristics of EHA for C919X aileron. To start with, the thermal simulation model of variable speed constant displacement EHA and variable displacement
variable speed EHA are established. By discussing two kinds of EHA under non-active heat- exchanging conditions, the operating points for heating or cooling and corresponding heat exchange power are achieved. Further, the structure, size, weight, operating mode and the differences of thermal characteristics between the two types EHA are illustrated. Based on 2- phase flow, a new kind of heat-pipe heat-exchanger which is integrated into EHA is developed. Lastly, the laboratory setup for measuring EHA's inner and outer temperature is established. With the simulation of EHA of different surface and different flight envelope, we can address the thermal characteristics of different types EHA. Accordingly, more theories as well as technical skills for the design and manufacture of more-electric primary flight control actuation system for C919X are available.

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Developing Generic Flight Schedules for Airport Clusters

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Airports have their operational focus on the short term. Nevertheless, a long term view is crucial for planning and developing their infrastructure and business. Airport models are proper for assessments and investigations in the field of airport research whereas such models often focus on single elements only. This scope is not sufficient to address the air transportation system as a whole. Therefore a generic airport model will be implemented that covers operational aspects, e.g. passenger and aircraft movement demand as well as resulting economic changes. The granularity should be as roughly as possible, reducing the complexity and computing time, but accurately enough to model crucial intra-airport relationships. The basis for the analysis build already designed airport clusters, i.e. the airport model does not represent one single airport but rather fits to an airport cluster. 7 clusters were identified and they are characterized by a certain number of attributes like the number of runways, aircraft movements and revenues.
In order to assess intra-airport relationships a flight plan, the main model input, is necessary. Therefore a methodology of developing generic flight plans, one for each cluster, will be implemented out of a variety of real flight schedules of the cluster representatives. Statistical and probability distributions are used to determine a suitable daily/weekly distribution of arrival and departure flights and a list of typical flights of such an airport cluster. Every airport-specific data (origin/destination information, specific aircraft type etc.) are transferred into generic categories. Another important aspect to be issued is the future development of the attributes, especially aircraft movements. This is forecasted by an already implemented model called Forecast of Aircraft Movements, short FoAM. Basic approach is the assignment of each flight leg worldwide to a distance, passenger number and aircraft category. For each combination of distance and passenger numbers a typical fleet mix is defined. The forecasted worldwide growth of passenger demand and the empirically determined fleet mix is applied to all legs in order to derive a future scenario. Assuming a certain seat load factor, the growth of the aircraft movements can be deduced from the overall aircraft movements generated by all legs.
The methodology will be implemented in JAVA and should be adaptable to category changes and further parameters. According to Figure 1, the objective is to get generic flight plans for future years on the basis of growth of passenger demand. Applying the methodology to an air transport network will show the functionality of the methodology and the possible development of the network in the long term.

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Autonomous robotic system for active debris removal: requirements, state-of-the-art and concept architecture of the rendezvous and capture (RVC) control architecture/system

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Recent studies of the space debris population in Low Earth Orbit (LEO) have concluded that certain regions have already reached a critical density of objects which will eventually lead to a cascading process called the Kessler syndrome. The collision between Iridium 33 and Cosmos 2251 and an increasing number of necessary collision avoidance maneuvers performed routinely by active spacecraft are just some of the reminders of the severity of the space debris issue.
Mitigation measures adopted by most of the major players in the space industry, along with current compliance to these measures by satellite operators, are inadequate to stabilize the space debris environment. Thus, there is a growing perception that we need to consider Active Debris Removal missions (ADR) as the only viable way of preserving the space environment for future generations. Among all objects in the current LEO environment, Ariane rocket bodies (R/Bs) are some of the most suitable targets for future robotic ADR missions, given their number, mass properties and spatial distribution. ADR techniques involving orbital robotics appear to be the most mature options, since technologies and theories for automated onorbit robotic capture and servicing of spacecraft already exist and have been successfully tested onorbit.
However, rendezvous and capture of large noncooperative objects is a highly challenging task, especially with an autonomous robotic system. In fact, until today it has not been performed without humans in the loop. Autonomy is necessary in particular in the final phases of the approach of the chaser vehicle (chaser) to the target vehicle (target), due to the limited reaction time available to address anomalies and/or communication problems that might occur.
A number of missions have been performed in the past with the objective of autonomously approaching and docking with a fairly controlled target. However, almost all of them suffered an onboard anomaly that in some cases completely compromised the mission, proving that, at present, the technologies necessary for autonomous proximity operations and capture even of a fairly controlled target lack in maturity. Therefore, to enable future robotic ADR missions there is a need for more advanced and modular systems that can cope with uncontrolled,

tumbling objects. The rendezvous and capture (RVC) control system is one of the most critical systems of future robotic ADR missions. Within that context, we will present a concept of a robotic spacecraft capable of autonomously approaching, capturing and manipulating rocket bodies. Moreover, a more detailed overview of the envisioned control architecture will be provided, bearing in mind the requirements for the most critical phases of an ADR mission, which are the close range rendezvous and final approach. The software modules of the control architecture covered by our work are the: navigation module, guidance module, control module and robotics module. Each software module is responsible for a particular function within the control system. The target is assumed to be non-cooperative, although well known a priori. Moreover, we provide a synopsis of the challenges that proximity operations pose for the design an autonomous robotic RVC control system. Finally, based on an assessment of these challenges, a future road map will be presented to highlight the overall framework of the research presented and provide an indication of critical technologies that necessitate further investigation.

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Accelerating MRO procedures for composite materials using innovative detection techniques

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In the past three decades composite materials have gained an increased popularity, especially within the aerospace sector. In this time-frame, innovation moved slowly away from the aerospace industry towards other sectors such as the information technology sector and the renewable energy sector. Aerospace innovation slowed down - nowadays other sectors are even surpassing the aerospace industry with the use of composite materials, such as the wind energy sector, the automotive sector (exclusive sports cars, and nowadays even for the general consumer market products) and the civil engineering sector (composite bridges). One of the factors in this, is the strict policy regarding certification for procedures and the use of materials and systems. This factor however can also be used in favor of innovation, by applying a consistent and long term research and development policy.
One of the main technological bottlenecks for the use of composite materials, is related to maintenance, repair and overhaul. The introduction in aviation of composite components (A330/340, A380, Boeing 777) and fuselages (Boeing 787, A350) has not led to a similar growth in the use of composites for repairs. Repairs in composite parts are either prohibited (leading to extensive replacements) or executed with metals (aluminum or titanium). One of the limiting factor for widespread use of composite materials in repairs is accurately and reliably locating a damage. Therefore composite parts are generally over-dimensioned. A fast and efficient detection method for barely visible damages on large surfaces may mean a huge leap in the adoption of composites for repairs, and an improvement of design parameters for composite parts . This lack of an appropriate detection method is also a limiting factor for other industries and could be used by a large community and bring the aerospace sector one step ahead.
Carbon and glass fibre reinforced polymers consisting of thermosets and thermoplastics are light in weight, they show an increased strength in comparison to conventional materials and a reduced sensitivity to corrosion and fatigue. A downside is their susceptibility to impact damage. When this occurs it is often difficult to identify: it either affects the reverse side of the material or causes an internal delamination. Conventional detection techniques either fail, or are rather labor intensive (such as Rontgen monitoring) and expensive. Especially the anisotropy of the material is causing problems in the conventional detection techniques.
In the current study we are investigating whether the physical principle of repeated reverberating signals allows us to generate a fast and efficient detection method for barely visible damages on large surfaces. The method we are investigating is based on detecting changes in the material using these signals. After performing a reference measurement on an undamaged material, a second measurement of the same material at the same location and a comparison of the signals should show that they are similar. However, when damage occurs the signal will change. Our method is not based on the analysis of the first arrival or an specific alteration in phase or time, but rather we are considering the entire reverberation of the signal. By analysing the cross correlation comparison of both signals, together with the autocorrelation function of the original signal, it is possible to distinguish changes in the occurring wave pattern over very large areas with a minimal number of sensors. Supporting analyses techniques, obtained from control theory, are also considered.
The underlying physical principle are the changes in the wave pattern. When a pulsed signal is created by one piezoelectric transducer and is received by another transducer, it will register so- called surface waves traveling through the material. When use is made of low frequent signals Lamb waves are generated. These waves have different propagation modes, which can be used to our advantage. Their wave behavior makes them sensitive to either surface effects (surface damage) or internal changes (delamination). This way we are capable of detecting different types of damages. At these low frequencies, waves attenuate much less than the more conventionally applied high frequency (MHz) waves used in NDT, so that large areas are covered. The described method compares favourably to current thickness, flaw and bond test ultrasonic test equipment. This new approach could also work on aluminum alloy materials (and other traditional materials), and simplify the maintenance of conventional aircraft.
The system, which is under development at the Amsterdam University of Technology in collaboration with Delft University of Technology and the Van der Waals Zeeman Institute of the University of Amsterdam, comprises of individual transducers that are permanently attached to the top surface. By testing samples under different environmental conditions, a varying working environment can be mimicked. In the current set-up the number of transducers is minimized to two sensors. However, when use is made of more transducers, it is already possible to make a simplified surface mapping of the investigated object, which makes the data analysis afterwards far easier. In contrast to other methods the number of sensors for a tomographic approach is reduced. Due to the enhanced 2D images generated by this approach, the operator needs a much lower entry level to use the equipment and is able to perform a much more detailed analysis in a fraction of the time. Our aim is to attain Technical Readiness Level 5 within three years to show feasibility and to entice companies to invest in the further development. We envisage that the described techniques will first be used for maintenance purposes, after certification. Over time, it will influence the design of new aircraft it may be used as an onboard Structural Health Monitoring system.

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Analysis Of Aircraft Configurations Including Propagated Uncertainties

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When analysing the potential of novel aircraft configurations on a conceptual to preliminary design level, the often limited amount of time available for investigating physical properties of design candidates dictates both the low fidelity level and amount of analyses that can be conducted. The increase in computational power over the last decades has resulted in an increase in analysis capabilities for assessing aircraft concepts. However, considerations based on analyses using methods representing high-fidelity physics-based analysis still find their application in detailed design phases only.
To create a proper basis for making design decisions in early design phases using the limited available information on the aircraft physics, supplementing that information by the uncertainty of the implemented analyses is required. The DLR project "Future Enhanced Aircraft Configurations (FrEACs)" is aimed at extending the early design phase with this required uncertainty information. The current paper investigates the analysis of aircraft configurations under consideration of propagated uncertainties in early design stages. Aside investigating sensitivities of the physical properties of aircraft, the propagation of uncertainties between individual modules in analysis workflows allows for determination of the overall uncertainty of these properties. The base for making well-grounded design decisions in conceptual and preliminary design stages is thereby improved.
In order to propagate uncertainties across multiple analysis tools, at first uncertainties have to be determined at the individual tool level. In a parallel publication [1], this uncertainty determination is described for the disciplinary analysis modules within a low-fidelity physics based aerospace toolkit [2]. According to the analysis question at hand, workflows are built up by connecting these modules in the distributed integration environment RCE [3]. In this way, an analysis process is generated for the evaluation of target functions on OAD level. Aircraft geometrical parameters, analysis results and uncertainty data are exchanged using the Common Parametric Aircraft Configuration Scheme (CPACS) [4]. Figure 1 shows an example of a workflow including uncertainty propagation components. Analysis modules are repetitively called to determine the sensitivities of input parameters with corresponding uncertainty band on its output parameters.
In the final paper, three aircraft configurations for a short-to-medium range design mission are analysed and compared: a conventional aircraft for reference purposes and a strut-braced wing; depicted in Figure 2. After setting-up the workflows and comparing results of the reference aircraft to available data for a standard short to medium range design mission for calibration purposes, physical correlations of the configurations are investigated for short range design missions (about 1000nm).
Analysis studies are performed to assess the potential in increasing aircraft fuel and cost efficiency for a constant set of design requirements. In determining the saving potential of the aircraft concepts, not only the absolute values of the figures of merit are compared, but also the uncertainty in the determination of these metrics. This offers the possibility to not only state that one concept is preferred above another, but especially with which level of certainty such a statement can be made.

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Crash Concept for Composite Transport Aircraft Using Tensile and Compressive Absorption Mechanisms

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Aircraft manufacturer are motivated by international competition to increase aircraft performance by introduction of innovative structural designs combined with advanced composite materials. Safety regulations require for future composite transport aircraft equivalent or better crashworthiness compared to nowadays transport aircraft.
Conventional primary aircraft structures which are made of aluminium alloys offer sufficient crashworthiness solely by its ductile failure behaviour. In contrast, composite materials show at complex load conditions generally brittle failure behaviour with low energy absorption. However, properly designed and subjected to defined load conditions (e.g. crushing) the mass-specific energy absorption (SEA) of composite materials exceeds the one of aluminium alloys.
In the past diverse crash devices were developed for energy absorption under bending, compression or tension loads. These crash devices can be integrated in fuselage areas with defined load conditions to improve crashworthiness of composite aircraft. Past studies identified generally reduced SEA of crash devices which are designed for bending loads (frame failure) compared to crash devices designed for tension or compression loads.
In this context, crash concepts for future transport aircraft were developed in which most of the kinetic energy is absorbed by tension loads in the cabin and cargo floors, and by compression loads in the vertical support struts below the cabin floor.
The crash concepts were investigated by finite element simulations of vertical drop tests using a two-bay fuselage section of a generic composite transport aircraft structure. A wide range of crash load conditions was considered with impact velocities of vi = 22-30 ft/s (6.7-9.1 m/s) as well as impact energies of 22-99 kJ, which also include cargo loading.
The developed crash concepts define a cascading crash kinematics in combination with parallel activation of different crash devices to achieve smooth energy absorption for all crash load cases. Large amount of the crash energy is absorbed by tension loads, in case of severe crash load cases further crush absorbers in the vertical support struts are activated. In this context, specific concepts were developed to enable controlled failure interaction of support strut crushing and rupture of the adjacent frame structure.
The numerical studies were performed with the commercially available software Abaqus/Explicit 6.13-2. The crash concepts were developed with the so called kinematics modelling approach in which the crash devices are represented by macro elements with specific load-deflection characteristics. The kinematics modelling approach offers advantages to efficiently investigate appropriate crash device characteristics on fuselage section level and to develop new crash concepts on preliminary design level.
The developed crash concepts showed some benefits compared to other known crash designs which mainly use crush absorbers in the cargo floor structure. In this context, the presented research work represents the basis for an alternative crash design that might be integrated in future transport aircraft.

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Fuselage aerodynamic drag prediction method by cfd

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The aim of this work is the development of a new methodology to predict fuselage aerodynamic drag through CFD aerodynamic calculations.

The investigation has been focused on typical turboprop fuselage geometry. The geometry has been divided into three main components: nose, cabin, and fuselage tail. Fuselage fineness ratio, windshield angle (Ψ), and upsweep angle (θ), have been used as independent (geometric) variables to derive the drag prediction methodology. These parameters have been varied one by one, keeping the others constant. Several fuselage geometries have been generated and then analysed with Star-CCM+ in viscous, compressible flow regime. Mesh has been carefully set-up looking at mesh solution independency, aerodynamic coefficients, and equation residuals convergence. Particular care has also been posed to the boundary layer, with 20 prismatic layers and a y+ < 1. The flow condition for all the aerodynamic analyses have been typical turboprop cruise condition of M = 0.52, Re = 17.4 million and 0 degree angle of attack and sideslip. Coupled flow, ideal gas, and Spalart-Allmaras turbulence model have been set-up for the simulations. Aerodynamic results have been collected for the analysed fuselages, focusing on the drag coefficient. In particular, from the CFD aerodynamic analyses, nose, cabin, and tail drag coefficient contributions have been isolated and related to the geometric parameters previously defined, in order to get a relation between geometry and drag coefficient for each fuselage component.
Reorganizing all the results, a fuselage drag prediction method (focused mainly on skin-friction contribution) has been developed and it is here proposed. The methodology allows the estimation of fuselage drag coefficient as the sum of the contributions of each component (nose, cabin, and tailcone). This approach does not allow the calculation of other sources of drag as leakage, wiper, surface roughness and excrescences. The hypothesis of effect's superposition has been also verified through the analysis of CFD results, since the geometry modifications of one part of the fuselage only affects the drag coefficient of that part.
The generic fuselage drag coefficient can be estimated according to Eq. 1. where:
The fuselage shape factors (Kn, Kc, and Kt) are presented graphically (Figure 3) and they include the drag coefficient contribution for each fuselage components. The ratios Swet component/ Swet represent a geometrical weight related to each component whereas the CDfp gives the Mach and Reynolds number effect.
Kn shape factor clearly shows the nose effect on drag and it is represented as function of FRn (nose fineness ratio) and windshield angle. The Kn factor increases when fineness ratio decreases (a shorter nose) and it also increases when nose windshield angle increases (steeper nose angle). Kc shape factor is a fuselage fineness ratio (FR) function and it decreases when FR increases, being Kc ≈ 1.0 when FR is higher than 10 (it means a flat plate effect).
The last effect is the fuselage tail-cone effect and it is represented by Kt shape factor. This factor increases when both FRt (tail-cone fineness ratio) and upsweep angle increase. It is useful to highlight that for upsweep angles lower than 10 degrees, curves tend asymptotically to a value around 0.7, remarkable sign that no more relevant separation occurs.
The proposed fuselage drag prediction method has been applied to the fuselage geometries shown in Figure 4. Results show a very good agreement for test cases 1, 2, and 3. The ATR72 case shows a difference in fuselage drag coefficient of about 6 drag counts. This is mainly due to the windshield protruding geometry of the original ATR72.
As conclusions, the fuselage drag prediction methodology can be applied to regional turboprop aircraft with reliable results and it is easily implemented in preliminary design code (or handmade calculations). Further investigations have been scheduled in wind-tunnel to validate CFD results.

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Clean Sky Technology Evaluator – Noise assessment and experience at airport level

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Clean Sky is a Joint Technology Initiative that aims to develop and mature breakthrough 'clean technologies' for air transport. The Clean Sky goal is to identify, develop and validate key technologies necessary to achieve major steps towards ACARE Environmental Goals for 2020. Cross-positioned within the Clean Sky Programme the Technology Evaluator (TE) is a dedicated evaluation platform. It has the key role of assessing the environmental impact of the technologies developed in Clean Sky and their level of success towards the ACARE goals. TE assessments consider all promising green technologies selected by ITDs (Integrated Technology Demonstrators in which these technologies are developed), not on a unitary basis, but grouped as clusters, identifying optimised new aircraft solutions named Concept Aircraft.
The approach in TE is to 'insert' Concept Aircraft into a number of evaluation scenarios. These Concept Aircraft are 'flown' (i.e. simulation scenarios are run) and their environmental performance is compared to that of Reference Technology Aircraft. Such comparisons or assessments are performed at three levels: Mission Level (single aircraft flight), Airport Level (relevant airports to evaluate community impact), and Air Transport System Level (global air transport system, evaluating global fleet and worldwide assumptions). Hence the TE approach aims to demonstrate the impact of Clean Sky output in the overall air transport system.
The presentation will focus on the TE Airport Level. For this level, a dedicated tool suite is developed to efficiently evaluate the Clean Sky environmental benefits, which is part of an overarching TE Information System. This tool suite links state-of-the-art airport models for simulating air traffic and assessing environmental impacts as well as aircraft models developed specifically by ITDs to represent the environmental performance of their Concept and Reference Technology Aircraft. On top it includes display facilities to graphically present the (environmental) differences between scenarios (in this case between a scenario without and with aircraft equipped with Clean Sky technologies in the fleet).
In addition to this tool suite, TE Airport Level initiated activities to exploit VCNS (Virtual Community Noise Simulator) for potential dissemination purposes: VCNS enables people to experience the sound and visuals of aircraft flyovers in a virtual reality environment.
With the efforts now under way and the assessment results emerging, the TE airport-level tool suite is demonstrating to be a powerful facility, which, together with VCNS, provides clear opportunities for airport assessments beyond the scope of Clean Sky TE.

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Auralization of novel aircraft configurations

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With the current stringent noise restrictions, novel aircraft configurations are designed to limit aircraft noise on the ground. Traditional noise contour programs, such as the Integrated Noise Model from the FAA, or the European equivalent ECAC.Doc.29, are used for that purpose. However, novel aircraft configurations are not adequately integrated in such a model. To that end, a more sophisticated model, predicting the source noise depending on its geometry and operating condition is required. Additional output data, e.g. spectral shapes for individual components, is required in order to fully assess the noise generation by these vehicles. Furthermore, noise contours present only a glimpse of the acoustic consequence on the ground. They fail to provide more insight than a mere indication of a specific noise metric. To assess the audible consequences of perceived noise levels on a more subjective scale, auralizations are required.

An auralization transforms a predicted noise signature at the source to an audible signal at a receiver location. This involves detailed source noise prediction and application of propagation processes, all in the time domain. Hence, auralization enables to actually listen to a flyover of an aircraft that is still in the design phase. To that end, we synthesize a novel aircraft configuration and compare it to a baseline aircraft. The aircraft design and the source noise prediction is done by TU Braunschweig's PrADO aircraft design synthesis code and DLR's PANAM code, respectively. The NLR/TUD auralization capability is used to generate audible output for each vehicle under a selected flight operation. In this joint NLR-DLR-TUDelft cooperation, we demonstrate that it is now possible to obtain an audible impression of radical new designs along their simulated flight path. Such impressions can serve as a feedback to designers that they are on the right track in reducing aircraft noise or to assess annoyance of future aircraft.

Aircraft design and noise prediction

The auralization process is applied to selected new vehicle variations of a conventional single- aisle, medium-range transport aircraft. This aircraft type has been selected due to its predicted market share of over 70% by 2030. By that time, the majority of all flight operations at larger airports will be represented by such vehicles, hence have a dominating impact on airport noise levels.

For the selected reference vehicle, fan noise has a dominating contribution to the overall noise impact along both approach and departure procedures. As a consequence, the new vehicle variations focus on advanced structural shielding of this important noise source. A dedicated design study revealed several promising concepts towards structural shielding without significant economical drawbacks. The investigated vehicle variants can be grouped into four categories according to the most dominant shielding device, i.e. main wing, empennage, fuselage / wing, and wing / empennage. For this auralization process, two promising vehicle designs have been selected. Next to the reference aircraft, the auralization is applied to a an aircraft with engines over the wing and to a high-wing design with engines mounted above the fuselage/wing junction.

The overall vehicle design and the flight simulation for all aircraft designs are performed with TU Braunschweig's PrADO software. All required input parameters for a noise simulation of these vehicles are generated and provided by PrADO. Noise shielding effects are incorporated by using a DLR Ray-Tracing tool, i.e. SHADOW. The overall noise prediction is performed with the PANAM tool, a (scientific) noise simulation created at DLR. Resulting time-level-histories and level spectra are then generated as a final output for the auralization process.

Auralization

The source noise prediction provides a one-third octave broadband spectrum at the source for each time step of the simulated flight. Additionally, there are discrete tones emanating from the fan, compressor and/or other tonal sources. The tonal sources can easily be auralized by sine waves, i.e. additive synthesis. However, for broadband sources this is inconvenient. To synthesize a broadband spectrum, use is made of white noise shaped according to the spectral shape predicted by the source noise calculation. Since the resulting spectrum is still in the frequency domain, an Inverse Fourier transform (IFFT) is used to obtain, the pressure-time wave form. To include changes in the underlying directivity pattern of an aircraft during a flyover, causing audible artificats if not treated, an Overlap-Add technique is used to stitch the output of the IFFT together. The result is a source spectrum in the time domain that can be used to be propagated to the ground.

During propagation there are three effects that account for the propagation phenomena. The first is atmospheric absorption, which is frequency dependent. Due to viscous effects and molecular relaxation, the acoustic waves are attenuated by the medium during propagation. Especially the latter is dependent on humidity and temperature and accounts for the majority of absorption. The atmospheric absorption depends, linearly, on the traveled distance and can be converted into a Finite Impulse Response (FIR) filter, which can be applied to the source signal.

To account for the spreading of sound, a gain is applied to the signal that is inverse proportional to the distance between the source and receiver, i.e. spherical spreading law. As such, a straight path between source and receiver is implied. Curved path calculations are also possible. By atmospheric refraction, acoustic rays that are shielded from ground-based observers (by smart aircraft designs) might still reach the ground. Such calculations can be taken into account although this is not yet done since the current study aims at solidifying the process of auralizing novel aircraft designs.

As a consequence of aircraft (or observer) movement, a Doppler shift is perceived by the observer. Application of Doppler shift, in the time domain, is achieved by a Variable Delay Line (VDL). A VDL delays the waveform by a variable amount, effectively compressing and stretching the waveform. Besides Doppler shift, the ground interference effect is also integrated by the VDL. A ground reflected wave hits the observer ear at a slightly delayed time, with respect to the direct wave, thereby resulting into a characteristic interference pattern. A soft ground and/or turbulence induced coherence loss can also be integrated.

The resulting waveform at the observer is thus comparable to an artificial microphone recording. A future step could be to introduce the resulting recording in a virtual acoustic simulator thereby simulating the flyover in a virtual reality scene and incorporating listener audio effects.

Application to a test case

The aircraft are simulated along representative approach and departure procedures. The auralization is performed at the three noise certification points, i.e. take-off/sideline/landing, to get a good impression of the resulting audible effects at relevant observer locations.

Conclusions

The calculated theoretical metrics, LAmax and SEL, are reproduced by the auralization. This ensures that the conversion from the simulation into the audible signal is adequately treated. The audible results promises a reduction in perceived sound on the ground. Our simulations confirm that is possible to do an audible prediction of an aircraft that is still in a preliminary design phase.

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Overall view of the European Collaboration in Aeronautics Research within GARTEUR

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The Group for Aeronautical Research and Technology in EURope (GARTEUR) is an independent organization for research collaboration in Europe in the field of aeronautics. Established in 1973 by three nations, GARTEUR today involves seven nations with major research and test capabilities in aeronautics (France, Germany, Italy, the Netherlands, Spain, Sweden and the United Kingdom) through a Memorandum of Understanding.
GARTEUR focus is on long term R&T to assure sustained competitiveness of European Aeronautical Industry. The GARTEUR scope covers civil, dual-use or defence applications and enables the transfer of aeronautical technology between civil and military fields.
GARTEUR is considered as a unique European forum of aeronautical experts from Academia, Research Establishments and Industry mainly functioning in a bottom-up approach and according to the principle of an overall balance of benefits between the member countries.
These objectives of GARTEUR are accomplished by performing joint research work in fields suitable for collaboration and within research groups specifically established for this purpose. Technology gaps and facility needs are identified and effective ways are recommended to the member countries to jointly overcome such shortcomings. Finally, scientific and technical information is exchanged among the GARTEUR member countries.
GARTEUR is organised at three main levels: the Council, the Groups of Responsables (GoR) and the Actions Groups.
The highest level is the Council composed of representatives of each member country who constitute the national delegations. These representatives come from all relevant Ministries and Research Establishments. An Executive Committee (XC) assists the Council. This XC is composed of one member from each national delegation, and a Secretary.
The second highest level is formed by the Groups of Responsables (GoR) that act as scientific management bodies. They also represent the think-tank of GARTEUR. The GoRs are composed of representatives from national research establishments, industry and academia. Currently, five GoRs manage GARTEUR research activities: Aerodynamics (AD), Aviation Security (AS), Flight Mechanics, Systems and Integration (FM), Helicopters (HC) and Structures and Materials (SM). Action Groups (AGs) form the third level of GARTEUR. AGs are the technical expert bodies that formulate the GARTEUR research programme and execute the research work. Potential research areas and subjects are identified by the Groups of Responsables and investigated for collaboration feasibility by Exploratory Groups (EGs).
It is worth underlying that GARTEUR operating principals provide for participation by organisations from non-GARTEUR countries in GARTEUR technical activities, under a special procedure subject to approval by the Council.
On the other hand GARTEUR has interfaces with the European aeronautical industry through Industrial Points of Contact in the Groups of Responsables and through industry participation in the Action Groups.
The objectives of the overall presentation about GARTEUR at the CEAS 2015 conference are the following:
Further describe the missions and principles of GARTEUR and its way to perform joint research work,
Provide details of its organization and rules of operations of the various groups (Council, Executive Committee, Secretariat, Groups of Responsables, Actions Groups and Exploratory Groups), Explain the position of GARTEUR on the European aeronautical R&T scene and its interactions with other European actors like EREA (association of European Research Establishments in Aeronautics), EU and EDA programmes and initiatives, Review current working groups in the field of "Aerodynamics", "Aviation Security", "Flight Mechanics, Systems & Integration", "Helicopters" and "Structure & Materials", Give examples of recent success stories.
In conclusion some indications on future GARTEUR activities and orientations will be discussed.

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A multidisciplinary design optimization advisory system for aircraft design

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Today's latest aircraft in service (A380 and B787) and in production (A350, C-Series) show both an outstanding level of performance and a reduced impact on the environment. This is the result of a continuous optimization of the airframe and engine design and a progressive mastering by engineers of the different interactions between systems and disciplines on the same configuration. However, the next generation of aircraft has to match even stringent constraints in terms of noise level, chemical emission and energy consumption, as is amongst others depicted in the ACARE Flightpath 2050. In addition, the exponential growth of the global demand for airplanes implies an improvement of the aerial vehicles safety to maintain an acceptable rate of accidents.
It is then clear that the design and especially the optimisation of the aircraft becomes a complex problem and the iterative engineering approach is no more applicable. There is then the clear need for new design methods and tool that will take into consideration the various multi- disciplinary aspects to optimize the complete product (aircraft, rotorcraft, other) according to specific criteria. These methods and tools need to be designed to handle complex, high dimensional, heterogeneous product models and knowledge and provide an efficient mean for design improvement and optimization.
Within this context, Multidisciplinary Design Optimization (MDO) can provide designers with the means to further improve the performance of already mature solutions, and support the exploration of innovative complex designs. The best design of a complex system can only be found when the interactions between the system's disciplines are fully considered.
However, some of the reasons for the limited exploitation of MDO in industry (in contrast with the growing interest and body of knowledge being developed in academia) are, among others, related to the intrinsic complexity of such discipline and its mathematical foundations together with the lack of awareness and understanding of the many available MDO architectures and their specific suitability to problems of different nature. Solutions that overcome these limitations are partly available, but they do not address all the four points mentioned.
In this paper, an innovative MDO advisory system will be presented that aims at enabling the user - not necessary an MDO expert – to describe the problem at hand, specify a number of solution constraints (accuracy, speed, etc..) and obtain in return (based on the knowledge stored in a knowledge base) a ranked list of suitable MDO architectures, with (links to) relative documentation, and a template to support its implementation (see Figure 1). The paper will present the current status of the development of such a system. Moreover, capabilities will be demonstrated to translate (hence automate all the software intensive operations) the selected or assembled MDO architecture, into a MDO workflow instantiation by means of a commercial workflow management system, ready for distributed (cloud-based) execution.

Figure 1 provides a schematic illustration of the proposed approach. On the top left the MDO problem is specified; the objective could be, for example, to design an aircraft with minimum fuel weight for a certain range and payload. Next to that the user will specify some preference concerning, for example, the computation time, or the needed accuracy, etc.
On the basis of these preferences and the specification of the MDO problem, a reasoning mechanism will suggest the most suitable MDO architecture(s) and optimization algorithm(s) to use, among those formalized in a central knowledge base (KB) (structured by ontologies) (Figure 1, bottom left). Selection criteria can be, for example, the number and type of design variables, or the need for intermediate results to be feasible. Once a given MDO architecture has been selected, e.g. a MDF (Multi-Disciplinary Feasible) or a IDF (Individual Discipline Feasible), the MDO advisory system will help the user to assemble the given MDO system according to the selected MDO architecture (Figure 1, bottom right).. At this point, dedicated translators could be used to translate the obtained MDO system (stored in the KB) into specific implementations in one (or more) commercial workflow management and optimization systems such as Optimus [4], where the actual optimization will take place (Figure 1 top right). Results (in terms of performance of the MDO advisor and execution of the workflow) are communicated back to the knowledge base, for future re-use.

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Cooling channel flow characterization using Particle Image Velocimetry and Laser Induced Fluorescence

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A detailed understanding of the flow and the heat transfer in cooling channels is important for designing optimal cooling circuits. This is particularly true for cooling channels with high heat loads and high thermal stresses, for example cooling circuits of rocket engines. Usually, the design process is based on RANS computations which often cannot be fully validated in detail due to missing availability of such information. Therefore, the design margins must be high to prevent structural failure due to cyclic heat loads (e.g. the Dog House effect). Hence, detailed measurements of the flow characteristics including local fluctuations of the temperature and the velocity field under well-defined conditions are necessary. This is possible using the high-quality, optical and non-invasive measurement techniques Particle Image Velocimetry (PIV) and Laser Induced Fluorescence (LIF) simultaneously. Such experimental results could be used as a validation platform for RANS and LES computations.
A generic cooling channel experiment with water as the fluent was designed and constructed [1]. The cooling channel has a rectangular cross section and a width of 6 mm and a height of 25.8 mm. The lower wall of the cooling channel is electrically heated and therefore provides a heat flux from the wall into the cooling fluid. The side walls and top are made from polymethyl methacrylate (PMMA) to provide optical access to the cooling channel. The channel consists of a feed line with a length of 60 times the hydraulic diameter to ensure having a fully established turbulent flow at the beginning of the test section. The test section itself also has a length of 60 times the hydraulic diameter to allow the full formation of the thermal boundary layer. A curved test section follows a straight test section to investigate the influence of the curvature on the flow, the secondary flow structures and the heat transfer. An overview of the cooling channel setup is given in Fig. 1a).
The flow fields in two and three dimensions are measured by use of standard Particle Image Velocimetry (PIV) and Volumetric Particle Tracking Velocimetry (V-PTV), while Laser Induced Fluorescence (LIF) is used to determine the temperature fields. V-PTV is used to measure the flow field in all three dimensions whereas standard PIV is applied time synchronous with the LIF measurements. The seeding particles are silver-coated hollow glass spheres with a diameter of 10 µm. A two colour / two dye technique is used when applying LIF. LIF is based on the phenomena, that the fluorescence intensity of specific dyes which were excited by a laser is temperature sensitive. Hence, measuring the fluorescence intensity allows gathering information about the temperature field. Rhodamine B is used as the temperature sensitive dye for two colour LIF. The temperature insensitive dye Rhodamine 110 is used as the additional dye giving information about the local laser light sheet intensity. This two colour technique allows a more accurate temperature determination than the more commonly used one colour technique.
The experimental setup is presented in Fig. 1b). The laser light source is a Nd:YAG double pulse laser with a wavelength of 532 nm and an energy of 60mJ per pulse. The laser light sheet with a thickness of approximately 1mm is focused by a plano-concave lens with a focal length of -50mm and a plano-convex lens with a focal length of 100mm. The light sheet is formed by a cylindrical lens with a focal length of -25mm. Three Imager pro / proX 11M cameras with Tamron SP AF 180mm lenses are used for acquisition of the PIV and LIF images. Depending on the requirements for the individual measurement, the cameras are used for the PIV images as well as the LIF images. Suitable band-pass filters transmit the wavelength of interest to each camera. The band- pass filter for the PIV camera transmits the 532nm laser light and the filters for the LIF cameras transmit the wavelengths in the regions of maximum emission intensity of the fluorescent dyes.
Fig. 2a) shows the velocity distribution and Fig 2b) the standard deviation (RMS) of the velocity, recorded with standard PIV. The slow flow velocity near the walls is visible as well as the increase in the RMS values. A temperature calibration curve for a one colour LIF method is depicted in Fig.3a). The fluorescence decreases about 2 % per Kelvin, which correlates well with literature values. A temperature profile with a heated lower wall is shown in Fig. 3b). The temperature boundary layer as well as the uniform temperature in the bulk flow far away from the wall is visible. The fluctuations in the region between y = 3 mm and y = 10 mm are existent due to pollution on the cooling channel's wall.

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Clean Sky Technology Evaluator – Air Transport System assessments

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The Clean Sky program is made up of 6 Integrated Technology Demonstrators (ITD) and the Technology Evaluator (TE). The ITDs are:
Smart Fixed Wing Aircraft (SFWA) addressing large aircraft technologies
Green Regional Aircraft (GRA) addressing regional aircraft technologies
Green Rotorcraft (GRC) addressing rotorcraft technologies
Sustainable And Green Engines (SAGE) addressing engine technologies
Systems for Green Operations (SGO) addressing aircraft systems

Eco-Design (ED) addressing aircraft life cycle assessment
The Technology Evaluator is a simulation network that assesses the performance of the technologies developed in the ITDs and clustered at concept aircraft level. TE assessments are done in order to evaluate emissions or noise improvements of Clean Sky aircrafts and fleets. From the beginning it was recognized that successfully monitoring progress towards the ACARE environmental goals (noise and emissions) would require a crosscutting evaluation platform in the Clean Sky Program. The TE was born from this need, and its composition reflects the need to pool know-how and simulation/modelling capability that exists among industry, the research establishments and academia.
In order to determine noise or emissions improvements the approach in the TE is to 'insert' Clean Sky conceptual aircraft into a number of evaluation scenarios. In essence: the technologies developed, matured and demonstrated in the Clean Sky ITDs are 'clustered' in coherent and mutually compatible solution-sets that define a potential future aircraft. These conceptual aircraft are 'flown' (i.e. simulation scenarios are run) and the Clean Sky configurations are compared to the most relevant benchmarks: most importantly the state-of-the-art of aircraft of similar size and role in the year 2000 (ACARE's baseline year). The comparisons are performed at a single flight, or 'mission'; at the level of illustrative airports; and finally across the global air transport system. So the TE approach aims to demonstrate the environmental impact in the overall aviation system of Clean Sky's (research and technology) output by illuminating the 'pathway' from technologies to aircraft and air transport system (ATS) performance.
The presentation of this paper will focus on the ATS level assessments, i.e. showing the Clean Sky technologies environmental impacts through global or regional aircraft fleet scenarios.

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Conceptual Design Method for the Wing Weight Estimation of Strut Braced Wing Aircraft

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This paper presents a design sensitive method for the wing weight estimation of braced wing aircraft. The method is simple to implement and suitable for conceptual design studies. Important non-conventional characteristics of braced wing aircraft such as strut reaction, high span and aspect ratio, thin airfoils, high wing loading and folding wing weight are captured by the method. A direct approach is proposed for the estimation of internal shear and bending moment distributions of the statically indeterminate structure. The load carrying structure weight is estimated with analytical cross-section sizing. A new method based on the wing loading is proposed for the secondary structure weight estimation. The method is validated with data from more than 25 conventional aircraft. Comparison with other strut-braced wing studies is presented. The data generated by the method is sufficient to create a first FEM model for further studies.
Strut-braced wing aircraft
The strut-braced wing (SBW) aircraft concept is not new. Early studies and designs back to 1950s such as the Hurel-Dubois aircraft already considered the advantages of braced wings to increase the span and aspect ratio improving the aircraft efficiency. Despite its advantages, the concept still has not found application in the commercial aircraft industry. The increasing oil prices and the requirement for environmental friendly aircraft are encouraging new studies of the concept.
One of the main uncertainties about the concept feasibility is related to the wing and strut weight. If the structure is proved to be light enough, the concept is very promising.
Due to the unconventional characteristics of the SBW, design-sensitive wing weight estimation methods must be developed to perform reliable feasibility studies. The method presented here is developed to fulfil this requirement. It is flexible and simple to implement. It can be easily used in conceptual design studies and is sensitive to main design parameters. Validation with several conventional aircraft shows good accuracy. Comparison with other available SBW studies presents the method application and discussion.
Method description
A typical weight estimation technique in conceptual design is to consider a station based sizing of the load carrying structure. One of the main difficulties of this approach for SBW is to estimate the wing bending and shear distributions including the strut reaction. Since the structure is statically indeterminate for a fixed root and the stiffness distributions are unknown, an iterative procedure is necessary. Currently, two approaches are used to solve this problem: 1) strut reaction based on simplified assumptions and 2) iterative sizing with semi-analytical or Finite Element Method (FEM).
The internal loads estimation method presented here is direct (as the first approach) but employs criteria derived from FEM results observation. One example of the internal loads distribution obtained is shown in Fig. 1. A good agreement with the reference results (FEM) is achieved. Seven selected load cases are considered for analysis. They include pull-up maneuvers, quasi-static gusts, ground handling bump, landing and 1g case for fatigue.
The load carrying structure is then directly sized based on the obtained loads distributions.
For the wing secondary structure mass (fixed leading and trailing edges, high-lift devices, spoilers, ailerons and miscellaneous) a new statistical method is presented. The method is based on the regression of aircraft secondary masses specific weight as a function of the wing loading. It is well suited for conceptual studies if no trades of thesecondary wing components are performed.
Validation with conventional aircraft
The accuracy of the method is verified with data from more than 25 conventional aircraft.
Comparison with other SBW studies
The method developed is applied to other SBW concepts and the estimated wing weight is compared to the references data. Since no actual SBW large commercial aircraft was built, this comparison is restricted to the assumptions and limitations both of the proposed and the reference methods. Nevertheless it is a good check of the assumptions and shortcomings of different approaches.
Output for FEM
The method outputs are sufficient to generate an initial FEM model with stiffness and mass characteristics. The obtained FEM is parametric and is readily available for further detailed analysis.

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Propeller and inflow vortex interaction: vortex response and impact on the propeller performance

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During the ground operation of aircraft, the interaction between the propulsor induced flow field and the ground may lead to the generation of vortical flow, commonly denoted as ground vortex, which can enter the aircraft engine. In order to understand the propeller induced ground vortex generating mechanism and its influence on the propeller, experiments and CFD study are conducted. The mechanism of generating ground vortices is studied by the combination of measurements of velocities just above the ground and measurements of the pressure on the ground. These measurements are supporting the understanding and discussion of the local characteristics of the generation of the ground vortex. The presented results enable the establishment of relationships between the thrust setting and the ground vortex generation, its strength and its unsteady character. Reynolds averaged Navier-Stokes calculations have been performed and validated by the experimental data. The computation results establish the three- dimensional ground vortex topology and assess the propeller in-plane force; both of which are difficult to test experimentally.

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Use of simulator motion feedback for different classes of vehicle dynamics in manual control tasks

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With the development of moving-based flight simulators in mind, a large number of researchers have considered pilot manual control behaviour in tasks where the motion of the vehicle can be felt by pilots. While it is known that the dynamics of the controlled vehicle are a key factor that determines the usefulness of motion feedback for pilots, currently available methods for analysing multimodal pilot control behaviour have not yet been systematically applied to study the usefulness of motion feedback over a wide range of different vehicle dynamics. Therefore, this paper describes a study of the effect of simulator motion feedback on task performance and pilot control behaviour for different types of vehicle dynamics using multimodal pilot identification techniques. An experiment was performed in the SIMONA Research Simulator at Delft University of Technology where participants were instructed to perform a heading tracking task both with and without motion feedback, for a wide range of different vehicle dynamics. The considered dynamics were position control (gain), velocity control (single integrator) and acceleration control (double integrator). The experiment results indicate that the performance of double integrator control tasks is significantly better with motion feedback than that without motion, but show no performance improvement for the gain and single integrator control tasks provided with motion, respectively. In addition, the analysis of pilot control behaviour clearly shows that for double integrator control tasks the motion feedback is fully utilized by the pilots, but for gain and single integrator control tasks the motion is not utilized by the pilots. The performance improvement seen for the double integrator control tasks with motion feedback is explained by the fact that pilots make explicit use of feedback on the accelerations of the motion of the vehicle. The experiment results confirm previous observations in the aspects of task performance and pilot adopted control behaviour that motion feedback is very important for controlled vehicle dynamics for which pilots need to generate lead (i.e., double integrator), but perhaps not for vehicles with more stable dynamics.

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Mach number control improvement in ONERA s1ma large sonic wind tunnel

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I. Introduction Improvement of wind tunnel productivity and data base quality is a key issue for all the major wind tunnel in the world. As a consequence, accurate Mach number control for large wind tunnels is essential. Indeed, a significant part of the tests performed in these wind tunnels deals with civil aircraft for which test matrix consists in a large number of polar in angle of attack at different Mach numbers. During pitch motion, pressure losses change in the wind tunnel inducing Mach number drifts which are penalizing both for data base quality and test productivity.
ONERA, on the framework of the 7th European Programme, launched in 2008 the study of a new S1MA Mach number controller based on hard and software improvements. This work is part of the European project ESWIRP (European Strategic Wind tunnels Improved Research Potential) which deals with the improvement of European strategic wind tunnels (DNW LLF, ETW and ONERA S1MA).
For S1MA new Mach controller, the objective is very ambitious since it aims to obtain Mach number stability during a pitch polar within ± 0.001at least up to Mach 0.9.
II. S1MA Mach number drift without control and Mach stability in steady conditions During aircraft tests, the model is pitched through a series of angles of attack at a requested Mach number (pitch polar) and drag strongly changed with pitch angle. Drag increase induces a stagnation pressure disturbance then propagates downstream to the fans and sets up a dynamic unbalance on their equilibrium. Finally, without an efficient Mach number controller, a Mach number deviation is observed.
To fix some order of magnitude, Mach number drifts, during pitch polar without any Mach control, for a civil aircraft mounted on a Z sting, can reach ±0.030 at Mach number 0.94.
A perfect Mach number controller has to cancel these drifts but, of course, residual drifts will still be present. Original objective, which was very ambitious, was to maintain Mach number drifts during pitch polar as small as the Mach stability in steady conditions.
III. Initial improvements of S1MA Mach number controller Since 1985, to increase test productivity, ONERA continuously improves its S1MA Mach number controller using a rough control of fan's RPM by increasing or decreasing the water mass flow on the Pelton turbines. With this first Mach number controller, a significant decrease of the Mach number drifts was obtained
for Mach numbers ranging from 0.72 to 0.86. However, at high Mach numbers, drifts were still very large. It was obvious, that an additional device, with a transfer function involving short delay and time response between action and Mach response was mandatory. The idea to use an air intake to generate pressure losses, opposite to the ones induced by the model incidence, was selected. IV. S1MA new Mach number controller ONERA launched in 2008, on the framework of the 7th European Programme, the study and the manufacturing of a demonstrator for a new S1MA Mach number controller.
The idea was to use fan's RPM control to compensate large pressure losses with some time delay in association with an air intake which can

generate limited but fast pressure variations in phase opposition with those of the model during its pitch motion.
A parameter identification by applying determined entries and observing associated responses in amplitude, delay, time response was done (Transfer function between the model pitch angle and the Mach response, transfer function between fan RPM and the Mach response, transfer function between air intake opening and Mach response) After these identifications, a long and complex optimization process using numerical simulations was carried out and process ended with an experimental adjustment of the new Mach number controller.
After this complex adjustment, Mach number drifts during pitch polar using the final controller were found as small as the natural fluctuations of Mach number in steady conditions, which is a great success.
V. Improvements generated on data base quality and test productivity For data base quality, as Mach number drifts can be considered as negligible with the new Mach number controller, model pressure distributions, dynamic measurements and acoustics measurement are now provided at the exact requested Mach number. Furthermore, this improved Mach number control will be of great interest for wake survey tests and laminarity tests for which aerodynamic stability is crucial. Considering wind tunnel productivity, loads interpolations are "easier", leading to the cancel of all the pitch polar which were requested for load interpolations purposes only. Then productivity gains around 25% have been obtained.
VI. Conclusion With the new controller, residual peak to peak Mach number drifts, during pitch polar, do not exceed the natural fluctuations of the Mach number in steady conditions which is a very impressive result.
This impressive improvement on Mach number stability generates an increase of the tunnel productivity of around 25% which is of great interest for the attractiveness of the S1MA World Class wind tunnel. It is equally important to underline that this Mach stability induces a great improvement of the aerodynamic data base quality for all the data than cannot be interpolated. This new Mach number controller is now used on a regular basis in the ONERA S1MA large sonic wind tunnel, for the financial and technical benefits of all our Clients.
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Composite laminates simulation using an enhanced peridynamics lamina formulation

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For aerospace applications load conditions justify the need for dynamic fracture analysis. The dynamic failure behaviour of composite materials can be extremely articulated: the dynamic loading may give rise to fracture behaviour which is different from that of quasi-static conditions [1]. The splitting mode (debonding between matrix and fibers) and matrix cracking are the most common intralaminar fracture mode in unidirectional fiber reinforced material under quasi static load condition. Extensive fracture and damage produced by interconnected splitting, matrix cracking, delamination and fiber breakage, are observed under dynamic loading conditions [2]. Recently a new continuum theory has been proposed: Peridynamics, this theory is based on a non local approach and it is formulated with integral equations. Peridynamics is suitable for dealing with crack propagation in solid materials and has been applied mainly to dynamic problems [3-4].
The study of composite materials in the framework of this theory has been addressed with two main approaches: one based on homogenized models and one based on the explicit model of fiber and matrix materials. One of the first examples of peridynamic model used to study the fracture and damage of a composite material is shown in [5] where the damage patterns in laminated composites subjected to bi-axial loading is analysed. The formulation has been improved to solve the case in which the discretization grid has an arbitrary orientation relative to the fiber direction of the unidirectional composite lamina [6, 7]. Then a homogenized peridynamic model has been introduced to take into account the transverse elastic module, using a 3D approach [8].
The explicit model of fiber and matrix is presented in [9], in this case the author underlines that the homogenized approach (effective from a computational point of view) is not always able to capture the splitting fracture mode. Explicit modelling of fibers (or fibers group) has the advantage of obtaining the most detailed solution and gives the opportunity to introduce dedicate fiber/matrix damaging phenomena (local debonding, porosity, inclusions…) but demands higher computational resources. However this last issue could be solved using an adaptive meshing approach [10]. As an example, dynamic analysis of an explicit fiber/matrix model has been carried out on a single layer composite plate with various fiber orientations. Fig. 1 shows the layout for the specimen in which a pre-existing crack has been introduced. The externally applied load generates a tensile stress. The body is discretized with a grid of nodes having equal spacing in the horizontal and vertical directions.
The model used for the analyses is composed by 2132 nodes and 74016 bonds. The horizon length d is equal to 3×Dx that provides an accurate solution in a reasonable time. The time step for the numerical integration is Dt=2.5E-8s and a medium number of 1000 steps has been used for a total integration time of 2.5e-6 s. The body shape, pre-crack length and the external load are maintained un-changed in all the examined cases. Fiber orientation is varied, the following angles are chosen: 0°, 90°. The following figures show the crack path evolutions as functions of time.
In all cases the lamina behaviour is “in plane” so in 2D approach no bending rotation is allowed. In this paper a new peridynamic model for fiber reinforced composite lamina will be used to simulate a composite laminate. Dynamic analysis of the progressive damage in composite laminates will be presented. The new lamina model will take into account the bending stiffness of a 2D formulation extending the approach described in [11] to an orthotropic material. The aim of this work is to study the evolution of the damage and the growth of a pre-existing crack in a composite laminate with different stacking sequences and various inclinations of the fibers with respect to the applied load. Results will be evaluated taking into account different grid sizes, horizon dimension [12], crack initial lengths and crack orientations.

