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# MASS AND PERFORMANCE ESTIMATION OF HYDROGEN AND BATTERY POWERED TRANSPORT AIRCRAFT CONCEPTS

## ODHAD HMOTNOSTI A VÝKONU VODÍKOVÝCH A BATÉRIAMI NAPÁJANÝCH KONCEPTOV DOPRAVNÝCH LIETADIEL

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**Abstract**

*This article introduces the scope and activities linked to an end of studies project. This project is a collaboration between UNIZA and ENAC and includes work of Pascal Roches and Thierry Druot on top of the student and his UNIZA tutor mentioned above. This article describes the environment of ENAC and the particular department CADO in which the project is being accomplished. It also sets the definition of the project, its main goals and deliverables. Finally, it shows methods of the work that has been done so far, that is the completion of the database of 324 commercial aircraft, which took the largest amount of time so far. It also introduces the software, which will be used to define different models required to calculate initial dimensions and performance parameters of battery or fuel cell concept aircraft.*

**Keywords**

*aircraft database, ENAC, CADO, HTP definition, VTP definition, polynomial regression*

## 1. Introduction

The definition of the concept of an aircraft is one of the very first stages of an aircraft design. Its objective is to establish the primary characteristics of an aircraft. Over the years, aircraft manufacturers have been perfectioning these characteristics to achieve the most efficient designs both in terms of aircraft performance and consumption. Many aircraft projects along the way reached commercial production and had varying levels of success in operation.

In the scope of this project, we have completed a database of over 320 civil airplanes of all sizes and missions (General Aviation, Business Aviation, Turboprop, Narrow Body & Wide Body Turbofan). For each aircraft, we have a total of 25 parameters, of which 13 represent the aircraft dimensions, 4 are weights (OWE, MTOW, MLW and fuel capacity) and the remaining 8 correspond to the aircraft performance.

Our goal is to find models, in the form of polynomial equations, which will approximate the relation between certain parameters (for example OWE vs MTOW, Total power vs MTOW or Passenger-kilometer vs Range). These models will then be able to size an aircraft (determine all its 25 main parameters) by using only a few input parameters. We will then modify these models in order to represent concepts of the future propulsion vectors. There are 3 main vectors being discussed nowadays:

1. Battery powered electric motor,
2. Hydrogen fuel cell powered electric motor,
3. Direct hydrogen combustion engine.

Finally, having established models for both conventional and future propulsion, we will compare those models in order to find the ones which are most suitable for certain missions.

## 2. Internship environment

### 2.1. ÉNAC (École Nationale de l'Aviation Civile)

It is the most important and best-known of the French grandes écoles specializing in aeronautics. It is one of the 205 colleges (as of September 2018) designated Grandes écoles by the Conférence des Grandes Écoles (CGE) accredited to deliver engineering degrees in France. Since 2011, it is the largest aviation school in Europe.

ENAC was founded on 28 August 1949 to provide initial and continuing education in the field of civil aviation. It is listed as a public scientific, cultural or professional establishment under the oversight of the Ministry of Ecology, Sustainable Development, Transport and Housing.

ENAC offers 30 engineering and technical programs in civil aviation and aeronautics in general. Some of the most notable ones include aerospace engineering, aircraft technicians, commercial airline pilots licenses, air traffic control, and flight instructors. The university also offers 3 Masters of Science programs and 12 Advanced masters degrees for students with relevant experience.

### 2.2. *L'équipe CADO (Conceptual Airplane Design and Operation)*

- Team which studies many key domains of air transport (Propulsion, Structure, Flight Mechanics, …)
- It also does a research leading to develop new links between the primary design stages and the operation of aircraft.
- For this research, the innovation dimension is an essential aspect (Electric propulsion, Big Data, Machine Learning and the problem of sustainability of air transport)

## 3. Organization of the project

### 3.1. *Project plan and objectives*

- Presentation of the stakes, tools and objectives
- Orientation in the aircraft database and its completion. Completion of the database.
- First analysis of the database on the performance aspects
- Method for the identification of the masses
- Construction of a model for estimating the masses of aircraft components.
- Application to the concept of battery powered aircraft and its limits (research of the technological frontier according to the energy density)
- Application to the concept of hydrogen powered aircraft and its limits (research of the technological frontier according to the energy density)
- Thesis drawing up and presentation.

### 3.2. *Deliverables:*

- Updated aircraft database
- Mass estimating model
- Master thesis for the University of Zilina
- Project report for ENAC

## 4. Initial approach to handle the subject

### 4.1. *Completion of the aircraft database*

The given database contained errors and blank spaces for some data. It was also divided into two separate files (Commercial Aircraft, Business + General Aviation) where sometimes one or both of the files entirely lacked required parameters. Our first task was therefore to fill in the missing data and check the existing.

To find the data, we used both literature and the internet. From literature, we used the following 2 encyclopedias:

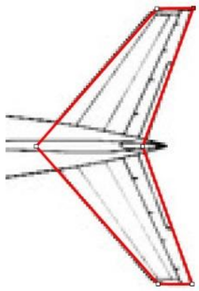
- Jane's: All the World's Aircraft – In Service [1]
- Élodie Roux: Avions civils à réaction [2]

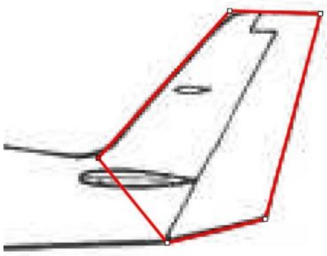
On the internet, the most complete data we found came from the following websites:

- jetav.com
- skybrary.aero

However, certain data was untraceable in any of these sources. This was mostly the case of more detailed dimensions, such as the HTP and the VTP area, or the Propeller diameter. Therefore, we had to measure these dimensions directly from the aircraft blueprints. The blueprints we used were usually coming from websites the-blueprints.com or drawingdatabase.com.

To measure the needed dimensions, we used the ImageJ software, in which we always set the scale first on a horizontal dimension (for example fuselage length) and then checked it on a vertical one (for example wingspan) or vice versa in order to check for the correctness of the blueprint or potential distortion due to non-linear zooming of the image. Finally, to find the area of the HTP, we used a simple method of extending the leading and the trailing edges as shown in figure 1. In case of the VTP of smaller GA aircraft, the area was approached by connecting the root of the fin with the lower inboard corner of the rudder, as shown in figure 2.





*Figures 1 and 2 (from left to right): Methods of measuring HTP and VTP surfaces. Source: Authors.*

### 4.2. *Concept modeling software*

While the database was being completed, Mr Druot built a software in Python capable of creating diagrams to see correlation between different parameters and calculating polynomial regressions of these correlations which then serve as the required models.

### 4.3. *Tasks to do in the near future*

- Establishing two major functions: OWE = f_structure(MTOW, type) and OWE = f_mission(MTOW, type)
- Replacement of the couple (conventional fuel; combustion engine) with (battery, electric motor)
- Exploring the field of the electric aircraft (development of the capacity and energy density through the years, prognosis to the future)

## References


[1] "Jane's | All The World's Aircraft: In Service Yearbook 20/21 https://shop.janes.com/Air-Space/All-The-World-s-Aircraft-In-Service-Yearbook-20-21/ (accessed Apr. 19, 2021).

[2] "Les Editions Elodie Roux - Avions civils à réaction : plan 3 vues et données caractéristiques." http://elodieroux.com/EditionsElodieRouxAvions.html (accessed Apr. 19, 2021).