

# Development of a concurrent engineering tool based on ESA's SCDE: Application to the Air Cargo Challenge 2015

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## Abstract

Nowadays the organizations face a fast paced and dynamic market with increasing customer demands. A set of new methodologies regarding product development and management of organizational resources have been risen for the past few decades as a means of adaptation to this new paradigm. Concurrent Engineering and Knowledge Management are two of this new trends and this paper focuses itself on these two key concepts applied on the European Space Agency's "Student Concurrent Design Environment" tool. A system was built from the tool, embodying the aforementioned key concepts and applying them to a practical case: the creation, by a students' team, of an airship model eligible to participate in the aeromodelism's competition "Air Cargo Challenge 2015". This test was intended to evaluate the suitability of the tool to the intended task and to gather feedback from the experience of each one of the members of the test team.

The tool was created using the software Microsoft Excel, working through functions and macros written in Microsoft Visual Basic for Applications and complemented with third party applications already included in the system. The shared folders system used on this system's design was the Dropbox, selected for its broad dissemination and for being of easy access to the common household user.

**Keywords:** Concurrent Engineering, Knowledge Management, Microsoft Excel, "Air Cargo Challenge 2015".

## Introduction

The current paradigm has forced organizations to evolve in order to adapt themselves to a more dynamic and unpredictable market with shorter opportunity windows [1]. New trends emerged in the past decades regarding product development and organizational

resources management being two of them Concurrent Engineering and Knowledge Management.

Concurrent Engineering is a method of product development in which the several departments work in parallel, since the project's inception, in an integrated and cooperative way, reducing development's time and costs while increasing the final product's quality [1] [2] [3] [4] [5].

Knowledge management is composed by all the processes that promote the conservation of the existing tacit and explicit knowledge within organizations, namely with their staff, converting that knowledge into information that is useful, accessible and independent of the conveyer [6] [7] [8].

These methods are currently used with success by the European Space Agency (ESA) on its Concurrent Design Facility (CDF) and by the National Aeronautics and Space Administration (NASA) allowing the planning of space missions within weeks in opposition to several months in the past and with lower costs [9] [10].

## The Generic System

As mentioned earlier, the tool was developed from the Student Concurrent Design Environment (SCDE) system provided by ESA. This system is based on Excel files and works through macros written in Visual Basic for Applications (VBA) language being possible to attach third party applications to complement its tasks, as in the example of this thesis. There are two types of Excel files on the tool: the system files and domains. The domains are the files responsible for the fulfilment of the functions of the tool and the system files are responsible for facilitating communication between the domains and for controlling the access to them. There are three system files: Parameters, Data\_Exchange and Users\_Data.

## Parameters

The Parameters file enables cross-domain requests. These requests can be, for example, requests for new variables, or even

an exchange of messages. Its structure consists of sheets with the title Requests to \*Domain Name\*, with a sheet for each domain of the system.

### **Data\_Exchange**

The Data\_Exchange file contains all variables present in the system and intermediates their exchange between domains: whenever a domain creates a new variable that is stored in this file, and whenever a domain requires a variable it is sent by the Data\_Exchange. This file has a button that allows the user to save a backup of the entire system.

### **Users\_Data**

In the Users\_Data file there is the information about each of the domains' access permissions, as well as the registration of active users and the files' access history.

### **Domains' Generic Structure**

The number and type of existing domains on tool is defined by the team before the start of the project and by its the nature. There is a domain with special status, Knowledge\_Management, which is always present and where is recorded all kinds of information created during the working sessions: creation of new variables, changing of their values, comments written by users, among others.

The generic domain's structure consists of the following sheets: Administration; Comments; Input; Output; Requested to Me; Requested by Me; Components; Calculations.

### **Administration**

Administration is the first sheet of all the domains. This sheet is responsible for all the domain's management related actions: login and logoff, display of warnings (upon receiving requests from other domains), among others.

### **Comments**

On this sheet are recorded all comments resulting of the activity of domain users. These can be automatically generated by the tool (for example: creating a new variable) or they can be introduced manually

by the users. All the comments are recorded in the Knowledge\_Management domain.

