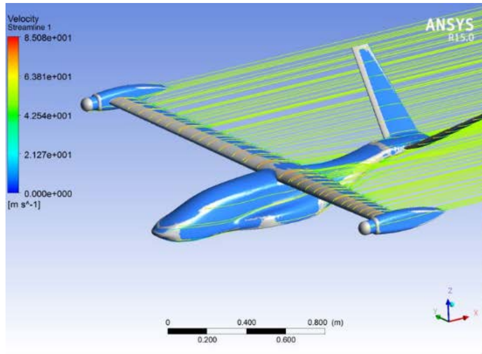
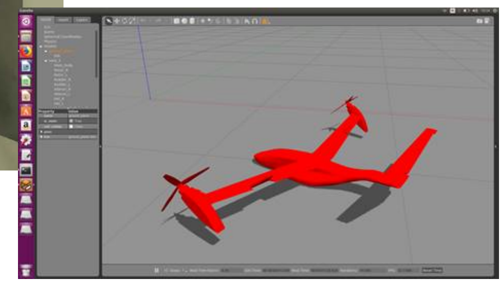
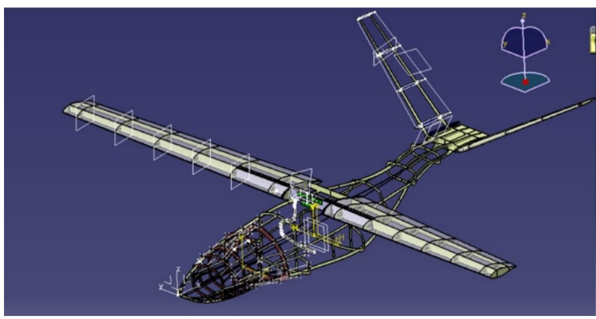
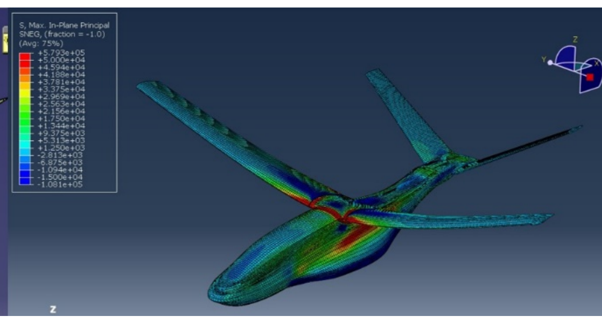




http://aero.us.es/sesteban/pages/RL_VTOL.htm

Development of Unmanned Convertible Aircraft for Rapid and Efficient Deployment in Emergency Situations: Project EMERGENTIA





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Ingeniería Aeroespacial ESI - Universidad de Sevilla

Outline

- Motivation: Project Emergentia
- Objectives
- Working Team
- Research Lines: Work in Progress
- Conclusions

Motivation - I

- Emergency Situations:
  - Hostile Environments: Elevated Risk
- Diversity of scenarios
  - Natural disasters
  - Accidents in high mountains
  - Wild Fires
  - Nuclear Catastrophes.
  - Epidemic
  - Humanitarian aid
- Require Search and Rescues (SAR) missions
  - Enviromental Costs
  - Economic Costs
  - Human Costs

EARTHQUAKE HAITI (2010)

FUKUSHIMA DAIICHI (2011)

EARTHQUAKE NEPAL (2015)

COAST GUARD ASTURIAS

"GREIM" ESPAÑA (2014)

Motivation - II

- What needs to be improved in SAR?
  - **Efficiency**
    - Reducing the timing of emergency services.
    - Arriving earlier to “Zero Zone" and implementing intelligent search algorithms.
  - **Sustainability**
    - Reducing economic and environmental costs resulting from the complex deployments of SAR missions.
    - Helicopters, ships and aircraft of great size and high cost of operation.
  - **Security**
    - Reducing potential human costs.

Efficiency + Sustainability + Security = Effectiveness

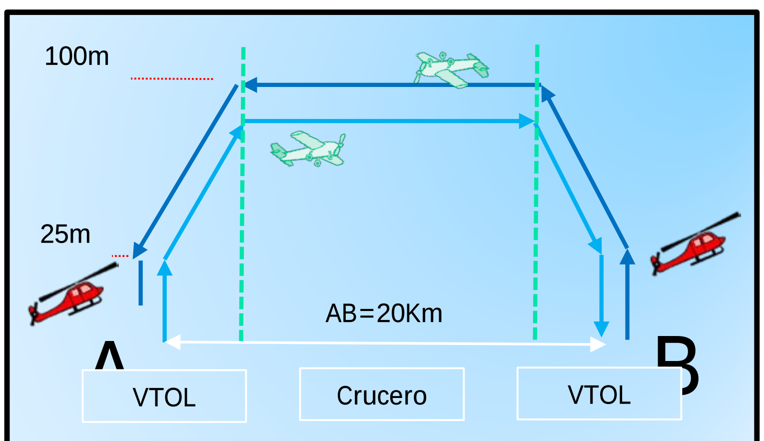
Need to listen to the FINAL USERS – Emergency Response Teams

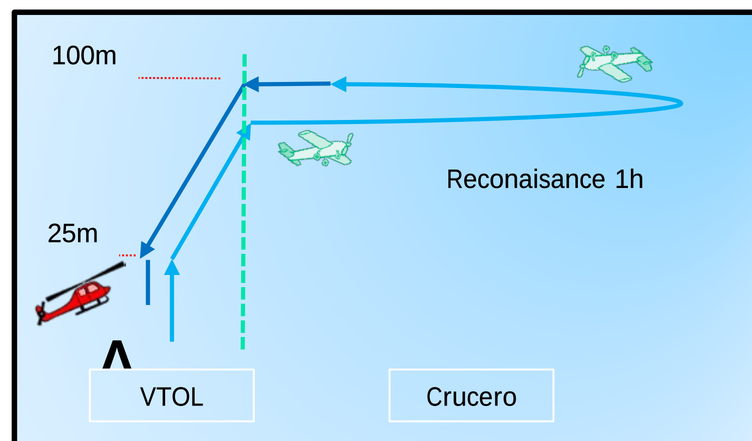
Objectives

- Design of an UAV prototype with **convertible capabilities** (fixed wing VTOL) specifically designed for emergency, search and rescue missions (**SAR**).
- After a throughout **brainstorming** study with the Spanish Emergency Services (**SAMU**) that provide support in catastrophic events, it was determined that the UAV should have the following **characteristics**:
  - **Reduced dimensions**
    - Transported in a medicalized vehicle,
    - Integrated within the fast response coordinated measures that are carried in emergency situations.
  - **Versatility**
    - Carry out a diversity of SAR missions, from monitoring to surveillance, transportation of medical payloads, or deployment of sensors, with the greatest possible autonomy and range.
  - **Simplicity**
    - A health professional can use it without the need for additional training.
  - **Compliance** with **airworthiness requirements**.

EMERGENTIA

DevElopment of an unManned convERtible aircraft for rapid and efficient deployment in emerGENcy situaTIons





Objectives

- Based on these requirements the following specific objectives have been determined for project EMERGENTIA:
  - Definition of design requirements and protocols for use of UAV in SAR missions (O1).
  - Advanced development of a Vertical Take-Off and Landing Convertible Plane (VTOL-CP) (O2).
  - Development of high efficiency embedded electronics and efficient power management (O3).
  - Development of energy generation and storage systems (O4).
  - Development of control and guidance strategies for autonomous operations (O5).
  - Development of a Hardware-In-the-Loop Simulation Platform (O6).

Working Packages

- To achieve the objectives, a work plan has been developed in 9 work packages (WP):
  - WP1. DEFINITION OF PROTOCOLS OF OPERATION IN SAR MISSIONS
  - WP2. STUDY AND PRELIMINARY DESIGN AND DEFINITION OF DESIGN REQUIREMENTS
  - WP3. STUDY OF THE AERODYNAMICS OF PROTOTYPES
  - WP4. PARAMETRIC STUDY OF THE PERFORMANCE OF PROTOTYPES
  - WP5. STUDY OF PROTOTYPES STRUCTURE
  - WP6. DEVELOPMENT OF HIGH EFFICIENCY EMBEDDED SYSTEMS
  - WP7. DEVELOPMENT OF GENERATION AND ENERGY STORAGE SYSTEMS
  - WP8. DEVELOPMENT OF AUTONOMOUS STRATEGIES FOR CONTROL AND GUIDANCE
  - WP9. INTEGRATION AND SIMULATIONS "HARDWARE-IN-THE-LOOP"
  - WP10. FLIGHT TESTS OF THE DEMONSTRATOR

Multidisciplinary Group

- **Universidad de Sevilla**
  - Departamento Ingeniería Aeroespacial y Mecánica de Fluidos de la ETSI (GIA)
    - Sergio Esteban, Miguel Pérez-Saborid
  - Departamento de Ingeniería Electrónica de la ETSI (GIE);
    - Juana María Martínez (JMH), José Luis Mora
  - Departamento de Ingeniería de Sistemas y Automática (DIESA)
    - Carlos Bordons, Manolo Gil Ortega, Manuel Vargas, Miguel Ángel Ridao
  - Departamento de Elasticidad y Resistencia de Materiales.
    - Jesús Justo, Luis Arístides Távara, José Reinoso, Israel García
  - Departamento de Ingeniería Mecánica y Fabricación
    - Daniel García Vallejo
  - Departamento de Ingeniería Gráfica
    - Cristina Torrecillas
  - Departamento de Enfermería de la Facultad de Enfermería, Fisioterapia y Podología.
    - Juana Macías Seda
- **Universidad Politécnica de Madrid**
  - Departamento de Aeronaves y Vehículos Espaciales (DAVE) de la ETSI. Aeronáutica y del Espacio de la UPM
    - Álvaro Cuerva, Óscar López, Cristina Cuerno, Cristóbal José Gallego, Sergio Ávila, Alejandro Sánchez
- **Universitat Politèctinca de Valencia**
  - Departamento de Ingeniería de Sistemas y Automática (DISA)
    - Xavier Blasco, Sergio García-Nieto

Multidisciplinary Group

- **Universidade Federal de Minas Gerais**
  - Departamento de Engenharia Eletrônica:
    - Guilherme Vianna Raffo, Janier Arias, Luciano Pimenta, Bruno Adorno, Patrícia Pena
  - Departamento de Engenharia Mecânica
    - Guilherme de Souza Papini
- **CEFET-MG - Centro Federal de Educação Tecnológica de Minas Gerais**
  - Dvn Depto de Engenharia Mecatrônica
    - Valter Leite Junior
- **Universidade Federal de Santa Catarina**
  - Departamento de Automação e Sistemas del Centro Tecnológico de UFSC.
    - Leandro Buss Becker, Julio Elias Normey Rico
- **CONICET**
  - INTEC Control Group
    - Antonio Ferramosca
- **University of Pavia**
  - Identification and Control of Dynamic Systems Laboratory
    - Davide Raimondo
- **SAMU (Servicio de Atención Médica de Urgencia)**
    - Carlos Álvarez Leiva, Juan González de Escalada Álvarez

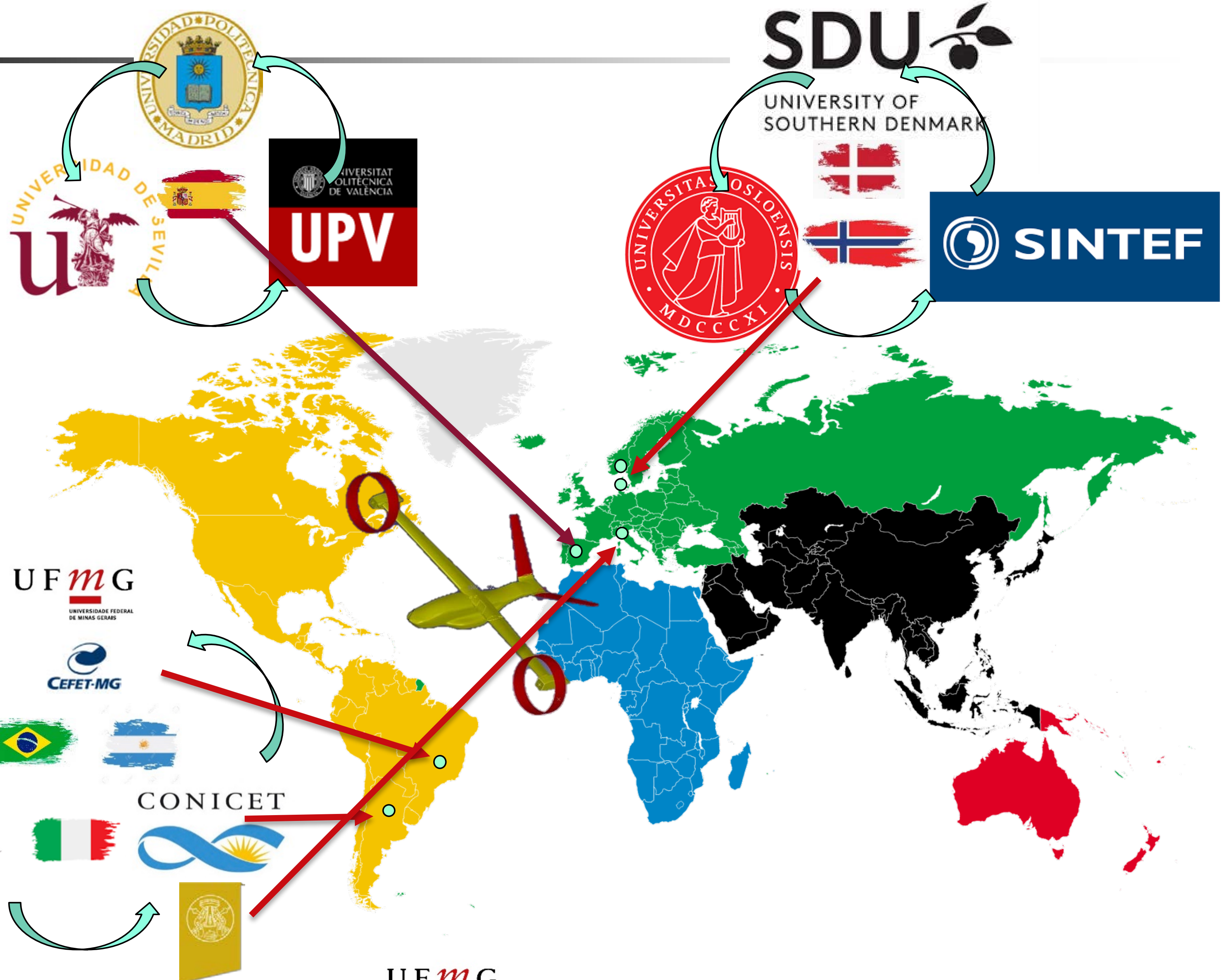
Multidisciplinary Group!!!

Stundets (just the Spanish Side!)

