CROP
Cycloidal Rotor Optimized for Propulsion

Project Final Report

Grant Agreement number: 323047

Project acronym: CROP

Project title: Cycloidal Rotor Optimized for Propulsion

Data of latest version of Annex I against which the assessment will be made:

Final report: ■

Period covered: from 01/01/2013 to 31/12/2014

Name, title and organisation of the scientific representative of the project's coordinator:

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CROP
Cycloidal Rotor Optimized for Propulsion

SEVENTH FRAMEWORK PROGRAMME

Declaration by the scientific representative of the project coordinator

I, as scientific representative of the coordinator of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate):
  - ■ has fully achieved its objectives and technical goals for the period;
  - ☐ has achieved most of its objectives and technical goals for the period with relatively minor deviations.
  - ☐ has failed to achieve critical objectives and/or is not at all on schedule.
- The public website, if applicable
  - ■ is up to date
  - ☐ is not up to date
- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 3.4) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 3.2.3 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator: Prof. Dr. José Pascoa

Date: ...5...../ ...5...../ 2015...

Signature of scientific representative of the Coordinator: ....[signature]....

4.1Final publishable report

4.1.1 Executive summary

In CROP project the preliminary design of a radically different propulsion system for aerial vehicles was achieved. The CROP concept is environmentally friendly and can be implemented in existing aircraft designs, which can be considered a key element for its rapid deployment into the air transport industry. It was indeed the resulting "crop" from a large scope of scientific developments that enabled to present this concept as feasible. The project have demonstrated the possibility of a novel propulsion system based on the cycloidal device referred as PECyT (acronym of "Plasma Enhanced Cycloidal Thruster"). With PECyT, CROP have shown that it is possible to conjugate the benefits of the strong unsteadiness of the flow with a plasma based boundary layer control.

4.1.2 Project context and the main objective

The project scientific approach relies upon CFD simulations coupled with experimental validation in order to prove the feasibility of the system and to define the optimal configurations, the operative regimes and the possible limitations related to its application. In particular, the project verified if this system could be applied as aerial thrust vectoring propulsion applicable to conventional and unconventional aerial vehicle configurations. The results were compared with existing technologies in terms of technological readiness, costs and barriers that could prevent future developments.

WP1 – Project Management

The CROP project constituted a systematic mean to achieve, and introduce, a future reality in aeronautic transport. CROP management comprised the work needed to support the fulfillment of project goals. The main goals of WP1 were:

- to precisely monitor the achievement of milestones in order to enforce the project schedule;
- to insure that the quality and time frame of the work carried out complies with the budget;
- to foster the share of information among all partners, in order to coordinate their work and secure mutual channels of communication;

WP2 –Scientific Coordination, Design and Implementation

This work package aimed to identify the key parameters for the design and implementation of CROP. Regarding the preliminary conceptual design several options were selected. The first concept, proposed by UNIMORE, is related to the implementation of CROP in airships. Here CROP is implemented as a way of increase the maneuverability of airships without employing semi-moving support systems for the propellers as in the case of the Zeppelin NT. In this conceptual design we aimed to develop an effective energetic optimization of an airship with a commercial payload of 5,000 kg, maximum service ceiling of 4000 m and a standard operative altitude of 2000 m. The second concept is related to a conventional aircraft configuration, where we have proposed solutions for conventional airplane and helicopter incorporations of CROP. GROB proposed that the usage of a conventional airplane opens the possibility of using the aircraft wings to produce Lift, while the rotor could only be used to provide the required thrust. POLIMI proposed three different concepts of compound helicopters with CROP. In this concept CROP is also used as a secondary propulsion system, since we kept the main helicopter rotor as the main source of lift. IAT21 proposed an innovative aircraft design with four contra-rotating fully electric rotors. In WP2 several key rotor design parameters were also identified: rotor blades geometrical characteristics; the pitch control mechanism; usage of different pitching schedules; power source; light weight electric drives; incorporation of PECyT in CROP. Another aspect that was addressed as a part of WP2 was the development of analytical design methodologies for the early stages of a cycloidal rotor project. With the developed models is possible to predict the magnitude and direction of thrust and also the power requirement for the operation at several conditions. Since the model takes into account several effects, related to the rotor motion in flight, it is also possible to use it in the definition of aircraft control guidelines.

WP3 –System simulation

This work package was related to system simulation. The most characteristic aspect of simulation was unsteady aerodynamics and aeroelasticity, but also mechanical, energy and system aspects are relevant in such a complex multidisciplinary system as a cycloidal rotor. The analysis of the fundamental aspects of cyclorotor aeromechanics was performed to understand what role is played by specific parameters. Simple analytical models have been developed and compared with existing models and numerical and experimental results for validation. On a separate level, computational fluid dynamics analysis were performed to understand the characteristics of the flow field and the influence of several parameters like the number of blades, the rotor solidity, the prescribed pitch pattern, and more. A model of the steady aeroelasticity of cycloidal rotor blades was developed to correct numerical results of 2D analysis for the effect of blade bending that results from centrifugal and transverse aerodynamic loads.

WP4 – Experimental Validation

IAT21 was the WP Lead for WP4 and has completed a full and detailed report for the experimental activity conducted in WP4. Please refer to the report on Deliverable D4.3 Detailed experimentation with a variety of different rotor configurations using 2, 4, 5, 6, 7 and 8 rotor blades per rotor assembly, and different disk structure, concluded that the most efficient configuration was achieved with 6 blades. A key design challenge early in the project was identifying the most robust, light and efficient mechanical 'offset' system for steering the pitch of the blades. This had to respond extremely fast to directions from the control system sent to servo motors on the offset. Several different designs were tested and the final solution identified. As Project CROP was looking to examine the concept of electric propulsion, with the potential for passenger flight, IAT21 confined their design and experimentation to a small electric concept demonstrator, identified as the D-DALUS L1e. This concept was therefore simulated, measured and evaluated against alternatives as stated in the original Experimental Plan and was further scrutinized and improved through detailed dialogue and demonstration to other CROP partners.

WP5 – Technology Evaluation

In this WP5 it was needed a detailed verification of the project against technology readiness to verify the feasibility of CROP. This has implied the verification of times for possible implementation on service into airlines, but also to verify if different level of alternative applications could be possible in future and to verify a detailed scale of times for a gradual entrance into service. In particular, it was important to verify the advantages that such a propulsive system can give against economic costs, and technological demands. It was also important to analyze if the proposed system could be applied with limited modification in certain types of traditional aircraft configurations. Also, to quantify the effectiveness of the results that could be obtained, and verify if different airplane concepts and configurations could be necessary to apply this novel propulsion system and to analyze the time necessary for preliminary study, engineering activities, testing and operative services for such an advanced propulsive concept. It was necessary also to evaluate if novel technologies greener and more efficient than today technologies could be developed to enhance the disruptive potential of the proposed propulsion system. This proof of concept was done under a strict control by WP2 and was produced using well confirmed data released by WP2, WP3 and WP4.

WP6 – Proof of Concept

The proof of concept work package consisted of two main subsections, the multimedia proof of concept and the hardware proof of concept. The multimedia proof of concept accumulated all the results obtained from analytical models, finite element and computational fluid dynamics models and presented them appropriately. This has included realization of deliverable CFD images to show the project enhancement as well as virtual reality clips to explain the concept of the project. The hardware proof of concept contained a combination of the hardware developed from various project partners. This involved the construction of experimental scaled prototypes of one of the proposed CROP concepts. Results from functional tests on the main equipment which appears critical for the CROP project was included. Since the project is a level 0 project, demonstration of the most important sub-systems is considered a sufficient proof of concept. A complete hardware proof of concept including all subsystems such as the PECyT is beyond the scope of this project.

WP7 – Dissemination and Exploitation

This work package prepared and supported the exploitation and dissemination of the results of the project achieving the following objectives: Provide the interface to the EU services and external actors; Offer the strategic interface for the project with reference to the EC policy issues; Produce a widely dissemination of project concept; Enforce the consortium participation into congresses and conferences; to issue exploitation plans for key project results; Develop relationship with the key actors integrating their opinions in the development of the project; Evaluate the results of dissemination; And Setup the application for patents according to project results.

4.1.3 Main S & T results

Results from WP2

Conceptual Design

A preliminary design was achieved at M9 (D2.4) with the support of the available literature, which was detailed in D2.3. In such report the general system's guidelines and design requirements were provided in order to define the project roadmap. Several design parameters were identified and analyzed within CROP. One aspect was related to the geometrical parameters of the cyclogyro, namely aerofoil section; number of blades; pitching axis location and chord-to-radius ratio. These were analyzed using CFD tools on D3.2. Another parameter was related to the cam design and to the possibility of having an individual actuation on the blades. This opened the possibility of defining and optimized pitching profile for the blades in terms of power loading, which was considered in D2.5 and D2.7. Considerations on the aeroelastic behaviour of a cyclogyro were also provided in CROP. On particular aeroelastic parameter is related to the blade bending, due to the centrifugal forces, and its effect on the aerodynamic efficiency of the airfoil. Such phenomena was considered in the mathematical expressions of D2.5 and the effect of the blade flexibility was analyzed in D3.2.

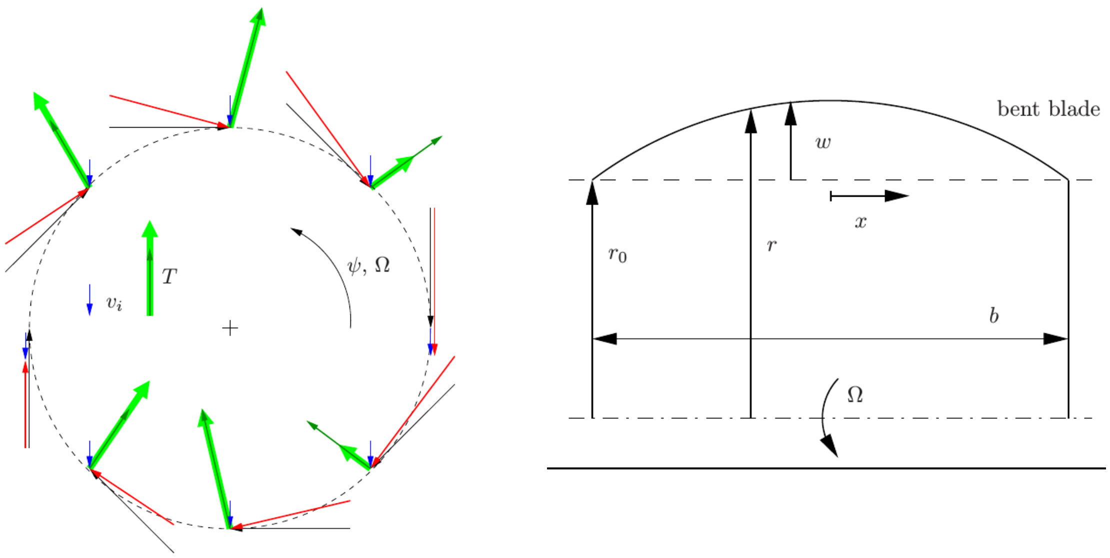
Special consideration was given to the power transfer between a stationary and rotating frame and several possible solutions were identified in D2.4, culminating on the design of a novel rotating transformer for high voltage and high frequency power transfer (D2.7). In the conceptual design (D2.4) the consortium identified 4 clear and separate air platform genres incorporating a cyclogyro/PECyT propulsion system: Helicopter, Fixed Wing, Dirigible and an unconventional aircraft design. More details about the design, performance and viability of such concepts were given in D2.8, D2.9.

Mathematical modelling

Several mathematical models were developed by the consortium partners (see D2.5 for more details), encompassing general system equations, static aero-elastic models, aerodynamic, kinematic and electrical system models. The aeroelastic aspects of the operation of a cycloidal rotor blade were described using simplified models with the aim of understanding system behavior and possible departure from the nominal operation. The modelling of the various electrical systems developed for CROP were also described, which include power dense electrical drives, actuation of individual rotating blades and for rotating transformers as a means for transferring high voltage electrical power to the rotating frame.

An algebraic mathematical model was used to obtain the pitching schedule required to produce a given thrust magnitude and direction. It was also used to compute the resulting thrust magnitude and direction for a given pitching schedule. The model was used to analyze the behavior of the rotor in several flight scenarios: hover; propulsion: reverse propulsion. The effect of the second-harmonic pitch control in the thrust and torque coefficients was also analysed with the algebraic model, see Figure 1.1 - a.

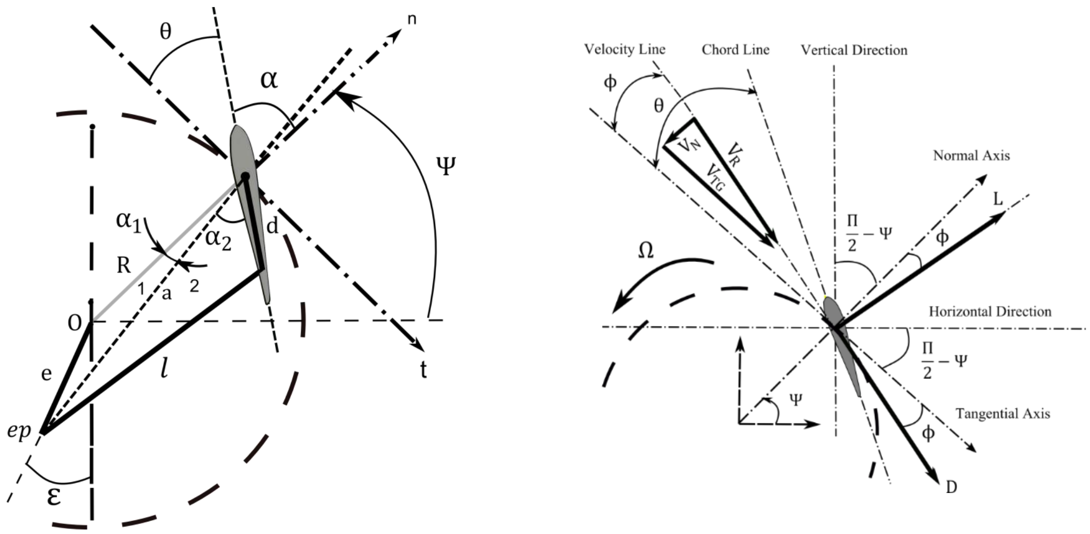
An aeroelastic model was also developed as a part of CROP. A simple design was selected in which the blades were supported at both ends by pitch bearings. Such model was used for analysing the effect of blade flexibility on the cyclogyro efficiency, see Figure 1.1-b.



a) b)

Figure 1.1 - a) Sketch of second-harmonic pitch control effect. b) Schematic of rotating flexible blade assembly subjected to bending.

