

DRESS: Distributed and Redundant Electro-mechanical Nose Wheel Steering System

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ABSTRACT

Scope of the DRESS project is to research, develop and validate a distributed and redundant electrical steering system technology for an aircraft nose landing gear. The new system aims to:

- reduce system weight at aircraft level, replacing the current hydraulic actuation system with an electric one.
- improve aircraft safety, achieving higher system redundancy levels compared to the current technology capabilities.

This paper presents an outline of different activities occurring in the DRESS project and also shows preliminary results of the new system performance.

INTRODUCTION

BACKGROUND

In the large commercial aircraft, landing gear systems have been traditionally operating using hydraulic power (Figure 1). However, it is widely recognised that there's a need from social and environmental reasons to improve the efficiency of aircraft and their associated systems.

Alternative power source (electric) sources are now considered for aircraft systems that have been traditionally hydraulically powered. Several research

programmes – currently underway – are taking more electric aircraft technologies through the final validation phase prior to deployment on aircraft programmes [1]. Continuous efforts are also being made by the aircraft manufacturers and the air traffic control sector to fully automate the aircraft approach, landing, ground manoeuvres and take-off. This will increase the air transport system efficiency by allowing the aircraft to potentially operate in all weather conditions.

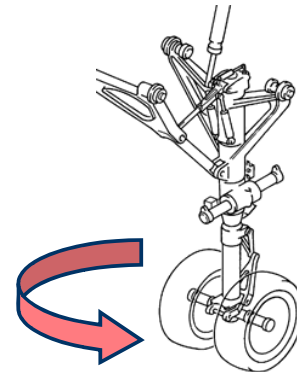


Figure 1: Nose Landing Gear

OBJECTIVES AND SCOPE

DRESS aims to develop a Distributed and Redundant Electro-mechanical nose wheel Steering System that increases significantly the levels of system reliability and availability. This would offer the aircraft with true, all-weather (zero visibility) operational capabilities.

Additionally, it would make it compatible with an automated ground guidance system, providing significant aircraft operational improvements and enabling more efficient air transport. DRESS meets the requirements of the More Electric Aircraft, incorporating electromechanical actuation technology. It also evaluates a modular control architecture based on a digital bus network, offering reconfiguration capabilities. Scope of the project was to design and develop a system that would eventually be validated on a representative system test rig.

PROJECT ORGANISATION

DRESS achieves this technology breakthrough by investigating in both fields of system architecture and electro-mechanical actuation. It brings together 13 actors of the European aeronautics industry including an aircraft manufacturer (AI), a landing gear manufacturer (MD), two Systems and Equipment manufacturers (SAAB, MB), a Research Institute (IA), five universities (INSA, UHA, UCL, UCV, BUTE), and three SMEs (TTTech, EAT, SPAB).

MB : Messier-Bugatti, France
 SAAB : SAAB Avitronics, Sweden
 AI : Airbus, UK
 MD : Messier-Dowty, France
 INSA : Institut National des Sciences Appliquées, France
 UCL : Université catholique de Louvain, Belgium
 UCV : Universitatea din Craiova, Romania
 BUTE: Budapest Univ. of Technology and Economics, Hungary
 UHA : Université de Haute-Alsace, France
 TTTech: TTTech, Austria
 EAT: Equip'Aero Technique, France
 SPAB: Stridsberg Powertrain AB, Sweden
 IA : Institute of Aviation, Poland

The project started in June 2006 and is due for completion at the end of 2009. It is funded by the EC as part of FP6.

SYSTEM SPECIFICATION

The first stage of the project was to define the technical specification of the new, electrically actuated system. In order to identify the details without focusing directly on the current hydraulic system, a functional analysis was performed. The criteria were identified based on performance, safety, reliability, operability, weight, environmental conditions, etc. A technical specification for an airworthy system was then issued. However, some technical requirements not applicable to the system lab demonstrator were released later on in order to fit with the budget and objectives of a research project. Some key specification parameters and features are summarised here. The maximum mechanical power required is around 1kW. The maximum angular speed is 20°/s. It must be possible to tow the aircraft with the nose wheel free to rotate. The probability of losing steering functionality was set to 10⁻⁹ per flight hour. This justifies the need for making the system redundant. Also, system robustness against shimmy is a key requirement.

The system specification document was regularly updated. It will also be re-issued at the end of the project after all experiments have been held and all lessons have been learnt. The document could then be used to specify a new steering system for future aircraft (if required).