### **Input and Output**

These sheets are responsible for the exchanges of variables between domains. The entry variables are sent from the Data\_Exchange file to the Input sheet of the domains. The exporting variables are sent from the Output sheet of the domains to the Data\_Exchange file.

### **Requested to Me and Requested by Me**

These sheets are responsible for the exchange of requests between domains.

### **Components**

On these sheets there are lists containing the components related information of each domain and its properties, such as: weight, price, area, size, voltage, among others.

### **Calculations**

On this sheet are carried out the calculations of each domain. These calculations can be performed directly by Excel's functions and macros or indirectly through the use of external programs.

### **Knowledge\_Management**

This domain is part of the knowledge management methodology and its use relates to the need of performing a thorough record of the decision-making process that occurred during the project's course and of the reasons behind those decisions. The collection and processing of information is intended to allow faster recognition and resolution of recurring situations by future teams, serving as a means of transmission of the knowledge acquired in previous projects.

### **Air Cargo Challenge**

The competition's rules dictate that teams must design, build and pilot a radio-controlled fixed-wing aircraft while documenting every step of the process. The aircraft must be able to take off from a 60 meters long runway while carrying the maximum amount of load and it must

complete the maximum amount of laps in a 100 meters long circuit in the time of 2 minutes, finishing with a safe landing afterwards [11].

All registered aircraft must comply with the following standards of design [11], namely:

- be of fixed wing;
- to perform the takeoff without external help (using only the power of its engine);
- to complete at least one lap of the circuit;
- not having any auto pilot systems nor any kind of control assistance;
- be equipped with the AXI Gold 2826/10 electric motor;
- have lithium batteries, up to a maximum of three cells in series;
- having the product of the battery's maximum continuous discharge times its capacity greater than or equal to 45;
- have an unchanged APC 13x7propeller Sport;
- have the desired transmission elements, ensuring always a rotation ratio between the engine and the propeller of 1:1;
- fit, while standing on its landing gear, in a 2,5 by 2,5 meters of side square;
- own a cargo bay with the minimum dimensions of 160x80x80 mm;
- have two support screws, in the cargo bay, with 8 mm diameter and spaced by 80 mm.

### Calculations

The take-off distance is defined as being the ground's covered distance by an aircraft departing from rest until it reaches a given reference altitude. The choice of a reference altitude is irrelevant in the context of the Air Cargo Challenge 2015 thus the calculations of the take-off distance will focus on its two initial stages: ground roll and rotation.

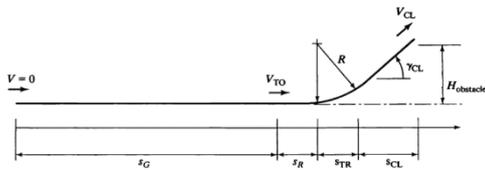


Figure 1 – Takeoff distance [12].

Ground rolling is the takeoff phase that comprehends the time between depart from rest and takeoff velocity achievement. The

distance travelled during this phase is identified in Figure 1 as  $S_G$ . The rotation phase starts when the front landing gear lifts off the ground after attainment of the takeoff velocity. This phase extends itself until the moment in which the main landing gear lifts off. The ground distance travelled during this period is the rotation distance represented in Figure 1 as  $S_R$ . Of the sum of the two previously defined distances we obtain the total distance of takeoff,  $S_{TO}$ ,

$$S_{TO} = S_G + S_R. \quad (1)$$

The minimum velocity for take-off,  $V_{TOmin}$ , is defined by the stall velocity,  $V_{Stall}$ , and is given by

$$V_{TOmin} = 1,2 V_{Stall} = 1,2 \left( \frac{W}{S} \frac{2}{\rho C_{Lmax}} \right)^{0,5}, \quad (2)$$

with  $W$  being the aircraft weight,  $S$  being the reference area,  $\rho$  being the air density and  $C_{Lmax}$  being the airfoil maximum lift coefficient.

### Ground Roll Distance

During ground roll the aircraft is subject to the ground effect, a phenomenon in which the interaction between the wing-generated vortexes wake and the ground causes an increase in lift and a reduction of the induced aerodynamic resistance.