Another analytical model was developed for supporting the structural and aerodynamic design of cycloidal rotors. The model was devised using an empirical parameter but includes first principles theory in order to account for the effects of unsteady aerodynamics. It includes the motion effect of a four-bar-linkage system (Figure 1.2 -a), and a detailed description of the velocity components on each airfoil (Figure 1.2-b).



a) b)

Figure 1.2–a) Pitch mechanical control system.. b) Horizontal and vertical components, for the resultant force, on a blade of cycloidal rotor in hovering state.

A simplified analytical model of the cycloidal rotor, which was subsequently used for the determination of an optimized blade pitching schedule was also developed. Hence, the model is not restricted to the assumption of the four-bar linkage pitching mechanism, and admits that an arbitrary pitching profile could be imposed.

Mathematical models were also developed for the various electrical systems developed for CROP, which include: power dense electrical drives; electromagnetic actuation of individual rotating blades; and a rotating transformer that can be used as a means for transferring high voltage electrical power to the rotating frame. In order to explore the feasibility of individual electromagnetic actuation of blades, the forces acting on the pivot point of the individual blades are modelled and an optimum pivot point was calculated to minimize the total torque acting on the pivot point.

Design methods

The mathematical models were applied for the design of cyclogyros within D2.6 and D2.7. They were first validated with experimental data from different sources and after applied for analysing the behaviour of a rotor at different operating conditions. A kinematic analysis was performed with UBI model. This is an important feature that is being covered by the analytical model. It can be used to assess the geometrical feasibility of the rotor, a critical component that some earlier analytical models did not take into account. By replacing the rotor blades by their chord line, an animated graphical representation of the rotor geometry can be generated.

The possibility of using the analytical models as a design tool was also addressed and a comparison with CFD results allowed us to unveil the limitations of using analytical models in the prediction of thrust and power in non-ideal operating conditions, where more stringent flow patterns occur, see figure 1.3.

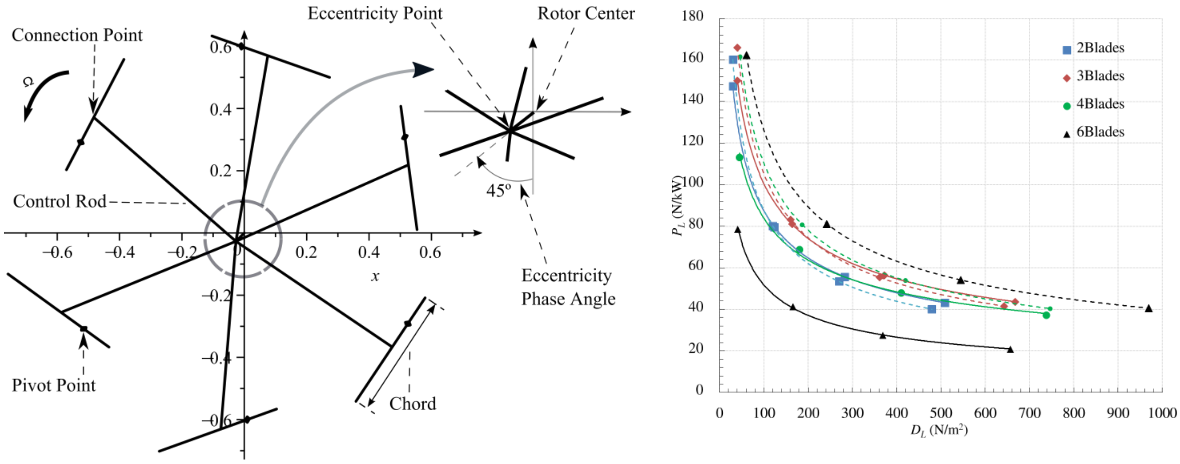


Figure 1.3–a) Using the analytical model to analyse the novel cyclorotor configurations. b) Power Loading vs Disk load (nº of blades test)

A care design was also employed in the electrical systems. Here the models of D2.5 were used to design electrical drives for the CROP concept aircraft. A proposed means for transferring power onto the rotating frame was also described along with the design of a rotating transformer to provide 28kV directly to the electrodes of the blade minimising the electronics required on the rotating frame for signal conditioning. One major contribution here is related to a novel rotating transformer (Figure 1.4) it was designed by Sheffield University.

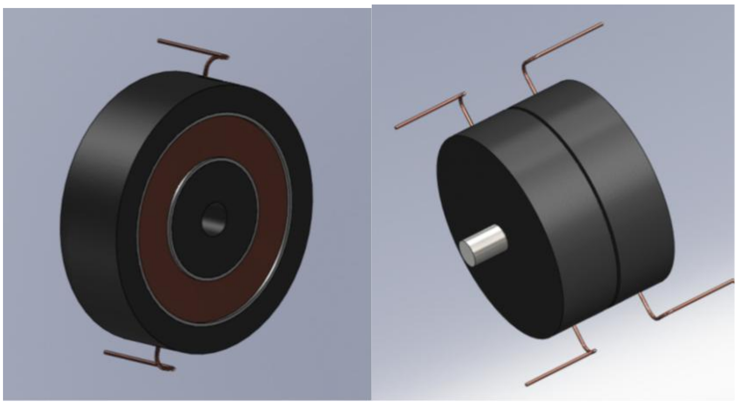
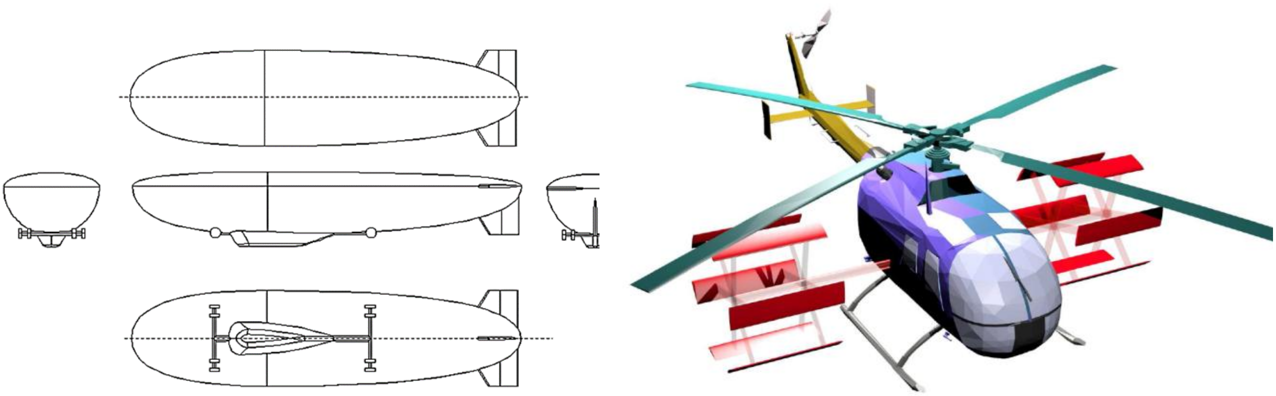


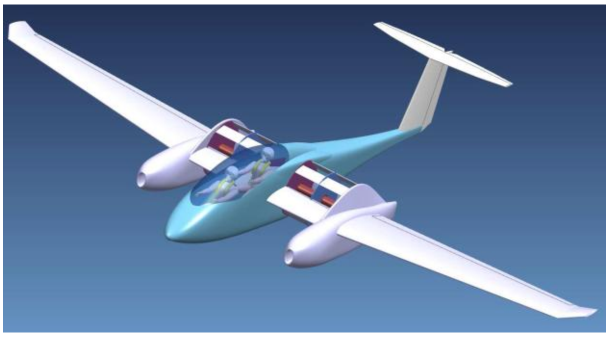
Figure 1.4 – 3D view of designed rotating transformer.

Integration into Aerial Vehicles

The integration into air vehicles was analyzed in terms of its performance and commercial viability (D2.4; D2.9; D2.8). Here the possible competitors of CROP were identified and four concepts were proposed: An optimized energetic self-sufficient airship; a modified GROB aircraft with STOL capabilities; a modified version of a MBB Bo105 helicopter, where the tail rotor is replaced by different configurations of cyclogyros; and finally the innovative concept D-Dalus which was already patented prior to the start of Project CROP (Figure1.5). The original CROP plan was to examine three alternative air platforms. However, because of difficulties of integrating the CROP system into common known conventional aircraft configurations (fixed wing airplane, helicopter) there was the decision to choose four aircraft designs in total for comparison.The proposed concepts of cyclogyro propelled aircraft were evaluated in terms of hover (figure 1.6) and propulsion performance. A comprehensive SWOT analysis between CROP concept and present day commercial vehicles was also performed.



a) b)



c) d)

Figure 1.5 – a) Airship (UNIMORE); b) “Heligyro” (POLIMI); c) “Cycloplane” (GROB); d) D-DALUS L3 (IAT21)

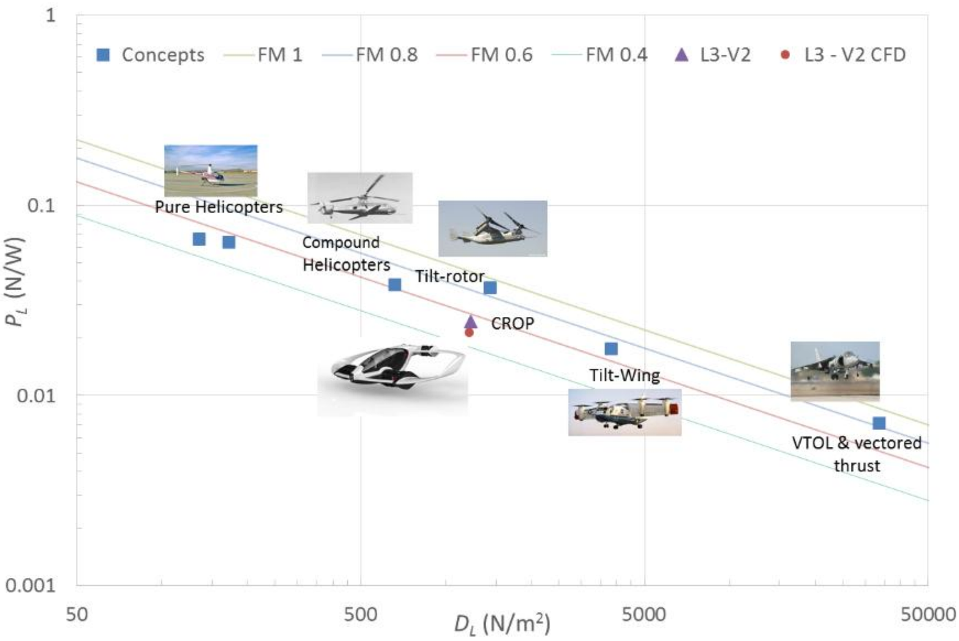


Figure 1.6 – Hover efficiency comparison between D-DALUS L3 and competitors.

Results from WP3

Computational fluid dynamics

Three 2D and two 3D CFD models were developed by the partners of the consortium: an unsteady two-dimensional Reynolds Average Navier Stokes (2D URANS) model using the Fluent software toolkit; a 2D URANS simulation using the OpenFOAM software toolkit; a three-dimensional actuator disk simulation using URANS with OpenFOAM; and both a 2D and 3D inviscid RANS, or Euler-type, simulation using OpenFOAM. The meshes used to implement the double rotation interfaces are shown in Figure 2.1 and 2.2.

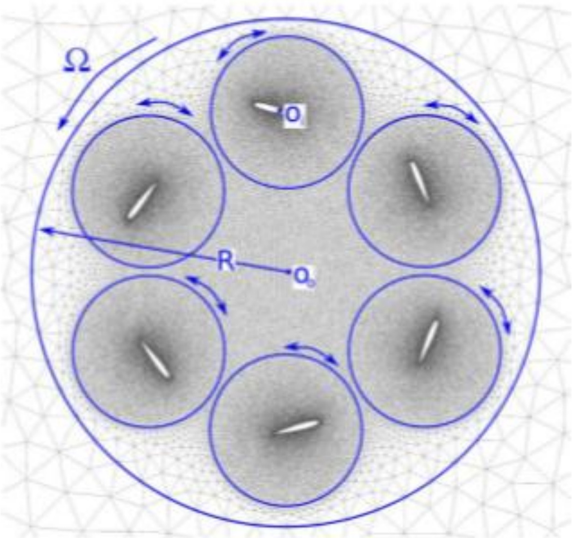


Figure 2.1: Embed rotating interface of the 2D and 3D in viscid open FOAM simulations.

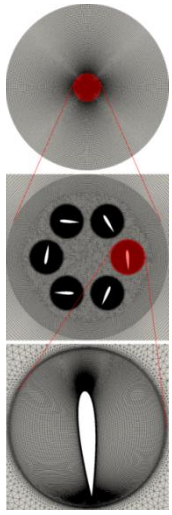


Figure 2.2: Embed rotating interface of the 2D Fluent simulation.