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Time-Efficient and Accurate Performance Prediction and Analysis Method for Planetary Flight Vehicles Design

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The aim of this article is to present a reliable design process of unmanned aerial vehicle to fly in terrestrial and extra-terrestrial atmosphere prepared for a vast spectrum of missions. It is a new methodology, which does not rely on similar designs but investigates the most adequate configuration using already existent tools adapting them for this specific aim. At the end of the process, a multidisciplinary parametric and iterative model is created, that combines the adequate configuration database with semi-empirical methods. The model can also be effectively modified given any changes in the design, manufacturing or flight conditions, which automatically updates the vehicle's overall performance and design features. The method intends to maximise the use of open source software and numerical codes such as Vortex Lattice Methods with bi-dimensional boundary layer analysis, OpenFOAM CFD analysis, FlightGear with the JSBSim flight dynamics model and Paparazzi autopilot for virtual flight tests, in order to develop tools to analyse the vehicle's performance such as aerodynamics, flight mechanics, structural integrity and flight strategy. It also incorporates experimental wind tunnel data such as aerofoil polar and semi-empirical methods improving the reliability of numerical analysis. Consequently, a multi-objective model is constructed which interconnects and parameterizes the analysis fields. The parameters of this model can be freely modified and, due to the multi-dependency of all the fields, each modification is propagated throughout the model, updating the global analysis of the vehicle. The method has been applied to predict and analyse the performance of conceptually distinctive configurations, such as box-wing, blended wing body or high-aspect-ratio aircraft. In one case the method avoided flight mechanics instability problems by correctly predicting the vehicle's behaviour in flight. In another case the multidisciplinary model allowed to successfully adjust the optimal flight conditions for a model whose mass has been altered due to manufacturing inaccuracies. The most representative example of verifying the accuracy and reliably of this methodology is the PRONTAS solar aircraft prototype. PRONTAS is a 16m-span 80kg unmanned solar plane capable of continuous flight at 8000m altitude using only solar energy. The design is focused on civil applications, which include wild fires detection and prevention, wild life migration studies, long-term climate study, search and rescue, satellite alternative etc. The project is lead by the Institute of Technology and Renewable Energy (ITER, Instituto Tecnológico y de Energía Renovables) in collaboration with Aernnova Engineering Solutions and Technical University of Madrid (UPM, Universidad Politécnica de Madrid). The project is financed by The Spanish Government (Ministerio de Economía y Competividad) and The European Regional Development Fund (ERDF). The project served as a teaching platform for aerospace engineers willing to gain experience in the design process of unmanned aerial vehicles with robust practical applications.

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Preliminary Design Rules for Electromechanical Actuation Systems – the Effects of Saturation and Compliances

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Electromechanical actuator (EMA) is a type of power-by-wire (PBW) actuator that is becoming widely implemented in aerospace industry. Given the application area, designing an EMA is highly constrained in weight, integration space, maintenance costs, dynamic performances, reliability, etc. In order to reduce the EMA's design time, cost and effort, it is of utmost interest to account for these constraints during the preliminary design stages. This requires simple and parametric models that can predict the main impact of the sizing variables on performance.

In the proposed communication, control of a linear EMA is the main regarded in terms of stability, settling time and overshoot. Since cascade control architecture is most often used for position control, linear control theory permits any desired dynamics for the system to be imposed. However, owing to the other constraints (e.g. mass, integration, etc.), the EMA operates in conditions that are not captured by the linear model used for controller design. For instance, since the airframe is designed under mass constraints, anchorage stiffness between the actuator and the load/airframe is not negligible. Since the driven load inertia and the force disturbances are important, the stiffness of the EMA's nut screw may become a critical parameter. In these conditions, the coupling between the structural and the actuator dynamics alters the performance of the whole actuation function that can even become unstable. As the actuator is also subjected to mass and volume constraints, the motor rated torque has to be minimized. Consequently, this limit introduces a saturation effect between the demanded and the produced electromagnetic torque. Thus, these technological limitations/imperfections make the real performance far different from the performance expected when a liner model is used for control design. Moreover, since the control becomes a constrained problem, some performance requirements may be even unreachable. In these conditions the controller will have to "live" with these limitations and still ensure the required performance.

In order to reduce the round trips between the mechanical designer and control engineer, this communication aims to give simple mathematical relations linking stiffness and torque limitation to the achievable dynamic performance by modelling and simulation in MATLAB/Simulink environment. Thus, the mechanical engineer can use these relations as "best practice rules" for the specification and preliminary design of the mechanical part, enabling the dynamic performance requirements to be met in practice. The control engineer may use these design rules to reduce the number of design iterations through rapid verification of consistency between closed-loop performance requirements and early choices and definition of the mechanical components. The proposed approach is illustrated in the case of an aileron actuator.

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Rotorcraft-Pilot Coupling Research in Europe: A Success Story in Collaboration

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For augmented helicopters with modern flight control systems, unintended and unexpected oscillations or divergences of the pilot-rotorcraft system have become an increasingly critical issue. The rapid advances in the field of high response actuation and highly augmented flight control systems have increased the sensitivity to aspects that lead to phenomena related to unfavourable Aircraft-Pilot Coupling (APC) and Rotorcraft-Pilot Coupling (RPC). The understanding, prediction and prevention of adverse RPCs is a challenging task requiring the analysis and simulation of the complete closed loop system consisting of pilot – control system – rotorcraft. Regarding numerous flight events in the past, several types of RPCs have been observed which can be differentiated by the frequency contents as well as by the underlying physics and human behaviour.

In Europe, comprehensive research activities were launched by the GARTEUR HC-AG16 action group (2005-2008) in order to improve the physical understanding of RPCs and to define criteria for quantifying the helicopters susceptibility to RPC. The GARTEUR research was further continued from 2010-2013 under the umbrella of the 7th European Framework Programme (FP7) in the project ARISTOTEL - Aircraft and

Rotorcraft Pilot Couplings – Tools and Techniques for Alleviation and Detection. Overall objectives of GARTEUR HC-AG16 were the establishment of guidelines for the development of means in order to prevent or suppress critical RPC incidents in future thus contributing to increased helicopter operational safety. Focus was given on the one hand to RPC phenomena in the frequency range up to approximately 1 Hz and on the other hand to coupling phenomena approximately between 2 Hz and 5 Hz.
The lower frequency band is characterized by adverse coupling phenomena dominated by helicopter low frequency dynamics i.e. flight mechanics characteristics, by the flight control system and by an “active” pilot keen to fulfil his mission task by actively manipulating the helicopter controls. In opposite the higher frequency bandwidth is governed by higher helicopter frequency dynamics i.e. elastic airframe and main rotor blade modes, by a “passive” pilot subjected to vibrations which are too fast to adequately react and by the cockpit controls layout affecting the pilots inertial response on the helicopter control elements. Of course there is an overlap between these classifications of rotorcraft-pilot coupling where a mix of models and procedures will be more adequate. Nevertheless, in the foreseen paper, numerical and experimental research activities will be discussed with this clear distinction for simplicity reasons.
The numerical studies within the GARTEUR action group were concentrated on a Bölkow BO105 rotorcraft model which served as a numerical test bed for all the partners. Although well known that the full scale BO105 is not prone to RPC issues the BO105 theoretical model was applied with additional numerical degradation of its characteristics in a way to provoke the different events of unfavourable RPC. In order to complement this theoretical work on the experimental side, a motion based flight test simulator of the University of Liverpool was used for validation issues.
The comprehensive application of the flight test simulator for this purpose in the GARTEUR action group was found highly favourable as it used exactly the same numerical helicopter models for prediction and experiment thus allowing to concentrate on the different “active” and “passive” pilot models for comparison. Flight test simulator campaigns were performed for the analysis of the “active” pilot behaviour in RPC prone operation environment and for the determination of the pilot transfer behaviour aiming on coupling problems of the “passive” pilot. A simulator campaign was performed including the structural dynamics properties of the airframe as well for simulations of “aeroelastic” RPC.
As follow-on the flight test simulations were extended in ARISTOTEL for better RPC understanding and prediction. Concerning rigid body RPC, pilot identification experiments were conducted in order to find pilot characteristics before and after an A/RPC triggered by a time delay introduced in the simulation model of the BO105 helicopter flying a stabilization task. The goal was to understand the pilot behaviour in the so-called ‘post-transition retention phase’, i.e. the phase in which pilots still believe they are controlling the vehicle operated prior to the change of vehicle dynamics followed by the pilots adaptation to the time delay applied in the controls. It was found that, once the task became RPC prone, all pilots try to adapt their strategy to the new dynamics of the aircraft by lowering their visual gain and increasing their lead equalisation to compensate for the reduced phase margin they had due to the added time delay. Also, within ARISTOTEL a new real-time detection tool for A/RPC was proposed, the so-called Phase Aggression Criterion (PAC). PAC achieves a 'detection' of an A/RPC through the observation of the PVS phase distortion and the pilot input rate. Observing pilot input allows one to check that the pilot is coupled with the oscillations (a prerequisite for PIO) whilst the phase difference allows one to see whether the commanded input is in-phase with the vehicle response. The combination of the two parameters at a finite point in time allows one to objectively assess whether an A/RPC has materialised. From the different ADS-33 tasks flown in the simulator, it was shown that the precision hover (see Figure 1a) and the roll step (see Figure 1b) are suitable for exposing RPC tendencies while slalom manoeuvre proved to be unsuitable for exposing RPC tendencies.
To understand what particular helicopter vibrations induce adverse biodynamic couplings (BDC) effects and what mission tasks are more prone to such effects, biodynamic test trials were refined and extended in the ARISTOTEL project to both helicopters and fixed wing aircraft. Figure 2 presents the experimental setup for pilot’s left arm biomechanical characterisation. For helicopters, the results revealed some important conclusions, for example: biodynamic feedthrough BDFT depends on the control tasks: for the different control tasks (i.e., different neuromuscular settings), a different level of BDFT was measured; BDC depends also on the control (disturbance) axis: the highest level of BDFT is measured in sway direction, followed by the surge direction. The least amount of BDFT is measured in the heave direction. This demonstrated that the biodynamic couplings (coming only from neuromuscular adaptation in this experiment) depended not only on more obvious features such as pilot weight and posture (which can vary from pilot to pilot) but also on more elusive factors such as pilot workload and task.
Concluding, this paper is intended to give an overview of the various numerical and experimental activities of research starting with the GARTEUR action group which laid the foundations for adverse vehicle-pilot coupling research and culminating in the ARISTOTEL project which refined research and extended the application to fixed wing crafts. Selected results were highlighted and discussed demonstrating the used approach to investigate different RPC phenomena in a schematic manner.

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Ecodesign for space and aerospace: what happens when we make ecodesign relevant for demanding applications?

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The European Space Agency (ESA) seeks to implement ecodesign in concurrent design for future space missions, as part of its Clean Space initiative. Ecodesign and quantitative environmental scores from life-cycle assessment (LCA) are acknowledged elements in cleaner production. This paper describes the challenges when adapting ecodesign to space systems.
Life-cycle assessment (LCA) provides environmental information over the life of products. It supplies the indicators for environmental decision-making in the design process, and covers materials extraction, manufacturing, use and end-of-life treatment. LCA is primarily concerned with environmental effects of technology on terrestrial systems, by emissions and use of resources. Impacts in LCA and ecodesign include human health, ecosystem damages and resource depletion [1].
Practices and tools for ecodesign are devised for mass production systems. Technologies for space, aerospace or other demanding applications differ from the traditional large volume productions in many ways. They require advanced materials, specialized manufacturing processes and small production volumes. Testing and functional requirements are also different when producing for space and aerospace. These factors have some significant implications for the LCA studies that are used to support ecodesign practices.
• Technologies for advanced applications are earlier in development. Literature concerning their environmental properties is immature or non-

existent – implying few or no LCA studies for the materials or processes involved. This presents a tough starting point for ecodesign.
• Ecodesign for space and aerospace combines a wide list of manufacture processes and materials, many of which are traditional and some are less developed. The consequence is that an ecodesign database for high-end manufacturing most probably is incomplete due to gaps for novel technologies and specialized materials, or becomes inconsistent in an effort to cover also the less matured technologies. An adaption of ecodesign to space applications require expanding the library of processes beyond large volume production – while at the same time maintaining a certain internal consistency.
• Most all ecodesign tools have been developed for commercial production systems, generally for large volume products. The specialized manufacturing processes and advanced materials used for demanding applications render any traditional ecodesign tool irrelevant. It is a significant challenge to ensure that information used in the ecodesign process is space relevant.
What is advanced today is general tomorrow. Ecodesign and life cycle assessment for advanced technologies ensure that we develop high-end manufacturing for a better production industry in the future. Based on an ongoing ESA study on LCA for manufacturing and space materials, we present results for a selection of advanced manufacturing processes and materials, and discuss the challenges involved in developing LCA for demanding applications, in an attempt to answer: what happens when we make ecodesign space-relevant?
Ecodesign information for advanced technologies. We discuss here two examples of applying LCA to space relevant technology. The final paper will cover additional issues, such as composite materials, additive layer manufacturing, electronic components (ICT and harnesses), batteries, single process and system manufacturing for space. Space relevant technology – the case for solar As environmental technologies, solar energy and photovoltaics are popular issues for ecodesign and LCA. However, space relevant PV is very different from what is installed on a building [2,3], and the literature on for PV for space application is non-existent. The best source is a study that concerns a space-relevant GaAS PV [4], though for a land-based installation and from 2006. Taking into account the rapid development in PV technology, and general efficiency gains in manufacturing and materials science since then, we may conclude that the relevant LCA literature is very scarce. Any evaluation of PV in ecodesign for space therefore requires covering new fields in LCA. Further insights from this process are shared in the full paper.
Technology completeness and consistency – the case for manufacture Manufacturing processes are a large field. Databases exist that include a variety of manufacturing processes, most notably the commercially available Ecoinvent database, However, all available databases for ecodesign have in common that they are compiled from a multitude of sources, each originating from various time periods, geographies and levels of technological maturity. Attempts have been made to remediate this (e.g., [5]), but challenges with internal consistency are a returning issue when complementing updated ecodesign data for specific technologies with other, perhaps older and possibly simpler, data points in order to gain coverage. Inconsistencies cause bias in comparison between production routes and may carry significant repercussions when applied to larger systems, like solar for space. Manufacturing and surface treatment are important issues in ecodesign for space.

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Understanding Fleet Impacts of Formation Flight

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An operational efficiency concept which is not yet common but could provide significant fuel burn and economic benefits to the air transportation system is formation flight. Formation flight is the practice of flying two or more aircraft in a specific pattern such that the induced drag of aircraft behind the lead aircraft can be reduced.
Previous work in this area has been accomplished by a number of researchers, including students at RWTH Aachen and Georgia Tech. This work has been focused on understanding the flight conditions on widely utilized aircraft, such as the Boeing 777, Boeing 757, Airbus A320, and Airbus A300, necessary to maximize the benefits of formation flight. The results of the these vehicle studies by RWTH Aachen have shown that the maximum benefit generally occurs with relatively small spacing of the aircraft, of only a few wingspans.
While these vehicle level studies have currently been limited to the aircraft aforementioned, further studies are being conducted for the purpose of generalizing the induced drag and fuel burn reductions achieved during formation flight based on basic geometric and aerodynamic parameters of the aircraft. The ultimate goal of this work is to produce estimates that can be used in fleet level analysis for any combination of aircraft occurring in real world operations.
In addition to the work completed between these universities at the aircraft level, the results from these aircraft studies will be included in fleet level estimates of fuel burn. This fleet level analysis provides a starting point for estimation of true benefits with a specific use case. In order to complete these estimates, cost and performance models have been developed, as well as algorithms to determine the optimal meeting and split up points of routes. These tools have been tested to assess potential candidate routes for formation flight for real air carriers.
Ultimately, the results generated from these initial studies of formation flight have been limited in scope, and can be expanded upon for more global air transportation considerations. However, based on the results from these studies, it seems likely that fuel burn benefits in the 4-6% range for air carriers could potentially be accomplished if full use of formation flight were to be implemented. While this may be unlikely due to the logistical and regulatory obstacles of implementing such a concept, these estimations still serve as a valid first order estimate of additional benefits that can be achieved through further use of operational efficiency measures.

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Experimental investigations based on a demonstrator unit to analyse the combustion process of a nitrous oxide/ethene premixed green bipropellant

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Satellite propulsion systems for orbit- and attitude control mostly operate with Hydrazine as Monopropellant. In respect to the REACH-Regulation there exists a growing demand of propulsion units operating with Green Propellants. Among the different Green Propellants, a very prospective candidate seems to be mixtures of Dinitrogenmonoxide and Carbon Hydrides, also known as Nitrous Oxides Fuel Blends. Within the research for alternative space propellants at the German Aerospace Center (DLR) in Lampoldshausen, a special mixture of

Dinitrogenmonoxide and Carbon Hydrides was selected and analysed for further applications in a satellite thruster. The mixture consists of Dinitrogenmonoxide as Oxidizer and Ethene as Fuel. It is a so called premixed Monopropellant, having the advantages of a Bipropellant (high ISP) as well as the advantages of a Monopropellant in respect to the simple propellant tank and feed system. For the design of a thruster operating with this fuel, the aim of DLRs ongoing research activities in this field is the analysis of the whole combustion process as well as the propellant itself. To conduct the combustion and propellant tests a demonstrator unit was designed as well as a tests bench was set up. The demonstrator unit was mounted in the test stand, a measurement and control system was programmed and first tests runs were carried out. The unit consists of an injection and ignition system, several segments to vary the length of the combustion chamber and a nozzle segment. The gaseous Ethene and Nitrous Oxide are mixed in a tube junction of the setup in front of the injection system. The conditioning of the propellant could be realized by different injector systems, an impinging injector, a showerhead injector or a swirl injector for later liquefied gases. To evaluate the heat flux imposed to the combustion chamber wall three thermocouples are implemented in each cylindrical chamber segment, which are positioned at different radial distances to the hot gas side wall surface. The combustion chamber pressure is detected by means of pressure transducers mounted in all segments. The ignition of the Nitrous Oxide/Ethene Fuel could be realized by different ignition systems: A glow plug, an igniter torch using gaseous Hydrogen (H2) and Oxygen (O2) or a spark plug. In a series of tests the occurring chamber pressure, the supply and injection pressure, the wall temperatures and the heat flux on the chamber segments were measured or calculated. During these experiments different N2O/C2H4 mass flow rates as well as varying Oxidizer to Fuel ratios were used. The mass flow rates were adjusted by using several sets of orifices upstream the mixing area in the feeding lines of the test setup. The effective diameter and the corresponding mass flow through the orifices were examined by numerous preliminary tests. To avoid flashback during the test runs a porous material was implemented into the feeding lines upstream of the injector. In addition to the combustion tests, several cold flow tests were carried out. These cold flow tests were used to compare numerical flow simulations of the Nitrous Oxide and Ethene gases with the experimental pressure data.

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Decision making for unmanned flight in icing conditions

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The widespread interest in a more extensive use of unmanned aerial systems (UAS) in the civil sector has led to significant efforts towards the integration of UAS in unsegregated airspace. This involves improving the safety and reliability of UAS and developing new regulations specifically for such systems, that will eventually make this process possible. One of the more challenging issues is the regulation and certification of UAS's flight in icing conditions.
In-flight icing degrades aircraft performance and control and can lead to accidents. The problem is enhanced in UAS's because in piloted aircraft an appropriate response to icing relies on the judgement of the pilot, who must evaluate each particular situation and decide how to handle it, based partly on the experience or intuition-guided interpretation of aircraft behaviour and sensory and visual cues. Hence the need was identified for a system that emulates the reasoning processes of a pilot in this context, i.e. that detects and quantifies icing, and assesses the overall situation and available data to reach an informed decision in response to the perceived situation.
This is considered an important step in enhancing the safety and all-weather capability of UAS and in aiding the process of their integration in unsegregated airspace.
This paper presents the development of an icing-related decision-making system (IRDMS) to permit safe unmanned flight in icing conditions. Two aspects are addressed in this study: firstly, (possible means for) the detection and quantification of icing in flight, and secondly the appropriate evaluation of and response to icing-related situations in the absence of an on-board pilot. Since icing is an aircraft-dependent process, the Cranfield Jetstream J31 was used as a test platform.
For the detection and quantification of icing in flight, two different approaches were investigated. The first approach exploits the drag increase caused by icing. Empirical data was used to derive an approximate relation between icing-related changes in drag and consequent changes in performance, and to define thresholds for icing severity levels in terms of said changes in performance. For the second approach, a relation was defined between icing and the changes in elevator trim required to maintain a particular steady flight condition. Here, threshold values denoting different icing severities were derived from relevant literature.
An initial assessment of the effectiveness of the drag-based icing detection method was made by means of flight testing. Results showed that the effect of icing on drag is indeed measurable, suggesting that in principle the proposed method is applicable. However a quantitative evaluation was found to be challenging, as in light icing the extent of the measured changes in drag was in the same order of magnitude as the measurement noise associated with the in-flight measurements, and so it was difficult to effectively distinguish the effects of noise from the effects of icing. Hence this method seems appropriate to determine moderate or heavy icing, but either alternative techniques or more accurate or filtered measurements are required to detect light or trace icing with any confidence in a real-world implementation.
The flight test data was also used to evaluate the threshold values chosen to represent different icing severity levels. As there is no uniform definition of icing severity and the definitions currently used in manned flight rely at least partly on the judgement of the pilot, this evaluation was based on the perceived icing severity described by the test pilot. The obtained results were used to make an initial evaluation and fine-tuning of the theoretically and empirically chosen threshold values. The chosen detection approaches are simple and for now limited to steady and level flight conditions. They were intended as a starting point to study the problem and to allow for initial development of the IRDMS. Simple approaches are however also of interest if the proposed system is to be implemented on small UAS with limited payload and computational power.
The second part of this study concerns the design of the IRDMS, whose structure is loosely based on a belief-desire-intention agent model. The suggested system identifies potential icing conditions from atmospheric data given by on-board sensors, and then uses ice detection sensor data and aircraft-related data to determine whether ice is in fact forming, how severe it is, and what its effects on the aircraft are. The aircraft data is evaluated based on the previously described detection techniques. Through fusion of the available data, the system evaluates the current situation and suggests appropriate responses to it, considering also available meteorological forecast data for the intended route. Possible responses include the activation of the appropriate anti-icing and de-icing equipment, immediate exiting of icing conditions by descending, climbing or moving out of clouds, and flight path re-planning.

Tests were conducted in a simulation environment in order to verify the software implementation and demonstrate its basic functioning by means of a number of case studies. For this, a basic icing accretion model was developed based on experimental data from the literature and on the previously described work on icing detection methods. This model was interfaced with an existing flight dynamics model of the Jetstream 31 in MATLAB/Simulink. Initial tests showed that the IRDM recognises icing effectively and suggests appropriate responses to it, which keep the vehicle in safe conditions at all times and comply with existing guidelines for manned aircraft.
A real-time implementation of the proposed system is expected to enhance UAS capability for operating in adverse weather conditions, thus increasing the potential range of application for such vehicles.

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RPAS Systems Overview and Configuration Tool

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1. Introduction Unmanned Aerial or Aircraft Systems (UAS), often referred to as Remotely Piloted Aircraft Systems (RPAS), gain more and more importance not only for military operations, but also for civil applications, such as filming or search and rescue. Talking about RPAS is not just about a modern unmanned aircraft itself, the operation involves ground facilities, human-machine interfaces and also legal aspects.
2. Methods In Austria, according to national law, the operation of RPAS is officially possible since beginning of the year 2014 [1, 2]. Regulations distinguish between two classes: Systems up to 150 kg MTOM (maximum take-off mass) operated within visual line of sight (VLOS) and up to an altitude of 150 meters above ground are covered within Class 1. Unmanned aircraft which do not meet these criteria need to be certified like any other civil aircraft, considering all conventional requirements (Class 2). For Class 1, systems are further divided into four categories A-D, according to the population at the area of application (undeveloped, unpopulated, populated, densely populated) and MTOM (up to 5 kg, 5 – 25 kg, 25 – 150kg) [3, 4].
In this work, an RPAS configuration tool is presented. The tool provides a basic design guideline, where the mandatory minimum equipment for every class and category can be easily identified. Equipment items are categorized following the ATA 100 referencing standards (ATA: Air Transport Association of America, respectively A4A: Airlines for America) [5]. Different configurations can be set up with the help of a growing database as source of information, including an overview of the components with appropriate manufacturers, product prices and technical data.
3. Results The result of a generic configuration for Class 1 is presented, although systems up to Class 2, operated according to instrument flight rules (IFR), can be generally designed by the help of the tool. The example represents the lowest category A. The other categories are more restrictive and apply for RPAS capable of carrying a much higher payload or at least have a higher total system weight being operated above a more crowded ground environment. Besides a detailed component list, the result shows a total estimate for system weight, volume (without airframe) and required power (without propulsion), but also a basic economic calculation. Figure 2 shows the section of the configuration tool used for the propulsion system. The ATA 100 reference is specified and mandatory items for the relevant category can be identified. The system data for the reference design is based on its aerodynamic behaviour. The required engine power for example can be determined by considering aircraft performance and design data like cruising speed, lift-to-drag ratio, total weight, motor and propeller efficiency. Additional sheets in the configurator tool support the selection process of actual products based on these technical specifications. Summarizing all sections for the physical measures and total costs leads to the final result for the given RPAS concept. Another optional part of the tool allows specifying overhead costs, resulting in an estimated sales price for manufacturers.
4. Discussion The RPAS configurator provides a handy tool not only to identify minimum requirements for an UAS in a technical manner, but also supports the selection of single products by manufacturers, specifications and costs. The current implementation represents Austrian legislation, but can also be modified to meet regulations of other countries. The component database itself can be maintained independently of the configuration sheets. All that can be helpful for companies in order to ease the process of developing RPAS according to given law, and therefore stimulate a high potential market within a currently often conservative industry.

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Numerical and Experimental Investigations on Subsonic Air Intakes with Serpentine Ducts for UAV Configurations

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Aerodynamic integration of air intakes with increasingly compact shaping and the optimization of their performance are challenging tasks for innovative design of advanced unmanned aerial vehicles (UAVs) featuring superior combat or reconnaissance abilities. In order to meet configurational requirements, diverterless intake designs with optimized entry shaping and sophisticated serpentine duct layout are primary goals in the overall development process. These design challenges, however, can generate intake flow characteristics, which can adversely impact the aerodynamic performance of the intake and the engine/intake compatibility.
The extension of Computational Fluid Dynamics (CFD) into application areas such as dynamic intake distortion prediction and thus engine/intake compatibility is made possible by modern hybrid methods and increasing computer resources. Within the Aerodynamics Action Group AG-46 "Highly Integrated Subsonic Air Intakes" of the Group for Aeronautical Research and Technology in Europe (GARTEUR) CFD computations were carried out for the EIKON UAV configuration which was designed and wind tunnel tested at FOI in Sweden. Partners in the international collaboration of AD/AG-46 were AIRBUS Defence and Space (Germany, Chair), ONERA (France, Vice-Chair), FOI (Sweden), AIRBUS Defence and Space (Spain), SAAB (Sweden), DLR (Germany), ALENIA Aermacchi (Italy), and MBDA (France).
A major objective of AG-46 was to investigate the capability of Detached Eddy Simulation (DES) methods to analyse unsteady flow phenomena of serpentine air intakes and their accuracy levels. Numerical results for a variety of wind tunnel conditions were compared with Reynolds-Averaged Navier-Stokes (RANS) and unsteady RANS (URANS) data as well as experimental results. The time evolutions of distortion coefficients (e.g. DC60) at the AIP very well demonstrate the highly turbulent flow in the separated region downstream of the S-duct and allow the comparison of the dynamic distortion behaviour with steady-state performance as well as experimental data, revealing an improved prediction of the time-averaged DC60 value with a DES simulation. Prior to CFD computations, investigations of a potential influence of not

considering the wind tunnel walls in the CFD calculations on the computational results were performed. The data revealed that the ventilated walls of the T1500 wind tunnel eliminate the blockage of the model within the closed test section and that free stream conditions can be applied for the computational boundary conditions. According to these results a well validated comparison between the CFD results and the experimental data for the UAV configuration could be expected.

A numerical study on intake lip shaping, which is a vital design parameter impacting aerodynamic drag and intake performance, was conducted, comprising an alternative round cowl design while maintaining low-observability features of the original W-shaped sharp intake cowl. A comparison of CFD results for the aerodynamic forces produced by the original sharp cowl design and the modified round cowl was performed. The drag and lift breakdown for the individual parts of the wind tunnel model as well as for the intake cowl itself allowed an improved assessment of the sources of the aerodynamic forces. Valid insight into the design of intake lips for innovative UAV configurations could be gained.

The impact of boundary layer ingestion versus boundary layer diversion was investigated in a trade-off study. Computations were performed applying Euler boundary conditions at the forebody, thus simulating the total removal or diversion of the boundary layer. The computed inviscid results were compared with the viscous data. Eliminating the boundary layer resulted in decreased total pressure losses and improved total pressure recoveries at the intake throat by approximately 2%, and led to an improvement of the distortion level in the AIP.

Internal passive flow control was investigated by employing numerical models for the simulation of vortex generators in the intake duct, and active flow control was studied by applying devices in form of micro-jets. Results were compared with experimental data.

At DLR in Göttingen experiments with a generic high aspect ratio diverterless intake model were performed in the cryogenic blowdown wind tunnel DNW-KRG with the goal to contribute to a better understanding and correlation of installed performance predictions of highly integrated innovative intake designs. In a parametric study the combined effects of boundary layer ingestion and an S- shaped intake diffuser on total pressure recovery and dynamic distortion at the engine face were investigated as a function of Mach number, Reynolds number, boundary layer thickness and intake mass flow ratio.

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Aerodynamic modelling of an active flow control system for flapless flight control in the preliminary design stages

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For highly dynamic control manoeuvres blown circulation control aerofoils are able to provide the required control moments without any complex kinematics as conventional flaps would imply. Blowing over a rounded Coandă trailing edge entrains the baseline airflow around the aerofoil to the desired direction and modifies circulation strength. Basically this system acts aerodynamically similar to a conventional flap where the momentum vector is bended upwards or downwards. The scope of the research activities on this flapless flight control concept is primarily the applicability on low aspect ratio flying wing configurations which are, into the bargain, designed laterally unstable. Here, the current concept promises to be suitable also for yaw control when air flow momentum is controlled differentially on the wing half spans. The high mass flow demands during this control mode could be met during cruise flight when the engines are operating at high power settings.

For substantive conclusions a global system model is essential including pressurised air sources, ducts and finally the control moment authorities by trailing edge blowing. The latter implies special challenges when computational efficiency and flexibility in terms of parameter variation is crucial for preliminary design stages.

Even if vast amounts of fundamental wind tunnel experiments have been performed so far numerical modelling is still necessary to fill the gaps of missing systematically collected data. By means of wind tunnel data the control force and moment reactions can be predicted qualitatively but rarely quantitatively for an arbitrary application with specific geometry.

For rapid and automated calculation of double-slotted circulation control aerofoils a tool has been implemented in Matlab. An automatic mesher generates a structured two-dimensional grid processing the baseline aerofoil coordinates, a desired Coandă radius and the given slot heights. The Reynold's Averaged Navier-Stokes Equations incorporating the Menter SST turbulence model are solved to obtain the control force and moment reactions as a function of blowing rate. The extrapolation to a finite wing by extended lifting line theory results in an aerodynamic data set which enables the evaluation of the aerodynamic performance of a given flapless flight control system.

After a short description of the modelling tool it is applied on a test case consisting of a low aspect ratio flying-wing configuration. A final performance assessment allows concluding statements about applicability and design drivers for the given test case.

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Aviation – Environmental Threats Simplified methodology of NOx and CO emissions estimation

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Based on the available information and authors self - assessments, this article presents turbine engine exhaust gases effect on the environment, especially near to the aircraft during their engines idle and take-offs settings.

The authors would like to draw attention of the aviation professionals to the fact that amount of exhaust from the turbine engine is so significant that may adversely change the ambient air near to the aircraft. Consequently increased level of carbon monoxide (CO), unburned hydrocarbons (UHC) during engine start–up and idle can be a threat to the ramp staff health. Also high emission level of the nitrogen oxides (NOx), during take-off, climb, cruise and decent is not indifferent for the environment around airport space as well as ionosphere . The paper gives an example of CO and NOx emission estimation based on ICAO Engine Emission Data Bank. Also provides calculation results of aircraft CO_2, CO and NOx effusion using fuel consumption data taken from aircraft Flight Data Recorder (FDR) in the so–called landing and take-off cycle (LTO) and during remaining flight phases of various aircraft types.

LTO cycle considered in this paper contains actual values of aircraft fuel consumption and duration of the airplane manoeuvres.

Fig. 1 shows difference between fuel consumption of "model" and overhauled engines, when Fig.2 presents emissions estimation for "model" engine.

Fig. 1Fuel consumption of: a-ICAO Emission Data Bank Engine; Fig. 2CO and NOx emissions for ICAO Data Bank Engine. b, c- test-cell results of overhauled engines It is cliché that engines during exploitation are deteriorating and have different characteristics hence such factors has

to be taken into consideration in emission calculations and each aircraft, even of the same type, has to be considered individually. Fig. 3 presents how emission of NOx differs between overhauled and ideal engine on high power settings. Approximate value of NOx emission for repaired engines has been calculated using as a standard equations describing curves of "model" engine (Fig.2).
Fig. 3NOx emission estimation on high power settings of: a-ICAO Emission Data Bank Engine; b, c- test-cell results of overhauled engines
Fig. 4 shows quantity of NOx and CO emissions estimations for all flight phases of long haul aircraft.
During same flight (Fig. 4) aircraft has emitted 150 000 kg CO2.
For short and medium range flights "share" of cruise phase in total flight duration is smaller in favour of LTO cycle.
Calculated on the engine characteristics basis the mass flow rate of exhaust gases, and knowledge of the aircraft real LTO cycle duration allow to estimate the amount of CO2, CO and UHC "left" at the airport space. The final answer to questions about threats to the ramp staff can be obtained after a detailed study of the pollutants concentration distribution zones (a task for us - engineers) and determine the safe limits of these gases for human (a task for medical services). High altitude emissions especially NOx and CO2, their influence on ionosphere requires more studies of climate experts. For now we are trying to estimate more precisely volume of pollutants.

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Multiscale Virtual Testing – The roadmap to the efficient design of composites for Damage Tolerance

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Damage tolerance is a key design driver for composite structures, among other reasons, due to the risk of damage due to low-velocity impacts (LVI). Such events occur with some frequency on composite applications such as airplane components. From ground operations to unavoidable bird collisions, there is a range of situations where an aircraft outer component may be subjected to unexpected impact loads. In most cases, such as tool dropping, the impactor has a relatively high mass but low velocity. The damage produced in such cases is mostly in the form of delaminations which are not easily noticeable through routine naked eye inspections. However, the spread of these delaminations over wide areas of the structure may severely compromise the residual compressive strength of the structure, possibly even below the limit load for which it was initially designed. Therefore, the ability to predict damage resultant from probable impact is of primary importance in the aeronautical industry.
Traditionally, impact damage models rely on either analytical calculations or extensive experimental data. By one side, analytical predictions of the impact damage resistance and tolerance of composite laminates are overly simplified and unreliable. On the other side, testing each promising design is time consuming and costly. Low-cost virtual testing by means of nonlinear finite element analyses can give valuable insight that will lead to an efficient selection/reduction of physical tests. Once the dynamics of the impact phenomena and the damage mechanisms are correctly simulated, progressive failure analyses can be a valuable tool in the accurate prediction of damage tolerance of composites.
This paper proposes a systematic strategy to determine the mechanical behaviour of composite materials under low-velocity impact using a multiscale numerical approach. A virtual design/testing strategy that takes into account the physical mechanisms of damage at the different length scales is developed and validated, so the influence of the microstructure and loading conditions can be taken into account rigorously. The multiscale approach describes systematically the material behaviour at different length scales from ply microstructure to laminate.
One of the advantages of this bottom-up multiscale approach is that changes in the properties of the constituents (fibre, matrices), the fibre architecture or laminate lay-up can be easily incorporated to provide new predictions of the macroscopic behaviour of the composite. Also, the observed scatter in material properties can be easily studied as well as its influence on the failure mechanisms. By using virtual testing, it also becomes efficient to study the effects of different initial and boundary conditions on the results which can be largely affected by small variations in these parameters.
At microscale level, the representation of the mechanical behaviour of a composite material is achieved by means of a Representative Volume Element (RVE) which accurately describes the mechanical behaviour of the different phases by means of constitutive equations. The matrix behaviour is modelled by a coupled damage-plasticity in order to handle the non-linearity due to plasticity in the matrix under compressive stress states and the quasi-brittle behaviour under tensile loads. On the other hand, a cohesive model where interfaces elements are inserted between fibres and matrix is adopted to address decohesion between the constituents. The relevant material properties of the matrix and interfaces are measured by means of instrumented nanoindentation and direct observation of the damage mechanisms and events (Figure 1a).
At mesoscale level (Figure 1b), laminates are simulated by means of thermodynamically-consistent damage models for plies and ply-interfaces defined in the context of the mechanics of continuum media (CDM). The ply model use physically-based criteria to predict the onset of matrix cracking and fibre fracture under tensile, compressive and shear loadings and take into account the effect of ply thickness on the strength. The model parameters (e.g. ply elastic constants, tensile and compressive strength in the longitudinal and transverse directions, shear strength, etc.) are determined by means of micromechanical simulations. The interface model, to simulate delamination between plies, is implemented as a surface interaction. The interface fracture energies required as inputs to compute the initiation and propagation of delamination are determined by means of characterization tests. The cohesive formulation is able to account for changes in the loading mode and crack closure effects, avoiding interfacial penetration of two adjacent layers after complete decohesion.

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GARTEUR Structures & Materials Action Group 32 – An European Research Project On Damage Growth In Aerospace Composite Structures

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The high specific strength and stiffness of composite materials make them suitable for use in aerospace structures. However, the high sensitivity of these materials to the presence of damage, arising after impact with foreign objects or caused by manufacturing defects and stress concentrators, makes designing with composites a very challenging task. The damage mechanisms in composites are very complex and can involve one or more constituents at a time. Delaminations, fibre breakage and matrix cracking can strongly reduce the load carrying

capability of composite structures leading, in general, to a premature failure. Moreover, depending on the composite internal layout and on the adopted manufacturing technique, the damage mechanisms may interact with each other, making it difficult to predict the residual properties of composite components.
In recent years, the inability in predicting the damage onset and its evolution in composite structures, has led to over-conservative designs, not fully realizing the composites promised economic benefits. Hence, in order to make the composites affordable in aerospace design, many research projects have been started in the last decade aimed to investigate the composites' damage mechanisms and to promote damage tolerant design approaches.
A number of GARTEUR (Group for Aeronautical Research and Technology in EURope) Action Groups together with several EU funded and MoDs funded research projects have been started on damage management in composite structures. All these research activities have contributed to increasing the knowledge of the composites structural response and failure mechanisms. However, in the last 20 years big steps forward have been made in the field of computational technologies and new "composites oriented" non-destructive inspection tools have been introduced. These innovative numerical/experimental features can be considered as relevant driving factors for the development of newer effective numerical approaches oriented to the prediction of damage on-set and growth in composites.
Furthermore, fifteen years of research and growing applications in industries have brought to life new needs, to be addressed by Research and Development, for example related to the presence of new composites typologies (textile composites) and new manufacturing techniques (RFI, RTM, fibres placement).
Finally the emerging tendency to adopt composite materials for primary structures opens new scenarios involving new safety issues which imply considering damage tolerance design approaches from the earlier phases of the design process (including optimisation) rather than limiting the use of damage on-set and growth numerical techniques to complex/expensive non-linear verification analyses.
Taking into account the above considerations, the GARTEUR Action Group AG 32 carried out between year 2007 and year 2012 a joint research work focused on "DAMAGE GROWTH IN COMPOSITES". The action Group was composed by C.I.R.A. (Centro Italiano Ricerche Aerospaziali - Italy), QinetiQ (United Kingdom), DLR (The German Aerospace Center - Germany), INTA (Instituto Nacional de Tecnica Aerospacial – Spain), SWEREA-SICOMP- Sweden, EADS-M – Germany, ALENIA AERMACCHI – Italy, Imperial College of London - United Kingdom, CNR (Centro Nazionale Ricerche – Italy), Lulea University of Technology – Sweden, SAAB – Sweden, ONERA (The French Aerospace Lab- France), University of Nantes – France and University of Naples "Federico II" – Italy.
The main objective of the Group was: "to develop integrated numerical/experimental methodologies capable to take into account the presence of damage and its evolution in composite structures from the early phases of the design (conceptual design) up to the detailed FEM analysis and verification phases" addressing the following issues:
Integration between numerical and experimental methodologies (oriented to the validation and to the interpretation of the most significant physical phenomena governing the damage mechanisms in composites)
Prediction of generalised composite damage (delamination, fibre breakage, matrix cracking, etc.), onset and evolution
Development of numerical methodologies oriented to the different design phases (fast methodologies for conceptual/preliminary design and detailed methodologies for analysis and verification)
The new methodologies developed in the frame of AG-32, able to support the composites design process and able to drive it towards a damage tolerant philosophy, can surely imply relevant changes in the way composite structures are adopted in aerospace industry leading to the reduction of the overall composite design time and costs by improving the efficiency of simulation tools and by reducing the number of experimental validation tests. The project structure and the main results from the AG-32, in terms of methodologies developments, experimental methods developments and validation experimental activities are summarized in this paper.

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Effects of Training Strategies on Acquiring and Retaining Manual Control Skills

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Evidence suggests that manual flying skills of pilots operating highly automated aircraft are declining due to the lack of opportunity to exercise such skills in the modern air transport environment. When the automation shuts off unexpectedly, for example, in an upset condition, these skills become vital to recover to a safe flight condition. In order to prepare pilots for such events and maintain or improve aviation safety, the training of manual flying skills needs to be optimized. Previous studies investigated the acquisition of manual control skills in target-tracking tasks using multimodal human operator models. The main goal of those studies was to investigate transfer-of-training effectiveness using different levels of simulator fidelity.
During a recent experiment that looked at transfer of stall recovery training it was observed that pilots experience different levels of learning performance depending on the time schedule of the experiment. Moreover, pilots experienced fatigue, showing degraded performance towards the end of the training sessions.
The purpose of this study is to investigate the effect of different training time schedules on the learning performance of the pilots. In addition to task performance, pilot modelling tools will be used to investigate how control behaviour changes during the training process. An experiment will be conducted where pilots will perform a fixed-base roll-tracking task. Participating pilots will be placed in different groups, each training with different time schedules. Moreover, different groups will train with either stable or unstable controlled elements. The main goal is to obtain an optimal training strategy for the acquisition of manual control skills that will yield the best learning performance while at the same time minimizing the effects of fatigue. The different controlled dynamics will be used to investigate the effect of task difficulty on this optimal training strategy. As part of the study, we will also investigate how the acquired manual control skills are retained over time. After the training sessions, pilots will participate in the same experiment after different periods of time and their performance will be re-evaluated.

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Comparison of the Potential Environmental Impact Improvements of Future Aircraft Concepts Using Life Cycle Assessment

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Background. The protection of the environment gets increased importance in civil aviation [1]. However, today aircraft are designed mainly for lowest Direct Operating Costs (DOC). Clearly, a better environmental protection can be achieved, if Environmental Impact (EI) is minimized and used as the objective function in aircraft design optimization. EIs over the entire life cycle can be calculated with a Life Cycle Assessment (LCA) defined in ISO 14040. LCA is the „compilation and evaluation of the inputs, outputs and the potential EIs of a product system during its life cycle" [2]. Admittedly, in a practical design of future civil aircraft, DOC will remain the most important objective, but better environmental protection could be achieved already with a multi objective design optimization in which EI are included and are given a least a certain weight. As often explained, most characteristics of an aircraft are fixed and determined already in the early phases of aircraft design. The same is true for the Environmental Impact (EI) of an aircraft which is also locked in by decisions made in conceptual aircraft design. Therefore, it is so important to include a full LCA already in conceptual design and not merely an analysis of the pollutant emissions resulting from aircraft operation. Summing up: Environmental protection is made a more important design criterion by including a comprehensive LCA (calculating EI) into the objective function for aircraft optimization already during conceptual aircraft design.
Extending the application of LCA in conceptual aircraft design. The authors showed already that with a simplified but still comprehensive LCA methodology the EI of an aircraft can be calculated already during conceptual aircraft design [3]. The authors showed further that using the EI as the objective function in conceptual aircraft design instead of using DOC has an influence on resulting aircraft parameters [4]. Not only aircraft parameters are influenced in new ways using EI as the objective function. This paper shows that EI can also be used to select the best alternative among several future aircraft concepts.
Future aircraft described and reviewed. The paper describes several promising future aircraft with different fuel concepts and reviews their pros and cons. The considered aircraft and fuel concepts are:
a) biofuelpowered or synthetic fuel-powered aircraft, b) hydrogenpowered aircraft,
c) hybrid-electric-powered or allelectric-powered aircraft.
Existing studies on these future concepts are analysed to get a first qualitative understanding of the concepts' impact on the EI of an aircraft. Also new technologies like a higher share of carbon fiber reinforced plastics are investigated concerning their influence on the EI of aircraft.
Future aircraft designed, optimized, and analysed. Aircraft are designed e.g. for hydrogen fuel, determining the best position of the liquid hydrogen tanks. For a selected design solution the aircraft parameters are optimized for minimum EI. The EI and the main contributors to the EI are analysed among the considered aircraft and their fuel concepts. The results of the investigated concepts are compared to those of the reference aircraft Airbus A320200 and also to a possible conventional successor of the A320, a turboprop aircraft optimized for minimum EI (presented in Figures 1 ... 3 in the attached file). The paper presents by how much future technologies could possibly reduce the EI of an aircraft and what concepts are favourable concerning their EI.
Selected results. A continued increase of the share of carbon fiber decreases the EI of aircraft due to savings in weight and therefore fuel even though the EI in the disposal phase is impaired. Considering the current European electricity mix, biofuels made of microalgae surprisingly lead to a doubling of the EI of aircraft. This is because of the high energy demand during the production of the biofuels. Biofuel-powered aircraft can therefore only substantially reduce the EI if the energy demand from the production is covered by renewable energy sources also having low EI. Hydrogenpowered aircraft also have the issue of high energy demand due to the production of hydrogen as well as water vapor emissions during cruise causing contrails and contrail-induced cirrus clouds both having substantial negative EI. In total, the EI would even be increased by few percent compared to the reference aircraft. But, by adapting the flight altitude to counteract the effect of contrail formation, EI could be reduced by about 70 %. If renewable energy sources are additionally used for the production of hydrogen, EI could be lowered by another 25 %. Hybridelectric and all-electric aircraft also only allow to drastically reduce the EI if their energy needs are covered by renewable energy sources. With the current European electricity mix, EI
could only be reduced by less than 20 %.
Summarized, as long as the share of renewable energy sources stays low (which will presumably be the case for the next decades), only a lowflying hydrogenpowered aircraft offers high improvements concerning the EI.

