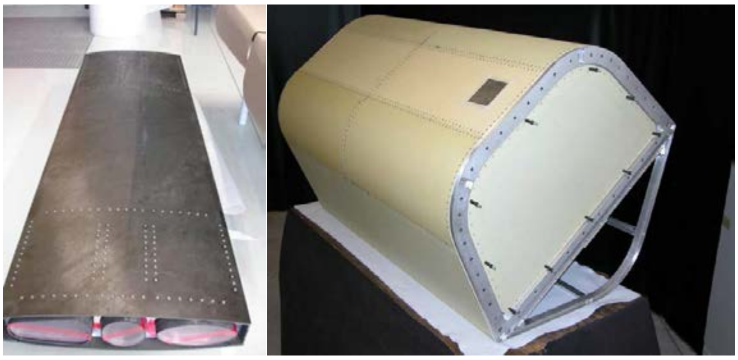
BaToLUS: Battle Damage Tolerance for Lightweight UAV Structures

The BaToLUS project, Battle Damage Tolerance for Lightweight (Unmanned Aerial Vehicle) UAV Structures, ended in May 2015. The results show how future lightweight aerospace vehicles such as UAVs can be designed and built for reduced vulnerability to battle damage.

Compared to more conventional combat aircraft designs, extremely lightweight structures exhibit different distributions of strength and stiffness. Parasitic protection cannot be the only solution to the vulnerability problem due to the resulting operational penalties being inherently very severe. Within the BaToLUS project, cost-efficient alternatives to a well-defined baseline configuration have been developed by improved structural design, aiming to offer increased tolerance against battle damage, whilst supporting the original requirements and keeping potential penalties small.

Thanks to BaToLUS, new rapid prototype modelling capabilities have been developed. Also, a generic design process, which includes "Vulnerability Load Cases", and novel high-fidelity simulation methods have been demonstrated. A large number of structural concepts for vulnerability-reductions have been identified, assessed and, for two of them, implemented and tested. Operational evaluation with respect to impacts on cost, weight and capabilities were considered at overall platform level, together with vulnerability analysis taking into account the demonstrated structural performance and aerodynamic damage characterisation.

The main objectives of the project have been (i) definition of a Remotely Piloted Aircraft System (RPAS) design and development process for vulnerability reduction to be integrated in the design process, (ii) demonstrate improvement of the current RPAS modelling, simulation and design capabilities, and (iii) provide a guideline on the costs associated with the development of a vulnerability-improved RPAS.



Example of a wing and a centre fuselage demonstrator developed in the BaToLUS project.

In detail

DEMONSTRATOR ANALYSIS

Based on results from previous projects, BaToLUS kicked off its activities by defining the environment within which the project was bound to operate: mission scenarios; threat scenarios; mission requirements; RPAS type (a specific MALE RPAS class was selected). These results guided BaToLUS development of vulnerability reduction enhancements to unmanned systems, based on a combination of current and future scenario analysis and mission requirements, to provide RPAS platforms with greater abilities to execute complex missions in a dynamic environment.

Following the definition of requirements, including structural, aerodynamic and vulnerability properties, and a threat analysis, a baseline MALE RPAS, called BaTMALE-B, was designed. The identified non-compliances (especially in vulnerability) were used to generate an improved design, called BaTMALE-I. Focusing on the wing and the centre fuselage, material coupons and components were numerically modelled and experimentally tested quasi-statically, dynamically as well as using low speed impact and ballistic set-ups.

DEMONSTRATORS DESIGN, MANUFACTURING AND TEST

A fully instrumented wing and centre fuselage demonstrators were designed, considering typical loads as well as "Vulnerability Load Cases". A ballistic test, derived from the threat analysis, on both wet structures was successfully carried out. Although BaTMALE is a MALE RPAS, elements from a tactical RPAS were incorporated in the centre fuselage design. For both demonstrators, the vulnerability performance was assessed using new high fidelity modelling techniques, focusing on the hydrodynamic RAM mechanism given the impact scenarios which were planned for the tests.

VULNERABILITY

Extensive work was carried out to generate BaTMALE-B vulnerability models in AVAL as well as INTAVAL. The use of two software tools for the same model allowed the comparison of vulnerability modelling techniques. Results in terms of probability of kill given a hit for the defined threat scenarios for BaTMALE-B were compared to the BaTMALE-I vulnerability analysis results.

This work stream was also used to define the term "Vulnerability Load Case" (VLC) and establish a baseline proposal of such load cases to be used in BaToLUS project within the Design Process and Demonstrator Analysis work streams. A set of parametric VLCs were proposed based on basic effects common to many threats and two different types of structures to interact with. Validation of the defined VLCs constitutes one of the most significant achievements of the BaToLUS project.

AERODYNAMICS

Aerodynamics of battle damaged wings was investigated. Wind tunnel 2D tests were carried out on an aerofoil with a circular hole simulating gunfire-type damage. Compared to an undamaged wing, the addition of damage increased drag, reduced lift gave a more negative pitching moment. 3D models were tested in a wind tunnel in order to determine the aerodynamic coefficients and the flow mechanisms of damaged wings. Additionally, a predictive method was developed and validated using the wind tunnel results. A numerical (CFD) method and model was carried out in order to extrapolate the predictions of the aerodynamic mechanisms at aircraft level. Validation of the predictive method is another of the most significant achievements of the project.

DESIGN PROCESS

It was found that BaTMALE-B complies with nearly all of the performance requirements, but only meets some of the vulnerability requirements. As a result of these two elements, a new Structural Design Criteria (SDC) was defined, based on the traditional process, but incorporating vulnerability (requirements and analysis) as part of the aircraft development process.

Who was there

The BaToLUS project was carried out by a consortium of leading European industrial and academic partners from Airbus Defence & Space Germany (project leader), Airbus Group Innovations France, BAE Systems, CEA Gramat, Dynamec Research AB, Fraunhofer Institut EMI, IABG, ONERA, and SAAB Aerosystems.

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