Cefiro: An Aircraft Design Project in the University of Seville

CEFIRD

Carlos Bernal Ortega, Andrés Fernández Lucena, Pedro López Teruel, Adrián Martín Cañal, Daniel Pérez Alcaraz, Francisco Samblás Carrasco

Sergio Esteban Roncero, Francisco Gavilán Jiménez, Damián Rivas Rivas





- Introduction.
- Aircraft Design at the University of Seville.
- Cefiro's Design:
 - Structural design and manufacturing process.
 - Aerodynamics.
 - Stability and control.
 - Engine and aircraft performance.
 - Production and systems integration.
 - Céfiro's Roll out.
- Conclusions.
- Future work.



Introduction

- Motivations:
 - Research
 - Some of the areas of research of the Department of the Aerospace Engineering at the University of Seville are:
 - Trajectory optimization.
 - ATM.
 - Aircraft design.
 - Aircraft dynamics and engine performance modeling.
 - Automatic flight control systems.
 - The need of advancing in many of these research fields calls for the use of scaled platforms (UAV).
 - Low availability of adequate commercial off-the-shelf scaled aerospace platforms creates the need of designing and building custom UAV testing platforms.
 - Education
 - The department's philosophy identified as necessary to dedicate an special effort towards aircraft design.
 - Unify the knowledge acquired by the student after 5 years of education.
 - Give the students a real vision of how the aerospace industry works.
 - Department's research and educational needs yielded in the project Cefiro.



Aircraft Design at the university of Seville

- Aircraft Design (Cálculo de Aviones) is a class taught during the last year of the Aerospace program at the University of Seville.
- The main objectives of the class are:
 - Teach the students all the aspects related with the design process of airplanes.
 - Learn how to use all the engineering tools, methods and procedures that are employed in the industry during the conceptual design process.
 - Unify all the knowledge learned throughout their degree and be able to apply those concepts to a real engineering problem.
 - Give them their first industry experience:
 - Learn to manage a big project with delivery and goal deadlines.
 - Experience the challenges of a competitive industry.
 - Students work in groups (5-6) and compete to design an airplane that meets the RFP.
 - Learn to work in groups: Concurrent Engineering
 - Teach them that there is no space for the concept of "cubical engineering."





Cálculo de Aviones" Designs - 2007-08





Cefiro: An Aircraft Design Project - I

- Department's research and educational needs yielded in project Cefiro.
- Cefiro's Request For Proposal (RFP):
 - Performance requirements
 - Endurance: 45 minutes.
 - Cruise speed 90-140 km/h.
 - Cruise altitude 500 m.
 - Modular design UAV
 - Easy Transportation.
 - Easy Reconfiguration.
 - Mission profile:
 - Defined mission profile.
 - Capability of adequate space for avionic systems (different missions):
 - Observation.
 - Experiments of identification.
 - Payload bay area able to transport 7,5 kg
- The level of details achieved during the preliminary design of Cefiro was limited to the scope of the Aircraft Design Class.





CEFIRO

Cefiro: An Aircraft Design Project - II

- Need to extend each one of the design areas to transition from a design concept to a prototype.
 - "Cálculo de Aviones" gave a good proof of concept design, but not good enough to be a flying airplane.
 - Each one of the main 5 design areas of the preliminary design were assigned to students in order to be optimized (thesis):



- Structural design and manufacturing process.
- Aerodynamics.
- Stability and control.
- Engine and aircraft performance.
- Production and systems integration.



EWADE. 2009. SEVILLA

CEFIRO

Structural design and manufacturing process

- During the preliminary design, emphasis was made that the UAV had to meet:
 - The performance requirements (RFP).
 - Construction requirements:
 - Use of conventional materials to ease the construction of first prototype.
 - Modular design: transportability and reparability.
 - Easiness and fast reparability Process: friendly to handle and repair materials.
 - Simple and sound construction process.
 - Extensive use of jigs: repetitivity and precision.
- During the design phase it was identified the importance of optimizing both the construction and fabrication processes:
 - Extensive use of Computer Aided Tools (CAD & CAM).
 - Improvement of the original design and construction techniques
- Analysis of stress and strain in the plane with Patran/Nastran was made in critical zones:
 - Union with wing and fuselage.
 - Tail-booms.
 - Nose and main fuselage union.









Modular design - I





CEFIRD

- Nose fuselage.
- Center fuselage.
- Wing divided in three sections.
- Tail.
- Tail-booms.



