Universitat Politècnica de Catalunya
·*Barcelona*Tech **(UPC)**

BACHELOR'S DEGREE FINAL PROJECT

Bachelor's degree in Aerospace Vehicle Engineering

Numerical study of the turbulent boundary-layer separation phenomenon on a wing.

BUDGET AND PLANNING

Author:
Claudio Bassa Viñas

Director:
Roberto Castilla Lopez

Call:
2019/2020 QP - Spring

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Escola Superior d'Enginyeries Industrial,
Aeroespacial i Audiovisual de Terrassa

June 24th, 2020

Contents

List of Figures

List of Tables

1 Budget

This section analyses the project from the *cost* perspective. The development of a computational investigation is composed of 3 main group of costs.

- The cost of the necessary physical equipment necessary for the development of the project, such as computer.
- The cost of the power used to perform the entire project.
- The cost of the time dedicated to the project.

1.1 Project equipment

The cost of the equipment stands for every material utility, hardware or software license that has been used to develop this project.

The project has been developed in the student's home, so there is any rent to pay for. The computer used is a relatively old laptop, the computer is an *ASUS X552C*[4], with a second monitor installed *Benq* [1]. Working with a second screen increments substantially the working efficiency of the project. A mouse was bought as well *Trust Optical Mouse* [2], together with a laptop refrigeration station, so to have a comfortable position to work from, while keeping the computer refrigerated, *Trust Ziva* [3]

There is not any cost associated to any software product license. One of the main advantages of working with *Linux* instead of *Windows* or *Mac OS* is that all the spreadsheets used, along with the CFD software are free, *open source*. The *MATLAB* license that has been used in this project corresponds to the university student product licese. There is not any cost associated to this license, since because the hours dedicated to *MATLAB* are relatively low, the *MATLAB* free trial would have worked likewise.

PROJECT EQUIPMENT		
Component	**Qty**	**Price (€)**
Computer – ASUS X552C	1	700
VGA wire	1	8.99
Dual Screen – Benq	1	199
Mouse – Trust optical mouse	1	12.36
Refrigerating Laptop mount	1	6.99
TOTAL (€)		**927.34**

Table 1: Project equipment cost

1.2 Power consumption

Basically, the only representative consumable cost of the thesis is the electric consumption. This electric expense is the result of the addition of the power required to power the main computer in the first place, the power required to power the second screen, and the power for illumination of the desk, which was barely used, during nights.

In the following table, there are a number of hours computed. The demonstration of all those hours is developed in the following subsection.

POWER CONSUMPTION					
Element	**Power (W)**	**time (h)**	**Power (kWh)**	**Power Cost (€/kWh)**	**Costs (€)**
Computer	200	780	156	0.1027	16.03
dual screen	80	780	62.4	0.1027	6.41
illumination	10	200	2	0.0843	0.16
				TOTAL	**22.61**

Table 2: Power consumption table

1.3 Work hours

The physical work hours dedicated to this thesis can be divided into several categories that correspond to different stages of the project.

1. Formation of *Linux OS*. Preparation of the computer. Uninstallation of *Windows* and *Linux* installation. Installation of all the other required programs, such as *openFOAM*, *MATLAB*, among others.

2. Investigation and formation about the physics and the equations that model boundary layer detachment phenomenon. Learning about the aerodynamics and fluid mechanics over the wing.

3. Learning about the *openFOAM* CFD software, the case preparation and configuration, the different turbulence models, how the eddie viscosity is solved, among others.

4. Preparation of the $2D$ aerofoil case. Design, preparation, configuration and simulation of the case. Simulation of the different number of cases, varying α and Re. Extraction of results and conclusions.

5. Preparation of the $3D$ wing case. Design of the geometry, meshing, case preparation and configuration. Realisation of different simulations. Extraction of the results and conclusions.

6. Preparation of the implementation of the *wing fence* to the $3D$ wing geometry. Design of the device, fusion of both geometries. Meshing of the entire case. Simulation. Extraction of the conclusions.

7. Redaction of the project Report and all the required documentation.

WORK HOURS			
Task	**time (h)**	**Cost (€/h)**	**Cost (€)**
1	40	15	600
2	70	15	1050
3	220	15	3300
4	185	25	4625
5	100	25	2500
6	60	25	1500
7	40	15	600
TOTAL (h)	**715**	**TOTAL (€)**	**14175**

Table 3: Work hours distribution table

1.4 Total cost of the project

The following table summarises the total costs of the project.

TOTAL COST OF THE PROJECT	
Area	**Cost (€)**
Equipment	927.34
consumption	22.61
Work Hours	14175
TOTAL	**15124.95**

Table 4: Total cost of the project

2 Project planning

There are a lot of tasks that need to be properly organised in order to develop and finish them properly. The timing and schedule is essential in order to be able to manage all the tasks in an efficient way.

