

THE UK VERTICAL LIFT NETWORK AND THE MENTOR PROJECT

Florent Dehaeze

UK VLN Chairman

Florent.Dehaeze@LeonardoCompany.com

Leonardo Helicopters (UK)

Abstract

The UK Vertical Lift Network (UK VLN), founded in 2013, aims at developing synergies between its members and promote collaboration within the UK rotorcraft research community. It is doing so by facilitating the involvement of other members of the network in new research projects. The network is also encouraging cooperation in educational and training activities, through the organisation of yearly events. The VLN collaboration led to the start of the MENTOR project (Methods and Experiments for NOvel Rotorcraft), which proposes to develop new methods to predict and analyse tiltrotor aircraft, using a multi-disciplinary approach linking aerodynamics, dynamics, control algorithms and flight simulation. The project aims at delivering a set of tools and methods to all members able to perform comprehensive analyses of tiltrotor aircraft.

1. THE VERTICAL LIFT NETWORK – MISSION AND OBJECTIVES

The UK Vertical Lift Network was founded in 2013 by AgustaWestland (now Leonardo Helicopters) and various UK Universities performing research activities related to the rotorcraft domain. Its main objective is to promote research in this domain and encourage collaboration between its members. At the time, due to the limited size of the community, it was seen as important to increase shared work to ensure that it thrives and stays competitive.

Since its creation, the network has been growing, admitting other industrial partners with an interest in rotorcraft science and SMEs. A list of the current partners is shown in Table 1. The members cover a broad range of rotorcraft-specific specialties, leading to the integration of multiple aspects in any research projects and ensuring that no gap is left. As a result, projects prepared and coordinated in the UK VLN can extend over a broad range of domains to comprehensively study a chosen topic. This is highlighted with the example of the MENTOR project, described in Section 3.

The partners meet quarterly, looking at the latest events and discuss the latest research proposal being prepared, aiming at increasing the collaboration, taking advice on potential partners specialised in other aspects of the topic at hand that couldn't be studied by them. The meetings are also used to keep all members up to date with the latest

news on research performed in other countries.

However, to develop the rotorcraft community, it was deemed necessary that additional events were organised to increase the size of the community and the number of researchers aware of the specificities of rotorcraft research.

2. CURRENT ONGOING ACTIVITIES

Further activities, on top of the quarterly meeting, are aiming at developing the community, particularly at the PhD/young professional level. The two main activities focus on the training of researchers in multiple specialties that are rotorcraft-related, and an annual workshop allowing every researcher to present their work to the rest of the community and exchange on their ideas.

2.1. VLN Training Events

The VLN is organising every year a set of training events that broaden the attendees' knowledge in rotorcraft science, and seeks to highlight specific aspects linked to working in this domain. The training events are opened to employees of all member institutions and are specifically aimed at PhD researchers and young professional willing to extend their knowledge. Prior to the CoViD crisis, three training sessions a year were delivered, each focusing on a special aspect and lasting two days.

The first training session was looking at

aerodynamics, aeroacoustics and flight mechanics. The second was interested in dynamics, vibration and control. The final event was focusing on experimental methods.

The events were well attended, and allowed the researchers to network and exchange on other aspects of rotorcraft science that their work might affect. For example, a PhD student focusing on aerodynamics would improve his understanding of the implications of changing the loads on the rotor on the aircraft vibration level and could adapt his research accordingly.

Due to the CoViD crisis, the events happened online this year, and the format was changed to multiple 2hr-long sessions online, each focusing on a single topic. This format stopped the access to hands-on experiments and networking, which was seen as negative, but allowed for bigger attendances due to the simplicity of joining online rather than having to travel. In the future, a mix of online and in-situ could be used, adapting it to the course requirements.

2.2. VLN Workshop

Every year, a workshop is organised where researchers from the rotorcraft community can present their work and discuss it. This is a good opportunity for them to receive feedback from experienced researchers on their previous work and future outlooks, as well as understanding how they work integrates in the broader research of the community.

The annual workshop is also a great networking opportunity, allowing exchanges between researchers and increasing the sense of community.

3. THE MENTOR PROJECT

A good example of a collaboration brought forward by the UK VLN is shown by the MENTOR project. A gap was identified in the methods used to simulate new configurations such as tiltrotor aircraft and compound helicopters. The University partners decided to focus a new research programme on this specific issue, using a particular emphasis on the whirl flutter case to assess the newly developed methods. This project started in 2018 and will finish in 2022.