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Progress in Inverted Joined Wing Scaled Demnostrator Programme

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The Institute of Aviation is leading the consortium dedicated to investigate properties of the inverted joined wing aeroplane configuration. CFD analyses, wind tunnel tests and flight tests of scaled demonstrator were undertaken to perform this task. This paper will present a summary of results achieved so far with particular attention put on CFD, wind tunnel and flight test results. Joined wing configuration is considered as a candidate for future aeroplanes. It is an unconventional aeroplane configuration consisting of two lifting surfaces similar in terms of area and span. One of them is located at the top or above the fuselage, whereas the second is located at the bottom. Moreover one of lifting surfaces is attached in front of aeroplane Centre of Gravity, whereas the second is attached significantly behind it. Both lifting surfaces join each other either directly or with application of wing tip plates (box wing). This concept has many possible advantages like induced drag reduction and weight reduction due to the closed wing concept. Unfortunately it is much more complicated to design than conventional aeroplane due to the strong aerodynamic coupling and static indeterminacy. Therefore it was not possible to build successful, safe and efficient aeroplane in this configuration before computer aided design systems became available and even its early versions were not powerful enough. Large meshes are necessary to describe it accurately enough for precise CFD analysis, so very capable computers were required and unfortunately unavailable. On the other hand potential weight reduction comes from the static indeterminacy of the joined wing configuration. Once again powerful computers were necessary to analyse it with FEM method with satisfactory accuracy. Moreover, static indeterminacy causes significant manufacturing problems due to tight tolerances required to assembly the joined wing with no random internal stresses. All these difficulties can be resolved with application of modern CFD and FEM software, increased computing capabilities and prototyping capabilities based on computer controlled machining. All of them are currently available, so attempts to design a joined wing aeroplane are more frequent. However in most cases researchers concentrate on configuration where front wing is attached at the bottom of fuselage and aft wing is installed either at the top of the fuselage or at the top of the vertical stabilizer. Our previous experience lead to the

conclusion that joined wing aeroplane could fly much better in upside down position. The most probable reason of this fact comes from the interaction between wings. Front wing wake is very close to the aft wing if gap between wings is too small. It becomes even smaller at high angles of attack if front wing is located below aft wing. As a result aerodynamic advantages are diminished. They may be recovered if aft wing is installed high at the top of the vertical stabilizer, however this requires strong stabilizer which decreases potential weight reduction. Configuration, with front wing above aft wing should work in the opposite way, thus delivering expected advantages, providing that fuselage is reasonably high.
Our recent CFD analyses confirm, that joined wing aeroplane L/D grows together with increasing gap between wings. Moreover, assuming the same gap, configuration with front wing above aft wing provides not only greater maximum L/D, but also greater L/D in wider range of angles of attack. In particular L/D at high angles of attack is greater in this configuration which suggests advantageous flight endurance. Configuration with front wing below aft wing is advantageous only at low angles of attack assuming that aft wing is installed at the top of the vertical stabilizer. However, as mentioned before, weight advantage should be reduced in this case due to the increased loads of vertical stabilizer. As can be seen from this result, final conclusion is not clear yet, which was the motivation to undertake our current project.
Multicriterial optimisation, performance, stability and control analyses of the joined wing unmanned aerial vehicle (UAV) are a main goal of the this project. They are being verified by wind tunnel and flight tests. It is believed that it will allow for collecting an extensive database of knowledge concerning joined wing aeroplane configuration. Most of analyses and optimisation in this project are conducted for UAV since this allowed for building inexpensive real flying test-beds. Three UAVs are to be tested in this project, one with wing span of 1,2m and two with wing span of 3m. Two of them are currently flying. Flight test campaign will last to the end of November 2015. Proposed paper will present its results obtained before the deadline for full paper submission. Moreover additional CFD analyses, flight simulations and wind tunnel tests are planned. They are to be compared with flight test results. Results of these analyses and comparisons will be presented as well.

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CompoWorld: an innovative approach to innovation and economic development

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Introduction
Seven years ago a Netherlands delegation visited Lockheed Martin to investigate business opportunities in connection with the Joint Fight Striker (JSF)/F35. Participants in the delegation were Fokker Landing Gear, NLR (Dutch Space & Aeronautics Laboratory) and representatives of the Flevoland region (Province, Investment Agency). During this visit a vital coalition was born in a triple helix configuration (private, public, knowledge) focussing on composite technology. After this visit the Municipality of Noordoostpolder and the Windesheim University in Almere, both part of Flevoland, joined this vital coalition. The market potential of composites technology was confirmed in a market study of 2011. This study concluded that the vital coalition in Flevoland had “golden” opportunities for further development, especially in the combination of aerospace knowledge and business opportunities and local Small and Medium Sized Enterprises (SME’s) with a joint ambition in composite technology.
Master plan CompoWorld
All these ambitions were translated into an Operational Program Compoworld, which was managed by a foundation CompoWorld, supported by all parties of the vital coalition as well as local SME’s. The Master plan CompoWorld contains three lines activities. The largest parts is an innovation program both for larger projects as well as SME’s. The second part is the connection between (vocational) training and the demands of businesses on the labour market. The third line is business development, which consists of promotional activities (www.compoworld.nl), an annual congress and efforts to attract composite technology activities to northern Flevoland. The Masterplan activities are financed by regional authorities (50%), contributions of knowledge institutes, companies and schools (45%) and sponsorship contributions (5%). Total budget for the period 2012-2015 is € 4,5 mln.
Results
The CompoWorld Master plan has initiated 11 innovation programs. Two of these project have resulted into a pilot plant at the NLR Composite location in Marknesse, two other projects have resulted into a successful application of composite technology in the infrastructure digging machines, a project launched with a SME innovation package has resulted in a sustainable mobile cleaning machine for shopping carts and baskets.
In the area of education and training CompoWorld has delivered an education package for vocational technical training as well as a Masterclass Composites. The project is well underway to establish a lector ship (research facility for practical applied research) for higher education in Flevoland. The business development activities have led to an annual composite technology congress in Flevoland, but also to increased employment with companies in Flevoland, both established and new, in the amount of 50 Full Time Equivalents (FTE) end of 2013. It is expected that this will increase to 250 FTE end of 2015.
Best practices
Improved partnership between NLR and participating companies. This partnership has led to a pilot plant at NLR Marknesse. The pilot plant is established with a 20 year perspective, and will enable companies to prove the technological and economic viability of a combination of engineering, materials and production technology. The first customers of the pilot plant are aircraft landing gear development and production, as well as offshore infrastructure providers.
Insourcing of SME innovative creativity with larger companies and NLR. The application of composite technology in the design of digging machines for infrastructural projects, is a successful cooperation of engineering capabilities, production technology and customer demand.
Cooperation between product innovators and composite companies. Due to continuous marketing and acquisition efforts, innovative entrepreneurs come to CompoWorld. These entrepreneurs are able to translate the opportunities that composite technology can offer, into concrete fast to market products. The Cleanforte, mobile cleaning device for supermarket carts and baskets, is the prime example.

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FEM analyses of joined wing aircraft configuration

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The article describes Finite Element Method (FEM) analysis of a novel aircraft configuration – joined wing, or in other nomenclature Prandtl plane. The aerodynamic configuration promises great induced drag reduction for high lift coefficients. To check the feasibility of the idea project MOSUPS was started. The project includes multidisciplinary analysis, design and building airworthy aircraft. After preliminary analysis it was proved that front upper wing and lower rear wing, which is less commonly used wings configuration, improves aerodynamic characteristics resulting from positive interference of the wings. Although, aerodynamic benefits where the original motivation for the concept of the Prandtl plane, this configuration can also bring structural benefits. Wings structure of the airplane creates closed frame, what is different from classical cantilever wings structure. Loads acting on the wings can be optimally distributed between the wings. Higher stiffness of the closed frame may significantly improve aeroelastic features of the lightweight structure.
FEM analysis were done to see how the initially proposed structure works. Three dimensional beam wings model was created. It showed some problems with considered simplifications in the regions of connection of wings to side plate. Problematic regions had high stress values. Additionally, any increasing of the thickness in affected regions significantly change internal loads distribution over whole wings. This makes optimization of the structure more difficult. Not all optimization algorithms assure convergence to solution. To investigate this phenomena more accurate shell model was prepared. Aerodynamic pressure loads, derived from panel method, were mapped on the airplane's structure. Numerical model for the FEM analysis was simplified, by elimination of the fuselage and the vertical stabilizer. Wings have added ribs and all panels have constant, not optimized thickness. Root profiles of the front and rear wings were fixed. Simple isotropic material was set for the first analysis. After the analysis there were found the same stress concentrations at the arc joints between the wings and the side plates connecting the wings. Possible solutions of this problem are discussed in the article.

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On the minimization of cruise drag due to pitch trim

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A blended-wing-body is an example of an aircraft configuration with multiple control surfaces. The most effective use of these control surfaces, e.g. to minimize cruise drag due to pitch trim, or to maximize pitching moment at low speed in an engine-out condition, leads to optimization problems. This kind of control optimization problems can be addressed by the method of Lagrange multipliers; this allows for multiple constraints, e.g. constant lift, each associated with one multiplier. The value of the multiplier is a measure of the severity of the constraint, e.g. the drag penalty of imposing pitch trim at constant lift. The estimates of the Lagrange multipliers for different control surfaces also indicate the evolution of the iterative process to find the optimum.
Three distinct initial conditions to start the iterative process are considered. The method is applied to multiple control surfaces, taking into account their mutual interactions and also the influence of shifts of center of gravity. It is shown in a particular case that it is possible to achieve pitch trim in cruise with drag reduction relative to the untrimmed case.
The minimization of cruise drag with pitch trim and unchanged lift, i. e. same airspeed and altitude, is considered for a flying-wing configuration, using several strategies from part A plus a few additional ones for a total of eight. Of the four non-optimal strategies, only strategy II of using the centerbody elevator alone leads to drag reduction, albeit with a large deflection and increased angle-of-attack. There is drag increase for the strategies: (I) of equal deflection of all control surfaces; (III) preferential deflection of inner control surfaces with an aeroelastic limit of 7.5º; (IV) equal contribution to lift for all control surfaces. The two optimal strategies V using Lagrange multipliers after a few interactions give: (VA) a drag reduction for a good initial condition like strategy II; (VB) a drag increase for a poor initial condition like strategy I.
A sub-optimal strategy VI of using multiples of optimal deflections, with a multiplication factor determined by lift equilibrium, requires a larger angle-of-attack, and thereby increases drag. The strategy VII of deflecting all control surfaces in two groups to minimize trim drag, leads to a larger angle-of-attack, and thereby increases drag. The strategy VIII of using the two most effective control surfaces with opposite drag slops gives the best compromise: (i) lift balance with unchanged angle-of-attack; (iii) second best drag reduction with small control deflections. The latter justify the use of linear aerodynamics and reduce the risk of adverse aeroelastic effects.

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On thermo-acoustic acoustic-vortical-entropy waves and flow stability

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The stability of combustion in jet and rocket engines is related to thermoacoustic effects and also to swirling flow that enhances chemical reactions. This problem is addressed by studying acoustic- vortical-entropy (AVE) waves that are considered as axisymmetric linear non-dissipative perturbations of a compressible, non-isentropic, swirling mean flow, with constant axial velocity and constant angular velocity. The axisymmetric AVE wave equation is obtained for the radial velocity perturbation, specifying its radial dependence for a given frequency and axial wavenumber. The exact solutions are obtained for small and large radius, respectively as ascending and descending series valid inside and outside a critical radius, where the isothermal Mach number for the swirl velocity is unity. Thus they specify exactly the perturbations of: (i,ii) the radial and azimuthal velocity; (iii,iv) pressure and mass density; (v,vi) entropy and temperature. It is shown that there are: (a) oscillatory solutions with decaying amplitude, corresponding to a stable mean flow; (b) monotonic solutions with increasing amplitude, corresponding to instability of the mean flow. The instability condition is that the frequency times a function of the adiabatic exponent is less than the vorticity (or twice the angular velocity); in this case, the instability typical of vortical flows dominates the stability typical of potential flows. This suggests a condition for stable combustion in a confined space: the peak vorticity (multiplied by a factor of order unity dependent on the adiabatic exponent) should be less than the lowest or fundamental frequency of the cavity.

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Jumbo City Flyer

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Aviation is forecasted to grow at around 5% every year for next few decades. The internal air traffic within Asia has increased substantially and this increased demand in Asia is driving the growth in aviation. A substantial part of the air traffic within Asia is marked within mega cities (with population of around 10 million).At present big aircraft (like Boeing 747 or Airbus A330 & A340) are being used to carry passengers between several of these cities which are separated by less than 2000km. However these large aircraft are optimized for long range missions and are thus inefficient when used on these short range missions. Apart from being expensive in terms of operating costs, these aircraft also produce more emissions per passenger km.
The present paper discusses a proposal for a short range aircraft which can carry around 500 passengers for the year 2025. The proposed aircraft called the “Jumbo City Flyer”, has payload characteristics similar to Boeing 747-400 but the fuel efficiency of a turboprop. This proposed aircraft can help in cutting down the emissions from aviation to a significant extent. The proposed aircraft is a new concept in civil aviation that has the potential to meet the future energy demands in aviation as well as being sustainable.

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Combined Launch System: a new concept to reduce the launch costs for Micro (Cube) Satellites and Debris hunting probes

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This paper introduces a simpler, cheaper, reliable and conventional concept for launching Micro- Scaled Satellites, To provide the students and young researchers the chance to launch their own projects and experiments and see it actually functioning in space through the simplicity of launch procedure, mission tracking and systems engineering, The main theme for this project is to serve both educational and commercial sides of space exploration using the scientific bases and experiments of Control and Aerodynamics on lighter than air dirigibles, Rocket Propulsion and Flight dynamics stability to increase the efficiency of all systems and decrease both complexity and cost by integrating simple designed systems and fine tuning of their objectives to reach the desired mission aspects, also the variety of missions the Combined Launch System could be used in, besides lifting the Micro satellites into orbits debris hunting which results to be an essential threat to most of the space related projects nowadays, in this paper also the innovations on the propulsive systems and orbital mechanics introduced to increase the lifetime and capabilities of a cube satellite or a small space probe for hunting and detecting debris, allowing more objectives and higher level of missions to be performed using them.

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Multidisciplinary design optimization of flight control system parameters in consideration of aeroelasticity

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In the process chain of aircraft development, a detailed model of the flight control system (FCS) is considered only at a late phase. Many parameters as the number and dimensions of the control surfaces or their effectiveness are fixed or at least limited within certain bounds at that point. Thus, only a small design space is available for the FCS development. Structural mechanics, aerodynamics, load determination and flight control system are disciplines, which interact with each other and must therefore work closely together. Depending on the structural stiffness, it might be necessary to take aeroelastic coupling effects between aerodynamics and structural mechanics into account as well. In this regard, developing a FCS is a multidisciplinary task. The FCS parameters, or flight control system degrees of freedom (FCS-DOFs), must properly be determined from the design space limited by the various disciplines, to meet the demanded control power. The former can be ratios of control surface deflections for a respective flight envelope, the latter is given by the control surface configuration and may be quantified in terms of control moments or its built up rates. Particular attention must be paid to the allowable ranges of the FCS- DOFs in order not to violate FCS constraints given by stability or robustness. In a complex system as a FCS, minor changes to one parameter might have major changes on others. Therefore, for its development, usually a complex, iterative parameter design process must be carried out. The techniques of multidisciplinary design optimization (MDO) were developed to solve problems, where multiple disciplines are involved, various interactions amongst them occur and solutions must be found, which fit ranges of constraints. Handling the interactions usually results in a solution of best compromise between the involved disciplines. Thus MDO is a suitable approach to solve the formerly described problem of determining the parameters of FCS-DOFs. For a complex FCS, applying methods from MDO leads faster to a FCS design, that fulfills the constraints given by the FCS design engineer and other disciplines. Thus, MDO may enhance and improve the process chain of developing a FCS. The first basic step is the analysis of the engineering problem. Determining parameters of the FCS follows objectives and constraints. Hinge moments, occurring due to control surface deflections, commanded by the FCS lead to mechanical stresses in the structure, which must not exceed certain allowable values. Depending on the structural stiffness, aeroelastic effects might affect the mechanical problem as well. Minimizing the stresses can be formulated mathematically as a multidisciplinary optimization problem. There are general thoughts to be kept in mind, when applying MDO to the design of a FCS. When changes to the aerodynamics or the aircraft structure occur, the FCS design must be adapted as well. Therefore it must be designed flexible, i.e. the parameters of the FCS-DOFs must not be determined as fixed values but rather as ranges. As a result it is crucial to determine the sensitivity of changes in the FCS-DOFs to the behaviour of the FCS. Multiple simulations of the modelled FCS must therefore be carried out and analysed. Numerically, the solution of an optimization problem may depend on the applied optimization algorithm and its parameters. Thus, a sensible selection of the optimizer means better solutions of the FCS optimization problem. The FCS designed with MDO can then be compared with a FCS designed in a more manual way. Performance and development time are key parameters for this comparison. The FCS of a generic MALE UAV is modeled in SCADE Suite, a model-based development environment for embedded software. This model aircraft demonstrates the theoretical idea of designing a FCS using MDO for an example roll manoeuvre. The DOFs to be optimized are the spoiler and the aileron deflection, commanded by the FCS. It must be cleared how best to deflect the spoiler and/or the aileron for the respective roll manoeuvre. An appropriate optimization solver helps to determine a best suitable ratio between the spoiler and aileron deflections of the generic MALE UAV, with respect to objectives as e.g. minimizing structural stresses. Results of the optimization runs will be presented and discussed. Using optimization algorithms in order to determine parameters of degrees of freedom of the FCS can then be compared with the conventional procedure. Not only numerical values of the design, reached with the respective design methodology, but also the time of development need to be compared therefore.

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Automatic Generation of Aeroelastic Simulation Models Combined with a Knowledge Based Mass Prediction

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Increasing competition during the last decade in the branch of unmanned aerial vehicles leads to new challenges for the military aviation industry. New aircraft have to be developed in shorter design loops and with reduced engineering costs. In response to these pressures, the focus in conceptual design is extending from using statistics towards an approach based on numerical simulation necessitating early availability of reasonable fidelity simulation models. This requires a highly automated and flexible model generation process. It promises a greater extent of more reliable information concerning new aircraft concepts during the first development steps due to increased fidelity of simulation results while a great design freedom is still available. It enables, for example, aeroelastic simulation and optimization with only low modelling effort and supports conceptional design of new and unconventional developments where no statistics are available. The mass of an airplane is one of the most important properties during the early design phases, because it has influence on all major design disciplines. Traditionally, it is estimated very early on the basis of statistics of already existing aircraft and updated throughout the design process. It is desired to reduce the structural mass of a new development as much as possible, to increase the performance and the payload capacity. Multidisciplinary design optimization is an adequate tool to ensure a minimum structural mass and a realistic thickness distribution. Here, the main problem is that the conceptual structural modelling does not allow all structural elements to be taken into account and some simplifications have to be done. This means that the mass of secondary structure, like rivets, paint or fittings is not taken into account, which leads to a mass underestimation. So the mass of non-structural elements and secondary structure has a major influence on the mass of the primary structure, e.g. ribs, spars and stringer has to be regarded. The in-house program Descartes has been under development for the last two years at Airbus Defence and Space. It provides abilities to automatically generate analysis models, such as structural finite element models and aerodynamic panel models, on the basis of a central CPACS (Common Parametric Aircraft Configuration Scheme) database providing a top level description of the aircraft on the basis of engineering parameters. From this Descartes generates a central parametric geometry model, which is the foundation to derive aeroelastic simulation models. Among others the structural FE (Finite Element) model is generated by Descartes consisting of thickness and material information. To minimise the gap between the idealised FE mass and the mass of a realistic structure in the early design, this approach combines knowledge based mass estimation with a global structural FE model. It is possible to apply knowledge based additional mass to the structural components in the FE model. Thus, there is a distinction between elements, representing e.g. spar, skin, stringer or caps, proper additional mass assumptions can made and this provides a sophisticated consideration of mass. Additionally, non-structural mass of e.g. fuel or systems is applied to selected nodes to complete the high quality mass modelling, which enables more precise input for the following simulation. Using Descartes` model generation abilities, the structural model is extended to an aeroelastic optimization model. During the next step, performing a structural sizing optimization, the FE element mass is optimised while the structural integrity is maintained using stress and buckling constraints. The optimised thickness results are returned to Descartes and the evaluation of secondary masses is repeated with the updated FE model. On the basis of these results a realistic mass estimation is possible for a given aircraft configuration in the conceptual design phase.
To show the abilities of this approach a mass estimation of a conceptual unmanned aerial vehicle (UAV) is performed. The introduced method is used to predict the optimized structural mass, as part of the overall mass model, satisfying predetermined mission requirements. The result of this is compared to the traditional approach.
The combination of an aeroelastic structural sizing optimization and knowledge based mass estimation in an early development stage offers promising opportunities for the conceptual design phase.

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Autonomous flying: a must for the future

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The IATA Roadmap 2013 has shown that most of the technologies currently being researched will have a marginal effect on fuel consumption of aircraft and thus CO_2 emissions. The technologies currently being developed in industry and EC programs like Clean Sky will not enable the industry to reach the IATA target of 50% CO_2 (Fuel) reduction by 2050. IATA identified 4 technologies that will bring substantial benefits: The Hybrid Wing Body configuration, active flow control, new engine core concepts and flying without undercarriage thanks to take-off and landing with ground power. The EC sponsored research project Gabriel in which AD Cuenta was a partner demonstrated the technical feasibility of using ground power to launch and recover aircraft. The most challenging part may be the fully autonomous landing on a sledge mounted on the MagLev ramp in cross wind conditions and heavy turbulence.
But future aviation is not just about emissions. The attractiveness of aviation to serve society is also based on low cost of transportation. Cost of flying has been reduced constantly despite increases in fuel prices. This is partly due to the high load factors in civil aviation. Today a load factor of 85% is common, which is at least 40% higher than in other transport modes. Direct operating cost have been reduced over time thanks to improvements in technology. Better engines, less drag and reduced weight have contributed to a constant reduction of fuel burn. The reduction in fuel overcompensated the increase cost for assets depreciation and maintenance. Indirect operating cost have gone down as well mainly thanks to internet bookings. In general productivity in aviation has reached limits as the A-380 is about the biggest still economically feasible aircraft (also due to airport restrictions), speed cannot be increased at reasonable cost and aircraft utilization is high thanks to short turnaround times of 25 minutes. Perhaps there are possibilities to reduce turnaround time even more thanks to different procedures and technologies. But one aspect is not considered in the IATA analysis and that is unmanned flying. Cost savings can be substantial if no pilots would be needed and ATM could be fully automated. Passengers
can be served by robots on board so no cabin crew is needed in future. (With adaptation of safety requirements).

Today we can see already some examples of unpiloted vehicles especially in the RPAS domain. Unmanned vehicles are remotely piloted via a line of sight data-link (up to 150 nm), via line of sight via satellite/ airborne relay, or these vehicles are programmed to fly a particular pattern. None of these solutions seem to work for civil commercial aviation in non-segregated airspace. Recent tests in the UK showed a 4 seconds delay between sending and receiving instructions. Far too long to apply in civil aviation.

Autonomous flying is the only option available. If there is no need for a pilot it will not only save substantial cost but would also prevent the pilot shortage that is predicted by Boeing and others. This is particularly relevant when air taxi operations and regional flying of both passengers and cargo will be feasible at affordable prices and substituting surface transport.

Experience with autonomous flight is limited thus far. The technological approach is missing although a number of elements of autonomous flight are already available. By autonomous flight we mean a flight executed by a device able to perform complete complex flying missions safely and very efficiently without human interference.

What do we need to accomplish this. What is the technological challenge? First we need to have much more reliable guidance and control equipment. Current equipment makes a pilot needed to correct the automation. If the pilot does not respond in a proper way it may lead to a crash, as demonstrated recently (Loss of control). Although these accidents are contributed to pilot error often the root course of accidents is in inadequate information provided by or functioning of equipment.

Second we need reliable sense and avoid systems. Data links need to be secure, hack proof and cheaper. Via ADS-B the position of aircraft should be known to other aircraft that fly direct routes from origin to destination. If automation allows aircraft to interact in a safe way, there is no need for air traffic control. That can be automated as well. This will save substantial cost. As part of the Single Sky initiative of the European Commission aiming at a single non segregated airspace in Europe the mission of the RTD program SESAR was to reduce ATM cost with at least 50%. Current estimates suggest that only a marginal cost reduction can be achieved. Full automation will bring cost benefits beyond the 50% aimed for.

We also need to look into certification and regulation. With current regulation autonomous flying is not feasible. Like FAA in the USA, EASA should be part of a technology development program to enable autonomous flight in 2050.

Another issue is public acceptance. It so expected that by 2050 cars will be able to drive autonomously so the public should be acquainted with autonomous vehicles. However there may be resistance to fly with fully autonomous aircraft. Therefore it is expected that cargo aircraft will be the first application of this technology, which should be feasible in 2040. Also small aircraft may be flown autonomously.

There is a need to start research in the area today in order to be prepared for 2040. Changes in aviation are taking a long time. SESAR tries to implement a modification in the ATM system that was already demonstrated in 1990, but may see the first application in 2030. So we need to be prepared. Still there is no reason to accept the idea of autonomous flight and start working towards its introduction.

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Integration of Mission Trajectory Management functions into CleanSky Technology Evaluation Process

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Clean Sky European Project is about to develop and demonstrate a large set of innovative technologies, covering all segments of commercial aviation. The Technology Evaluator (TE) of Clean Sky is a dedicated group composed by research centers which assesses the environmental impacts and benefits (noise, fuel burn and gaseous emissions) of the overall Clean Sky ITD output at three aircraft operational levels: single mission, ATM (airport) and ATS (global world fleet). TE assessments shall consider all promising green technologies selected by ITDs, grouped as clusters, forming optimized new aircraft solutions prepared under responsibility of manufacturers in Clean Sky's ITDs.

For large aircraft segment, the link between ITD and the TE is managed by Airbus through WP2.3 of SFWA ITD. In order to provide to the TE representative evaluation of future aircrafts equipped with Clean-Sky technologies (including open rotors capabilities in operational conditions), it was deemed essential for WP2.3 to develop a concurrent European industry process able to translate innovative technologies into simplified conceptual aircraft models for technology evaluation. In this process, Airbus specifies the conceptual aircraft relevant to evaluate Clean Sky technologies, collects and converts the technologies into this conceptual aircraft to evaluate the performance, the noise and the local emission gains induced by the ITD technologies. To manage interface complexity and to protect industrial property, the Clean Sky large aircraft conceptual platforms are included and delivered to the TE, for operational evaluation, through an integrated and innovative calculation tool, developed by Airbus for TE needs, called PANEM.

This article will focus on the specificities of the integration into PANEM of Mission Technology Management (MTM) functions, such as Adaptive Increase Glide Slope (A-IGS), Multi-Criteria Departure Procedure (MCDP) or Multi Step Cruise (MSC).

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Green Micro-Resistojet Research at Delft University of Technology: the New Frontiers of Cubesat Propulsion

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CubeSats are a special type of research spacecraft in the nano-satellite class (launch mass in the range from 1 to 10 kg). The standard CubeSat is often called a "1U" CubeSat, has a volume of exactly 1 litre (10 cm cube), a mass of no more than 1.33 kg and typically uses commercial off-the- shelf components. Simplification of the satellite infrastructure and use of off-the shelf electronic components make it possible to design and produce a working satellite at low cost. Although CubeSats originated in the Academic environment, several research institutions and commercial companies are also involved in CubeSat research around the world.

Without a dedicated propulsion system, the CubeSat platform can never totally realize the potential of replacing its larger counterparts, imposing a limit on the exponential growth that CubeSats launches have shown in recent years. Propulsive capabilities would enable the CubeSat platform to engage in a wider range of missions such as those characterized by many satellites flying in formation or in a constellation, possibly even in low altitude orbits. The strict mass, volume, and power limitations typically imposed by CubeSat requirements need unique micro- technologies to help develop a compliant propulsion system. Micro-electromechanical systems (MEMS) at a micro-scale size and high level integration are considered to be the most suitable for this class of satellites.

Currently, in the aerospace industry, there is a growing interest in green, non-toxic propellants. This is especially true for Cubesat micro-

propulsion systems, given their wide use in Universities as a training means for students, and also because most Cubesats are still launched piggyback and shall not to endanger the primary payload. Unfortunately, almost every good-performance propellant is apt to be a very active chemical; hence, most of these propellants are corrosive, flammable, and/or toxic. One of the most typical “green” propellant choice is the use of an inert gas. However, this leads to large storage tanks or, alternatively, to excessively high tank pressures. Ice or liquid water is another potentially promising green propellant, due to its higher mass density. Electro-thermal micro-thrusters using water as propellant can potentially provide a comparable specific impulse to advanced chemical systems and can generate enough thrust and delta-V level to accomplish the needs of a typical CubeSat formation flying mission.
The Space Engineering Department at Delft University of Technology has a well-recognized worldwide leading role in the design, development and launch of educational nano-satellites. In the current roadmap of the group, formation flying of two or more satellites represents one of the most important milestones, with an initial demonstration expected during the DelFFi mission, planned for launch in 2016. To accomplish the requirements associated to this kind of formation flying missions, several types of water-propelled micro-thrusters are currently under development, mostly based on MEMS technologies. These include a low-power free molecular micro-resistojet (FMMR) and a more conventional micro-resistojet. Both these concepts offer many potential advantages, such as high integration capability, small volume, light mass, fast response, high thrust mass ratio, high reliability, easy integrability in a thruster array. The FMMR, with its low plenum gas pressure of around 500 to 1000 Pa, can provide a thrust level in the order of several μN to a few mN and is suitable for precise attitude control of CubeSats. The water micro-resistojet thermally gasifies liquid water to a high temperature vapour for expulsion via a conventionally shaped nozzle, and has a wide potential for in-orbit maneuvers of CubeSats due to its higher thrust level and specific impulse.
The research work currently ongoing at Delft University of Technology on water propelled MEMS micro-propulsion systems for CubeSats will be presented in this paper. Numerical simulations on the FMMR and the water micro-resistojet, as well as their experimental validation, will be introduced. The micro-thrusters design and their theoretical and experimental performance will be described. The flow field characteristics inside the thruster micro channels will be analysed by means of numerical and analytical models, and a trade-off to determine the optimum flow channel geometry will be presented and discussed.

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Wind tunnel model support and wall interference corrections in DNW-HST- ensuring high data quality standards -

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The DNW High Speed wind Tunnel HST is a closed-circuit, pressurized transonic facility used by industry to support the development of new aircraft and launch vehicles at close to actual flight Reynolds numbers. Test section dimensions are 2.0m* 1.8m (width*height).
As part of a continuous effort to increase measurement accuracy a dedicated project together with NLR and Embraer has been successfully completed focusing on further refinement of tunnel model support and wall interference corrections.
As part of this joined project, results from various wind tunnel test activities and numerical analysis were applied to validate the improved correction procedures, tailored to the rear sting set-up in the HST test section with slotted walls. The picture below shows the wind tunnel model upside down on a dorsal sting during support interference measurements to assess the effect of the dummy rear model support. The rear support consists of a straight rear sting and the double roll boom (green part). The shape of the newly manufactured dorsal sting is based on an aerodynamically optimized design of NLR.
In order to better understand the support and wall interference phenomena occurring in the HST test section, individual effects were measured for the rear sting as well as the double roll boom. Wall pressures were analysed in a systematic way to establish the wall interference effects. This resulted in a very effective and accurate methodology. The accuracy of the corrected measured model drag, lift and pitching moment appeared to be within the uncertainty range of the model load balance.
The paper will discuss the adopted support interference and wall interference procedures. Final measured data will be compared with available data measured in other wind tunnels and CFD.

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Validation and Assessment of Turbulence Model Impact for Fluid-Structure Coupled Computations of the NASA CRM

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Over the past years, DLR's contribution to the AIAA Drag Prediction Workshop (DPW) series has included both purely CFD-based studies and accompanying fluid-structure coupled (FSC) simulations. The latter include an analysis of the DLR-F6 wind tunnel model and comparison to test data from NASA Langley’s National Transonic Facility (NTF) for DPW-III [1], and an investigation of aeroelastic effects of the NASA Common Research Model (CRM) for DPW-V [2]. In both cases, a significant influence of model deformations on the overall aerodynamic properties was found. So far, the studies carried out were targeted on consistency aspects of the FSC simulations and the assessment of the impact of aeroelastic deformations on the aerodynamic properties. Within ESWIRP, the focus is now set on:
• the validation of computed deformations against wind tunnel data by comparing FSC simulations to measured ETW and NTF deformation data, and
• the investigation of static aeroelastic effects and their consistency.
Fluid-Structure Coupled Simulation Procedure
DLR's FSC simulation procedure, Figure 1, is based on a direct coupling of high-fidelity CFD and computational structural mechanics (CSM) methods [3]. The simultaneous interaction of outer flow field and flexible aircraft structure is modeled through alternately solving the Reynolds-averaged Navier-Stokes equations and the basic equations of structural mechanics, and the interpolation of aerodynamic forces and structural deflections over the common surface of CFD and structural grids. For the investigations described here, DLR's in-house flow solver TAU [4] and the commercial structural analysis code NASTRAN® [5] were used.
Results
In Figure 2a) the overall lift and drag coefficients obtained from static FSC simulations, together with experimental data from the ETW wind tunnel test campaign (Run 182, Ma=0.85, Re=5×106 q/E=0.3342), are plotted as a function of angle-of-attack. Lift is slightly over-predicted

by the FSC computations with a mostly constant offset. However, the slope is fairly well matched to the experimental data over the entire angle-of attack range. Drag is also over-predicted to some extent with deviations increasing towards maximum lift. In Figure 2b) wing tip bending and twist deformations with respect to the c/4-line are plotted as a function of angle-of-attack. A good correlation of wing bending deformation between coupled simulations and experimental data is observed up to $\alpha \approx 3°$. For higher angles-of-attack bending is increasingly underestimated. Wing twist deformation also reveals a fair agreement of FSC results and ETW test data over the angle-of-attack range. The strongest deviations in twist are found for $\alpha < 4.5°$. Overall, a good agreement is seen between the computed bending and twist deformations and measured data with deviations moderately increasing towards wing tip.
Conclusions
The influence of wing deformations on the aerodynamic properties of NASA's Common Research Model has been computed using FSC simulations and compared to ETW test data for Run 182 at Re=5×106 . A generally good agreement of FSC results to test data was observed. This also includes wing pressure distributions (which due to space limitations are not shown here) up to and including the high angle-of-attack regime. As a result, the validation of deformation simulations appears justifiable. Yet, deviations in bending and twist between FSC and test data were found to be inconsistent, which is most likely due to measurement accuracy limitations.

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Visual tracking of ground and air targets

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Object tracking is one of the most important components in a wide range of applications in machine vision, such as building surveillance systems for unmanned systems, human computer interaction for control unmanned vehicles, tracking and object recognition, tracking and landing runways, fire detection, object tracking enemy.
Systems based on various sensors are created for control the unmanned aircraft. Technologies of visual control are the most promising. Systems visual control uses video cameras installed on board unmanned aerial vehicles as sensors. Nowadays the camera is the most attractive sensor due to its relative low cost, compact size and easy replacement of the equipment in case of breakdown. An integral part of the control system of unmanned aerial vehicle tracking system is tracking objects. Visual tracking - this is one of the most active areas of research in computer vision. Despite the considerable progress that has been made in recent years, the problem still remains not solvable.
We have proposed a method for tracking unmanned aerial vehicles which is trained in the online mode, by means of developed scheme model updates. The ability to retrain the system with further another object tracking is not possible, that improves the accuracy of proposed system, even in dark places. Consider the description of our proposed method of tracking objects in unmanned aerial vehicles.
Schema description of the proposed tracking method
The proposed method of visual tracking of objects consists of several parts:
- representation scheme;
- search mechanism;
- model update
Consider each of the stages separately:
1. Representation scheme
Histogram local sensitivity used for the objects represent. Histograms of local sensitivity are invariant to changes in illumination and show good results in the problem of tracking and object detection.
2. Search mechanism
Two methods respond for search mechanism:
- location of the object based on Part Based Detector (PBD);
- find offset of the object in the search area;
Localization of objects based on the PBD is required when initializing objects tracking, at the time of loss of the object of the search area and the reference frames to improve the tracking reliability. Search object offset based on the knowledge of the object placement in the previous frame, the histogram of local knowledge sensitivity preceding frame object tracking. Model of a random forest has been chosen for efficient search and matching object from the previous frame to the current frame.
Our proposed method is based on the union (addition) of two methods. Due to it the reliability significantly increases.
3. Model update
The object is represented by a local sensitivities histogram. Tracking features varies in long time that leads to significantly deterioration of objects visual tracking. Therefore, a method of updating the information of the local sensitivity of the histogram is proposed to improve the reliability:
1. Find all the various regions of the histogram between the template object and the histogram of the object at the current frame.
2. If the number of differ regions is smaller T1 (lower threshold is chosen experimentally), then go to item 7.
3. If the number of differ regions is more T2 (upper threshold is chosen experimentally), then the object is considered lost and run PBD.
4. If the number of differ regions is over T1 and less T2 then run the update method of the histogram information
5. Nearest clusters computed from the training sample in the histogram on the current frame to update the histogram. Random forest model is selected as a classifier model.
6. Updating the template histogram is performed using regions derived from a histogram of the current frame and the regions selected from the nearest cluster on the previous step.
7. Get a new frame.
Due to the training sample clustering proposed tracker cannot retrained and track an object of another class. In multiple tracking crossing paths problems turns up. Our method uses an optimization algorithm solved the problem assignments (Hungarian algorithm) to solve this problem. This algorithm makes it possible to separate the two close trajectories.
Our work present the results of our method testing in comparison with the method of Track Learn Detect (TLD) on five standard video sequences. Experimental results show that the proposed method provides good results in accuracy and robust of the tracking in comparison

to state-of-the- art methods.

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Decision-making inconsistencies in ATC: an empirical investigation into reasons for rejecting decision support automation

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The issue of automation acceptance is not just an academic one. The ATM community has for some time recognised that insufficient acceptance (for instance, of new advisory systems) can jeopardise the introduction of new automation (Bekier et al., 2012; Kauppinen et al., 2002). Mismatches in human and automation strategies underlying decision-making have been identified as playing a part in the observed acceptance issues. To achieve acceptable and effective teamwork between human and automation it is necessary to develop systems that better acknowledge and respond to individual differences, and harmonise human and automation decision making strategies. The current state-of-the-art automation indicates that we have not achieved this milestone yet. Several past projects explored the potential benefits of strategic aiding automation, but until now all had been limited in one important regard: they could not
ensure that automation strategy matched that of the human. Starting from another perspective, the Multidimensional Framework for Advanced SESAR Automation (MUFASA) project set out to explore the role of strategic conformance between human and automation: if automation could be developed in such a way that it perfectly mirrored the way an operator worked, would the operator accept it?
To date, through a unique experimental protocol, the MUFASA project has developed and empirically tested a simulation platform capable of capturing operator performance and using it in such a way that a given operator's own previous performance can be presented as "automation" through unrecognisable replays. In essence, "automation" was now, for the first time, able to perform exactly like the operator. Simulations involving 16 air traffic controllers revealed a main effect of conformance with conformal advisories being accepted more often, rated higher, and responded to faster than were non-conformal advisories. Notice that "conformal" advisories were unrecognizable replays of that given controller's previous performance, whereas "non-conformal" advisories were those of a colleague who had chosen an alternate solution. Qualitative analysis of controllers' conflict resolution performance indicated that controllers were inconsistent both internally and in comparison to their colleagues. If this is true, it challenges the majority of automation design that follows a "one-size-fits-all" approach. One speculation is that controllers are simply inconsistent over time in the solution and strategy they might choose to employ.
Alternatively, it could be that controllers are not necessarily opposed to automation per se, but to advisories from any source (even, say, from a colleague). At the highest level, the scientific impact of MUFASA has been to provide some long-needed empirical insights into the fundamental building blocks of human-machine coordination. The original project provided meaningful initial data into the critical importance of both acceptance and strategic conformance that have the potential to determine automation use (Hilburn et al., 2014; Westin et al., 2013).
Results and unanswered questions from the MUFASA project lead us to propose an extension to explore three potential research topics. Utilizing the existing research platform developed for the MUFASA project, research is now underway, with experiments scheduled for January-April, and planned to be completed by June 2015. In a series of real-time simulations, we will explore the following questions:
Transparency – does automation transparency impact acceptance or agreement? Christoffersen and Woods (2002) argue that in order to cooperate with smart technologies you need more information (i.e., richer interfaces), not less. On the other hand, too much information can overload the user and negatively affect cooperation. The effects of automation transparency in regulating the amount of information available are worth investigating from an academic as well as an operational perspective.
Consistency – to what degree do controllers agree on resolution strategies? Are controllers internally consistent in their resolution strategies over time? We will determine the structure and extent of both inter- and intra-consistency and how it affects automation design.
Source Bias– are controllers biased against automation per se, or against any external source of advice? Would they show a similar level of bias against a presumed human advisor as against a presumed machine advisor? Subsequent experiments will investigate the effects of human vs automation advisory source on advice acceptance and controller performance.
The paper intended for the CEAS conference in Delft 2015, will primarily focus on the consistency research and results obtained in the associated human-in-the-loop simulations. Research into controller consistency can be divided into inter-controller consistency (i.e. agreement between controllers) and intra-controller consistency (i.e. within, internal consistency). Generally, controllers are considered as homogenous (high inter-controller consistency) in their resolution strategies, but while overlooking individual differences perhaps has been sufficient for today's ATC system researchers have argued for more tailored, individual-sensitive automation needed for successful human-automation teamwork in future ATC (Langan-Fox et al., 2009; Stankovic et al., 2008; Willems & Koros, 2007). Decision support systems acknowledging individual differences become increasingly important for user attitudes and performance in decision-making situations with vaguely defined tasks and problem-solving processes, of which ATC is a prime example (Liu et al.,
2011). In terms of intra-controller consistency data are both sparse and unclear. Some data point to consistency (Magyarits & Kopardekar, 2001), other data suggest controllers are inconsistent (Westin, 2012), or that inconsistency increases with traffic complexity (Thomas et al., 2001).
The results will have an operational impact in that they can inform operational communities about the do's and don'ts of automation design, and how decision support tools support the operator—not only in terms of considering individual differences of the operator, but also to which extent operators are consistent over time. The lessons from this research are not limited to ATM, of course, and apply to any number of other domains in which automation is being designed to assist the human decision making process.

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Simulation Driven Design and Additive Manufacturing. A new design process to unleash potential of Additive Manufacturing freedom

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Additive Manufacturing has become sufficiently mature in which is absolutely necessary to make use of the benefits that it provides. In the past, engineering design was limited due to manufacturing constrains and design tools. Now a day, the scenario is completely different. By combining the benefits of design freedom from Additive Manufacturing and Optimization driven design, we can open the gates of a whole new structural design method through a process that involves conceptual (topology) optimization, abstraction and application of design principles in geometry creation, detailed (shape) optimization and design validation. Together, this method offers the best practices to design incredibly light, strong and efficient structures, exploiting the creativity and design freedom in a short period of time using efficient software tools. There are still challenges and questions that come into the application of this method, such as: new design principles taking into account manufacturing constrains from Additive Manufacturing and design validation.

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Economical Assessment of Commercial High-Speed Transport

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Since the dawn of aviation, mankind has been intrigued and motivated to cross long distances non-stop in a very short time. Driven by technology development in aerodynamics, propulsion and lightweight structures, commercial aircraft manufactures could gradually bridge longer ranges from coast-to-coast over trans-Atlantic up to trans-Pacific. However, the travel time did not necessarily follow the same trend as the cruise speed got stalled at around the sonic barrier. Concorde realized as the first to break this paradigm for commercial aviation though this endeavour was lacking a commercial success. The fuel consumption is often too easily quoted as the basic reason, but one often forgets that the technologies deployed for Concorde were stemming from the late 50's and beginning of the 60's. Compared to subsonic aircraft designed in the 60's and 70's (such as Comet or DC-9), the Concorde was actually competitive in range, despite its larger sfc. However, the political hurdles to get it deployed on routes with commercial interest at that time delayed its introduction dramatically and frightened the embracement of Concorde by other airliners. This unavoidably downsized the number of manufactured aircraft below the critical size needed to recover the development costs.
Meanwhile, ranges for subsonic aircraft designed in the 90's have almost doubled, mainly due to improved aerodynamical designs, availability of light-weight and high-temperature materials, lower sfc due to higher bypass ratios, higher TIT, etc. Similar improvements could be applied to a successor of the Concorde to improve its sfc or range for the same flight speed: implementation of a bypass ratio of 0.5 to 1 or higher instead of presently none, application of more advanced cooling concepts for turbine blades, use of light-weight heat resistant materials, use of a Variable Cycle Engine rather than using an afterburner or reheat….
Less known to the public is that these kind of prospective studies were carried out to improve the performance of the Concorde already four months after the start of scheduled services in 1976. This project should lead to the Concorde B model based upon modifications on aerodynamics, systems, weight, fuel tanks and the propulsion unit. This should allow the operating range, primarily designed for the connection Paris London-New York, to be increased to allow connections of the type:
Other European capital cities - East Coast of the US in one sector
United States - Japan in two sectors
Europe - Australia in three sectors
The above is an example of how the economic viability of any aircraft system throughout its lifetime is largely dependent on the timely introduction of contemporary technologies.
Despite the mothballing of Concorde, there is worldwide a regained interest in commercial high- speed transportation ranging from supersonic business jets (ref. HISAC, US, Russia), up to hypersonic speeds. During the last 10 years, the European Commission has co-funded long-term research projects on commercial high-speed transportation such as ATLLAS I and II, LAPCAT I and II and FAST20XX. Also, national activities such as the ZEHST program in France or the JAXA Hypersonic Transport (HST) in Japan indicate the need and wish to establish the required basic technologies, as well as the design of conceptual vehicles to improve their overall performance. As the above projects have grown towards a certain maturity in conceptual layout and basic proof of technical feasibility, their performance figures in terms of ranges, speed, capacity, etc allow to preliminary assess their economic viability in an operational environment.
In this context, European and Japanese researchers have teamed up to map a path for developing high-speed air travel in a joint EC-Japan funded project HIKARI. One of the HIKARI work groups deals with the estimation of the demand and operating costs, based on high-level requirements, in order to provide insights as to the economic viability of high-speed transport. This will feed a second activity, which will provide elements to justify the economic interest of high-speed transport and gain public acceptance. They will also look at potential technologies, environmental impact, and other factors to provide a vision of our transport of the future.
Relying on the results already obtained by the HIKARI consortium, the aim of this paper is to assess the potential future market demand for a highspeed aircraft and estimate the costs and ticket prices of such a vehicle. To address the potential future demand for a highspeed aircraft, the eligible origin and destination city-pairs (OD CPs) and the potential network (hereafter, HIKARI network) for such a vehicle need to be identified first. Then, the number of premium passengers flying over this network, during the next 20 years is forecasted. Based upon technical characteristics of the potential future high-speed aircraft, it is finally possible to determine the number of vehicles that would be necessary to accommodate this expected future demand.
In order to determine the number of vehicles that would be necessary to accommodate the expected future demand, several high-level assumptions were taken, such as, two alternative vehicle capacities (100 and 300 seats); two speed clusters for the high speed aircraft (Cluster 1, with an average speed of 4260 km/h, i.e. covering Mach 3 to 5 aircraft and Cluster 2, with an average speed of 7100km/h, i.e. covering March 6 to 8 aircraft), etc.
Importantly, the market study shows that there is a market for a potential future high-speed transport aircraft. Among the main results obtained in this paper, it is worth to highlight the following:
Ticket prices decrease with aircraft capacity; the HST is economically competitive with the classically used aircraft with respect to premium passengers.
Based on a theoretical equilibrium determination exercise, which equilibrium is defined as a vector of ticket price, market share and expected number of vehicles necessary to accommodate the identified market, results show a trade-off between market share and aircraft units. More specifically, while the equilibrium market share is at most 10% for the 100-seater and 25% for the 300-seater aircraft, the number of deployed aircraft with the former (100-seater) is nearly 50% higher than with the latter (300-seater aircraft).

There is only a neglible preference for a higher speed (average speed of 7100km/h) on the market share over the lower speed (average speed of 4260km/h)
Relying on Concorde dataset, the market share was presently at best limited to 32%. As the 300- seater passenger aircraft have equilibrium points (up to 26%) close to this maximum, the share and the number of aircraft would actually be larger if the limitation of 32% would be lifted.