The ground roll distance,  $S_G$ , is calculated from the acceleration,  $a$ ,

$$S_G = \int_0^{V_{TOmin}} \left( \frac{V}{a} \right) dV = 0,5 \int_0^{V_{TOmin}} \frac{dV^2}{aa}, \quad (3)$$

where  $V$  is the aircraft velocity and the  $a$  is the acceleration given by

$$a = \frac{g}{W_{TO}} \sum F_x = \frac{g}{W_{TO}} [T - D - F_f], \quad (4)$$

with the gravitational acceleration,  $g$ , the aircraft takeoff weight,  $W_{TO}$ , the aerodynamic drag force,  $D$ , the thrust,  $T$ , and the friction force between the wheels and the ground,  $F_f$ , which is given by the expression

$$F_f = \mu [W_{TO} - L_g], \quad (5)$$

where  $L_g$  stands for the lift under the ground effect and  $\mu$  is the friction coefficient whose value depends on the surfaces in contact. The values within the interval  $\mu \in [0,03; 0,05]$  are deemed acceptable [13].

The diagram of the forces acting on the aircraft during takeoff (lift, aerodynamic

drag, weight, thrust and friction between the wheels and the ground) is represented in Figure 2.

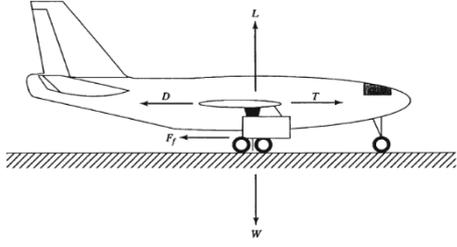


Figure 2 – Diagram of the acting forces on an aircraft during ground roll [12].

$L_g$  is the lift generated during ground roll and is given by the following expression

$$L_g = qSC_{Lg}, \quad (6)$$

Where  $C_{Lg}$  is the lift coefficient during ground roll – its calculation will be explained ahead – and  $q$  is the dynamic pressure given by

$$q = \frac{\rho V^2}{2}. \quad (7)$$

The total aerodynamic drag is given by

$$D = \frac{\rho V^2 S}{2} (C_{D0} + kC_{LG}^2), \quad (8)$$

With the profile aerodynamic drag coefficient,  $C_{D0}$ , the lift induced drag coefficient,  $k$ , and the lift coefficient with ground effect,  $C_{LG}$ .

We can now move on to the ground roll distance calculation, having all the elements for the application of (3), whereas that the wing loading is constant. We have then

$$a = f_1 + f_2 V^2, \quad (9)$$

with the auxiliary functions,  $f_1$  and  $f_2$ , given by

$$f_1 = g \left( \frac{T}{W} - \mu \right) \quad (10)$$

and

$$f_2 = \frac{g\rho}{2W} (\mu C_{LG} - C_{D0} - kC_{LG}^2). \quad (11)$$

We have finally the ground roll distance,  $S_G$ , given by

$$S_G = \int_0^{V_{Tomin}} \frac{dV^2}{f_1 + f_2 V^2} = \frac{1}{2f_2} \ln \left( \frac{f_1 + f_2 V_{Tomin}^2}{f_1} \right). \quad (12)$$

## Rotation Distance

At this stage of the take-off the aircraft is subjected to an angular acceleration that increases its angle of attack until it achieves 80% of the maximum value of the lift coefficient [12]. It is assumed, by convention, that this phase lasts from one to three seconds. As the ground speed remains constant and assuming that the rotation phase lasts a second in this case study, we will have the rotation distance given by

$$S_R = V_{TO}. \quad (13)$$

In the bibliographic element [14], Pereira acknowledged that the resulting value of (13) was extremely high. He defined then a fixed value for the rotation distance that we adopt here

$$S_R = 2 \text{ m}. \quad (14)$$

## Takeoff Velocity

The equation (12) allows us to find the distance required for take-off assuming prior knowledge of the takeoff velocity. Considering that the aircraft will need to traverse all the runway in order to takeoff it is possible to do the inverse calculation with (12) and obtain the velocity the plane reaches the end of the runway,  $V_{TO}$ ,

$$V_{TO} = \sqrt{\frac{f_1}{f_2} (e^{2f_2 S_G} - 1)}. \quad (15)$$

Assuming that the airplane will travel the entire length of the runway to perform the takeoff maximizes the load weight that it will be able to transport. If the value obtained in (15) is higher than the minimum velocity required for takeoff the difference between both represents the velocity margin that can be sacrificed in order to increase the load weight.