3.1. MENTOR's Objectives and Project Structure

The MENTOR project is developing the necessary tools and methods, as well as, fundamental experimental techniques to plug the knowledge gap emerging in the design and analysis of next-generation rotorcraft. A strong emphasis is put on the

multi-physics simulation method that is being developed in the project, which will allow for the aerodynamics and dynamics of these complex new rotorcraft to be analysed with high-fidelity. Additionally, a physics-rich simulator will allow for real-time tools to be called and executed as necessary using algorithms that would normally fall under the sphere of design tools. Finally, all tools will be validated against a new experimental database, generated using facilities from many members. The work is divided in 3 work packages, representing these 3 main tasks. The programme structure is shown in Figure 1.

3.1.1. WP1: Multi-Physics Methods

The first work package will be looking at the development of the multi-physics methods.

The first task is the development of a high-fidelity tool for the detailed analysis of novel configurations (a tilt-rotor is used as an example). This will be undertaken by Glasgow University with their established track record with the HMB3 CFD solver [1] and its associated aeromechanics, acoustics and dynamics modules.

The second task is devoted to the development of a trimming method for multi-rotor vehicles. This is necessary since aircraft like the tilt-rotor have much more trimming states and strategies than helicopters. For example, the trimming can be achieved using lift from the wing or powered-lift from tilted rotors. Using common vehicle templates to allow the exchange of data between the trimmer and the aerodynamic tools will result in a high-fidelity simulation ahead of what has so far been demonstrated in the UK and the USA. This task will result in a flight dynamics model of a tilt rotor aircraft structured in such a way that it can be easily merged with other prediction codes (e.g.CFD and CSD) to produce a multi-physics simulation of a tilt rotor vehicle.

The third task aims to deliver efficiency to the high-fidelity tools to make them usable for engineering analysis using novel computer architectures and relatively small computer clusters. Emphasis will be given on the emerging architectures like GPUs and the Intel Phi MICs. The codes developed in the previous tasks will be written efficiently for parallel computing and use on HPC clusters. It will also look at the best way to code software with compatibility on multiple technologies.

The final task will focus on the development of a modular dynamics code that will allow the detailed modelling of the structure and mechanisms involved in these novel flying machines. The complexity of the rotor head, the dynamics of the blades, and the non-linearity of the structure will be considered by this tool

that will also be linked with the methods from the previous tasks, and will be compatible with HPC simulations.

Once all the tasks are performed, WP1 will deliver an integrated set of simulation tools, compatible with HPC simulations for further efficiency.

3.1.2. WP2: Physics-Rich Simulation

The main objective of WP2 is the delivery of a set of simulation tools focusing on real-time predictions, using lower-fidelity methods. These methods can then be used to study phenomena such as the coupling of pilots and automatic flying control systems.

The first task in this work package will be the development of such lower-fidelity models using results from the higher-fidelity methods developed in WP1. FlightLab will be used to implement the new model. The model will be based in the University of Liverpool, but will be accessible to other partners who will be able to contribute to its development, thanks to a new network developed in the project. Developing a new distributed network protocol will link codes from different disciplines and provide a unique capability.

The second task will see the development of an envelope protection software, reducing the risk of unforeseen interactions and instabilities. It is expected that phenomena like stall will be detectable on novel rotorcraft via sensors looking for harmonic content in signals that is not multiple of blade passing frequencies. Flight transition will also be studied with flutter suppression control methods operating. In particular, higher-level control methods will be investigated to smooth any undesired transient behaviour.

The final task will look at the aircraft performance, delivering a flexible tool to estimate the performance of flying machines and provide reasonable estimates on the effects of design changes to the performance of the vehicles.

At the end of this work package, a complete set of tools, fully integrated with the ones developed in WP1, will be available to all members of the network.

3.1.3. WP3: Fundamental Studies of Aerodynamics and Flow Control

This work package will focus on delivering multiple sets of experimental data to validate the work in the previous work packages, and assess flow control methods to control phenomena such as stall.

The first task will use a rotor rig developed in a previous project to assess rotor performance specifically in the case of tiltrotor aircraft. The rig, allowing for the use of rotors with a diameter of about 1.2m, will allow the extraction of test data on a tilting rotor interacting with a wing. These interactional data will then be used to validate the tools developed in WP1 and WP2.