Multiphysics Analysis: PECyT Solution

A Multi-Dielectric Barrier Discharge CFD simulation was conducted using as a basis the 2D URANS simulation and modifying the model to incorporate the electrode. The simulated configuration is shown in figures 2.3 and 2.4. They show the effects on the flow when changing from single to multi actuation and when going from no actuation to actuation. The main result obtained by using the DBD actuators is that the formation of the separation bubble is inhibited, when the blade angle of attack changes from 24° to 20°.

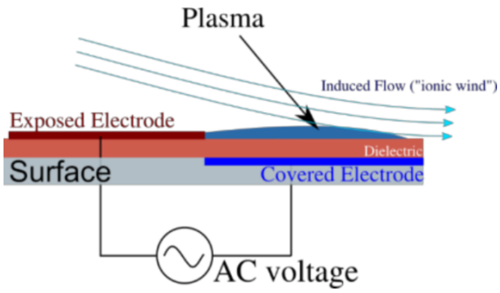


Figure 2.3 : DBD Model with multiple actuators.

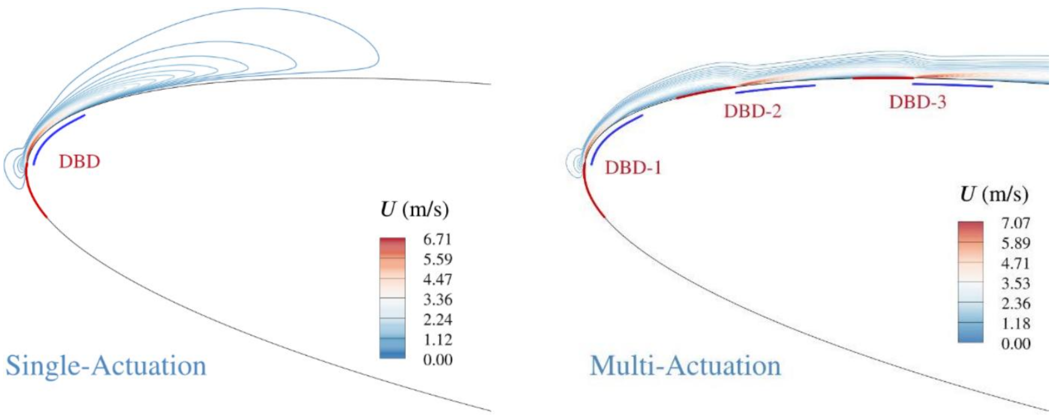


Figure 2.4 The effects of single (left) and multiple (right) Electrode.

Vehicle Simulations

- Tandem Seat Cockpit Aircraft

The concept proposed by Grob was analyzed by a 2D URANS CFD analysis. The goal was to look at the influence of the aircraft wing on the 400 kgf cycloidal rotors which would be added in a configuration similar to the one shown in Figure 2.5.

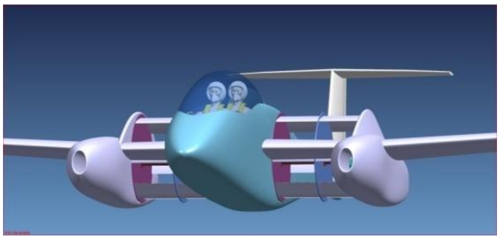


Figure 2.5 : The GROB concept aircraft.

The results from the analysis showed that the presence of the wing possibly increases rotor efficiency by the creation of trailing vortices. The wakes generated by both the rotor alone or in presence of the wing are analogous, as shown in figure 2.6 and 2.7.

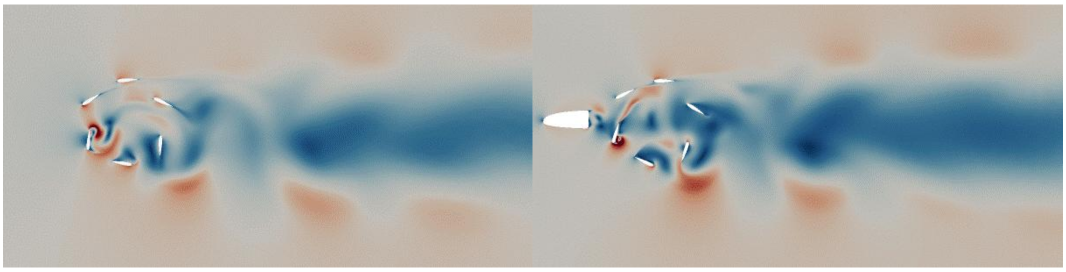


Figure 2.6 : Standalone rotor.   Figure 2.7 : Rotor behind aircraft wing.

- Heligyro

Polimi studied 3 different helicopter concepts where the tail rotor was replaced by cycloidal rotors. The goal was to optimize the configuration and choose a geometry which would reduce the helicopter energy demand. The three configurations that were considered are shown below in figure 2.8. The configuration which was studied more in-depth is the leftmost one, the so-called Heligyro. This is because it showed the best efficiency.

Figure 2.8: Simulation of alternative or competitive configurations

In order to compare the proposed configuration with a currently available commercial alternative, a BO105-like fully aeroelastic multibody vehicle model was used to compute the power demands of the helicopter at various operating conditions. Thus, the main rotor power and torque, tail rotor power and torque, tail rotor thrust, magnitude and direction were obtained. With the data thus available it was possible to get a basis for comparison under specific operating conditions, as shown in figure 2.9.

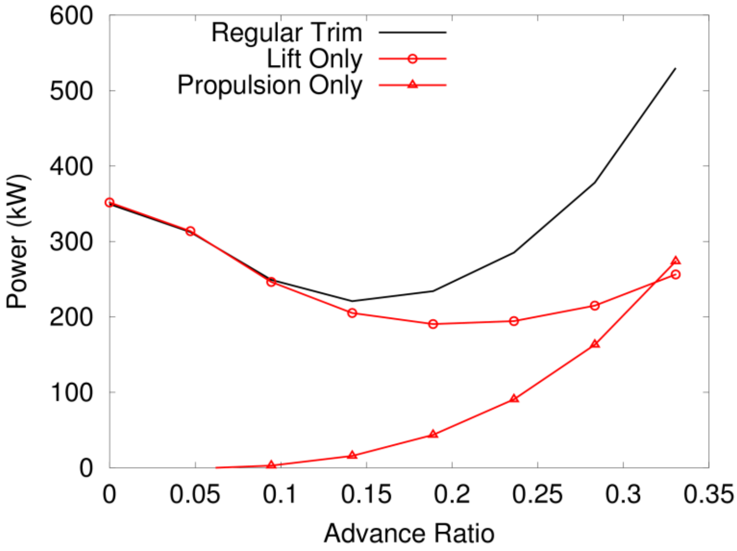


Figure 2.9: Separation of powers.

The figure 2.10 shows that the Heligyro power requirements are similar to those of original helicopter. However, they lead to believe that there is a possible energy reduction of the power demand at high velocities for the lateral cycloidal rotors configuration. It is also expected that security, maneuverability, and stability will all be advantaged by such a configuration.

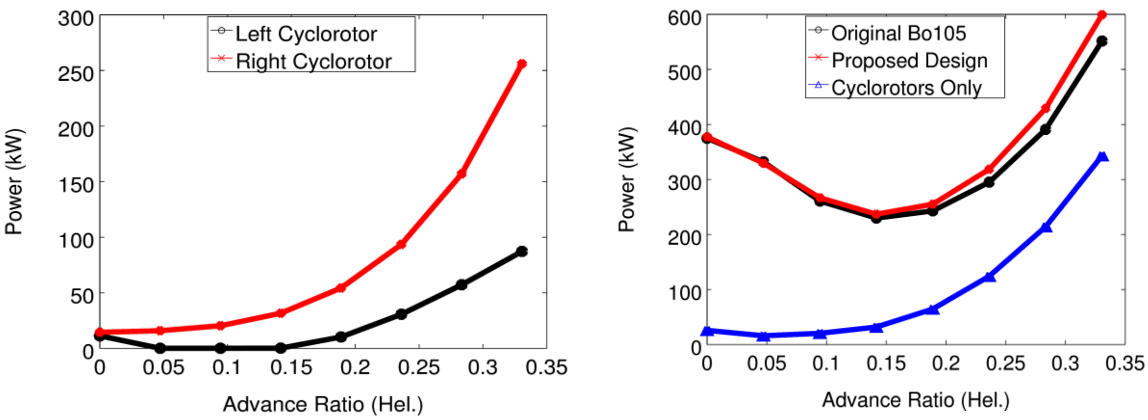


Figure 2.10: Heligyro power requirements compare with the original helicopter

• Airship configuration

Favorable findings came from the 3D actuator disk simulation carried for the airship. The idea is to propel the ship with cycloidal rotors. The figure 2.11 shows how the rotors influence on the airship aerodynamics is almost negligible. Drag and lift are unchanged.

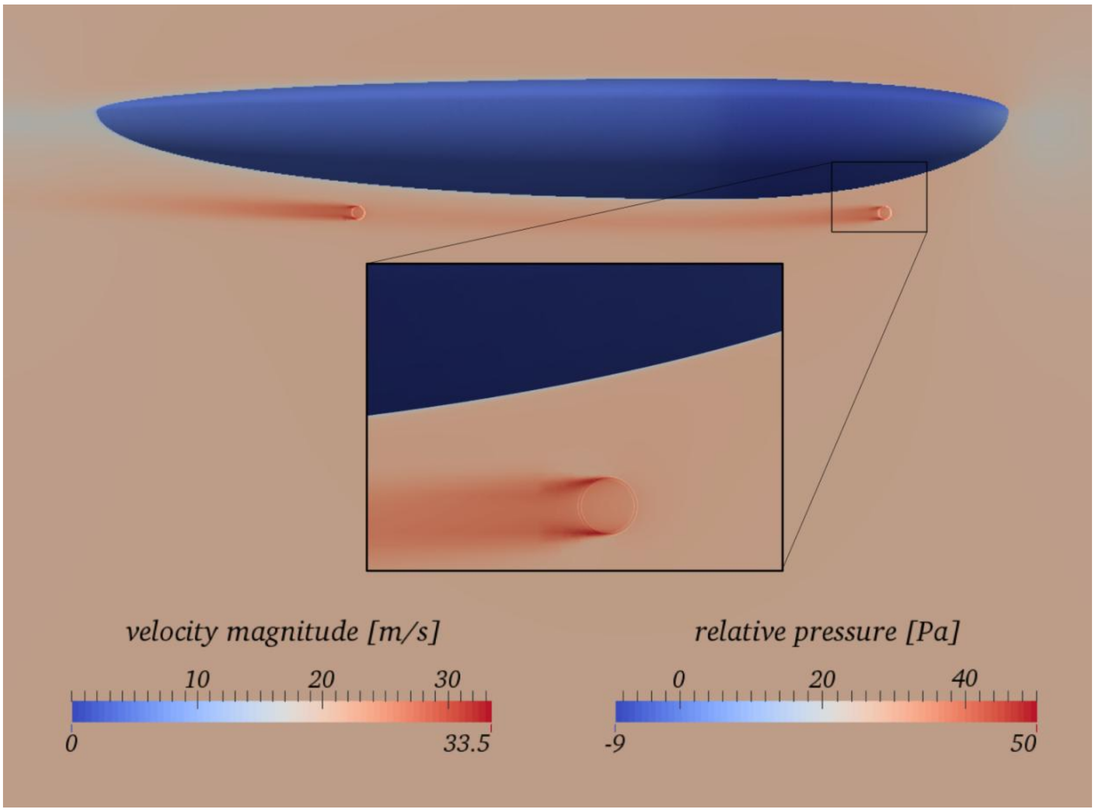


Figure 2.11: Airship propulsion CFD simulation with actuator disk

As a conclusion of this WP3:

• The Models developed give a strong basis for further development. It is a success to have been able to create and use CFD, CSD, and DBD coupled models.

• The Governing methods were used to optimize the sizing of cycloidal rotors for manned flight. Tools developed also allow optimizing, for the desired working condition, the cycloidal rotors pitching functions, the airfoil, and all the other design parameters.

• The Stability Analyses showed that flow is not adversely effected by flexibility. However, resonance control may be required for a zone where the flexibility and angular velocity become large.

• The Vehicle configuration show that coupling the cyclogyro with a wing is a possible avenue. The Heligyro promises to reduce power consumption while increasing manoeuvrability. It was also showed that the cycloidal rotor can be used for airship propulsion

Results from WP4

Validation of preliminary evaluations

Confir maximum safe rotor speed:

IAT21 built an electrically powered test rig that allowed a rotor assembly to be tested at various speeds. The speed was measured using stroboscopic lighting and high speed cameras. Several rotor assemblies were tested, each having different blade structures, shapes or mechanical linkage. The designes were tested to destruction in order to determine the maximum safe rotation speed. These tests allowed IAT21 to identify a structural design that gave the components greatest strength and lowest weight. The safe rotation speed determined for the L1 rotor (300mm diameter) was 3,850 rpm

Confir bearing temperature and lifespan of bearings:

The forces at the circumference of the rotor are several thousand g and therefore the bearings are highly stressed. In early trials the bearings burned within seconds. IAT21 used their patented new bearings and conducted measurements of the temperature after sustained use. The new bearings proved to be ideal for the cyclogyro and their temperature remained constant throughout tests lasting over an hour.