- WP1. DEFINITION OF PROTOCOLS OF OPERATION IN SAR MISSIONS
  - Ismael Andrades (TFM), Gonzalo De Lizaur (TFM), Ana Fernández (TFM), Álvaro Moreno (TFM)
- WP2. STUDY AND PRELIMINARY DESIGN AND DEFINITION OF DESIGN REQUIREMENTS
  - Jorge Carreño (PFC)
- WP3. STUDY OF THE AERODYNAMICS OF PROTOTYPES
  - Alfonso Sancho (PFC), Raimundo Blanco (TFG), Daniel Pinazo (TFG & TFM), David Barea (TFG), David Buellis (TFM), Fernando Pérez (TFG), Victoria Prieto (TFG), Antonio Miguel Fabrique (TFM), Francisco Ortega (PhD)
- WP4. PARAMETRIC STUDY OF THE PERFORMANCE OF PROTOTYPES
  - Juan Diego Sánchez (PFC), Diego Manzano (TFG), Marta Nuñez (TFG)
- WP5. STUDY OF PROTOTYPES STRUCTURE
  - Miguel Peña (TFG), Javier Mora (TFG & TFM)
- WP6. DEVELOPMENT OF HIGH EFFICIENCY EMBEDDED SYSTEMS
  - Lidia Parrilla (TFG), Laura María González (TFG), José Antonio Moreno (TFG), Alejandro Remujo (TFG), Joaquín Soriano (TFG), Dunia López (TFG), Diego Manzano (TFG)
- WP7. DEVELOPMENT OF GENERATION AND ENERGY STORAGE SYSTEMS
  - Juan Ramón Parra (TFG & TFM)
- WP8. DEVELOPMENT OF AUTONOMOUS STRATEGIES FOR CONTROL AND GUIDANCE
  - Luis García-Baquero (TFG), Marta Nuñez (TFG), Álvaro Ojeda (TFM), Álvaro Morilla (TFM)

Building H2020 Consortium

- **Denmark**
  - Southern Denmark University (SDU)
    - Agus Ismail Hasan & Ulrik Pagh Schultz
    - SDU UAS Center (https://www.sdu.dk/en/Om_SDU/Institutter_centre/sduuascenter)
- **Norway**
  - Research Centers & Universities
    - SINTEF
      - https://www.sintef.no/en/
    - Oslo University:
      - http://www.thedrive.com/tech/22881/oslo-university-hospital-to-launch-aerial-blood-sample-
  - Companies
    - KVS Technologies. SME. Monitoring and control of drone operations. Incl. communication.
      - http://kvstech.no/
    - KONGSBERG Seatex. Various types of sensors.
      - https://www.km.kongsberg.com/ks/web/nokbg0237.nsf/AllWeb/FFB39491418C5293C1256E580030555D?OpenDocument
    - KONGSBERG Digital. KOGNIFAI digital platform.
      - https://www.kongsberg.com/en/kongsberg-digital/
    - SEVENDOF. SME. VTOL drone.
      - https://www.sevendof.com/
    - Versor IO. SME. SLAM for drones.
      - http://versor.io/



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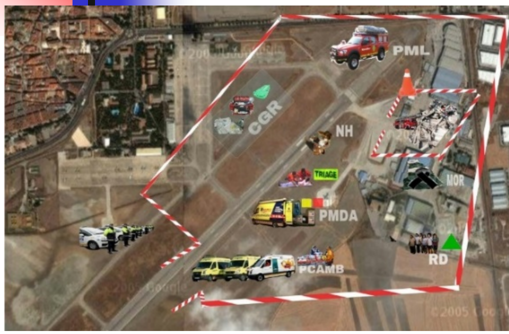
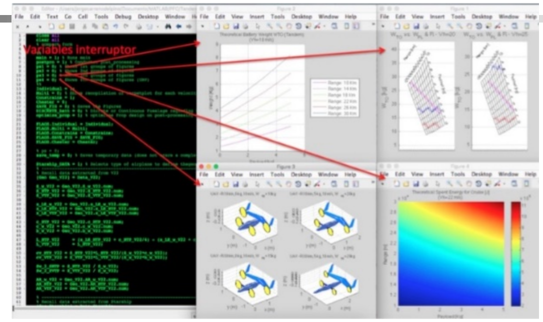
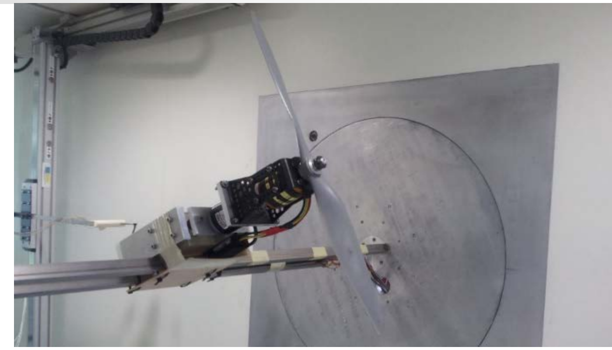
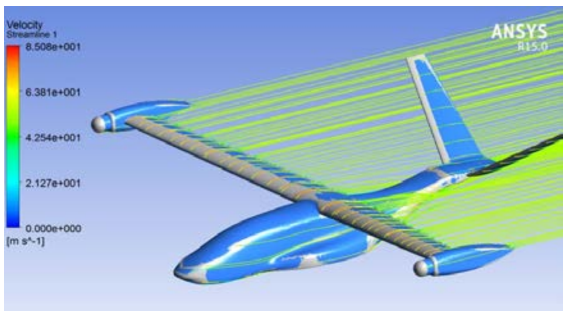
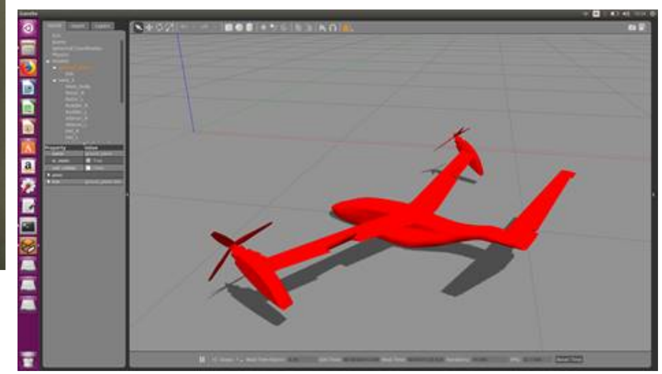
Research Lines

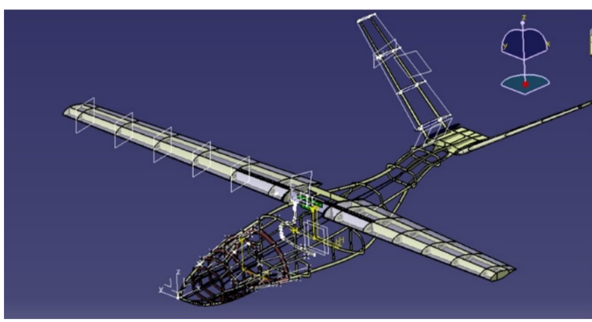


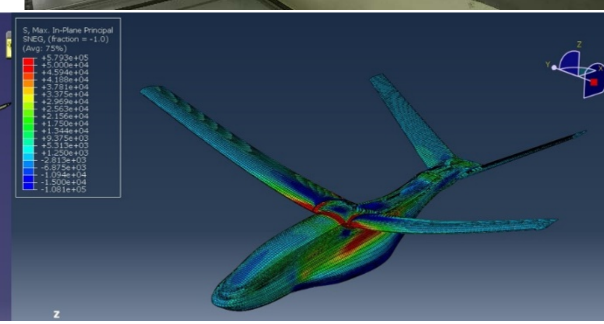


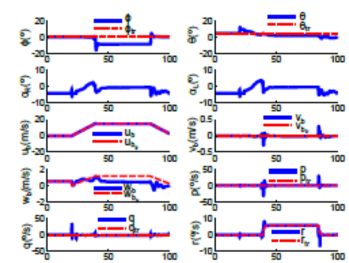


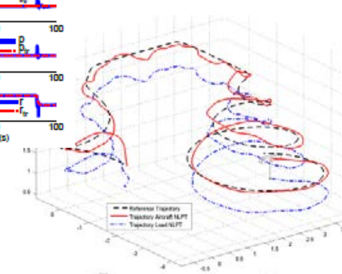








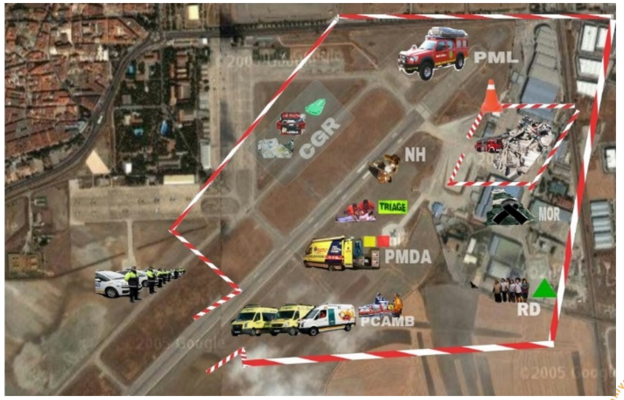




- Objectives:
  - Development of an extensive study of the current operational protocols in SAR missions in both the civil and military spheres.
  - Identify the needs of the SAR teams.
    - Requirements being identified jointly with the Servicio de Atención Médica de Urgencia (SAMU)
    - Define the high level requirements for the design process: Design Oriented to a Mission.

Definition of Operational Protocols in SAR Missions - II

- Tasks:
  - T1.1 Study of operating protocols in SAR missions:
    - Identification of current needs and shortcomings of emergency services, aimed at generating low-level requirements of the VTOL-CP prototype:
    - Define the Request For Proposal (RFP): range, payload, speeds
  - T1.2 Development of operating protocols in specific SAR missions for the use of RPAS VTOL:
    - Identification of improvements in SAR mission services thanks to the use of RPAS and adaptation of the protocols:
      - automation of triage processes, transport of blood products, medical equipment.
  - T1.3 Development of high level design requirements for the use of RPAS in emergency tasks:
    - Identification of the conditioning needs of the prototype to adapt to the services identified in T1.2 (temperature, vibrations, space ...)

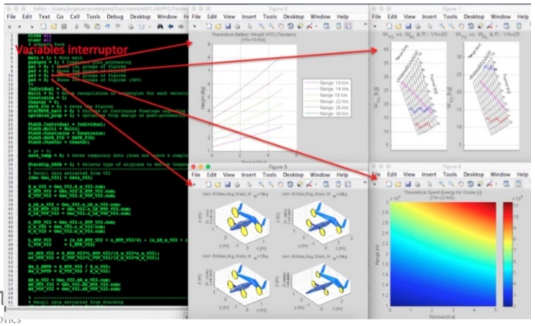


STUDY AND PRELIMINARY DESIGN - I

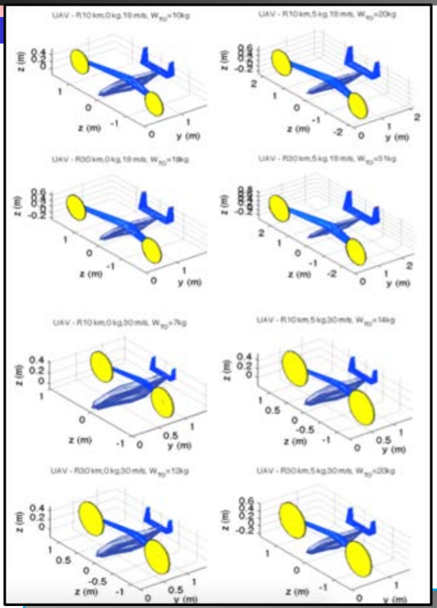
- Objectives:
  - Development of the preliminary design according to the requirements from emergency perspective
    - Development of <u>two prototypes</u> in parallel,
    - Generating the <u>high level requirements</u>: freeze the design and serve as entry point for the in the WORK PACKAGES.
- Tasks
  - <u>T2.1. Preliminary design of the VTOL-CP prototype:</u>
    - Sensitivity study varying parameters of mission type: mission ranges, payloads, climb and forward flight regimes)
    - Define the family of missions to be performed.
  - <u>T2.2 Definition of the high-level requirements of the VTOL-CP aircraft:</u>
    - Concurrent preliminary design with principal design areas for the definition of:
      - propulsive requirements, power and necessary energy, aerodynamic loads, general dimensions of the prototype (weight break-down, and geometry), performance and stability and control.

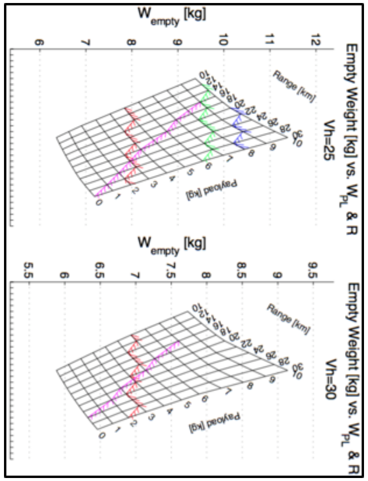
- WTO= 18,8Kg
- W_{empty}= 8,6Kg
- S_{HTP}= 0,17m^2
- S_{VTP}= 0,18m^2
- S_w= 0,45m^2
- b_{max}= 2,26m
- L_{fus}= 1,67m
- W_{bat}= 5,2Kg

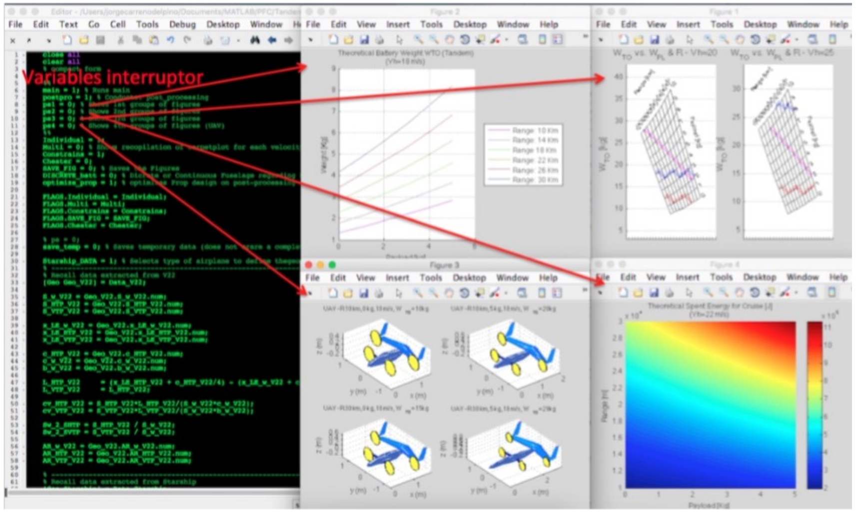
- WTO= 18,2Kg
- W_{empty}= 8,4Kg
- S_{canard}= 0,05m^2
- S_{VTP}= 0,22m^2
- S_w= 0,38m^2
- b_{max}= 1,56m
- L_{fus}= 1,49m
- W_{bat}= 4,7Kg

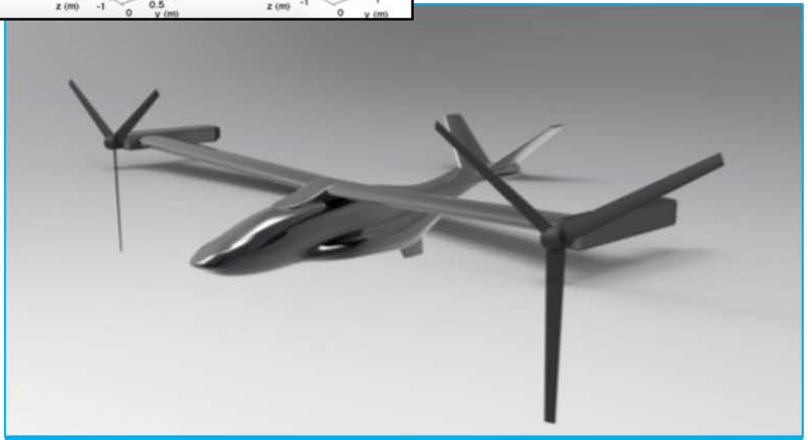


STUDY AND PRELIMINARY DESIGN - II









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- L_{fus}= 1,49m
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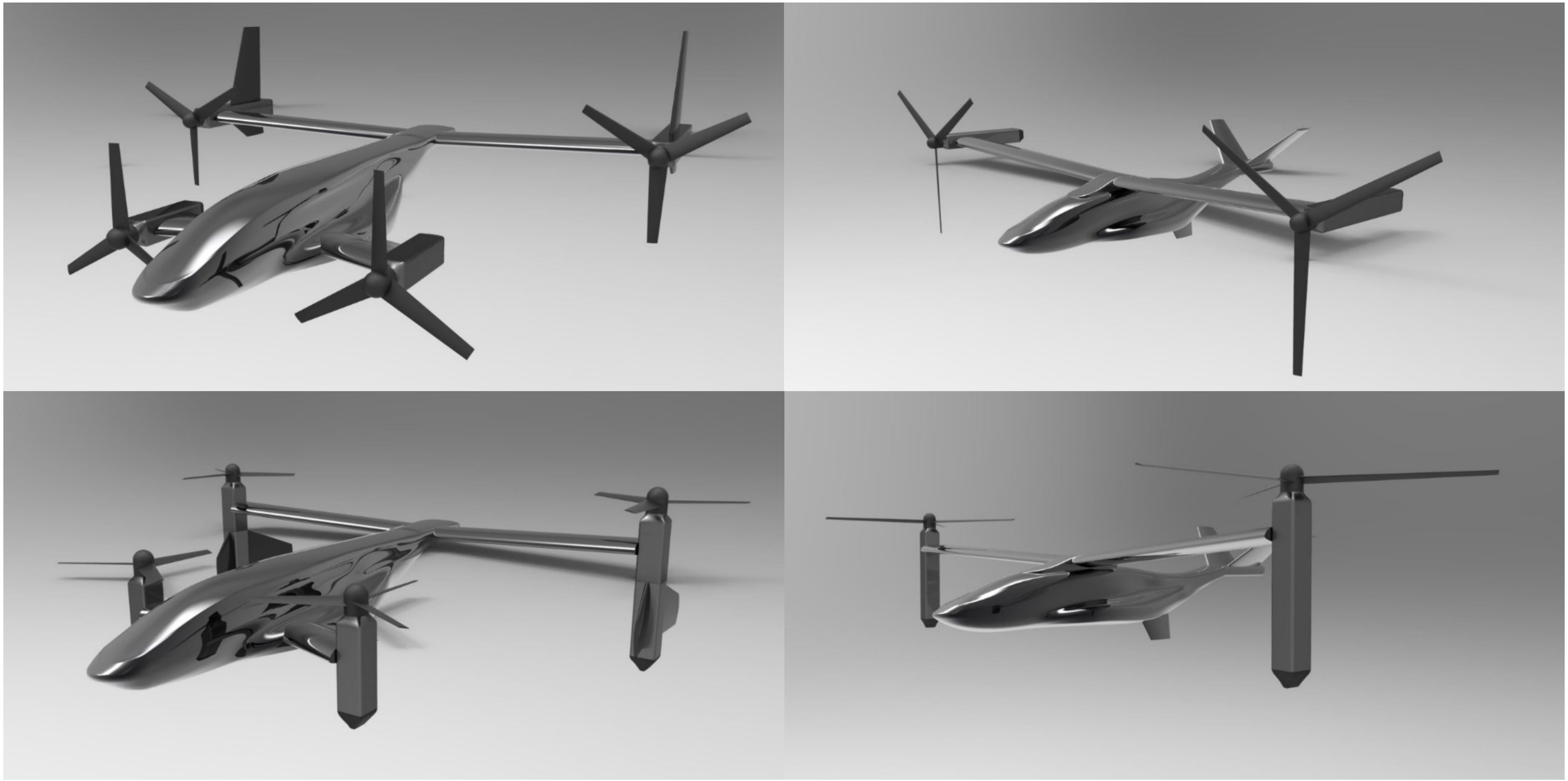
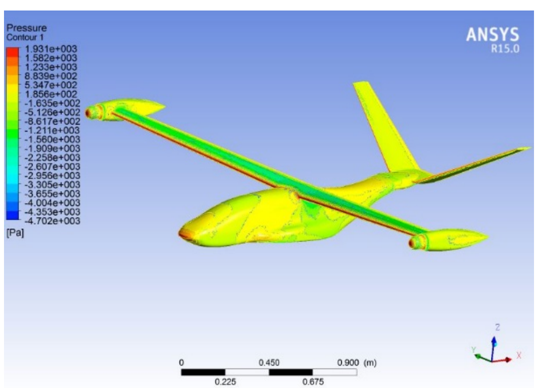
STUDY AND PRELIMINARY DESIGN - III