A second task will be the evaluation of the use of minitabs to alleviate stall near the spinner and the wind/nacelle junction. Work will include a dimensioning stud of the tabs and wind tunnel testing will be performed at a small scale.

A third task will look at passive flow control devices of the form of Vortex Generators, vanes, tabs, bumps and small passive features that have potential to locally change the flow without adding too much adverse effects on the overall configuration. A similar approach to the one in the previous task will be used. Finally the last task will look experimentally at the wing structural response, and the frequency content of it. It will then be able to qualify stall onset criteria that will be used in WP2.

3.2. Collaboration within the Project

This project involves many Universities, who will need to work in a very integrated fashion to ensure the compatibility of their tools. Table 2 highlights which University is taking part to each work package. Furthermore, many tasks will require the collaboration of multiple universities, who will share the tools and the results. The ability to cooperate at various levels requires a higher integration level than has been happening before in rotorcraft domains. This project is seen as a strong evolution of the way the members cooperate and if successful could pave the way to a much stronger cooperation between all participating actors.

3.3. Current Status and Deliverables

The project has so far made progress on all fronts with the rotor rig at Glasgow standing assembled and undergoing tests on its drive train and data acquisition systems. The current state of the rig is shown in Figure 2. A complete shake test of the rig equipped with a set of blades has also been completed and dynamics models are currently under development allowing for the safe operation of the rig and providing input to the numerical methods of MENTOR. Furthermore a new set of blades, shown in Figure 3, was designed using the CFD tools developed during MENTOR and they are currently in the manufacturing stage. Similar progress is made with the facilities at the University of Bath where a

novel system for suspending a wing in the tunnel with multiple motion degrees of freedom is setup. The COVID-19 pandemic did not allow for the tests to begin yet but it is expected that they will begin shortly. Similar progress is reported for the flow control tests at Cranfield University with a specific rig undergoing manufacturing and assembly.

On the computational front, the tools planned for development at the University of Glasgow (CFD solver) are already shared with the partners and the same is done for the lower fidelity methods developed at Manchester. The resulting tool set includes panel methods, free and prescribed wakes and can be used by all partners. Having low and high fidelity methods was one of the aspirations of MENTOR, and sharing these within the UK VLN is a great way to achieve integration of research and synergies across the country.

Dynamics tools related to multi-body dynamic analysis of rotors were also put together at Bristol University and are soon to be released to the UK-VLN. The lack of an open and extendable multi-body dynamics tool has always been a problem for the research community that had to develop several case-specific methods to complement the CFD and low-fidelity simulations with aeroelasticity. The tool is designed to be easy to use and is currently undergoing tests using the rotor rig at Glasgow as a test case for proving its functionality and flexibility in modelling complex rotor heads and assemblies. Flight simulation tools are also important for rotorcraft research and a generic platform is being put in place by Liverpool University allowing for different modules to be used and tested. The flexibility in the design of the simulation platform allowed for trimming and flight mechanics modules from Glasgow to be used alongside control methods from Leicester University. The final setup is expected to be the standard software platform across several flight simulators available within the UK VLN, including the facilities at the University of Liverpool and the University of Glasgow.

The outcomes of the project are collected using a central Sharepoint site and are disseminated using publications in Journals, conference presentations, participation in workshops and due to COVID-19 virtual events.

The MENTOR project also delivered a design of a simple low-speed tunnel that is to be used for STEM activities at schools and colleges enhancing the awareness of students of aerospace research and innovation. The tunnel design is to be shared freely and it is designed for easy construction using pre-cut components and standard motors and fans. A demonstration of a setup showing low-speed flutter

is also under development along with instructions for educators with ideas they can explore in class.

4. CONCLUSIONS

The UK VLN, through networking and the organisation of training events and workshops, is allowing the UK rotorcraft research community to increase their cooperation and collaboration, and improved the interactions between all members. The start of new projects benefiting from the strengths of each partner and increasing the sharing of resources and tools is improving the competitiveness of the network in the world research environment. This is being demonstrated by the MENTOR project, creating a set of tools that is available to and shared by all members.