Confir all up weight of craft within planned parameters:

The first D-DALUS L1e CROP tested model, built in CROP Year 1 (2013), comprised 4 rotor assemblies, a chassis but no wings and weighed 17kg without batteries (dry weight).The design team realised that they needed to reduce the dry weight of the craft to around 12kg in order that launch and flight could be achieved. For flight with wings and batteries mounted the whole aircraft should weigh less than the total thrust capacity of the 4 rotor assemblies. This presented a problem if the maximum safety speed of the L1e rotors had been capped for safety at 2,700rpm. At these speeds the MTOW of the aircraft could not exceed 16kg. Alternatively, if the blades could withstand speeds of around 4,000rpm a MTOW of around 28kg could be achieved and potentially this could be raised further with integration of the PECyT. For this reason the Project Team advanced work on the composite materials, scheduled for WP4.2, and attempted to design a blade structure that would sustain higher rotation speeds and, at the same time, be lighter and allow the aircraft overall dry weight to be reduced. The design team continued the quest for stronger and lighter component parts throughout the course of Project CROP.

Shape of thrust/rpm curve: Experiments with the L3 rotor at the Technical University of Munich produced a thrust curve that correlated well with predictions, as seen figure 3.1:

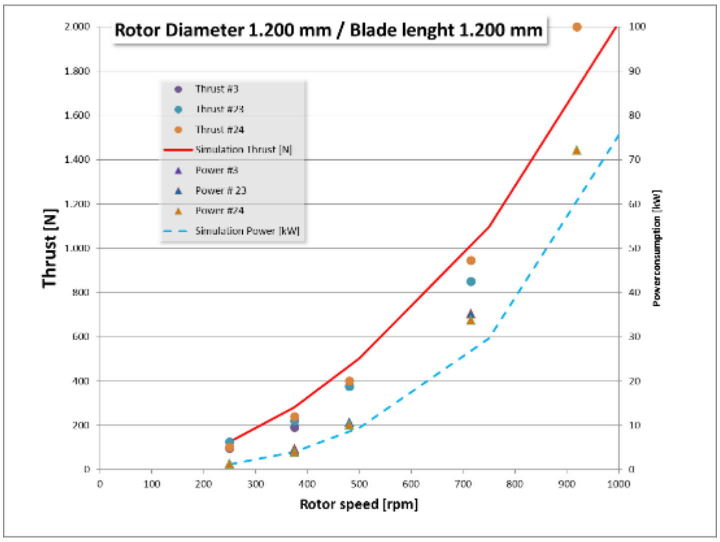


Figure 3.1: Rotor Thrusts predicted and proved

This indicated that thrusts of 2,000 Newton's could be achieved at 1,000rpm for rotors at 1.2m diameter. The lighter components reduced the weight of the craft and provided a net payload capacity of over 7kg, see figure 3.2.

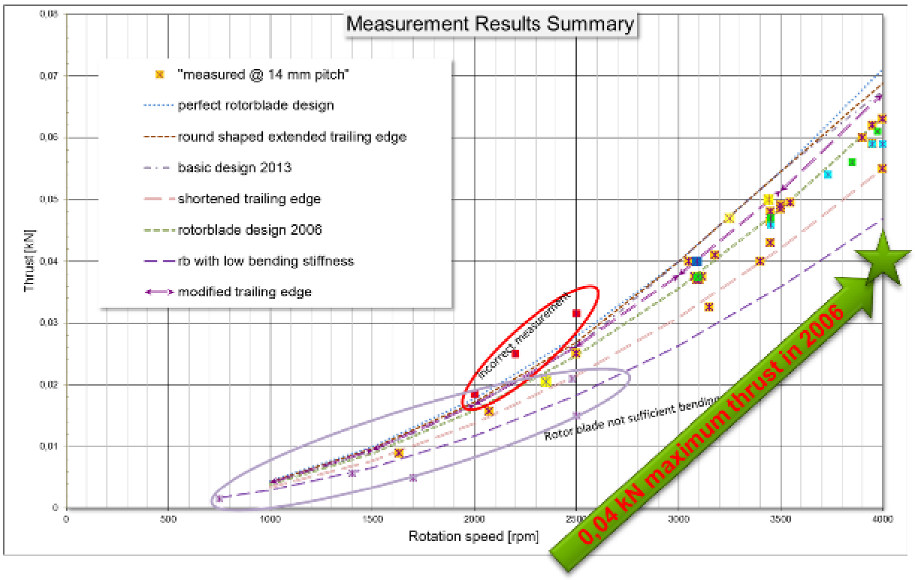


Figure 3.2: CROP L1e Rotor Thrust Achieved

Endurance time of rotor assembly at normal running speed:

For an eventual passenger aircraft it would be necessary to ensure that the rotor assemblies could run continuously for at least 10 hours. However, in Project CROP the endurance tests were conducted purely to ensure that the 4 rotor assemblies could operate safely in the laboratory for the duration of a flight test of the aircraft. As the L1e is electrically powered, flight test endurance would be limited to a maximum of 20 minutes – the capacity of the L1e experimental batteries. IAT21 built a test rig for the rotor assembly and ran the rotor assembly for an hour at the projected operating speed for flight tests. No overheating was detected and no breakages occurred for the rotor assembly constructed from the new composite components manufactured using designs developed in WP4.2.

Air body integration design: IAT21 needed to design a winged body that:
- Was light enough to fit within 20kg MTOW for the L1e:
- Provided chassis strength for the aircraft
- Was efficient in both forward flight and vertical launch. This presented two conflicting demands: a larger wing area offers high efficiency in forward flight, and a small wing area presents lower resistance for vertical launch. (figure 3.3).

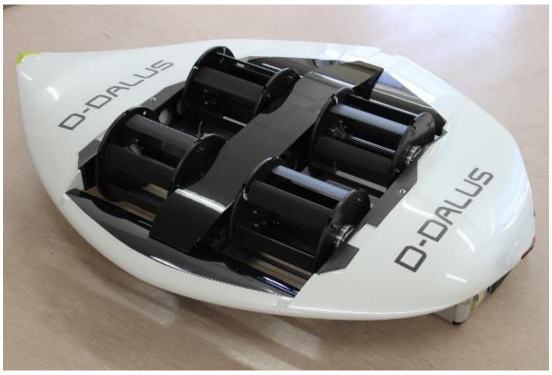


Figure 3.3: CROP L1e Resin Model for First Wind Tunnel Tests

The wind tunnel tests confirmed that the shape, with minor amendments, was the most efficient for the typical mission profile. The winged body structure was then produced using manufacture methods derived from the optimization of blade composite structure in WP4.2. This achieved an increase in structural strength and a weight reduction of around 60%.The final CROP L1 e was then constructed and integrated for final wind tunnel tests.

Experimental validation of CFD/CSD

The Validation of CFD-FEM involved:
- Review internal structural designs of carbon-fibre components based upon destructive tests at D4.1
- Review rotor and air-frame designs based upon results of 4.1 and retest
- Supply consortium partners with data for rotor assembly for PECyT integration design
- Integrate tunnel tested D-DALUS L1 airframe with 4 rotor assemblies
- Define, design, construct and test aircraft control electronics and ‘Black Box’ data recording
- Construct safety test cage and data monitoring systems
- Set up trials record and software documentation system
- Exchange rotor assembly data with PECyT system design team so that they can model and conduct with/without comparative tests
- Conduct indoor lab model thrust and flight tests
- Identify performance optimisation modifications

- Implement performance optimisation modifications
- Video trials (high speed and normal)

The Validation also involved building and testing whole systems (several versions of a complete rotor assembly, for example) and the construction of a full lab model of a flying demonstrator that was then used to reveal relative thrust achieved through each selected enhancement. Key to this evaluation was the construction of laboratory instrumentation for recording data against parameters identified in D4.1.

Results from WP5

Preliminary Technological Evaluation

The analysis of technological feasibility related to the CROP system design has been performed in continuous collaboration with WP2, starting from the very initial stage of the project development. In particular, the guidelines were set for the design of possible system alternatives, which resulted in the four vehicle concepts discussed within the project. These have been reviewed at the end of the project, outlining their pros and cons and their level of readiness:

Airship concept: The airship concept presented by UNIMORE is endowed by many favorable characteristics:
- It is a completely “green” concept, since it is thought as being self-sufficient, thanks to the roof-mounted photovoltaic panels.
- Its design is the result of an optimization process which takes into account aerodynamic performance, power consumption needs and solar energy harvesting: in particular, the resistance to forward flight has been theoretically proved to be extremely low (with a drag coefficient based on the hull volume equal to 0.023); moreover, the optimal exploitation of photovoltaic power from roof-mounted panels allows the full coverage of the power required by the cyclorotors.
- In this configuration, cycloidal thrusters are needed for forward propulsion only: this means that they can be used in their most efficient operating mode, i.e. in forward flight.
- The calculated values of thrust required for forward advance of the airship are very much in line with the capabilities of the rotor configurations studied in this project.

However, the concept, despite appearing as extremely promising, has only been verified by theoretical calculation and CFD, hence it is currently far from a prototypical state.

Two-seater ultralight aircraft concept: the ultralight two-seater by GROB represents a more conventional configuration, where the cycloidal rotors are exploited for short take-off and landing (STOL) and thrust vectoring. Within CROP, preliminary 2D CFD results have been carried out to investigate the interaction between the leading edge of the wings and the cyclorotor, in forward flight. It was ascertained that the loss in thrust due to the presence of the leading edge is compensated by a decrease in power. This can be regarded to as a very favorable aspect for the application of CROP to conventional aircraft configurations. However, only a draft design of the concept has been carried out, and the verification is only partial and conceptual.

Manned/unmanned D-DALUS aircraft: The aircraft concepts proposed by IAT21, named D-DALUS are the closest to the prototypal status of all the vehicles devised within CROP, as detailed in D4.3 “Experimental final report”. The D-DALUS concept has been illustrated in its unmanned and manned versions. The final configuration envisaged by IAT21 is propelled by either fully electric and hybrid engines, and is expected to be capable of vertical take-off and landing (VTOL) and to be extremely maneuverable and stable. In this configuration, propulsion is provided solely by cycloidal rotors (four in the preliminary design).

For the unmanned design, aerodynamic data have been obtained out within the project for both the chassis and the cyclorotor performance. The latter have been made available for the conditions of hovering and forward flight. Data in hovering have been widely employed for validation of CFD and analytical models. As for forward flight conditions, wind tunnel results provided by IAT21 indicate that thrust efficiency increases with forward speed. As it will be shown in the next section, this makes the proposed vehicle concept a competitive alternative to traditional helicopters. Such a results would need however a more extensive verification by further tests.

Moreover, the concept has not yet been translated into a real prototype, although a partial real-world proof of concept has already been provided.

CROP Helicopter tail rotor replacement: The idea by POLIMI is to replace the tail rotor of a helicopter by two lateral cycloidal rotors. The concept is referred to as the heligyro. The work done by POLIMI showed that the concept has the potential to reduce the power consumption. At high velocities the energy savings may become interesting. This improvement would partly come from the removed necessity of the main rotor to generate the propulsive force. Cycloidal rotors are more efficient at that task and the relieved main rotor can operate at higher forward speeds. It is also known that the presence of plates at the tip of a wing has a non-negligible influence on its performance. The development of an autorotation method for the heligyro aircraft would not only increase the security of the vehicle but also cut the energy consumption for cases where the vehicle wishes to lose altitude.

Finally, the research performed showed that the optimal pitching schedule for the cycloidal rotor is not the one obtained by the simple four-bar mechanism. It is thus expected that the same phenomenon is observed for the case of the heligyro. Improving the method for pitch control is thus a possible avenue for improvement. One of such methods would be the use of a hybrid drive where the engines power the main helicopter rotor and an electric generator which is then used to rotate the cycloidal rotors. In this approach, the cycloidal rotors can benefit from a variable rotation velocity.

Technological Evaluation

The results of CROP open the possibility of novel VTOL aircraft architectures. If the design attention is focused on performance, it allows for the definition of novel air vehicle concepts, which can reach high subsonic speeds. If attention is focused on energy efficiency, solutions with better energy efficiency than helicopters can be identified.
An energy analysis has thus been performed comparing the IAT21 D-DALUS aircraft concept, for which IAT21 has made available wind tunnel drag and lift measurements in forward flight and hovering conditions, and a more traditional aircraft like the Compass Knight 3D RC helicopter.

The comparison between D-DALUS and a helicopter can be realistic assuming equal masses. A parameter which could allow an effective comparison refers to load factors. Disk loading represent with adequate accuracy the performances of an helicopter and is an indicator about the efficiency of the rotor system. An adequate parameter can be defined to describe the performances of a vehicle propelled by CROP. It is fundamental the definition of a parameter which could be compared with rotocycloidal propulsion.

Disk load can be defined as the ratio between the mass of an helicopter and the area of the main rotor disk. This definition allows some considerations which are implicit in the definition above. In general, a low disk-load means an increased efficiency of the rotor and in general better performances of the vehicle.

The results from wind tunnel testing and the estimation of the thrust of a single propeller allow for an effective comparison with helicopter. Assuming the same climb speed (2.5 m/s differs in reason of the propeller areas) and the same thrust nearly equal to weight, it is possible to verify that the propulsive efficiencies are quite different.

During vertical climb typical propulsive efficiency of a helicopter is in the range 0.80 - 0.85. Consequently, by considering the same climbing speed, the efficiency of the quad rotor is about 0.3. The power ratio during climb required by the helicopter is less than 1/3 in comparison with the quad rotor architecture.

During climb the increased body-lift of the quadrotor architecture allows a much lower energy consumption assuming the same constant speed. Assuming both moving at 15 m/s it can be verified by wind tunnel tests, that the contribution of the body lift combined with propulsion is from 130 to 170 N at max angular speed of 3650.

A 5 degree angle of attach of the vehicle has been also assumed. In this case, the lift required is about 40 N. According to equations (1) and (2), it means that a power about 0.5 kW can ensure the desired climb conditions. Required rotation speed is about 1150 rpm.