Aerodynamic Study - I

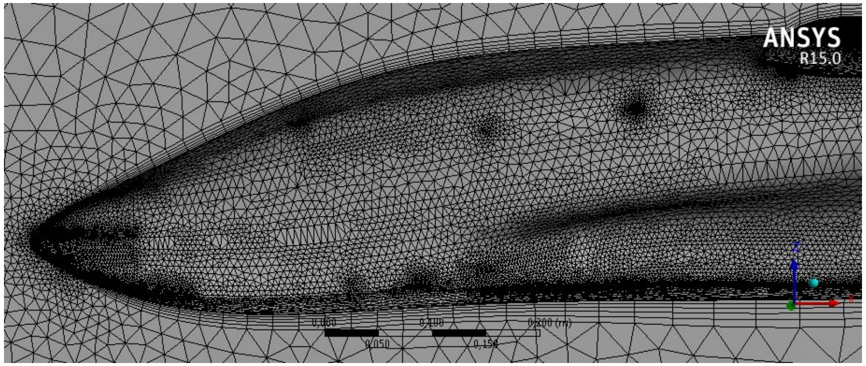
- Objectives:
  - <u>Detailed study of the aerodynamics</u>:
    - Fuselage, aerodynamic and stabilizing surfaces, engine nacelles and rotors
    - Complete flight envelope: different angles of attack, side slip, Reynolds number and Mach number.
  - Use of <u>computational tools (CFD)</u> along with experiments in <u>wind tunnel</u> later to <u>validate</u> results.
  - Generate <u>advanced dynamic models</u> using aerodynamic studies (theoretic and experimental)
    - Analyze both the <u>stability and performance</u> of the VTOL-CP in its entire flight envelope:
      - Forward flight, axial flight, transition flight
    - Determination of <u>aerodynamic loads</u> for structural studies.

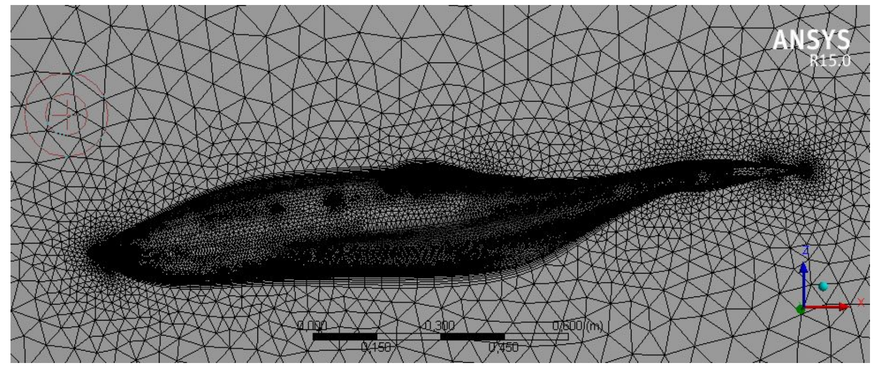


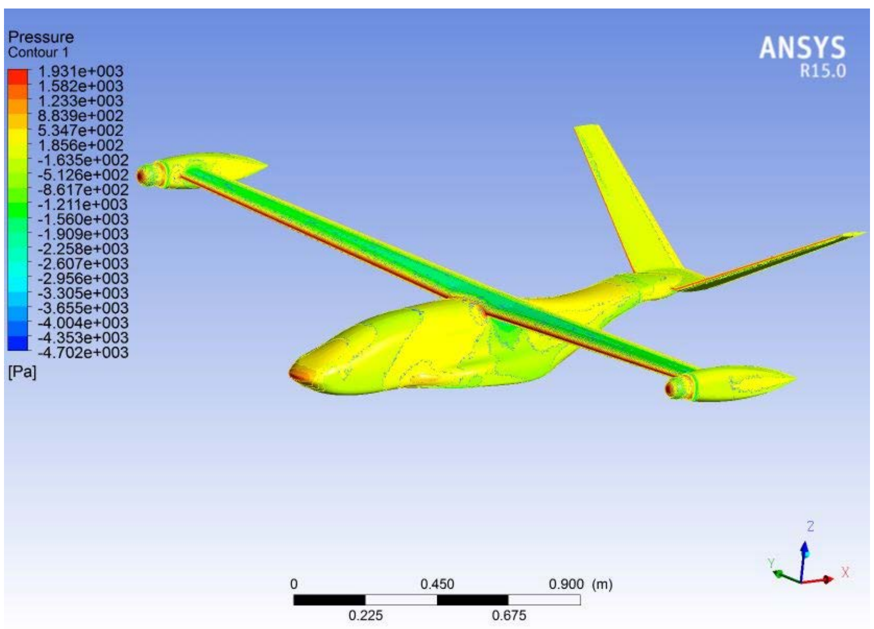
Aerodynamic Study - II

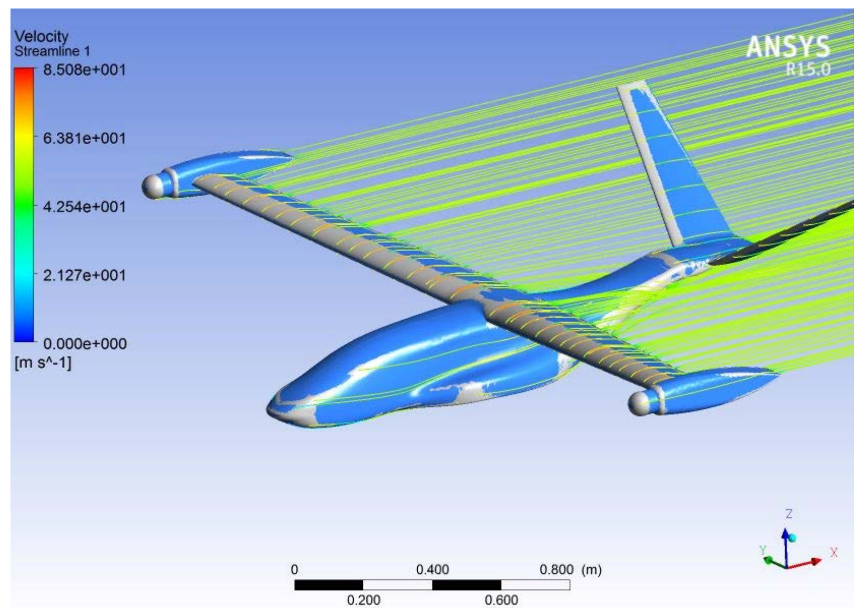
- Tasks
  - T3.1. Preliminary determination of the aerodynamic properties of the subsystems of the VTOL-CP prototypes: numerical methods.
  - T3.2. Numerical study of aerodynamic properties of VTOL-CP prototype subsystems.
    - Aerodynamic properties of both the fuselage, the aerodynamic and stabilizing surfaces, and the propulsion systems as a function of velocity, angle of attack and side slip angle.
  - T3.3. Validation of the numerical results using wind tunnel experiments of the VTOL-CP prototype subsystems.
    - Wind tunnel experiments to validate the aerodynamic models and propellers obtained in T3.2.
    - Developing aerodynamic and propulsive models based on speed, angle of attack and side slip angle
    - Fixed and variable pitch propulsion systems.
  - T3.4 Validation of numerical results, wind tunnel and in-flight tests:
    - Using the aerodynamic data obtained during the flight test phase, validate the results obtained in the theoretical and experimental studies (wind tunnel) , to facilitate the tasks of development of future prototypes