Copyright Statement

The authors confirm that they, and/or their company or organization, hold copyright on all of the original material included in this paper. The authors also confirm that they have obtained permission, from the copyright holder of any third party material included in this paper, to publish it as part of their paper. The authors confirm that they give permission, or have obtained permission from the copyright holder of this paper, for the publication and distribution of this paper and recorded presentations as part of the ERF proceedings or as individual offprints from the proceedings and for inclusion in a freely accessible web-based repository.

5. REFERENCES

[1] <http://www.gla.ac.uk/cfd>

Table 1: List of the UK VLN members

Partner	Type
Leonardo Helicopters UK	Industry
Hybrid Air Vehicle Ltd.	Industry
Nova Systems Ltd	Industry
Vertical Aerospace Ltd.	Industry
Cranfield University	Academia
Imperial College London	Academia
The University of Bath	Academia
The University of Birmingham	Academia
The University of Bristol	Academia
The University of Glasgow	Academia
The University of Leicester	Academia
The University of Liverpool	Academia
The University of Manchester	Academia
Aircraft Research Association	Research institute
DSTL	Government body
Axsym Ltd	SME
Sophrodyne Aerospace	SME
Taylor Aeronautics Limited	SME

Table 2: Universities Workpackage Breakdown in the MENTOR Project

Workpackage	Universities
WP1: Multi-Physics Methods	University of Bristol University of Glasgow
WP2: Physics-Rich Simulation	University of Leicester University of Liverpool University of Manchester
WP3: Fundamental Studies of Aerodynamics and Flow Control	Cranfield University University of Bath University of Bristol University of Glasgow

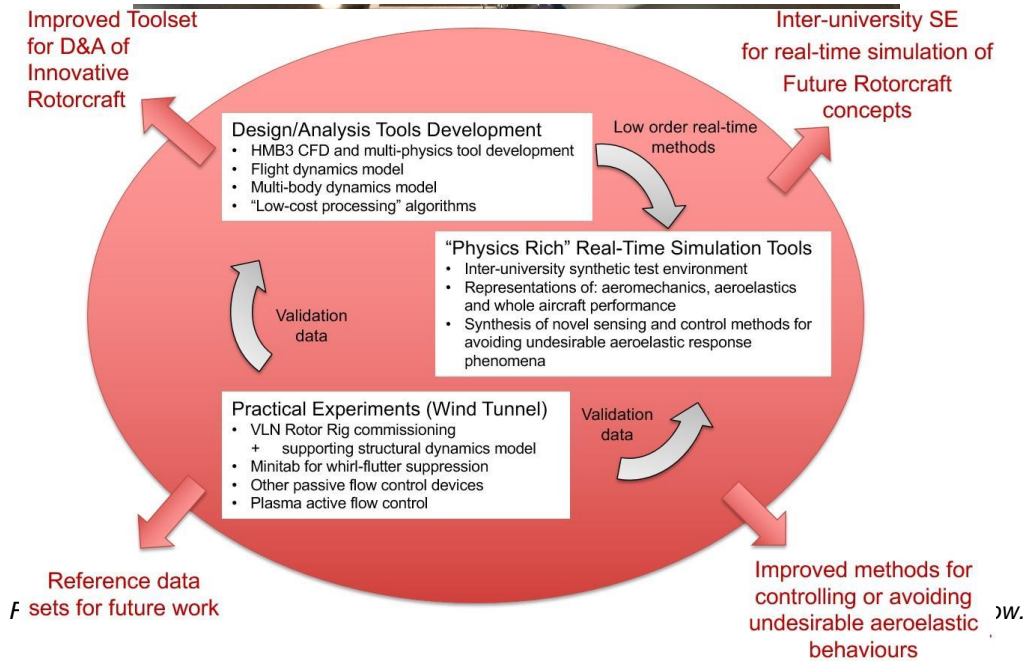


Figure 1: Overview of the MENtOR project.