Modular design - II





EWADE. 2009. SEVILLA

Construction process - I







Fuselage

EWADE. 2009. SEVILLA

Construction process - II





Construction process - III



Construction process - IV

Nose Fuselage







EWADE. 2009. SEVILLA

Construction process - V





Aerodynamics - I

- Compromise between performance and the mission configuration.
- Optimize for the chosen design:
 - Pusher configuration.
 - Double vertical tail configuration.
 - Surfaces, span and wing geometry, control surfaces and tail.
- Study of complete drag polar using several methods:
 - Classical methods:
 - Composite build up methods.
 - Equivalent friction methods.
 - Extensive use of computer aided methods:
 - Vortex Lattice parametric wing model.
 - CFD:ANSYS CFX 10.0.
- Airfoil design
 - Wing profile NACA 2415.
 - Tail profile NACA 0012.
- Optimization of the wing profile, and tail configuration.
- Design and analysis of the control surfaces: ailerons, flaps, elevator and rudders.
- Polar studies for all the mission configuration.
- Concurrent engineering process.









-0.5

-1

EWADE. 2009. SEVILLA

-1.4

-1.6

0 0.2 0.4



The necessity of a precise estimation of Cefiro's dynamic and static behavior yielded in a very complete stability and control study.

Stability and control

- Use of classical tools to study the static and dynamic responses.
 - Longitudinal and lateral static stability.
- Static margin analysis:
 - Payload studies.
- Optimization of aerodynamic surfaces (concurrent engineering).
 - Wing position.
 - Shape, size and location of the tail.
 - Trim analysis.
 - Incidence of the tail.
 - Pusher configuration effects during critical maneuvers.
- Great deal of work was directed towards obtaining a parametric model able to estimate the stability derivatives:
 - Merge of the available literature: F. Smetana, B. Pamadi, J. Roskam.
 - Comparison of analytical methods with a real airplane (B-747).
 - Yielded an extensive dynamic study:
 - Dynamic longitudinal stability: Phugoid and Short Period.
 - Dynamic lateral stability: Spiral mode, Dutch roll and Roll subsidence.



EWADE. 2009. SEVILLA





Static longitudinal stability



Dynamic longitudinal stability



Propulsion and performance analysis - I

- The necessity of characterizing the performance of Cefiro, required an extensive study:
 - Performance Study:
 - Take off and Landing.
 - Climb and Descent.
 - Cruise.
 - Mission Analysis.
 - Complete study of the performances for the RFP mission.
 - Study of Endurance and Range:



CEFIRD

- Optimization of velocities vs. fuel consumption, altitude and throttle settings (theoretic).
- Propeller modeling
 - Combined blade element and momentum theory models (w & w/o tip loses).
 - Analytical tool to determine engine performance for varying propeller geometry.
 - Validation of model using available real data.
- Engine Modeling:
 - Theoretical modeling balancing power requirements.
 - Validating model with data from engine test-stand (in progress).



Propulsion and performance analysis - II



Propulsion and performance analysis - III



Propulsion and performances analysis - IV





Propulsion and performances analysis - V



Engine Modelling



-





0









Production and systems integration - I

- During the design phase it was identified the importance of optimizing both the construction and fabrication processes.
- In order to do such integration it was identified the need of having a well defined construction and integration of systems sequence:
 - Organization of parts and procedures.
 - Integration of structures.
 - Fuselage Integration:
 - Nose and main fuselage.
 - Fuselage Wing.
 - Wing-tail.
 - Landing gear integration.
 - Tail-booms integration.
 - Systems Integration
 - Engine and electronic systems
 - Testing Procedures
 - Engine systems integration: from test-stand to airframe.
 - Electronic testing: batteries, RF range, servos.
- Interior harnessing of system.
- Exterior Covering.
- Flight Testing:
 - Engine characterization: Fuel consumption and thrust estimation.
 - Flight test and validation of prototype.











Production and systems integration - III











EWADE. 2009. SEVILLA



Regulador de voltaje Sistema de ignición Servo de accionamiento de la del motor palanca de gases del motor



Conclusions

- Cefiro has turned out to be a great educational experience for the students.
 - The students have been exposed to the challenges associated to all the phases involved in the construction of an airplane.
- During the design phase it was identified the importance of optimizing both the construction and fabrication processes:
 - Extensive use of Computer Aided Tools (CAD & CAM).
 - Improvement of the original design and construction techniques.
 - Have been updated into the CAD in real time, allowing their immediate use.
 - The construction process of the Céfiro v2.0 has already incorporated these improvements.
- Demonstrated:
 - The importance of the concurrent engineering approach to optimize the design process.
 - Capability of designing and constructing a custom design UAV.
 - The use of aircraft design as a tool to complete the education process of the aerospace engineers:
 - Gives the students an insight view of what's required to design, construct, and test and airplane.







Future work

- Extend the experience to more students.
 - Would be desirable to have bigger facilities and faculty to allow the rest of the students to enjoy the same and invaluable experiences:
- Short Term Actions:
 - Improvements on Cefiro's Design:
 - Weight reductions.
 - Simplification of construction techniques.
 - Progressive implementation of new materials.
 - Model engine performance.
- Long Term Actions
 - Implementation and testing of avionics systems.
 - Modeling aircraft dynamics and performances.
 - Tele-operation via FPV.
 - Autonomous flight.