## Ground Effect

The proximity to the ground has an influence on the performance of the aircraft, in particular in the lift and in the drag generated. The interaction between the vortices generated in the wing of the aircraft and the ground results in the induction of an

upwards velocity in the wing that decreases the auto induced downwards velocity, resulting in a reduction of the induced drag and an increase in lift [15].

This increase in lift for any angle of attack can be regarded as an increase in the lift coefficient variation with the angle of attack,  $C_{L\alpha}$ , caused by an increase in the effective aspect ratio of the wing [16].

The ground effects causes a change in the value of the angle of attack for zero lift,  $\Delta\alpha_{0g}$ , reducing it in general [13]. This change is given, in degrees, by

$$\Delta\alpha_{0g} = \left(\frac{t}{c}\right) \left(-0,1177 \left(\frac{c}{h}\right)^2 + 3,5655 \left(\frac{c}{h}\right)\right), \quad (16)$$

where  $t$  is the airfoil thickness,  $c$  is the wing's mean chord and  $h$  is the distance between the wing and the ground.

To obtain the values of  $C_{L\alpha}$  and  $C_{L\alpha g}$  - the lift coefficient variation with the angle of attack with ground effect - we use the following formula:

$$C_{L\alpha} = \frac{2\pi AR}{\left(2 + \sqrt{AR^2(1 + \tan \Lambda) + 4}\right)} \quad (17)$$

which gives values in  $\text{rad}^{-1}$  and where is  $AR$  the wing's aspect ratio and  $\Lambda$  is the wing's sweep angle.

Finally, the lift coefficient with ground effect is given by

$$C_{Lg} = C_L \frac{C_{L\alpha g}}{C_{L\alpha}} - C_{L\alpha g} \Delta\alpha_{0g} \frac{\pi}{180} \quad (18)$$

where  $\alpha_0$  is the angle of attack for zero lift.

The ground effect causes an alteration in the induce aerodynamic drag,  $\Delta C_{Dig}$ , expressed by

$$\Delta C_{Dig} = -\sigma' \frac{C_L^2}{\pi AR}, \quad (19)$$

with the coefficient of influence of the ground effect in the induced drag,  $\sigma'$ , given by

$$\sigma' = \frac{1 - 1,32 \left(\frac{h}{b}\right)}{1,05 + 7,4 \left(\frac{h}{b}\right)} \quad (20)$$

for  $0,033 < \left(\frac{h}{b}\right) < 0,25$ .

The aerodynamic drag coefficient with ground effect is obtained from

$$C_{Dg} = C_{D0} + C_{Di} - \Delta C_{Dig} \quad (21)$$

With  $C_{Di}$  being the aerodynamic induced drag coefficient.

### Thrust Calculation During Takeoff

During takeoff the thrust generated by the aircraft varies. However, in order to obtain the equations regarding the calculation of the ground roll distance it was assumed that the T/W ratio remained constant throughout this phase. Since the aircraft works with an electric motor, this assumption implies considering a constant thrust throughout the ground roll phase. To compensate for this deviation between the real value and the obtained an average value of thrust is used, corresponding to the thrust verified for 70% of the take-off velocity [13].

### Domains

The following domains were defined for the realization of the Air Cargo Challenge 2015 project: Aerodynamics, Avionics, Configuration, Cost, Propulsion, Stability and Control and Weight and Structures.

In addition to these domains the system also includes the following and previously presented files: Data Exchange, Parameters, Users Data and Knowledge Management.

### Aerodynamics

In this domain are carried out all the calculations related to the aerodynamics of the aircraft. To perform these calculations, the system uses two external tools: The Javafoil program and the XFLR5 program.

<b>Open XFRL5</b>
<b>Selected Line</b>
17

Figure 3 – Detail of the Models List sheet from the Aerodynamics domain.