As state before, there are 7 differentiated tasks along this thesis (Presented in different colours in the following *gantt diagram*.

2.1 Formation on the multiple operating systems and programs for this project

Before the start of the formation in aerodynamics and fluid mechanics part, or in the different turbulence models, or even any simulation, it is necessary to learn and understand how the different programs work.

To begin with, *Linux*. I have always been a *Windows* user, all the CFD software used in this project requires *Linux*. Not only a strong *Linux* formation is necessary, but also the technique and the necessary knowledge to delete *Windows* from the computer and proceeding the installation of *Linux* is necessary. It is not something extremely tricky, but it requires its time. Even more if it is the first time. Some margins on the time computation should be taken into account since sometimes, the *Linux* installation does not works and the entire process needs to be done from scratch.

Once *Linux* is installed, a substantial installation time is necessary as well, since the way of working from the terminal is different from the *Windows.* Some formation and spare time needs to be dedicated in the installation and unstallation of a software in *Linux*. The installation of several necessary programs, such as *openFOAM* ore $MATLAB$ is necessary.

2.2 Investigation of the Physics and equations of the present study

The present study or thesis, based on the turbulent boundary layer detachment phenomenon is a really specific part of the physics. Therefore, a research, study and formation on this particular field of fluid mechanics and aerodynamics applied to this aeronautical case needs to be carried out. Moreover, since it involves CFD resolution in the turbulent regime, it involves a substantial knowledge of the different ways pf solving turbulence, *eddy viscosity* and different turbulence models. All this is explained in greater detail in the project report.

2.3 Learning about the *openFOAM* CFD case

Learning the *openFOAM* way of working requires its time as well. The case preparation and configuration. *openFOAM* offers a wide range of configurations and options. Therefore, solving a case or a tutorial is quite easy. However, meshing and solving a particular case with the specific requirements takes a lot of time.

2.4 Design, preparation, configuration and simulation of a $2D$ aerofoil case.

Usually to learn about *openFOAM* CFD software, a good path is to perform and understand the tutorials that are provided with the CFD solver. However, when it comes to a design from scratch of a case, the amount of time applied is drastically increased.

Firstly, a design of the case needs to be carried out. In this case, the aerofoil used, the intended simulation conditions, the decision weather or not the *Trailing edge* should be open or closed, among a long list of aspects.

Once the design stage is completed, the case folders preparation needs to be carried out, along with the meshing process. Then, once one simulation is performed, an evaluation of the convergence and accuracy of the results needs to be carried out. Once all is performed, the case is ready to be used for the intended propose. All this process takes a lot of time, even more if it is the first time. That's the reason this part of the project has one entire week detinated.

2.5 Preparation of the $3D$ wing case.

This case distribution is somehow similar to the previous $2D$ case. Firstly, there is one solid part of definition. Where the geometry of the wing needs to be defined, along with its specifications. The meshing process and the fist simulation and verification process. Once all those steps are completed, the case is ready to perform the intended simulations.

Since the preparation of a case has already been done in the $2D$ case, there is less time designated in the preparation case for this $3D$ geometry, However, the meshing process is slightly more complicated since it is carried out using a existing *openFOAM* utility. Therefore, an entire week is designated as well.