SYSTEM ARCHITECTURE TRADE OFF STUDIES AND SELECTION

ACTUATOR ARCHITECTURE

Trade-off studies were performed to define the mechanical path topology and size the reducers and electric motors [2]. A top-down generation of architectures combined with a bottom-up filtering with respect to technological constraints led from a very high number of solutions at functional level to a limited number of embodied architectures [3]. The motor and power control electronics study has also run in parallel. Figure 2 presents the final trade-off between the three "favourite" architectures, highlighting the arrangement eventually selected for DRESS. An active/active configuration is used, where each mechanical path provides half of the required effort. The worm gear technology was selected with torque summing at turning tube level. In case of failure, the faulty path can be de-clutched and the wheel is controlled using one path only. The study also validated the choice of the high power density, split-phase permanent magnet, synchronous, Stritorque motor. Fault tolerance at motor level was not needed and a state-of-the-art, single channel architecture is used for each motor.

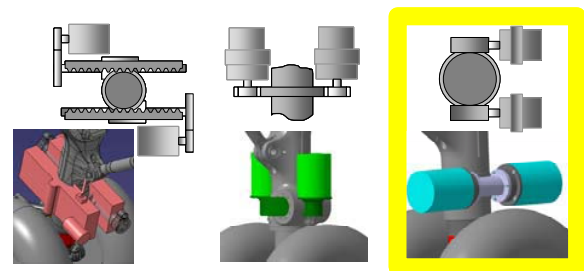


Figure 2: Actuator Trade-off

CONTROL SYSTEM ARCHITECTURE

The system architecture shown in Figure 3 is based on a deterministic time triggered field bus. The main feature of this distributed architecture is to locate the Electrical Control Unit as much as possible closer to sensors and actuators. This implies the use of a data bus that saves weight and improves data transmission.

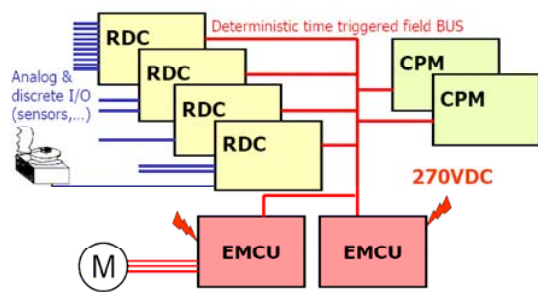


Figure 3: Control System Architecture

The bus connects the:

- Electric Motor Control Unit (EMCU) that drives the electric motors
- Remote Data Concentrator (RDC) that manages the inputs and outputs
- Core Processing Module (CPM) that handles nodes dedicated to computation

It is an open and modular architecture, based on separation of the Inputs/Outputs processing and steering function processing. Additional functions and nodes can easily be added.

DATA BUSES TECHNOLOGIES

During the control system architecture trade-off, two types of communication were considered:

- Event-triggered (ET): non-deterministic with collision management
- Time-triggered (TT): deterministic with no possible collision

Several data buses were also considered, as follows: CAN, TTCAN, A429, ADFX, MIL-STD 1553B, A659 SAFEBUS, FlexRay and TTP.

TTP is a real-time communications protocol used for interconnecting modules in distributed, fault-tolerant, real-time systems. It offers bit rates of 25 Mbit/s in synchronous and 5 Mbit/s in asynchronous transmission. TTP is truly deterministic, providing highly predictable communication patterns; also the complete system behaviour is determined during the design phase. Additionally, the true determinism allows accurate system simulation. The databus fully supports redundancy management:

- Each replicated node is assigned to its own sending slot.
- Each receiver has the same consistent view of the system and uses the same agreement function to compute the message values that are used for further computation.

On the backside, with TTP all communication partners need to know the global schedule. In the worst case, a change in the frame-sending pattern requires an update of the configuration data for all modes. Nevertheless, as soon as all nodes know the TTP schedule, the node suppliers could develop separately their hardware and software: this was particularly applicable for DRESS, where SAAB has developed the EMCU and Messier-Bugatti the RDC and CPM. Different hardware had to be integrated together and using TTP, it was possible to minimise this integration process. Moreover, bandwidth can be reserved in the schedule for future extensions.

TTP standardisation activities are on going, as follows:

- SAE AS6066 TTP physical layer
- SAE AS6003 TTP communication protocol

The TTP databus is used in the Airbus A380 Cabin Pressure Control System and in different systems in the Boeing 787 Dreamliner. It was decided to use this databus as a local fieldbus for the DRESS Control system. Its features meet the demanding requirements of the DRESS system. Using this databus could also allow easy integration with other systems like the braking control system, the LGERS system and the monitoring system.

DEMONSTRATOR DESIGN & MANUFACTURE

ELECTRIC MOTOR AND POWER ELECTRONICS

The system thermal behaviour was a key issue. As a result, thermal studies were carried out, investigating several system mission profiles. Figure 4 shows the electric motor chosen and the power control unit designed and manufactured according to the system trade off choices.



Figure 4: Electric Motor and Power Control Electronics