Aerodynamic Study - III

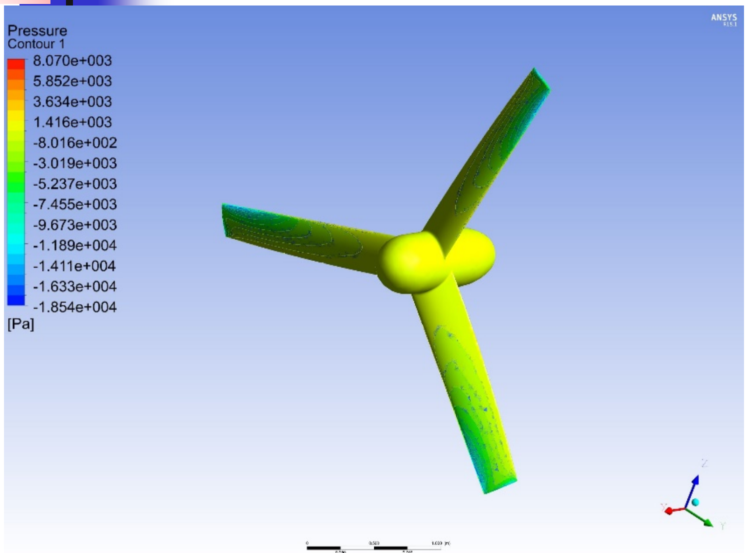


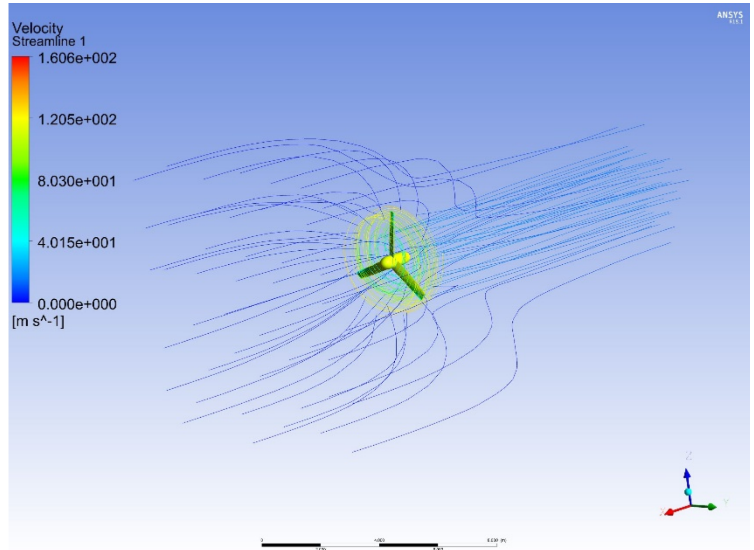


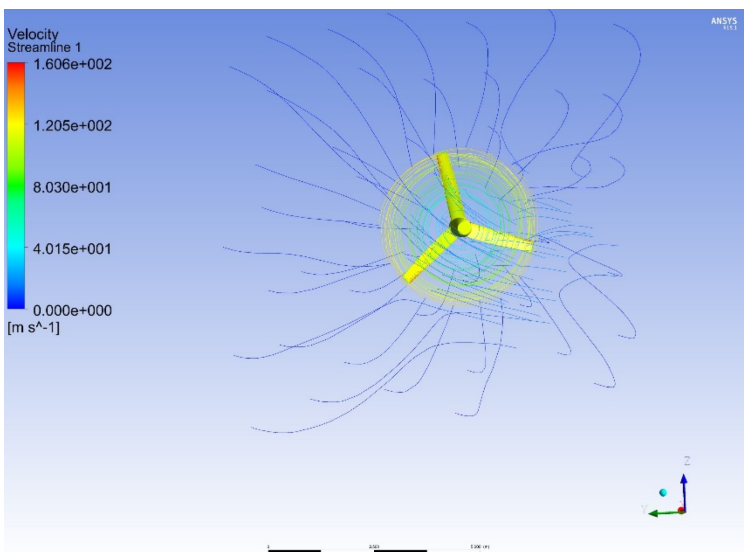


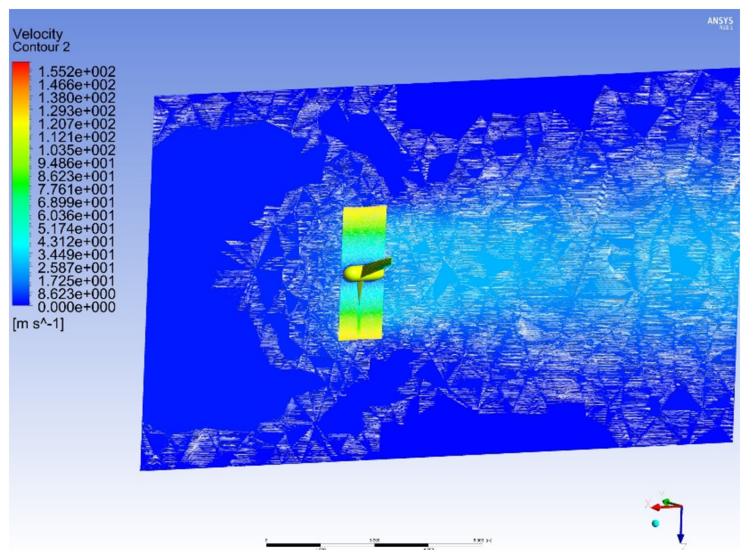


Aerodynamic Study - IV

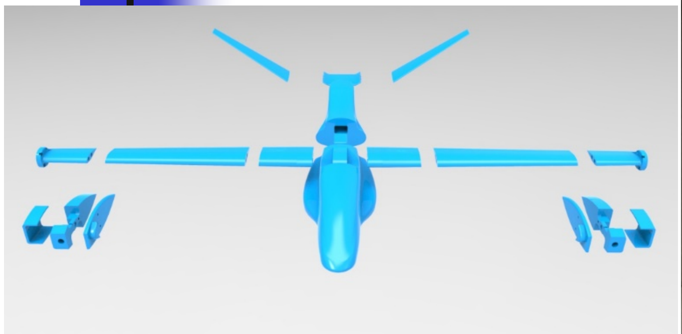


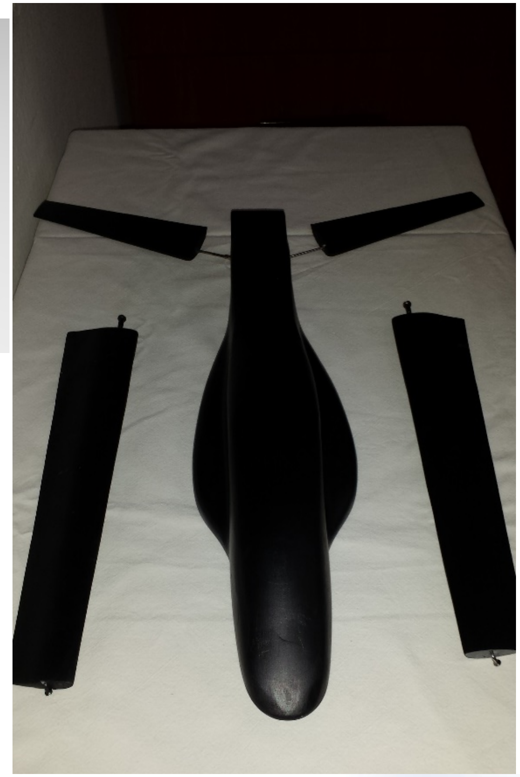


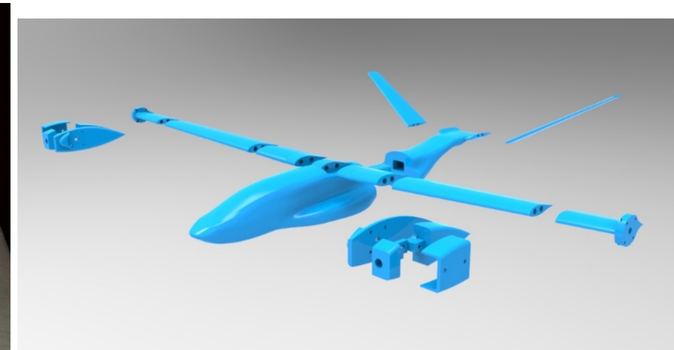


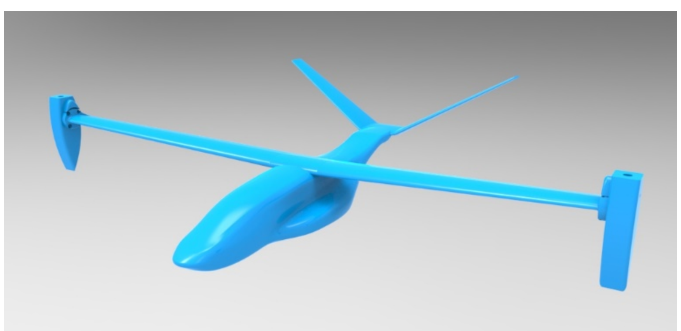


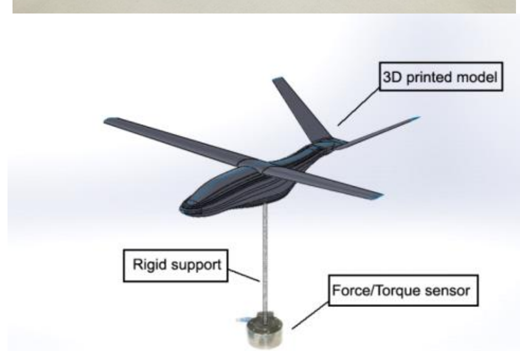
Aerodynamic Study - V

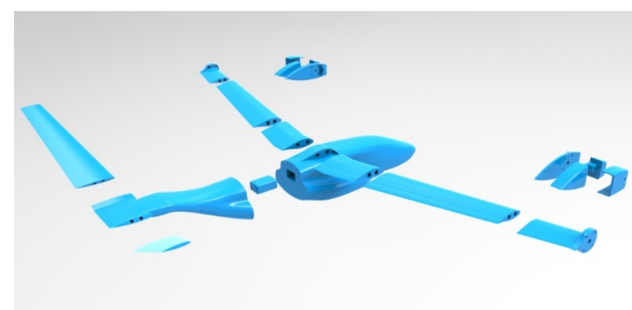






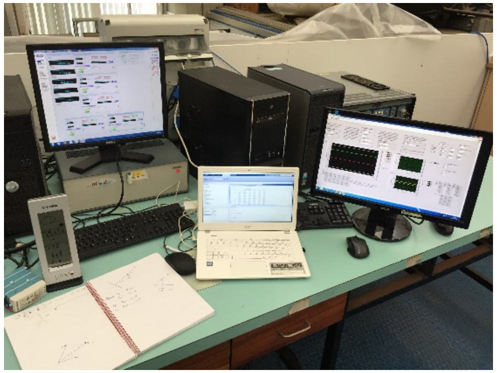
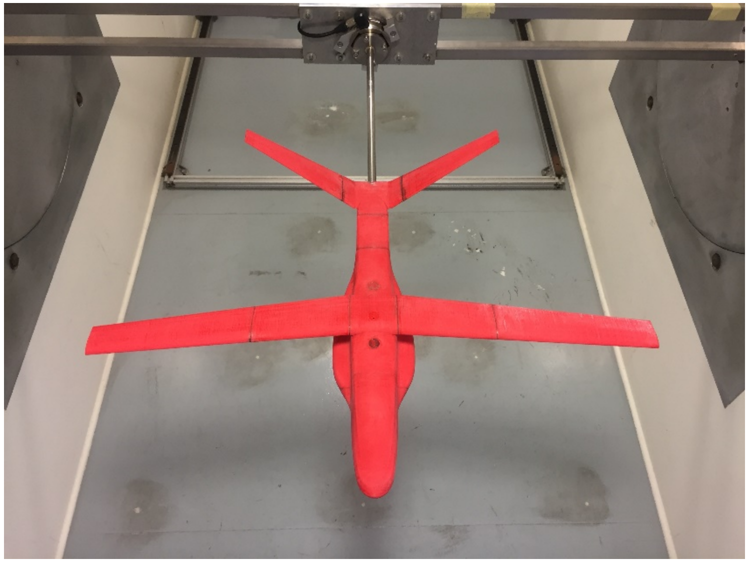


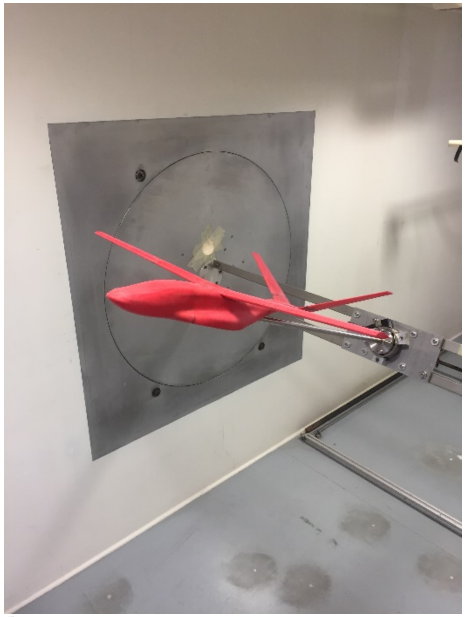


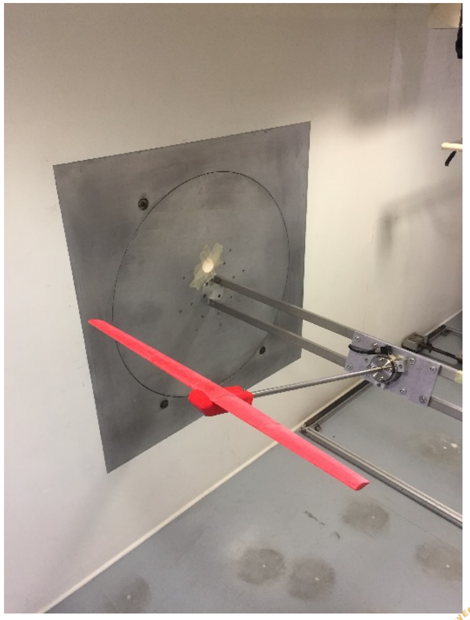


Aerodynamic Study - V

Wind Tunnel Experiments

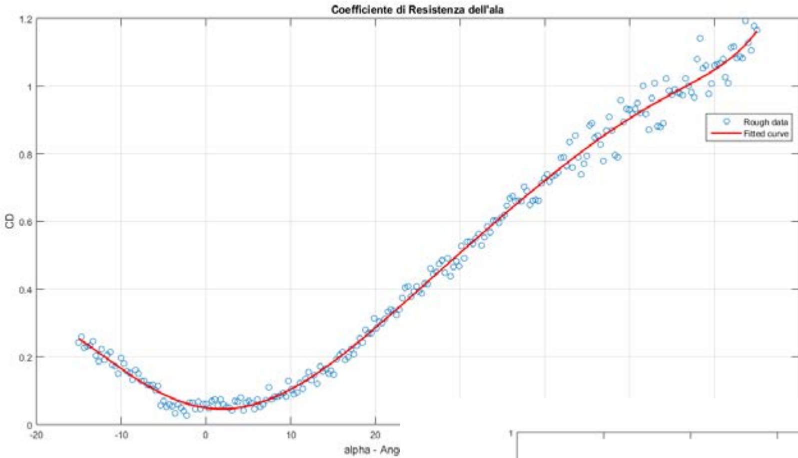



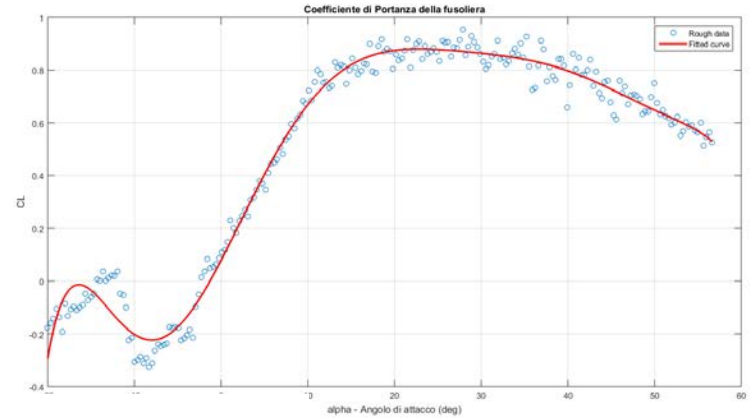


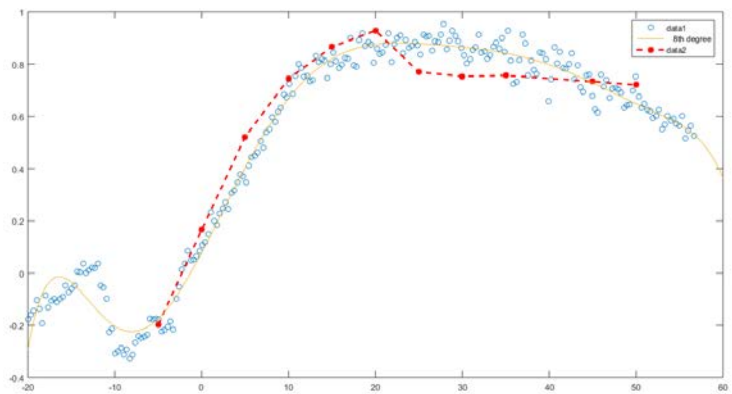


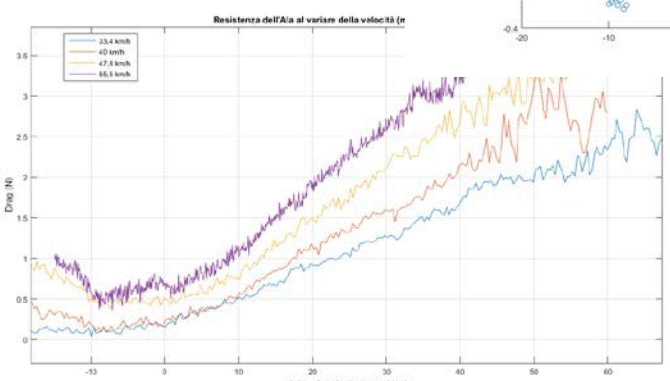
Aerodynamic Study - V

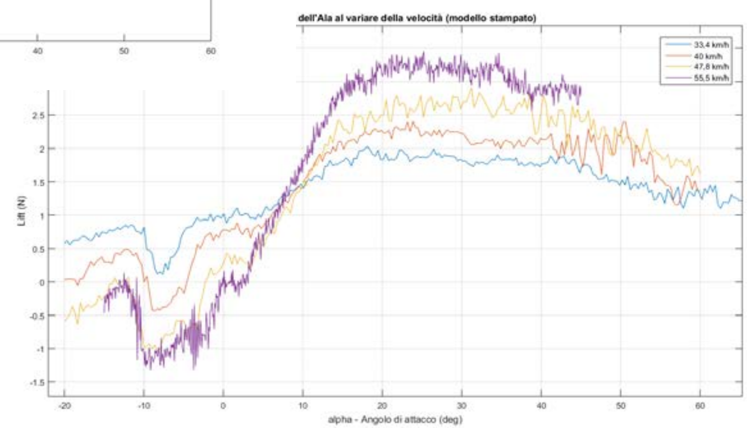
Wind Tunnel Experiments









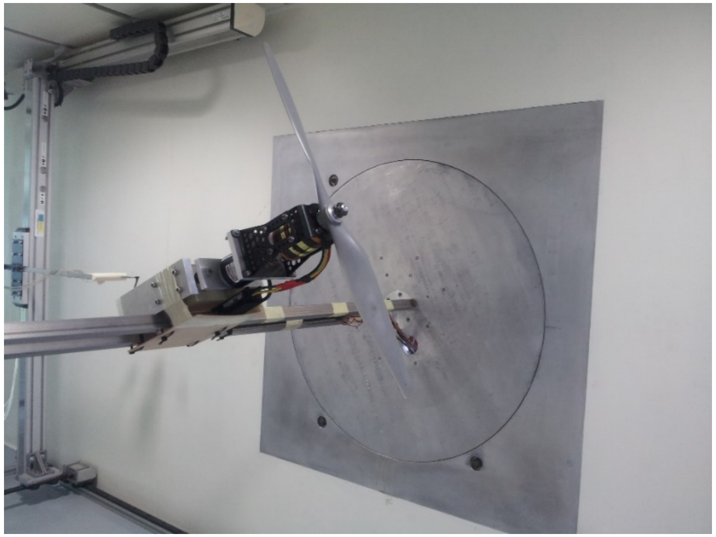


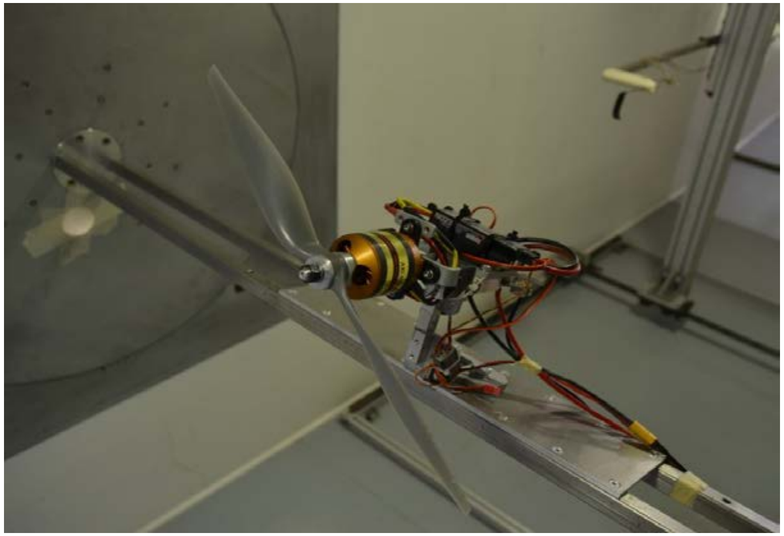
Aerodynamic Study - VI

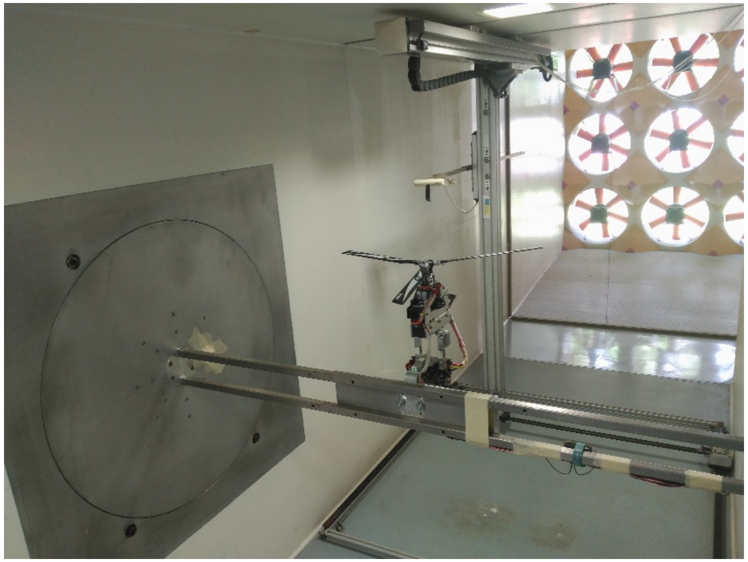
- Tilt-Rotor Propulsion sensitivity studies: fixed and variable pitch
  - Design and construction of a test-bench for prop-testing in wind tunnel
  - Several speeds (0-22 m/s)
  - Several blade pitch angles: 0,4,8,12, degrees:
  - Several tilt angles: 0,5,10,15,20, 30, 45, 60, 75, 90 degrees:

Commercial available test bench (RC Bench Mark Dynamometer Series 1580)