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Wind Tunnel Test For Breakthrough Laminar Aircraft Demonstrator Europe at DNW-LLF

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The purpose of the CleanSky Smart Fixed Wing Aircraft Integrated Technology Demonstrator (SFWA ITD) is to bring innovative technologies, concepts and capabilities currently from Technology Readiness Level (TRL) 3 to 6 by demonstrating the potential to contribute to a step change in fuel consumption level. The Smart Fixed Wing Aircraft ITD is addressing the integration of passive and active flow and load control technologies into new Smart Wing concepts, to achieve a significant reduction in aircraft drag (10%) and wing drag (25%) using laminar flow concepts and applying innovative control surfaces for load control. To prove the project objectives, flight tests are planned with the BLADE (Breakthrough Laminar Aircraft Demonstrator Europe) flight test demonstrator. Prior to demonstration of these new technologies in flight, large scale experiments have been conducted at realistic close to flight conditions to support the flight clearance process by identifying critical flight conditions and validating Computational Fluid Dynamics tools.
In the framework of the CleanSky project designated with the acronym BLAME (Breakthrough Laminar Aircraft Model wind tunnel testing in Europe) low-speed aerodynamic wind tunnel tests were carried out on a A340-300 aircraft model. The tests were conducted in the 8m x 6m closed test section of the Large Low-Speed Facility (DNW-LLF). The DNW-LLF is well known for its low 'free-stream' turbulence level and thus suited for laminar flow investigations. The main aim of this test campaign was to check the installation effect of the outboard wing natural laminar flow (NLF) panel on the A340-300 Airbus flying demonstrator aircraft MSN 001, designated the BLADE aircraft. This paper will focus on the measurement techniques used for this test campaign.
To establish the effects of the NLF panel (installation) aerodynamic data was gathered using, among other techniques, a strain gauge internal balance. Measurement uncertainty will be discussed based on an earlier proposed uncertainty definition and on wind tunnel data for this model. For this (well maintained) model a large set of aerodynamic data is available spanning more than 20 years providing the opportunity to gain insight in the application potential of the proposed uncertainty definition.
In this campaign two challenges emerged, from a wind tunnel simulation point of view. The first was correct simulation meaning it was vital to obtain the locations of the laminar to turbulence boundary layer transition line on the NLF panel. Despite the large scale of the model and the facility (attaining a relative high Reynolds number) the Reynolds number effects have to be taken into account. The location of the transition line was visualized by means of the Infra-Red Thermography technique. (IRT).
The second was the deformation of the wing section at the location of the NLF panel. This information is essential in comparing measured experimental NLF panel flow behaviour with theoretical results. The deformation measurements were done by means of an optical measurement technique using CCD cameras to determine the local wing twist deformation. In the paper the technical solutions to master these challenges during the large scale wind tunnel test will be described.

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Future of Aviation

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Mobility is key to the wealth and well-being of postmodern societies – so is human creativity and aspiration. Looking into today's visions of the potential of aviation, there is just as much to learn about air transport today as there is about future mobility and transport.
The International Forum for Aviation Research (IFAR) brings together the world's aviation research organizations to foster the exchange of perspectives and identification of mutually beneficial collaboration opportunities. IFAR provided top level representatives of aviation research organizations with a distinguished forum for a discussing the future of aviation and mobility over the coming decades. During the past year IFAR members had the opportunity to consider the future of the air transport system as a vital part of the next generation of mobility and transport systems in a globalized world in the middle of this century.
This activity represents a unique opportunity for the most influential nations in global aeronautical research to offer views based on very different cultural and educational backgrounds. IFAR members have different perspectives and professional experiences, and many members have published future strategic visions for aviation. Accordingly, IFAR members are well qualified to discuss the aeronautical future from a wide variety of different perspectives.
The focus and level of ambition of individual IFAR member organizations is often captured in regional or national strategic research agendas. However, to date these various perspectives have not been commonly analysed and discussed in a global context. Given the global nature of elements of the value chain of the air transport system, it proved beneficial to commonly look for predominantly (but not only) global solutions, areas of commonality and regional aspects to tackle the challenges of the future.

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Integrated multidisciplinary engineering solutions at Fokker Aerostructures

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As a tier 1 supplier, Fokker Aerostructures needs to be able to quickly respond to market demands from aircraft integrators such as Airbus and Dassault Aviation. To distinguish itself in the current competitive market environment, Fokker needs to be able to rapidly respond to new product opportunities and apply innovative technologies in the offered solutions. The aim is to reduce development lead time and improve design quality. The latter means developing more lightweight designs that can be manufactured at lower cost.

To achieve this, design automation and optimization techniques are being developed to perform detail design studies, incorporating more requirements to a higher level of detail. These studies form the basis for simplified decision making models that can allow short operational design lead times and multidisciplinary design optimization. Robust design techniques must be applied to account for uncertainties in requirements and design inputs.
Fokker currently conducts two research projects that address the challenges above:
- Tapas 2, where new thermoplastic manufacturing technologies and the design methods associated with these technologies are developed.
- Rudder in a Month, which aims to reduce the development lead time of an aircraft rudder to a single month. This paper presents the initial results of both research projects focusing on the collaborative engineering approach in both projects.

In Tapas 2 an integrated design process is developed focusing on the initial development phases. This integrated design process is an extension of the Design and Engineering Engine philosophy developed at TU Delft applied in an industrial setting. By developing this process the potential advantages of the new thermoplastic manufacturing methods can be quantified.
The Rudder in a Month project investigates performing major parts of product development before the actual proposal phase. This should result in low development lead times once a product program is started. This approach, also called ‘front loading’ of the design, starts by defining high level standard solutions for aircraft components such as a rudder. These standards are generated through Knowledge Based Engineering applications and by performing design space exploration studies. With this development approach, disciplinary experts will be more involved in defining standards upfront. The standard solutions should enable quick selection of design concepts and enable Multidisciplinary Design Optimization.

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Investigations of ETW slotted wall interference using the NASA CRM model

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Wind tunnel wall interference is still an important issue for increasing the accuracy of test results during the aircraft design phase. In recent years, the manufacturers of transport aircraft have been imposing more and more stringent requirements for the accuracy of experimental investigations in wind tunnels. This is caused by the needs on a more reliable determination of aerodynamic characteristics of the aircraft and, accordingly, its economic effectiveness. Striving for most accurate performance measurements in wind tunnels requires enhanced knowledge on interference effects introduced by the flow boundaries. Considering slotted wall wind tunnels, the subject appears extremely complex due to the presence of strongly 3-dimensional slot flow and the non-homogenous boundary condition.
The experiments were performed in the ETW cryogenic wind tunnel in February 2014 using the NASA Common Research Model to investigate slotted wall interference effects and form a test case for the verification and validation of CFD tools for in-tunnel simulations. These tests were performed in the frames of ESWIRP subproject “Time-resolved wake measurements of separated wing flow and wall interference measurements” funded by the European Commission in the 7th framework program.
The ESWIRP sub-proposal was submitted by a consortium of renowned European research institutions and universities. Besides ONERA (Aerospace research center) from France as project leader, University of Stuttgart and DLR (German Aerospace Center) from Germany, TsAGI (Central Aerohydrodynamic Institute) from Russia, ICAS (Institute of Thermomechanics) and VZLU (Aerospace research and test establishment) from CzechRepublic, VKI (von Karman Institute for Fluid Dynamics) from Belgium and UCAM (University of Cambridge) are members of the team. Two problems were to be solved during test campaign: investigation of unsteady wakes past an aircraft wing under stall and buffet conditions and slotted wall interference in the wide range of Reynolds number.
Currently the possibility appears to apply CFD methods for the problem of permeable wall interference due to significant increase of computer operation memory and calculation speed. A special software Electronic Wind Tunnel (EWT-TsAGI) was developed at TsAGI to support wind tunnel testing including cryogenic conditions. The new CFD approach for wall interference investigations requires additional experimental data (for example wing deformation) in comparison with classical methods. Therefore, the necessity appeared to perform wall interference experiments in the ETW at the new level of technology. The main objectives of the fulfilled wall interference investigations were to increase the accuracy and reliability of ETW wall interference corrections, to investigate the Reynolds number influence on wall interference and to create test case for verification CFD tools for wind tunnel simulation.
The model used in this investigation was the NASA Common Research Model (CRM), which was initially designed to be the basis for the fourth AIAA drag prediction workshop (DPW-IV). This configuration consists of a contemporary supercritical transonic wing and a fuselage that is representative of a wide-body commercial transport aircraft. The CRM was designed for a cruise Mach number of M = 0.85 and a corresponding design lift coefficient of CL = 0.5. The CRM was instrumented for force and moment measurements, wing pressures, wing-root strain gages and dynamic pressures.
Standard measurements were performed during testing in ETW including forces and moments, flow parameters and model pitch angle. Measurements of specific parameters such as the pressure distribution on test section walls, the wing deformation as well as the model position in the test section were done for the CFD wall interference investigations.
The preliminary defined test program was fulfilled considering the scientific objectives of the wake and the wall interference studies and allowing to compare experimental data with CFD results presented in the Drag Prediction Workshop 4 (DPW4)and experimental results in two NASA wind tunnels (NTF and 11ft). Four additional polars at $M\infty$ = 0.697; 0.703; 0.847; 0.853 were served to define the derivatives of model aerodynamic characteristics versus Mach number for the further data correction procedure.
A brief description of European Transonic Facility (ETW), the NASA CRM model and the Electronic Wind Tunnel (EWT-TsAGI) is given along with a description of the test campaign. CFD results of the ETW simulation by means of EWT-TsAGI are presented. Here, the focus is made on a description of the Cryogenic solver features and on validation procedures.
Analyses of Mach and Reynolds numbers effects on wall pressure measurements were performed. The Mach number influence on wall pressure coefficients shows a very similar effect to the Prandtl- Glauert one in the investigated Mach number range from 0.2 to 0.87. This gives an opportunity to apply also linear methods for the wall interference problem on slotted wall configurations up to a Mach number of 0.87 and likely higher.
EWT code was verified by comparison of calculated wall pressure distribution with experimental data.

The wall interference was estimated by the comparison of wall Cp measurements with CFD results (EWT-TsAGI) for 2 basic cases – the blockage effect (at zero lift coefficient value) and the interference of the wing vortex sheet with slotted walls: The measured Cp distribution at the zero lift coefficient was subtracted from the corresponding data at CL=0.5. It has been assumed that the distribution of the wall pressure coefficient Cp is weakly depending on the Re number regarding blockage effects and practically independent on wing vortex sheet interference.

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Assessment of Pulsed-Jet Actuators to Increase Maximum Lift of a Mid-Range Aircraft

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Active Flow Control (AFC) is a subject that has gained considerable interest in the past years as a solution to the never ending demand of further improving the efficiency of aircraft. However, the number of instances where AFC has successfully transitioned from a laboratory prototype to a real-world aeronautical application is small. One of the most important applications of active flow control is the delay of separation to increase the maximum lift coefficient of an aircraft with high-lift devices. Even with modern simulation techniques using high-fidelity computational fluid dynamics (CFD) it is difficult to give a reliable prediction of the effect of AFC on the maximum-lift coefficient of a full-scale transport aircraft that employs sophisticated high-lift devices. Theoretical studies on a two-dimensional wing with slat and flap demonstrated a possible increase of clmax of 0.7. Even though the benefits are difficult to quantify, the penalties in terms of power consumption and weight addition can be estimated using knowledge-based design principles and first-order analysis techniques. In this paper the effect of a pneumatic pulsed-jet actuator on the fuel weight and maximum take-off weight of a midrange, high-subsonic jet transport is considered under the assumption of an assumed increase in maximum lift coefficient. It is investigated what increase in the maximum lift coefficient is required to justify the added weight and power off-take that are accompany the integration of pulsed-jet actuators. This reverse approach to the assessment pulsed-jet actuators does not require an expensive and unreliable CFD investigation and can gives a first indication of the feasibility of such a system.
The approach that is taken is as follows. First, a set of top-level mission requirements is specified. In the subsequent level an automated conceptual design process for transport aircraft synthesizes an aircraft based on top-level requirements according to the process documented by Elmendorp et al. Here, the performance indicators such as fuel consumption and maximum take-off weight are estimated for various aircraft configurations and technology implementations. This layer, in turn, interfaces with a more detailed design layer which contains an automated design methodology for the system architecture of the new technology. Here, the technology performance metrics such as system weight and power consumption are estimated.
For this case study, the Pulsed Jet Actuators (PJA) under development by Fraunhofer ENAS are used. This type of actuator makes use of piezoceramics to achieve the pulsation of the jet stream. Four standard strip of 10 orifices are mounted next to each other to form a strip 40 cm long containing 40 orifices. The Fraunhofer PJA concept is based on single piezoelectric elements that are suitable to switch every single orifice individually. The chamber's inlet is connected to an air supply and the outlet is formed as an orifice.
To compute the weight and power consumption of the PJA system, the full system architecture inside the aircraft is automatically designed. Apart from the actuators, this consists of pneumatic piping with optional pump and an electrical wiring system to power and control the actuators. Both systems are automatically designed using design rules that were captured from industry practice. The design software merely uses the location of the actuators, power centers, and pressure source to automatically determine the shortest route for piping and wiring using predefined paths and levels of redundancy. Subsequently, the weight of the system is estimated and the required power (both electrical and pneumatic) is computed.
The method described above was applied to a test-case with similar top-level requirements to an Airbus A320. Two key performance indicators (KPIs) are investigated: fuel mass and take-off mass. From the results it can be deduced that a typical increase of CLmax on the order of 0.2-0.4 is required to justify the added weight and power off-takes of the engine. Based on the theoretically estimated (two-dimensional) clmax of 0.7, it seems plausible that PJAs can lead to a decrease in fuel consumption and maximum take-off weight for a mid-range aircraft such as the A320. However, if experimental studies demonstrate that the gain in CLmax remains below 0.4, it is not beneficial for fuel consumption or maximum take-off weight to integrate these PJAs in a mid- range aircraft.

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DNW innovations in wind tunnel testing - New moving belt system for Large Low speed Facility -

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The German Dutch Wind tunnels DNW is one of Europe’s most advanced and specialized organizations for wind tunnel testing. DNW’s eleven wind tunnels include subsonic, transonic and supersonic facilities, and provide experimental aerodynamic simulation capabilities to a global user community at large. DNW provides techniques for aerodynamic, aero acoustic or aero elastic simulations and tests of scale models in a controlled environment. Its experimental simulation techniques capture the essence of the issues to be investigated.
The Large Low-speed Facility (LLF) in Marknesse (the Netherlands) is an industrial wind tunnel for the low-speed domain. It is a closed circuit, atmospheric, continuous low-speed wind tunnel with one closed wall and one configurable (slotted) wall test section and an open jet. Low speed means testing of aircraft in take-off and landing flight configurations and therefor DNW focusses its investments for the LLF on safety (ground proximity, powered and unpowered) and environmental issues (acoustics) related testing capabilities.
Recent DNW-LLF upgrade programs focussed on ground proximity simulation (procurement of a new moving belt system) and significant reduction of background noise levels to improve its capabilities and market attractiveness. The main driver for the latter initiatives is a clear trend i.e. continuous reduction of aircraft noise levels. Funding support was provided by the Ministry of Economic Affairs (the Netherlands, the German Aerospace Center DLR and the European Commission through EU 7th Framework European Strategic Wind tunnels Improved Research Potential ESWIRP.
To realistically represent the proximity of the ground a moving belt ground plane technique is in use at DNW-LLF already for quite some time. Its ground plane consists of a flexible belt that moves at wind speeds upto 40 m/s. In recent years a new system with associated drive and

controls has been developed by MTS Systems Cooperation (US) that allows testing at 80 m/s with a stable 6 m wide ground floor since the original polymeric belt has been replaced by steel sheet. MTS, succeeded in developing the system for DNW-LLF, based on technology especially used in automotive wind tunnels (that only have a width of 1.1 – 3.2 m). The 1 mm thick sheet runs on large hardened steel rollers. A sophisticated suction/blowing system keeps the belt flat under large aerodynamic loading when testing aircraft in ground proximity. A boundary layer removal system and the reinjection scoop complement the system. By optimizing scoop, breather and flap settings a homogeneous static pressure distribution above the major part of the belt has been achieved for the whole belt speed range.
The new system has been successfully taken into operation in spring 2013 and applied for various industrial tests at DNW LLF. The paper will further detail the various development steps taken for the new moving belt system, elaborate on the calibration activities conducted and show some results of typical applications.

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Flight-physical aspects and methods of future military aircraft designs

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Modern multirole combat aircraft have to cover a wide scope of performance and manoeuvrability imposing challenging flow-control measures to achieve care-free handling and at the same time to meet range and payload capacities. The longevity of such designs has to be achieved by capability stretching not only via equipment modernization but with the same effort by smart aerodynamic enhancers. The selection of which is assisted by modern flow simulation tools and sophisticated test-facilities, however the design and shaping still is an art when complex flows have to be tamed. Long-range reconnaissance and surveillance tasks materialize into unmanned aircraft of some previously unknown design-space. Fragile, high aspect-ratio configurations – sailplanes only at a first glance -, experience some Reynolds-number effects and become efficient only via the integration of high performance wing technology. The so called asymmetric war-fare will challenge nowadays surveillance and counter-insurgency capabilities with anti-air-systems. Simple missiles, the adaptation of even older combat aircraft or militarized civil general aviation ones may force higher speed and agility into these platforms and these being combined with some signature challenges. More and more influenced by compromises in between flight-physics and signature, the requirements of performance, manoeuvrability and low RCS-signatures must be fulfilled by a common shaping. This may relinquish traditional elements of design in the medium and higher angle-of-attack regime, at sub- and transonic speeds. Constraints are imposed on control-systems. Slats, flaps, roll-devices and classical yaw-controls together with classical flow control via vortex-generators are undesirable. Here the flight-physical properties must be designed into the plan-form, profiles, twist and a continuous blending of these. This can be achieved only with a deeper understanding of the flows complex behaviour to allow for capable and safe designs. Many features of these complex vortex-systems, eventually being combined with transonic effects, especially at the borders of the flight-envelopes, are not yet understood to make the development a straight forward approach. Some aerodynamic problems are presented and modern methods for analysis and design are discussed. Very often numerical flow-simulations help to analyse the task at hand properly. However, many challenges only can be accessed and solved by high-fidelity physical models and the simulation of complex geometries. For these ends, a very detailed validation must be provided by suited experiments also in the transonic regime and even more so at true flight Reynolds-number conditions.

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Autonomous planning and replanning of a single Unmanned Aerial Vehicle: strategies and simulations

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The aim of this paper is to define and elaborate the main features of an Unmanned Aerial System (UAS) in order to make it as autonomous as possible. In this context, the authors would propose and verify possible strategies for an autonomous replanning of a route in case out-of-nominal situations would happen. This activity has been performed within the framework of SMAT F2, an Italian project in which Politecnico di Torino is involved. SMAT (Sistema di Monitoraggio Avanzato del Territorio – Advanced Territory Monitoring System) is a project funded by Regione Piemonte and Fondo Europeo di Sviluppo Regionale (F.E.S.R.), now at its second phase, that studies and demonstrates an advanced monitoring system able to comply with planned task (e.g. traffic monitoring, pollution monitoring, plantations observation and measurements, etc.) and to prevent and monitor different types of emergency events (e.g. floods, fires, landslips, etc.).
In the first part of the paper, a general methodology to perform an autonomous re-planning is proposed, with a particular attention to the techniques already proposed and studied by other research teams [1], [2]. This activity can be seen as a preliminary study to create an algorithm able to propose alternative routes in case replanning actions would be required. In this context, it was necessary to define how many and what kind of critical conditions the UAS has to recognize and correct autonomously. All these critical conditions have been separated in different scenarios.
After having analysed in depth the requirements provided by the principal task partners, it was decided to limit the analysis to the following scenarios:
Weather phenomena (No Fly Zone or NFZ) and Permanent No Fly Zone Avoidance; New Targets/New Waypoints from SSC;
Vehicle Failure/Payload Failure that require to land;
Vehicle Failure and Payload Failure that degrade the overall mission.
With the aim of studying the replanning algorithms for each above-mentioned scenario, the earlier phase of this work leads with the definition of the logical processes that stand behind them. The most important purpose of this activity is to define the main requirements and all the logical processes required to allow the mission planning and re-planning. This phase of the work produced two different outputs. The first consists in a flow chart definition aimed to describe the logical processes of the mission re-planning. The other output is a top-level requirement definition.
For this purpose, a typical System Engineering approach has been proposed and applied, exploiting its iterative and recursive characteristics. All these evaluations would be a guideline for the generation of a code able to autonomously propose in real-time replanned routes, like those proposed in literature [3], [4].
The second part of the work deals with the simulations of the previous identified scenarios using a specific software called STK (Systems Tool

Kit, previously Satellite Tool Kit). This tool is able to determine not only the assets, the attitude, the dynamic position in the geographical space and in the time of the considered UAV, but also the existing relationships among the objects modelled including possible relationships (i.e. accesses) taking into account a certain number of simultaneous constraining conditions.
In conclusion, the paper would like to highlight some peculiar aspects of an autonomous re- planning in order to enhance the efficiency and efficacy of an Unmanned Aerial System. This is considered as a fundamental step to develop and simulate replanning solutions for a fleet of UAVs.

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A new computational framework for UAV quadrotor noise prediction

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Noise emissions play an important role on the sustainability of aviation due to its negative impact on human health. Most research has been focused in rotorcraft and fixed-wing aircraft noise prediction, but emergent generations of aerial vehicles, in the form of Unmanned Aerial Vehicles (UAVs), present a new field of study. The prediction of UAV noise is a challenging new field of research, given the wide range of applications. This work presents a numerical framework for noise prediction, already validated for rotorcraft, applied to a quadrotor UAV. The framework is composed by in-house aerodynamics and acoustics tools, which take advantage of GPU programming to significantly accelerate the simulation. In order to obtain reliable experimental data, exhaustive experimental tests were performed in the controlled environment of an anechoic chamber. The present work describes the numerical and experimental framework for UAV quadrotor noise prediction and the correlation between the results.

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Design Methodology for Trailing-Edge High-Lift Mechanisms

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In today's highly competitive aviation industry, continuous efforts are being directed towards reducing design time and simplifying systems. One of the prime aspects of aircraft design is the development of high-lift systems such as flaps and slats to increase the maximum lift coefficient of the aircraft. The associated design and integration of high-lift systems is highly multi-disciplinary and iterative in nature, due to tight dependencies between aerodynamics, mechanism kinematics, and structures. The maximum lift coefficient is often actively constraining the size of the aircraft wing. Therefore, the design of the high-lift system should preferably be done early in the design cycle to investigate what combination of flaps and slats are required to meet a targeted maximum lift coefficient. At the same time, it is of interest to know at what cost, in terms of mechanism complexity, weight, size and required actuator power, this maximum lift coefficient is achieved. Various mechanisms should be considered and analysed in the early phases of the aircraft design to judge which one is most suitable. Unfortunately, synthesizing various mechanisms given a set of three-dimensional geometrical constraints for stowed and (partially) deployed position(s) is complex and time consuming. Therefore, this paper details a design and analysis methodology to swiftly and accurately determine the topology of kinematic mechanisms for single-slotted (Fowler) flaps. In addition, based on the flap loads, a first order estimation of actuator power and mechanism weight is given.
Current methods for weight and power estimation of high-lift systems rely on empirically derived equations which are not sensitive to design variables and/or load cases. To improve the current design process and provide a design-sensitive estimate of the weight and actuator power, a new methodology has been developed, employing knowledge-based-engineering techniques. One of the main challenges that needed to be overcome was the automated mechanism synthesis that would allow the parallel deployment of inboard and outboard flap on tapered and swept wings while keeping the distance between the two flaps at a minimum to prevent air leaking from the lower flap surface to the upper flap surface. This challenge was overcome by employing a series of design rules to automatically orient and position the flap based on simple designer input on the flap gap, flap overlap and flap deflection in deployed and/or partially deployed position. The high-lift system that could be designed using these rules included four common kinematic mechanisms: dropped-hinge, hooked-track, four-bar linkage, and linked track. The development scope was limited to single-slotted flaps.
The developed methodology works as follows: a clean wing geometry is first generated, after which the designer first determines the edge flap layout in terms of size and location on the wing. Subsequently, the flap settings need to be specified using common aerodynamic design parameters such as flap gap, overlap, and flap deflection. If a dropped-hinge mechanism is selected the designer can only specify these parameters for on deployment condition. If any of the other three mechanisms is selected, two positions of the flap can be specified (e.g. a take-off and landing position). Furthermore, the designer specifies the number of flap supports and the spanwise position of their location. Based on that input, the kinematic mechanisms are automatically synthesized using the design rules. Support structures such as tracks are all modelled as trusses. The designer is still able to dictate important design detail such as the relative position of the actuation point (dropped hinge mechanism), the dimensions of the support truss (four-bar mechanism) or track height (hooked track and link track mechanism). These have an effect on the structural weight of the mechanism but also on the depth and therefore the drag of the mechanism. When a feasible design is obtained, a multi-body model of the mechanism is generated. Using a multi-body analysis it is possible to estimate the loads inside the mechanism and the control actuators, provided that an aerodynamic load is acting on flap. The aerodynamic normal load on the flap is determined using an empirical estimation method by ESDU. Based on the loads inside the mechanism components, definition of material allowables and safety factors, the mechanisms and actuating drive train are sized. This leads to a determination of system weight and drive motor power.
In order to get an indication of the applied sizing method accuracy, a measurement of the outboard hooked-track mechanism of a VFW-614 flap has been carried out. The measured weight is compared to a modelled hooked track mechanism, synthesized and sized specifically for the VFW-614 wing. The results show a 13% underestimation of mechanism weight, which is likely to be caused by modelling simplifications and an erroneous normal load prediction. However, given the simplifications in the model and analysis methods, these results were considered to be acceptable.
The method described above was used in a fictional trade study for the inboard mechanism of the Boeing 777 outboard flap. Based on the

results in terms of weight, depth, and required mechanical work, the following conclusions were drawn. Only the four-bar linkage and linked-track mechanism met the aerodynamic positioning targets at cruise, take-off and landing. The four-bar mechanism had a moderate fairing depth (35% of flap chord) and was the lightest of the two (61kg). It had a large peak power (11kW) and actuation torque (47kNm) that could be reduced by choosing a suitable screw pitch and transmission gear ratios. This design should be favoured when low weight is prioritized. The link-track mechanism was heavier (66kg), but had a shallow depth (20% of flap chord) and therefore required a smaller fairing. Its peak power was only 1.2kW and had a small required actuation torque of 12kNm. This design should be favoured when small fairings and a small motor are prioritized.

The developed methodology has been integrated in a software application. The geometry is modelled using the knowledge-based engineering software GDL. The multi-body analysis is carried out in SimMechanics and the sizing routine is performed in Matlab. After a design cycle is completed, an automatically generated report presents the obtained feasible design. The total computation time for a typical flap on a standard desktop PC for the synthesis, analysis, and sizing is less than one minute. The application provides designers with the possibility to combine the aerodynamic, kinematic and mechanical aspects in one design environment. By quickly obtaining geometrical and sizing estimates, in addition to identifying design sensitivities, trade-offs can be made earlier in the design process. This reduces the design time and simplifies the design process for the kinematic system of high-lift devices.

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Envisat removal by robotic and net capture means. Results of the Airbus DS led e.Deorbit Phase A ESA study

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In the frame of the Airbus DS led e.Deorbit Phase A ESA study, Airbus DS and its project partners SSTL, Aviospace, DLR and GMV have studied three different mission options for the removal of Envisat from orbit at phase A level.

The e.Deorbit mission primary objective as stated by ESA is as follows: "Remove a single large ESA-owned Space Debris from the LEO protected zone". This mission represents a new type of mission with specific needs like navigation, capture, controlled deorbit or alternatively reorbit. Three mission options were considered and analysed in the study: 1/ Flexible link and deorbit, 2/ Rigid link and deorbit and 3/ Reorbit (either flexible or rigid link).

Airbus DS recommended selecting Envisat as target. Envisat has ceased operations in April 2012 and fits the criteria (high mass, high collision probability, high altitude, ESA owned object in LEO) specified by ESA in the study objectives.

Potential mission concepts for the three mission options were analysed and traded with following result: 1/ Flexible link and deorbit = Net capture, 2/ Rigid link and deorbit = Robotic capture and 3/ Reorbit = Robotic capture.plus disposal by electric propulsion

The three selected mission concepts were elaborated w.r.t. the definition of the mission phases, the characterization of the capture technique, the analysis of the GNC performances for the definition of the thruster and navigation configurations and the chaser configuration including the main subsystems. The system budgets for the mass, the delta-V and the power were generated for all mission options. The risks and the opportunities for such missions were defined considering the likelihood and the severity of each risk item. The communication infrastructure including the ground stations and the potential link obstruction by the target were assessed. The deorbit and reorbit strategies were as well identified applying chemical and electrical propulsion respectively. The system level trade-off to select the Airbus DS led Consortium preferred system concept and alternatives were conducted resulting in the following ranking: 1/ Robotic arm capture and deorbitation (Option 2), 2/ Robotic arm capture and reorbitation (Option 3), 3/ Net capture and deorbitation (Option 1). The scores obtained for each mission option are close together.

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Clusterization of airport cities and cluster dynamics for an air passenger demand network topology forecast based on socio-economic development scenario

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1. Introduction

Forecast of air passenger demand is an important basis for planning in the constantly changing aviation transportation system. The aircraft industry, and researchers, study air passenger demand and develop forecast models for it using various techniques and levels of aggregation. Each shows various methods to calculate the demand in particular airports (Erma Suryani et al) or on particular routes (Dr. Md. Jobair Bin Alam et al, Tobias Grosche et al). However, these studies do not present a method of forecasting an evolution of air passenger demand between cities at a global level. They fail to take into account the potential for changes in the number of airport- connected cities when forecasting demand within an air transport system.

The study Forecast of origin-destination air passenger demand between global city pairs using future socio-economic development scenarios proposes a method of forecasting an evolution of the air travel passenger demand between cities, taking into account the probability of changes to the number of airport-connected cities within an air transport system. In other words, the proposed method forecasts passenger demand as well as changes to the topology of an ‘air passenger demand network’, within a forecast period. The method computes air passenger demand at any given point of time within the forecast period. The method has two steps: forecasting the potential for demand between city-pairs and calculating demand on new and existing connections. Forecasting the potential for demand between city pairs determines whether the potential for demand between a given city-pair exists. It does this by first defining a utility as an ‘attractive force’ between cities. This attractive force is in turn presented through a gravity model based on socio- economical information of cities, in pairs, and the distance between them.

To define air passenger demand in the demand network between cities in a discrete "slice" of a socio-economic scenario the probability of air passenger demand appearing has to be assessed. Because socio-economic conditions vary between cities, a clusterization of cities based on socio- economic factors must be made.

2. Clusterization

The basic idea of clusterization is to divide a set of cities into several groups (clusters) where each cluster represents a subset of cities. Cities

in a cluster are united by similar characteristics. In
other words, if clustering is done by socio-economic indicators, cities within one cluster possess the same socio-economic indicators, compared with cities in other clusters.
In this study normal mixture approach is used to divide cities into groups by socio-economic indicators. This approach estimates the probability that an element (city) is in each cluster. The normal mixture approach is chosen because it works well in overlapping areas. In the overlap areas, cities from several clusters share the same space. It is especially important to use normal mixtures rather than other clustering methods (e.g. k-means clustering) if one wants an accurate estimate of the total population in each group.
This study introduces ‘cluster dynamics’. Cluster dynamics is a method of calculating the probability that a given element (city) will appear within a given cluster at a given point in time. This method is how the cities are allocated to the various clusters. This process reveals the changes over time of city distributions within the clusters. During the forecast period, cluster centres remain fixed as at the base year and do not change. Over the forecast period, the socio- economic indicators of the cities change. These changes effect the probability of membership of given cities in given clusters.
3. Preliminary results
The starting point of the forecast is the air passenger demand network of the base year 2012. From the ADI (Sabre Airport Data Intelligence) database received 4435 settlements where is at least one airport from which in 2012 at least one passenger had a flight from/to that settlement. City populations and city GDP make up the socio-economic characteristic used within the study. City population data has been obtained from the UN and the MaxMind database. GDP data has been compiled from the World Bank and the UN. Socio-economic scenario on city level has been developed using Randers “2052” scenario. Socio-economic development scenario on city level contains time series of city GDPs and city populations 2012-2050 for every city obtained from ADI database for 2012.
For the base year clasterization to 9 clusters has been made by city populations, city GDP and GDP per capita. Nine clusters cover ‘small’, ‘middle’ and ‘big’ cities by populations and ‘poor’,
‘middle class’ and ‘rich’ cities by GDP. Number of cities in each cluster and clusters means (cluster centres) is shown in Fig.1.
Cluster dynamics is shown in Fig.2. For the purposes of the study, cluster names derived from cluster means (of population and per capita GDP) were adopted.
4. Outline
The final paper will present the detailed description of clusterization process. The paper will include:
Detailed justification for choosing the normal mixture approach for clusterization, clustering parameters and number of clusters;
Description of cluster dynamic approach;
Cities clusters changes based on socio-economic forecast; and
Implementation of cluster dynamics for an air passenger demand network topology forecast.

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Giving Space to Space: Bachelor Education in Space Engineering at Delft University of Technology

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The Faculty of Aerospace Engineering at the Delft University of Technology has a strong educational and research reputation and is, with about 1400 BSc and 1000 MSc students in 2014, one of the largest educational institutes in the Western world dedicated to aerospace engineering. The faculty covers almost all technical and societal topics related to aeronautical and space engineering, design and operations. The 3-years BSc and 2-years MSc in Aerospace Engineering are fully taught in English and attract about one-third of international students (32% of the total) who contribute to create an open-minded stimulating environment and a good awareness of cultural diversity.
In the period 2006 till 2010, the BSc and MSc programs of the Faculty went through an extensive innovation and development phase, resulting in the current curriculum aiming at educating “T- shaped” graduates. The broad bar of the T-shape is provided in the BSc, by educating a broad academic background in the basic engineering sciences as well as consolidated knowledge of aerospace engineering and technology and the development of academic intellectual and engineering skills and attitudes to analyse, apply, synthesize and design. The stem of the T-shape is provided in the MSc, that teaches in-depth aerospace engineering and focuses on detailed knowledge of and experience in one or more sub-disciplines. This, in turn, allows students to become prepared for a successful career in aerospace engineering.
This paper will focus on the BSc program in particular, which is structured to resemble a real design engineering cycle. To this respect, five of the six semesters of the BSc are dedicated to one of the steps of the design cycle: exploration, conceptual design, detailed design, test & simulation, verification & validation. The remaining semester is devoted to a minor program, for which the students are encouraged to look into another engineering field or discipline. The prime
objective of the minor program is the broadening of student’s capabilities in engineering, natural or social sciences: a broadening of the bar of the T-shape beyond their discipline, or beyond engineering at large.
The programs are set in the context of the practice of design and research in aerospace engineering. Especially the BSc is about how one engineers aircraft and spacecraft. It follows the Conceive-Design-Implement-Operate (CDIO) approach and focuses on aircraft and spacecraft engineering and technology and professional roles and activities of aerospace engineers. A characteristic of the BSc curriculum is the presence of a significant number of courses that focus on specific aspects of aerospace engineering and technology already from the first year of study. These courses are structured in a multi-disciplinary way, often featuring an “aeronautical” and a “spaceflight” part within the framework of the same course. In addition, each semester includes one design project of increasing complexity from knowing to application, synthesis and evaluation. Each project either has a compulsory aeronautical and spaceflight component for all students, or offers a choice for any of the two.
As a direct consequence of this structure, the BSc program is characterized by many courses and projects over the full three years that share common aerospace principles and contain specific
subject matter about space engineering and technology. These include, in particular:
-) Introduction to Aerospace Engineering (1st year 1st semester), on the fundamental principles of rockets, orbits, launch trajectories and

spacecraft configurations;
-) Aerospace Design and Systems Engineering Elements I (1st year 2nd semester), giving an introduction in the systems engineering methodology and a first general characterization of the different sub-systems of spacecraft and launch vehicles;
-) System Design (2nd year 1st semester), a design project for groups of 8-9 students intended to provide to the students a first opportunity to familiarize with the spacecraft design process;
-) Aerospace Design and Systems Engineering Elements II (2nd year 1st semester), on the fundamentals of systems engineering and the most important design aspects related to the spacecraft Attitude Determination and Control and Communications sub-systems;
-) Test, Analysis and Simulation (2nd year 2nd semester), a design/research project for groups of
8-9 students aiming at processing, analysing and discussing real experimental data coming from actual space tests or missions;
-) Flight and Orbital Mechanics (2nd year 2nd semester), on the detailed equations of motion and perturbations of launch trajectories, planetary orbits and interplanetary transfers;
-) Propulsion and Power (2nd year 2nd semester), on the fundamentals of space electrical power systems and rocket propulsion;
-) Systems Engineering and Aerospace Design (3rd year 1st semester), on the tools, techniques and basic concepts of space systems engineering;
-) Aerospace Flight Dynamics and Simulation (3rd year 1st semester), on the stability and dynamic behaviour of space vehicles;
-) Design Synthesis (3rd year 2nd semester), a design project for groups of 9-11 students intended to provide to the students an opportunity to obtain “design experience” through the design of a space mission/spacecraft/space launch vehicle, in which the problems are open-ended and authentic
The paper will highlight the challenges and opportunities connected to incorporating and interweaving space engineering education with aeronautical engineering, as experienced by the lecturers and tutors directly involved in the courses. The learning objectives of specific courses and projects, their teaching and learning styles as well as their implementation and required facilities will be discussed in detail. The feedback received from students on individual courses and on the whole program will also be presented and discussed.

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European Personal Aero-Transportation. Using of the Double-Flutter Flight Principle for Manufacturing of Personal Flying-Cars by European Aircraft and Car Manufacturers

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It is very clear that the car industry is in a great difficulty due to market demand decreasing. A first cause is oil reserves which will vanish in the next several decades. Substituting of regular car with electric car will be only a temporary solution for personal transportation because another root cause of decreasing of cars demand still stands: crowding of cities and roads with interminable lines of cars. It is very clear for everybody that in the most of our cities the classic car lost its main advantage: speed. On the other thousands of cars staying in traffic creates another problem: carbon dioxide and monoxide emissions and the subsequent greenhouse effects. Not only cities are crowded. Even the motorways and roads outside the cities became crowded. It seems that increasing of classic car number arrived in a critical point and new solutions for our civilization development should be found now. The 100+ years of history of classic car as the main personal transportation mean of our civilization came to an end and another mean should substitute it. The present paper affirms that the next personal transportation mean will be the flying-car using the double-flutter flight principle exposed by the authors in a previous paper. The double-flutter flight principle consists in lift producing by means of two flutter moves. A piston engine having an oscillating spindle induces vibration of an elastic grid which at its turn induces oscillation of a number of blades. That grid together with oscillating blades forms an efficient permeable surface which pushes downwards the surrounded air. According to the law (theorem) of momentum conservation a force appears which is lifting the flying-car upwards. According to calculations, the flight of flying-car using the double-flutter flight principle is about three times more efficient than the present helicopters. On the other hand, the flying-cars using the double-flutter flight principle are much more reliable than helicopters because these flying-cars do not use rotors for lift (rotors of helicopters flying in cities can hit buildings, electricity cables, trees etc.).European car producers together with aircraft manufacturers should take into account possibility as the classic car to be substituted with the flying-car in the not very far future. Conversion of classic car production lines in manufacturing lines for production of flying-cars is affordable if the flying-car uses the double- flutter flying principle. This affordable conversion is sustained by the following facts: the flying-car that uses the double-flutter flying principle uses current piston engines with reasonable adaptations for reduction of weight and delivery of power by means of oscillations move instead of rotation. The composite manufacturing lines will be used with small changes for manufacturing of cabin, engine fairing and permeable surface grid of flying-car. In the first instance the price of a flying-car will be higher than the price of a classic car but in 10-15 years the prices of the two should be about the same. This will happen because the flying-car using the double-flutter flight principle in essence a simple machine which is not more complicated than the classic car: The cabin is made of composite materials having 2…5 chairs, the engine is a piston one which transmits power to the permeable surface by means of a connecting rod which is articulated by the middle of the engine crankshaft, the landing gear is composed of three small wheels placed under cabin. Developing of European flying-car could be an important and desirable action of European Community because the world market for flying-cars is evaluated at €400 billions per year.

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Space Capsule Using Energy of Gravitational Field for Flight Control

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This paper presents a space capsule which uses energy of gravitational field of Earth for flight control. This capsule can be used for current transportation between Earth and International Space Station (ISS) or the future space hotels. The Space Shuttle was considered for three decades the best solution for transportation of materials and crews to Earth’s orbits and back. However, reality has shown that the space shuttles are extremely expensive vehicles both to be built and maintained than the classic rockets and space capsules. In addition, the reliability of space shuttle as transportation mean was proved to be under reliability of classic mean represented by rocket + space capsule.

These facts brought again to life the classic rocket and capsule. Specialists estimate today that over the next 50-100 years, rockets and space capsules will be the main transportation means to space and back to Earth. On the other hand, it is estimated that transportation needs between Earth surface and Earth orbit will increase due to increasing of frequency of transports to the International Space Station and developing of the new commercial branch of space tourism. At present there are already announcements that national and private space stations and space hotels will be built in the next years on Earth orbit. The increased traffic between orbit and the Earth's surface will raise difficult problems related by cost and safety. It will be really very costly as re-entry of tens of capsules to be assisted day and night by large control teams of scientists located on Earth as in the present. It is expected as the transportation capacity of a capsule to increase to 5-7 places or more and crews to have a more important role in manoeuvring of space capsule. The new space capsules should be much improved in order to accomplish these new transportation requirements. The space capsule proposed in this paper is advanced space equipment able to face the future challenges generated by the increasing of space traffic. The new capsule is braking in atmosphere as the classic one using ablative layers and parachute. In addition the new capsule has two extendable symmetric self-rotating plates which can be used to create additional lift and manoeuvring of capsule. The plates are telescopically folded inside the space capsule. These plates can rotate independently in bearings fixed by capsule structure. After the capsule speed is reduced by parachute, the plates are extended progressively. Due to Mouillard effect, the plates begin to rotate and an aerodynamic force square to direction of capsule speed appears. This force is decomposed in a vertical force (lift force) and tangential force which is a traction force as in the case of a glider. These forces are used both for reduction of capsule descending speed and for capsule manoeuvring. The capsule manoeuvring can be done easily if for example the length of the left side plate is reduced in comparison with the length of the right side plate. Experiments done at low scale shows that capsule turns in this case to left. Another possibility is to create symmetric holes in the both plates. The both holes are closed by sliding covers. When for example the cover begins to open hole of right plate while the hole of left plate is still closed, the experiments show that the capsule turns to right. The descending speed of capsule can be controlled by means of plates' length. If the length of plates increases, the lift force increases and descending speed decreases and vice-versa. Such a capsule can even land on a regular tarmac because the descending speed and flight direction can be controlled by means of the length of plates. Another important advantage of the new type of capsule is that the two plates constitute a backup for parachute. In the case of a classic capsule, if the parachute does not open, the capsule and crew are completely lost. In the case of the new type of capsule, if the parachute fails to open, the plates are progressively extended and the capsule is braked by the drag produced by the Mouillard effect while the lift produced by the same effect Mouillard changes the capsule trajectory in a gliding one. Thus, the capsule begins to fly like glider, can be maneuvered like a glider and can land on a regular tarmac. In this case, although the breaking force created by plates is smaller than the braking force created by a parachute, the trajectory is much lengthened and the breaking of capsule in air is done in a longer time.

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Special Equipment Which Uses Concentrated Solar Light for Earth Protection Against Asteroids-Advanced Design and Technology

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This paper presents advanced design and technology of special equipment (here called 'cannon') which uses concentrated solar light for destruction of dangerous asteroids.

According to Einstein General Theory of Relativity, elliptical orbit of any cosmic body is rotating around ellipse center (i.e. the perihelion of orbit is moving continuously). On the other hand, the trajectories of cosmic bodies are permanently affected by the gravity of other cosmic bodies which are moving, too. In the case o asteroids which have relatively small masses, orbit changes can be important leading to the danger of collision with Earth. At this moment our civilization has practically no efficient and reliable mean to destroy or diverge the dangerous asteroids form their collision trajectory with Earth. The idea of the cannon which uses concentrated solar light for Earth protection against asteroids is a new one. This idea was presented for the first time by the authors of this paper in 2014. Mainly, this equipment is composed of one large and one small parabolic mirror having the same focal point and coincident axes. The mirrors are positioned face to face i.e., the concave side of the large parabolic mirror is oriented to the concave side of the small parabolic mirror. The light rays coming from Sun are focalized by the large parabolic mirror to its focal point. The light rays are then reflected by the small parabolic mirror (which has the same focal point as the large parabolic mirror) in parallel rays along the parabola axis. The beam of concentrated light having diameter 'd' equally to the diameter of small parabolic mirror passes through one hole having diameter 'd+' placed in the center of large parabolic mirror. An articulated

mirror tube is fixed on the convex side of the large parabolic mirror by means of a spherical articulation. This mirror tube is used for directing of the concentrated light beam toward the asteroid. The power of canon is of the order of terawatts and it can vaporize for example an iron asteroid of 100 tones in seconds. If asteroid too heavy, the concentrated light beam can vaporize only locally the asteroid matter and the reaction force created by vapours will deviate the asteroid from the collision trajectory with Earth. Due to the high speed of light, this type of canon can hit the asteroid when it is still at a long distance by Earth. The cannon can be built on an orbit around the Earth and then it can be placed on a solar orbit as the Kepler telescope. When such a cannon is placed permanently on a terrestrial orbit, it can be used for cleaning of space surrounded by debris.

In this paper are done calculations of cannon mass, power and heat transfer for several diameters of the large and small parabolic mirrors. The paper presents advanced design of mirrors based on hexagonal, square or triangular cells and a new technology for manufacturing of reflecting foils of mirrors. The resistance structure of mirrors is composed of multiple hexagonal, square or triangular cells made of titanium tubes having very thin walls. The titanium tubes are gold plated for a good reflectivity. The reflective material of mirrors is a gold plated graphene foil which is lighter and stronger than the classic material Mylar. The gold has a high reflectivity and the graphene strongly dissipates the heat in space through radiation as a black body. In this way, the both parabolic mirrors are intensively cooled. The gold plated graphene foil is stretched on the hexagonal, square or triangular cells composing the resistance structure of mirrors.

This equipment which will operate near Earth will be the subject of natural bombardment with particles of the so called unorganized matter of Universe (micrometeorites, interplanetary dust and gas, solar wind, cosmic radiation, etc.). The effect of unorganized matter on equipment integrity and operating capacity is be analysed in this paper. This analyse will permit evaluation of equipment active life in space. The advanced design and technology presented in this paper is a basis for development of design and technology of real equipment placed in space for Earth protection against asteroids and cleaning the space by debris.

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Aerodynamic Validation of a Parametric Airfoil Description

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This paper reports the aerodynamic validation of a parameterized modelling of wing profiles. The parameterization uses 4 piece-wise C1 continuous cubic Beziér curves to model the wing profile envelope. A large set of wing profiles were compared with respect to similarity between parametric model and point cloud data. In particular boundary layer properties such as transition point position and skin friction distribution; also critical Mach number and stall behaviour is compared between the two sets of wing profile modelling in order to support the conclusion that the two methods are equivalent.

I. Introduction A fundamental part of aircraft design involves wing airfoil design and optimization, establishing an outer shape of the wing, which has good aerodynamic performance for the design mission, good internal volume distribution for fuel and systems and which also serves as an efficient structural member supporting the load of the weight of the aircraft. There are different methods for airfoil modelling used, depending on where in the design loop the work is done. In the conceptual phase a flat plate might suffice as wing profile model, while in later stages the airfoil might be selected from a database or being modifications of database airfoils. One key aspect of the data making up the airfoil is how it is stored. Several approaches to parameterization of wing profiles can be found in the literature: Airfoils can be described by point clouds as done in most airfoil libraries [1] or they could be described as mathematical functions as is the case with the NACA 4 digit libraries [2] [3] and as the Joukowsky airfoils [4]. A more modern representation method is the class function/shape function transformation CST method[5]. The wing profile representation method used for this paper, the Beziér interpolation is described in [6].The airfoil's top and bottom curves are both modelled by two cubic Beziér curves in parametric form, being C1 continuous at the defined top and bottom points. At the leading edge, the profile will also be guaranteed C1 continuous, whereas the trailing edge is allowed to be discontinuous to allow for a trailing edge gap.Generally a four part cubic Beziér curve requires 13 control points are needed to define the curve, giving 26 variables when both x and y coordinates are taken into account. However when some symmetries and simplifications are taken into account the number of independent parameters is reduced to 14. In order to ascertain that the parametric model indeed is accurately modelling the aerodynamic properties of the original point cloud airfoil, a comparative study was made. The Aerodynamic properties of a large set of airfoils were analysed using the CFD software Fluent. The computation was performed used automated grid generation with C-grids and grid convergence analysis for both the point cloud airfoils and the parameterized airfoils. The turbulence was handled with Menter's SST k-? model, developed to accurately predict separation in adverse pressure gradient flow. Skin friction and pressure coefficient distributions at flight Reynolds and Mach number were collected together with stall angle of attack and post stall behaviour. Figure 1 shows the skin friction coefficient of a Withcomb profile modelled with the point cloud representation and the parameterized curves. Figure 2 show the Nearfield Mach number distribution of a parameterized Whitcomb profile set at zero degrees angle of attack at the critical Mach number. The difference in critical Mach number is less than 1% between the original point cloud and the para meterized profile. By collecting comparative data for a large set of profiles, a statistical analysis of the entire cohort was possible. The preliminary results show a good agreement between the aerodynamic properties of the point cloud representation and the parameterized. In conclusion, the two methods can be said to be equivalent.

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A distributed simulation framework for rapid deployment of research demonstrators

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In aeronautical research the scientist often faces the challenge of demonstrating their results in a way that is more end-user friendly than tables and charts. In Airbus Group Innovations (AGI), demonstrating disruptive technologies already from a very low technology readiness level is essential to confirm customer interest and gather feedback about how they can be further developed. As a result, several lightweight but ad-hoc tools are developed to provide visualization, human interaction and software in the loop capable demonstrators – a non-value adding task that consumes time that would be better used in the improvement of the technologies being developed. This scenario led us to identify the need to develop a unified simulation framework for rapid prototyping of simulations in a research environment. In this work, we describe the result of this development, the main design decisions and some example applications.