The helicopter Compass Knight 3D requires a max power about 1.8 kW and requires full power during vertical climb operations. And about 1.4 are necessary to ensure the same climb ratio defined above. During horizontal flight it is immediate to evaluate a minor consumption of the quad rotor, about 30% of the one required by helicopter. Results for different flight condition can be summarized in the Figure 4.1.

	Av. Speed (m/s)	**Length** (m)	**Power helic.** (W)	**Power quad rotor** (W)	**Energy helic.** (J)	**Energy quad rotor** (J)	**Energy gain** (J)	**Energy Gain** %
P0-P1	2.5	5	1600	2600	3200	5200	-2000	-62.5%
P1-P2	15	201	1400	500	18760	6700	12060	64.2%
P2-P3	20	5000	1300	400	325000	100000	225000	69.2%
P3-P4	15	201	1400	500	18760	6700	12060	64.3%
P4-P5	2.5	5	1600	2600	3200	5200	-2000	-62.5%
Energy gain by quad rotor					368920	141900	227020	61.54%

Figure 4.1: Energy gain by quad rotor

Technological Evaluation of global concept

An assessment of the technology readiness level (TRL) achieved by the project has also been brought forward. The methodology employed for the assessment is the Technology Readiness calculator devised by Nolte et al. for the US Air Force in 2003. Although not entirely coinciding with UE classifications, this TRL assessment tool has been deemed as sufficiently exhaustive for the purpose of the present technology evaluation.

At first, the TRL assessment tool provides a quick “top level view” in which, by answering suitable short questions, a first estimate of the TRL is given. A screencast is reported, indicating TRL 2 as a preliminary estimate.

Afterwards, more detailed set of questions have to be answered to check if a certain level is reached, and to which extent. In particular, a percentage of fulfillment should be granted to a set of objectives for each technology readiness level.

From the questionnaires (figures 4.2, 4.3, 4.4 and 4.5), it appears evident that TRL 2 can be considered as fully reached, while not all the objectives of TRL3 appear as fulfilled. Hence, it can be inferred that the CROP project has reached a full TRL 2, and its actual final TRL stands between 2 and 3.

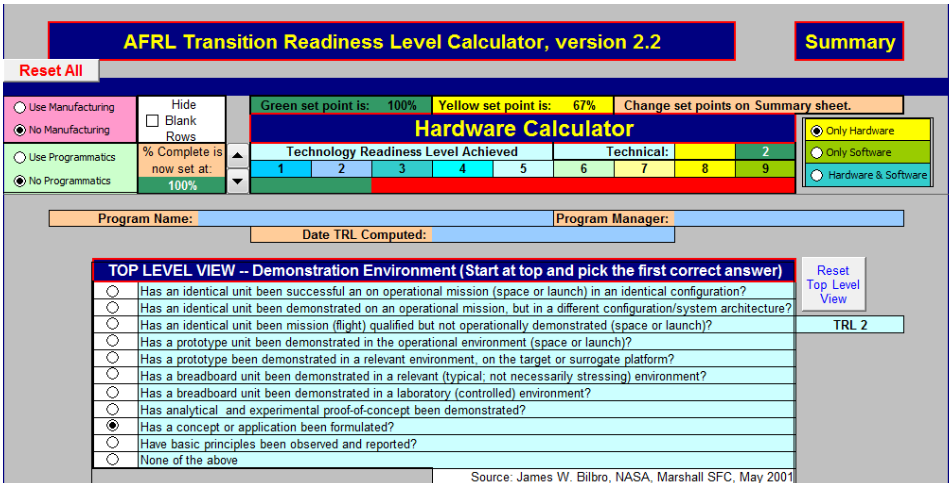


Figure 4.2: TRL assessment: top view.

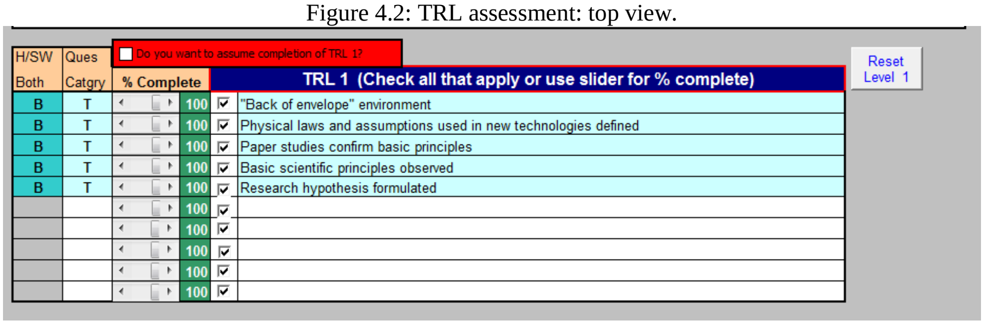


Figure 4.3: TRL assessment: level 1.

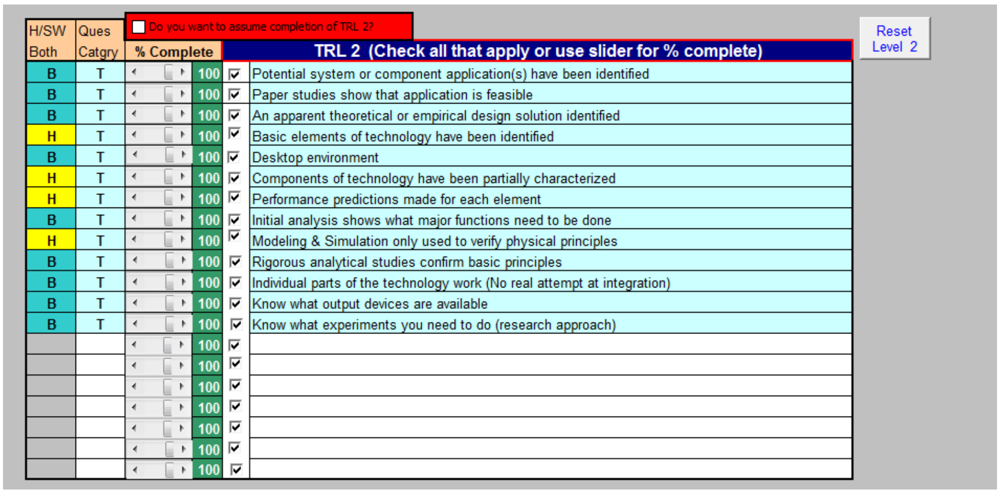


Figure 4.4: TRL assessment: level 2.

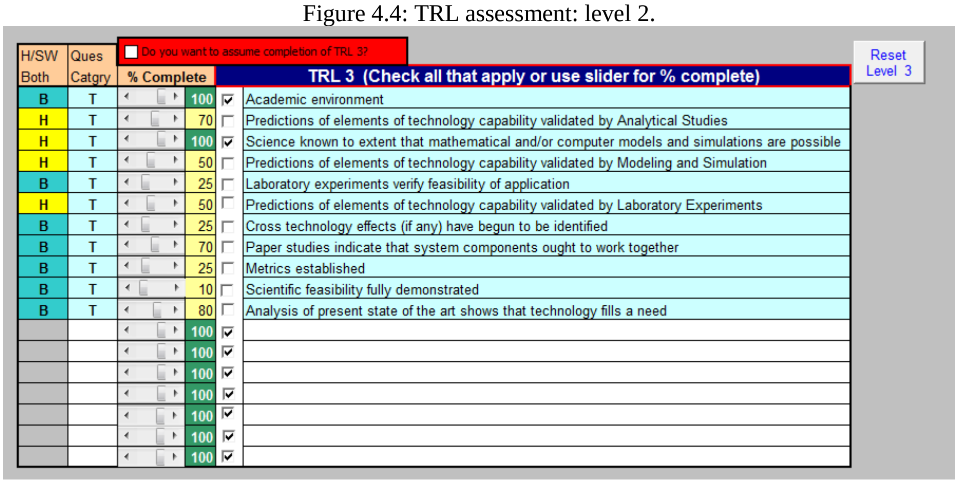


Figure 4.5: TRL assessment: level 3.

Results from WP6

Multimedia Proof of Concept

The purpose of this task, as detailed in the original 'Description of Work', was the adapt the most significant multi-physics simulations produced in both WP2 and WP3 and present them in manner suitable for public delivery to the European Commission and other stakeholders in order to allow them to evaluate the project outcomes. To this end, many of the key findings from the CROP project which demonstrate the performance of the various propulsion units and aircraft concepts, were consolidated into two videos:

Video 1 https://www.youtube.com/watch?v=IBC6izUPGdU – This 'Aircraft Concepts' video combines introductory material on the project and a review of various aircraft concepts generated as part of WP2.

Video 2 https://www.youtube.com/watch?v=5emtt_wkO_o – This 'CFD modelling video presents a series of simulation results.

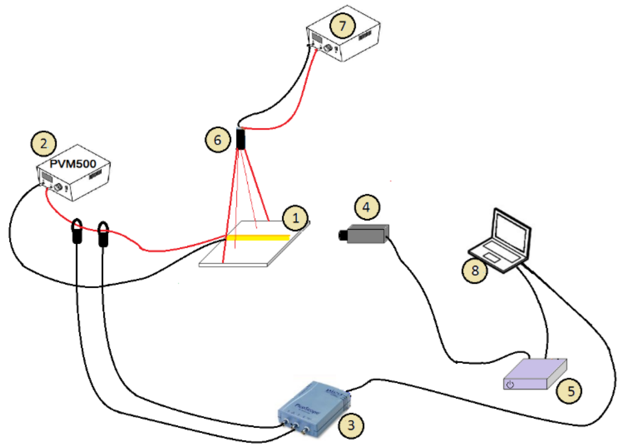
A draft of the videos were presented in the final meeting, with extracts featuring in the associated public dissemination bid, and several suggestions were made for additions. These suggestions were adopted, and the various additions form elements of the final video. A brief accompanying deliverable report D6.1 was completed summarizing the work undertaken and detailing the links to the Sharepoint and YouTube locations of the video.

Proof of concept

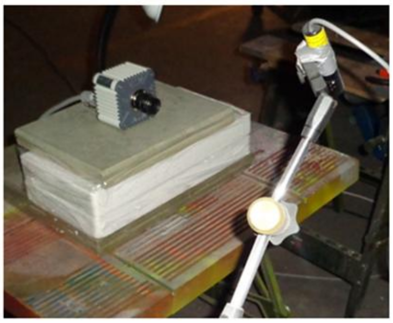
This task was focused on a more scientific and quantitative proof of key concepts, drawing on the technical outcomes of WP2, WP3 and WP4. This task complemented the more general audience proof of concept undertaken in task 6.1. The proof of concept activities included several experimental verifications of models and analysis from earlier WPs and practical demonstrations of some key technologies.

Dielectric Barrier Discharge plasma actuators

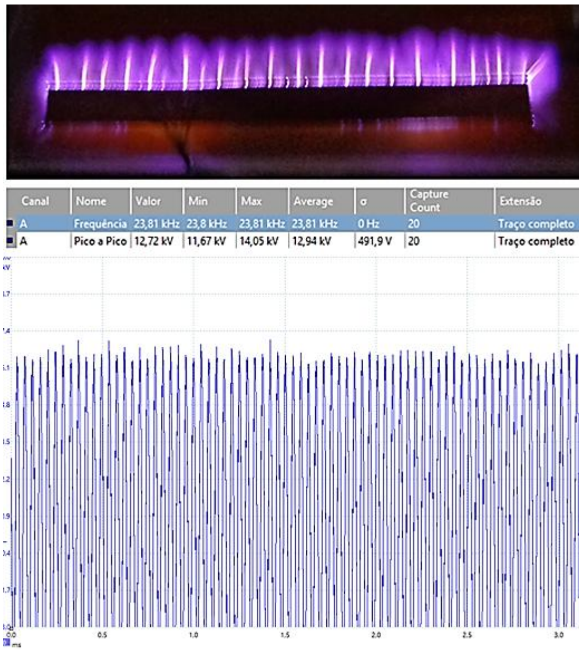
During the CROP project, UBI refined and enhanced a model able to predict the net force generated by the Dielectric Barrier Discharge (DBD) plasma actuator with acceptable accuracy. The model was modified through scaling the components of the body force and by introducing these new scales in the split-potential model to simulate body force distribution generated by the plasma. A key achievement was to undertake a series of PIV measurements using the set-up shown in Figure 5.1. One representative results is also shown in Figure 5.1, which provided compelling experimental evidence of the potential benefits of the DBD concept.



Schematic of the experimental setup (1-DBD plasma actuator; 2-PVM 500; 3- PicoScope; 4- CCD camera; 5- Control Unit of the camera; 6- Laser; 7- SteamLine Laser System; 8- Computer).



CCD camera and laser for PIV measurements



DBD plasma actuator and respective waveform (12 kVpp and 23,8 kHz, scale: 500μs/division).

Figure 5.1: UBI experimental set-up and typical results

Another important contribution to demonstrat the benefits of the DBD actuator concept in terms of its aerodynamic efficiency when dealing with stalled flow over a pitching aerofoil was a series of advanced studies using the DBD model. It is believed that in pitching aerofoil, as in cyclogyros, the unsteady flow mechanism (e.g dynamic stall) when combined with the effect of the PECyT system could delay flow separation at high angles of attack. Two different arrangements of DBDs (single- and multi-DBD) were considered operating in two different regimes (steady and unsteady). A full description of these studies is presented in D3.2 and a paper published by consortium members during the project, D6.1. The main outcomes, all of which have advanced the concept of DBD actuators and demonstrated their utility, can be summarized as:

- It was demonstrated that the inclusion of multi-DBDs could be more beneficial than using a single DBD for delaying stall and to obtain a faster reattachment of the flow.
- An optimal arrangement of actuators in terms of position need to be selected in order to obtain a maximum multiplication effect of the induced flow velocity. A control algorithm similar to the one of Lombardi et al. should also be implemented in the steady actuation mode in order deactivate the actuation in most of the down stroke cycle where the DBDs are reducing the aerodynamic efficiency of the aerofoil.
- The unsteady actuation has demonstrated a superior performance on the up stroke phase of the cycle. Although not being able to delay stall, it was responsible for an increase of 20% C_L over a relevant portion of the down stroke phase.