This domain has the generic structure of sheets, with the addition of an extra sheet named Models List. In this sheet there is located the interface that allows the user to summon the above mentioned external programs and there is a list containing data of the previous design iterations. The list is built by manual insertion of the data

extracted from the external programs. In the field Selected Line (Figure 3) the user must enter the number of the line containing the data to be transmitted to the sheet Calculations. In the Calculations sheet the macros there present perform the necessary calculations to account for the ground effect on values of  $C_L$  and  $C_D$ . The output of this domain are the aerodynamic coefficients:  $C_{Dig}$ ,  $C_{Lg}$ ,  $C_{Lmax}$  and  $C_{D0}$  as well as the data concerning the weight and cost of components of this domain.

### Avionics

This domain contains the avionics related components' list. The list contains components such as the Electronic Speed Control (ESC), batteries, servos, controls, radio receivers, among others. As there are no calculations within the framework of this domain the Calculations sheet has been removed. The rest of the domain's sheet structure is equal to the generic structure. The output of this domain is the name of the selected components and their weight and cost related data.

### Configuration

This is the domain responsible for evaluating the performance of the aircraft considering all the aspects of its configuration that are relevant for this purpose. Its output is the take-off velocity. Configuration has the previously mentioned sheets' generic structure with the addition of the Models List and Graphics sheets. In the Calculations sheet there are performed calculations regarding takeoff distance, the load's weight and the rules of the competition. The Takeoff Status field displays a message that informs the user whether the aircraft complies with performance requirements that are required to successfully takeoff or not (Figure 4).

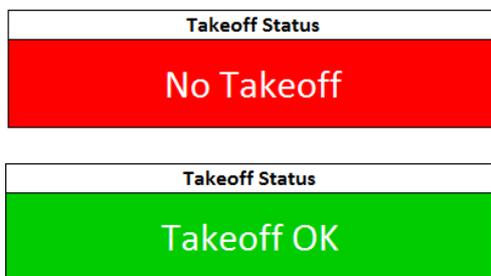


Figure 4 – Aircraft's takeoff status information.

On the Models List sheet there is the interface that allows the user to save the present model design iteration. The List Results button, present on the Models List sheet, makes a new entry in the list of design iterations of the model. Each line of the list contains the information about that model version's performance. The macro of this button updates, in the Graphics sheet, the graphics with the data from the new iteration. In the graph of Figure 5 is shown the relationship between the length of runway required to perform the take-off and the lift coefficient with ground effect. Every time that the List Results button is used the graphic is updated with the introduction of a point with the new values of the two plotted variables.



Figure 5 – Graphic example from the Configuration domain.

### Cost

This domain is responsible for keeping track of the project's costs. It receives the costs' information of other domains' components and it contains information of other miscellaneous costs such as, for example: the inscription's cost on the Air Cargo Challenge 2015, the competitors' travel and stay costs and other costs that might arise with the course of the project. Cost's structure of sheets is the generic structure and it does not export any variable to the other domains.

### Propulsion

In Propulsion there are made all the propulsion's system related calculations. To perform these calculations, the system resorts to two external tools: The Javaprop program and the online Estimate Electric Motor & Prop Combo tool. The two programs complement each other and are opened simultaneously by the macro that is associated with the Open Thrust Calculator button present in the Calculations sheet of the domain.

The online tool contains a database containing market available ESC, batteries,

electric motors and propellers. It allows the user to simulate the performance of various combinations of these elements with different weather conditions (temperature, altitude and atmospheric pressure) returning values such as, for example: the engine's voltage, the engine's static efficiency, the propellers' static impulse, the revolutions per minute of both, among others. This information is complemented with information generated in other domains and allows the Javaprop program to calculate the propeller's thrust during takeoff. This thrust and the weight and cost related information of the components of the propulsion system of the aircraft are the output of the domain. This domain has the generic sheets' structure with the addition of an extra sheet named Models List and the replacement of the Calculations sheet for the Selected Propulsion System sheet. The Models List sheet organization is identical to that of the homonymous sheet in the Aerodynamics domain, having the interface that allows you to open the external programs above and a list containing data on multiple iterations. The list is built by manual insertion of data extracted from the programs. In the Selected field (Figure 3) the user must enter the number of the line containing the data to be transmitted to the Selected Propulsion System sheet, whose function is to inform the user about the properties of the selected propulsion system. In this domain the calculations are all done in the auxiliary programs being that the reason behind the exclusion of the Calculations sheet.