The initial envisaged applications for such a framework were the integration of trajectory optimization, weather radar and computer vision activities developed within AGI.

At the beginning of the conceptual development phase a challenge was identified – how to convince users to spend their time adapting their existing tools to the new framework? This major risk was mitigated by adopting a design philosophy of minimum effort for the end user and maximum tool flexibility. Without the first, potential users would reject the solution right from the beginning. The second is essential to make sure the users can keep using the tool during their whole research project.

Another critical point during the development phase was making sure that the user could quickly benefit from using the framework. This was done by implementing a large standard library, with tools such as human interaction and 3D rendering – modules that require a lot of effort to be implemented and are not part of our core research activities.

After the development of the requirements document, we started searching for existing solutions that could be adopted. (In the final work, we intend to show the list of solutions we considered with an analysis of each one.)

With the existing solutions not being able of providing the needed ease of implementation, it was decided that a custom framework would be implemented. The resulting program is a distributed simulation framework (DSF) that allows several modules to communicate via a simple text-based protocol over network sockets. This opens the possibility of having modules written in different languages, running in different computers to communicate and operate together.

DSF is built on a client-server architecture, where each client is responsible for one simulation feature (Flight Dynamics, Image Rendering,

User Input, etc.) and the server is responsible for storing and exchanging data between the different clients and controlling the simulation time. Every communication cycle is done in the following order:
• Server collects data that will be sent to a client (e.g. altitude);
• Server sends data to the client;
• Client process data (e.g. uses altitude data to calculate pressure);
• Client answers server as fast as possible with the new data (e.g. sends pressure back to server);
• Server receives data; that is stored in a buffer; and
• Server updates nodes.
This way, every communication cycle is organized in a “server request, client answers” protocol. The data sent on each message pair is pre-established during the connection of the client to the server by exchanging an XML file called contract. (The final paper will describe the synchronization features available in DSF to guarantee real-time capabilities and fully deterministic behaviour)
The generation of synthetic flight images is included on the DSF framework as a modification of the open-source, multi-platform FlightGear Flight Simulator. FlightGear is capable of generating realistic images:
• Of several locations;
• In different weather conditions;
• with an arbitrary number of 3D models (e.g. aircraft, buildings, weather features).
This allows the creation of virtual cameras, that can be used both for visualization and image processing algorithms. The data can be transmitted by inter-process communication methods to the desired modules or be displayed to the user.

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COBRA contactless de-tumbling

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COBRA is a proposed technique to control the motion of a non-cooperative satellite by means of the interaction between the thruster exhaust gases from the chaser and the target satellite. In the original ESA SYSNOVA study the COBRA concept was investigated as an active debris removal system, using contactless technology to deorbit a space debris object and to control its attitude. It was found that the concept is more effective for controlling the attitude of a debris object. An experiment was proposed to modify the attitude state of a space object in the COBRA IRIDES project, which has now been cancelled due to lack of propellant in the chaser spacecraft.
Currently, research continues to effectively use the COBRA concept for detumbling a debris object and controlling its attitude motion prior to capture operations in an ADR mission.
The advantages of the COBRA concept are the following. COBRA is a contactless method to influence the attitude of an uncooperative space object. As such, it removes or reduces the need for complicated synchronization manoeuvres (in which the chaser follows the attitude motion of the target) or complicated manipulator path planning to capture the target. The debris can first be brought into a state in which it is easier to handle by means of a capture device. Furthermore, COBRA is a method that requires very little hardware or new technology in addition to what is already required for rendezvous with space debris.
Many debris objects in LEO eventually settle in a slow rotation state, typically 1 to 2 revolutions per orbit following capture in either an orientation determined by the gravity gradient or the local magnetic field. A notable exception is Envisat, which is currently rotating at a rate of 3.5°/s. If the debris is rotating faster (here assumed to be at an angular velocity of about 1°/s and faster) then direct capture becomes more difficult. The surface speed of the object is of the order of cm/s or larger, and spin synchronisation ΔV of the order of m/s to tens of m/s. Special attention needs to be paid to the detumbling. Detumbling can be performed either pre- or post-capture. If the detumbling is performed pre-capture, then contactless methods such as COBRA are required to detumble the debris. Otherwise, special considerations need to be made in the design of the approach strategy and the detumbling strategy after contact. Pre-capture detumbling is an interesting option in the following cases:
- Structure of capture point of the target, or capture mechanism of chaser unable to withstand high stress (fixed-link detumbling more difficult or impossible);
- Irregularly shaped object with large appendages (higher collision risk);
- Debris capture methods susceptible to rotation rates;
- Fast rotation and high characteristic decay time (higher collision risk);
- High priority target (limited waiting time).
The COBRA concept has an advantage over other detumbling methods because it can handle all conditions stated above. That is, COBRA imparts low structural loads on the target, can operate at a distance outside of the envelope of the target motion and can slow down the target rotation rate to an acceptable value within a reasonable amount of time. Furthermore, 2-axis attitude control can be achieved.
The control of the target object attitude relies on two effects. First, the target object may have an asymmetric shape. In this case the chaser will impart a torque on the target even if the gas jet is directed at the centre of mass of the target. Second, the gas jet can be pointed away from the centre of mass such that the pressure distribution on the surface of the target is non-symmetrical with respect to the centre of mass, even if the target is symmetric. A combination of both techniques ensures that any object can be controlled.
In the first case, a switching strategy can be devised to de-tumble the target. The thruster is switched on when the moment arm is greatest and switched off when the moment arm is small. This strategy works at all distances for which the thruster can efficiently impart a force on the target. The need for accurately pointing the thruster is fairly low for this strategy.
In the second case, the control strategy relies on thruster pointing. For a radially symmetric (spherical) target body the level of torque imparted depends on the differential plume pressure as a function of the angle with the thruster bore sight. This strategy becomes less effective for larger distances because the angular diameter of the target decreases as the distance increases.
Figure 1 shows the detumbling of an asymmetric satellite using a switching strategy. The full paper will contain an analysis of detumbling and attitude control experiments of a target debris object to be performed during a future mission to capture and de-orbit a space object.

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Propulsive performance of a c3h4/h2o2 rocket prototype for future green bipropellant thrusters

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In current liquid rocket engines, in both monopropellant or bipropellant configurations, the feeding system provides the propellants at a pressure that allows them to be injected into the thrust chamber by means of turbo pumps or pressurized systems such as direct gas pressurization, flexible bags within tanks or piston pressurization1,2.Even if the engine can be operated in pulse mode, the feed system is currently designed in order to guarantee the nominal steady state operation and, consequently, the nominal feed pressure should be higher than the expected one inside the combustion chamber due to pressure losses inside pipelines, valves and injectors. Except for the propellant itself, most of the weight of the propulsive system consists in the pressurizing system3.PulCheR (Pulsed Chemical Rocket with Green High Performance Propellants) 4,5 is a R&D project funded by the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n°313271. The main aim of the project is to demonstrate the feasibility of a new propulsion concept in which the propellants are fed in the combustion chamber at low pressure and the thrust is generated by means of high frequency pulses, reproducing the defence mechanism of a notable insect: the bombardier beetle6,7. The radical innovation introduced by this concept is thee limination of any external pressurizing system even if the thruster works at high pressure inside the combustion chamber. At each pulse, pressurization of the combustion chamber gases takes place due to the decomposition or combustion reaction, and the final pressure is much higher than the one at which the propellants are stored. The pulsed chemical rocket concept is potentially able to substitute many currently used propulsion systems for accessing space. The feasibility of this new propulsion concept will be investigated at breadboard level in both mono and bipropellant configurations through the design, realization and testing of a platform of the overall propulsion system including allits main components. In addition, the concept will be investigated using green propellants with potential similar performance to the current state-of-the-art for monopropellant and bipropellantthrusters.8,9 The final test campaign will experimentally investigate the propulsive performance of the system in terms of specific impulse, minimum impulse bit and thrust modulation. The present paper aims at presenting the experimental results attained on the rocket prototype specifically designed for exploring the stationary (not-pulsed) propulsive performance of the bipropellant thruster with particular reference to: thrust, combustion chamber temperature, specific impulse, efficiency, propellants mixing and combustion. The test campaign has been carried out in ALTA's Green Propellant Rocket Test Facility using as selected green propellants a light unsaturated dhydrocarbon (propyne) and hydrogen peroxide.

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A Methodology to Enable Automatic 3D Routing of Aircraft Electrical Wiring Interconnection Systems

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1 Design challenges in the development of the aircraft Electrical Wiring Interconnection Systems The Electrical Wiring Interconnection System (EWIS) is one of the most complex systems installed on aircraft. The EWIS of A380, for example, contains 530km of cables, 100,000 wires and 40,300 connectors [[1]]. The complexity of the EWIS is deemed to further increase in new generation More-Electrical-Aircraft (MEA) and Full-Electrical-Aircraft (FEA) [[2]]. Significant advances in the design method of such a system are necessary, not only to efficiently address the growing amount of electronic systems to be interconnected, but also to comply with the growing amount of safety constraints stipulated by Certification Authorities[[3]].

The design process of the EWIS consists of two main parts, generally addressed as electrical design and physical design. In the first part, the power and data signal interconnection between the various electronic components is established; in the second part the actual routing of the many wire harnesses is developed. The methodology proposed in this paper specifically addresses this second phase of the design process, where the most convenient routing of the cables must be identified, according to the space available and Main Route Architecture (MRA) (i.e. the so called motor way) in the aircraft and in order to connect the various systems according to the electrical definition established in the electrical design phase. The 3D routing of the wire harness is particularly complex, not only because of the intrinsic complexity of the EWIS system, but also because of the sheer size of design requirements to be respected (no go areas, areas requiring special cables protections, allowable bend radius of cables, allowed areas to clamp the harness to the structure, etc.), and the frequent changes in the aircraft structure (which cause reconsidering attachment points, or demanding new routes because of limited available space, etc.). Due to the limited time available to perform their work and the frequent last minutes changes, wire harness designers works under high pressure and their work, which is still mostly manual (supported by Computer Aid Design (CAD) systems), is prone to errors.

Considering the fact that a large amount of harness components are selected from catalogues and that the nature of the wire harness design work is largely repetitive and mostly based on rules, in the authors' opinion, there are a lot of opportunities to automate significant part of the design process. A number of researchers [[4], [5], [6], [7], [8]] have focuses on the design automation and computer aid design of EWIS. However, no or very limited solutions to automate the 3D routing part of the EWIS design process have been found. Also the current leading Mechanical CAD (MCAD) software tools used in industry are not able to generate wire harness 3D model automatically, and still demand a lot of manual work by expert designers.

2 Knowledge Based Engineering and Multidisciplinary Design Optimization to automate 3D routing of wire harnesses

In this paper an innovative approach is proposed to support the automation of the 3D routing of the aircraft EWIS. This approach is based on the combined use of Knowledge Based Engineering (KBE) and Multidisciplinary Design Optimization (MDO). KBE technology is exploited to capture the typical rule-based approach of the wire harness design and to enable the automation of all the geometry manipulations required to perform the routing task. MDO is used to systematically explore the large design space provided by the 3D routing problem, while accounting for the many design constraints, aiming at discovering minimum cost solutions. The main objectives of the proposed methodology are the followings:

Automate the generation of the 3D wire harness models, by capturing and systematically reusing the experts' knowledge;

Automatically update the wire harness model when changes occur either in the routing environment or in the electrical design phase of the EWIS.

3 Design methodology and methods
The basic idea behind the proposed approach is that a 3D wire harness routing problem can be modelled as an optimization problem, where the objective to minimize is represented by a cost function that account both for the total length of the wire harness and the cost of the protection layers required to route the harness in area with harsh environment (e.g. heat, vibration, wet). The design variables are represented by the coordinates of the clamping points of the wire harness, hence by the position of the various fixing elements used to fasten the cables to the aircraft structure (the reader can imagine the position of these clamping points as the waypoints in a GPS route planner). The optimization parameters are represented by the position of the various points where the harness has to be connected (e.g. the production breaks where a harness is connected to another harness, or the receptacles of the various electrical systems to connect) and by the required number and gauge of the various wires or cables. The various design rules, such as maximum allowed bending radius of cables, maximum distance between contiguous clamping points, minimum distance between cable and support structure, minimum thickness of the cable protection sleeve for certain environmental conditions are formulated as constraints for the optimization problem. A KBE system is used to support the optimization process by reading in the geometry of the aircraft (the routing environment), modelling the cables as b-splines curves, measuring length and bend radii, checking for geometry collisions, etc. In practice, the KBE system takes care of all the geometry modelling and querying operations that are necessary to compute the variable states and the objective function and to evaluate the constraints during the various optimization iterations.
The challenge of solving the optimization problem described above is that the number of design variable, i.e. the number of the harness clamping points is not known a priori. Indeed, it is a function of the harness routing, which is actually the goal of the optimization problem. To this purpose, a two-step, hybrid optimization process had been devised. In the first step, called Initialization, a grid of potential clamping points is generated in front of the structural elements where the harness is allowed to attach. Then an optimization algorithm is applied to route a simplified harness model on such a grid. As results of this initialization step, a preliminary routing of the harness is obtained together with a number and position of clamping points and breakout points. At this point, being the number of design variables and their initial values known (i.e. the number of clamping points and breakout points and their coordinates), a second optimization process can be applied. In this second step, called Optimization, a detailed geometrical model of the wire harness is used, and the design variables are varied in order to minimize the cost objective function, while satisfying all the constraints.
4 Results
The proposed method has been successfully implemented into a demonstrator software application and several test cases have been run to validate the system functionality. These tests have demonstrated that the tool is capable to handle cases of representative complexity and deliver Digital Mock-up (DMU) of routed harness in full automation, while accounting for all the set constraints. When changes are enforced either in the routing environment or in the definition of the electrical system, the optimization process can be run again to efficiently account for any modification. Figure 1 shows the result of the automatic 3D routing of a few wire harnesses in a fuselage section. The geometry of the aircraft was generated on purpose using a commercial CAD and used as input to the 3D routing system, which generates the harness DMU, ready to be re- imported in the CAD system.

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Pulcher-pulsed chemical rocket with green high performance propellants: second year project overview

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PulCheR (Pulsed Chemical Rocket with Green High Performance Propellants) is a project co- funded by the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreementn°313271.More in detail, the project has been proposed in response of the fifth space call (FP7-SPACE-2012-1), under the topic Key Technologies for In-Space Activities (SPA.2012.2.2-02). Radical innovation, disruptive technologies, research topics with long term vision, high-risk ideas, development of components with highly advanced performances as well as new system concepts and wide range of research opportunities were the keywords of the call. In the light of this, the PulCheR project has been proposed at the end of 2011 and it has been positively evaluated by the European Commission, officially starting on January 1st, 2013The project is mainly aimed at demonstrating the feasibility of a pulsed propulsion system1,2 in which the propellants are fed in the combustion chamber at low pressure and the thrust is generated by means of high frequency pulses. The project has been inspired by the defence mechanism against predators of a notable insect: the bombardier beetle.3-5The PulCheR propulsion system concept is intended to mimic the defence mechanism of the bombardier beetle
for generating an efficient thrust by high frequency pulses, borrowing by nature the concepts of low pressure feeding of propellants, quasi-constant volume combustion and high frequency pulses.
The PulCheR thruster operation relies on the unsteady combustion for generating high pressure peaks inside the combustion chamber that allow for increasing the combustion temperatures (as a result of the quasi-constant volume combustion) and the performance of the thruster always operating in pulse mode. The radical innovation introduced by this concept is the elimination of any external pressurizing system even if the thruster works at high pressure inside the combustion chamber. At each pulse, pressurization of the combustion chamber gases takes place due to the decomposition or combustion reaction, and the final pressure is much higher than the one at which the propellants are stored. The weight of the feeding system is significantly reduced because the propellants are fed at low pressure and there is no need for turbopumps, high pressure propellant tanks or gas vessels. The feed pressure becomes independent on the chamber pressure and the performance degradation typical of the blowdown mode in monopropellant thrusters can be avoided.
The pulsed chemical rocket concept is potentially able to substitute many currently used propulsion systems for in space applications. It can be employed for low orbital flight and beyond and subsequent re-entry (allowing also for re-usable vehicles), and can be used in space vehicles for typical manoeuvres around a planet or during interplanetary missions. Since the beginning of 2013, the PulCheR Consortium has been investigating the feasibility of this new propulsion concept at breadboard level in both mono and bipropellant configurations through the design, realization and testing of a platform of the overall propulsion system including all its main components. In addition, the selected green propellants6-8 (High Test Peroxide and methylacetilene) have similar propulsive performance to the current state-of-the-art for monopropellant and bipropellant thrusters. The final test campaign will experimentally investigate the propulsive performance of the system in terms of specific impulse, minimum impulse bit and thrust modulation. The present paper aims at presenting an overview of the main

results of the activities performed int he second year of the project and its current status.

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Eco-Space Project - Environmental Impact of new technologies

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In the current industry, environment begins to be a major criterion for development of new products. Success of a technology is due to its innovative and low cost assets but also due to its sustainability.
Competitiveness involves industries to see beyond environmental regulations by integrating eco- efficiency of products and technologies as choice criteria for future development.
By dealing with high performances technologies, space sector do not escape of the need to develop products with a minimized environmental impact.
Started in 2013 the Eco-Space project, R&T Airbus DS project, has been initiated in order to face this challenge.
Main objectives of the project are to develop and enhance eco-design approach within new development and promote and give consistency to the “green” initiatives.
The development of “green technologies” (i.e. technologies with low environmental impact) is one axis followed by Airbus DS in order to reduce environmental impacts of its own products.
As sustainable technologies should be compliant with regulations, induce less environmental impacts and cost reductions, one key objective of Eco-Space project is also to integrate Life Cycle Assessment methodology and contribute to reach the cost target.
Assessing the “green” aspect of a new technology entails the following question:
“Which criteria must be validated for a technology in order to be labelling as a ‘green technology’? “What should be set-up in order to ensure a consistent communication?”
By focusing on only few specific criteria (ex: avoiding REACh impacted substances or decreasing CO2 emissions), too many technologies are claimed to be “green technologies” without matching with essential criteria.
For space sector, environmental criteria have to been settled in order to enhance sustainable technology developments.
Within Airbus DS, these drivers conduct to create a dedicated label in order to ensure that new technologies reach environmental and costs targets of the company.
Therefore it is necessary to master and assess cost and environmental impacts of new technology compared to conventional technology answering to the same application.
Similar existing approach such as European Union initiative called ETV (Environmental Technology Verification), EPD (Environmental Product Declaration)… have been implemented within industry.
In order to be exhaustive and avoid shifting of environmental impacts, Life Cycle Assessment has been chosen as a base for the methodology developed by Airbus DS.
Life Cycle Assessment (LCA) is a driver for decision making which allows quantification of product’s environmental impact from raw materials extraction phase until end of life.
This multi-criteria methodology is based on the analysis of every aspect and phase of a product or technology through its entire life cycle, covering environmental impact indicators such as Global Warming Potential, Ozone Layer Depletion, Human Toxicity, Resource Depletion, etc.
The oral presentation purpose is to present the approach followed by Airbus DS in order to determine key criteria for a “green technology label”:
- Selection of intended “low environmental impact technology” within the Airbus DS new technologies portfolio
- Perform Environmental and cost study on pilot cases
- Determine first macro criteria
- Validation step on other new technologies
- Definition of “Green Technology label” for Airbus DS Space Systems
As this methodology has been applied on several pilot cases covering various applications within space sector, green technology assessment of one of these pilot cases will also be presented as an illustration during the presentation.
In this way Airbus DS is committed to the ESA Clean Space Initiative and contributes to the big challenge for space industry: keeping the competitive advantage for Europe and decreasing the environmental footprint on Earth and Space.

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An ecological flow-based decision support tool for future 4D-trajectory management by air traffic control

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Both the SESAR and NextGen research projects in Europe and the United States are set out to majorly overhaul and modernize the current Air Traffic Management (ATM) system in order to cope with the foreseen air traffic growth. In both projects, the main focus lies on the introduction of Trajectory-based Operations (TBO) as a new form of tactical Air Traffic Control (ATC). This transition from the current, primarily manual, form of control towards highly precise time-based movements leans heavily upon the introduction of advanced automation support.
There is a general consensus in operational communities that the human controller should remain actively involved in the decision making process. That is, given that the stakes are high and that the work domain can be characterized as `open' (i.e., there are too many uncertainties and unforeseen events), this rules out a fully automation solution. Therefore it is imperative to design effective decision support tools which support the human controller in performing this new task.
In previous research, and following the principles of Ecological Interface Design (EID), an ecological constraint-based controller decision

support tool was developed. This support tool provides the controller with a visual representation of the safe and unsafe areas in which a selected aircraft may be rerouted to avoid a conflict and/or to circumvent adverse weather. In essence, this representation supports the current decentralized (i.e., aircraft by aircraft) form of air traffic control.

A human-in-the-loop experiment showed that such a decentralized form of control can be effective for resolving local, small scale perturbations, but becomes less effective in more complex scenarios (i.e., higher traffic density, unstructured traffic scenarios). Here, three main contributors have been identified:

- The effect of manipulating the trajectory of one aircraft to the control space of the other aircraft in the sector was not directly visible, and
- Controllers sometimes opted for solutions close to the boundary between safe and unsafe areas, reducing the flexibility of the system to cope with uncertainties, and
- Such a decentralized form of control requires a high amount of knowledge-based decision making (i.e., mental integration of information and planning ahead) to achieve more globally optimal solutions.

Further, various ethnographic studies and field surveys, performed within the current Air Traffic Controller (ATCo) population provide anecdotal evidence that the expert strategies applied by ATCos are often part of a larger plan. Such strategies, for instance, treat the traffic as groups of aircraft (i.e., clusters or bunches), and partition the traffic movements into sector-wide traffic flows rather than individual trajectories. Perhaps, when a decision support tool supports a more centralized form of strategic planning, the aforementioned issues could be mitigated by design.

This research aims to develop a novel flow-based ecological decision support tool for 4D-trajectory management by air traffic control. For this purpose, and by following an approach based on Cognitive Systems Engineering (CSE), the following steps will be taken. First, a functional decomposition will be made of the work domain (or ecology) of trajectory-based air traffic control. By arranging the elements and functions in the Abstraction Decomposition Space (ADS), this will allow to identify the systems' part-whole (i.e., decentralized vs. centralized) relationships of the flow based control task. That is, the elements which support the mental integration of decentralized information, and which support centralized control strategies will be made explicit. Next, by taking an EID approach, the various elements and functions which define the centralized control ecology will be transformed into meaningful visual representations to the controller. These representations are in essence the tools with which the controller can apply centralized control. Finally, an interactive prototype of a flow-based controller decision support tool will be developed and validated in a human-in-the-loop experiment. This article will address the design process, the prototype decision support tool, and the findings from the initial validation experiment.

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Solution Space-Based Complexity Metric for ATC

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Air Traffic Controller (ATCo) workload is considered to be one of the main limitations in the capacity of the current Air Traffic Management system. The limited options available for implementing changes in this system and their possible effects on ATCo workload have made it subject of many investigations. (Hilburn 2004) One of these topics is the analysis of ATCo task demand load (the objective, subject-independent aspects of workload), which finds its motivation in the reduced costs of implementation, its non obtrusive nature, and its possible implementation as an evaluation metric for ATC sector design.

Several sector complexity metrics have been proposed for estimating ATCo task demand load, being Aircraft Density and Dynamic Density by far the most studied ones. Reliable prediction of ATCo workload based on objective metrics has, however, showed to be a great challenge. Hilburn (2004) elaborated on how complexity metrics developed so far depend heavily on the sector in which they've been developed, making its direct use in other sectors unreliable for task load estimation. Hilburn (2004) concludes by saying that no complexity indicator is context-free. This leads us, in general, to the conclusion that a complexity indicator should be context-dependent. Another complexity metric proposed in the literature is one based on the Solution Space Diagram (SSD). Having its foundations in the Velocity Obstacle theory (Mercado et al. 2014), the SSD is a two-dimensional representation that covers all heading/speed combinations possible for a specific aircraft, indicating which velocity vectors offer "safe solutions" and which velocity vectors lead to an impending conflict with another aircraft (van Paassen et al. 2010). Hermes et al. (2009) and van Paassen et al. (2010) have shown that the area that represents unsafe solutions in the SSD have a significant correlation to subjective workload ratings. Hence, apparently, the solution space effectively "captures" elements of the environmental context that predict task difficulty.

In a previous study, Abdul Rahman (2014) included the SSD in a comparison of sector complexity metrics that evaluated them in terms of their transferability in capturing dynamic complexity across different controllers and sectors. The comparison was based on results from a human-in-the-loop simulation with two different sectors with varying route layouts. Experiment results revealed that the SSD area metric had a higher correlation with the controller workload ratings that the number of aircraft or the unweighted NASA Dynamic Density metric. It also showed that the weighted NASA metric had higher correlations to workload than the SSD, indicating that the SSD area metric is a better alternative when tuning for a specific sector layout is not feasible.

The SSD area metric as used in all previous studies was averaged on all aircraft inside the sector at any given time. This implicitly assumed that each aircraft had an equal influence on workload. This is of course a caveat in all previous studies, since aircraft that just entered the sector cannot pose the same level of difficulty as aircraft that have a conflict that must be solved in a very short period of time.

In an attempt to set out a step further towards the elaboration of a context dependent task load metric, this paper aims to analyse the task context of the rerouting task with the Cognitive Task Analysis (CTA) framework. The CTA is a set of methods for identifying cognitive skills, or mental demands, needed to perform a task proficiently (Militello and Hutton 1998). In a study performed by Kilgore et al. (2009), a CTA corresponding to the same controlling goal that falls within the scope of this paper (the rerouting task) was elaborated, and as a result a set of subtasks required to achieve the main controlling goal were identified. The current study proposes a set of metrics that relate to the number of times this set of tasks have to be executed at any given time. The convenience of this approach is the possibility to study the contribution of every subtask to the overall task load by means of correlational analyses. The study hypothesizes that these metrics, in combination with the SSD area metric (to estimate for the difficulty of the task) evaluated only for aircraft pairs that require conflict

resolution, provide a better estimate of task load, and therefore a higher correlation to subjective workload ratings.
In order to test the hypothesis, human-in-the-loop simulations with subjects who received certain degree of training in ATC were conducted.
In order to test the capability of the metrics proposed in this paper to capture task load in different task contexts, two ATC sectors with varying geometries and route layouts were simulated. Results showed that, for different traffic samples, the metrics proposed showed similar or better correlations to subjective ratings of workload than the Dynamic Density metric and SSD area metrics based on the entire aircraft population within the ATC sector. Furthermore, the approach proposed in this paper led to identify a set of subtasks that might have required the most effort from the controller.

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Integrating sustainability in the design of space activities: development of eco-design tools for space projects

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The European Space Agency (ESA) has launched the Clean Space initiative with the objective of increasing attention to the environmental impacts of its activities, both on Earth and in space.
In order to better understand the environmental impacts of the space sector, ESA successfully applied Life Cycle Assessment (LCA) to assess the environmental impacts of space projects over their whole life cycle, from resource extraction through manufacture and use to end-of-life, covering spacecraft and launcher-related activities as well as ground segment activities.
ESA has adopted the eco-design approach to design future space missions in a more environmentally friendly way: eco-design is a preventive approach to mitigate the environmental impacts of a product (good or service) as early as possible in the design phase.
ESA wishes to disseminate life cycle thinking and eco-design by establishing a common framework that can also be used by other European space organisations when performing space mission design. This framework includes methodological and software tools as well as a database dedicated to space activities.
The eco-design software tool is currently under development and testing at ESA's Concurrent Design Facility (CDF). It will be connected to CDF's design framework, i.e. the Open Concurrent Design Tool (OCDT).
In order for system engineers to be able to consider environmental performance as a criterion in their design choices, the tool will provide the following results. Firstly, multicriteria results (i.e. different environmental indicators measuring the impact on climate change, non-renewable resource consumption, air pollution, water pollution, etc.) will allow identifying the "hotspots" in the analysed system: which activities in the life-cycle mostly contribute to the environmental impacts? Where is there mostly room for improvement?
Secondly, the calculation of a single environmental score (aggregating the multi-criteria results) will make the comparison of several design options easier.
The eco-design tool relies on a database which contains environmental data on each individual activity in the life-cycle of a space project (material production, manufacturing processes, etc.). The robustness of the results provided by the eco-design tool greatly depends on the robustness of the database, and for that it is crucial that the database be as representative of the space sector as possible: it needs to depict as closely as possible the specificities of activities carried out in the space sector.
A major challenge for this is the data availability for "space-specific" activities, for which the European space industry has a major role to play, in view of cleaner and more sustainable space activities.

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Development of Flow Structures in the Near-Field Wake Region of the Common Research Model

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The flow around a generic transport aircraft configuration has been studied using both steady and unsteady simulations. The NASA Common Research Model has been used for this purpose, as experimental data obtained in the cryogenic European Transonic Windtunnel was available for comparison and validation. Steady RANS simulations have been performed over a large range of angles of attack at different flow conditions. In addition, unsteady results using URANS and DES methods have been obtained at high angles of attack. The latter results form the basis for the study of phenomena occurring at stall conditions. Such flight conditions are characterized by massive flow separation at the wing and highly unsteady flow in the wake. The wake flow may interact with the empennage, applying unsteady and possibly undesirable aerodynamic loads.
The capabilities of URANS methods to resolve the significant flow structures and scales between wing and empennage have been studied. The ability to maintain a spectral gap, i.e. a separation of scales between resolved and modelled turbulence, has been assessed. The mean and instantaneous flow fields in the wake obtained from URANS and DES (see Figure 1) are compared to time-resolved Particle Image Velocimetry (PIV) data. Furthermore, simulation results have been used to analyse length scales and turbulence spectra in the wake. The evolution of these wake characteristics downstream of the wing has been studied, as well as their impact on the horizontal tailplane.

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Feasibility Study for a Tailless Aircraft with Post Stall Maneuvering Capability

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In this paper a feasibility study for flight control of a tailless fifth generation combat aircraft is demonstrated. This is implemented using three mechanisms. First there is thrust vectoring as the primary mode of control, secondly there is the differential canard control, and thirdly there is also differential control of the trailing edge control surfaces. This means that the fail safe control system can be achieve even without a vertical tail. In this paper this is demonstrated through full system simulation involving the flight dynamics of the aircraft including the flight actuation systems. Keywords: flight control, post-stall, system simulation, tailless Introduction The vertical tail of a combat aircraft represents a substantial parasitic drag. Furthermore, in a supersonic aircraft it also tend to ad volume in the rear and hence wave drag. Through the use of modern flight control system it is possible to use tailless designs with a substantially reduced drag, especially in the supersonic region.

Thrust vectoring is a well-known technology that has been used to achieve this at least in prototypes. The X-36 experimental aircraft also demonstrated a tailless configuration. The aircraft used in this study was presented in Munjulury et al 2013, and is loosely based on the X-36 but rescaled for a different set of requirements. However, the fail safe condition for this is not straightforward, since some kind of control is needed also in an engine out situation, to maintain control at least to give the pilot time to access the situation and mitigate the consequences. With a canard configuration it is possible to generate side forces through differential deployment. This was already shown in Re and Capone in 1977, where a wind tunnel model with canard hinged on axis slanted 16 degrees compared to the horizontal plane was tested. This means that the fail safe condition can be achieved. In this paper this is demonstrated through full system simulation involving the flight dynamics of the aircraft including the flight actuation systems.

Flight Control Simulation For evaluating the performance of the aircraft in a realistic scenario a system simulation model was built that could be used in a mission simulation. The flight dynamics model is here based on a 6 degree of freedom rigid body model that is connected to an aerodynamic model. The aerodynamic model can have different number of wings, with an arbitrary number of control surfaces, and a body with its characteristics. It is here based on a static version of the model presented in Jouannet et al 2005, although the unsteady effects can of course also be included. The coefficients are derived from a model in TORNADO, Melin 2000. The system is implemented in the Hopsan simulation package developed at Linköping University.

Figure 2 – Hopsan system simulation model. Right, flight trajectory of S-manoeuvre and subsequent transition to post-stall flight. There is a 25m loss of altitude during the transition with the controller used here. The drift is because of wind that is not corrected for.

The flight control system is shown in Figure 4. The top section is the engine control, which both has a speed regulator and a controller that is activated to maintain altitude at high angle of attacks. To maintain altitude there is an altitude control unit that generates reference pitch angle. An attitude control unit controls the attitude angles of the aircraft from the reference attitude angles. In addition there is feedback control for the thrust vectoring of the engine nozzle.

The yaw command is used to control the difference angle between the canards and also to compensate for the resulting roll moment by generating opposite roll command to the ailerons. This was method of control was suggested in Re and Capone 1977. where the rotation axis of each canard have an angle to the horizontal.

In Figure 4 the trajectory of an S-manoeuvre followed by a transition to post-stall high alpha flight is shown using thrust vectoring. There is a loss in altitude in this manoeuvre Figure 4 – Flight trajectory of S-manoeuvre and subsequent transition to post-stall flight. There is a 25m loss of altitude during the transition with the controller used here. The drift is because of wind. Conclusions In this paper it was demonstrated how system simulation was performed at a conceptual design stage to test the feasibility of a tailless aircraft concept. It showed that it could be possible to ensure satisfactory fail safe operation by providing multiple modes of yaw control, and through the redundancy in the control system. Most effective is the use of thrust vectoring, but it is shown that the aircraft can be controlled using control surfaces alone which are critical in an engine out situation. Furthermore, it has been demonstrated that the system design and system simulation can and needs to be performed already at the conceptual stage, especially with new configuration with greater technological risks.

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ANDROID Small Active Debris Removal Mission

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In recent years the concern about the future exploitation of space has been growing due to the risk that uncontrolled space debris poses to the space environment and therefore to the survivability of operational spacecraft. Two main regions of concern exist, GEO, where most of the commercial telecommunications satellites orbit, and LEO, where many scientific missions observing the Earth fly. Of special concern is the sun synchronous orbit, of special interest for Earth sciences. The population of debris in this region has been growing, increasing the risk of a collision and hence the exponential increase in the number of debris. One of the possible solutions to this problem is Active Debris Removal. Recent have studies shown that the situation could be contained if 5 to 10 debris objects are removed per year. Initially those debris objects should be the ones posing more risk, usually large objects (high mass, high surface, high energy). But smaller debris objects should be also targeted.

ANDROID mission is proposed as an affordable solution to deorbit small targets (200kg). the mission can offer the opportunity to exercise different technologies and strategies that can be required for missions targeting larger debris. AnDROiD mission has been studied by GMV with the support of QinetiQ Space for platform design, Space Research Centre Polish Academy of Sciences for the robotic arm design and GMV Romania for the net system design. System level sizing has been carried out as well as investigations and definition of the most critical technologies for the mission, namely the guidance, navigation and control system and the capture mechanisms.

The mission has been sized to offer the possibility of attempting at least two different capture techniques before the actual deorbiting of the target, a rigid method (robotic arm) and a flexible one (net system). These technologies are representative of the broarder set of capture techniques that are being studied at the moment for different missions, ranging from clamps or tentacles to harpoons. The robotic arm capture will be performed first, followed by a set of secondary GNC experiments. A second capture of the target will be performed with the net system for later deorbit of the compound. PROBA2 has been selected as target of opportunity. PROBA2 was launched on the second of November 2009 by a Rockot launch vehicle. The main goal of mission was technology demonstration while at the same time provide scientific observations of the Sun. Currently it is still operational in a sun-synchronous orbit at 718km altitude with a local time of ascending node of 06h24 am.

By the time ANDROID is put into orbit PROBA2 will have exceeded its operational lifetime. Therefore it has been considered for the goals of the study that PROBA2 will be non-operational, though having an operational target would widen the set of experiments that could be carried out as well as provide additional information for the validation of the results. Initial analysis indicates that PROBA2 should be spinning at an angular rate of 5 revolutions per orbit. Two grasping points have been identified. The adaptor ring, selected as baseline point due to its generality with respect to other missions, and the DSLP antenna as backup (TBC).

The ANDROID mission is to be launched in a shared launch into LEO. The total mass of the system is expected to be under 350kg, therefore there should be no problem in finding a candidate launch opportunity. Furthermore, SSO is a popular orbit for which several flights are done

per year. The most popular orbits are around 650km altitude dawn dusk (quite close to the target orbit of Android) and 820km altitude 10:30 LTAN. A launch opportunity should be selected so that the DV and time required to arrive to the final orbit is minimised.
The flight system is based on the PROBA NEXT platform, which is the successor of the PROBA1, PROBA2, and PROBA-V/egetation) satellites developed by QinetiQ Space. The PROBA-NEXT platform is a fully redundant all-purpose and generic platform that can host payloads in the range of 150kg and that can deliver more than 600W of power. For the purposes of ANDROID it is complemented with a small Robotic Arm for the debris capture, Net System and a complex GNC system in charge of autonomous proximity operations. The GNC system is based on standard AOCS equipment and complemented with relative navigation sensors.
Feasibility analysis of the mission has been carried out together with the preliminary definition of the critical subsystems. Technology maturity for the different elements has been analysed and a development roadmap proposed for each of the main technologies. The paper will provide de details of the mission design as well as the development roadmap and schedule.

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The constructal principle and character law, hyperbolic, of natural design, a new paradigm of aerospace systems

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In recent years, it is often talking more about design, a new concept, transdisciplinary, that goes beyond, as is known, the term engineering, commonly used today in technique.
In our view, the design, which includes engineering (measure), aesthetics (beautiful) and architecture (construction), involves a qualitative evaluation of a system that adds and complements the quantitative assessment of him.
This aspect, of quality, is ever present now, in addition to many other features, through the idea of beauty or what is called aesthetics.
So, engineering, an important component of technical sciences, involves a reductionist treatment, cartesian of the system, which, essentially, involves dividing the whole into parts, analyse them in detail and techniques of computer calculation, and then integrate them, which lead them, to an underestimate of the system, entirely.
The aircraft is not an integration, summation of the main components, structure, propulsion system and all avionics equipment, but it is a holistic concept, overall and integral, representing interactions, interconnections and, in other words, the relationship between them. If engineering is, primarily, a technique treatment through analysis and synthesis, design is based on the idea of integrity, namely to establisha constructal principle and a character law that, unites and binds, the two principles of existence, in general, respectively, principles of harmony and complementarity, or which is harmonic complementarity.
The paper, set the physical and mathematical foundations of the global, holistic and natural model of performance of an aerospace propulsion system from turbojet engine family, having as foundation the law of hyperbolic harmony of the universe, taking as a basis, the duality between the thrust, via the gas dynamics function of momentum and mass, by gas dynamics flow function. We get, thus, another point of view on thrust but, also a complete solution of David Hilbert's fourth problem. It is also found
- introduction of the hyperbolic harmony principles by combining universal principles well known of complementarity and harmony;
- introduction and use of specific concepts for turbojet engine;
- using, instead of absolute amounts of intake, mass, thermal and geometric coefficients, in evaluating specific thrust force;
- development of new solutions, modern of non-pollutant turbojet engines;
- transformation from simple engine design to complex engine concept design, ie, engineering, aesthetics and architecture as well as transformation, through complementary, linear jet engine in a ortho-turboreactor engine.

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Development of a certification module tailored to Aircraft Multi Disciplinary Optimization

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Because of stringent environmental and energy constraints for the next generation of civil transport airplanes, research centers, universities and industry explore innovative configurations that show potential benefits with respect to the “tube and wing” architecture. To assess the gain provided by such solution, many overall aircraft design studies [1] as well as high-fidelity optimizations are carried out [2]. However, the highest lift-to-drag ratio and/or the smallest empty weight do not guarantee the overall success of the configuration. In order to obtain a viable operational concept, the design process must indeed take also into account the certification constraints that affect the airframe sizing [3].
In the FP7 EU project GABRIEL, an advanced system to assist take-off and landing based on electro-magnetic propulsion has been developed. In order to determine the profits associated to this concept at the aircraft level, a Multi Disciplinary Analysis and Optimization process has been set up taking into account basic certification constraints. Results confirmed that the regulatory texts have a non-negligible impact in the definition of an aircraft at the conceptual level [4].
A further review of the European Aviation Safety Agency (EASA) Certification Specifications for large passenger airplanes (CS-25 [5]), showed that a classical performance analysis model based on a point mass approach is not sufficient to assess all type of constraints. The Multi Disciplinary Analyis and Optimization process used in the GABRIEL project has been thus enhanced by adding a complete six degrees of freedom to simulate dynamic manoeuvers [6].
As the paragraphs of CS-25 are closely related and affect various disciplines, the optimization set- up leads to the definition of a separated module gathering all certification constraints. The most important asset in this new layout is the possibility to run the optimization with two distinct objectives. In the first (and most common) case, the optimizer converges to a set of design variables providing the most efficient configuration based on the outputs of the simulator (block fuel, handling qualities). In the second case, given a frozen configuration, the optimizer can explore the possible variations in the certification constraints. It is believed that this second approach is key in the tailoring of the regulatory texts to advanced and unconventional aircraft configurations.
The full paper focuses on the development of this certification module. Details are given on how various paragraphs of the CS-25 have been converted into a numerical model to allow automatic iterations in automated optimization loops. The paragraphs to be considered are

associated with: Subpart B Flight; Subpart C Structure; Subpart E Powerplant.
To conclude the description of the study, examples are provided showing the coupling between the Multi Disciplinary Analysis and the certification module. The first resulting trends obtained for a generic aircraft are also provided.

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APIAN-INF: a Low-speed Aerodynamic and Aeroacoustic Investigation of Pylon – Pusher Propeller Interaction Effects

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A wind tunnel test campaign, named APIAN-INF (APIAN In Non-uniform Flow), was performed at the DNW Large Low-speed Facility (LLF) to study the pylon – propeller interactions associated with pusher propellers. Propeller performance and noise emissions were investigated using a Rotating Shaft Balance, propeller blade kulites, stereoscopic Particle Image Velocimetry, and inflow and out-of-flow acoustic instrumentation. Pylon trailing edge blowing was studied as a means to lower the propeller noise emissions by decreasing the velocity deficit in the pylon wake. As a secondary part of the test program, the application of Swirl Recovery Vanes (SRVs) was investigated. At the end of the test an acoustic calibration program was performed using two different calibrated sound sources. Preliminary out-of-flow microphone data show that the installation of the pylon upstream of the propeller increased the noise emissions by up to around
10 dB, with the largest increase occurring in the downstream arc. Pylon blowing successfully reduced the noise levels towards those observed for the isolated propeller. The installation of SRVs downstream of the isolated propeller resulted in a distinct increase in sound pressure levels of the higher blade passage harmonics, while the total noise emissions did not increase by more than about 1 dB due to the tonal dominance of the first harmonic.

Introduction

Because of their high propulsive efficiency compared to turbofans, propellers are generally considered as an interesting option for the propulsion system of future generations of passenger transport aircraft. The large rotor diameter(s) combined with interior noise constraints have driven possible propeller aircraft lay-outs towards a rear-fuselage mounted pusher propeller configuration. In this setup, the propeller blades operate in the wake of the upstream pylon, leading to non-uniform inflow on the propeller disk, hence unsteady blade loads and associated increased propeller noise emissions. Previous literature[1-6] has shown that pylon blowing can mitigate this noise penalty due to the pylon wake interaction by re-filling the pylon wake deficit. Performed in the EU-funded ESWIRP project, the study described in this paper was named APIAN-INF and involved contributions from Airbus, DLR, DNW, INCAS, TsAGI, TU Delft, TU Braunschweig, and the University of Cambridge. The main goal of APIAN-INF was to carry out a detailed investigation of the performance and noise penalties due to pylon – pusher propeller interactions, performed in an industrial quality, high-fidelity, large low-speed wind tunnel facility.
The effects of pylon blowing were considered, while as a secondary part of the test for the isolated propeller the application of Swirl Recovery Vanes (SRVs) was studied from both aerodynamic and aeroacoustic points of view.

Experimental Setup

The complete test campaign was performed at DNW LLF using a powered propeller model positioned downstream of a typical pylon model equipped with a trailing edge blowing system. An open jet configuration with 8x6m outlet allowed a wind speed range of 0 – 80 m/s. Tests were performed with and without the pylon, while for the isolated propeller also measurements were performed with SRVs installed. A fixed support structure was used to position the model near the wind tunnel center and allow yawing of the structure. During the experiment the propeller performance and noise emissions were measured using a Rotating Shaft Balance (RSB), kulites installed in the propeller blades, stereoscopic Particle Image Velocimetry (PIV), and inflow and out-of-flow acoustic instrumentation. The inflow and out-of-flow microphone measurements covered a range of flyover directivity angles. Three different microphone arrays were installed in the test section at different directivity angles relative to the propeller.

Preliminary Experimental Results

At the time of writing of this abstract the processing of the final experimental results had yet to commence. Therefore, only some preliminary experimental results are discussed here. Detailed results will be discussed in the final paper.
The propeller performance data obtained from the RSB returned the expected characteristics for the measurements at zero sideslip. The effect of installation of the pylon on the time-averaged propeller performance was negligible. When operating the pylon – propeller combination at sideslip angles of ±6 degrees on the other hand, differences in thrust of about 15% were measured compared to the symmetric case at a thrust coefficient of 0.4. The thrust increased when the pylon’s tip vortex rotated in an opposite sense relative to the propeller, while it decreased for the inverse situation. This was attributed to pre-swirl effects, which were most pronounced at high advance ratios.
Pylon wake profiles measured using PIV confirmed that the pylon blowing technique successfully reduced the velocity deficit in the pylon wake. However, because of the small thickness of the trailing edge blowing slit the resulting wake profiles were not completely uniform. PIV results obtained in the propeller slipstream were used to study the evolution of the tip vortices and blade wakes, as shown in Figure 2. Similar data from the isolated propeller with SRVs installed will be used to assess the effectiveness of the vanes in reducing the swirl in the propeller slipstream. The acoustic measurements confirmed the dramatic effect on the noise levels of the non-uniform inflow caused by the pylon wake. Preliminary analyses of the out-of-flow microphone data for a single propeller operating condition (representing a low thrust setting) showed that the noise penalty due to installation of the pylon was up to approximately 10 dB. The largest increase in noise levels was found in the downstream arc. Application of pylon blowing at the optimal mass flow rate decreased the noise levels towards those of the isolated propeller. The installation of the SRVs increased the sound pressure levels of the higher harmonics by up to 8 dB. However, because of the dominance of the first blade passage harmonic the increase in overall sound pressure level compared to the case without SRVs was limited to a maximum of approximately 1 dB.

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ESA’s e.deorbit mission and its roadmap to Active Debris Removal

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Since 2012, the European Space Agency (ESA) has studied a mission to perform Active Debris Removal (ADR) of a large space debris in low Earth orbit. The objective of the mission is to remove an ESA owned heavy debris from the 800 to 1000 km altitude near polar region. The removal is performed either by moving the target at high speed and high precision into the Earth's atmosphere allowing the target to burn up due to aerothermal dynamic forces, or to move the target to a high altitude where the chance of collisions with other satellites is minimal. Several system studies have been performed, first internally in the form of pre-phase A studies done within ESA's Concurrent Design Facility, and also phase A studies done by large satellite integrators contracted by ESA. Apart from the system studies, several technology development activities have started and some other are planned to start. In orbit testing may be required for several new technologies. All these activities together lead to a roadmap to a European capability to perform Active Debris Removal.
Four questions will be answered: what the boundaries of e.deorbit? How is e.deorbit executed? How can we enable success? And what do we see when we re-assess e.deorbit on a regular basis?
In terms of boundaries, e.deorbit and all technology development activities fall within ESA's Clean Space initiative. With the Clean Space initiative, ESA will devote increasing attention to the environmental impacts of its activities, both on Earth and in space. A roadmap is created that brings the required technologies to a level where they are qualified through on-ground verifications by end of 2016. At the same time, the detailed design phase is scheduled such that a proposal can be prepared for the next Ministerial Council of 2016. The last boundaries are formed therefore by the stakeholders, consisting of the sponsors of all e.deorbit related activities, as well as active and passive stakeholders.
E.deorbit is currently in detailed design phase. The execution of this phase focusses on consolidating all requirements for the implementation phase, which follows the System Requirements Review (SRR). The SRR marks the end of the first detailed design phase (B1). Envisat is the proposed space debris to serve as the target for ADR as it is ESA owned, in an 800 km altitude Sun Synchronous Orbit and of very high mass (8000 kg). Driving requirements are discussed in this paper, focussing on how the space element (e.deorbit) is affected by the launch element (launcher performance), ground element (the visibility of ground stations), target element (the unstable movement of the target and where to capture it), space environment element (in particular the safety requirements upon re-entry). The conceptual design phase focussed on three design options: 1) a robotic arm based solution that re-enters the target, 2) a flexible link based solution (capturing the target using a net or a harpoon) that re-enters the target, and 3) a robotic arm based solution that pushes the target to a high altitude (i.e. above the LEO protected zone as defined by ISO-standards). During the detailed design proposal phase, contractors were allowed to propose one preferred solution that re-enters the target, and focus the detailed design on this solution only. A strong focus on risk mitigation is pursued in the detailed design phase, while a cost ceiling for the e.deorbit platform was given.
In order to enable success, a strong team work is pursued for e.deorbit. A concurrent design team at ESA, consisting of study manager, system engineers, cost and risk engineers and several specialists on subsystems that drive the design are working together to manage the work done by the contractors. Frequent communication with the contractors using video-conference connections are executed that allow for fast response to contractors questions and fast decision making. Several key-point meetings are put within the schedule, that each time narrows the amount of solution in order to refine better the preferred solutions. Finally, a motivation is noted within both the team working for e.deorbit as well as the public, as satellite collisions and re-entries are more and more in the news and even subject of Hollywood movies. There is a general movement (such as in the car industry) towards more sustainable solutions, and this raises sympathy for space- related sustainable solutions too. This is noted in the wide media coverage of e.deorbit and Clean Space related activities.
Nevertheless, it is important to re-assess the status of e.deorbit on a regular bases and assess the risks of the design and progress. For example, currently the system studies are progressing at rapid speed, being on track to provide detailed inputs to a proposal for the e.deorbit implementation phase to be submitted to the Ministerial Council 2016, however some of the technology development studies are not at the same speed, or suffered a late start, sometimes due to lack of support, so that solutions need to be found to synchronize all activities before the SRR. But reaching the SRR is an achievement in itself: the e.deorbit mission started from scratch as no ESA programme was requesting this. Yet due to a motivated team of both ESA, industry and delegations, and the push of the Clean Space Initiative, the study matured to a phase B1 level. It is a challenging mission that requires new developments as capturing a uncooperative space debris using a spacecraft and then de-orbiting it, has never been done before, and will allow Europe to take the lead in Active Debris Removal technologies.

