NACRE Report Summary

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Final Report Summary - NACRE (New aircraft concepts research)

The ultimate aim of the NACRE project was to integrate and validate technologies that enabled new aircraft concepts to be assessed. As such, it did not concentrate on one specific aircraft concept, but it developed solutions at a generic aircraft component level (cabin, wing, powerplant system, fuselage) which would allow the results to be applicable to a range of new aircraft concepts. For each of the major aircraft components, the multidisciplinary investigations explored the different associated aspects of aerodynamics, materials, structure, engines and systems with the goal of setting new standards, together, for the future of aircraft design, thereby ensuring improved quality and affordability, whilst meeting the strengthened environmental constraints (emissions and noise), with a vision of global efficiency of the air transport system.

The NACRE partners defined a set of concepts tailored to address specific subsets of design drivers:
- two Pro-green (PG) aircraft concepts put a major emphasis on the reduction of environmental impact of air travel;
- the passenger-driven Flying wing (FW) concept was developed using the final result of the VELA project, with a view to maximise efficiency for passenger transport and for low-fuel consumption;
- the 'inside-out' designs of Payload driven aircraft (PDA) cabin concepts aiming at optimised payload and appreciable quality of future aircraft for the end users;
- the Simple flying bus (SFB) put the biggest emphasis on low manufacturing costs and the minimum cost of ownership.

Irrespective of what final future product configurations might ever look like, these concepts acted as basic vectors, describing and stimulating the future capability developments. More than the intrinsic value of any of them, what is of importance was the consistent capability enhancement that they prepared. The general project objectives were thus to use these concepts in order to:
- explore alternative routes for the major aircraft components better suited to their specific targets and which would have been rejected in a balanced approach;
- provide better answers to the full range of requirements by developing, and, in some cases, validating the associated envelope of innovative component designs and associated technologies.

The project was split in four Work packages (WPs), the objectives and the work performed of which were the following:

WP1 - Novel aircraft models

- Task 1.1 - PG A/C: The primary objective was to define two preliminary innovative aircraft concepts aiming at the maximum environmental performance in both carbon dioxide (CO2) emissions (fuel burn) and external noise level through the mastering of the key areas related to advanced wing design and unconventional engine integration; those innovative aircraft concepts would feature both advanced engines integrated on top of fuselage for maximum noise shielding and advanced wings designed for best achievable fuel burn performance.

- Task 1.2 - PDA: Task 1.2 covered a single payload-driven or passenger-driven domain, but it was actually divided into two
separate activities, with two totally different approaches:
(i) a real passenger-driven design approach, from the inside out, starting from cabin requirements and design followed by structure then aerodynamic assessment. The specification of this configuration would be centred around the needs and packaging of the aircraft payload, with a strong focus on driving alternative cabin designs; and
(ii) providing guidance and requirements, and integration feedback to a follow-on project of VELA for the flying wing activities aiming to develop and improve a baseline configuration upon which key technical achievements are assessed.

Task 1.3 SFB A/C: The primary objective of Task 1.3 was to drive the research on innovative aircraft component concepts with the following targets:
(i) to reduce the cost of acquisition, operation, and maintenance from the aircraft operator perspective; and
(ii) to reduce the cost of manufacturing, customisation, and support from the aircraft manufacturer’s perspective. The key aircraft SFB components to be addressed are: advanced fuselage, efficient manufacture-driven wing, innovative empennage, powerplant systems concept (engine and integration).

Task 1.4 Innovative evaluation platform (IEP): The goal of Task 1.4 was to study an alternative to existing test practices by assessing and showing the benefits of an IEP. The IEP should be considered as an additional test facility, which in some cases could be competitive with the existing test facilities not only in terms of cost, but also by providing new capabilities and/or more availability or flexibility. This IEP was intended to be evaluated in flight to challenge the expected added value compared to the existing experimental tools. The initially limited knowledge of the potential and benefits of this type of experimental platform called upon studies to gain more experience in this field.