- The numerical results obtained for the DBD actuation in unsteady operation mode can only be considered qualitatively. This is due to the fact that the small vortices, which are generated by the DBD and convected in the suction side of the aerofoil, are being averaged by the k-ω SST transition turbulence model. In order to properly resolve these small flow disturbances, a more accurate, more computationally expensive, turbulence model needs to be used. This could be achieved by using a fully three-dimensional Large Eddy Simulation.

These various component levels found a theoretical exploration of the potential enhancement of cyclogyro hover efficiency while using DBDs. The results have demonstrated that a 20% increase in lift is achievable in regions of large flow separation, a finding which is consistent with that observed experimentally by several researchers.

Power Transfer for DBD system

The experimental testing of the DBD system and the CFD modelling reported above provides a strong case for the merits of a PECyT system. However, in order to realize a practical system, it is necessary to establish a means of transferring electrical power into the rotating frame of reference from a stationary source on the vehicle to power the electrodes and/or any associated control electronics. Although the power levels are modest (fractions of a Watt) it is very challenging because of the high voltages involved. To meet this challenge, a rotating transformer was identified, which provides both power transfer across a gap and step up of the voltage. A design study was performed on a representative specification, viz. an electrode voltage of 5-40kV, a frequency on 1-20kHz and a power of ~15mW.

Experimental and modeling studies to demonstrate and enhance forward flight efficiency

This important aspect of demonstrating one of the key benefits of a cyclogyro propulsion system was undertaken by IAT21. The IAT21 D-Dalus concept is based on a four cyclogyro rotor propulsion system integrated into an aerodynamic wing-body creating lift in forward flight. A concept like this provides a multitude of functionality, including vertical launch and landing; hovering and remaining stable in the air; transition into forward flight; backward flight at low speed; rotation about all three axes; reversed thrust when landing and the ability to 'glue down' on moving or slippery surfaces; landing on sloped surfaces.
This immense maneuverability is complemented by arguably the key benefit for future adoption in many applications, viz. enhanced efficiency in forward flight compared to other rotorcraft.

In Project CROP, IAT21 worked on the composite component design and manufacturing process to develop components of very low weight yet higher strength than currently available commercially. Based on the results of the dynamic simulation IAT21 progressed to additional FEM simulation of stresses, bending and torsional tension and deformation of the most critical parts such as rotor blade, connecting rod and rotor disc that take place. The key breakthrough during the period of the CROP project was the L1 propulsion unit (2014 version) which produced almost double the thrust compared to the 2006 version.

During the CROP project, the proof of concept activities undertaken by IAT21 concluded that:

- D-Dalus creates lift in forward flight. A helicopter cannot do this. As a result, simulations proved that D-DALUS can be around 60% more efficient for a standard mission profile than conventional rotorcraft.
- IAT21 designed cyclogyro rotors can be integrated with helicopters to provide a 'compound' aircraft that could be up to 60% more efficient than conventional rotorcraft.
- IAT21 designed cyclogyro rotors can be integrated in the wings of a conventional fixed-wing aircraft and this could achieve around 40% more efficiency.

Results from WP7

The dissemination plan (MS17) gives an overview about upcoming public activities of the project partners for publication and dissemination of the CROP project and its content.

GROB designed the project website at the beginning of the research period in order to give an overview about the project, its content, project partners and for future results and news. At project duration half time the website moved to www.crop.ubi.pt to give a more common URL and a better association to the EU funding project. As a consequence thereof the content was updated.

A project leaflet was created and printed for dissemination at trade fairs, airshows, etc.
The newsletter was distributed in its final version by end of January 2014. The final newsletter will be distributed in March 2015 due to inclusion of the very final results, feedbacks and news.

4.1.4 Main S & T results

Dissemination vs. Exploitation

Although dissemination and exploitation are closely related, they are distinct processes. While the mechanisms often overlap, dissemination (including also information provision and awareness rising) can take place from the beginning of a project and intensify as the results become available, however exploitation can only happen, when it becomes possible to transfer what has been developed into new policies, products, service or standards. Exploitation is a process that goes beyond the project lifetime, so that its results are sustained for the future reuse. For this reason, and considering the late stage of the project, this document will be conceived as a main trigger for that exploitation is developed progressively after project finished.

The exploitation type depends on the achieved research result and on the time horizon of the exploitation activity, some activities, by using the direct technical improvements, usually have a relatively direct impact within a short time frame, while others leverage their research results and going for a long-term impact through the networking community, in order to derive strategic guidelines.

The CROP Exploitation Plan covers long term time to application, sustainability, and roadmap for exploitation of the foreground and IPR generated by the partners during the project. At this final stage, the plan make an inventory of the possible trajectories and tools expected to be used. In this plan, each participant describes its achievements as far as dissemination is concerned, followed by its plans for use, commercialization, further research and standardization effort, which is expected to happen in synchronization with the results exploitation process in the after project time.
Relevant factors that have set the basis for a good exploitation of CROP results are:

- Cooperation among strategic partners with complementary business roles, in order to align the requirements, and system/ sub-system component design.
- Experimental validation based on lab tests, in order to get early feedback during the research stage. This allowed a time-to-application and up scaling for the CROP developed elements and components.
- Standardization, in order (1) to ensure that the resulting concepts will be further developed into products after the research stage and (2) to foster European stakeholders to follow CROP research results.
- Filing of patents, that is being prepared, in order to protect the produced innovative knowledge.

CROP Industrial exploitation approach

CROP industrial partners (i.e. a manufacturer and an engineering SME) are focusing their exploitation activities on improving their current operation and business position in the existing markets, and on the creation and preparation for the new markets, with the intention to secure their strong leadership. These companies can speed up the deployment of new technologies, which are expected to result in new usage scenarios, and through that attract new customers. The companies will ensure this process by transferring results from the research departments, related to CROP, directly to their products development, marketing, and maintenance procedures.

Externally, the industrial partners are also exploiting the direct technical improvements. Participation in CROP and the resulting acquired experience and expertise is providing the essential time-to-market advantage over the competitors. CROP partners are better prepared for new markets, products, and services and can position themselves early on. They can also work towards the creation of new customer relationships by creating a community around their new offerings. Such direct transfer into the new technologies might be particularly appealing for the SME partner who can, e.g., rapidly exploit services appearing around the CROP concept development. These exploitation goals are achieved by educating the customers and business relations of the industrial partners regarding the new technical possibilities and by developing attractive offerings. CROP intends to provide its results to the forthcoming test-bed projects, in order to ensure an early adoption of the developed approaches within the aeronautics research community, which is expected to build a solid foundation for the future European and world-wide research. The right of partner is to decide to protect some of its results, before any kind of dissemination of the achieved result is made, and in addition, the mostly open source based dissemination of other results, will be a strong support for the industrial partners' external exploitation.

The exploitation of the strategic guidelines by industrial partners is perhaps even more important, allowing an advance preparation for new business models and business roles, thus, being a key strategic opportunity for the longer-term development of their business beyond current transport systems, both in Europe and globally.

It will also become possible for the CROP partners to start up dedicated companies to underpin such new business models. In addition, training for personnel, engineers, etc., can be started early, thus, bringing an advantage over the competition. Overall, it is important to be aware of such future strategic developments, which allows CROP's partners to embrace new usage scenarios and to prepare technical solutions, rather than being overwhelmed by them. Therefore, for them this will lead to new business opportunities on the long run. All of this will be achieved by informing key personnel in the companies about the relevant strategic results, ranging from board members, e.g., Chief Technology Officers to product and marketing divisions.

The manufacturers, within the consortium will be aware of the operators' adapted and new business models introduced, thus, being well positioned for serving this new demand in a market that is not only shifted, but also enlarged.

Notwithstanding, industry-driven exploitation will shape the forthcoming technological landscape by making CROP results, as the core ingredient of the future transport systems. It will enable the consortium members of being best positioned in these forthcoming markets, but it will also, overall, ensure that the European companies and markets continue to play a leading role, worldwide. In line of these exploitation activities, CROP industrial partners will use strategic results to create new markets and business opportunities, foster new customer relationships, and create new, competition-friendly, highly efficient, unbundled technological structures.

Academic Exploitation

The exploitation goals of academic partners (i.e., universities and research institutes) are different, yet complementary, to those of industrial partners. Technical developments are being integrated quickly into the post-graduate teaching curricula and research agendas of the CROP partners, giving themselves, as well as their graduates, a competitive edge, when compared to other universities, namely those in USA. Academic partners will also make sure that these developments are carried into future national and international research projects, deeply rooting CROP results in R&D activities. They have already published high-quality papers from CROP's results, academic partners have obtained improved international visibility and improved their position in attracting the best international Ph.D., M.Sc. and graduate level students to their institutions. In order to spread the CROP approaches widely among the academic, engineering and aeronautics community, academic partners have also exploited the project results to organize tutorial-style and research seminar-style into training schools of high academic standing at their institution.

The academic partners performed exploitation by delivering research and teaching activities that could have a strong impact on many important courses and supporting consulting contracts. Universities and research institutes are thus able to exploit the results through the training of highly qualified engineers in Master and PhD programs. Academic partners are also been asked to prepare the workforce for the future technological landscape, both for direct work in industry and for research; this development is particularly important for SMEs, who are often not themselves able to train personnel in these new air-vehicle technologies. The long run result of the efforts of the academic partners will be to place the approaches developed in CROP in the mainstream of teaching in engineering, electric and control and communications systems.

Competitive positioning

- **Why CROP can be considered unique and potentially successful?**

At the outset CROP proved that cyclogyro rotor systems could be efficiently applied as a new disruptive form of air propulsion, facing strong skepticism in the scientific, academic and aerospace sectors. After just 24 months the CROP Consortium has proved that, not only can cyclogyro propulsion systems be used in unique forms of VTOL and high agility aircraft, but that they can also be integrated into existing helicopters and fixed wing aircraft to achieve up to 60% more efficiency in forward flight compared to conventional propulsion systems. These 'compound' aircraft had not been foreseen before Project CROP commenced. The CROP electrically powered 20kg D-DALUS L1 concept demonstrator successfully launched and transitioned to forward flight in the laboratories of IAT21 in Traun (Austria); proving that the CROP cyclogyro concept could eventually be used in air vehicles, perhaps even passenger craft.

- **The project value proposition: what are we offering to the market?**

The D-DALUS cyclogyro concept may now be offered under licence to major aircraft prime manufacturers seeking to develop a solution for the obsolescence of conventional propulsion systems in V/STOL applications.

- **Area of application and transferability to other sectors of CROP results**

IAT21 have also been examining the cyclogyro concept, and their patented ultra-low friction bearings in:

- ✓ Domestic and industrial wind turbines (with the ability to operate at very low and very high wind speeds out of reach to conventional turbines and thereby potentially doubling the productive capacity and increasing the efficiency of wind generation.
- ✓ Commercial water turbines for river, estuary and off-shore operation using similar technology to the D-DALUS cyclogyro rotors.

This has been made possible through work during Project CROP, to develop composite materials structures and manufacturing processes that deliver components of exceptionally high strength, long life expectancy and low weight.

- **Activities necessary for delivering the value proposition**

IAT21 plans to expand their work to cyclogyro rotors of larger dimensions and to examine the extraordinary phenomena of increasing efficiency with increase in air speed. They plan to examine the forward speed/net thrust curve beyond speeds achievable in conventional wind tunnels to attempt to discover the full extent of this efficiency increase.

- **What the market is asking for?**

The market is seeking:

- ✓ air propulsion systems that allow vertical launch and landing (to remove the necessity for new European runways to match passenger growth forecasts).
- ✓ A highly agile craft that can fly in swarms and accommodate sudden changes in pattern necessary when other aircraft join or depart the swarm.
- ✓ A fast aircraft that can exceed the speeds of conventional helicopters.
- ✓ A highly efficient aircraft that serves the environment through reducing carbon and nitrous pollutants.
- ✓ A safe aircraft that can operate in close proximity to obstacles, ground crew and other aircraft.
- ✓ An aircraft that can operate in extremes of weather and can land on pitching and rolling decks in rough seas.

- **Who might be interested in using our results?**

The following are potential customers for the scientific results of project CROP:

- ✓ Prime aircraft manufacturers such as Agusta-Westland, Lockheed Martin, Sikorski, Airbus and Boeing.
- ✓ Automobile manufacturers seeking long term to move into the aerospace sector, eg: BMW, TATA Motors, Honda.
- ✓ Government research agencies such as dstl in UK, EASN, NASA Langley and DARPA in the USA.

- **Market trends**

The VTOL market is burgeoning for UAVs. 5 years ago this was a realm exclusively dedicated to Defence/Military applications but now drones are under consideration for a constantly expanding commercial civil UAV sector, addressing such roles as border security, maritime search and rescue, remote installation observation and repair, package delivery, and humanitarian operations.

- **Potential barriers to entry the market**

Air Traffic regulations are rapidly changing to accommodate VTOL aircraft and UAVs. However, these regulations lag behind the advances in technology and the political will is currently contaminated by the perception of such craft as weapon systems. Major prime aircraft manufacturers may see cyclogyro propulsion systems as a threat to their market dominance. This must be carefully avoided by working closely with such manufacturers in partnerships that yield compound aircraft solutions.