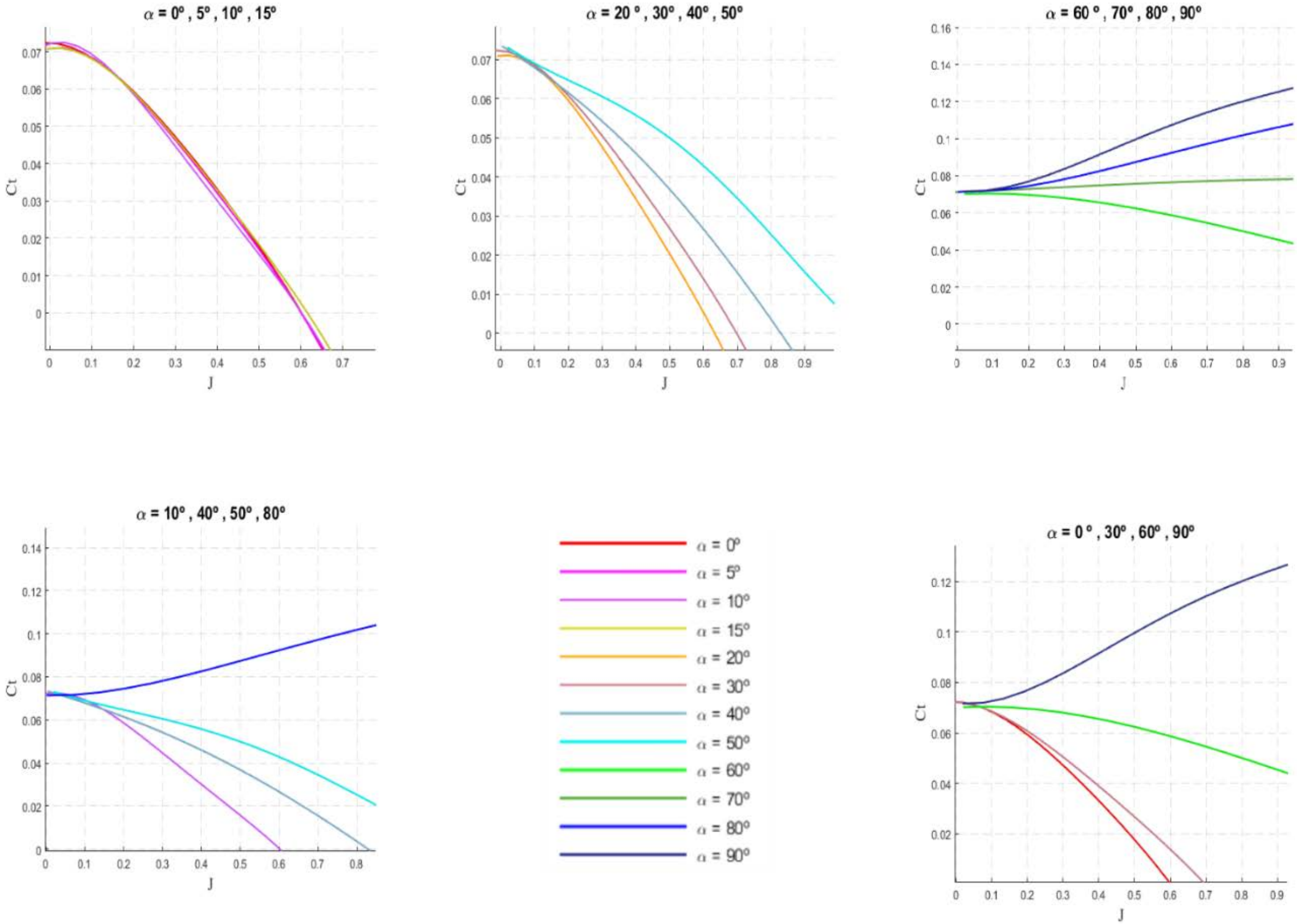
Aerodynamic Study - VII







Aerodynamic Study - VIII



Aerodynamic Study - IX

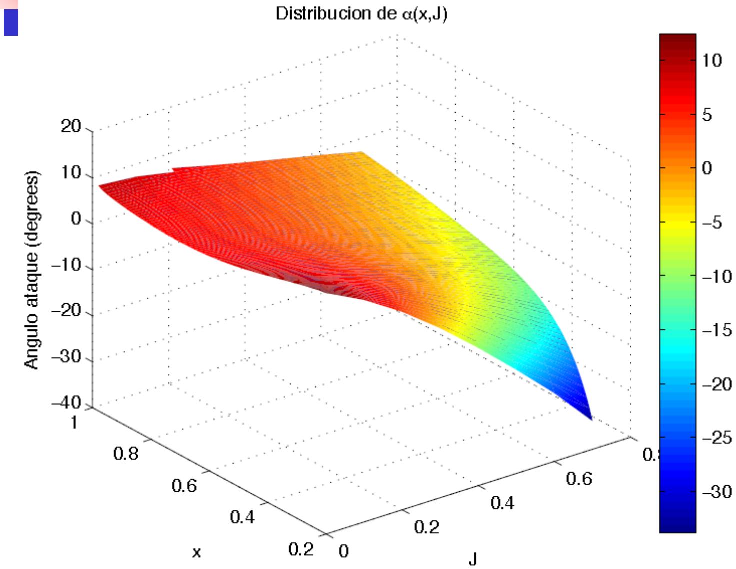


Figura 49 Distribución del ángulo de ataque (x,J)

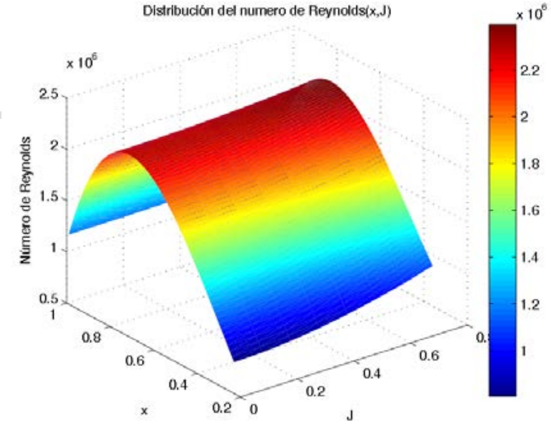


Figura 52 Distribución número de Reynolds (x,J)

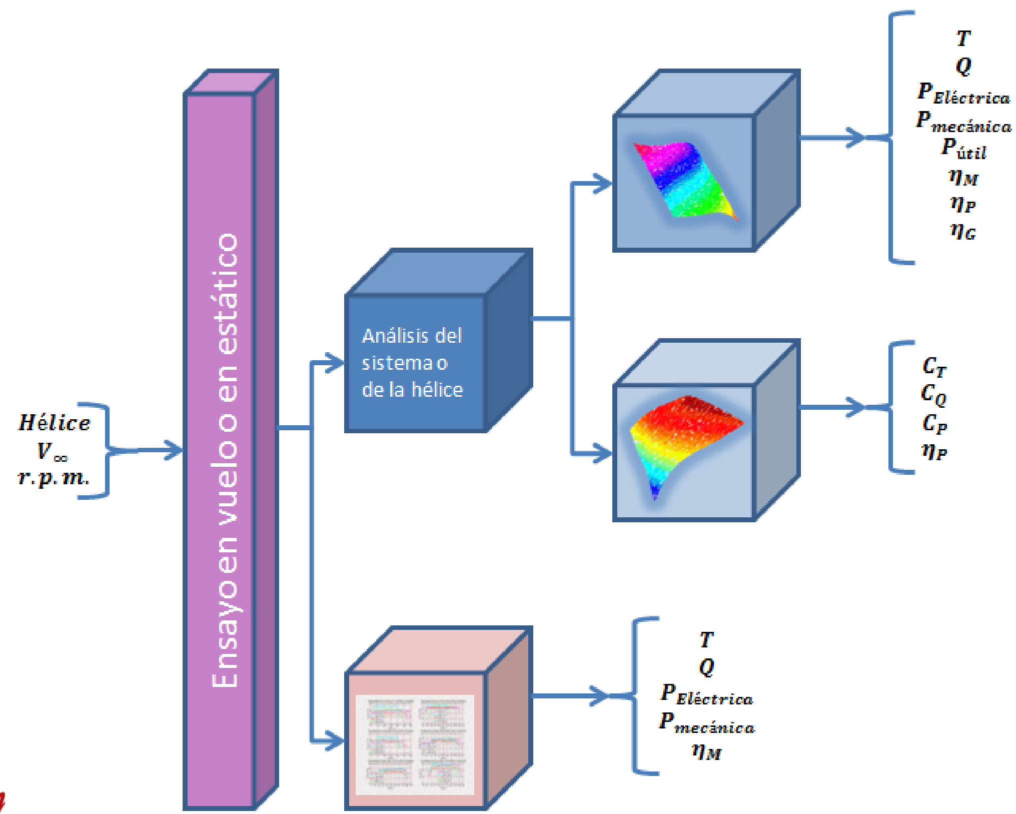
Theoretic Models

$$C_T = \int_0^1 \frac{1}{2}\sigma(x)\sqrt{x^2+\left(\lambda_c+\lambda_i(x)\right)^2}\left(C_{l_\alpha}\alpha(x)x^2-\left(\lambda_c+\lambda_i(x)\right)C_d(x)\right)dx$$

$$C_P = \int_0^1 \frac{1}{2}\sigma(x)\sqrt{x^2+\left(\lambda_c+\lambda_i(x)\right)^2}\left(C_l\left(\lambda_c+\lambda_i(x)\right)x+C_d(x)x^2\right)dx$$

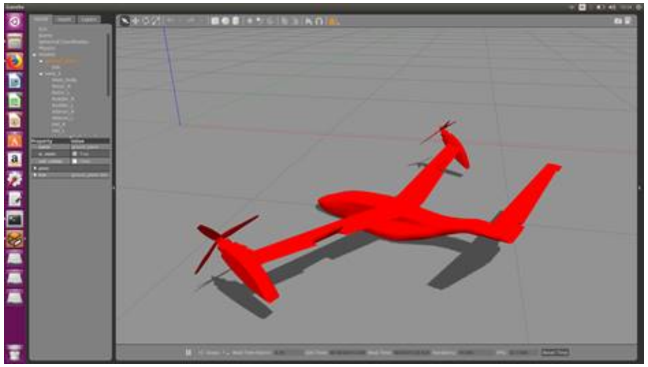
$$C_l(x) = C_{l_\alpha}(\alpha-\alpha_0) = C_{l_\alpha}\left(\theta - arctan\left(\frac{\lambda}{x}\right)-\alpha_0\right)$$

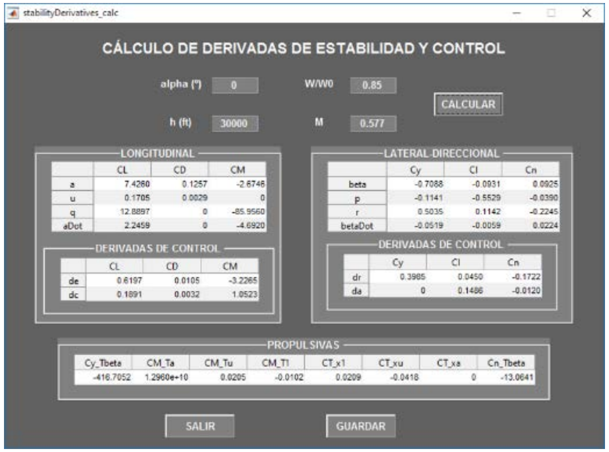
$$C_d(x) = \delta_0+\delta_1\alpha+\delta_2\alpha^2+\delta_4\alpha^3+\delta_4\alpha^4$$

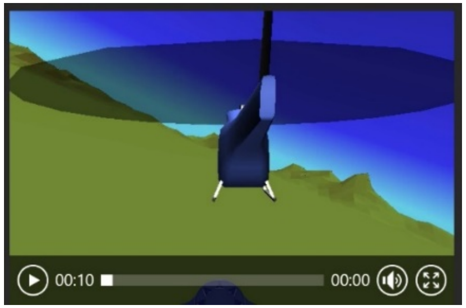


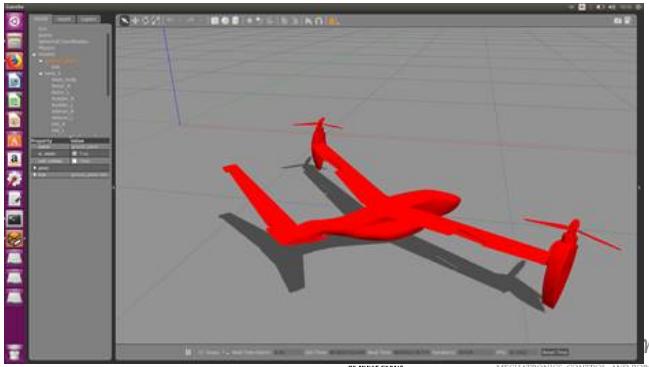
Flight Mechanic Study - I

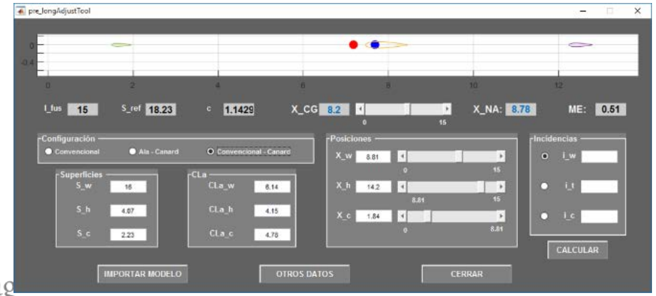
- Objectives:
  - Parametric analysis on the different considered design options
  - Study of aircraft flight mechanics with special emphasis on the complexity of transition maneuvers.
    - Static and dynamic stability studies along with performance analysis of the aircraft attending to the different phases of flight
    - Study of the dependencies with the available energy systems.









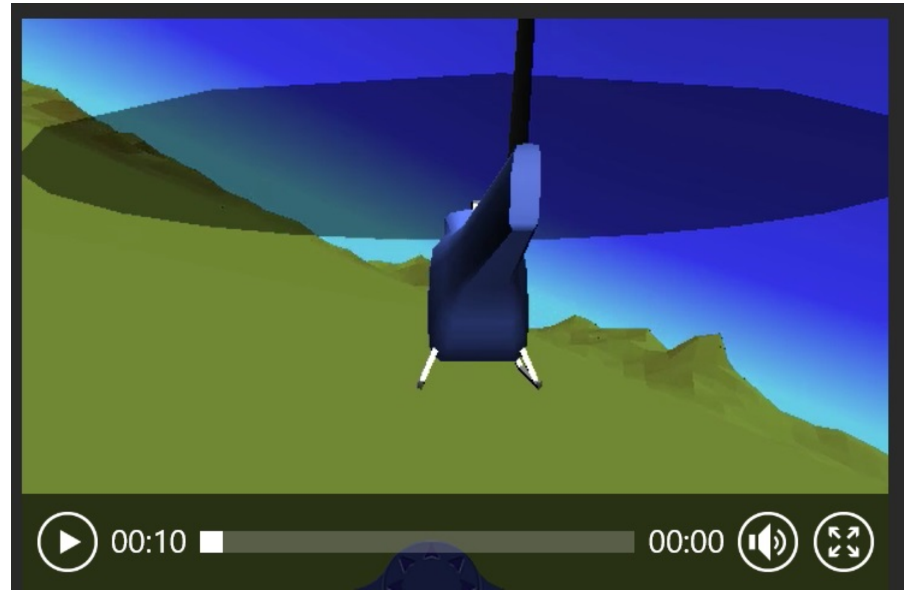


Flight Mechanic Study - II

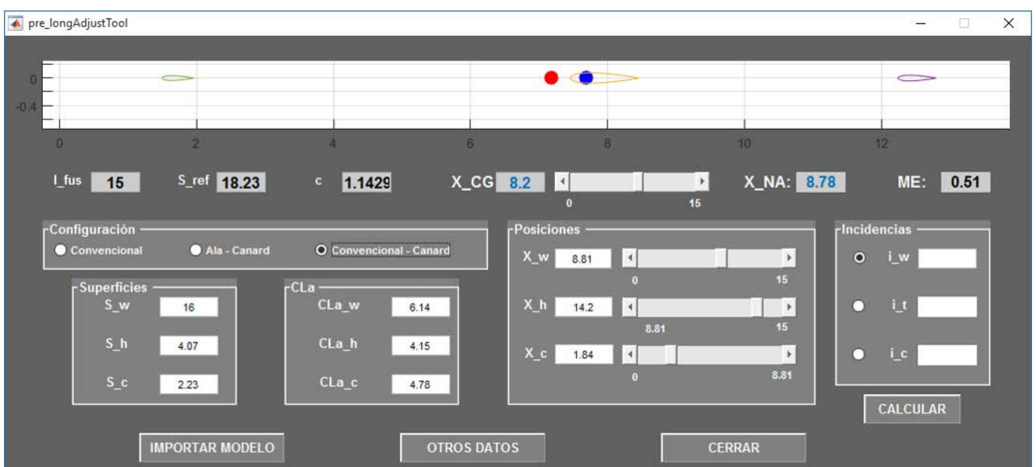
- T4.1. Study of preliminary static stability of the proposed prototypes:
  - Study of trimmed longitudinal flight
  - Study of lateral directional flight
  - Study of flight controls for the entire flight envelope.
- T4.2. Study of advanced dynamic stability of the proposed prototypes:
  - Dynamic response to disturbances
  - Study of trimmed longitudinal and lateral directional flight response to the controls for the entire flight envelope.
- T4.3. Validation of static and dynamic stability studies using wind tunnel experiments:
  - characterization of the stability properties of prototypes with wind tunnel experiments.
- T4.4. Computational simulation of the flight mechanics of the two missions:
  - Sensitivity analysis of the performances of the different prototypes and their actions reassessing the missions based on the results obtained in both WP2 and WP3 and using results T4.3.
- T4.5 Validation of actions with results of flight tests:
  - Using the performance data obtained during the flight test phase, validate the results obtained in the theoretical studies to facilitate the tasks of developing future prototypes.