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Impact of rocket launches on chemical and aerosol composition of the atmosphere

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We present the outcome of the European Space Agency (ESA) project ATILA (Atmospheric Impact of Launchers). Attention was paid to the impact of the exhaust products emitted by rocket propulsion systems on the atmosphere at various altitudes. In particular, the effects on stratospheric ozone, global aerosol distribution and loading, and the resulting changes in radiative features of the atmosphere were investigated.
The study was conducted in 3 upscaling steps:
• formation of hot gas and the nozzle-exit conditions (scale: tens / hundreds of metres, tailored engineering models, parameterizations),
• early and intermediate evolution of the rocket plume (scale: kilometres, computational fluid dynamics (CFD), intermediate diffusion models),
• impact on the Earth's atmosphere (scale: 10 km to globe, chemical transport model (CTM)).
The CFD computations were used for a few selected cases, thus forming the reference points for interpolation and extrapolation. The altitude of 18.7 km was chosen as a reference, owing to the measurement data available for the Athena II test case. Further, the altitudes 30 km, 42 km and 50 km were selected as reference altitudes for the CFD computations. Other computations were performed for the altitude range of 10-60 km in steps of 5 km. The data coming from the diffusion model in 5 km increments was linearly interpolated before being fed into the CTM. The trajectories of the rockets were calculated in the beginning using the in-house trajectory tool Tosca of DLR-SART.
At larger scales, the effect of a single launch can possibly be noticed only at local-to-regional level. Corresponding CTM computations were performed at 10 km resolution for the ESA launch pad in Kourou. Results for all 19 ESA launches during 2007-2009 showed complicated shapes of the regional plume dispersion but next to no effect already a hundred km away from the launch pad. Comparisons with satellite

data, such as MODIS AOD, confirmed that very little traces of rocket launches can be observed. Indeed, the modelled aerosol optical depths due to the rocket aerosols are at least an order of magnitude lower than the regional background.
The impact on the stratospheric ozone also proved limited and altitude-dependent. The largest effect was predicted below and above the main ozone layer but inside the main layer the reduction was very small.
Arguably the main reason for the very limited effect of an individual launch is that all main exhaust products exist in the air in non-negligible quantities, so that the rocket impact ends when the plume is sufficiently diluted. An exception are aerosols, more specifically, aluminum oxide and, possibly, black carbon. Assessment of their impact starts from understanding their fate in the atmosphere and possibilities of accumulation somewhere over the globe (amounts released by individual launches are again minuscule). Consideration of this possibility went beyond the ATILA description of work and has been co-supported by the ASTREX project of the Academy of Finland. To perform the long-term assessment, the SILAM chemistry transport model was run over 34 years with an hourly time step and 1.44 degree horizontal resolution over the globe covering the altitude ranges from the surface up to 60 km with 60 stacked layers. Out of the whole period of space launches 1957-2012 with 5301 launches at 1228 sites (225 ESA launches, 1970-2012), the 34-year period, 1980-2013, was taken as the one covering over 99% of the total emission. The spectrum of the released particles was represented with seven bins for aluminum oxide and four bins for soot.
The bulk budget of the long-term simulations showed that indeed the aerosols from the rockets tend to stay long in the atmosphere. By present day, their abundance has stabilized, owing to a dynamic equilibrium between the new launches and removal processes.
Spatial distribution of the aerosols strongly depends on the location of the launch site. There is a substantial inhomogeneity in the aerosol distribution, which shows the clear tendency of the masses to accumulate in polar regions at the altitude of 20-30 km. This tendency is worrisome because there the concentrations may eventually become sufficient to influence the heterogenic processes related to the ozone destruction cycle. The aerosol surface area concentration almost reaches 0.01 mg2 cm-3, which constitutes up to 5-10% of the background levels in these regions.
Importantly, particles from equatorial launches of ESA tend to stay longer and distribute more equally between the northern and southern polar regions than those emitted at higher latitudes in the Northern Hemisphere.

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How many satellites need de-orbit technologies? Future scenarios for passive de-orbit devices

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Space debris represents a major risk to future space missions, this is why ESA, within the Clean Space initiative, is establishing requirements to mitigate the production of new space debris. The international awareness of the problem is reflected in the IADC (Inter-Agency Space Debris Coordination Committee) mitigation guidelines, which indicate the removal of space systems that interfere with the LEO region not later than 25 years after the End of Mission.
Propulsion-based de-orbit is a space-proven technology; however this strategy can strongly limit operational lifetime, as fuel mass is dedicated to the de-orbiting.
Previous reliability studies have identified the propulsion subsystem as one of the major contributors driving satellite failures. It has also been seen that this subsystem experiences significant degradation on orbit and even when it (partially) fails, it is likely to have major effect on mission capability.
This issue brings the need to develop affordable de-orbit technologies with a limited reliance on the system level performance of the host satellite, ideally largely passive methods. Passive disposal strategies which take advantage of aerodynamic drag as the de-orbit force are particularly attractive because they are independent of spacecraft propulsion capabilities.
This paper investigates the future market for passive de-orbit devices in LEO in order to aid in defining top-level requirements for the design of such devices.
This is performed by considering the compliances of projected future satellites with the IADC de- orbit time, to quantify the number of spacecraft that are compliant or non-compliant with the guidelines and, in this way, determine their need for the previously discussed devices.
In addition, future scenarios for de-orbiting with a more proactive approach can be evaluated. This takes into account the need for increasing the removal of micro and smaller satellites from LEO much faster than the 25 years guidelines, e.g.: decreasing the number of years for lower altitudes. A potential increase in micro and smaller satellites (mostly without propulsion) in the coming years is confirmed by different projections, in particular in the commercial sector.
The satellites included in this analysis are divided into different categories: satellites not equipped with a propulsion subsystem, satellites with limited propulsion capabilities, satellites with propulsion that might carry a passive de-orbit device as a back-up for use in the event of on-board failures.
The study is performed by using the SpaceTrak database which provides a future launch schedules, and reliability and trend information for launch vehicles and spacecraft types; the de-orbit analysis is carried out by means of simulations with STELA.
A case study of a passive strategy is given by the De-Orbit Mechanism (DOM) technological demonstrator which is currently under development at Cranfield University.
The device is designed to deploy a drag sail at the end of the satellite mission thus enlarging the effective satellite area and hence, allowing satellites in LEO to comply with IADC debris mitigation guidelines. The DOM design is based on previous Cranfield Space Research Centre experience in de-orbit sails (e.g.: Icarus 1 on the TechDemoSat-1 mission). DOM will fly on board the upcoming ESEO mission (European Student Earth Orbiter, an ESA-funded educational mission).
The DOM engineering model is currently undergoing test activity; this will constitute a useful input to reach a scalable design capable of de-orbiting a range of satellites with no need for significant re-engineering.

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CFD Analysis of a blowing pylon system for the APIAN propeller in pusher configuration

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The development of new technologies compromised with the environment is one of the most encouraging challenges for the industry in our era. Therefore, a renewed interest of the aircraft industry in single- and contra-rotating open rotors has emerged in the last years (CleanSky program [1], Rolls-Royce Deutschland Ltd & Co. KG [2], Airbus [3]). Although these engines are practically replaced by turbofans since the 1950's, which are able to fly higher, faster and are more silent, the propellers had a revival in the late 1970's owing to the Middle East oil crisis due to their promising features, in terms of efficiency and fuel consumption. However, its development was suspended when combustible prices shrank back. Hence, the current economic and social scenario have become a perfect atmosphere to resume the research in such propulsion systems. This technology stands out as a great solution for subsonic aircrafts (ranging from Mach 0.60 to 0.85) for regional transport performing efficiencies of almost 80% thanks to their ultra-high bypass ratio, that leads to reductions in fuel consumption and in gas emissions up to 30% in comparison with turbofans [4]. Nevertheless, noise generation is still an issue for propellers that needs further research to be solved. The pusher configuration (where the propeller is positioned downstream of the pylon) appears to offer some advantages related to the reduction of cabin noise, since the engines can be located at the aft of the aircraft, avoiding in this way the direct lateral airborne path of noise from the propeller to the cabin. Moreover, this configuration reinforce safety for the passengers in the event of a blade release, considering that the possibilities of impact with the airframe are scant. While this configuration reduces the cabin noise, it turns out to increase the community noise due to the unsteady loads on the blades generated by the perturbations produced upstream by the installed pylon. The wake of the pylon reduces the axial velocity of the propeller's inflow for the blade that passes right behind it, modifying its local angle of attack [5]. This paper introduces a CFD analysis of the effects mentioned before on the APIAN's propeller aerodynamic performance in pusher configuration and studies how these are smoothed by means of active flow control, i.e. by injecting flow at the pylon's trailing edge with a blowing system. Some recent works started the research for the exploit of these techniques to relief the pylon-propeller interactions in contra-rotating open rotors (CROR) based on CFD simulations in [6], as well as experimental tests of single-rotating turboprops in [7]. In the present investigation steady and unsteady Reynolds Averaged Navier-Stokes (RANS/uRANS) computations are carried out with the unstructured DLR TAU-code [8] for low-speed flight conditions. First, for the isolated propeller case (Figure 1, see pdf attached), which are used as reference. The isolated pylon is also simulated to find out the optimal blown mass flow, which is necessary to fill the velocity deficit in the pylon wake. In the next, unsteady computations for the same setup tested at the DNW-LLF wind tunnel (propeller, pylon and test bench) were performed; with and without blowing. In addition, simulations without propeller (pylon and test bench) are carried out to assess the influence of the potential flow field induced by the wind tunnel instalation to get a fair comparison with the experimental test.

The first simulations without blowing exhibit the influence of the pylon as periodic loads appear over the blades. Next, the blowing case with a suited mass flow is performed. The outcomes show that perturbations are successfully damped, achieving a performance comparable to the isolated reference propeller. Furthermore, a section is also dedicated to the meshing strategy, which includes trending approaches such as hybrid grids or moving blocks (employing Chimera technique). Last, the method is validated with PIV data obtained during the wind tunnel test campaign performed during the ESWIRP projects [9].

This work was performed embedded to the APIAN-Inf project in collaboration with several European partners leaded by the DNW, the TU-Delft and Airbus, within the framework of the ESWIRP program and pretends to contribute to the establishment of a reliable method for design and optimization for open rotors.

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All moving tail plate interaction on an aerodynamic characteristic of the rocket plane in tailless configuration

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Suborbital space tourism flights are one of the most promising branch of aerospace technology. Currently is a big market demand on suborbital vehicles. So far, only flights of the technology demonstrator were performed but there is no operating commercial spacecraft. However a few companies are working on such vehicles. Following concepts are developing: a rocket plane lifted by another aircraft (e.g. Space Ship Two & White Knight Two), a one stage horizontal take-off rocket plane (e.g. Lynx), vertical takeoff and landing system (e.g. Armadillo Aerospace). Also at Warsaw University of Technology is developing a concept of a system to space tourism flights. The main assumption of the project is two tailless vehicles bonded together which form a conventional airplane configuration, where the second vehicle is used as a tail of the whole system. This system is called Modular Aeroplane System – MAS. The MAS's mission profile assumes that only the rocket plane performed a space flight. The carrier is used to lift the second vehicle above the densest atmospheric region. The rocket plane's re-entry flight is a glide and the vehicle is not equipped with a thermal shield. Therefore the vehicle needs a system which prevent to an excessive acceleration. So, one of the most interesting features of the rocket plane is a strake. The strake is generating a vortex lift phenomenon which increases aerodynamic forces and in turn will reduce the vehicle sink rate and prevent to the structure overheating. So, the initial reentry speed of the vehicle should be small, therefore the problem of strake's sharp edge heating should not occur. The second unique feature of the rocket plane concept is the all moving tail plane on the wing tips, where the upper set can be rotated and is used to control of the pitching and yawing channel. So far, a lot of CFD computations and optimization of the strake's shape were made. Also experiments in a wind tunnel were carried out. After the optimization of the strake geometry the lift forces is increased, but it causes that the pitching moment characteristics is poor. Therefore research on influence of the strake forward flap and hinge strake was carried out and results of this investigation were presented on the last CEAS conference. The rocket plane to perform the mission needs operate at high angles of attack due to the vortex lift generation. However to fulfil this condition the control surfaces should ensure proper effectiveness. The static, dynamic stability and trim condition of the rocket plane at the high angle of attack should be assured. Therefore, the next step of aerodynamic improvement of the rocket plane is investigation.

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Using wing modal deformation for improvement of CFD results of ESWIRP project

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A CFD analysis of ESWIRP test campaign using rigid NASA CRM was done. Large difference was seen between the CFD and experimental data. A model deformation during the wind tunnel tests was the main reason for these differences. It was decided to use a modal analysis of a wing of CRM to improve accuracy of CFD results. On-line mesh deformation using 20 modes in total was used during coupled CFD simulations. It has been showed that the addition of the wing deformation into CFD simulation did improve the accuracy of obtained aerodynamic coefficients and wing deformation. The results from the coupled CFD simulation are the focus of this paper.
I. Introduction
A model deformation has indispensable effect on the aerodynamic characteristics in cases that the ratio of dynamic pressure over Young module is high. These cases correspond to the wind tunnel measurements with realistic Reynolds and Mach numbers corresponding to the flight Re and M of an airliner. Among other effects the elasticity of a wind tunnel model has to be taken into account during CFD simulations to improve the accuracy. The methods how to implement the model deformation into CFD simulation ranges from the simple to the complex ones. Among the simplest method belongs the correction of the wing deformation obtained from the comparison wind tunnel and CFD results. On the other end there is a coupling between CFD and FEM solvers (Fluid Structure Interaction – FSI). Between these two methods is usage of the modal analysis, which can be done independently on the CFD simulations and it is not so demanding as FSI. The ESWIRP sub-project “Time-resolved wake measurement of separated wing flow and wall interference measurement” was measured at ETW facility. CFD simulations using rigid and elastic model were part of this project. A NASA Common Research Model (CRM) of an airliner has been used for this study. It represents the widebody commercial transport aircraft with supercritical transonic wing.
II. Results A. Modal analysis
The modal analysis has been used to obtain the model’s deformation. The structural model of whole airplane has been downloaded from the CRM website. It corresponded to the structural
wind tunnel model. Twenty modes have been calculated and each mode has its own displacement of all nodes on the wing. These displacements were used for on-line deformation using mesh deform utility during CFD simulations. The mesh deform was active after each iteration. B. CFD results
The CFD solver has been running in two modes, RANS and URANS, respectively. The modal coupling option has been switched on during the URANS simulations and the elasticity of the model has been taken into account. Low-speed and high-speed conditions with effect of Re were considered. The lift and drag curves are depicted in Figure 1. It can be seen that the elastic model provides more accurate results in comparison with the rigid model for lift and drag coefficients, respectively. There are still some differences in CL, mainly for smaller AoA. We suppose that it can be caused by the simplification of the structural model (wing only) and the omission of the higher modes. A wing deformation (twist and bend) have been also compared (not shown here). The Cp distributions at specific cross sections corresponding to the elastic model were closer to the experiment in comparison with the rigid model.
III. Conclusion
The CFD results have been improved by taking into account the wing deformation of the model. The CL and CD are closer to the experimental results in whole range of AoAs. In spite of consideration of the wing deformation some differences in CL and CD persist. The biggest differences are related to the smaller AoAs. The reasons for these differences could be caused by the simplification of the model using only the wing deformation during CFD simulation. Cp distributions of elastic model at specific cross sections are in a good agreement with experiment.

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Analysis of the NASA Common Research Model European Transonic Wind Tunnel Test Data and NASA Test Data

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As part of the European Strategic Wind Tunnels Improved Research Potential (ESWIRP) project, a test campaign was conducted in the European Transonic Windtunnel (ETW) on the NASA Common Research Model. These data were obtained at chord Reynolds numbers of 5, 19.8 and 30 million for a wing/body/tail=0 degree incidence configuration. The data from the ETW were then compared with data at the same Reynolds numbers over the same configuration that was obtained in the National Transonic Facility at NASA Langley Research Center. Force and moment, surface pressure, and wind bending and twist data will be presented and analysed in the final paper. The analysis of the data will attempt to explain why the two wind tunnel data sets vary widely.

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Analysis of Electric Propulsion for De-Orbiting of Sun-Synchronous Satellites

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During the last decades the importance of satellites for the every day life has increased continuously, leading to an increase in the number of satellites deployed into space. Most of the satellites delivered into space are not removed from their operating orbit. Given the growing number of objects in space, especially in the Low Earth Orbit (hereafter LEO) the possibility of collision with recent space debris (satellite or launcher fragments) increases. These collisions could lead, depending on the size of the impact object, to minor damages (no mission failure), to major damages (mission failure), to partial fragmentation (break up of satellite parts) or in the worst case to a total fragmentation of the satellite. The latter can easily produce up to 1000 fragments of various sizes from micrometers to meters in diameter. Therefore, recent and future satellites should be transferred into an end-of-life orbit or de-orbited according to the Space Debris Mitigation Guidelines in order to decrease the amount of space debris and thus guarantee access to space for future generations.
Among the various possible orbits in LEO (160 km < h < 2400 km) the most interesting ones with respect to the avoidance of space debris are those with an inclination i>90°, the so-called sun- synchronous orbits (hereafter SSO). Due to the oblateness of the Earth, the right ascension of the ascending node increases and leads to a rotation of the orbit. Assuming a total fragmentation of a SSO satellite, its fragments will encounter different variations in their orbital elements due to the oblateness of the earth and the atmospheric drag. Therefore the fragmentation cloud will envelope the Earth roughly 1 year after the collision, presenting an enormous threat for recent and future

objects in space.
According to the Space Debris Mitigation Guidelines, a satellite in LEO should be removed 25 years after the end of its operation. Given the recent and possible future advances in the field of electric propulsion together with the fact that an SSO satellite spends most of its orbital time in sunlight, in this paper we investigate the possibility and capability of electric engines for the de- orbiting of SSO satellites.

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A semi-empirical methodology for balanced field length estimation of jet-engined aircraft in early design phases

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Field performance is one of the key aspects of airplane design. In the very competitive commercial aircraft business of today, field performance is subjected to narrower design margins and very stringent market constraints. In addition, great uncertainties characterizes the estimation of take-off field length in early design phases, due to inaccurate data about the the airplane under development and outdated methods for performance estimation. This way, incorrect sizing often takes place in the conceptual phase, leading to loss of competitiveness. Reviewing and updating these established methods for calculation of field performance, mainly by including new parameters, better calibrations or new inputs weighting could greatly contribute to the proper airplane sizing.
During these early phases of the aircraft design, the use of numerical simulation and integration to calculate performance is not practical, considering that it involves several aerodynamic characteristics of the airplane, which have an error margin greater than the required precision. Also, some unpredicted or unconsidered effect, such as interference drag or aerodynamic efficiency, can lead to largely inaccurate results, which would not be noticed without an adequate way to validate the numerics. For this reason, semi-empirical methods are historically used to this purpose, assuming that a relatively conventional design will follow historical trend, usually providing smaller deviations from actual results.
Concerning take-off performance, there are many well established methods that provide reasonable results and that have been used for a long time. Among them, the best known and widespread one is the “Take-off Parameter” (TOP). Due to its simplicity, it is the standard method of aircraft design courses, and it is used as well in preliminary studies in the aeronautical industry. However, TOP prescribes a fixed linear relationship between the involved quantities, and it is strongly dependent on calibration, which reduces considerably its efficacy. Methods based on TOP, using quadratic calibrations, for instance, were proposed, which results in increased compliance to calibration data, but not guaranteeing its uncorrelation to these inputs.
A more comprehensive method for field performance estimation was proposed by Egbert Torenbeek in the 70s in his Synthesis of Subsonic Airplane Design book. More recently, Torenbeek proposed another method in the new Advanced Aircraft Design book, containing another method for field performance calculation, proposing an “upgrade” of TOP, by adding a component for take-off airborne distance, including a few parameters. The method outlined in Torenbeek first book includes several aircraft characteristics that are very sensitive to the field performance and are not addressed by other methods, but in a way that the empirical characteristics are not overseen, assuring reasonable results. Some of these improvements include engine related characteristics, second segment performance, reaction time to engine failure (considering a balanced takeoff) and friction coefficient of the runway, and it is possible to use empirical values for these parameters, if they are available in the current project stage. This feature also allows a level of customization of the method, in order to obtain better accuracy updating specific segments inside it.
The proposed method for field performance calculation contemplates auxiliary methods to consider effects of characteristics that have been defined for the aircraft in design, already. Thus, airplane behaviour is better described, relying less on calibration. In addition, the new method replaces fixed values used in the original methodology for estimations specific for each design, working as a compilation of methods. Sources of these methods include diverse airplane design bibliography, ESDU material and experimental results. Including a more precise modelling of turbofan engines behaviour, or predicting second segment rate of climb, based on available parameters, for starters, has resulted in moderate improvements, even without the complete set of additions, suggesting a promising outcome for the final modified version of the method. Parametrization of fixed components of the original methodology, taking into account aircraft characteristics, has also demonstrated to be a secure source of improvements in accuracy.

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Aeroelastic Concepts in Civil Aircraft Wings Design

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Commercial aircraft conceptual designers generally use a combination of experimental and relatively low fidelity analytical methods and simplify the design problem by quantifying design parameters based on experience and a historical database of existing aircrafts. Although, these methods are an effective approach early in civil aircraft design, their efficiency may be restricted when designing for many new technologies. Using a design situation that includes parameterization of design and analysis models and also the models and conceptual design parameters would enable us to update higher reliability models as the conceptual design parameters are changed. This is a particular requirement in the current context of increasing complexity and challenging economic situations. Higher fidelity methods could be employed, with this capability, to make better decisions during aircraft conceptual design.
Aircraft designers have generally tried to limit the effects of aeroelastic deformations. However, due to the fact that lightweight aircraft design has received a considerable attention in recent years, the aeroelastic study of aircraft parts such as a wing has become really important. As structural flexibility increases, aeroelastic interactions with aerodynamic forces become an increasingly important consideration in aircraft design and aerodynamic performance. Consequently, accurate prediction of the aeroelastic instabilities is really important to estimate actual flight performance in the design procedure. Furthermore, loading heavy engine nacelles that are subjected to enormous follower forces is the basic configuration of the most modern transport aircrafts. The geometrical and physical parameters of a high thrust heavy engine changes the aeroelastic characteristics of the original wing and have a complicated influence on the aeroelastic characteristics of aircraft wings [1-4]. This occurs because of the engine inertial and elastic coupling effect with the wing.
In this paper, the aeroelastic analysis of a commercial aircraft wing in the conceptual design phase is considered. The aeroelastic analysis is

performed using NASTRAN and ZAERO software. The aircraft wing structure is modelled in NASTRAN. Then the aerodynamic loadings due to the wing structure deflections are computed in ZAERO. By coupling these two software, the aeroelastic analysis of the wing is conducted and flutter and divergence speeds are identified (figure 1). Results show that the aircraft fuselage and the fuel located in the wing fuel tanks have considerable role on static and dynamic aeroelastic instabilities.

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Design and optimisation methodologies for Additive Layer Manufacturing (ALM) considering uncertainties

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Additive Layer Manufacturing (ALM) is a class of production methods where objects are produced by adding material to the work piece to make 3D objects, on a layer-wise manner. This work is focused on Selective Laser Melting (SLM), an ALM process that is used to manufacture metallic components. This process possesses a significant amount of advantages over conventional manufacturing methods, with the almost unlimited geometrical freedom being one the most important, at the same time this process is affected by some technical challenges, which represent opportunities for research and development. In this work, a design and optimisation methodology that considers several types of uncertainties is outlined, explained and validated. The design and optimisation cycle consists on the use of topology optimisation in order to obtain an optimised baseline geometry and subsequent robust and reliable shape and size optimisation analysis that minimise sensitivity of the component to actual real world operation uncertainties. This methodology considers various types of uncertainties, namely in the loading and boundary conditions, mechanical properties and component's geometry.
In order to reduce the gap between the current state of SLM as a manufacturing process and the application of this technology to industrial manufacturing, some of this technology's technical challenges have been addressed. During this work, a detailed mechanical characterisation was performed, considering the inherent sources of variability and also the effect of the surface finish on fatigue properties. As a case study, the developed methodologies are applied to the design and analysis of an aircraft bracket where the ALM method is compared with conventional manufacturing solutions.

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Conception of service offers: from strategy to technology and the other way around.
The case of Health and Usage Monitoring Systems (HUMS) in the management of missiles stockpiles

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Objectives and theoretical and practical relevance
The premises of this article are twofold. Firstly, as part of its Vision2020 for EADS, Louis GALLOIS, who was then President of EADS, defined the development of services as a key strategic guideline for the company. Secondly, several developments of data logging devices paved the way towards improved services in the area of missiles stockpile management. The founding question of this article is, therefore, the identification of service-offers based on Health and Usage Monitoring Systems (HUMS), which data loggers are a cornerstone of. The objective of this article is to present the different methods and tools used, during an 18 months project, to create consistency between a generic goal of service development and specific HUMS technologies.

Approach, method and key references
The general approach followed in this article is described in the adjacent graph. It offers a three-level description of the services building blocks: data loggers, other technological blocks and other non- technological blocks.
For the first level (data loggers only), we propose a characterization of the different developments with respect to the classical literature on product exploration (LOCH et al., 2006).
Secondly, for the second description level (data loggers and other technological blocks) we elaborate on a dual approach, developed during the project, mixing top-down and bottom-up orientations. This dual approach followed three objectives:

- identify the relevant service offers;
- guarantee the coherence of the service objectives and the envisioned solutions (top-down);
- Guarantee the feasibility and technical credibility of the envisioned solutions with respect to the service objectives (bottom-up).

Finally, for the third description level (data loggers and other technological and non-technological blocks), this article offers an adaptation of the Characteristics-Based Model (GALLOUJ & WEINSTEIN, 1997) for service description. We also draw on the work of Sylvain LENFLE (LENFLE, 2005).

Theoretical development, research models and findings
For each of the three levels of service building blocks description presented above, we present the following developments.
On the first level (data loggers only) the article describes a very classical exploration trajectory (LOCH et al., 2006). The first data loggers developments followed a “trial and error” trajectory. With the complexity ramp-up of later developments, this trajectory shifted towards “learning and selectionism”.
On the second level (data loggers and other technological blocks), the article presents the different step of reconciliation of the top- down and bottom-up approaches. Such reconciliation paved the way to the creation of a service-oriented technology roadmap for all technological blocks associated with missiles stockpile management services.
On the third level (data loggers and other technological and non-technological blocks) the article presents an adaptation of the classical Characteristics-based model (GALLOUJ & WEINSTEIN, 1997) summarized in the adjacent graph. The main evolution offered here is the distinction between users (the armed forces) and customers (the procurement agencies). Such distinction is fundamental in the defence sector.

Conclusion and contribution to the field

The main contributions of the project that we describe in this article are the following. Firstly, we clarified the value propositions of the service opportunities in the field of management of missiles stockpiles. Secondly, we offered a structured approach to match services and technological requirements. Thirdly, we expanded the scope of service description outside of the traditional product-oriented perimeter. Finally, we paved the way towards a ramp-up in the implementation of stockpile management services with the creation of a dedicated project team. More importantly, the different methods and tools described is this article can be used to structure and describe future services within and outside the company.

Managerial implications

The different models and tools used during the project and related in this article had several virtues on a management level. Firstly, it compiled information that was previously disseminated throughout the organisation. Secondly, it provides a common set of references and a common language to coordinate the actions of very diverse participants. Thirdly, it provides a powerful communication tool to promote stockpile management services across the different layers of the organisation and towards potential customers.

In addition, the expansion of the service description scope outside of the traditional product-oriented perimeter, puts emphasis on what is yet to be done by the dedicated project team. This notably includes the organisational and human resources implications as well as the process, business model and contractual obligations.

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Aerodynamic Design and Shape Optimization of Transonic Joined-Wing Civil Transport

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This paper shows a dual-approach design of a joined-wing aircraft for transonic flight. The inverse design and drag minimization by adjoint solver will be carried out.

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Characteristics of locked and free-wheeling ducted fan based on wind tunnel tests and CFD analyses

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The presented paper is describing ducted fan tests performed for a new generation of joined wing aircraft. . In order to fully integrate propulsion system with an aircraft and get reliable results from flight tests, propulsion systems must be thoroughly tested. Due to the recent development in electric propulsion systems, new possibilities are arising. Stopping and restarting the motor in flight allows better determination of aircraft performance (for example lift to drag ratio) during flight tests of dynamically scale flight models. Free-wheeling and braked tests of ducted fan and unshrouded propellers for comparison have been performed in different conditions. In a conventional unshrouded fixed pitch propeller in a free spinning (wind milling) situation such prop has much more drag than when it is stationary (locked). Wind tunnel tests have proven than ducted fans have much different results and the lowest drag is possible when the fan is free spinning. In order to validate it and find the mechanism of this occurrence, CFD analyses have been performed. As the results of ducted fans' free-wheeling and locked characteristics are different to unshrouded propeller they also make emergency procedures different in case of an engine cut off during the flight.

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A Multidisciplinary and Practical view in Aeronautical Engineering Education

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The traditional teaching process on engineering is based on cognitive orientation, where the knowledge acquisition is driven by teacher in the role of principal active agent which tends to make students a passive agent in the teaching-learning process. In this model, there is no incentive, motivation nor formal space to develop self-learning. Moreover, the traditional teaching brings to student a compartmentalized knowledge (no connected to other scientific areas) without practical application. This view from engineering education brings to the future engineers often perceptions that a certain specific knowledge will not be useful for their education and professional development. This educational approach do not satisfy a post-modern world where the human being is inserted in a dynamic environment that knowledge is available easily in an interdisciplinary way. Thus, the limitations of the traditional education proposal face a new world boosted the university to research alternative teaching-learning processes able to form engineers with holistic view, integrating theory and practice, through active learning based on skills and competencies. New educational models based on learning by doing to use elaboration of design even if it is simple but it brings to students perceptions that success on learning depends on them in realize a design by active way. The Technological Institute of Aeronautics (ITA) still follows a traditional teaching model in engineering where the first two years at Institute, students attend only basic sciences courses (Mathematics, Physics, Chemistry, Drawing, Computer).After the first two years, students will start their engineering field. This curriculum is not well adapted to a new learning scenario motivating the multi-disciplinarity and practice. In this sense, the ITA introduced changes in two disciplines for beginner students (first year). Before 2014, the courses of metrology and technical drawing were given in a traditional way no correlating both courses and without a practical view about the relevance of these courses for future engineers. In 2014, it was thought in the Physics department at ITA a new teaching-learning process which the responsibility for earning will be attributed to student during active attitude in accomplishing a design that connects several interdisciplinary knowledge through a practical view. To reach an innovated teaching- learning process the metrology and technical drawing courses were pedagogically rethought by interdisciplinary knowledge package with a practical insight. The key to this strategy has succeed was to assembly an air-model (figure), since the great interest of students in aeronautical design. Students built an air-model using the knowledge from courses as well as the inter-disciplinarity between them.

The interdisciplinary knowledge package proposes by building the air-model aims to consolidate the following items:

Consolidate knowledge on specific course Consolidate knowledge on multidisciplinary view Increase motivation
Stimulate creativity
Experiment a practical view of the knowledge
Encourage critical thinking
Promote capabilities of analysis and decision
Develop skills and competencies to work in groups and to management stress
For pedagogical goals are achieved in terms of competencies and skills in metrology the air-model build process works as a real production process where the production tolerances are obtained by measuring of the air-model parts as spars, ribs and stiffeners comparing among different groups. Furthermore, the error propagation concept could be realized by measurement of the air-model weight. About competencies and skills in technical drawing students draw the air-model three views to realize specification needs during the build process. The air-model assembly was made in the small aircraft laboratory at ITA where students had the first contact at institute with materials, structures and tools that involves the aeronautical design. The air-model performs its flight in a unique trim condition showing the concept of equilibrium in flight dynamics. In addition, materials are added as extension on air-model to increase aspect ratio and stabilizing surfaces in order to present geometric variation effects on aerodynamic design. All details of the implementation of this interdisciplinary knowledge package will be shown in the full paper.

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A High-Precision Position Turn-Table as the Reference for Angular Accelerometer Calibration Experiment

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Calibration tables commonly known as turn tables are widely used to produce motion input to excite inertial sensors. Its mounting platform's orientation can be single-axis, or two to three axis degree-of-freedoms. The measurements from the turn-tables-generated motion have been applied not only to different types of inertial sensors such as linear accelerometers and gyroscopes, but also for groups of sensors in for instance Inertial Measurement Units (IMU).
The calibration table (CT) operated by Control and Simulation Section, Faculty of Aerospace Engineering – TU Delft, is a high-precision position turn-table, which means it provides the angular displacement measurement. In addition, the CT controller computes and processes the angular velocity from the measured data, since it is used in the control feedback loop. However, the calculated angular acceleration data contains noise as a result of the double differentiation, hence needs further processing to be used as a valid reference in angular accelerometer (AA) calibration.
The CT and sensor data acquisition systems (DAS) are different independent units, which produces additional issues in the data post-processing. For example, the nominal table's sampling frequency of 2 kHz only allows for a division by an integer, which will require a resampling process for sensors with a fixed sampling frequency that does not match the 2 kHz. With regards to the data recording, both DAS have their own start and stop command logic which leads to unsynchronized results.
This paper identifies the CT – AA systems issues that affect the sensor calibration experiments, as well as the possible solution on how to carry out the AA calibration experiment. The CT system consists of two subsystems: the controller and the turn table, whereas AA included two subsystems: the sensor and its DAS. The discussions are limited to motion, sensing and data collection in the experiment without the electrical and mechanical properties of the CT servo and actuator system.

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An optional APU for passenger aircraft

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Background: Passenger aircraft are equipped with an Auxiliary Power Unit (APU). Its main purpose is to provide the aircraft on the ground with electric, hydraulic and pneumatic power. These three forms of power are called secondary power. The APU often only provides electric and pneumatic power with hydraulic power converted from electric power by an electric motor driven pump. Any device that produces secondary power could be an APU, but traditionally APUs are always small gas turbines because of their high power-to-mass ratio. A multifunctional fuel cell system is discussed as a possible future APU alternative [1]. However, today most airports offer electric power and pneumatic power (compressed air) thus rendering the APU obsolete. Furthermore, many APUs are "non-essential APUs" with respect to their function in aircraft certification. Still all passenger aircraft are equipped with an APU. APU alternatives: Bio fuel powered gas turbine, hydrogen powered gas turbine, fuel cell, Diesel engine, pressurized air bottles, battery, and "no APU" at all. These are the investigated alternatives for a classical kerosene powered gas turbine APU. Necessity of an APU: Operation on the ground, in normal cruise flight, and on ETOPS flights is investigated. Further investigated are: Aircraft scheduling by the airline, selling an Aircraft with unconventional APU or even without APU. Stakeholder views of the APU: The view of pilots, airlines, aircraft manufacturers, APU manufacturers, airports, and of the residents is considered [2]. Ground operation without APU: Considered are electric supply, air conditioning, engine start, and taxiing without APU and engine operation. Trade-off: APU alternatives including "no APU" are compared with respect to mass (see Figure 1), energy consumption, maintenance requirements, spare holding costs, delay and cancellation costs.
These criteria are qualitatively combined in the Scoring-Model (Nutzwertanalyse) and finally also quantitatively combined in a method Direct Operating Costs for aircraft SYStems (DOCsys). Result: The option "no APU" shows strong advantages. An aircraft manufacturer should design a new aircraft type such that it offers the APU only as option. An airline operating from remote airports with little infrastructure will order the type with APU. Most airlines operating (mostly) from well equipped airports will buy the aircraft type (mostly) without APU. The "no APU" option shall be offered in two variants: a) the aircraft is void of all APU interfaces (cables, tubes, ducts), hence an APU retrofit is not possible during later life of the aircraft or b) the aircraft is equipped with all APU interfaces (cables, tubes, ducts) hence an APU retrofit is possible. Option b) has the advantage of a possible retrofit of an APU when the aircraft is sold which avoids the possibility of excessive losses in the aircraft's resale value. This advantage, however, has to be balanced against the higher purchase price of the first-hand aircraft.

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Air Traffic Flow Optimisation With Trajectory Uncertainty

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Aviation has changed society dramatically over the past 100 years. The economic and social benefits throughout the world have been immense in “shrinking the world” with the efficient and fast transportation of people and goods. The growth of air traffic over the past 50 years has been spectacular, and will continue in the future, particularly in the growing markets of the Far East. However, since 2000, society’s perception of Air Transport has changed due growing environmental awareness, the rise of oil prices in 2008, and the recent financial crisis. In the future, aviation is likely to face even more radical challenges – with some arising from its own success. Globally civil aviation emitted 666m tonnes of CO_2 into the atmosphere in 2008. In response to the likely volume of activity in the future, aviation must bring about step changes in technology and operational procedures to improve its environmental performance by keeping total climate effects at sustainable levels. With the aim of a global solution, International Civil Aviation Organisation (ICAO) is promoting efforts in four key areas: improved technology, efficient operations, effective infrastructure and positive economic measures. The International Air Transport Association (IATA) has declared a target to stabilise net CO_2 emissions (carbon neutral growth) by 2020 with a long-term aspirational goal to reduce aviation net carbon emissions by 50% in 2050 compared to 2005 level. ICAO is seeking the mandate to implement the necessary actions for aviation. The current state of air traffic is restricted and congested due to the increasing number of aircraft and an out-dated ATC infrastructure. The Federal Aviation Administration (FAA) has predicted air travel demand to more than double within the next 20 years. Congested skies and flight delays lead to higher fuel consumption and the technology of current air traffic management (ATM) systems is dated in comparison to the demands of emerging fleets. The development and implementation of a new ATM concept is proposed by the United States (NexGen) and the Single European Sky ATM Research Programme (SESAR) in Europe. These systems are based on increased data sharing across all stakeholders, ie. airports, ATC, weather monitoring, airlines, etc. Improved operational practices and aircraft deployment across a network can reduce fuel-burn by about 5%, through measures such as better flight planning, speed management, aircraft selection, equipment weight reduction and taxiing with one engine shut down after landing. Improved air traffic control resulting in more direct routes and reduced delays could reduce overall fuel burn by 6 - 12%. In 2006, in Europe alone, additional distance flown due to non-optimal routing was 441 million km, equivalent to about 4% CO_2 emissions. This paper proposes the development of a realistic Air Traffic Flow Optimisation framework that defines optimal trajectories based on intended destination, aircraft performance, conflict detection and resolution and weather conditions.
It is intended to explore the fuel saving benefits of utilising prevailing tailwinds. A key element in this Air Traffic Flow Optimisation framework is that it is information rich, i.e. all necessary information is available and accessible, and flight data and intentions, are known in advance. Wind Model En-route wind data are commonly provided by the local weather or meteorological services agencies. Flight crew use this information for flight planning to determine if favourable tailwinds are available and if adverse weather conditions exist along the route. Wind predictions, even to very high altitude, are also used for balloon flights as well launch and recovery of spacecraft. In the USA, the National Weather Service of the National Oceanic and Atmospheric Administration (NOAA) provides this service, while in Australia it is the responsibility of the Bureau of Meteorology (BoM). The BoM also provides wind data for the Indian Ocean, Pacific Ocean and Tasman Sea regions. Wind data is usually provided as wind direction and wind speed over a regular grid for a number of discrete flight levels and at various times of the day, usually 6 hrs intervals. The understanding of the psychical properties and behaviour of the atmosphere as increased significantly over the past decades that show that correlation between measured data and forecasted data is within 1 m/s. As wind properties can be represented as a vector, 4D interpolation will be performed to estimate the wind properties at every point. The cubic interpolation function utilises a third order polynomial curve fit, whereas the spline interpolation function utilised a higher order function. The small difference between the computational times of these functions in addition to this factor was the primary decision driver towards the selection of the cubic interpolation function. The cubic interpolation function as utilised in the proceeding research is governed by the convolution sum. The format of the initially retrieved wind vector data was provided as magnitude and true bearing values over the desired longitude, latitude and time domain. The first interpolation step was designed to increase the number of available wind data points over the initial time window. A second interpolation step takes place after the selection of the optimal aircraft flight level, in order to increase the density of data points in the local longitude and latitude directions. Two separate four dimensional interpolation functions were required for each of these steps to generate interpolated data for both the local wind bearing and magnitude data sets.
Fig. 3 illustrates the difference between the wind vector data initial input fidelity and that of after the second interpolation step. The red arrows indicate the local wind bearing and magnitude values of the initial wind vector data for the given longitude and latitude coordinates at a sample flight level and time instance. For the purpose of this research, level of accuracy in the initial wind vector model is grossly insufficient to ensure the generation of an optimal flight path. The blue arrows demonstrate the fidelity of the wind vector data after computing the second interpolation function. The introduction of basic aircraft flight parameters was necessary to further evaluate the suitability of each flight level for an optimal flight path. These metrics include the approximate flight bearing of the aircraft from origin to destination, and the time window over which the flight is occurring. To determine the most effective flight level to operate at, the total dynamic pressure of each flight level was used as a comparison metric.

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Computation of Thermodynamic Cycle for Novel Detonation Aircraft Engine

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The paper presents several methods of computing the thermodynamic cycle for a novel detonation based, aircraft engine. The research effort presented herein is part of the Framework Programme 7 research project no. 335091 - TIDE, funded by the European Commission.
The interest of the scientific community on the research and development of pulse detonation engine has grown in the last few years, due to the potential gain in specific power. Very rapid species and energy conversion happens during detonation. This rapid conversion rate, which could be 2 or 3 orders of magnitude faster than in a flame, can lead to several advantages for propulsion application, first of all being the higher efficiency, which can be reached by constant volume combustion, compared to a constant pressure process. Detonation differs from

other combustion processes in the way in which the physical phenomenon evolves. The detonation is formed by a leading shock wave which propagates in the explosive mixture. The propagating shock wave triggers the chemical reactions and thus, the heat release. The detonation wave rapidly propagates inside the chamber resulting in a nearly constant volume heat addition process that determines a high pressure in the combustor and provides the thrust. Due to the rapidity of the process, the equilibrium state in pressure cannot be reached and the process thermodynamically behaves as a constant volume process. The latter is more efficient than a constant pressure process, typical of conventional propulsion systems.

The paper presents three different methods of computing the thermodynamic cycle for a detonation based engine, presented in more detail elsewhere [1]. The engine consists of a centrifugal compressor that admits atmospheric air and delivers it at low speed into a group of detonation chambers, guided by the compressor blades and splitters. The admission of air in the detonation combustors is controlled by the aerodynamic forces occurring in the engine. Fuel is injected in the combustor and mixed with the high pressure air, and a high frequency detonation process occurs, providing a sudden increase in pressure and temperature. The detonation exhaust gas is, then, evacuated through supersonic nozzles aimed at converting the high gas pressure into thrust. The exhaust nozzles are designed such that a shock-free, low loss flow is obtained.

The thermodynamic cycle starts from state 1* defined by the standard atmospheric pressure and temperature. The specific volume is, then, determined by the equation of state for air, and the enthalpy and the entropy at 1 bar are determined as functions of temperature using curve fitting functions existing in the literature [2].

The gas evolution in the compressor (1* - 2*) is described using two approaches: firstly as an isentropic adiabatic compression (state 2*id), and secondly as a non- isentropic adiabatic compression (state 2*). The total pressure at the end of the compression process is assumed known, since it is one of the main design parameters of the engine. Since the entropy is constant for the isentropic compression, and determining the entropy at the same temperature and at 1 bar using the equation:

spatm,T=sp,T+Rln(p/patm)

where s is the entropy, p is the pressure, patm is the atmospheric pressure, and R is the air gas constant, the temperature T and, subsequently, the enthalpy,can be determined using the above mentioned curve fitting equations [2], and the specific volume using the equation of state for air. For the non-isentropic compression, estimations of centrifugal compressor loss coefficients existing in the literature [2] are used to determine the real compression work, Wc, required to raise the pressure at the specified value, and, hence, the real enthalpy, h2*:

h2*=h1*+Wc (2)

where h1* is the enthalpy at state 1*. With the enthalpy known, the temperature can be determined using the above mentioned curve fitting equations [2] and the specific volume using the equation of state for air. With the known temperature and pressure, the entropy at state 2* is determined using the curve fitting equation and Equation (1).

The detonation evolution (2* - 3*) is computed using three different models [3]: the Humphrey cycle, the Fickett - Jacobs cycle, and the Zeldovitch - Neumann - van Doring cycle. For all cycles, an ideal and a real state can be defined. In the ideal case, the detonation temperature is assumed to be the adiabatic flame temperature for the selected fuel. For the real state heat losses due to heat transfer through the combustion walls and incomplete combustion are considered, so the temperature is decreased by a temperature loss coefficient estimated form the literature [2].

For the Humphrey cycle, a constant volume heating, is describing the detonation. The pressure is determined using the equation of state for burned gas, and the enthalpy and the entropy are determined using the curve fitting equations together with Equation (1).

For the Fickett - Jacobs cycle, the detonation is modelled as a compression with heat addition process. Under the Chapman - Jouguet theory the heat release through detonation is assumed instantaneous, and the process is identical to a Rayleigh heating and the process can be regarded as being in local thermodynamic equilibrium [3]. Thus, the pressure and the temperature after detonation are the coordinates in the p-v plane of the point defined by the intersection of the reactive Hougoniot curve corresponding to the selected fuel adiabatic flame temperature (real or ideal) with the tangent raised from the point defining the state before the detonation (state 2*) to the same reactive Hougoniot curve [3]. It is important to know that even if the equation of state remains valid in state 3*, the actual gas constant is not known, as its value changes throughout the detonation process from the value for air, to the value for exhaust gas. A mean value can be determined by applying the equation of state with the now known values for temperature, specific volume, and pressure after the detonation. The enthalpy and the entropy are determined using the curve fitting equations together with Equation (1), using the previously determined mean gas constant value.

For the Zeldovitch - Neumann - van Doring cycle, the detonation is modelled via a two stage process: fist a shock wave compression along the inert (no heat addition) Hugoniot curve (path 2* - 3'*), followed by a Rayleigh heating (path 3'* - 3*). Thus, the pressure and the temperature of the intermediate state 3'* are the coordinates in the p-v plane of the point defined by the intersection of the inert Hougoniot curve corresponding to state 2* with the tangent raised from the point 3* determined for the Fickett - Jacobs cycle (under the Chapman - Jouguet theory) to the reactive Hougoniot curve corresponding to the selected fuel adiabatic flame temperature (real or ideal) [3]. The temperature of the intermediate state is determined using the equation of state for air. The enthalpy and the entropy are determined using the curve fitting equations together with Equation (1). The parameters characterizing state 3* are identical to state 3* in the Fickett - Jacobs cycle, since the heat addition follows the Rayleigh model.

The expansion evolution (3* - 4*) takes place both in the combustor, and in the exhaust nozzle and can be, again, regarded as either an isentropic (state 4*id), or a non-isentropic expansion (state 4*). The total pressure at the end of the expansion process is assumed atmospheric. Since the entropy is constant for the isentropic compression, the temperature at state 4*id can be determined using the curve fitting equations, and the specific volume using the equation of state for combustion gas. For the non-isentropic compression, estimations of the exhaust nozzle energy loss coefficients existing in the literature [2] are used to determine the real exhaust gas energy, We, and, hence, the real enthalpy, h4*:

h4*=h3*-We (3)

where h3* is the enthalpy at state3* (either according to the Humphrey cycle, or according to the Fickett - Jacobs and the Zeldovitch - Neumann - van Doring cycles). With the enthalpy known, the temperature can be determined using the curve fitting equations and the specific volume using the equation of state for combustion gas. With the known temperature and pressure, the entropy at state 4* is

determined using the curve fitting equation and Equation (1).
The cycle is closed by a fictitious 1 bar isobar.