### Stability\_Control

This is the domain responsible of performing the aircraft's stability analysis. This domain uses three external programs to fulfill its task: the XFLR5 program – opened with the XFLR5 Open button shown in Figure 6 - and the online tools Aircraft Center of Gravity Calculation and Canard Center of Gravity Calculation - invoked via the Open Static Stability Calculator button, also represented in Figure 6.

The online tools allow the user to perform an initial sizing of the aircraft through the introduction of several geometric properties of the main wing and of the horizontal stabilizer (or canard) such as, for example: the angle of sweep, the chord tapering, the span, the distance between the two leading edges and the static margin. These tools calculate the area of the wing and the neutral point's position, the aerodynamic center's

position and of the aircraft's center of gravity position, differing only in the configuration of the plane that they are sizing: main wing-horizontal stabilizer in the case of Aircraft Center of Gravity Calculation tool and canard-main wing for the Canard Center of Gravity Calculation tool.

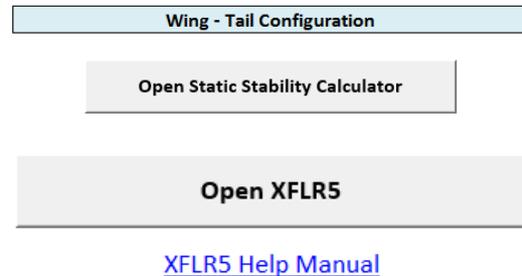


Figure 6 – Stability\_Control domain's Calculations sheet details.

The XFLR5 program allows the user to perform a complete stability analysis, including longitudinal and lateral stability study of the system, as well as obtain the respective initial conditions response graphs, modal response, forced response and root locus.

This domain has the generic sheets structure with the addition of an extra sheet named Models List and the replacement of the Calculations sheet for the Selected Configuration sheet. The organization of the Selected Configuration sheet is identical to that of the homonymous sheet in the Propulsion domain containing the interface that allows the user to open the external programs and containing a list with data from previous iterations. The list is built by manual insertion of the data extracted from the external programs. In the Selected Line field (Figure 3) the user must insert the number of the line containing the data to be transmitted to the Selected Configuration sheet that, as in the case of Propulsion, serves to convey to the user the information from the list of Models List sheet, in particular, the geometric properties of the selected configuration.

This domain has as outputs the area, average wingspan and the wing sweep distance.

### Wheight\_Structures

This is the domain responsible for calculating the total weight of the empty aircraft. On its sheet Components there is a list of components of several types used by all systems in general, such as bolts, nuts,

among others. The weight related information of these components is added to information received from the other domains and thus obtaining the aircraft's total weight. The sheets structure of this domain is the generic one and its output are the total weight of the empty aircraft, the costs of this domain's components and the distance between the aircraft's wings and the ground when supported in its the landing gear.

### Tests Results

After completion of the process of adapting the tool to the Air Cargo Challenge 2015 project there was the need of conducting a series of tests with the goal of assessing the functionality of the whole system. The next stage was the validation of the tool.

Ideally the validation would be made by resorting to the Instituto Superior Técnico students' team that was going to participate in the competition. However due to incompatibilities of calendar, this was not possible. Since it was not possible to evaluate the performance of the tool along a real project, where it would be used from the planning phase through the production phase of the model, the SCDE tool was tested in a fictional project. The SCDE was used to perform the initial planning phase of the development of the model of an aircraft eligible to compete in the Air Cargo Challenge 2015, by a team of former alumni of the Instituto Superior Técnico. The goal of this test was to evaluate the tool related intuition of users as well as the dynamics of a work session.

The first test session began with a brief explanation of the tool's operation and with the briefing of the rules of the competition. After that the test team proceeded to the design session which began with a debate between all the present members. In said debate there were set some of the intended properties of the aircraft model, taking into account the objectives and rules of the competition.