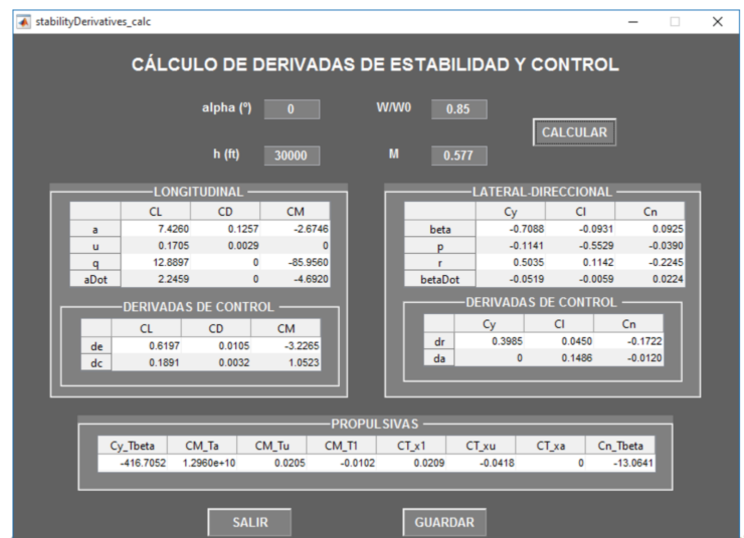
Flight Mechanic Study - III

HEROES



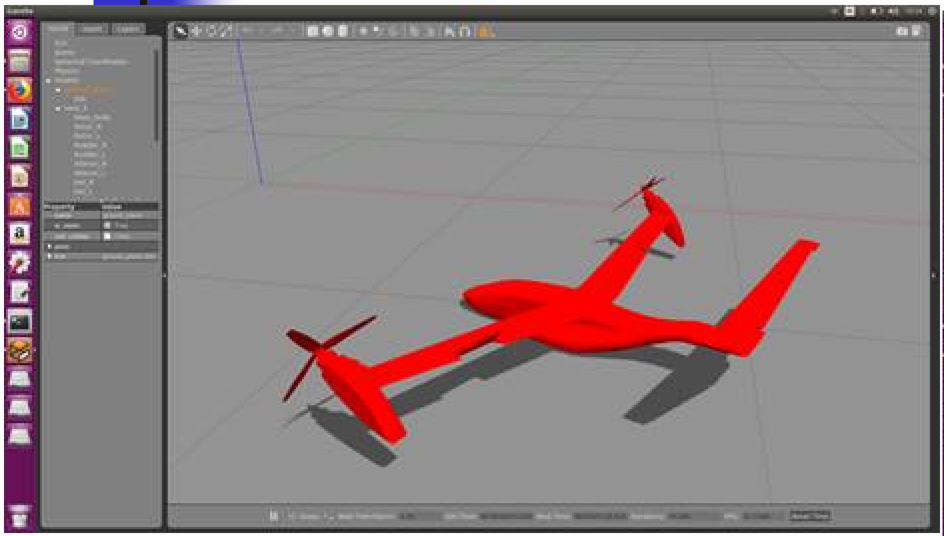
ASPro

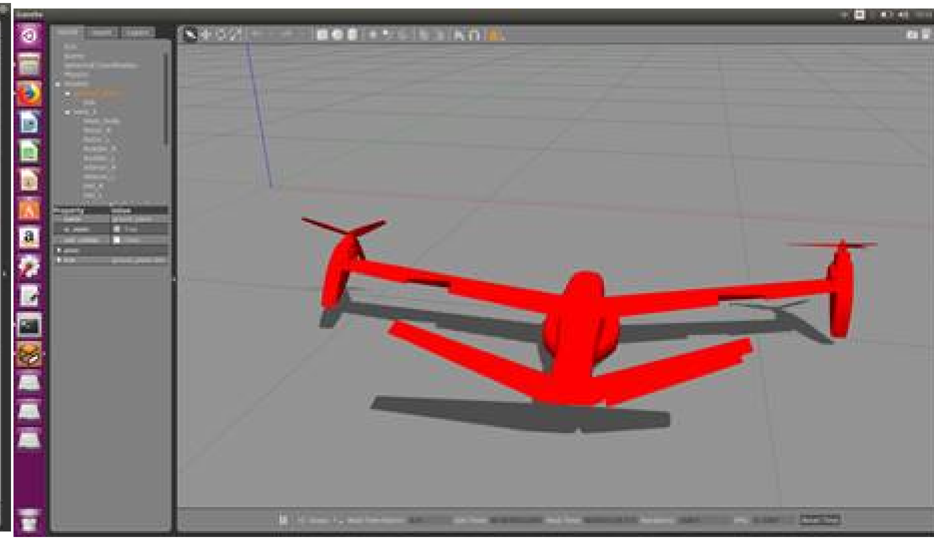




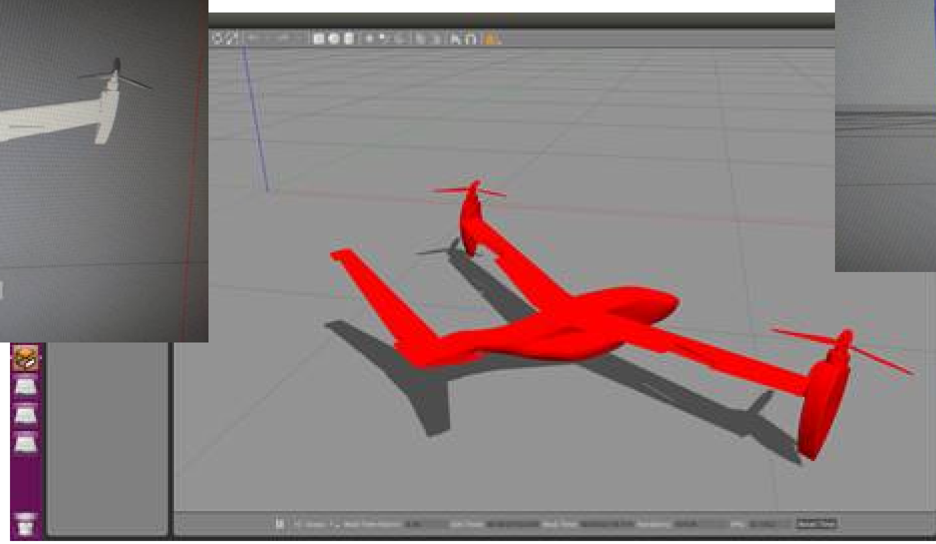
Flight Mechanic Study - IV

ProVANT



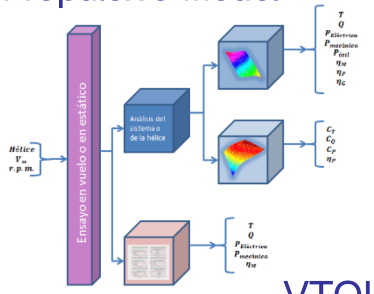


GAZEBO

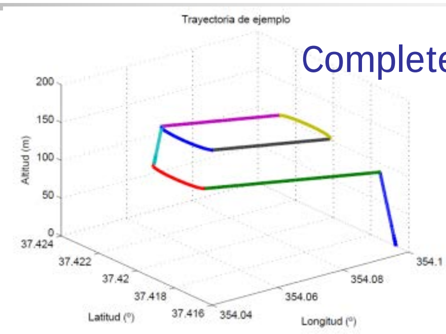


Flight Mechanic Study - V

Electric Propulsive Model

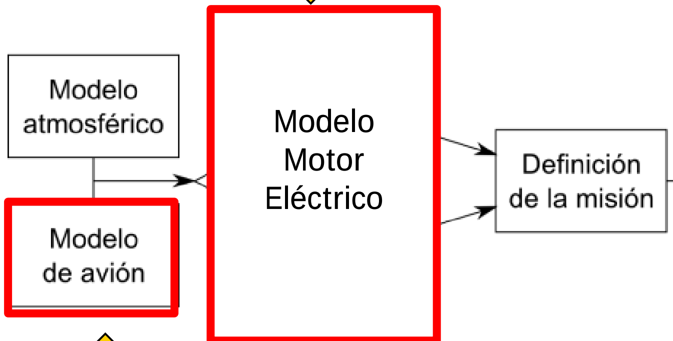


Complete flight profile



GAZEBO

VTOL Flight Dynamics Simulator



$$m \cdot \frac{dV}{dt} = T - D - m \cdot g \cdot \sin \gamma$$

$$m \cdot V \cdot \cos \gamma \cdot \frac{d\chi}{dt} = L \cdot \sin \mu$$

$$m \cdot V \cdot \frac{d\gamma}{dt} = L \cdot \cos \mu - m \cdot g \cdot \cos \gamma$$

$$\frac{dm}{dt} = -\frac{c_P}{g \cdot \eta_P} \cdot T \cdot V$$

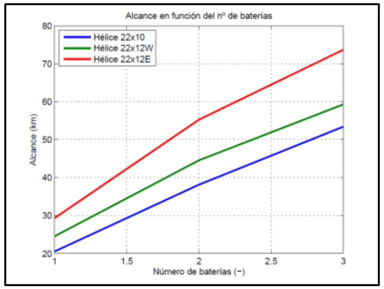
$$\frac{dx}{dt} = V \cdot \cos \gamma \cdot \cos \chi$$

$$\frac{dy}{dt} = V \cdot \cos \gamma \cdot \sin \chi$$

$$\frac{dh}{dt} = V \cdot \sin \gamma$$

Aerodynamic Model

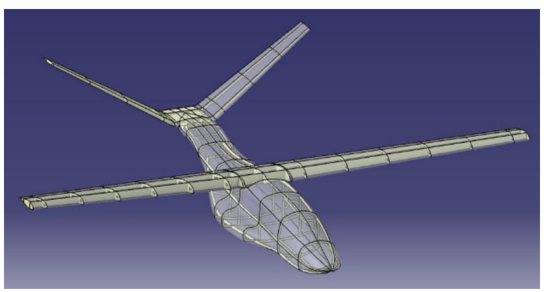
VTOL Trajectory Optimization

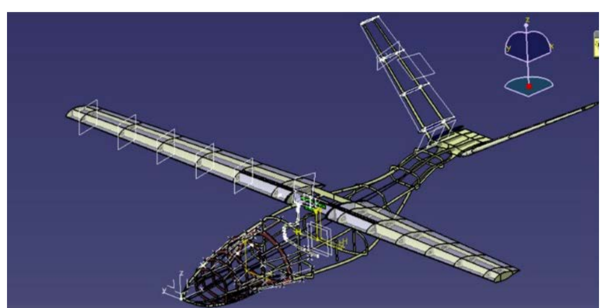


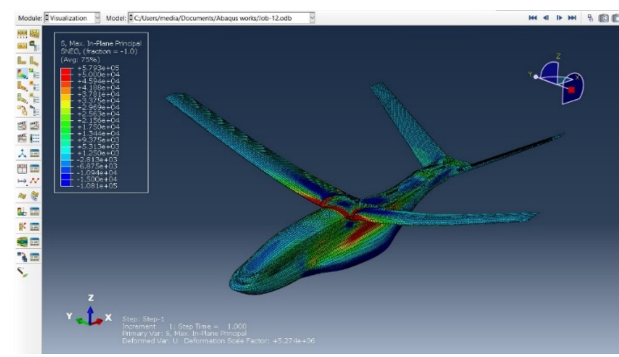
Range vs prop and # batteries

Structure Study - I

- Objectives:
  - <u>Structural study of the aircraft: </u>use of computational tools (FEM) of the aircraft
  - The study will define the structure of both the fuselage and the aerodynamic surfaces capable of supporting both the aerodynamic and propulsive loads of the two prototypes along the entire VTOL-CP envelope.
  - Develop technological demonstrators that will result in the manufacture of prototypes for the realization of destructive and non destructive structural tests.
    - Candidate for structure in CAD and
    - Manufacturing processes for Phase II of design will also be developed.



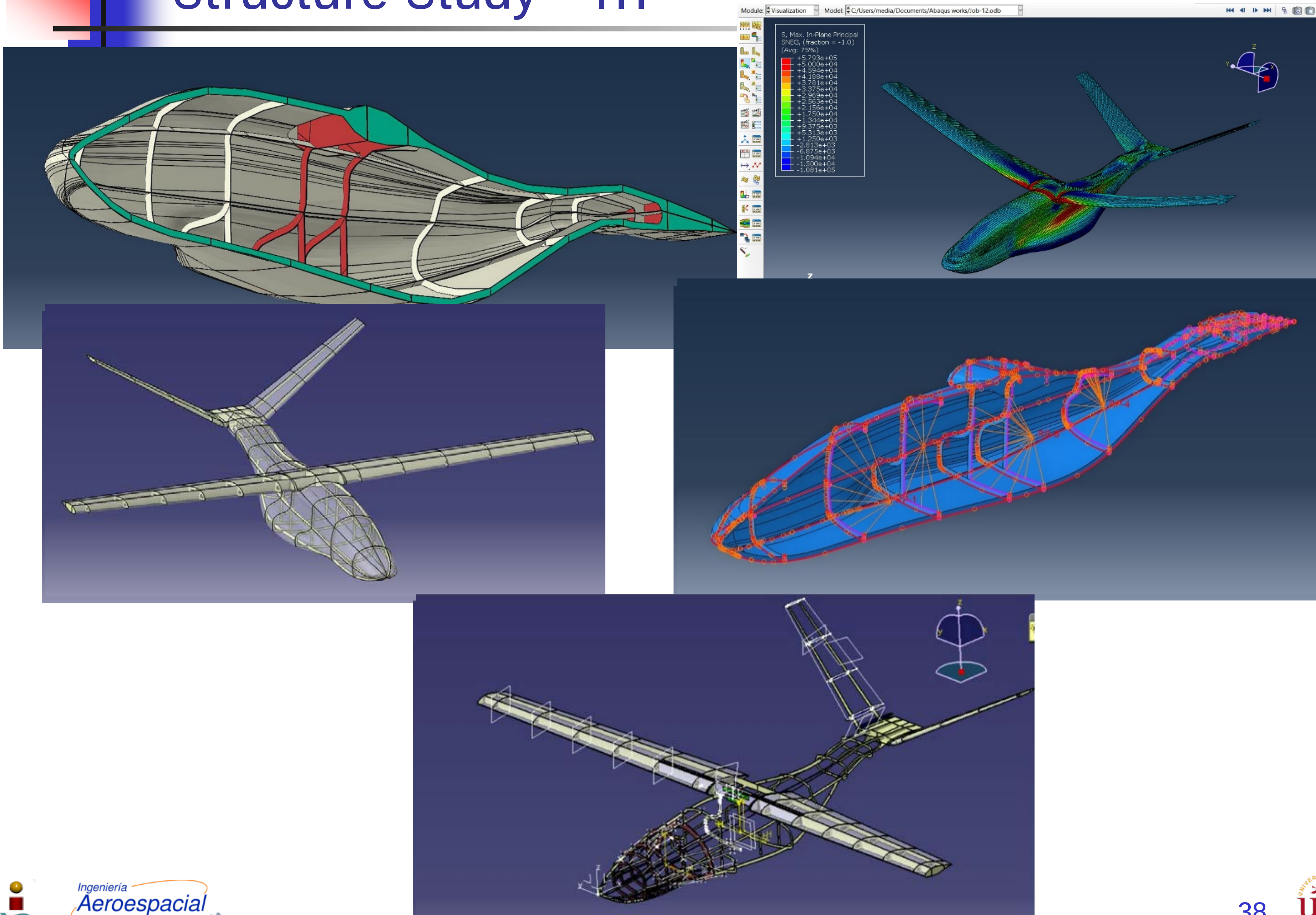




Structure Study - II

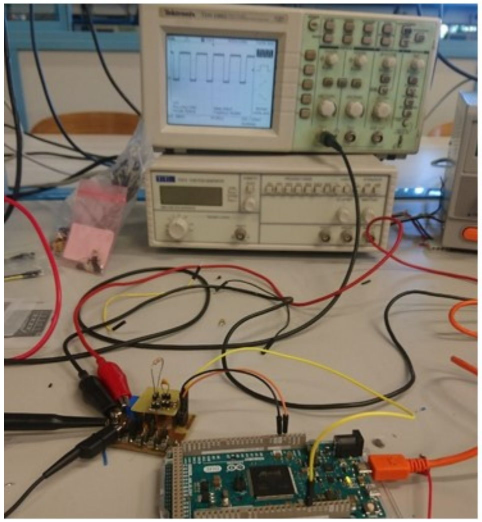
- Tasks
  - T5.1. Preliminary structural load estimation:
    - Define a preliminary structure of the different components.
    - Estimation of the flight envelope diagram (V-n):
      - define the load factors for the advanced structural study
  - T5.2. Advanced structural study:
    - Propose a breakdown of laminates and preliminary structures based on experience in the development of aerospace structures
    - Studies completed with FEM models
  - T5.4 Manufacturing technological demonstrator
    - Validating the manufacturing.
    - Focus technological demonstrator on one of the two models:
      - gradually integrate the different technological demonstrators

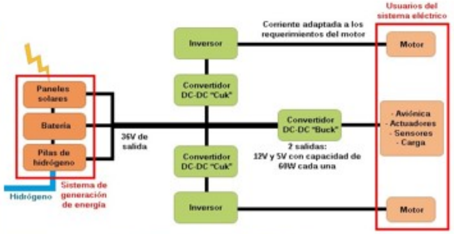
Structure Study - III

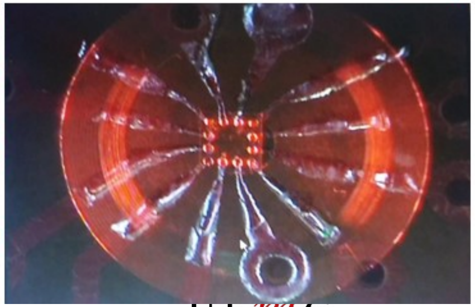


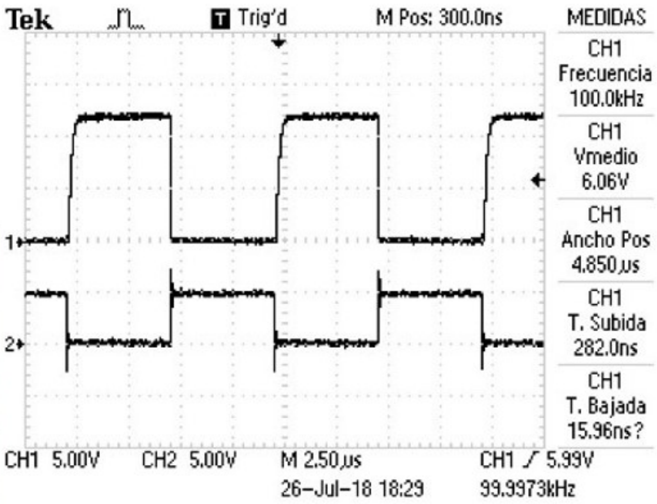
High Efficiency Embedded Electronics Systems - I

- Objectives:
  - Development of <u>efficient onboard electronics</u> to <u>reduce energy consumption</u>, optimizing the ability to perform extended missions (large Range and Endurance) without losing payload capacity.
  - <u>Development of advanced avionics.</u>
  - Development of <u>hardware architecture</u> and the necessary <u>electronic systems</u>.
  - Study of <u>new building materials</u> such as <u>Silicon Carbide</u> (SiC) and <u>Gallium Nitride</u> (GaN) to optimize the performance of control and power electronics of the aircraft.