- **Potential competitors**

Europe currently holds the World lead in cyclogyro propulsion technology and has patents protecting that technology. However, competition is rapidly developing in the USA, China, South Korea and Singapore. Both the US and UK governments have expressed considerable interest in this technology yet currently seek to absorb this technology without contributing to the cost of development within Europe.

Financial Investments

In regard to future funding we highlight three key points.

1 –The consortium identified different fonts of public and a private funding. We already made one follow-up application to the H2020, under the FET instrument (CEAT Proposal in Sep. 20149,and there are also negotiations with private business groups.

2-The consortium has been expanded with the addition of new industrial partners and research centers that brings kills to continue to raise the level of TRL to a pre-trade situation.

3-It is essential to get a funding of about 3 million Euros to raise the level of TRL to a situation where private investors consider strategic to invest in this new technology.

Conclusion and future work

The project can be rated with overall success since the very beginning, particularly in relation to the participation in conferences, journal publications, and the dissemination of the project's press release in various websites, magazines and media.

With the present and new partners, and proper investment, we believe that a greener air-transport paradigm and technology solution can be established to serve society, boost European economy and generate income to flow back into technology provider sources.

The initial CROP exploitation plan was based on conservative assumptions achievements far overcome the initial predictions. It provided different strategies for different partners to use CROP results in real industrial environments and to spread it to others within the eco-system of corresponding partner. The CROP exploitation plan is hand in hand with the dissemination plan and in this way information flow to and from external parties will be provided. This will help CROP partners to tailor project outcomes and results in such a way as to make them relevant beyond the life of the project. In addition to this, partners will generally keep on identifying groups and organizations that could potentially be interested in CROP outcomes and determine whether any modifications would be required for them to be able to exploit it. It is also necessary to keep regional, national and European authorities and polic makers in the loop to communicate CROP project results, since new policies may be required for deployment of CROP project results.

4.1.5 Main contact details

The address of the project public website:
crop.ubi.pt

Contact details of the project's coordinator:
Prof. Dr. José Pascoa, Universidade da Beira Interior (UBI),
Convento de Santo Antonio, 6200-001 Covilha, Portugal
Tel: +351 275329763
E-mail: pascoa@ubi.pt
www.clusterdem.ubi.pt

List of partners:

- Universidade da Beira Interior, Portugal
- Università di Modena e Reggio Emilia, Italy
- IAT21 - Innovative Aeronautics Technologies GmbH, Austria
- The University of Sheffield, United Kingdom
- Grob Aircraft AG, Germany
- Politecnico di Milano, Italy

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4.2 Use and Dissemination foreground

List of project meetings

During all project we had face meetings, video meeting in consortium and bilateral meetings between some partners of the consortium.

Face-to-face Meetings

- Covilhã Kick-off meeting, 20-21 Jan 2013 (Portugal)
- Milan Meeting 2-3 December 2013 (Italy)
- Sheffield Intermediate Meeting 28-29 April 2014 (UK)
- Aachen Meeting 27-29 October 2014 (Germany)
- Brussels Final Meeting 17 December 2014 (Belgium)

Figur4.2- Group Photo in Brussels Final Meeting

Videoconferences

- FP7 CROP Plenary Web-ex call conference - 20/03/2013
- FP7 CROP Plenary Web-ex call conference - 02/05/2013
- FP7 CROP Plenary Web-ex call conference - 06/09/2013
- FP7 CROP Plenary Web-ex call conference - 08/10/2013
- FP7 CROP Plenary Web-ex call conference - 16/06/2014
- FP7 CROP Plenary Web-ex call conference - 12/11/2014
- FP7 CROP Plenary Web-ex call conference - 10/12/2014

4.2.1 Dissemination

Background papers

Abdollahzadeh, M, Páscoa, J.C., Oliveira P.J., “Numerical Investigation on Efficiency Increase in High Altitude Propulsion Systems Using Plasma Actuators”, in Proc. VI European Conference on Computational Fluid Dynamics ECCOMAS CFD 2012, 16 pp, 2012.

Páscoa, J.C. and Ilieva, G., “Overcoming stopovers in cycloidal rotor propulsion integration on air vehicles”, ASME 14th International Conference on Advanced Vehicle Technologies, Paper No.DETC2012-70894, 2012.

Páscoa, J.C., Dumas, A., Trancossi, M., “A novel look at the performance of the cyclorotor propulsion system for air vehicles”, in ASME International Mechanical Engineering Congress and Exposition Paper NºIMECE2012-85544, 2012

Páscoa J. C., Xisto C. M., Göttlich E., (2010), "Performance assessment limits in transonic 3D turbine stage blade rows using a mixing-plane approach", Journal of Mechanical Science and Technology, Vol. 24(10), pp.2035-2042.

Dumas, A., Anzilloti, S., Zumbo, F., Trancossi, M., ”Photovoltaic Stratorspheric Isle for Conversion in Hydrogen as Energy Vector, Proc. Of The Institution of Mechanical Engineers, Part G, Journal of Aerospace Engineering, Vol. 223, Nº 6, 769-777, 2009.

Dumas, A., Anzilloti, S., Madonia, M., Trancossi, M., “Effects of Altitude on Photovoltaic Production of Hydrogen”, ASME 5th International Conference on Energy Sustainability – ESFFUELCELL2011, Paper Nº54624,2011.

Wang, J., Sun, Z., Ede, J. D., Jewell, G.W., Cullen, J. J. A., Mitcham, A. J., ‘Testing of a 250-Kilowatt fault tolerant permanent magnet power generation system for large civil aero engines’, AIAA Journal of Propulsion and Power, Vol 24(2), 2008, pp. 330-335.

Powell D.J., Jewell G.W., Calverley S.D., Howe D., ‘Iron loss in a modular rotor switched reluctance machine for the ‘more-electric’ aero-engine’, IEEE Transactions on Magnetics, Vol. 41(10), 2005, pp. 3934-3936.

Gysen B.L.J., Gibson, S., Clark, R.E., Jewell, G.W., ‘High temperature permanent magnet actuator for failsafe applications, IEEJ Transactions on Industry Applications, Vol. 128-D, No.10. 2008. pp. 1198-1202.

Owen, R.L., Zhu, Z.Q., Thomas, A.S., Jewell, G.W., Howe, D., ‘Alternate Poles Wound Flux-Switching Permanent-Magnet Brushless AC Machines’, IEEE Transactions on Industry Applications, Vol. 46(2), 2010, pp.790-797.

M. Mattaboni, P. Masarati, P. Mantegazza, “Multibody Simulation of a Generalized Predictive Controller for Tiltrotor Active Aeroelastic Control”, Proc. IMechE Part G: J. Aerosp. Engng.,226(2):197-216, February2012 doi:10.1177/0954410011406203

M. Benedict, M. Mattaboni, I. Chopra, P. Masarati, “Aeroelastic Analysis of a Micro-Air-Vehicle-Scale Cycloidal Rotor”, AIAA Journal, 2011, 49(11):2430-2443 doi:10.2514/1.J050756.

L. Cavagna, P. Masarati, G. Quaranta, “Coupled Multibody /CFD Simulation of Maneuvering Flexible Aircraft”, Journal of Aircraft, 0021-8669 48(1):92-106, January-February 2011, doi:10.2514/1.C000253.

P. Masarati, M. Morandini, G. Quaranta, D. Chandar, B. Roget, J. Sitaraman, “Tightly CoupledCFD / Multibody Analysis of Flapping-Wing MAV”, 29th AIAA Applied Aerodynamics Conference, Honolulu, Hawaii, USA, 27-30 June 2011 (AIAA-2011-3022).

CROP – Papers Publications

Leger J. A., Páscoa J. C., Xisto C. M., (2015) "Analytical Modeling of a Cyclorotor in Hovering State", accepted for publication in Proceedings of the Institution of Mechanical Engineers Part G: Journal of Aerospace Engineering. doi:10.1177/0954410015569285.

C. M. Xisto, J. C. Páscoa, M. Abdollahzadeh, J. A. Leger, P. Masarati, L. Gagnon, M. Schwaiger, D. Wills, "PECyT - Plasma Enhanced Cycloidal Thruster", Propulsion and Energy Forum 2014, Cleveland, OH, July 28-30, 2014, doi:10.2514/6.2014-3854.

Xisto, C. M., Páscoa, J. C., Leger, J. A. (2014), "Cycloidal Rotor Propulsion System With PLasmaEnhaced Aerodynamics" ASME International Mechanical Engineering Congress & Exposition - IMECE 2014, Monteral, November 14–20.

Xisto, C. M., Páscoa, J. C., Leger, J. A., Gerlach, A. (2014) "Multi-Dielectric Barrier Discharge plasma actuator for cycloidal rotor active flow control", 4th EASN Association International Workshop on Flight Physics and Aircraft Design, Aachen, Germany, October, 27-29.

Leger, J. A, Páscoa, J. C., Xisto, C. M. (2014) "Aerodynamic Optimization of Cyclorotors", 4th EASN Association International Workshop on Flight Physics and Aircraft Design, Aachen, Germany, October, 27-29.

Trancossi, M., Dumas, A., Xisto, C. M., Páscoa, J. C., Andrisani, A. (2014), "Roto-Cycloid propelled airship dimensioning and energetic equilibrium" SAE 2014 Aerospace System and Technology Conference, Cincinnati, Ohio, USA, September 23-25.

L. Gagnon, M. Morandini, G. Quaranta, P. Masarati, "Cyclogyro Thrust Vectoring for Anti-Torque and Control of Helicopters" AHS 70th Annual Forum and Technology Display, Montreal, Canada, May 20-22, 2014

C. M. Xisto, J. C. Páscoa, J. A. Leger, P. Masarati, G. Quaranta, M. Morandini, L. Gagnon, D. Wills, M. Schwaiger, "Numerical Modelling of 3D Geometrical Effects in the Performance of a Cycloidal Rotor", 6th European Conference on Computational Fluid Dynamics (ECFD VI), Barcelona, Spain, July 20-25, 2014.

Monteiro J. A., Páscoa J. C., Xisto C.M., (2013), "Analytical Modeling of a Cyclorotor in Forward Flight", in Proc. SAE Aerotech 2013, Montreal, Quebec, Canada Nº 2013-01-2271 doi:10.4271/2013-01-2271

Leger J.A., Páscoa J.C., Xisto C.M., (2013) "Parametric design of cycloidal rotor thrusters", Proceedings of ASME 2013 International Mechanical Engineering Congress & Exposition, IMECE2013, November 15-21, San Diego, California USA

L. Gagnon, G. Quaranta, M. Morandini, P. Masarati, C. M. Xisto, J. C. Páscoa, "Fluid-Structure Interaction Analysis of a Cycloidal Rotor", submitted to AIAA conference, June 2014, Atlanta, USA.

L. Gagnon, M. Morandini, G. Quaranta, P. Masarati, G. Bindolino, J. C. Páscoa, C. M. Xisto, "Conceptual Design of a Cycloidal Rotor Solution for Propulsion and Control", 40th European Rotorcraft Forum 2014, Southampton, UK, September 2-5, 2014.

L. Gagnon, M. Morandini, G. Quaranta, P. Masarati, "Cycloidal Rotor Aerodynamic and Aeroelastic Analysis", 4th EASN Association International Workshop on Flight Physics and Aircraft Design, Aachen, Germany, 27-29 October, 2014.

Leger A. J., Páscoa J. C., Xisto C. M., (2013) "Kinematic and Dynamic Parametric Analysis of Cycloidal Rotor Thrusters", Proceedings of ICEUBI 2013 – International Conference on Engineering, November 27-29, UBI, Covilhã, Portugal.

S. Elfein, D. Wills "Efficiency Increase in ForwardFlight Researched at Cyclogyro rotor VTOL Aircraft", M. Schwaiger, October, 2014.

M.Schwaiger, D. Will, S, Elflein "D-Dalus VTOL - efficiency increase in forward flight", AEAT-12-2014-0205

Exhibits

Outreaching

Events for Consortium

- CROP Kick-off Meeting 20-21-January Covilhã Portugal
- FP7 workshop Cruiser-Feeder-Airship-and-Innovative-Propulsion-for-Greening-the-Future EU Transport, 26-April 2013, c/o Aero-Friedrichshafen Germany.
- IPAS - International Paris Air Show – Le Bourget - France
- CROP Milan present Meeting 2-3 December 2013 - Italy
- CROP Intermediate meeting March 2014 Sheffield - UK
- 4thEASN – CROP Workshop - October 27-29, 2014 in Aachen, Germany.
- CROP Final Meeting December 2014 Brussels – Belgium.

Other Events

- ICEUBI2013 –International conference of Engineering of University of Beira Interior, 27-29 November 2013
- AHS 70th Annual Forum and Technology Display, Montreal, Canada, May
- 50th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, July 2013, Cleveland, USA
- ASME 2013 International Mechanical Engineering Congress & Exposition, IMECE2013, November 15-21, San Diego, California USA
- "ClusterDEM European Project Dissemination" , Covilhã, July 2013
- Workshop on Aeronautics research looking for "The Origins of Innovation" – April 2013 (ONDE?)
- European Rotorcraft Forum 2014, Southampton, UK, September 2–5 2014American Helicopter Society annual forum – May 2014 (ONDE)
- ASME 2014 International Mechanical Engineering Congress & Exposition, IMECE2014, November 14-20, Montreal, Quebec, Canada.