In this session there were noticed some weaknesses of the tool, in particular the absence of a framework that allowed the record of the several iterations' resulting data. The aftermath of this session was the development of the Models' List sheet that is now present in the Aerodynamics, Configuration, Propulsion and Stability and Control domains.

The second testing session took place after undertaking of the necessary changes in the SCDE system. There were performed

two design iterations. After the session there was carried out a survey to the members of the test team. In said survey the team answered questions about their experience with the SCDE tool. After the delivery of the answered questionnaires it was requested to the members of the test team to contribute with suggestions about improvements that could be made to the tool.

From this debate the following conclusions rose:

- the importance of providing the tool with a clear and comprehensible set of instructions, in order to allow for a quick and easy adaptation to the tool;
- the importance of eliminating existing ambiguities in the interface of the tool, in particular through the creation of pop-ups balloons of comments that explain the functions of the different cells' content;
- the use of visual differentiation of the cells in which the user is allowed to edit values enhanced with the lock, through the use of the Excel's protection of cells option, of the cells whose values should not be changed.

### Conclusion

We live in a globalized world, guided by a more competitive and fast paced market where the windows of opportunity are increasingly reduced and consumer demand is growing [1]. This paradigm has forced organizations to evolve and to adopt new methodologies in response to the changes in its surroundings. Two of the resulting methodologies of that adaptation to the modern times are the Knowledge Management and the Concurrent Engineering.

Knowledge Management is made up by the set of procedures related to the collection, storage, availability and recovery of the existing knowledge within organizations [6] [7] [8].

The Concurrent Engineering is a new product development methodology that advocates a holistic approach to the problem of design - looking to integrate, as soon as possible, as much as possible of the constituent disciplines of the product life cycle in the decision-making – and the simultaneously engagement in the product's design related activities [1] [2] [3] [4].

These two methodologies are related as CE relies itself in KM in order to maximize seizing of the knowledge generated along the projects' execution. When applied with success, KM and CE both allow to perform an optimization of the resources used by organizations. This optimization is driven by cost reductions and by the reduction in the launching time of new products, as well as by the increase of products' quality [1] [2] [3] [4] [5].

Both CE and KM are based on the human component, the team, which must follow a set of procedures, aided by an adequate infrastructure of information technologies in order to successfully implement the two methodologies [1] [2] [3] [6] [7] [17] [18]. This paper aim was the implementation of a generic tool to serve as the support to the practical application of these two concepts. The main objective of this work was the implementation of the generic SCDE tool and it was successfully achieved. The secondary objective was testing the tool through its utilization in a practical case, having been selected to this effect the Air Cargo Challenge 2015 competition. Ideally the SCDE tool's test would be conducted through a close collaboration with a competition's participating team however this was not possible to accomplish. A team composed of former aerospace engineering alumni was assembled in order to perform the test. The team experienced the system on two occasions and contributed to this article through their opinions.

The tool has been shown to work well and, after a proper explanation and greater familiarization of the users with the it, proved to be intuitive and of easy utilization.

### **Future Work**

Although it works properly, the tool is only capable of performing preliminary calculations. This is due to some mathematical simplifications made in the calculations of the performance and the due to the absence of tests with a real model. The realization of two tests in the context of a fictional project allowed, in each one of them, to identify gaps in the tool. So it will be expected that the use of the tool in support of a real project, from the concept creation to the assembly of the aircraft (in the case of the Air Cargo Challenge), will provide the tool with other capabilities that will improve the accuracy of its calculations, allowing it to create more realistic models.

Other suggestions for future work in the context of the SCDE tool applied to the Air Cargo Challenge, is the implementation of a Risk domain, through the collection of data on the previous editions. This data collection will allow the realization of a study focusing on identifying the main factors to be taken into account when carrying out a risk analysis in the context of this competition. For example: the influence of weather conditions, the materials used in the construction of aircraft, damage in shipping, among others.

Another aspect to improve in this work is related to the specifications of the Microsoft Excel itself, that limits the operations that involve the system files — which are invoked by all the domains. The Excel does not allow that the edition of files takes place simultaneously. So the operations that involve the realization of changes to the system files, performed by the domains' macros have to be conducted by the team leader, in order to avoid the creation of conflicted copies. There are two suggestions for the future work to be carried out on this topic. The first suggestion is to use another software as the system support tool. The other suggestion is to change the dynamic of the processes between the domains and the system files, in order to avoid this kind of situations.