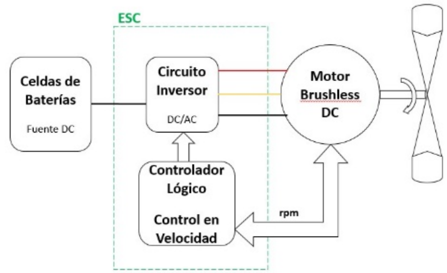


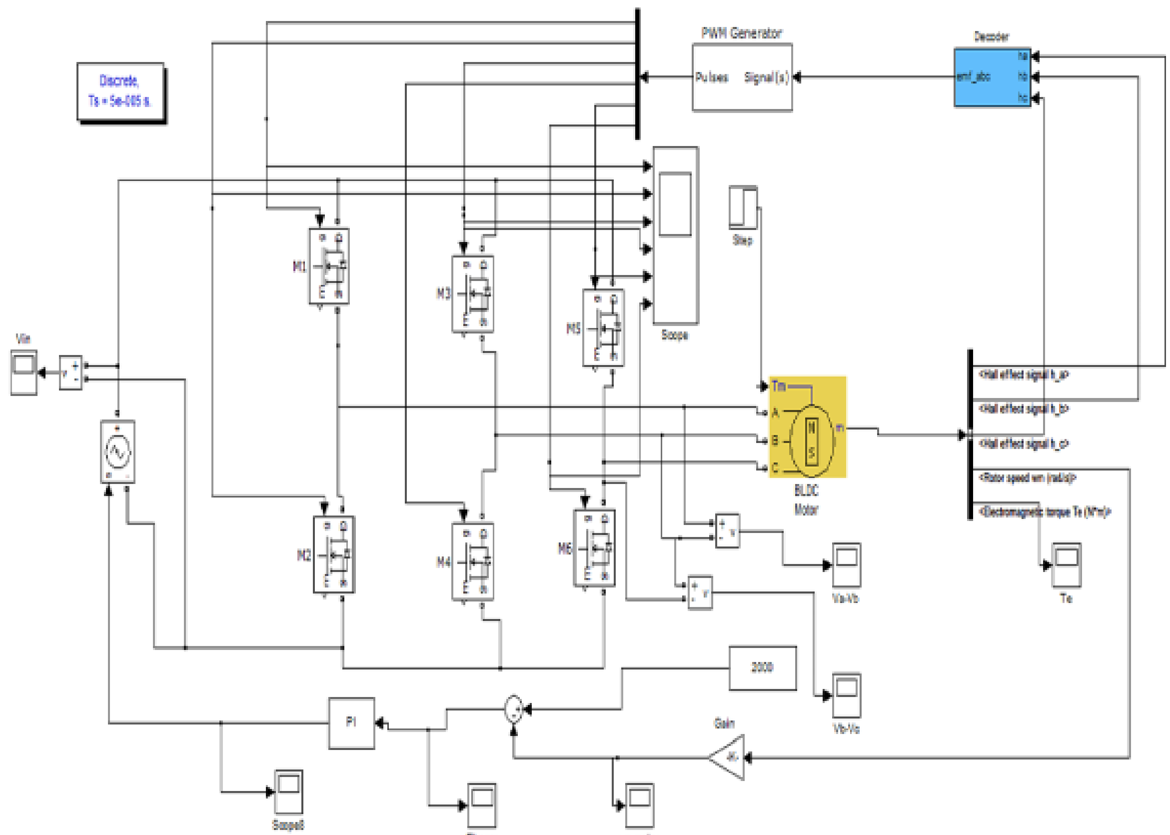


High Efficiency Embedded Electronics Systems - II

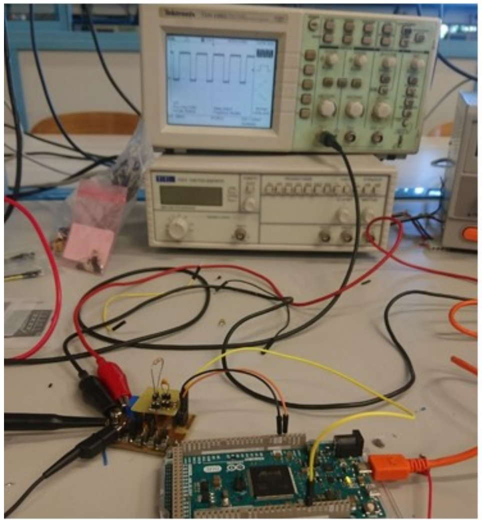
- Tasks
  - T6.1. Design of advanced electronic systems for RPAS:
    - Optimum design of the electronic speed control system (ESC) of the motor / motors
    - Improve the performance of the batteries using bidirectional DC / AC converter and a DC converter / DC high energy efficiency and minimum size and weight,
    - Additional storage systems using new technologies (supercapacitors).
  - T6.2. Performing experimental tests to validate the designs developed:
    - validation by simulation of the electronic speed control and by experimentation of the DC / DC converter
  - T6.3. Integration of the electronics developed for its optimization in size and weight.
  - T6.4. Study of the application of technologies for the development of advanced avionics in RPAS:
    - Techniques will be investigated, such as the substitution of mechanical, pneumatic or analog electronic systems by digital systems or the use of advanced technologies (radio emergency beacons to locate RPAS in emergency situations).
  - T6.5 Integration and validation of the technological demonstrators in flight platforms:
    - the different technological demonstrators of this WP will be integrated gradually

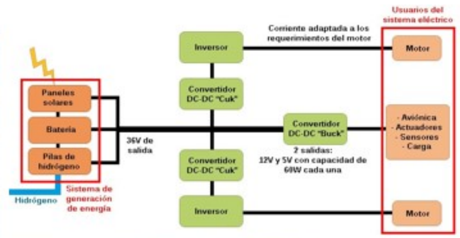
High Efficiency Embedded Electronics Systems - III

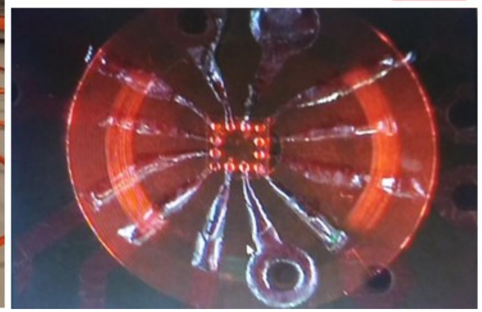


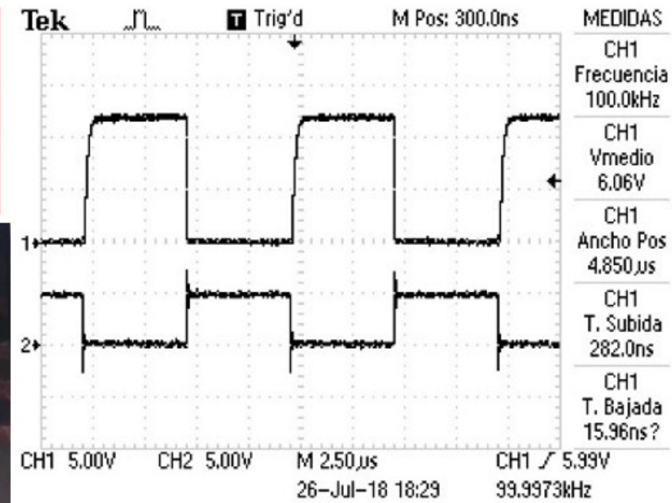


High Efficiency Embedded Electronics Systems - IV

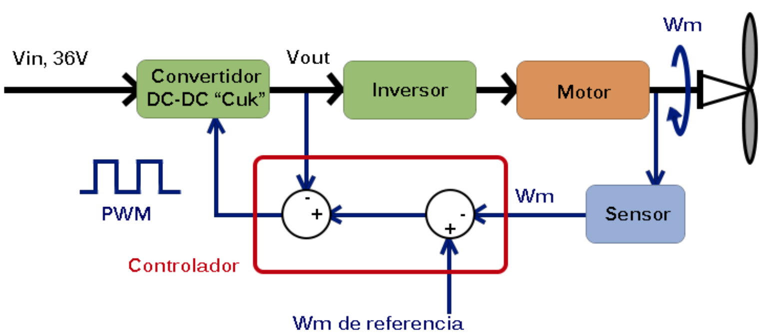




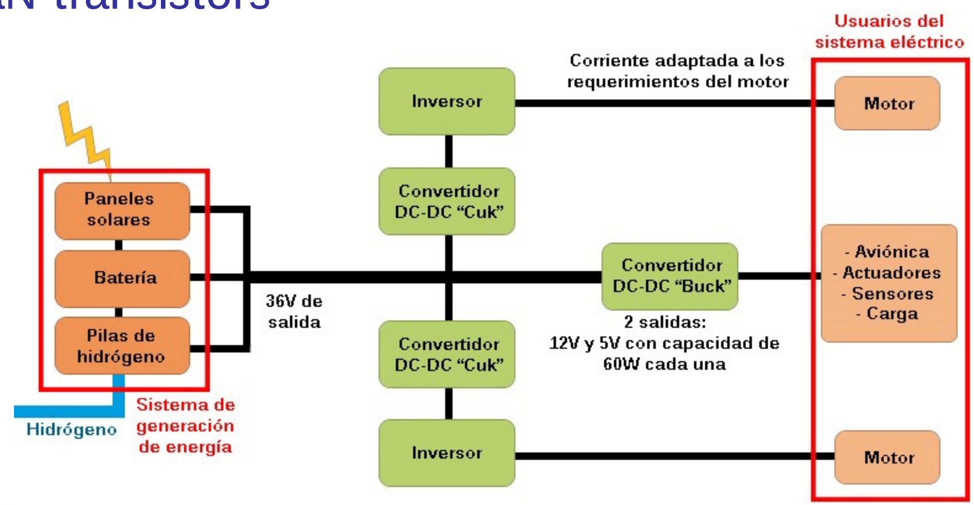




Trigger test with GaN transistors



Acontro and feeding of electric engine



Power Conversion system

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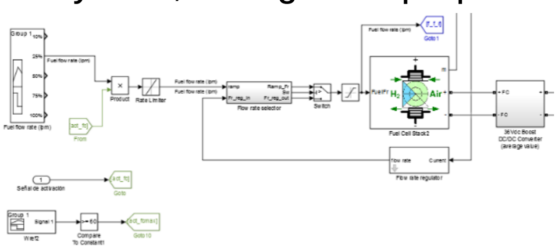
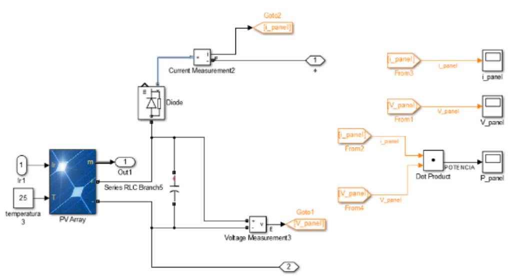
macro@ufmg MECHATRONICS, CONTROL AND ROBOTICS
Ingeniería Aeroespacial ESI - Universidad de Sevilla

Energy Generation and Storage Systems - I

- Objectives:
  - Development of <u>power generation systems</u> using <u>fuel cells and solar cells</u>.
  - Evaluation of the feasibility of using <u>energy storage systems in supercapacitors</u>.
  - Development of the <u>hardware systems</u> and the <u>hybridization logic</u> that will allow to <u>use</u> the <u>different energy sources</u> according to the <u>propulsive demands</u> at each moment of the mission
- Tasks
  - <u>T7.1. Design of advanced power generation systems for UAVs:</u>
    - Feasibility study of the use of both hydrogen cells and solar cells.
  - <u>T7.2. Design of advanced energy storage systems:</u>
    - Study superconductors and low-density systems.
  - <u>T7.3. Development of control system for energy management:</u>
    - Development of optimum control algorithms.
  - <u>T7.3. Technological Demonstration Construction:</u>
    - Integration of generation system, storage and propulsive system

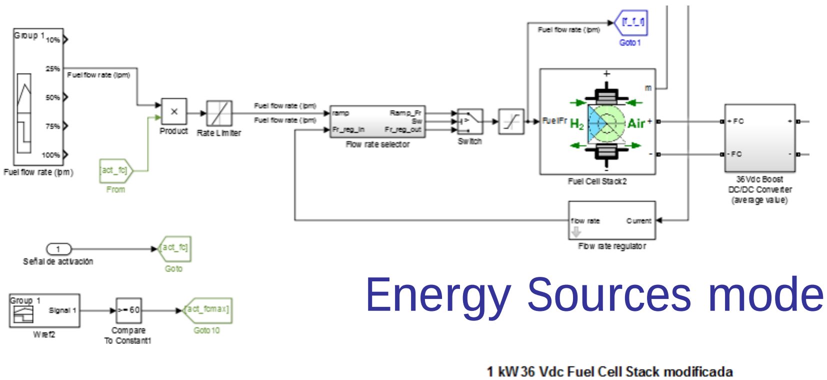


1 kW 36 Vdc Fuel Cell Stack modificada



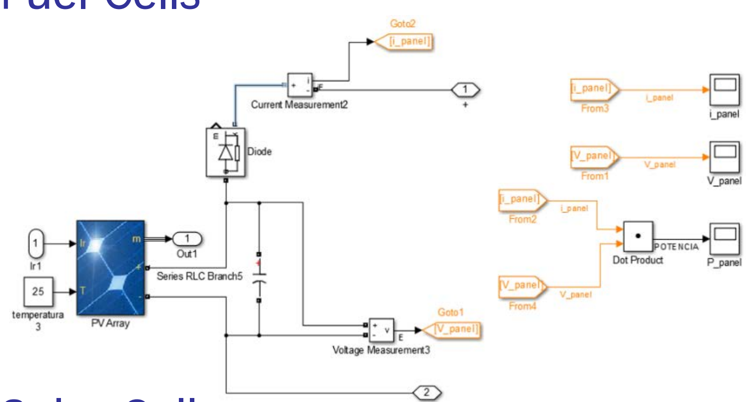
Energy Generation and Storage Systems - II

Batteries

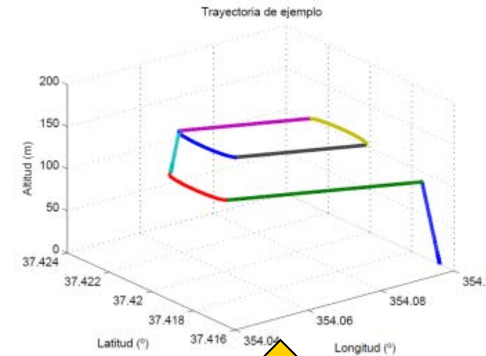


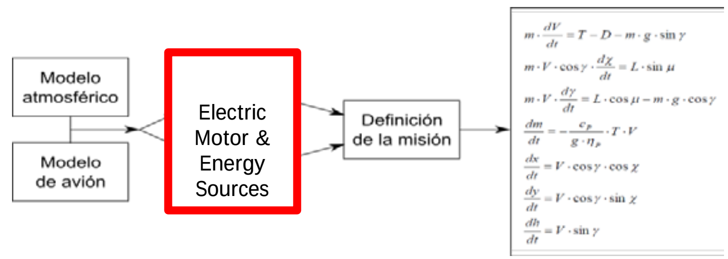
Energy Sources models

Fuel Cells

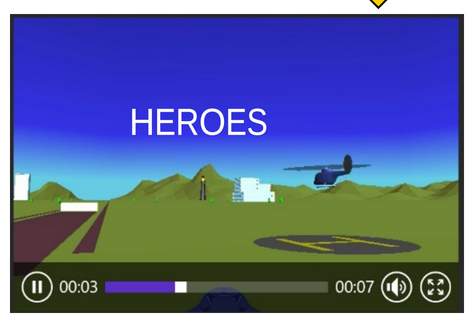


Solar Cells





VTOL Flight Dynamics Simulator

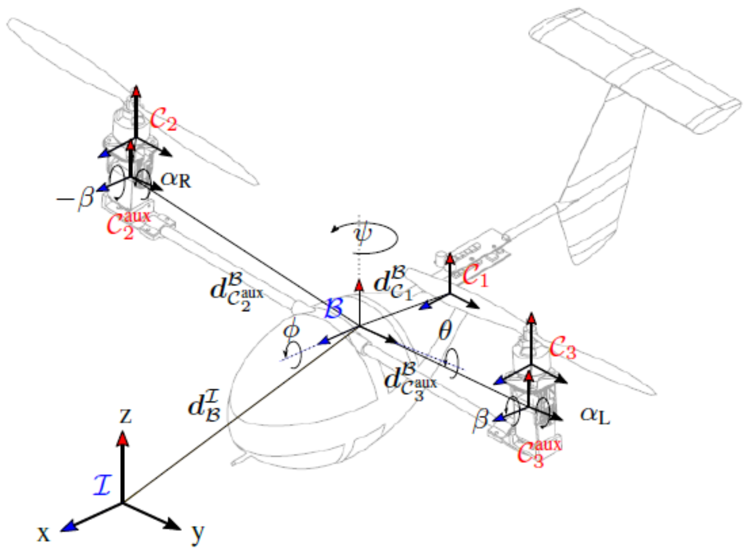


HEROES & GAZEBO SIMULATOR

Autonomous Strategies for Control and Guidance - I

- Objectives:
  - Control and Guidance System (SCG) for the safe and autonomous operation of the aircraft in SAR missions.
  - Simulation model of the control system to collect the behavior of this unconventional aircraft during critical phases such as the transition between airplane mode and rotary wing mode, low speed flight.
  - Low-level control systems to stabilize the aircraft and guidance systems for minimum energy consumption
- Subtasks
  - T8.1. Definition of the architecture of the SCG:
    - Design of the general architecture of the SCG will be carried out: interactions between the different control loops, operating frequencies of each of them and the required performance of the different sensors on board.
  - T8.2. Design of low level control systems:
    - Development of novel control strategies that allow regulated flight in the different phases of flight.
  - T8.3. Design of guidance systems for the execution of missions in an autonomous and efficient way:
    - Optimal Trajectory Module (MGTO), Trajectory Tracking Module (MST), Load Transport Module (MTC).
    - In order to test the guidance system in an aircraft simulation model, it is necessary to have the low level control systems, so that the simulation tests associated with the guidance can be understood as tests of the complete flight control system