WP2 - Novel lifting surfaces

Task 2.1 - Advanced wings: This task aimed to explore the integration of wing engineering disciplines to establish the potential of a range of novel wing concepts. A range of key multidisciplinary trades and innovative integration solutions were identified for each concept for further investigation. Configuration trade studies would be performed around each wing concept leading to a preliminary integrated wing solution focused on the given design driver.

Task 2.2 - Flying wing: The aim of this task was to research innovative solutions for the most important issues of passenger carrying flying wing aircraft, which were addressed sufficiently in previous research programmes. These were mainly in the areas of:
(i) cabin layout and passenger safety;
(ii) structural solutions;
(iii) control and aerodynamic performance.

Task 2.3 - Innovative tail integration: Task 2.3 aimed to explore the feasibility of a novel tail design for a civil aircraft configuration. The results would be assessed at overall aircraft level in WP1, Task 1.3 by comparing with a datum conventional empennage bearing the same functionalities. This would be achieved through a multidisciplinary investigation and assessment.

WP3 - Novel powerplant installation

Task 3.1 - Rear engine integration: This task aimed to assess the two powered tail concepts, defined for maximum shielding of engine noise sources and best achievable fuel burn. This would be achieved through a detailed analysis in terms of aerodynamics and acoustics. The two concepts would be addressed through numerical computations to assess their aerodynamic performance, to identify possible critical phenomena at take-off/landing conditions and to predict engine installation effects on noise generation and propagation and therefore on noise shielding potential. Aerodynamic concept performance and tail characteristics at cruise flight conditions for one concept and acoustic characteristics of jet and fan noise
on a generic configuration would be evaluated by wind tunnel tests.

Task 3.2 - Radical engine integration: The objective of this task was to investigate the problems raised by a radical integration of the engines on the aircraft airframe. For instance, for a PDA type configuration, there is an interest to install the engine close or partly buried inside the airframe: the pitching moment due to the engine thrust is reduced and the trimming is obtained with less penalties, the aircraft weight is reduced without any pylon, the engine noise radiated is also reduced due to a masking effect of the airframe. For a PG type configuration, there is an interest to install the engines on the rear part of the fuselage and relatively close to it to reduce noise emissions and to improve the aerodynamic performances of the wing, without the negative effect of the engine installation. But major issues can occur for the engine due to a bad aerodynamic quality of the intake flow due to the proximity of the airframe, and even for extreme configurations the possible ingestion of the thick airframe boundary layer. In addition, the certification issues can be critical for the case of engine burst event and, for this purpose, material and energy absorption analysis should be considered.

Task 3.3 - Hung engine integration: The main objective was to provide the engine integration perspective for the SFB as far as the complete propulsion system architecture is concerned.

WP4 - Novel fuselage

Task 4.1 - Powered tails: This task aimed to explore the integration of engines over the rear fuselage for the maximum shielding of engine noise sources and best achievable fuel burn. This was an innovative rear integrated fuselage design including the empennage, together with the presence of large nacelles in this area: all components were close together and highly interacted with each other. This new concept also required structural architecture and integration studies.

Two different powered tail concepts were defined and optimised aerodynamically through an integrated approach in order to master interactions between aircraft components and obtain best possible performance.

Task 4.2 - Advanced cabin: The objective was to initiate preliminary technical studies of wide-fuselage PDA concepts. This would enable the NACRE team to understand the fundamental advantages and challenges relating to aircraft designed around the requirements of the payload (passenger or freight). This approach to design could be referred as ‘inside out’ i.e. wrapping the structural and performance aspects around the needs and desires of passengers. This approach could result in fuselage designs that are non-circular. Furthermore, concepts would be established that would increase cabin flexibility with regard to improved economics and increased functionality.

Task 4.3 - Cost-efficient fuselage: The primary objective was to investigate innovative low-cost designs of simple fuselage for advanced aircraft concepts in Carbon fibre reinforced plastic (CFRP). Taking into account the whole fuselage (from the nose to the rear), it would explore fuselage architectures and system installations, based on two families of concepts, through global design and sizing approaches. This task would also address the major aspects of fuselage design, such as quick and easy system installation, innovative manufacturing technologies, advanced structure design, weight assessment for advanced materials, development and manufacturing schemes, and on operation and maintenance cost.

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