In the current tool each domain has a Components' sheet, in which there are lists containing the respective components and some of its properties. With the evolution of the tool or with its application in larger projects than the Air Cargo Challenge, it is expected that the use of this architecture of sheets in the domains becomes impractical. A suggestion for an alternative is the creation of a central database, using for example the Microsoft Access, in which are stored the data of all the components used in each project, updating the same with each project and integrating it into the framework of SCDE tool.

The Knowledge Management domain can also be improved. An example would consist of writing macros that automatically generate reports with predefined text and blank spaces to be filled with data selected by the user.

## Bibliography

- [1] Falasca, M., Fetter, G., *An Optimization Model for Concurrent Engineering: Incorporating Life Cycle Costing and Supply Chain Design Early in the New Product/Service Development Process*, Department of Business Information Technology, Virginia Polytechnic Institute & State University, Virginia.
- [2] Ferreira, I. M. L., *Enhancing the Conceptual Design Phase of Complex Engineering Systems With an Integrated Methodology and Support Tools*, Instituto Superior Técnico, Lisboa, 2012.
- [3] Stjepandić, J., Wognum, N., Verhagen, W. J.C., *Concurrent Engineering in the 21st Century, Foundations, Developments and Challenges*, Springer International Publishing, 2015.
- [4] Fine, C.H., Golany, B., e Naseraldin, H., *Modeling Tradeoffs in Three-dimensional Concurrent Engineering: a Goal Programming Approach*. Journal of Operations Management, 2005.
- [5] Bandecchi, M., Melton, B., Ongaro, F., *Concurrent Engineering Applied to Space Mission Assessment and Design*, Agência Espacial Europeia, 1999.
- [6] Al-Bastaki, Y., Shajera, A., *Organizational Readiness for Knowledge Management: University of Bahrain Case Study*, Proceedings of the 16th European Conference on Knowledge Management: ECKM2015, Academic Conferences Limited, 2015.
- [7] Barbeira, M., Franco, M., Haase, H., *Knowledge Sharing in Networks Within the Healthcare Sector: Measuring Knowledge Management Capabilities*, Proceedings of the 16th European Conference on Knowledge Management: ECKM2015, Academic Conferences Limited, 2015.
- [8] McInerney, C., Koenig, M. E. D., *Knowledge Management Processes in Organizations: Theoretical Foundations and Examples of Practice*, Morgan & Claypool Publishers, 2011.
- [9] <http://technology.jpl.nasa.gov/team-x-reaches-1000th-study-looks-forward>, consultado em Abril de 2016.
- [10] CDF Infopack 2015, ESA, 2015.
- [11] *Air Cargo Challenge 2015 Regulations*, Euroavia, 2014.
- [12] Corke, T. C., *Design of Aircraft*, Prentice Hall, New Jersey, 2003.
- [13] Raymer, D. P., *Aircraft Design: A Conceptual Approach*, American Institute of Aeronautics and Astronautics, Washington D. C., 1992
- [14] Pereira, V., *Development of a Concurrent Design Facility Based on ESA CDF: Application to Aircraft Design*, Master Thesis, Instituto Superior Técnico, Lisboa, 2009.
- [15] Brederode, V. de, *Fundamentos de Aerodinâmica Incompressível*, Departamento de Engenharia Mecânica, Instituto Superior Técnico, Lisboa, 1997.
- [16] Roskam, J., Lan, C. E., *Airplane Aerodynamics and Performance*, DAR Corporation, Kansas, 1997.
- [17] Béliveau, J., *Middle Managers' Behavioral Exemplarity: A Sine Qua Non Condition for Knowledge Transfer*, Proceedings of the 16th European Conference on Knowledge Management: ECKM2015, Academic Conferences Limited, 2015.
- [18] Dourado, J. P., Silva, R., Silva, A., *Concurrent Engineering: an Overview Regarding Major Features and Tools*, International Conference "Managing Services in the Knowledge Economy", Universidade Lusíada de Vila Nova de Famalicão, Vila Nova de Famalicão, 2011.