- 11th World Conference on Computational Mechanics, Barcelona, Spain, July 20–25.
- SAE 2014 Aerospace System and Technology Conference, Cincinnati, Ohio, USA, September 23-25.
- AIAA Modelling and Simulation Technologies Conference, Atlanta, Georgia, USA, June 16–20,
- SAE Aerotech 2013, Montreal, Quebec, Canada, September 24-26

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List of dissemination products:

- CROP logo and all image of the project;
- Project web-site http://crop.ubi.pt
- Project brochure
- Project initial poster
- CROP Scientific Poster
- Project post-cards
- CROP facebook group
- CROP twitter group
- CROP LINKED IN group
- CROP Google Plus Group
- CROP WiKipedia page
- CROP project presentation (.ppt)
- CROP roll-up
- CROP Newsletter
- CROP Press-releases (PT/EN)

Press and media coverage

1-RTP
The RTP- Portuguese public television is the most watched television channel in the country.
http://www.rtp.pt/play/p47/e105694/portugal-em-direto/279614

2-Youtube-UBI Channel
The University of Beira Interior has its own channel on Youtube, where it publishes videos of its activities with emphasis on the national media.
http://www.youtube.com/watch?v=-t--EbyFumc

3-LocalVisão
The Localvisão is a cable television channel in Portugal, which has started as Web channel.
http://videos.sapo.pt/eKZMU4osCPpzCaZrYA99

4-RCB
The "RCB-RádioCova da Beira" is the reference radio of the region of Beira Interior, with headquarters in the city of Fundão, and emits in frequency throughout the whole center region of Portugal.
http://www.rcb-radiocovadabeira.pt/pag/17002

5-CiênciaHoje
The "CiênciaHoje" (Science Today) is a national journal of Science, Technology and Entrepreneurship, making coverage of all large projects of these three areas.
http://www.cienciahoje.pt/index.php?oid=56749&op=all

6-URBIetORBI- Journal of UBI
The URBIetORBI is themean of communication of UBI. They have a newspaper, a radio and television channel. The most relevant one is the newspaper, which is read weekly, not only inside the institution, but in the entire region of Beira Interior.
http://www.urbi.ubi.pt/pag/11092

7-Kaminhos Magazine
Kaminhos is a multimedia magazine used for information and commercial distribution. It presents itself as a generalist communication project that aims to provide a public service of independent information, beyond the traditional journalism.
http://www.kaminhos.com/artigo.aspx?id=9055&seccao=0

8-Guarda.pt (Digital)
The Guarda.pt is an online newspaper, based in the city of Guarda, at the north side of Beira Interior, and it's a generalist journal that provides service throughout the region.
http://www.guarda.pt/noticias/sociedade/Paginas/ubi-desenvolve-aeronaves-futuro.aspx

9-Cnoticias.net
The Cnoticias is a general newsnot printed website. It covers the news throughout the central region of Portugal.
http://www.cnoticias.net/?p=101105

10-The Daily BEIRAS.PT
This Daily is a generalist Journal that, despite being national, has a more intense coverage in the central region of the country.
http://www.asbeiras.pt/2013/01/universidade-da-beira-interior-acolhe-projeto-para-criar-novo-motor-aereo/

11-NEUBI–Students Association of Electromechanical Engineering of UBI
The NEUBI is run by students of the course of Electromechanical Engineering, keeping their official pages always up-to-date with information on projects involving the Electromechanical family.
http://www.neubi.pt/index.php/classe/195-ubidem-lideram-projecto-europeu-de-sistemas-de-propulsao

12-CRUP
The Council of Rectors of the Portuguese Universities (CRUP) is a coordinating entity of the University education in Portugal and includes as members all the public universities and the Catholic University of Portugal. It has made references to the CROP in its official website.
http://www.crup.pt/pt/imprensa-e-comunicacao/recortes-de-imprensa/4441-ubi-lidera-investigacao-europeia

13- ClusterDEM
The ClusterDem at the Electromechanical Engineering Department, C-MAST-Centre for Mechanical and Aerospace Sciences and Technologies, in University of Beira Interior is a

laboratory equipped with High-Performance Computer clusters for performing numerical simulation on Multiphysics.

http://clusterdem.ubi.pt/index.php?option=com_content&view=article&id=20:crop&catid=6:projects&Itemid=4

14-João Pedro Jesus

The company *"JoãoPedroJesus"* is a company that does works of photography, video and multimedia applications. They provide services to other businesses or organizations in their areas of operation.

a) Video

http://www.youtube.com/watch?v=bJPCxAMXljE

b) Time_Lapse

http://www.youtube.com/watch?v=69a2PUwZrw0

15- Web newsletter

Dissemination of CROP first newsletter

a) http://www.crop-project.eu/nl/01/newsletter.html

b) https://www.ubi.pt/Ficheiros/Entidades/Universidade/CROP%20Project_Newsletter%281%29.pdf

16- Cordis

Official Page of CROP in CORDIS Platform

a) http://cordis.europa.eu/result/rcn/149497_en.html

b) http://cordis.europa.eu/project/rcn/106045_en.html

17- WCCM web site

Open access web site of 11th World Congress on Computational Mechanics (WCCM XI

http://www.wccm-eccm-ecfd2014.org/admin/files/filePaper/p1848.pdf

18- Wikipedia

Project CROP it is sited and iran reference in Cyclogyro definition. In this Page we can see that all of the pictures present are from CROP Project

http://en.wikipedia.org/wiki/Cyclogyro

19- crop Web Site

The site has been visited by hundreds of people seeking information about the project.

http://www.crop-project.eu/

20- D-Dalus Website

This is the website created by IAT for D-Dalus dissemination.

http://d-dalus.com/en/home.html

21- AULP

AULP – Association Of Universities of Portuguese Language is an international NGO that promotes cooperation and exchange of information between universities and higher institutes. They are more than140 members of the eight Portuguese-speaking countries-Angola, Brazil, Cape Verde, Guinea-Bissau, Mozambique, Portugal, Sao Tome Principe, Timor-and Macau. They promoted the crop project in their web site.

http://aulp.org/node/112469

22-Doppeladler

This is a Blog related to new innovative technology. They have more than

http://www.doppeladler.com/forum/viewtopic.php?t=2517&p=41649

23- Pesri

Blog Managed by professor Paul Stewart. He is a reference in Energy and Environmental Studies.

http://www.pesri.net/blog/?p=1338

24- Brother projects

Crop is new in the web site of its project brothers, MAAT and ACHEON

a) http://www.eumaat.info/
b) http://acheon.eu/

25- Net Centro

CEC -Business Council Centre /ICC-Centre for Trade and Industry is anon-profit association, founded in 1993,representativeoftheNUTIICentralBusiness Associations, as well as the districts of Aveiro, Castelo Branco, Coimbra, Guarda,Leiria and Viseu in Portugal.

http://www.netcentro.pt/Conteudos/Artigos/detalhe.aspx?idc=1268&idl=1&idi=28125

26- Universia

Web Journal about Portuguese science and Innovation.

http://noticias.universia.pt/tag/universidade-da-beira-interior/

27- Espelho da Interioridade

It is a Blog about the Interior of Portugal, highlighting good practices wherever possible to overcome the barriers that interiority.

http://espelhodainterioridade.blogspot.pt/search/label/Empreendedorismo?updated-max=2013-01-30T15:22:00-08:00&max-results=20&start=20&by-date=false

28- Mix

It is a Brazilian blog about brief news.

http://www.mixdoconhecer.com.br/?p=243~

29- DiHitt

Portuguese web site about General news

http://wwwdihittcombrornilo.dihitt.com/n/opiniao-e-noticias/2014/12/17/tecnologia-aerea-ubi-apresenta-amanha-em-bruxelas-sistema-de-propulsao-inovador

30- Ciência PT e nova tech

a) http://novaeratecnologiarm.blogspot.pt/2013_06_01_archive.html

b) http://www.cienciapt.net/pt/index.php?option=com_content&task=view&id=107686&Itemid=185

31- CROP Proof of concept

The first video 'CROP_D6.1_USFD_v01'focusses on the various aircraft concepts generated as part of WP2 which illustrates the possible realisation of the crop concept in various civil aerospace applications.

The second video 'CROP_D6.1_USFD_v02' is directed towards the realization of CFD images to show the project enhancement including the improvements achieved by precisely controlling the airflow over the wing by implementation of dielectric barrier discharge.

Video 1: https://www.youtube.com/watch?v=IBC6izUPGdU
Video 2: https://www.youtube.com/watch?v=5emtt_wkO_o

List of deliverables

Deliverable Number	DeliverableTitle	WP Number	Lead	Due Date - Month	Nature	Dissemination level
D1.1	Kick-Off Meeting Presentation	WP1	UBI	1	O	PU
D4.1	Experimental activity plan	WP4	IAT21	1	R	RE
D2.1	Organizational guidelines and general rules	WP2	UBI	3	R	RE
D2.3	Bibliography Analysis	WP2	UNIMORE	3	R	CO
D7.1	Web site and Upgrades	WP7	GROB	3	R	PU
D7.2	Leaflet	WP7	GROB	3	O	PU
D7.3	Dissemination plan	WP7	GROB	4	R	RE
D2.4	Preliminary Design	WP2	UBI	9	R	RE
D1.2	Periodic Report	WP1	UBI PM	12	R	RE
D2.6	Design methodologies report	WP2	UBI	12	R	RE
D3.1	CFD/CSD ANALYSIS Report	WP3	POLIMI	12	R	RE
D3.3	Vehicle CFD/CSD analysis report	WP3	POLIMI	12	R	RE
D4.2	Experimental intermediate report	WP4	IAT21	12	R	RE
D7.4	Newsletter	WP7	GROB	12	O	PU
D6.1	Multimedia proof of concept	WP6	USFD	22	O	PU
D1.3	Final Report	WP1	UBI	24	R	RE
D2.2	Dissemination Quality Report	WP2	UBI	24	R	RE
D2.5	Mathematical models	WP2	USFD	24	R	RE
D2.7	Design methodologies final report	WP2	UBI	24	R	PU
D2.8	Study of integration into Aircrafts	WP2	GROB	24	R	RE
D2.9	Performance viability assessment of the integrated vehicle	WP2	UBI	24	R	PU
D3.2	CFD/CSD analysis final report	WP3	UBI	24	R	RE
D3.4	Vehicle CFD/CSD analysis Final report	WP3	UBI	24	R	PU
D4.3	Experimental final report	WP4	IAT21	24	R	RE
D5.1	Technology evaluation Report	WP5	UNIMORE	24	R	RE
D5.2	Technology evaluation of global concept	WP5	USFD	24	R	RE
D6.2	Proof of concept	WP6	UBI	24	R	PU
D7.5	Exploitation plane valuation	WP7	UBI	24	R	RE
D7.6	Evaluation of dissemination results	WP7	USFD	24	R	PU
D7.7	Final Newsletter	WP7	UNIMORE	24	O	PU

List of milestones

Milestone N°	Milestonetitle	Responsible	WPs	Due Date (month)
MS1	KickOff Meeting	UBI	WP1	1
MS11	Experimental activity planning	IAT21	WP4	1
MS3	Organizational Guide lines and general rules	UBI	WP2	3
MS4	Bibliography analysis	UNIMORE	WP2	3
MS16	Website and upgrades	GROB	WP7	3
MS17	Dessimination plan	GROB	WP7	4
MS5	Preliminary Design	UBI	WP2	9
MS2	Periodic Report	UBI	WP1	12
MS6	Design methodologies report	UBI	WP2	12
MS9	System CFD analysis	POLIMI	WP3	12
MS12	Experimental activity report	IAT21	WP4	12
MS14	Informatic Proof of concept	USFD	WP6	22
MS7	Study of integration into aircrafts	GROB	WP2	24
MS8	Assessment against other commercial air Vehicles	UBI	WP2	24
MS10	CFD analysis final report	UBI	WP3	24
MS13	Experimental activity final report	IAT21	WP4	24
MS15	Proof of concept	UBI	WP6	24
MS18	Final report	UBI	WP1 eWP7	24

4.2.1 Exploitation

The partners of CROP project developed and implemented an exploitation plan. This plan was aimed at ascertaining the ownership of results and at identifying the use of the results that are planned by partners. To have a complete vision of the exploitation plans, the timing of exploitation as well as the access rights to other partners' was agreed upon partners. The project results were registered in the table below during the lifetimeof the project.

	Exploitable Result Title	Exploitationdescription	Date ofachievement	Comments
UBI	Further activities on PECYT, publishable in scientific journals (Papers)	Experiments/LES modeling	3rd Quarterof 2015	National financing through FCT-Portugal is supporting this after-project activities
	Applying for funding within H2020 and Portuguese foundation of Technology	Border Security call / FET / FCT	January 2015 /March2015/ August2015/ September 2015	we are searching financial for experiment
UNIMORE	Complement the experimental analysis of f. fligth with CFD + Interaction with LE	CFD	May 2015	additional funding is being searched

IAT21	Analysis (exp) for eff. In forward speed, influence of virtual chamber, verify the limit of AR vs max eff.	Experimentsonwindtunnel	3rd Quarterof 2015	we are searching finacial for experiment, including private funding.
	1. High efficicncy design of D-DALUS Cyclogyro rotor assembly 2. Potential for High efficiency compound cyclogyro helicopter 3. Potential for High efficiency compound cyclogyro fixed wing aircraft	1. Use in VTOL UAVs and ultimately in VTOL passenger aircraft 2. Joint development with major helicopter primes 3. Joint development with major fixed wing aircraft primes	Final of 2015	Private funding is being sought to support these activities in after-project
SHEFFILD	Study of ground effect. Inclusion of a vane (electromechanic)	ExperimentsandComputationalMultiphysics	July 2015	Additional funding is being searched
	PECyT integration into a cyclogyro, rotating transformer.	Experimental activities	July 2015	Additional funding is being searched
GROB	Exploring implementation of CROP Propulsion system into their current production airplanes	Engineering activities	Final 2015	GROB Company self-support
POLIMI	Testing needed for interaction with main rotor. Influence of lateral wind. Experimental validation of flexibility	CSD/CFD/ experimental	July 2015	Additional funding is being searched

Table 1 –Exploitation results