Falcon

Foreseeing the next generation of Aircraft

D2.1. Report on the validation of the structure solvers

Date of delivery - 31/12/2025

MSC Software

Funded by the European Union

The project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101138305.

1. DOCUMENT TRACK INFORMATION

Project information	
Project acronym	FALCON
Project title	FALCON: Foreseeing the next generation of aircraft
Starting date	01/01/2024
Duration	48 months
Call identifier	HORIZON-CL5-2023-D5-01-09
Grant agreement No	101138305

Deliverable information	
Deliverable number	D2.1
Work Package number	WP2
Deliverable title	Report on the validation of the structure solvers
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Due date	31/12/2025
Submission date	16/12/2025
Type of deliverable	Report
Dissemination level	PUBLISHABLE SUMMARY

Revision table			
Version	Contributors	Date	Description
V0.1	Yves Detandt	5th December 2025	Initial version,
V0.2	Yves Detandt (MSC Software) Ondrej Meca (VSB-TUO) Michal Molcan (VSB-TUO) Florian Kaiser (KIT) Mathias J . Krause (KIT) Mark Robinson (MSC Software)	12th December 2025	Revision 1
V0.3	Yves Detandt (MSC Software)	15th December	Final review with co-authors
V1	Yves Detandt (MSC Software)	16th December	Final version approved by co-authors for submission

List of acronyms	
CA	Clean Aviation
EC	European Commission
EU	European Union
FSI	Fluid-Structure Interaction
FEM	Finite Element Model
GDPR	General Data Protection Regulation
IPR	Intellectual Property Rights
KERs	Key Exploitable Results
KPIs	Key Performance Indicators
LBM	Lattice Boltzmann Methods
PEDR	Plan for Exploitation and Dissemination of the project Results
R&I	Research & Innovation
WP	Work Package

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2. Introduction

Falcon project is dedicated to develop and validate Fluid-Structure Interaction simulation processes. The approach is to build and validate separately the structure solutions (Deliverable 2.1), the flow solutions (Deliverable 2.2) and the coupling of the two in Deliverable 2.3. The present report focus on the structure solutions proposed in Falcon by different partners:

- KIT develops a monolithic solver in the OpenLB framework : the objective is here to solve simultaneously structure and flow equations
- IT4I develops a coupling mechanisms in structure solver ESPRESO
- MSC Software develops a coupling between the commercial solvers: MSC Nastran structure solver developed in the 1960's and extensively validated on industrial applications and ProLB developed by CS and based on lattice-Boltzmann method.

The outline of the report is to present and demonstrate the accuracy of each solution in respectively sections 3, 4 and 5.

3. Validation of structure solver in OpenLB

All KIT-developed methods of WP2 and WP4 are realized in the context of the open source (GPL2) C++ framework OpenLB, a major open-source project for the implementation of multi-physics simulations based on the lattice Boltzmann method (LBM). Being in active development since 2007, it not only provides an extensive library of LB models covering a large variety of multi-physics applications but supports transparent execution of optimized LB models on heterogeneous high performance computers. The objective of Task 2.1 for KIT is to develop an LBM based explicit structure solver for a monolithic approach (Task 2.3). The stability and accuracy will be studied based on academic benchmarks e.g. from Hron & Turek. For FALCON and the present Deliverable 2.1, the target regarding OpenLB is to implement and validate LBM-native structural solvers. This report not only describes the effort taken to implement and validate the first structural solver into the OpenLB framework, but also shows an initial application case for the structural solver.

4. Validation of ESPRESO

This deliverable presents the development, verification, and initial integration of a structural numerical model intended for use within the Fluid-Structure Interaction (FSI) toolchain under development in the FALCON project. The overarching objective is to establish an open-source, fully reproducible structural modelling capability that can be seamlessly coupled with the OpenLB Lattice Boltzmann (LBM) flow solver. The structural component is based on the ESPRESO framework, which will serve as the primary structural dynamics engine within the partitioned FSI approach.

As a first milestone, the structural model of the TC1 demonstrator wing has been re-implemented in an open-source branch of the project. This model is used both for validation of structural solvers and as the structural subsystem in subsequent aeroelastic coupling developments. The model is built upon the reference MSC Nastran dataset provided in project documentation and is intended to represent the real mechanical behaviour of the high-aspect-ratio wing demonstrator, including its bending-dominated response, torsional characteristics, and the influence of the movable tip mass.

The deliverable describes:

- the construction of the structural model,
- the finite element discretisation strategy for the spar, sections, and tip pod,
- the verification of the model against reference modal data.

This work forms the foundation for the forthcoming aeroelastic simulations and provides the validated structural model required for coupling development in subsequent project tasks.

5. Validation of Nastran

Nastran is a structure solver developed in the 1960's by NASA (**Na**sa **St**ructural **An**alysis) and extended and commercialized by MSC software starting from the 1970's. As a standard solution adopted by many industry sectors, MSC Nastran has been extensively validated on academic and industrial applications over the last 5 decades, and remains a reference solution in the field of structure simulations.

Based on Finite Elements Method, MSC Nastran includes a large collection of structural elements, from 1D beam elements to complex 3D elements modeling multi-layered composites. Different advanced numerical schemes are also available to ensure stability of the most complex dynamic solutions. Accuracy and performances are constantly improved and assessed to secure the numerous design process relying strongly on MSC Nastran simulations.

As the solver has been extensively validated over the last 5 decades, we focus on validation cases corresponding to Falcon configurations.

6. Conclusions

The report reviewed the different solutions developed and progressively validated on academic configurations:

- **KIT** creates a structure extension in **OpenLB** framework solving at the same time the flow and the structure parts. The solution is demonstrated on academic validation examples as this complex technology requires a careful assessment of the accuracy.
- **IT4I** prepares the FSI connections in **ESPRESO**, while demonstrating the efficiency and accuracy on industrial TC1 configuration
- **MSC software** prepares the FSI connection to fluid solution by assessing the MSC Nastran accuracy on Hron&Turek and on TC1 configurations.

These 3 solutions are ranked from the most innovative to the approach which is based on the most validation tools. The solvers are carefully validated on academic configurations, testing their accuracy with reference solutions. This validation is key to qualify the process on industrial configurations to reach a higher maturity level which is one key objective of Falcon project.

In the second part of Falcon project, the validation will continue to be expanded over industrial configurations where experimental results are available. This effort will probably lead to not only correct existing feature developed in this 1st part of the project, but we expect new development to complete the existing offer and perfectly match the industrial expectations. During these industrial validation activity, the preliminary validation performed in the present report will be key to increase the velocity by closing possible options.

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