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High-Speed PIV Applied to the Wake of the NASA CRM Model in ETW at High Re-Number Stall Conditions for Sub- and Transonic Speeds

Konrath, Robert ()
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The Particle Image Velocimetry (PIV) has been applied to highly turbulent flow regions in the wing wake ofa typical civil wide-bodied transport aircraft model at flight Mach- and Reynolds numbers to determine the ir high-frequency properties. Flow fluctuations produced by the separated flow of a stalling wing propagate further downstream and induce increased dynamic loads on the aircraft empennage and, therefore, their characterization with respect to their energies and frequencies is of particular interest. The measurements took place in the pressurized cryogenic European Transsonic Wind tunnel (ETW) and have been carried out in the framework of the European research program ESWIRP [1]. The model used was the NASA Common Research Model (CRM) provided by NASA Langley for this investigation. In the present paper the employed high-speed PIV setup is described and results are discussed comprising sub- (M = 0.17) and transsonic (M = 0.85) stall conditions reaching Reynolds numbers of 17and 30 million, respectively.
In the paper the cryoPIV arrangement of the high-speed flow measurements in the ETW is described in more detail discussing also issues to cope with in such a facility as optical effects occurring inside the wind tunnel plenum and test section. Further results will be discussed using turbulent energies and frequency spectra of the velocity data considering both sub- and transsonic stall conditions.

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The influence of the drag dynamic stall in the vawt starting efficiency

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In this paper was studied the behaviour of a vertical axis wind turbine at the starting moment. To capture this behaviour has been done a series of numerical analysis with CFD methods. The complexity and the unsteady characteristics of this type of wind turbine can be study by using the RANS models. The flow in this case was study for one value of tip speed ratio (TSR=1). For determining the influence of the dynamic stall two cases were study, one case with an airfoil standalone and one case with airfoil in configuration on vertical axis wind turbine Darrieus type. Because of the low Reynolds number, the SST transition model was use to do study. All the simulations were done in 2D with two domains, rotor and stator. The mesh was done with CEM CFD using the blocking method. For this study the NACA 0018 airfoil was used.

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Rotorcraft Noise and Emissions Reduction Process for CleanSky – The Measurement of Success

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To minimise the future pollution impact of the aeronautics sector the Clean Sky Programme (Ref: http://www.CleanSky.eu), a consortium that harnesses the best skills and abilities of over eighty- six organizations representing leading European aircraft manufacturers, research and academic institutes, has been developed. The Programme's aim is to construct and operate aircraft, incorporating new and innovative technologies that meet the emission and noise reduction targets set by the Advisory Council for Aeronautics Research in Europe (ACARE).
The object of the work is to present the novel approach adopted by the Green Rotorcraft Integrated Technology Demonstrator (ITD) and the Technology Evaluator (TE),that enables the continual environmental impact assessment of the developing Clean Sky technologies. The environmental impact (noise and emissions) of the Year 2000 helicopter fleet forms the baseline for the Programme's Technology Evaluator (TE) analysis. To establish the datum, four weight classes of baseline generic rotorcraft have been analytically modelled using Platform Hosting Operational & Environmental Investigations (PhoeniX) to represent the flight hour weighted Year 2000 helicopter fleet. 'PhoeniX' is a software tool developed for Clean Sky by the Green Rotorcraft sub-project (GRC7) incorporating previously established software programs. Using the inputs of rotorcraft geometry, aerodynamics, flight conditions, mission profile and atmospheric data the helicopter flight dynamics model EUropean ROtorcraft Performance Analysis (EUROPA) provides aircraft trim conditions and rotor power required for HELicopter Environmental Noise Analysis (HELENA) and the engine models (GSP code or Turbomeca engine deck) respectively. The outputs noise footprints and fuel flow/gas emissions are generated for each assessment point.
Throughout the duration of the Programme, PhoeniX models will be created to predict the noise and emissions of four reference Year 2020+ conceptual turbo-shaft engine helicopters, one diesel engine light helicopter and one tilt-rotor, all without Clean Sky Technologies. To establish the potential environmental benefits, the final assessment stage is to generate models that incorporate Clean Sky technology developments into the above reference version i.e. innovative rotor blades, reduced noise engine installations, improved airframe designs, integration of High-Compression (diesel) engine technology and advanced electrical systems to reduce drag, elimination of the use of noxious hydraulic fluids and reduced fuel consumption. The models generated will be used by the TE to calculate the noise on ground, exhaust gas emissions and fuel burn generated for three levels: A complete mission between two way-points; a process described as Mission Level. For Operational Level the TE will evaluate the noise generated, fuel burn and air quality at the local take-off and landing locations including the impact on neighbouring communities. Global Level provides a scenario comparison between the years 2000 and 2020+. The 2020+ scenarios will reflect a fleet with varying percentages, starting from zero, of Clean Sky technologies and compare it to the baseline data for the year 2000. The outputs will represent total fuel consumption and emissions for all flights during a specific period. Evaluation at this final level will determine the level of success that the combined technologies represent and whether the goals of Clean Sky have been met in full. Latest examples of the TE's case data will be provided to represent the levels of assessment completed to date.

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Design, implementation and evaluation of a system to support Well Clear

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For Remotely Piloted Aircraft Systems (RPAS) to meet the intent of ICAO's Annex 2, a technical solution is being developed to enable a Sense and Avoid[1] (SAA) capability. A SAA system must be capable of both Traffic Avoidance[2] (i.e. remaining "Well Clear") and Collision Avoidance. It is generally accepted that the Collision Avoidance function should be automated on-board the aircraft to mitigate against datalink intermittency and to provide an additional safety net should an encounter between aircraft progress past the other layers of safety. Both from an operational and from a design perspective there is a need for an objective, quantitative definition of "well clear". The Sense and Avoid Science and Research Panel (SARP[3]) considered three concepts for the definition of well-clear. All concepts use a spatial threshold as part of the criterion. A so-called Velocity Scaled Protection Volume (VSPV) concept, additionally uses a time constant to compute two separate spatial thresholds: One based on ownship velocity and one based on intruder velocity. The other concepts use a temporal threshold based on the relative velocity between ownship and intruder. The quantitative definition was tuned to yield a 1.5% probability of an NMAC in case of an unmitigated well clear violation. In August 2014, the SARP recommended a quantitative definition of well clear to RTCA SC-228.
To aid the pilot in remaining well clear, several concepts for the conflict prediction and resolution function are being pursued. These concepts differ in the design of the graphical user-interface but also in the level of automation (LOA) applied for Decision Selection. With a LOA of 2, the conflict prediction function offers a complete set of decision/action alternatives. An example of a concept in which this LOA is used is the conflict probe display. The conflict prediction function uses the well clear definition to compute whether and if so where a well clear violation is predicted to occur for a specified range of manoeuvre options, and presents the resulting conflict space to the pilot. Every manoeuvre that is predicted to avoid the conflict space is a potential option to remain well clear. Based on this and other information, the pilot can select a manoeuvre. In case the LOA of the function is increased to 4, the system will only present a single manoeuvre option to the pilot. This is more comparable to a Traffic alert and Collision Avoidance System (TCAS) Resolution Advisory
(RA). Two designs of a conflict probe display have been realized as extensions to a CDTI. With both systems, the algorithms that define the well clear boundary and the spatial and temporal thresholds can be manipulated. The implementations have been used in a range of evaluations, both in simulation and actual flight test. The full paper will discuss the design aspects and decisions, the implementation and results in more detail.

[1] For the purposes of this work, "Sense and Avoid" and "Detect and Avoid" are two terms referring to the same functionality.
[2] For the purposes of this work, "Traffic Avoidance" and "Self Separation" are two terms referring to the same capability.
[3] The SARP is a U.S. government funded organization designed to bring together SAA community stakeholders to close known research gaps.

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A methodological approach for the Product Development Process optimization of aircraft components

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The way the product development process (PDP) is executed in industry is changing over time. Over the years, a paradigm shift can be observed, where starting from a purely technical process, the PDP is now integrating both technical and business process aspects. The overall process performance is becoming increasingly important. This has resulted in product development techniques like concurrent engineering and lean product development principles.
The goal of the PDP is to deliver a product that meets all technical requirements, while keeping lead time and development cost as low as possible. Maximizing technical performance while minimising development costs and lead time is a great challenge, especially in case of complex product such as aircraft and aircraft systems. Here the number of interacting systems and involved disciplines is large, and the type and strength of such interaction is not always easy to grasp and manage effectively.
For many companies, lead time is the most important performance measure of their development process, because their competitive edge on the market depends on it. A reduced time-to-market results in a reduction in cost-of-delay and a larger market share [2].
The challenge is to keep track of the performance of the product and process simultaneously, and be able to adjust the process on time reacting effectively and efficiently to changes. This becomes even more challenging if multiple disciplines and development locations need to be managed.
This paper describes the implementation of a proposed methodology to optimize the PDP process of an aircraft rudder, accounting for different criteria such as lead-time, recurring and non-recurring costs, risk and combinations thereof. Two use cases are taken into account: (1) optimisation of a known process prior to the start of the process;(2) optimisation in the course of a project, in which tasks might have progressed and/or resources allocation modified, (e.g. another project demands attention of all stress engineers), and/or customer requirements changed (e.g. a different load spectrum needs to be used).
The rudder development process is representative for a typical complex product PDP, where both manual and automated tasks are present and multiple departments (e.g. stress-, design-, manufacturing and cost engineering) are involved. The development process of a rudder also is highly iterative. An example can be found in the design of a hinge of a rudder, here design starts often at the centerline of the hinge (e.g. a bolt or pin) and the development team works outward towards the rudder outer mold line, which constraints the hinge contour. During this process multiple disciplines are taken into account to assess strength, cost, manufacturability, material combinations etc. These disciplines influence each other and hence a change in for example the material of the pin can leads to a redesign of the diameter based on stress calculations.
The proposed implementation makes use of a Workflow Management System (WfMS) with an integrated optimisation tool to give the user the possibility to formalize and optimally reconfigure a certain PDP flow, accounting for the two use cases above.
The paper illustrates the possible performance optimization of the rudder PDP, by changing the sequencing of tasks and their resources allocation, taking into account the current status of the PDP (e.g. progress of tasks, fixed parameters etc.) and the available resources. To be

able to perform this optimisation, DSM partitioning will be used to assess the possibilities of re- sequencing, parallelisation of tasks, reducing feedback loops. Figure 1 shows the strength of mapping a workflow (a) on a DSM (b) followed by partitioning of the DSM (c). Also the opportunities of overlapping tasks with low product data sensitivity will be assessed by means of numerical partitioning algorithms [1].
The DSM model is used to optimise process sequence for lead time and modularity. E.g. minimising the impact of changes on the total lead time by minimising the feedback loops in the DSM. Also the clustering of tasks in the DSM would allow for effective process innovation, targeted by innovating the clustered tasks by application of KBE automation. By mimicking the automation of a task the effect on leadtime of the total process can be assessed.

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Environmental prospects in aviation: a study from the Air & Space Academy FC

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The environmental context is reviewed: environmental issues (noise, local emissions and air quality, greenhouse gas and global warming), closely linked to technical, economic and social issues, involving multiple interactions between many factors and actors evolve fast, clouding the 2050 horizon with uncertainties. Underlying stakes are growing and matching efforts are needed in order to address them, take adequate measures and implement efficient solutions. In technological and operational fields, efforts are needed, properly balanced among the different criteria, developing cross-disciplinary expertise to better apprehend the environmental issues. The proposed solutions should be based on a thorough assessment of needs, assets and interactions, and their Implementation properly refined and regulated, with a view to ensuring global optimisation, promoting equal treatment and protecting the viability of the sector. Besides, communication, which is sensitive on the environmental aspects of air transport, should be unbiased, coherent and credible.
Noise limits are set by a strong, proven framework at international (ICAO standard) and national levels and introducing periodically stiffer limits and refined certification procedures, that stimulated technical progress and significantly reduced noise pollution (perceived noise reduced by 75%, cumulative noise, noise exposure areas reduced). As research is going on and the fleet is renewed, the overall trend should continue, despite the air traffic growth. All in all, the FC projected a total acoustic energy reduction of 15 to 20% between 2010 and 2050. The decoupling of noise and traffic is projected to be achieved even for aircraft equipped with noisier counter- rotating open rotors. Those results do not however take account of local situations and should therefore be placed in context, notably for some potentially critical platforms, where noise will have to be closely monitored, factoring into the analyses and the regulatory framework all elements contributing to acoustic exposure (e.g. land use regulations, noise disturbance generated by an isolated event or exacerbated by repetitive events).
The ICAO Balanced Approach, with its four main pillars: noise reduction at source (that requires continued intensive research and development with proper funding), land use planning and management, noise abatement procedures and operational restrictions, is a key principle to be applied everywhere to efficiently manage noise issues around airports, both from an environmental standpoint and an economic perspective. In order to keep the noise reduction advantage provided by technologies and operational procedures, it is crucial that the full set of applicable regulations be enforced, and that undue building construction be prevented. The responsibility for managing and controlling urban development plans should be entrusted to a designated authority, to be set up or reinforced whenever necessary.
Local emissions and air quality: the overall situation of nitrogen oxides (NOx) is similar to that of noise, in that total emissions will be relatively stable between 2010 and 2050, based on FC forecasts for traffic growth and for reductions in fuel consumption and NOx emissions through dedicated technological advances. The corresponding standard is periodically reinforced and the engine certification procedures (ICAO) updated. As is the case for noise, local situations concerning low altitude NOx emissions may need to be monitored, especially where air quality limits can be exceeded under the combined effect of various contributors. Although aviation is a minor offender when compared with surface access transport, facilities and housing, the issue can put a curb on airport development. It is also important to ensure that the results of research and development efforts into NOx emissions meet expectations.
Particulate Matter emitted by aircraft/engines are the object of growing concern, due to their impact on air quality and human health. Scientific knowledge remains limited. The role of particulates in cirrus cloud formation at altitude (impacting the greenhouse effect) is still poorly understood. Research on particulate matter should be intensified, and a new specific ICAO standard is envisioned in coming years. The quantities emitted will benefit from reductions in fuel consumption. Nevertheless, their impact, combined with growing emissions will make particulates a major issue in the future.
Concerning greenhouse effect and global warming, Aircraft fuel consumption and CO2 emissions have benefited from spectacular improvements in the past, thanks to engine and aircraft performance improvements, in response to growing mobility needs and an exacting market. Industry and ICAO have set ambitious goals for the future: a 1.5% increase in fuel efficiency per year until 2020 (2% for ICAO), carbon neutral growth from 2020, and a halving of total CO2 emissions by 2050 relative to 2005 (industry). The FC has analysed the various factors driving fuel consumption and CO2 emissions between 2010 and 2050, and has forecast the following cumulative gains in fuel consumption per passenger.km: 25% from technology and new aircraft introduced, 37% cumulative when air traffic, operational improvements, increased load factor are factored in, and 47% reduction in CO2 emissions, after adding the benefit of biofuels and various types of carbon compensation effects. Since air traffic is growing at a faster pace than improvements (multiplier slightly higher than 3), total fuel consumption will double during the period, with total CO2 emissions growing by a factor of 1.6. These results are well below the Industry/ICAO goals and the European objective of Flightpath 2050, notably the “carbon neutral growth” from 2020 (including biofuels). The objective of halving total CO2 emissions by 2050 relative to 2005 appears even further out of reach. So, it seems unlikely that technical progress - although it remains a key factor in reducing the sector’s CO2 emissions, implying intensive research efforts - will fill the gap versus the stated objectives. Carbon compensation may contribute to closing in on them, but in order to avoid damaging effects on air transport, it is vital that “compensation” measures be managed on a worldwide basis, ensuring equal access, non- discriminatory treatment, unbiased competition and costs compatible with the sector’s viability. Other forms of carbon compensation may be considered. All means need to be combined, with ICAO playing a major role.
Environmental Interdependencies and trade-offs between noise, local and global emissions are inherent to the cross-disciplinary nature of the subject and intrinsic to all phases of design, from initial selection of overall goals to choices of configurations and technologies. They impact propulsion system design, integration and operation. There are many environmental trade-offs, linked to physical principles and factors (e.g.

engine internal temperatures, bypass ratio, specific fuel consumption, aerodynamic drag and nacelle acoustic treatment area), with varying impacts on noise, fuel consumption and NOx/CO2 emissions. Such trade-offs concern all new aircraft and depend on the overarching requirements adopted, in close connection with economic performance drivers. They are challenging to analyse and resolve due to the complexity, uncertainties and evolving characteristics of the phenomena involved. As the levels of technical refinement and component efficiency approach ultimate physical limits, each evolution brings some undesirable effects, making arbitration more and more tricky between noise, engine specific fuel consumption (hence CO2) and NOx emissions. The choices of engines and configurations will be crucial in the future (e.g. open rotors vs advanced turbofans) and will need to factor in all effects and requirements.

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Carbon Dioxide Emissions from Air Traffic Internal to Industrialised States and between them

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In 2013 the Air and Space Academy Foresight Committee projected that in 2050, about, the aeronautical industry CO2 emissions reduction objectives claimed in 2010 for the future of aviation worldwide was likely out of reach.
Drawing on a regional segmentation of the air traffic, differentiated in the same way as it was considered by the United Nations with respect to CO2 emission from fixed installations, a new study focused on projected CO2 emissions from the industrialized States, internal and between them, air traffic. This with the intent to understand, objectively, their contributions to the said objectives.
The study suggests that:

1) the European posture which consisted in including regional aviation emission in its emission trading system, can be considered as paradoxical with regard to CO2 variation and international agreements pertaining to CO2 emission;
2) bearing in mind that the likely natural evolution of factors and effects of the presently industrializing states becoming in turn industrialized, might tend also towards a moderation in air traffic and CO2 emission growth beyond 2050, the measures to be consequently taken to control aviation CO2 emission should be contemplated within an evolutionary time frame, anticipating the extinction of carbon compensation system, thus preventing perennial penalizing system, disregarding any discriminatory measure not respecting the spirit of international agreements;
3) iii) the growth of the air transport operated by the industrialized States comes essentially from the links between them and therefore the balance of the operations by flags of the two states of each link should then be kept in future bilateral agreements.

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The implications of aerospace requirements on the design-space of a permanent magnet starter/generator

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I. Introduction
In the past decade a trend towards more electric aircraft was initiated in an effort to improve efficiency and decrease system weight and cost of ownership. To this end innovative technologies are required and in the case of rotating electrical machines, permanent magnet (PM) machines are a leading contender. Due to the aerospace's strict safety requirement, PM machines are normally only considered for machines and seldom for generators, as they are pose an inherent safety risk under fault conditions (specifically short circuits) due to the inability to remove the magnetic field from the rotor. This paper therefore outlines what measures need to be taken to realize a PM starter/generator (S/G) that fulfils the aerospace safety requirements. During starting the S/G must deliver 6-8 times the torque it encounters during generation. A fully functional starter/generator, along with the associated inverter and electronics, is constructed and tested as proof of this concept.
II. Safety analysis
In order to fulfil the low failure probabilities imposed by aerospace requirements a safety analysis was performed in order to identify the most safety critical aspects. A detailed overview of the exact safety analysis (with regards to implications on the design space) will be presented in the final paper, wherein different short-circuit failures of the machine were identified as possible causes of overheating and/or fire. These are:
Short-circuit on the terminals of the machine.
Internal short-circuit. There are a number of possible internal short-circuit configurations, with the fault probabilities dependent on the machine and winding configuration.
In order to meet the low failure probabilities a chain of mitigation measures is required as discussed in the following sections.
III. Resultant fault mitigation measures A. Short circuit on the terminals of the machine
In the event that a one or all of the phases undergo a short-circuit at the terminals of the machine a means to limit the current is required. [1] suggests that since the machine is designed to thermally withstand nominal current it follows that designing the machine with a one per-unit (p.u.) inductance will limit the current to its nominal value under terminal short-circuit conditions. Due to the high torque requirements during starting a one p.u. inductance will have negative implications on the V.A. rating of the inverter and required DC bus voltage [2]. A lower system volume was obtained by thermally designing the machine to withstand a short-circuit current for 0.27 p.u. inductance (Fig. 1).
More detailed analysis of the currents and flux within the machine reveals that lowest losses (and hence heating) will be obtained for a symmetrical short-circuit, (i.e. all three phases are connected together), since it results in the most balanced currents and lowest rotor losses. Therefore, under any short-circuit conditions on the terminals of the machine an external short-circuit of all three- phases will be applied in order to ensure the lowest loss condition.
A detailed investigation of internal short-circuits, specifically turn-to-turn short-circuits and the failure mechanism, within PM machines is given in [3]. [4] further outlines that for a machine incorporating parallel strands (which is the case here) a three-phase terminal short-circuit will help to reduce the losses within the fault. The result is that under an internal short-circuit condition the fault mitigation method is to also apply and external three-phase short circuit.
IV. Fault detection system

Both these fault mitigation measures (which are required to bring the design below the specified failure probability) require the accurate detection of either a terminal short or an internal short- circuit, upon which the external three-phase short-circuit is applied (discussed in the next section). The fault detection system is based on monitoring the difference between the neutral point of the machine and the average voltage of the three-phases produced by the inverter. This detection method was conceptually tested in software, and is currently implemented in hardware with a dedicated DSP. Initial testing shows that the majority of short-circuit conditions can be detected. A more detailed description of the fault demodulator and detectable conditions will be given in the final paper.

V. External three-phase short-circuit implementation

An external short-circuit can either be implemented by a dedicated short-circuit circuit, or alternatively, the inverter (which is done here). This in turn places the requirement of a very low failure probability on the inverter and supporting electronics (gate drivers, power supplies, etc.), since they are now directly in the chain of fault mitigation measures. A detailed outline of all the components and software which are directly within this critical chain of fault mitigation measures will be given in the paper.

VI. Boundary conditions imposed on the design space

The conditions imposed by these fault mitigation measures produce the final design space in which the design can be realized. The boundary conditions making up this design space therefore need to be taken into consideration when optimizing the S/G and the inverter.

The final paper will illustrate what penalties this new design space enforce on the S/G system in terms of weight, volume and development time, as compared to an unconstrained design. It will also be shown whether the selection of a PM machine system is still in fact advantageous, as compared to more fail-safe systems (such as the use of a switched reluctance machine).

VII. Conclusion

The implications of selecting a PM starter/generator for aerospace applications was analysed from a safety perspective and a large number of necessary conditions were identified to bring its failure rate to within acceptable values. Consequently these conditions formed the boundary conditions of the available design space within which the design had to be realized.

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The Importance Of Non-Linearities In Aircraft Preliminary Design

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Usually in preliminary design phase many assumption and simplifications are made to have a fast and preliminary sizing of aircraft component. However, neglecting some effects can lead to wrong design with the need sometimes to come back to initial conceptual or preliminary design phase after some more advanced analysis made with higher fidelity methods (i.e. CFD Navier- Stokes numerical aerodynamic calculations). The aim of this work is to highlight the importance of several non-linear effects that usually are not considered in preliminary sizing, but are extremely essential to have a reliable design which can satisfy design requirements even with a certain safety margin. The paper will present some analysis of non-linear effect influence on aircraft longitudinal and directional stability and control which can significantly affects the sizing of horizontal and vertical tail leading to wrong prediction and possible not-compliance with design requirements. The example and calculations were performed through ADAS software, already presented at CEAS 2011 conference. As a relevant example, following figures show the importance to consider non-linear effects for the correct design of a vertical tailplane. The example refers to a regional turboprop aircraft similar to ATR72. As well known the vertical tail design should be designed basically for minimum control speed requirements and for possible achievable equilibrium in side-slip at low speed (approach) and high angles of sideslip with maximum rudder deflection. The maximum achievable sideslip angle should be higher than 12-15 deg. Figure 1 show the initial design performed with only consideration on minimum control speed. The thrust of one engine has been considered and the equilibrium has been imposed to design a suitable vertical tailplane. The assumption refers to a classical vertical tail with rudder chord ratio of 0.35, with vertical tail aspect ratio of 1.55 and with a rudder extension of 80% of the vertical tail available span. The horizontal tail effect has been carefully considered.

The first design was characterized by a vertical tail area of 12 m2 to satisfy Vmc requirements (=1.1 Vs1). The same figure 1 show that this Sv lead to a ratio between directional stability derivative and control stability derivative equal to about 0.43. In Figure 2 it can be clearly seen that this vertical tail area leads to a directional control derivative much higher than the stability derivative. In fact the directional stability of the aircraft seems to low, even the control requirements for OEI conditions are met. Figure 2 show the importance to consider non-linear effects due to non-linear instability of fuselage and non-linear behaviour of rudder efficiency and vertical tail lift versus beta to check the possibility to equilibrate the aircraft directionally at high angles of sideslip (through comparison of the two yawing moments). If the VT area is increased to 17 m2, the ratio of two derivatives become close to 1 and the aircraft is characterized by good stability, However, as can be observed from Figure 3, the second vertical tail leads to a maximum achievable sideslip angle (estimated taking into account all non-linear effects) lower than 15 deg.

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Micro Laser Sintering capabilities opens the door for long endurance flights supported by light weight and precise micro parts

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The research of the medium or far space is one of the major assets of people to find their roots. So the requirements are increasing to requirements to technologies and equipment for a capability of consequent lightweight structures. The aerospace science and the R&D departments of space agencies are developing and innovating all fields with the goals of functional integration and miniaturization of the devices. Further new materials influence the parts and devices which cause new technologies for manufacturing. The new processing technology of Micro Laser Sintering has got the potential to serve applications which meets the requirements for medical parts latest generation. The technology produce micro parts from small article size powder and a CAD model by a small focussed laser beam. In result complex and very precise parts can be manufactured. The quality of surface meets new estimations. All et all with such a technology the development of medical equipment gets a boos, because non producible parts become contrivable.

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Landing Gear Conceptual Design and Structural Optimization of a Large Blended Wing Body Aircraft

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The Blended-Wing-Body (BWB) is a revolutionary concept for commercial aircraft .In the past years a number of design suggestions have been proposed for the BWB such as several wing planforms or a number of distributed propulsion system. However, there have been only few proposals for BWB landing gear configurations despite its significant effect on the overall aircraft performance. The landing gear system is one of the largest aircraft systems which contributes a large part to the overall aircraft weight. Landing gear attachment loads are usually design load cases of major airframe parts such as the rear fuselage and the wing center section. As a result, a well-considered conceptual design of the landing gear system plays a significant role in the final design of the aircraft. The state-of-the-art landing gear conceptual design process is based on experience from existing aircrafts. This process reaches its limitation, however, if the landing gear system must be designed for an unconventional aircraft like the BWB, where no data is available for comparison. Because of these reasons the objective of this work is to propose a design process for the conceptual design of the BWB landing gear system. The work focuses on the following design aspects: a BWB ground loads determination, a BWB landing gear weight estimation, the assessment of the ground loads effect on the aircraft structure and finally the proposal of a conceptual landing gear configuration.
This work introduces a new integrated Multidisciplinary Optimization process to investigate these design issues. There are two essential elements proposed in this process. The first element is the determination of the unknown dynamical ground loads for a BWB. The Multi-Body Simulation, MBS, method is selected for this task. Figure 1 shows an example of the landing gear MBS model for the ground load determination. The second element is the landing gear weight determination. An analytical conceptual design method is implemented to design each landing gear component individually for the weight determination.
The capability of the new process is validated by a conceptual redesign of the landing gear system of an aircraft comparable to the implemented BWB. The process is then implemented for the landing gear conceptual design of a large (MTOW~700t) BWB transport aircraft. Figure 2 shows the implemented BWB aircraft. Four different configurations of different numbers of main landing gears (MLG) of 4, 6, 8 and 12 are designed, analysed and optimized.
According to the results from the validation design case, the process has been proven to be able to realistically predict the ground loads for the BWB. It has been found that the lateral ground loads from the asymmetric landing case play a significant role for the landing gear design. The MLGs must be positioned in a triangle-like topology in order to distribute the landing energy from this landing case. Figure 3a shows an example of the landing gear topology result. Concerning the total system weight result, it has been discovered that the total system weight is reduced with an increase in the number of MLG. The weight reduction comes from the lower ground loads of the high MLG number configurations. However if the number of MLG is too high this advantage will be outstripped by too many MLG components. As the result, the concept with 8 MLGshas an optimum total system weight for the given BWB configuration. Figure 3b shows the total system weight result. This study of the total system weight trend as the function of MLG number and position is not possible before with the classical conceptual design method where mostly the MTOW is the only parameter used for the weight determination. Finally, the obtained knowledge, the new process accomplishments and open problems are discussed.

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Damage identification in composite panels using acousto-ultrasonic waves

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Operational cost in aviation is an important factor of the total cost of an aircraft. These cost can be divided in direct maintenance cost and indirect costs due to unscheduled maintenance time. The use of composites introduces the additional uncertainties: invisible defects can require unexpected ground time. By embedding sensor systems in composite aircraft structures, inspection can evolve to monitoring, known as Structural Health Monitoring. The advances in this field are on the one hand considerable, but on the other hand the TRL level of these solutions is yet insufficient to find real applications. The challenges are the complexity of the composite material, the high density of sensors required for a robust damage assessment and the high frequencies required for the interrogation of the structure. A solution with a lot of potential is the Smartlayer, originally developed by the Stanford university. A layer of sensors is embedded in the structure, where each sensor can act as an actuator while the others act as receivers. By sequentially assigning each sensor as an actuator, a series of actuator-sensor paths is formed, covering the area enclosed by the sensors. The time signal of the paths contains information on the current state of the structure. This information can be extracted in multiple ways, though in all cases, a reference measurement is required. Moreover, the way the path information is converted into a possible damage location is far from trivial. A composite panel with Omega stringers is equipped with a SMART Layer sensor system. Measurements are performed on the pristine structure and again between and after multiple impact damages were applied. During the measurements, an acousto-ultrasonic signal is send from each sensor to all other sensors in a predefined set of sensors (the workspace). A damage index surface plot for the workspace area is calculated using different algorithms, based on correlation functions and on actuator-sensor path information of the signals. Visualisation of the damage and control of the settings of the damage identification algorithms is implemented in a Matlab based software with graphical interface. It visualises the damage locations, based on user settings and also allows the user to select and isolate damaged regions for further analysis. The research has led to a better understanding of how to transform the path damage indices to a damage location, but also provides an intuitively method for the user to optimise the settings for the damage identification for each individual case. The graphical interface allows the user to extract relevant information on the structural integrity of the structure without requiring the user to have thorough understanding of all the details of the algorithms to analyse the time response data. The output of the data can be used as input for Probability of Detection models, further supporting the entire maintenance decision procedure. Future developments are directed towards further improvements of the damage assessment algorithms and increasing the level of interaction between the user and the software.

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Citric acid aerospace stainless steel passivation: a green approach

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The aim of the present work is to propose a completely green sustainable stainless steel passivation procedure, using baths based on citrus fruit waste derived citric acid, as a promising alternative route to the currently employed nitric passivation process. Stainless steels are widely used in the aerospace sector, because of their high mechanical properties and corrosion resistance. A clean and polished stainless steel part spontaneously forms a chromium oxide film that completely covers all its surface and prevents further surface corrosion by blocking oxygen diffusion to the steel surface, and blocks corrosion from spreading into the metal's internal structure [1].However, during machining process a microscopic amount of exogenous surface contamination may be transferred to the surface of the stainless steel work piece [2]. If not removed, these foreign particles can reduce effectiveness of the original protective film. In order to maximize the natural orrosion resistance and to remove contaminants from the surface, an acid cleaning of stainless steels, called passivation, is commonly performed in industry. Passivation process is controlled by industrial standards [3] and it is almost exclusively based on the use of a nitric-hydrofluoric acid mixture ($HNO3$) [4]. The process is undoubtedly economic and leads to excellent results, but the use of nitric acid involves extremely serious ecological problems. Actually, highly polluting nitrogenoxide (NOx) vapours are released to the atmosphere, and high nitrate concentrations are dissolved in wash water and spent baths, both types of pollutants requiring treatment prior to disposal. The removal of NOx from air and of nitrates from baths involves huge plant operation problems and high operating costs, with no certainty about the obtainment of targets complying with the regulations in force [5].In the recent past years, passivation treatment in citric acid ($C6H8O7$) baths has been found to be a successful greener passivation process. Citric acid is a biobased acid which exists in greater than trace amounts in a variety of fruits and vegetables, particularly in citrus fruits such as lemons and limes, comprising as much as 8% of the dry fruit weight [6]. It can be performed on a large number of stainless steel families, and it is considered environmentally friendly in every respect. However, it has not been clearly demonstrated if citric acid passivation is an adequate alternative to nitric acid passivation [7].On the basis of these considerations, selected stainless steels were submitted to the passivation in both citric and nitric acid baths, in order to compare these two procedures in terms of effectiveness (potentiality of the citric acid based passivation) and processing time. As a preliminary step, a green sustainable method for citric acid extraction, from citrus fruit waste, is attempted. Corrosion tests were performed using traditional (potentiodynamic anodic-cathodic polarizationtest) and advanced (EIS, bulk electrochemical impedance spectroscopy and LEIS, localised electrochemical impedance spectroscopy) electrochemical techniques. The samples were investigated before and after corrosion tests with optical microscopy (OM), scanning electronmicroscopy (SEM-EDS), x-ray diffraction (XRD) and x-ray photoelectron spectroscopy (XPS).

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Implementation of GNSS-based RNAV-flight procedures – quantification of potential benefits for business aviation users

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The objective of this paper is to discuss and quantify the potential benefits of the implementation of (augmented) GNSS (Global Navigation Satellite System)-based RNAV-procedures at airports in Europe form a business aviation perspective. Although business aviation represents only a fraction of the total air transport demand measured by aircraft movements or even passengers, it has a significant value to businesses and the economy. With GNSS signals now being available to European aviation users augmented by EGNOS (European Geostationary Navigation Overlay Service) a considerable number of airports can highly increase their accessibility and value to business aviation by adding GNSS-based IFR (Instrument Flight Rules)-Procedures which previously could only be realized using highly expensive ground based equipment such as instrument landing systems (ILS).Business aviation serves a small fraction of air transport demand measured by aircraft movements or even passengers but contributes considerable values to businesses and the economy. Beyond being one among many location factors for site selection of businesses, air transport access including business aviation serves high value purposes and using a time-value approach, the average business aviation's value of time figure is estimated to be 8 to 15 times higher than the value of time of an average air transport passenger on a business trip [1].More than other air transport segments, business aviation by definition requires fast, reliable and flexible connectivity to both, economic centers (e.g. company headquarter sites) and relatively remote locations (e.g. production sites, suppliers, customers) [2].Previously in many regions, access by business aviation was limited by the availability of flight procedures allowing aircraft operations even in adverse weather conditions (reliability) at airports that simultaneously allow ad- hoc scheduling (flexibility) and fast passenger processing. While most remote and/or small airports allow unrestricted ad-hoc scheduling and quick passenger transfer between landside (car) to airside (business aircraft) they mostly lack the financial possibilities to afford expensive navigation infrastructure such as ILS to ensure reliable business aviation services independent from most weather situations. On the other hand airports with adequate navigation infrastructure in most cases primarily serve scheduled airline services. This usually complicates and slows down the airport processes for business aviation passengers. In addition, those airports serving economic centers are also often slot coordinated so that flexibility in arrival and departure times is highly restricted, drastically reducing the usefulness to business aviation. An exemplary evaluation of the current situation is shown in Figure 1. Figure 1: Exemplary accessibility assessment of South- West Germany measuring road access times to the nearest airport equipped with a runway 1500 m or longer and IFR capabilities comparing the results with and without the inclusion of slot restricted airports. It becomes evident that from a business aviation perspective the economic centres of Frankfurt (EDDF) and Stuttgart (EDDS) are only accessible through major airports offering only restricted flexibility though slot coordination and relatively time consuming passenger processes. Today, the availability of certified high precision satellite navigation services (GNSS with EGNOS) provides new possibilities to economically equip small airports (measured by air traffic volume) with IFR capabilities and thus maximizing the regional coverage of highly efficient business aviation services in Europe – see Figure 2.Figure 2: Satellite based approach procedures allow cost effective IFR-upgrades at many airports by providing ILS-comparable utility reducing weather impact on flight operations at much lower costs. The proposed paper will show how Satellite based flight procedures helps to improve the business aviation accessibility and level of service in a European context. In a case study the macro-economic value of the implementation of such procedures will be estimated.

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Future wing Hybrid Laminar Flow Control suction system design and analysis

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The work presented is part of the Active Wing Active Flow- Loads & Noise control on next generation wing (AFLoNext) project work package 1.2 which aims to prove the engineering feasibility of the Hybrid Laminar Flow Control (HLFC) technology for drag reduction on a wing by means of large scale wing ground based demonstrators. AFloNext receives funding from the European Community's Seventh Framework Programme FP7/2007-2013, under grant agreement n° 604013. The context of this work is given by the continued development of civil transport aircraft with reduced fuel burn and emissions. The airframer can directly influence this by lowering airframe drag thanks to maintaining laminar flow on a large proportion of wing windswept surfaces. As the cruise Mach number increases beyond Mach 0.70 it becomes increasingly difficult for wing shape alone to maintain a laminar boundary layer due to the increased Reynolds number and wing sweep required to limit compressibility drag. The use of HLFC can alleviate the situation through applying suction ahead of the wing box through the windswept surface stabilising the laminar boundary layer and delaying boundary layer transition. Applying HLFC to the wing leading edge is not a simple undertaking since many constraints are given by load carrying structure, suction skin, high lift / shielding devices, wing ice protection system and HLFC suction system. Each on its own has to fulfil its proper requirements while sometimes conflicting with those of interfering or adjacent structures and systems. The existence of conflicting requirements and integration constraints ask for a trade-off study which is carried out in close collaboration between SONACA, City University London and Airbus Group Innovations. Airbus Group Innovations has the responsibility of defining the sectional shape, suction distribution and suction system. SONACA develops the suction skin concept and the wing ice protection system. City University London studies the Initial feasibility of suction chamber layouts. The paper is split into 4 main sections: Section 1 details the toolsets used to perform the studies described in this paper which include the 2.5D transonic aerofoil solver, integral boundary layer methods including the effects of suction, boundary layer stability analysis methods, methods to determine pressure losses within the HLFC suction system and methods to calculate suction pump power including pump drag. These methods are integrated together into a set of tools able to perform multi point suction optimisation studies used throughout this paper.
Section 2 presents analysis undertaken to define a suitable aerofoil pressure distribution philosophy that is compatible with the use case flow conditions (Mach=0.82, Altitude 33,000ft, Sweep=32 deg, Chord = 3.5m). Aerofoil roof top pressure distribution philosophies ranging from conventional turbulent aerofoil (mildly decelerating roof top) to a Natural Laminar Flow (NLF) type (strongly accelerating) had suction distributions optimised for each design point (CL=0.48, 0.55, 0.63) to deliver minimum net drag (viscous, wave & pump drag contributions). Balancing pump power requirements against viscous and wave drag components presented a roof top pressure distribution philosophy / geometry that was best suited to the use case and was taken forward for further analysis. Section 3 details the evolution of the suction chamber layout from the early layouts that were very much aerodynamically optimum. The later layouts incorporated constraints due to the ice protection system and chamber extents necessary to integrate with the chosen SONACA suction skin concept while minimising the aerodynamic impact of these constraints. Section 4 continues to show details of multi point suction optimisation studies where net drag over 3 design points is minimised while observing requirements to have the suction distribution variation for the 3 design points achievable with variation in pump rpm only but with constant metering hole geometry. Included here is a sensitivity study to determine allowable departures from spanwise pressure uniformity within the chambers that gives minimal variation in wing drag. Finally, conclusions are presented whereby the integration of the suction system and pneumatic ice protection system has presented a significant conflict requiring the leading edge chamber to be dual use since it is critical for both controlling cross flow instabilities and ice protection. This complication limits the creativity of the HLFC system; development of a suction skin with an electric ice protection system could open the design space for more creative HLFC suction systems including partially passive suction architectures.

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Noise predictions of a hypersonic air transport vehicle concept during the landing and take-off cycle

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The work described in this article is performed in the framework of the European project HIKARI [1]. The main objective of the HIKARI project is investigating the possibility of designing a high speed transportation aircraft in a joint cooperation between Europe and Japan. This article will describe the noise performance of a pre-cooled turbojet engine for high-speed transport for the landing and take-Off (LTO) cycle. Based on jet noise models, a noise analysis is carried out for a precooled turbojet (PCTJ) engine at certification points (ICAO Annex 16 [2]). A comparison is made with maximum allowable noise levels as provided by ICAO Annex 16 and where possible, certification noise levels of relevant aircraft that are available in open literature.
To model the jet of the hypersonic passenger aircraft the semi empirical model of Stone [3] has been used. The jet noise model of Stone consists of a source model for mixing and shock noise. The implemented model has been verified with the measurement results and the predictions of Stone. These three dataset are equal, from which it can be concluded that the model has been implemented correctly.
The proposed hypersonic jet has a rectangular shape with a bevel. This shape is not included in the jet noise model of Stone; this model is based on a circular jet. To compensate for this a shape correction is used based on measurements performed by Bridges [4].
The jet noise model of Stone and the shape correction based on Bridges are implemented in NLRs in-house prediction tool Enoise [5]. Enoise uses source models to predict the noise contribution as a function of time at user defined positions. The positions are defined on bases of the ICAO certification points. An ISA atmosphere, spherical spreading, atmospheric attenuation [6] and ground reflection [7] are taken into account.
The simulations are based on the input values provided by JAXA for the jet. The flight paths for the LTO cycle are based on conventional take-off and landing procedures (e.g. acceleration/decelerate, climb/descent angle). The final take-off speed and the approach speed are provided by JAXA. The three certification procedures (flyover, lateral full-power and approach) have been simulated with Enoise. During the take-off procedure, for the modelled PCTJ engine, shock noise has the largest contribution in the forward arc. Mixing noise is dominant in the rearward arc. During the approach procedure there is no shock noise contribution, during this approach the jet Mach number is below 1.

Once the final input values have been set, an updated calculation will be performed and the results will be evaluated with certification noise levels of relevant aircraft that are available in open literature.

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Thinking out of the Box: unwrapping the 'Flying Car'. How to combine personal transport in the air and on the road

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Personal transport refers to the idea that one should have freedom of choice in means, time, routing and destination. That's probably one of the main reasons of the immense success of the automobile. You use your car when you want and how you want. A very convenient ' door to door' solution. But there are limitations. The modern infrastructure supporting our cars is under pressure and various parts of our world are still difficult to reach due to poor road infrastructure. The popular Dutch bicycle is perhaps most flexible and personal with respect to freedom but is unfortunately limited in range and comfort.
Group based or public transport such as trains, airlines, ships etc.) are limited in location of departure and arrival and do not provide you 'door to door' mobility at your choice. A ' personal' taxi would be nice when affordable but these are limited in service area by all kinds of permits and regulations. And no privacy as in the comfort of your private means of transport.
It is therefore no surprise that the concept of a flying car is such an attractive proposition. You can drive when you want (and can..) and fly whenever you need to (or want to....) and simply park at home giving you a feeling of being in control of your travels and have great fun while doing it.
But how to combine these modes in one craft?
The 'simplest' flying car approach was to take an existing fully functional car and bolt some wings, engines, tail etc. on top of it. Interesting, but such a configuration will not fit the road anymore and the weight is enormous. The car and aircraft engine use(d) different fuels and are also subject to different legal regulations. Parking? Imagine a simple manoeuvre such as parking at the supermarket. It will be more than a night mare. So, the wings need to be left behind somewhere when driving to the supermarket.......
Other inventors circumvented such drawbacks by adopting a 'flying saucer approach' nicely demonstrated in the famous Jetsons cartoon series. But the fuel efficiency of these make them unpractical. The Moeller Skycar is an example of this.
So, other innovations (or miracles....) are in need to obtain a flexible and practical flying car that can 'transform' into the desired mode of transport without having to mount or remove components to switch between the desired transport modes. Examples of the 'transformer approach' are the Terrafugia with its folding (fixed) wings and the PAL-V One with her folding rotary wings. Other means for packaging lift devices temporarily is to store them in the fuselage structure as pursued by the Aeromobile that applies 'swept wings' (F111) to store them when not in use.
All flying car designs face enormous challenges with respect to obtaining realistic dimensions, low weight and adequate performance to meet the demands of physics, regulations, appearance, practical utility and last but not least the dreams and perceptions of potential investors and customers. Pleasant, easy and safe to fly, fun and comfortable while driving.
The presentation will give a short review on the history of the flying cars, the certification challenges of using aviation systems (lift devices etc.) under intense driving conditions and vice versa, why most designs failed to become commercially viable and review the new ways ahead in more contemporary designs. An important aspect but often overseen is the 'Operational concept'. How to integrate a flying car effectively and comfortably into the existing infrastructure. Where can it take off and land? At any suitable place or not? What kind of solutions are envisaged? Are existing regulations promoting innovations or not? What will be the role of ATC, if any?
The presentation will use the PAL-V as a main example to discuss the challenges and illustrate that the 'gift' of Flying car(s) has been finally unwrapped to be(come) an appreciated partner in the quest for real, practical and comfortable personal transport.

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Statistical Time and Market Predictive Engineering Design (STAMPED) Techniques for Preliminary Aircraft Sizing

Barrett, Ronald (The University of Kansas)
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A new technique for preliminary sizing and design of certain aircraft categories will be presented. These Statistical Time and Market Predictive Engineering Design (STAMPED) methodologies can be applied to many different product lines with historical data bases (even outside of the aerospace industry). The generalized terminology and trend-tracking methods will be presented for a generic broad, established category of goods. The generalized terminology will then be refined and focused on aircraft, then one or more categories of aircraft including regional turboprops in particular will be used as an example. By using STAMPED techniques it will be shown that “classical” preliminary aircraft design techniques which call upon the use of “appropriate” numbers for certain engineering values can be replaced with far more exacting, historically based methods to determine certain aircraft characteristics in the preliminary aircraft design stage. An example tracking power loading and wing loading of regional turboprops shows that “classical” design methods of choosing ranges of maximum lift coefficient can be replaced by observing market trends and statistical variable means and standard deviation trends with time. An analysis of the regional turboprop market over the past 30 years shows a decided concentration of power and wing loading at specific values with well defined trends stretching into the future. An extrapolation exercise using STAMPED techniques shows market direction projected into the future for projected IOC dates. The study concludes with a presentation of several STAMPED trends for a number of aircraft variables over the past 30 years. A final tracking shows strong sensitivity of several aircraft design parameters to spot oil prices through time with consistently decreasing lag times between oil price and market trends.

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Contributing to Orbital Sustainability with an Independent Decommissioning Device for Satellite and Launcher Space Implementing Space Debris Mitigation Measures

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The increasing population in space of defunct satellites and other man-made debris is an issue that is getting strongly the interest of legislators, agencies and industry. In order to guarantee a safer and sustainable access to orbit is necessary to stop the systematic non operative defunct satellites concentration increase in orbit. This seems to be feasible with an approach based on a preventive debris removal solution, whereby a dedicated and independent de/re-orbiting propulsion system is installed on the satellite prior to launch allowing a safe and quick decommissioning of the spacecraft before it will become a debris.
Such an approach will allow Satellite Operators to be compliant with current international and national space debris mitigation regulation, and would help Space Agencies and National Governments to reach that 90% disposal manoeuvre success rate which now looks the target, according to many specialists, to achieve a stable and sustainable orbital debris regime in combination with the Active Debris Removal missions currently under developed.
Most Space Agencies (e.g. ESA and NASA) and National Governments (e.g. France) already require performing a controlled disposal manoeuvre. In particular, for satellites and rocket stages in Low Earth the objective is to minimize any potential hazards to other operational satellites in space and to assets or people on Earth. For the Geostationary Orbit and for satellite constellations in Medium Orbits, as well as in Low Orbits, the aim is to preserve the long term sustainability of the orbital slots and therefore the availability of the service. Non-compliant operators can still ask for waivers, however Space Agencies and National Governments have already announced to strongly limit granting those waivers: the French Government has recently stated that no exceptions to space debris mitigation regulations will be allowed beyond 2020.
As such, satellite and rocket stages disposal at the end-of-life is becoming expensive in terms of fuel budget and launch mass. Propulsion system components redundancy is required to match a good level of reliability at the end of life. This has and will have an impact on satellite design. To avoid redesign and new qualification, debris mitigation countermeasures would have to take into account future scenarios (orbital debris concentration in 20 years), making the satellite heavier and more expensive and leading to an immediate increase in launch costs. For this reason, D-Orbit has developed an innovative package, designated as D-Orbit Decommissioning Device, or D3, composed by a solid propellant motor and a control / command unit. The device can be completely autonomous, even if the satellite is defunct: this feature will considerably increase the post-mission disposal success rate, which is so far still far below acceptable levels. The D-Orbit Decommissioning Device is designed to be as compact and independent as possible and able of quickly and safely disposing of a satellite at its end-of-life in a controlled manner, freeing up the orbital slot for the replacement satellite even in case of satellite failure. Compared to the satellite’s station keeping propulsion, the D-Orbit Decommissioning Device offers a higher performance-to mass ratio and an optimal disposal maneuver time-to-mass ratio.
Moreover, with such a device on-board, a Satellite Operator would be able to exploit the full amount of liquid propellant on-board and delegating to the device the end-of-life: this will ultimately lead to an operational life extension.
The D-Orbit Decommissioning Device will allow a reduction in the duration of end-of-life manoeuvres down to less than one hour for LEO satellites and down to a few hours for MEO and GEO Satellites. Such a quick and controlled manoeuvre allows a reduction of the post-mission- disposal and debris monitoring operation costs, especially for large satellite constellations, as well as a reduction of the operator’s liability for in-orbit or on-ground collisions.
This paper will present the design and the main technical features of the D-Orbit Decommissioning Device, the operational scenarios, the operational and economic advantages for operators and space stakeholders, the level of compliance with current and possible future space debris mitigation regulations, the safety features and the potential benefits on a long term Space Debris mitigation strategy.