2.6 Preparation of the *wing Fence* implementation in the $3D$ wing.

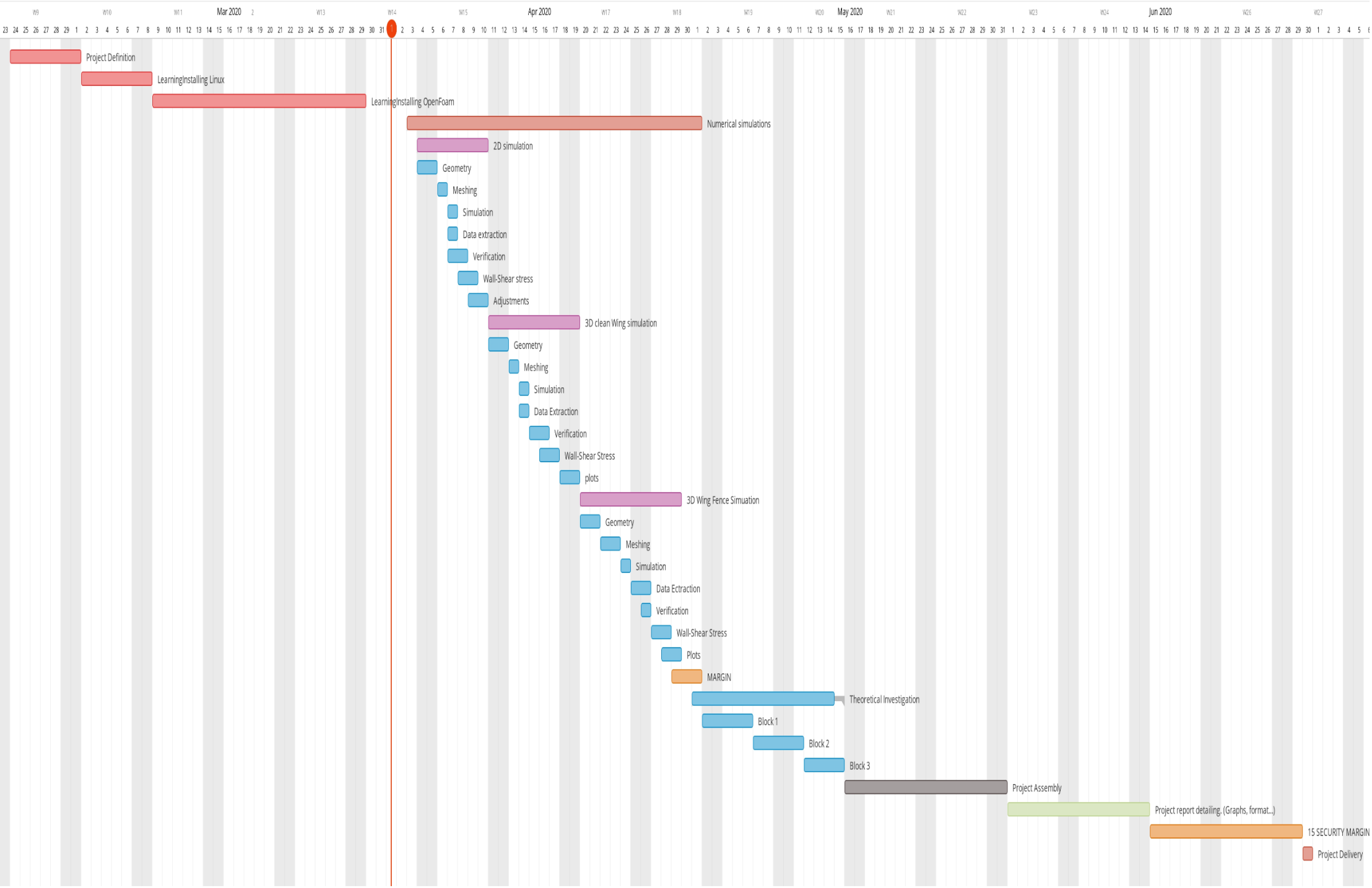
Of all the mentioned cases, this is the one which requires less preparation time. The meshing is a relatively simple process since it is directly extracted from the previous $3D$ clean wing case. However, as it is described in the report, the *wing fence* generates turbulence with oscillating values, so the post-process requires more time than the expected. 1 week of time is dedicated to this section as well.

2.7 Redaction of the Project Report

The redaction of the Report is quite straightaway once all the simulations are done and the post-process finished. 4 weeks are designated to this phase, with a 3 weeks margin for security, in the case some simulation does not provides the desired results and need to be prepared from scratch.

Example Project

Read-only view, generated on 01 Apr 2020



Blibliography

[1] *BenQ ZOWIE XL2411P - Monitor Gaming de 24" FullHD (1920x1080, 1ms, 144Hz, HDMI, Black eQualizer, Color Vibrance, DisplayPort, DVI-DL, Flicker-free, Altura Ajustable) - Gris Oscuro: Benq: Amazon.es: Informática*. URL: https://www.amazon.es/BenQ-ZOWIE-XL2411P-Sport-DisplayPort/dp/B075JGL4WV/ref=sr_1_fkmr0_2?dchild=1&keywords=benq+senseye+3&qid=1592759629&s=computers&sr=1-2-fkmr0.

[2] *Trust Optical Mouse - Mini ratón óptico con Cable, Negro: Amazon.es: Informática*. URL: https://www.amazon.es/Trust-16591-Rat%C3%B3n-%C3%B3ptico-botones/dp/B0028YR53Q/ref=sr_1_2_sspa?__mk_es_ES=%C3%85M%C3%85%C5%BD%C3%95%C3%91&dchild=1&keywords=mouse&qid=1592759674&s=computers&sr=1-2-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEySDYzRjU2Nlo5U0ozJmVuY3J5cHRlZElkPUEwNDc4MDA0S1RNT.

[3] *Trust Ziva - Soporte de refrigeración para Ordenadores portátiles, Color Negro: Amazon.es: Informática*. URL: https://www.amazon.es/gp/product/B073SC6V36/ref=ppx_yo_dt_b_asin_title_o08_s00?ie=UTF8&psc=1.

[4] *X552CL — Portátiles — ASUS España*. URL: https://www.asus.com/es/Laptops/X552CL/.