Autonomous Strategies for Control and Guidance - II



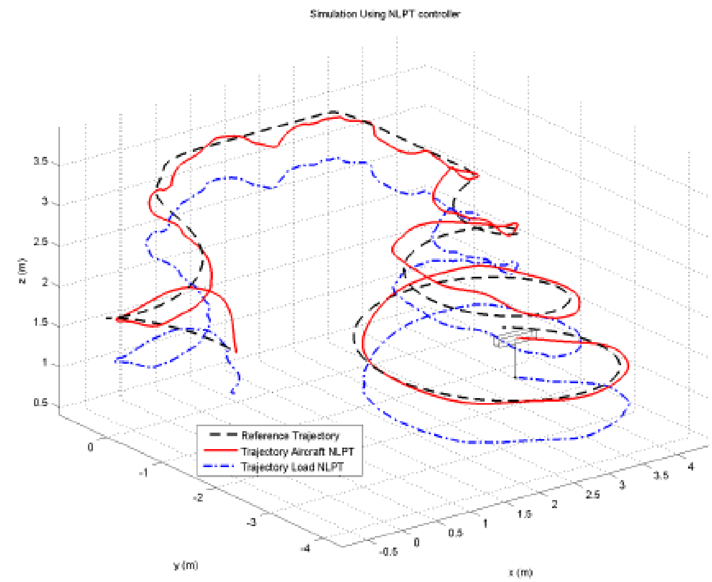
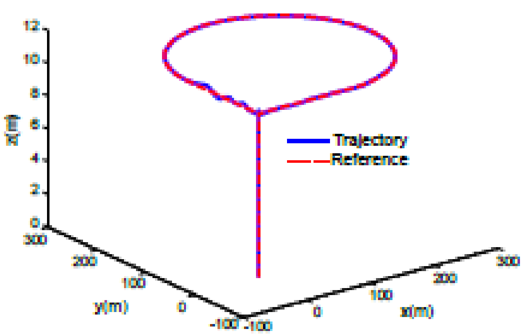
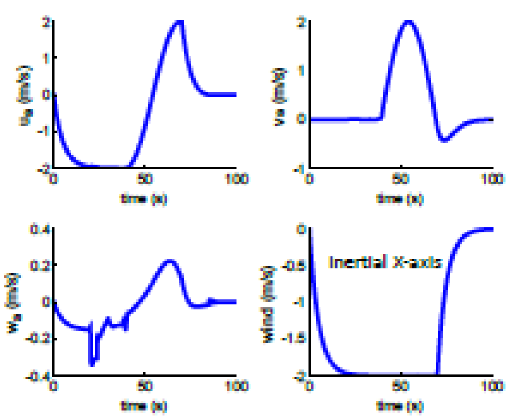
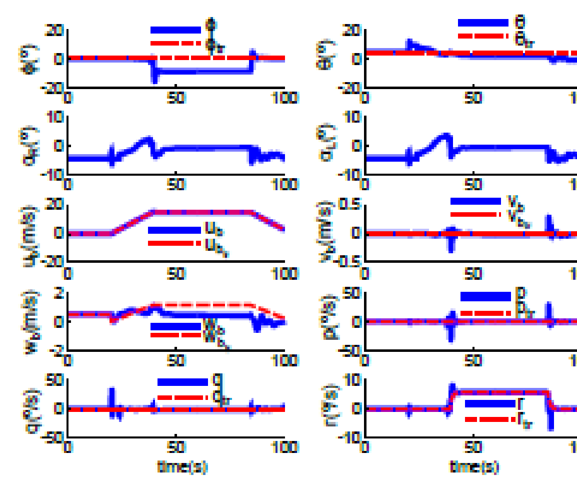


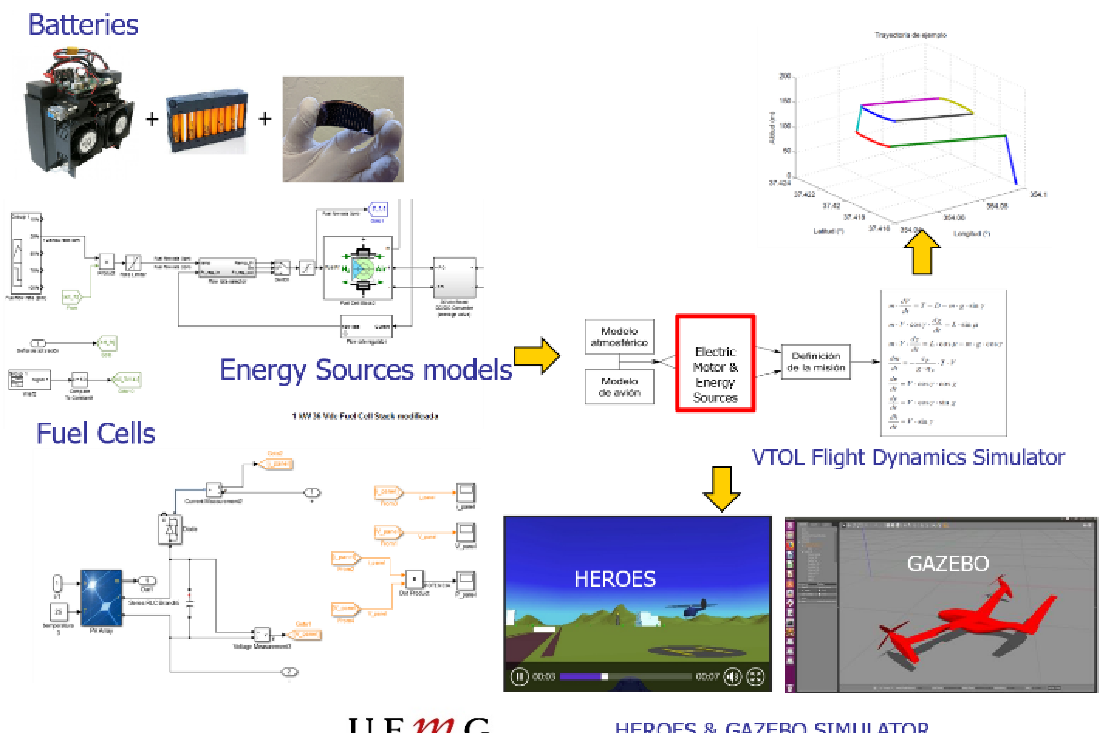
Figure 5.2: Path tracking of the aircraft for the LKFUI simulation.







- Objectives:
  - Development of the <u>cyberphysical systems</u>, which will later be integrated in an <u>advanced simulator</u> forming a <u>HIL simulation platform</u>.
  - <u>Gradually integrate</u> the different <u>technology demonstrators</u> in the HIL.
  - The HIL system will <u>allow to minimize risks that may appear during the integration phase</u> through the correct verification of the operation of the systems operating autonomously.



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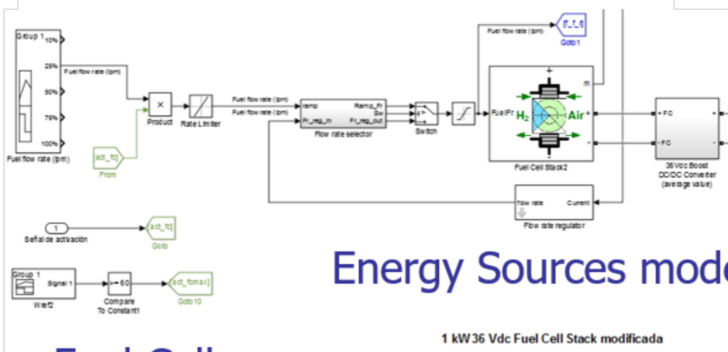
Ingeniería Aeroespacial

“Hardware-in-the-loop" Integration and Simulations - II

- Tasks
  - T9.1. Design of the onboard computer system for RPAS:
    - design of the hardware and software architecture of the on-board system, allowing the optimization of the whole with respect to the computational and structural cost (minimum weight and dimensions).
  - T9.2. Development of simulation models:
    - development of the dynamic models of each of the subsystems that integrate the aircraft that reflects the global behavior of the same during the different phases of flight (emphasis on more complex phases such as transition) .
  - T9.3. Integration of systems and functional tests:
    - Development of test plans that verify the requirements, giving rise to a specification memory and tests performed: fundamental to demonstrate the safe operation of the aircraft and thus obtain future authorization for perform real flight tests.
  - T9.4. Development of a HIL simulation platform:
    - Development of a HIL simulation platform that models the behavior of the real aircraft during the execution of missions, verifying the behavior of the entire on-board computer system, the control and guidance algorithms .
  - T9.5. Test Bench Trial Campaign:
    - Exhaustive campaign of essays in bank in the environment HIL developed. The results obtained in these tests will serve to define the protocols of the flight tests that will be developed in the Phase II of design.

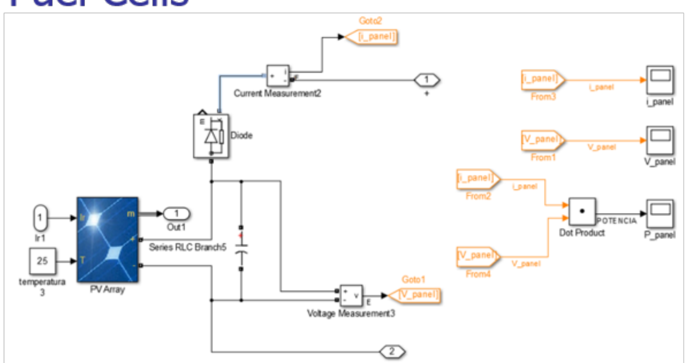
“Hardware-in-the-loop" Integration and Simulations

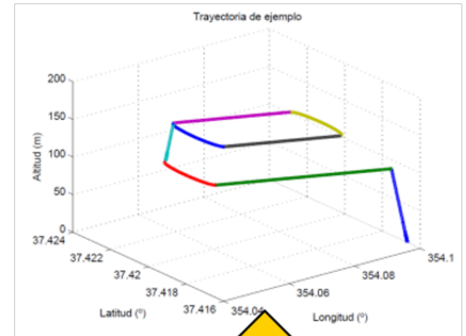
Batteries

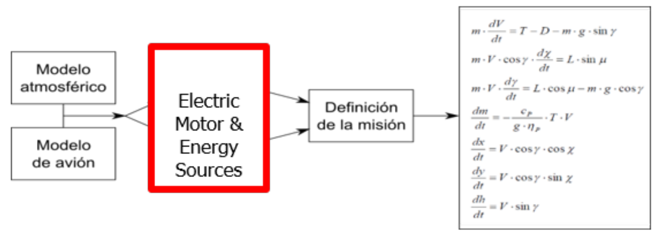


Energy Sources models

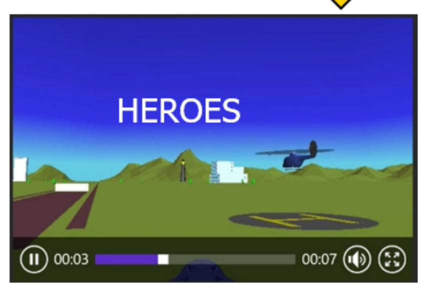
Fuel Cells







VTOL Flight Dynamics Simulator



HEROES & GAZEBO SIMULATOR

Ingeniería Aeroespacial ESI - Universidad de Sevilla

UFMG Universidade Federal de Minas Gerais

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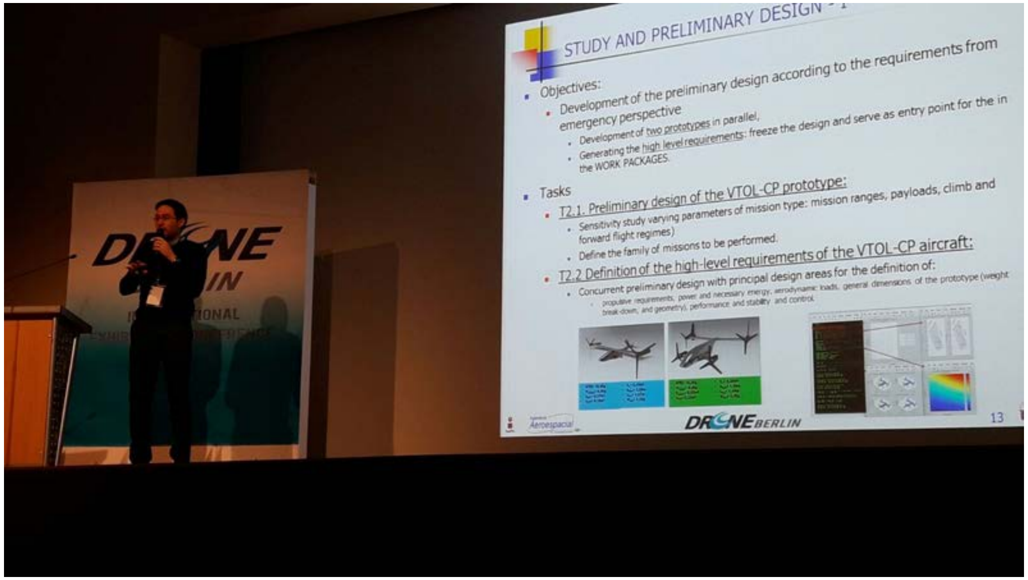
Scientific Production

- A compilation of the publications related to the EMERGENTIA Project are collected in http://aero.us.es/sesteban/pages/EMERGENTIA_publications.htm:
  - Journal Articles (4)
  - Thesis (13)
  - Master Thesis (13)
  - Congress (34)
  - PhD (On Going) (2)



Grants

- **Spanish Grants:** The project has not received any financial support in Spain. The proposal has been presented to
- Proyectos y Ayudas a la Investigación » Nacionales » Plan Estatal de Investigación Científica, Técnica y de Innovación (2013-2016 & 2017-2020)
  - RETOS 2014, 2016, 2017 & 2018: Positive evaluation, but not enough priority to assign funds.
- Proyecto «Explora Ciencia» correspondientes al Programa Estatal de Fomento de la Investigación Científica y Técnica de Excelencia, Subprograma Estatal de Generación de Conocimiento, en el marco del Plan Estatal de Investigación Científica y Técnica y de Innovación 2013-2016.
  - EXPLORA 2015, 2017: Positive evaluation, but not enough prioroty to assign funds.
- **Brazilian Grants:** In Brazil the project has received funding to the following projects:
- Title:**Desenvolvimento de um Veículo Aéreo Não Tripulado Convertível com Fontes de Energia de Renovável**
  - Financial Support: Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) - Brasil
  - Grant: Edital MCTI/CNPq 01/2016 - Chamada Universal - Brasil
  - Participant Institutions: Universidade Federal de Santa Catarina (UFSC) - Brasil, Universidade Federal de Minas Gerais (UFMG) – Brasil, y Universidad de Sevilla(US) – España
  - Duration: 14-06-2017 / 13-06-2020, 36 meses
  - Principal Investigator: Julio Elias Normey Rico (UFSC)
- Title: **Estratégias de Controle Robusto Sujeito a Restrições para VANTs Convertíveis**
  - English Title: **Robust Constrained Control Strategies of Convertible UAVs**
  - Grant: FAPEMIG
  - Tipo de convocatoria: Demanda Universal
  - Participant Institutions: Universidade Federal de Minas Gerais (UFMG) – Brasil, Universidad Tecnológica Nacional, Argentina, Universidad de Sevilla(US) – España, University of Pavia, Italia
  - Duration: 12/12/2017 - 11/12/2019, 24 meses
  - Principal Investigator: Guilherme V. Raffo (UFMG)

Conclusions

- Lack of financial aid, has limited studies to the single wing prototype.
- Design of an UAV prototype with convertible capabilities for SAR missions.
- Emphasys made: Reduced dimensions, Versatility, Simplicity.
- Design to comply: Efficiency + Sustainability + Security = Effectiveness
- Objectives:
  - Definition of design requirements and protocols for use of UAV in SAR missions.
  - Advanced development of a VTOL-CP
  - Development of high efficiency embedded electronics and efficient power management.
  - Development of energy generation and storage systems.
  - Development of control and guidance strategies for autonomous operations.
  - Development of a Hardware-In-the-Loop Simulation Platform.

Going to Lauch a H2020 Initiative

NEED INTERNATIONAL PARTNERS!

OPEN TO ANY SUGESTION AND COLLABORATIONS

Thank You...

http://aero.us.es/sesteban/pages/RL_VTOL.htm