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New green polymer composites processed by Additive Manufacturing for “clean space” applications

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Additive Layer Manufacturing (ALM) is an intrinsically green technology as it allows using less material than when using conventional manufacturing techniques. In terms of carbon footprint reduction, it is suggested that there are five primary environmental and sustainability benefits to the adoption of additive manufacturing [1], i.e. containment of the required raw materials amounts, reduction of the need for energy intensive and wasteful manufacturing processes, design of more efficient products with better operational performance, reduction of the final product weight and possibility to manufacture the parts closer to the consumption point [1].
A major contribution to satellite demissability could be achieved by merging the ALM contribution to the use of polymers. Indeed, these materials have far lower melting temperature than metals and would likely burn during atmospheric re-entry. In fact one of the space debris mitigation requirements is the removal of space systems that interfere with the LEO region, not later than 25 years after the end of the mission [2].
At present, the choice of ALM processable polymers is relatively limited, particularly in the case of fused deposition modelling (FDM) technology. Therefore together with the development of ALM technologies, the range of materials available for such process needs to be increased [3]. In this framework, the aim of this work, following a bottom-up methodology, is to produce new green polymeric and composite materials by ALM processes, starting from the modification of the raw material composition, to improve the component final performance in non structural space applications. Polyetherimmide (PEI) was chosen as polymeric matrix due to its elevated mechanical properties and processability, thermal resistance, high strength and stiffness and broad chemical resistance, unlike most other amorphous thermoplastics [4]. Biosilica (derived from the skeletons of diatoms, a class of algae) and/or nanoclays (e.g. montmorillonite, bentonite, cloisite and halloysite) were chosen as green reinforcing fillers [5]. Different amounts of fillers were tested to identify optimal composition. Samples were prepared by means of solvent casting and melt mixing processing, and their Morphology (scanning electron microscope, FEG-SEM), thermal (differential scanning calorimetry DSC), and thermo-mechanical properties (dynamic mechanical thermal analysis DMTA) as well as mechanical performance (tensile tests) of produced materials were analysed and assessed.

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Aircraft Preliminary Design: the Windowless Concept

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1. Introduction
Based on market forecasts, air traffic is expected to double by next 20 years and the whole airliners fleets will be increase with about 35000 new aircraft. According to this perspective, production and management costs will play a key role, as well as green design perspective. In this context the objective of this paper is to perform a preliminary design of a short-medium range windowless aircraft, with the aim to reduce fuselage weight. A feasibility study will bring to the assessment of weight and cost reduction in consideration to the introduction of innovative screens, to give passengers the possibility to see through the fuselage itself. An analysis of pros and cons has been performed to evaluate the possibility of such introduction in next generation aircraft.
2. Methodology
The proposed methodology consists in the preliminary design of a short – medium range aircraft, considering some defined design parameters and constraints. The activity will finally lead to weight reduction evaluation, in case the same aircraft will be designed windowless. The neutral hole theory is considered as reference for weight reduction estimation: in a fuselage, window holes have to be reinforced by stiffening panels, in order to reproduce a neutral hole condition, without any strain effect. They are not required in case of windowless configuration, so that all stiffening and transparent panel weights are computed and compared with the external metal sheet and added display weights. The resulting weight reduction results from that comparison multiply by a sensitivity factor.
The main challenge is providing passengers with the same comforting aspect of a traditional window, avoiding any claustrophobia feeling. Since it is a psychological reaction to an uncomfortable condition, one of the most challenging solutions is to recreate a condition similar to fuselage windows, by the introduction of technologically advance displays. OLED (Organic Light Emitting Diode) screens are considered for that purpose, and the employment of auto-stereoscopy and gaze-tracking techniques are evaluated, in order to create the same window perspective.
3. Case study and results
The design approach consists in the preliminary design of a short medium range aircraft, in accordance to some defined requirements (see table 1). Some existing configurations have been considered as reference, in relation to a proper market survey (e.g. AirbusA319, Boeing 737 and Sukhoi Superjet 100). The defined design parameters are considered as input for a novel study of a windowless configuration.
4. Conclusions
In this paper a preliminary design of an innovative windowless aircraft has been performed, in which the introduction of advanced display will take the place of the window itself. Some key advantages have been proved, such as:
fuselage weight reduction. This will lead to both fuel consumption and operating cost reduction; aircraft higher reliability; maintenance cost reduction; design commonalities between passenger and cargo configurations.
The total weight reduction between a traditional and windowless configurations is evaluated about 16.5%.

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Dispersion and chemical composition of Athena II rocket plumes: Model simulations versus in-situ aircraft measurements

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During launches, rockets release large amounts of gases and particles into the atmosphere. For Solid-fuelled Rocket Motor (SRM), launches often result into the release of chemically active radicals (chlorine radicals, nitrogen oxides,...), and alumina particles into the stratosphere. In-situ aircraft measurements within SRM plume wakes have shown that, as a result, ozone is largely destroyed within plumes because concentrations of ozone-destroying chlorine radical concentrations can be several orders of magnitude higher in the plume than in the undisturbed atmosphere [Ross et al., 1997]. This transient effect lasts for several hours or as long the exhaust plume is not completely mixed with the ambient air.
We present here numerical simulations of the evolution of SRM plumes and of their chemical compositions in the stratosphere. The focus is on the short-term effect on ozone. The evolution can be divided into two phases: near field phase (jet emerging from the nozzle exit) and far field phase. These two phases are characterised by different driving physical (rocket fluid dynamics versus atmospheric dynamics) and chemical (high temperature versus low temperature chemistry) processes. The temporal and spatial scales are also very different. The spatial scale of interest for the near field plume is of the order of a meter whereas the scales in the far field plume range from several meters to tens of kilometers typically. Exhausts spend about a second in the near-field plume whereas the far-field plume lasts several hours typically. No models are able to treat simultaneously, on one hand, very high temperature chemistry (including afterburning) and jet dynamics and, on the other hand, low temperature (ambient temperature) chemistry and relevant atmospheric dynamical processes. Therefore, we use two specific plume chemistry models for each phase with the results of the near-field plume model being used as inputs for the far-field plume model.
The near-field plume simulations are compared to previous model calculations and the model- calculated chemical evolution of the far-field plume is evaluated against in-situ aircraft measurements carried out in Athena rocket plumes during the ACCESS (Atmospheric Chemistry of Combustion Emissions Near the Tropopause) campaigns [Popp et al., 2002]. The model- calculated dispersion rate of the far-field plume is also evaluated against plume diffusion rates derived from videos, photos, lidar measurements, as compiled by Smith et al. review [1999]. We finely analyse the fate of reactive chlorine and nitrogen in the plume and the possible role of heterogeneous chemistry on alumina particles.

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Morphed vertical tailplane assessment for certification requirements

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The appearance of new materials and smaller and more capable actuators enable the morphing controlled deformation of the aerodynamic shape of wing like type of structures. This contribution presents the studies and conclusions of incorporating a novel morphing rudder for a commercial transport aircraft from the certification conditions perspective.

The fin and morphed rudder aerodynamics characteristics have been CFD modelled, and the results obtained point out the efficiency of the VTP design in engine-out scenario when improved with the morphed rudder. The lateral force developed by the morphed rudder is 16% higher than the conventional one for the same overall deflection. The studies also confirm that feasible morphing rudder architectures are achievable through new 3D printing materials and processes, see figure 2. The weight impact of these solutions is negligible in front of the aerodynamic benefits.
A commercial transport aircraft 100 passengers, two engines- low wing podded, has been modelled by means of a Matlab code for lateral-directional stability studies under engine-out conditions. The aircraft key parameters are included in Table 1.
The engine out condition is considered at critical take off speed, sea level conditions (air density 1.237 Kg/m3), Mach 0.25 and aircraft velocity 85 m/s. Table 1. Reference aircraft key parameters.
The maximum rudder deflection is set to 30º and the aircraft bank angle to 5º, for both configurations. The engine-out stable flight aircraft required slippage angle, , for the original and the morphed configurations are obtained by means of the aforementioned Matlab code. The available yaw moment coefficient is analysed for both configurations resulting on an increment of 8 %. Therefore it is concluded a decrease of 4% the aircraft minimum control speeds as defined in reference [3]. These results indicate that further studies are required for cruise conditions and rest of mission scenarios in order to assess the introduction of the novel morphing rudder on the aircraft, especially for the potential benefits in EROPS operations for twin engine airplanes.

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Aerial Delivery dynamic model validation by Flight Test

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Aerial delivery is a typical operation of military transport aircraft that consists of payload extraction during flight. The operation starts with the aircraft in steady flight and the ramp open. From this moment on, two phases can be distinguished: the payload units movement backwards inside the fuselage and the payload unit release when it reaches the ramp edge.
Airworthiness regulations require the critical loads during this process to be combined with atmospheric turbulence loads. For this purpose, a set of scenarios is considered, covering ramp structure, rear fuselage and ramp-to-fuselage junctions.
In particular, dynamic loads analyses envisage two situations that are the most severe in each of the two phases: The turbulence encounter during first phase, critical in the instant of time when the payload unit reaches the ramp edge and the aircraft dynamic response due to the ramp spring- back when the payload unit leaves the ramp.
In the classical dynamic loads approach, the aircraft incremental dynamic response is linearly superimposed to the steady "1g" loads obtained from steady flight. In the aerial delivery operation, as the cargo payload moves backwards to the ramp edge, the aircraft flight conditions and the steady loads change. For this reason, the classical "incremental + 1g" approach is no longer valid for aerial delivery analyses and an "incremental + pseudo-1g" approach is required.
From the structural point of view, the non-linearities in the ramp-fuselage interfaces are one of the most relevant parameters of this study. For this reason, it has been necessary to use a nonlinear approach, different also to the classical linear analyses used for most of dynamic loads calculations. The loads alleviation due to the non-linear Flight Control System is also included in the analyses.
In the last years, Airbus DS Military Transport Aircraft has been involved in its large military transport aircraft A400M certification. In addition to the certification loads calculation, this has implied an exhaustive flight test campaign that started in 2013.
This paper is devoted to present the A400M aerial delivery dynamic loads calculation methodology and validation by means of flight test. Some of the aerial delivery dynamic loads are among the A400M sizing critical load cases. Therefore the validation of the aerial delivery loads model is a critical issue in the certification path.
The aspects detailed above will be covered in this paper by showing:
- Different dynamic loads models used for A400M aerial delivery for their use in the linear and non- linear methodologies.
- Pseudo-1g approach for quasi-steady flight.
- Dynamic response to the payload unit release. Comparison between linear and nonlinear methodologies will show that this is a local effect and that the nonlinear methodology is only required to obtain loads of some specific ramp components (actuators and z-ties).
- Aircraft response to a discrete tuned gust produced during the extraction process.
- Aerial delivery dynamic loads model validation by flight test.

Concluding remarks will highlight how these results constitute a step forward in the understanding dynamic response of the ramp. The paper will end with suggestions for further work in this topic.

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Analysis of the flow in a propulsion nozzle subjected to a fluid injection

Chellou, Nassir (Hassiba Benbouali University of Chlef)
Benarous, A, Guendez, M. (Hassiba Benbouali University of Chlef)

The aero-thermodynamics propulsion systems is one of the fields of fluid mechanics where decisive progress is still needed to improve performance and meet the continued demand to orbit increasingly heavy payloads. It's the chemical propulsion that use the thermal energy during combustion of propellants, which remains the most reliable way to meet the requirements of high demands for the thrust, specifically to lift-off. For those of propulsion, the nozzle is the body to convert most effectively heat energy into kinetic energy of the mixture. The divergent portion of a nozzle is the seat of an exhaust gas flow at high enthalpy, where a fraction is transmitted to the walls, thus altering its lifetime. The long periods of operation and amplitude of the heat flux set in the issue, require cooling technique film for the wall of the diverging portion. For weight constraints, it is a fraction of the flow of fuel supplied to the combustion chamber, which is injected into a section of the diverging form of a gaseous film adjacent to the wall. The injection conditions should be adjusted in order to avoid problems associated with shock losses and local re-ignitions. This work represents a numerical investigation of the dynamic and thermal of a compressible flow in the nozzle BKE-DLR, representing a laboratory scale model of the Volvo nozzle of the European Vulcain cryogenic engine 2. The reactants H_2/O_2 are injected at 50 bar, with a mixture ratio of 6.2 in a cylindrical combustion chamber, wherein the thermodynamic conditions (pressure, temperature) are taken as reservoirs values for the flow relaxation. The axisymmetric nozzle with an exit area ratio of 57 is subjected to a GH2 film cooling in a section where the ratio is equal to 32. Energy & Euler's equations are solved on a non-uniform structured grid, using a finite volume method according to the Roe scheme for convective terms. A zero-dimensional calculation (0D) allows the use of thermodynamic relations to predict aero-thermochemical variables at each section of the divergent, especially in the downstream region of the injection section. The compressible flow in the absence of cooling is numerically reproduced on the axisymmetric model to predict the thrust level and the rate of loss by divergence. The results are compared with values predicted by thermodynamic calculations. The cooling is then carried out for the two cases, sonic and supersonic injection port, wherein a cooling index is defined as a reduced temperature. The distribution of the efficiency index for several downstream locations of the injection zone, is confronted with the measurements on the test bench (DLR). A parametric analysis is also conducted on the effects of the injection angle relative to the wall and the injected flow rate, on the level of thrust and on the cooling efficiency.

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Green Solid Propellants for Launchers

Wingborg, Niklas (Swedish Defence Research Agency, FOI)
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State of the art solid propellants are based on the oxidizer ammonium perchlorate, AP. AP is in many ways an excellent oxidizer but unfortunately it has negative impacts on the environment and on personal health due to:

* Ozone depletion
* Ground water contamination
* Thyroid gland interference
* Acid rain formation

The ESA Clean Space initiative emphasize the development of green technologies to reduce the environmental impact of space programs, taking into consideration the overall life-cycle and the management of residual waste and pollution resulting from space activities, both in the Earth eco-sphere and in space. Finding substitutes to AP is thus of interest.
This paper presents ways to reduce the environmental impact of solid propellants by replacing AP with alternative oxidizers such as AN, ADN and HNF. Results from the recently completed EU FP7 project HISP (www.hisp-fp7.eu) and the current Horizon 2020 project GRAIL will be presented.

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Dynamic Measurements on the NASA CRM Model tested in ETW

Hensch, Ann-Katrin (European Transonic Windtunnel ETW)
Quix, H. (ETW)

The European Transonic Windtunnel (ETW) hosted a test campaign within the frame of the European infrastructure project ESWIRP (European Strategic Wind tunnels Improved Research Potential). The project was funded by the European Commission "to enhance the complementary research potential and service capabilities of 3 strategic wind tunnels in Europe both in terms of productivity and quality" and to enable a trans-national access to these dedicated facilities for research institutes and university. ETW as Europe's unique testing facility for high Reynolds number testing is one of these strategic wind tunnel facilities in Europe, enabling tests under real flight Reynolds and Mach numbers at defined aeroelastic conditions. Within the ESWIRP project an international consortium was selected to prepare a test campaign to perform an unsteady wake analysis combined with wall interference investigations by demonstrating the capability to efficiently apply complex techniques under cryogenic conditions. In cooperation with NASA the NASA Common Research Model could be used as wind tunnel model, allowing to build up a public available database and giving the chance to compare results between wind tunnel facilities around the world. The present paper concentrates on the analysis of dynamic data acquired during the test campaign to assess the eigenmotion modes of the model. Therefore it describes the applied instrumentation system, the achieved results and the analysis to identify the eigenmotion modes.

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Additive layer manufacturing of monolithic catalyst bed

Essa (University of Birmingham)
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Additive Manufacturing for Space applications on European Space Programs

Bonvoisin, B. (European Space Agency)
Gumpinger, J., Ghidini, T., Pambaguian, L., Pigliaru, L., Makaya, A., Gerard, R. (ESA)

Founded on the background of sintering manufacturing and powder metallurgy processes, for two decades, Additive Manufacturing techniques (AM) allow making parts by stacking thin layers of materials one upon the other instead of machining away large amounts off a metal billet.
The market for this technology is growing exponentially and AM is even seen as a new industrial revolution for several industrial sectors. AM is opening new horizons on various domains of the space business. Telecommunication & scientific satellites, launchers and exploration missions will be positively impacted by AM capabilities. The potential benefits from the additional design freedom will have a significant impact at system level in terms of mass, cost, lead time and ecological footprint. This impact must nevertheless be quantified for each specific selected application.
This paper gives an overview of recent activities lead by ESA in the field of Additive Manufacturing for applications on European space programs. The ESA view for increasing the technology maturity level for space sector will be presented.

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Additive manufacturing of space propulsion hardware

Smith (European Space Agency)

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Characterisation of Material Demisability for Spacecraft Components

Merrifield, Jim (Fluid Gravity Engineering)

Jams Beck (2Belstead Research Limited), Georg Herdrich Adam S. Pagan (University of Stuttgart), Volker Liedtke (Aerospace & Advanced Composites), Benoit Bonvoisin (ESA)

With an increasing number of satellites scheduled to perform an uncontrolled entry at end-of-life, attention is increasingly directed towards the safety of people on Earth with respect to those debris items that make ground fall. Many components undergo destructive entry, which is characterised by break up events and ultimate demise as a result of the considerable heat fluxes and dynamic pressures suffered during hypersonic descent. It is widely acknowledged that spacecraft manufacturers have a responsibility to mitigate the risk to people and property resulting from satellite re-entry events to acceptable levels. Design for demise is an attractive alternative to controlled re-entry strategies, since system margin is not consumed by the additional subsystems needed for the latter approach. A key aspect for design for demise is material selection. As such, the characterisation of materials in terms of their propensity to demise under representative re-entry conditions is an enabling step towards design for demise. In this paper, we report on progress towards the thermal and mechanical characterisation of spacecraft materials using plasma wind tunnel and static facilities. The underlying key material characteristics and phenomenology found to govern demisability are discussed and presented.

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Impact of additive manufacturing on spacecraft engine design

Hyde (European Space Agency)

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Architectural Design and Testing of a De-orbiting Subsystem

Tiedemann, Lars (HPS)

Karl Dietrich Bunte (5etamax space), Tiziana Cardone (ESA), Robert Hahn, Sven Langendorf, Arne Riemer (HTS), Maximilian Klebor (HPS), Sebastian Meyer, Patric Seefeldt, Tom Spröwitz, Marco Straubel, Maciej Sznajder (DLR)

Space debris is one of the major threats to manned and un-manned space vehicles. With the increasing number of spacecraft launched into orbit, fatal collisions become more likely, generating more de- bris. Reducing environmental impact of space pro- grams is one of the main tasks of the ESA Clean Space Program. Within the scope of this program, ESA has initiated a number of activities aimed at developing technologies for space debris mitigation. The objective of the Architectural Design and Test- ing of a De-orbiting Subsystem (ADEO) project is to develop and test a passive de-orbiting subsystem based on a deployable drag sail for satellite in a Low Earth Orbit (LEO) in order to accelerate de-orbiting and ensure compliance to debris mitigation requirements. This paper presents the objectives and the current status of the ADEO project, presenting concept trade-off analyses, preliminary subsystem architectures and verification planning.

One major contribution to comply with debris mitigation requirements is to reduce the orbit life- time of satellites after completing their mission. This can be achieved either by active means (e.g. thrusters) or by passive means that rely on the residual atmospheric drag present in LEO. Drag sails can efficiently provide additional drag required to accelerate orbit decay. This method is particularly attractive for small satellites < 1000 kg without thruster systems which could be used for a controlled de-orbiting manoeuvre.
The objective of the ADEO project is to develop a generic, robust and lightweight deployable drag sail subsystem to ensure that a small LEO satellite is safely de-orbited within 25 years after mission completion. The activity is planned for a duration of 18 months and includes the following tasks:

- requirements review and consolidation,
- concept trade-off and selection,
- requirements definition for the selected concept,
- subsystem design and analysis,
- breadboards design, test planning and execution,
- subsystem test plan and demonstrator design,
- demonstrator manufacturing, assembly and test-rig adaption, and
- subsystem test campaign.

In the past, several developments like the solar sail evolved, which is similar to the activity described in this paper. Contrary to drag augmented de-orbiting, solar sails make use of solar pressure. One major difference is that solar sails are usually deployed at the beginning of the mission and not at the end of the mission as it is the case for the de-orbiting subsystem. The subsystem design takes into account higher level system and mission requirements. Breadboards and coupons will be produced and tested to simulate the long lifetime requirements of 45 years including 5 years on-ground storage. The suitability is verified by evaluating different concepts with respect to the following criteria:

- mass,
- robustness,

- scalability,
- passive stability, and
- adaptability.

Subsequently, a demonstrator model will be de- signed, manufactured and tested to verify its suit- ability for de-orbiting and further development to- wards future in-flight validation. The test campaign includes ambient deployment test, vibration test, rapid decompression test, thermal cycling test and a vacuum deployment test.

One major challenge for the design of a drag sail based de-orbiting subsystem is the hazardous environment in combination with the long mission life time. The most significant environmental sources for potential subsystem damages are: space debris, ultraviolet radiation and atomic oxygen. The design needs to be robust in order to be damage tolerant while providing passive stabilization to the satellite and avoiding generation of additional space debris. Booms supporting the drag sail membrane and deployment mechanisms need to be ultra-lightweight and stowed for > 15 years in orbit before deploying reliably. In LEO, the drag sail membrane is exposed to micrometeoroid and space debris bombardment due to its large area perpendicular to the satellite flight path. While the membrane itself is subject to a dedicated development project (Deployable Membrane), all other previously mentioned aspects are within the scope of the ADEO project.

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Development and Testing of Deployable Membrane for De-Orbiting Systems

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Due to the increase of operational spacecraft, the number of controlled and un-controlled objects in Low Earth Orbits increases rapidly. In effect, space debris may be considered one of the major threats for spaceflight in general. In order to reduce the environmental impacts of space programmes, in particular space debris, ESA has initiated the ESA Clean Space Programme, dedicated to developing technologies taking into account the overall lifecycle, pollution and waste management. Within the Clean Space Programme a project has been started with the objective to develop and test a deployable membrane for a passive de-orbiting system for small spacecraft.
The paper will present the intermediate status of work within the ESA project, in particular focusing on membrane material evalution testing and material trade-off, membrane joint design, membraneto-structure interface design and further test planning.

One major approach of reducing and preventing space debris, in particular in Low Earth Orbits is to quickly de-orbit non-operational satellites after their operational lifetime by accelerating their descent. This can be achieved by active means, e.g. by thrusters or by passive means by increasing the atmospheric drag of the satellite. In particular for small satellites, lightweight passive drag sails are considered a very efficient way of accelerating the de-orbiting.
ESA has initiated an activity which shall advance the technology required for such passive means of de-orbiting. The objective of this activity is to develop a lightweight, robust and reliable membrane which can be used as a drag sail for passive de-orbiting.
The activity covers the following aspects:

- State-of-the-art review of materials, sails technologies, packaging concepts and
- deployment concepts
- Material trade-off
- Material testing
- Definition of joining techniques, interfaces to booms, packaging and deployment technique
- Breadboard design, manufacturing and thorough testing
- Impact tests, ageing tests

The atmospheric drag required for passive de-orbiting significantly depends on the density of residual atmosphere. In consequence, the effect rapidly decreases with increasing altitude. While in orbits below 600 to 650 km the drag force is the dominant force acting on the satellite, this is not the case in higher orbits. Between 650 km and 750 km, depending on the atmospheric conditions, the drag force is in the same order as the solar pressure force. Above 750 km orbit altitude aerodynamic drag based de-orbiting with passive attitude stabilization is not suitable.

The major requirements for a membrane to be used as a drag sail are:

- Ultra low specific weight to allow for sufficiently large, yet lightweight sails
- Low storage volume
- Long lifetime (resistance to solar and cosmic radiation, particle radiation, space debris, etc.)
- Tolerance to long storage time under difficult environmental conditions
- Resistance to wide temperature range during storage and operation
- Mechanical robustness and damage tolerance

In particular, debris particles will be a major source of damage to the sail, considering an operational sail lifetime of up to 25 years in compliance with the European Code of Conduct for Space Debris Mitigation for Agency Projects. The debris size ranges from microns up to meters and due to the velocity of several kilometres per second, debris impacts are highly energetic. The membrane will inevitably be subject to impacts by space debris considering its large surface area and the long orbital lifetime. Thus, the membrane needs to be designed with sufficient margin, so that the required aerodynamic drag is sustained. Consequently, the effects of space debris impacts need to be studied in further detail and crack propagation needs to be minimised. Additionally, the effects of storage and ageing, in particular due to atomic oxygen, ultraviolet and cosmic radiation need to be considered since mechanical properties are prone to degradation.
This paper presents the intermediate status of work within the activity, in particular focusing on membrane material evaluation, testing and material trade-off, membrane joint design manufacturing (e.g. bonding, welding, etc.), membrane-to-structure interface design and further test planning.

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Introducing eco-design to ESA - An overview of the activities towards a coherent eco-design approach

Huesing, Jakob (European Space Agency)
Julian Austin, Tiago Soares (European Space Agency)

World leaders from nearly 200 countries participated in the latest UN climate change conference in Lima to discuss the future of the world's climate, human contribution, and possibilities to minimise the effect of human activities on the environment. With the two main contributors to climate change, China and the USA, announcing a bilateral 'climate deal', the responsibility to address challenges such as carbon emissions and resource depletion follow for everyone everywhere. As one of the consequences, an increasing amount of new and upcoming legislative measures address these demands.
In the space sector, environmental issues have only recently started to come under closer consideration. Yet through the risks of supply chain disruptions and the increasing environmental awareness of costumers, client operators, employees, and stakeholders, the sector will face new challenges. Aware of its unique position towards the European space sector and industry, ESA is proactively promoting awareness and striving to achieve a deep understanding of environmental impacts. For this reason, in 2011 ESA introduced Clean Space. Branches 1 and 2 of this initiative aim to streamline its activities in the area of environmental impact assessment, eco-design and development of newer and greener technologies. As a by-product, these activities will create a competitive advantage for the European space industry. ESA takes a system level approach to develop a framework to support projects in monitoring their supply chain for compliance with existing and future regulation, evaluating environmental impacts, and identifying possible sustainable alternatives while minimising the overall system level impact to the project.
This paper aims to give an overview of the different activities within branches 1 & 2 of Clean Space, how they are organised to build upon and supplement the results and outcomes of the preceding or parallel activities and how these activities feed into a coherent eco-design approach at ESA. Initial studies addressing the environmental impact of the European launcher family established the applicability of Life Cycle Assessment (LCA) to the space sector. Subsequent studies broadened ESA's knowledge about specific methodologies to assess the impact of space activities and helped to define a methodological framework for its application in space. A database with data sets for space specific materials and manufacturing processes and space propellants is being developed in addition to a database that aims to track the use of hazardous materials (e.g. as defined by REACh) throughout the life-cycle of a space product to proactively mitigate supply chain disruption risks. These efforts then culminate in the creation of an ESA handbook on the methodological framework for the use of LCA in space.
Based on the assessment of the environmental impact of space activities, the following step aims to introduce eco-design principles into the design of future space missions. A first step in doing so will be the introduction of a preliminary LCA tool into ESA's Concurrent
Design Facility (CDF) to enable the environmental impact as an additional design parameter. Furthermore, ESA aims to carry out pilot studies to assess the application of eco-design to space products and will introduce an internal eco-design course to promote the awareness of the environmental impacts of our activities during the design process of space missions.
Finally, the eco-design activities are framed by studies on the effective communication of environmental impacts to support European space industry and its stake holders to turn a potential threat into opportunity.

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ESA green propulsion progress

Valencia-Bel, F. (European Space Agency)
D. Greuel, A. Gernoth (ESA)

In 2011, Europe's Research Evaluation Authorisation and Restriction of Chemicals (REACH) added Hydrazine to the Candidate List of Substances of Very High Concern (SVHC). This has caused increased concern over the future restrictions on the production and use of Hydrazine.
There is thus a greater demand for green propellants. A stronger focus is needed to bring green propellants and associated propulsion system components to an operational state in the near term. Also, it raises the concern on the potential inclusion of other conventional propellants (e.g. MMH, UDMH) into the SVHC list. In 2012, ESA identified and stressed the need to invest more efforts on the development of green propulsion technologies and submitted a paper in the Space Propulsion Conference in Bordeaux with the intention not only to describe the most promising green propellant candidates but also to define priorities, describe tasks and the top level requirements to develop replacements for conventional spacecraft propellants. Also, ESA in coordination with industry and the national delegates, generated a green propulsion roadmap describing ongoing activities and defining the focus and prioritisation of the green propulsion technologies to elaborate a future strategy and to establish a strong base as a key to the competitiveness of European Industry.
This paper provides an update and describes the current status on REACH regulations, current and prospective activities within ESA on green propulsion, European industrial initiatives (e.g. green propulsion working group) and other relevant green propulsion on-going activities within Europe. Finally, a description of the main challenges on the definition of requirements and technology development is provided.

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Findings and conclusions from the AtILA project

Murray,N. (European Space Agency)
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ESA, through the Cleanspace office, has been striving to better its understanding and awareness of the environmental and atmospheric issues linked to its space activities. Over the past few years the Cleanspace office has initiated a number of projects and initiatives to reach this goal and further, to explore mitigation strategies. One such project is the AtILA project, whose ambitious aim is to understand the impact of our launch plumes on the atmosphere. Although it is generally considered in the rocket and atmospheric communities that due to the low frequency of launches worldwide, rocket emissions do not have a significant impact on the global environment there is the need to qualify this statement with scientific analysis and reason. The AtILA projects aimed to do this by computing the transient impact of the ESA launcher plumes from the small scale at the nozzle exit to the large global scale.

This never---before---preformed exercise has answered some of our questions but also posed new questions such as the long---term role of fine exhaust alumina on ozone depletion. This paper will present the methodology used as well as explore some of the important findings and conclusions. The limitations, open questions and work to be done will also be discussed leading to a conclusion on the current situation and the way forward.

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Developing a standardised methodology for space-specific Life Cycle Assessment

Austin, Julian (European Space Agency)
Jakob Huesing (Rhea for European Space Agency), Tiago Soares (European Space Agency), Luisa Innocenti (European Space Agency)

Environmental protection has become an extremely prominent subject resulting in rapid development of environmental legislation. European industries, particularly those in consumer goods, are being called by the European Commission through the Joint Research Centre to evaluate their environmental impacts.
This is done through the use of life cycle thinking, and more specifically Life Cycle Assessment (LCA), an internationally standardized tool (ISO 14040 and 14044 [1]) widely accepted as the best way to assess one's environmental footprint. The use of Life Cycle Thinking (analysing a product from cradle to grave) avoids burden shifting; transferring impacts from one part of the life cycle to another, from one region to another, from one generation to the next etc. The European Commission, through the Joint Research Centre, is implementing standardised LCA methodologies called 'Product Environmental Footprints' with specific 'Category Rules' (http://ec.europa.eu/environment/eussd/smgp/product_footprint.htm) for several industries but as of yet the space sector has been exempt.
Performing LCA in the space sector is unique, due to many specificities of the industry and therefore the ISO standards do not suffice as a rigorous methodology to follow. At ESA, these difficulties have been tackled and LCAs have been carried out on the European launcher family (Vega, Ariane 5 ECA/ES) as well as four complete space missions (Earth-observation, telecommunications, meteorological and science). Studies are also currently underway on LCAs of materials and processes and space propellants specific to the space sector.
Furthermore, industry has begun work in the area, with Airbus DS, CNES and Arianespace all performing environmental impact studies. In order to aid communication in the area, and to be able to exchange and understand results, it is important to establish a standardised LCA methodology for the space sector, from an early stage. The European Space Agency is performing this role, developing a handbook titled 'Space System Life Cycle Assessment (LCA) Guidelines'. This internal handbook will provide the methodological framework for users to perform LCAs in the space sector, at system or component/equipment level, as well as guidelines on how to communicate on the results. Such a methodology will harmonise and encourage future LCA studies from both ESA and industry, and provide a necessary step towards the longer term goal of eco-design, where a product is designed in such a way as to reduce the environmental impacts.

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Airbus Defence and Space Global Approach to Space Debris Mitigation

Duhamel, Thierry (Airbus Defence and Space)
Daniel Briot (Airbus Defence and Space)

This paper will address our approach to Space Debris Mitigation with a global system perspective from requirements to design and operations. We will review the various studies and development already performed by Airbus DS to support the implementation of Debris Mitigation. Priorities for future technology development will also be presented.

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CleanSat: the Clean Space's response to the space debris situation

Soares (European Space Agency)
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There is an increased attention to safeguarding Earth's orbital environment, as reflected by the number of relevant regulations that are being set forward worldwide. ESA has published an update of the ''Space Debris Mitigation Policy for Agency Projects'' in March 2014.. These complement national and international regulations on the matter, such as the French Space Operations Act (FSOA), fully applicable to European launchers and satellites manufactured and/or operated from French territory as of 2020, and the Space Debris Mitigation Guidelines of the United Nations Committee on the PEACEFUL Uses of Outer Space (UN COPUOS).
In this evolving regulatory context, support to the compliance with SDM requirements contributes to fostering European industry innovation and competitiveness.
ESA through its Clean space initiative is preparing a programme called CleanSat. This programme aims at providing an efficient framework for the fast implementation of innovative technologies, supporting the evolution of the LEO platforms for compliance with space debris mitigation in a coordinated approach at European level.
CleanSat embodies Europe's response to worldwide market demand for SDM compliant solutions. The preparation of CleanSat is being carried out in close link with the European System Integrators and in particular the three Large Systems Integrators (LSIs) – Airbus Defence and Space, OHB and Thales Alenia Space.
CleanSat challenges, objectives, achievements and future steps will be presented.

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Simulating and testing throw-nets for space debris removal

Wormnes (European Space Agency)
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EU environmental regulation and the space sector: an overview

Ariaudo, Paolo (PWC)
Scatteia, Luigi (PWC)

Protection of the environment, sustainable development and climate change control represent key policy areas for the European Union. In past decades, several policy initiatives were developed within the EU, resulting in a considerable amount of legislative work devoted to promote an environmentally sound European economy, with the ultimate overarching objectives to foster an environmental footprint reduction for European industries and services and to promote sustainable development.
Much of the EU legislation directly impacts (or deliberately targets) specific industrial sectors, such as emission reduction in automotive industry. Some of the legislation affected several industrial sectors and markets in a general sense, like for the Space sector. An overview on the impacts of EU environmental legislation on the EU Space sector (upstream – industry, and midstream – operations) is provided here. The overview looks at the global and European space market, and the effects that environmental legislation may have on European industrial competitiveness, for example by anticipating global trends and promoting the developments of new products and processes within the space domain. The overview also looks specifically at the applicability to space activities of available environmental foot-printing procedures and tools.

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A potential framework for the safe and permanent passivation of a LEO battery bus power system

Alcindor (SSTL)

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Future Sky

Eijssen, Paul (EREA)

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People, Planet, Profit: the Making of the Clean Sky 2 PPP

van Manen, Ron (Clean Sky JU)

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The Clean Sky programme is one of the 5 original Joint Technology Initiatives [JTIs], a new instrument created under FP7 with the aim of accelerating the pull-through of innovations by de-risking and validating technology in major, integrated demonstration projects. Now 6 years in operation, it is evident that this public-private approach has succeeded and is showing promising results.
Clean Sky 2 will continue and extend the “PPP” approach under the new Horizon 2020 Research and Innovation Programme [H2020]. The socio-economic and political context under which H2020 was created and will operate has changed considerably from the mid-2000s when the initial JTIs were developed, and H2020 will address a much broader scope balanced across scientific excellence, key societal challenges and importantly: industrial leadership. The announcement by former EC President J.M. Barroso on July 9th 2014 of the European Commission’s Innovation Investment Package, launching a total of over 20bn€ of public and private investment through the renewed JTIs and other public-private instruments demonstrated the European Commission’s commitment to reinvigorating European economies, kick-starting growth and investment, and laying the ground for Europe’s knowledge based and sustainably competitive industries. The announcement capped two years of intense preparation of a Joint Technical Proposal from 16 leading European aeronautics players, coordinated by the Clean Sky JU as “programme office”. Clean Sky 2 has now taken off with over 4bn€ in total committed funding, 2.5 times the original Clean Sky budget, and with a jointly architected 10-year roadmap for its execution. It will move well beyond the original Clean Sky “flight envelope” in terms of addressing a balance of next-generation solutions versus long-term technological breakthroughs; an agenda formally addressing industrial competitiveness and new mobility solutions; and a dedicated “outreach” to Europe’s academia and young researchers to build human capital.
The speaker will reflect on the approach taken in bringing Europe’s main industrial interests and research actors together towards a compelling “vision for the future” that meets the challenges set under H2020 and sets the scene for the next decade of aeronautics research in Europe: and in so doing can “finish the job” of addressing the ACARE SRA Goals for 2020 and make the first important steps towards the even more challenging goals set in the new SRIA for 2035 / 2050.

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Active Flow Control Applied at the Engine-Wing Junction

Fricke, Sebastian (previously German Aerospace Center DLR)
Vlad Ciobaca, Anna Kröhnert, Jochen Wild (DLR), Olivier Blesbois (Airbus Operations)

The integration of UHBR (Ultra High Bypass Ratio) engines mounted under backward swept wings may lead at low speed to local flow separations on the wing suction side in the wake of the nacelle. These local flow separations can trigger the total wing stall which degrades the total aircraft performance. This paper presents a numerical study of AFC (active flow control) applied at the engine-wing junction of a generic full scale wind tunnel model to suppress the local flow separations. The AFC method is based on the principle of fluidic actuation and assembles a pulsed blowing with a 180° phase shift between the neighbouring nozzles. Its working principle is the production of vortices that enhance the mixing of the boundary layer and the free stream flow. The free stream flow in the wake of the nacelle is compromised due to the wakes of local flow separations and longitudinal vortices such as the strake vortex. The computation results show that pulsed blowing is capable of suppressing the local separations. It is shown that a certain blowing velocity exists that is required for the suppression of the nacelle-wake separation. Additionally the influence of the pulse frequency was analysed with a parameter study. It was shown that the local flow separations were suppressed by both low and high pulse frequencies.

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The Clean Sky Experience: a Cluster Core Partner's perspective

Kortbeek, Peter (Fokker Technologies)
Kos, Johan (National Aerospace Laboratory, NLR)

In 2008 the Clean Sky 1 program was started. In four ITD's Dutch clusters participated as "Core Partner". Each cluster consisted of academia, a research institute, SME's and Industry. Beside the Dutch clusters there were also clusters from Switzerland (RUAG), Romania (INCAS) and Italy (CIRA).
In many aspects , the Clean Sky program deviated from the standard FP7 programs. The size was unique, a special body - the Joint Undertaking - was established and the participants had to go through piles of contracts to assure that the work could be executed properly. The collaboration in a value stream on joint demonstrators, either ground based or actually flying, added a new dimension in collaborative research and development.
In the presentation, the authors look in retrospective what the Clean Sky program has revealed. The focus will be on the work, performed in the Smart Fixd Wing Aircraft ITD, where the Dutch Cluster worked on topics like an innovative flap concept, an RTM Load Introduction rib, and an advanced aft body demonstrator. The way of working and the results of the collaboration will be presented.
In the presentation the balance of efforts and revenues of Clean Sky 1 will be discussed, and an outlook and expectations will be shown for the Clean Sky 2 program, the successor of CS1.

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Challenges in Introduction and Certification of Thick-Walled Composite Components in Landing Gear

Sijpkens, Tjaard (Fokker Landing Gear)
Smeets, Mike (Fokker Landing Gear)

Accident rates in commercial aviation are at a historic low. For a large part this is the result of using learned lessons of past accidents and incidents, and translate these into rules and procedures that must be met when certifying new aircraft. This proceduralization of safety has served us well in achieving low accident rates. However, it also tends to constrain new technologies as the rules and procedures are generally based on past technologies. As a result the benefits of new technologies cannot be exploited to the full extend. For instance, currently, deterministic rules and procedures are required for certification of aircraft structures. This works quite well with isotropic metals in mind, however does not support the design flexibility of composites. As a result composite structures used to be constructed quasi-isotropic ("black metal" or "black aluminum"). For composites more probabilistic rules and procedures would be preferred.
In this presentation thick-walled composite landing gear components will be used to example the challenges that exist when introducing new technology for certification using current regulations.

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Model based system assessment and trajectory optimization on aircraft level

Re, F. (DLR)
Schlabe, D., Müller, R. (German Aerospace Center DLR)

The identification of aircraft level benefits like the reduction of mass, drag, power offtake, and consequently fuel-burn is a key aspect in assessing new technologies like green taxiing systems, electrical environmental control systems, and optimized aircraft trajectories. A basic means to determine these deltas is a detailed dynamic model of the aircraft containing the flight dynamics, kinematics, aerodynamics, engine behaviour and emissions as well as systems for ground operations.
This paper shows the principles of this model-based approach and gives quantitative results with respect to fuel consumption, NOx and noise emission for two examples.
The first example is a trajectory optimization task. Hence, a modular integrated model combines aircraft dynamics, 4-D trajectory generation and following, aircraft electronic flight control system, models for accessing remote terrain and weather data, wind & turbulence models, as well as criterion models such as noise and pollutant emissions and contrail formation. The model has been developed in the Modelica modelling language using the FlightDynamics library which makes it possible to easily exchange or (de-) activate submodels depending on considered scenario. Using an external optimization tool on a selected scenario, Pareto-optimal solutions could be achieved with reductions for 50dB noise area of 0-6% and 15-4% for CO emissions with respect to an unoptimized baseline trajectory.
In the second example, an electric driving system used for taxiing without main engines is considered. While this system is expected to reduce the fuel consumption and emission on ground, the added weight will worsen the in-flight performance, thus compromising the overall balance. The benefit resulting from this technology is strongly dependent on the aircraft and missions flown on a case-by-case basis. Different gate-to-gate mission simulations with realistic trajectories have been performed using the same aircraft model as in the first example. Finally, the emissions and fuel consumptions are compared over the whole mission as well as in each flight phase. Different flight missions and configurations have shown significantly different overall results, ranging from a fuel saving of 2.6% to an extra consumption of 0.3 %. For the case with the largest fuel saving, overall CO and HC polluting emissions could be reduced by 33 % and 47 % respectively. NOx emissions on ground were reduced by 65 % to 77 %.
This kind of model-based approach can be extended to a set of pre-defined missions, thus allowing the assessment of the new technology in a realistic, everyday operational situation and ultimately helping stakeholders in the decision whether adopting the new technology in a concrete case. Additionally, the application of multiobjective optimization allows finding optimal system architectures and trajectories for several environmental related objectives.
Finally, an outlook will be given to show how a global aircraft assessment and optimization platform can be established. Its core is based on the FlightDynamics library and it interfaces to several local system design platforms like one for the electrical system.

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Flight Management System improvement : Optimized Steps in cruise

Delpy, Patrick (Thales)

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Tbd

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Multi-use 48kW DC/AC and AC/AC Power Electronic for unpressurized area

Engler, Alfred (Liebherr Elektronik)

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In order to achieve the goal replacing hydraulic systems by electrical systems, the power density is a key parameter for electrical designs. Especially applications in unpressurized area require hermetic sealed heavily weighted housings. The approach to replace these housings by a sealed weight reduced open box design with liquid cooling covers design challenges like coating, humidity, bedewing, low pressure, arcing, corona and partial discharge. One of the design goals is a HV management plan including new design rules for open box design, avoiding arcing and partial discharge.
The power electronic designed for HV AC and DC networks in duplex architecture, with and without HV input filter and inrush current limiter. A couple of environmental engineering tests according DO160 for unpressurized area accomplished successfully. In particular, two coated units passed altitude test in first attempt. Development of measurement methods of assembled power electronic in order to proof partial discharge free design will complete the design study. The achieved reduction of weight thanks to the new housing concept looks promising, further investigations will follow.

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Automation in Aerospace Composites: State at NLR and future developments

Thuis, Bert (National Aerospace Laboratory - NLR)

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The world fleet of civil airplanes will double over the next twenty years. This means that there will be a demand of 32,600 new aircraft by 2034. The majority (70%) of these new aircraft will be single aisle. Large OEM's at present are building single aisle aircraft at a rate of 40 – 50 aircraft per month. In order to be able to meet the demand for new single aisles production rates have to be increased to 65 – 75 aircraft per month (source Aviation week & space technology, April-May 2015).
To meet the challenging production rates and the ambitious cost and weight savings automated manufacturing, assembly and inspection concepts have to be developed in order to:

- Improve accuracy;
- Improve reproducibility;
- Improve output (kg/hour);
- Reduce scrap rates.

At the National Aerospace Laboratory – NLR new automated composites manufacturing and inspection concepts are being developed according to the Robot Based Composites Manufacturing Concept. In this concept relatively standard robot systems with various end effectors are used in combination with other automated manufacturing processes like braiding and press forming to increase flexibility in product range.
At NLR the research on automated composites manufacturing has its focus on automated fibre placement for thermoset, thermoplastics and dry fibers, press forming and an automated composites manufacturing pilot plant for resin transfer molding.
In the presentation these processes will be highlighted by showing some examples of several R&D programs. The presentation will end with a summary of future developments at NLR in the field of automated composites manufacturing.

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Research and Development of Time and Energy Managed Operations (TEMO)

Bussink, Frank (National Aerospace Laboratory NLR)

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In the last decades continuous descent operations (CDO) have been a subject of extensive research, and have proven successful in reducing noise, fuel and gaseous emissions. However, different aircraft types and weights, along with weather conditions, create a wide variety of possible trajectories and as a consequence, CDO trajectory predictability has proven difficult for air traffic control. Numerous researchers have addressed this problem by suggesting new concepts of operations and/or flight guidance methodologies. NLR and TU Delft both part of the GSAF (Green Systems for Aircraft Foundation) consortium and partner DLR have developed the Time and Energy Managed Operations (TEMO) concept: a new integrated aircraft planning and guidance concept that uses direct collocation methods to optimize the vertical trajectory; and speed-on-elevator guidance to achieve a continuous engine-idle descent, while satisfying time constraints.

The research leading to these results received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) through the Clean Sky Joint Technology Initiative under Grant Agreements Number CSJU-GAM-SGO-2008-001 and was performed within the Management of Trajectory and Mission (MTM) work package of the area of Systems for Green Operations (SGO).

This presentation will provide a brief introduction of the TEMO-concept and an overview of the research performed during 2011-2015, starting with the results of the technology readiness level 3 (TRL-3) batch study. In this study the performance of the algorithm was analyzed, and a comparison was made between TEMO and a conventional FMS in terms of time adherence performance and environmental impact. During the TRL-4 activities different human machine interfaces (HMI) were created and evaluated with pilots on NLR's fixed-based

flight simulator, as to determine what information is required to meet all TEMO objectives. In 2014 additional piloted evaluations were performed covering a full motion flight simulation experiment at NLR's Grace and another piloted experiment at DLR's fixed-based flight simulator GECO, that combined all previous activities and demonstrated that the technology had reached TRL-5. All this then served as a precursor to the flight test activities, which will be performed at the end of 2015, independently using NLR's Cessna Citation II and DLR's Airbus A320 Atra aircraft.

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Introducing Air to Air Refuelling (AAR) into Civil Aviation

Nangia, Raj (consultant)
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Over the last decade, the Air-to-Air Refueling (AAR) ideas are being explored towards civil application. There is now renewed confidence that AAR has the potential to bestow a step change towards higher efficiency in civil aviation. AAR origins, of course, are from Military circles where for last 80+ years. Aircraft are designed, taking for granted, that AAR is available on demand. The military tankers essentially operate like "garages" in sky. The missions need to be successful rather than be overly concerned about fuel usage. Often tankers accompany and refuel shorter range aircraft over longer missions. However, the civil operations are aimed at saving fuel and the tankers will operate over shorter radii.

An overview of metrics provides the understanding of the sensitivities involved in aircraft design and setting up the operational concepts for an AAR-system. This yields the study cases on anticipated aircraft performance and missions. Operational issues and constraints e.g. Turbulence, Air Navigation Services and environmental impact are discussed.

The AAR system. introduced as replacement for today´s Inter-Continental air travel system would give fuel savings and CO2 emission reductions 15-30% (depending on mission range). Additionally, there are 30-40% weight savings.

To maintain transport capacity, more AAR cruisers may be needed. However, the total flying mass (metal) in the is lower.

The highest benefits from AAR in civil air traffic as the system transforms towards point-A to B rather than the "hub-spoke" solution. The smaller AAR-cruisers inherently give the opportunity for smaller airports to make new connections compared with the larger baseline cruisers. For a sustainable growth of aviation and meeting the demands from continued urbanisation, there is a clear need to mitigate short flights to other transport modes. The relief in capacity from reducing number of short flights can then be used for long flights, where aviation transport, for the foreseeable future is the only viable solution.