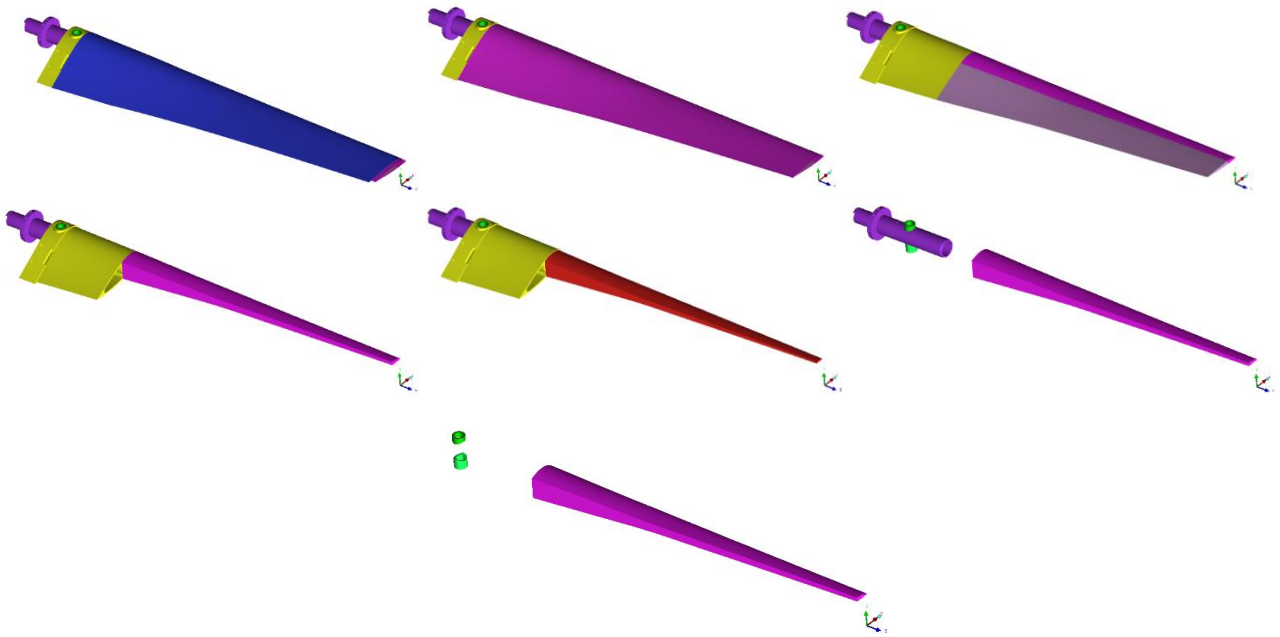


Figure 3: Components of the blades to be used with the rig.

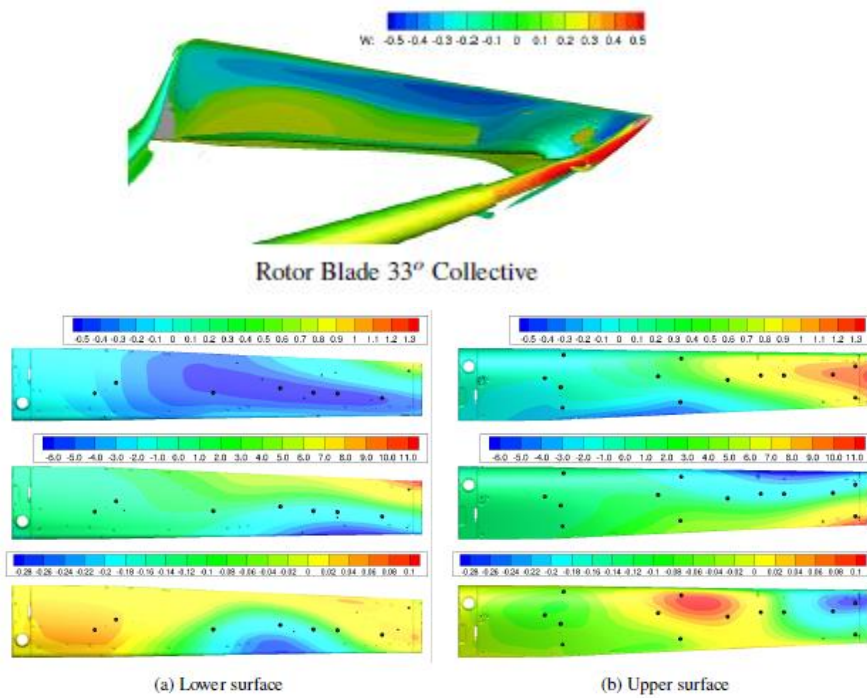


Figure 4: Aerodynamic analysis and first bending-torsion displacements for the blades to be tested during MENTOR.